India's Green Hydrogen Ambition: An Electricity Systems Reality Check

The mathematical impossibility of India's green hydrogen targets (2026-2070)

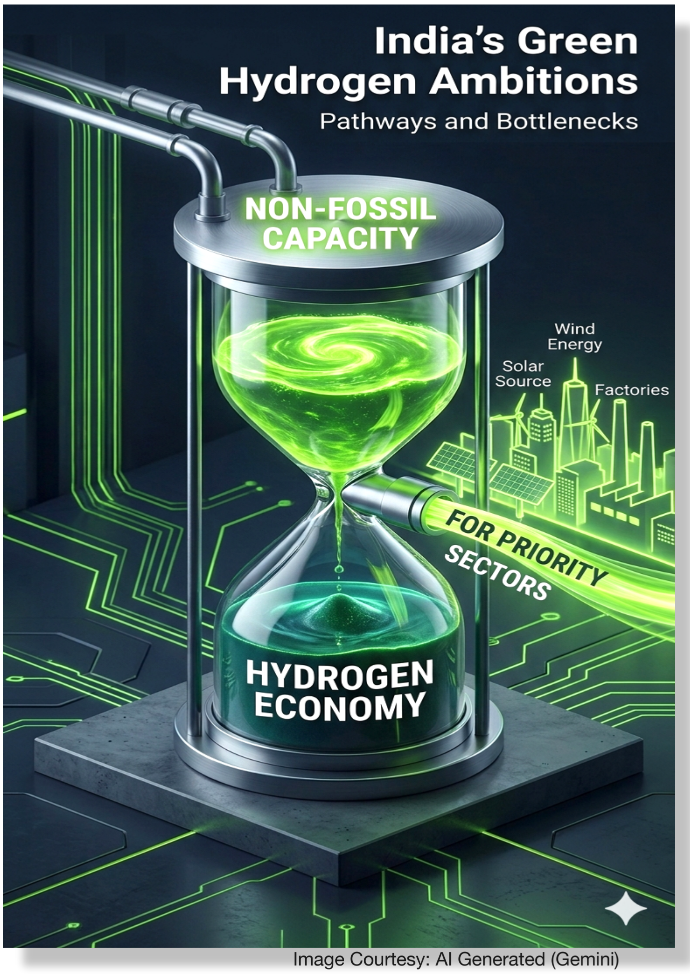


Image Courtesy: AI Generated (Gemini)

May 2026

By:

Dr. Vikrant Venkataraman
Director & Founder

©VenkaCon Research, Scientific and Technical Consulting

www.venkacon.com

VenkaCon
Pure facts & knowledge

I. Introduction:

Most nations have **codified hydrogen strategies and policy frameworks aimed at domestic production to bolster energy security and reduce import dependencies**. These strategies often proceed under the sweeping assumption that entire economies can transition to hydrogen as a primary fuel. However, a fundamental question remains:

Can a nation generate enough hydrogen to satisfy even its existing industrial (grey) demand, let alone support a full-scale hydrogen economy?

India's roadmap to **Net Zero by 2070** centres on the National Green hydrogen Mission (NGHM). The mission positions hydrogen as the critical vector for decarbonising 'hard-to-abate' sectors such as steel, shipping, and heavy transport [1]. However, a significant '**Supply Ceiling**' of green hydrogen exists. The total annual yield of non-fossil electricity is a constrained resource that must first satisfy the rising demand from primary sectors - industry, residential, commercial, agriculture, and transport.

This report analyses the feasibility of India's green hydrogen potential within the context of its physical and grid-scale constraints. This report also explores the widening gap between available **'residual' non-fossil electricity**, **curtailed electricity** and the projected demand for green hydrogen. The analysis is bifurcated into two critical horizons:

- ✴**The Growth Phase**: 2026 to 2040
- ✴**The Saturation Phase**: 2040 to 2070

Key Production Milestones (2026 Status):

- **Current Capacity**: As of early 2026, India has commissioned approximately 8000 tonnes per annum (TPA) of green hydrogen production capacity [2]. This is **0.12% of India's total 2026 demand.**
- **2030 Target**: The Government of India remains committed [3,4] to **producing 5 million metric tonnes (MMT)** per annum by 2030.

- **Largest Operational Plant**: JSW Energy recently commissioned [5] India's largest operational green hydrogen plant (**3800 TPA**) in Vijayanagar, Karnataka, marking a pivotal step towards 'green-steel' production.

Definitions:

- **Green hydrogen** - Hydrogen produced via electrolysis powered exclusively by renewable energy sources (Solar, Wind, Hydro).
- **Low-carbon hydrogen** - Hydrogen produced from a mix of renewable and low-carbon firm-power sources (e.g. Nuclear).
- **Residual non-fossil electricity** - Non-fossil electricity (TWh) left after allocation for priority sectors.
- **Curtailed non-fossil electricity** - Non-fossil generated electricity (TWh) that could not be absorbed into the grid.

Core Research Questions:

To evaluate the viability of India's green hydrogen ambitions, this report addresses the following:

- **Demand Dynamics**: What is India's current total electricity demand, and what is its projected trajectory through 2070?
- **The Capacity- Generation Gap**: How will non-fossil capacity grow, and more importantly what will the actual non-fossil generation (TWh) be once efficiency and grid constraints are factored in?
- **Resource Competition**: Which priority sectors (Residential, Industrial, Agriculture) compete with electrolysers for non-fossil electrons, and how is this energy allocated?
- **Market Scale**: What is the current demand for industrial hydrogen (Grey), and is the green transition even capable of replacing this existing baseline?
- **The Curtailment Fallacy**: Can curtailed electricity provide a meaningful volume of green hydrogen, or is it a marginal gain that cannot support heavy industry?
- **Economic Viability**: Is green hydrogen production a viable business case when accounting for low capacity factors and high infrastructure costs?

Note on Methodology: This analysis assumes that **non-fossil capacity addition** and **net generation efficiency** are the ultimate deciders of green hydrogen feasibility. Without accounting for these constraints, hydrogen production risks relying on conventional fossil-heavy grids, defeating the purpose of the decarbonisation mission.

Electrolysis technology is the most mature technology on the market as on date. Therefore any meaningful quantities of green hydrogen production must come from it. All calculations (for green hydrogen production) in this report are therefore based on non-fossil electricity being supplied to electrolyser systems which in turn produce green hydrogen.

II. Non-fossil capacity & Non-fossil generation

A foundational challenge in energy planning is the distinction between **Installed Capacity (GW)** and **Actual Energy Generation (TWh)**. While non-fossil sources including - solar, wind, large hydro, nuclear, biomass, geothermal, and other small sources - are growing rapidly, their capacity share does not translate 1:1 into energy share. This disparity acts as a reality check for global green ambitions: achieving a grid powered entirely by non-fossil sources remains decades away, and India is no exception.

This distinction is especially critical for the **National Green Hydrogen Mission**. Hydrogen is only classified as ‘Green’ if the electrolysis process is powered by non-fossil electricity. Therefore, the availability of these ‘green electrons’ is the ultimate bottleneck for green hydrogen production.

The Efficiency Leap (2026-2040):

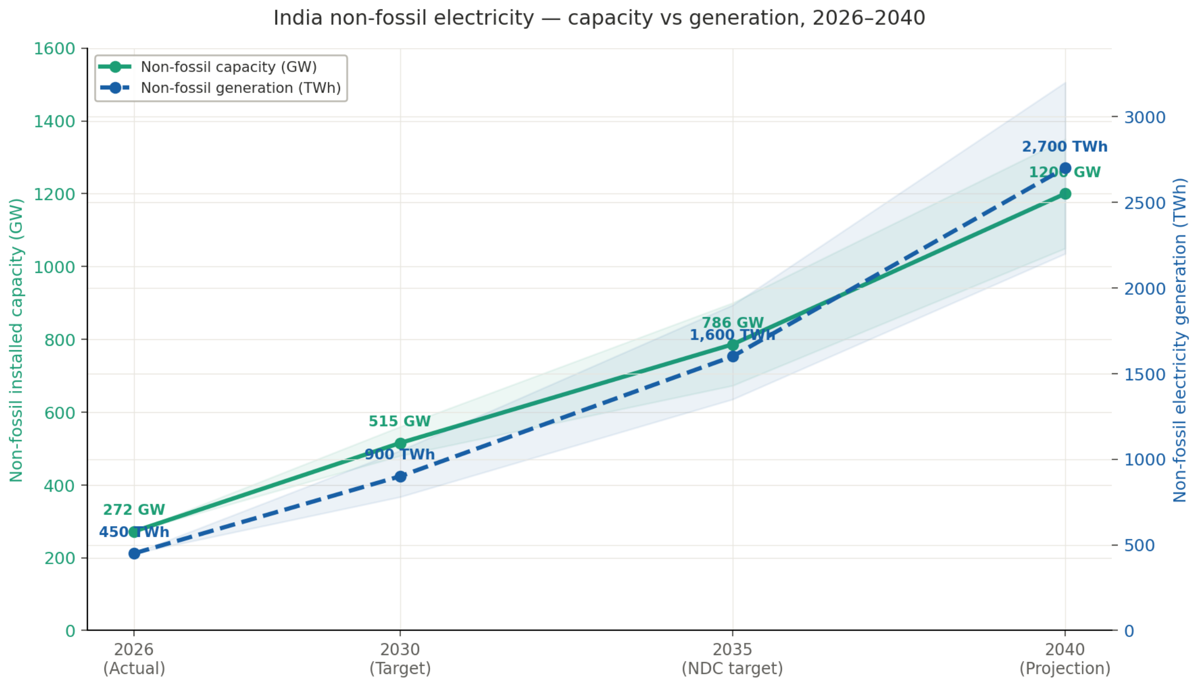
Fig 1. shows the non-fossil capacity installed and the non-fossil based generation in India from 2026 until 2040 (projected). What is clearly visible is that the relationship between installed capacity and energy output is non-linear.

As shown in Table 1, India’s non-fossil fleet is projected to undergo an ‘efficiency leap’ through 2040. During this phase, TWh generation grows faster than GW capacity due to technological improvements (e.g. bifacial solar panels, larger wind turbines) and improved asset utilisation. This is indeed great technological progress.

Currently, in 2026, there is a **26 percentage-point gap** point gap between capacity share and generation share. This is primarily due to the inherent CUF (Capacity Utilisation Factor) of different technologies.

- **Solar PV**: ~18-22 % CUF [6]
- **Onshore Wind**: ~25-35% CUF [7]
- **Coal (Thermal)**: ~60-80% CUF (base-load operation) [7|

Even as non-fossil sources cross 50% of total capacity, they generate only about a quarter of the nation’s actual electricity. While grid integration and storage will narrow this gap by 2040, the low CUF remains a structural constraint for sizing electrolysers, which require high utilisation hours to remain economically viable.

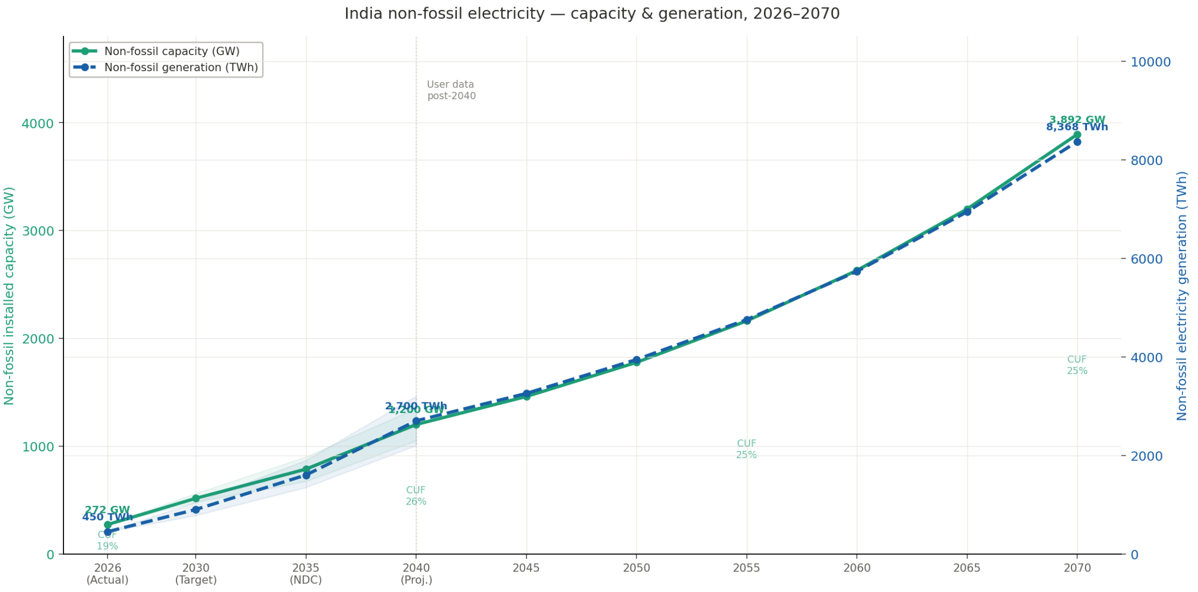


Sources: CEA actual data (Jan–Feb 2026), CEA NEP 2022–32, 20th Electric Power Survey (Mar 2026), IEA WEO 2025 STEPS.
Bands show low–high projection range. Left axis: installed capacity (GW). Right axis: actual/projected generation (TWh).

Fig 1: Non-fossil capacity and non-fossil generation 2026 - 2040, India

Year	Non-fossil capacity (GW)	Non-fossil generation (TWh)	Non- fossil Capacity share# (%)	Non-fossil Generation share (%)	Multiplier (TWh/GW)
2026	272 (actual)	~450 (annualised)	52%	~26%	1.65
2030	500-560 (target)	780-1050	~67-70%	~32-38%	~1.75
2035	673-900 (NDC target)	1350-1900	~60-70%*	~40-50%	~2.03
2040	1050-1350 (projection)	2200-3200	~75-80%	~55-65%	~2.25

Table 1: Non-fossil capacity (GW) and generation (TWh) and % share [8,9]
*NDC commits to 60% - trajectory likely exceeds it
#Capacity share percentage fluctuations reflect the phased decommissioning of older thermal plants vs. new RE additions



2026–2040: CEA actual data, CEA NEP 2022–32, 20th Electric Power Survey (Mar 2026), IEA WEO 2025 STEPS. Bands show low–high projection range.
2045–2070: User-supplied capacity and generation data. CUF = generation ÷ (capacity × 8,760 hrs).

Fig 2: Non-fossil capacity and non-fossil generation 2026 - 2070, India (under 4% CAGR)

The Saturation Plateau (2040-2070):

An extended projection of the non-fossil capacity addition and generation from 2040 till 2070 is shown in Fig 2. Beyond 2040, the narrative shifts from an ‘efficiency leap’ to ‘**diminishing returns**’. While the multiplier (TWh/GW) rises to 2.25 by 2040, it begins to stagnate as the grid faces the **saturation of intermittent sources**.

The CUF (Capacity Utilisation Factor) is the interesting story here. It rises from ~19% in 2026 to ~26% by 2040, reflecting improving grid integration and storage. But as solar penetration increases, the system-wide CUF is projected to plateau and slightly decline from its 2040 peak to **~24.5% by 2070**. This is physically consistent with a solar dominant mix; without a 1:1 matching in long-duration storage, every additional GW of solar adds less useful energy to the grid due to midday peaking. This creates a ceiling for ‘residual’ electricity available for hydrogen production.

Cautionary Note:

- ➡ Non-fossil capacity figures above include registered grid-connected and rooftop solar. Unregistered behind-the-meter (BTM) generation is excluded, though it represents a marginal percentage of total TWh and is largely consumed on-site, leaving it unavailable for national-level hydrogen production.
- ➡ BTM is quite unlikely for non-fossil sources other than solar or wind.

➡ While Nuclear and Offshore Wind offer higher utilisation factors, the sheer economic advantage of Solar PV ensures it will continue the bulk of capacity additions. Consequently, the **system-wide CUF will be gravity-bound by solar intermittency**, reinforcing the plateau effect after 2040. Therefore, the CUF assumed in the modelling here is more or less realistic. A more detailed explanation in given in *Appendix 1*.

III. The Resource Competition Framework

Non-fossil electricity is not a dedicated resource for hydrogen alone; it is the foundational energy vector for the entire economy. In a decarbonising grid, hydrogen must compete for ‘green electrons’ against established priority sectors. This report treats these sectors as having ‘First Dibs’ on the non-fossil electricity pool to ensure that essential services are decarbonised before energy is diverted to secondary conversion processes like electrolysis.

The Hierarchy of Demand:

The following sectors are modelled as **Priority Claimants** on non-fossil generation:

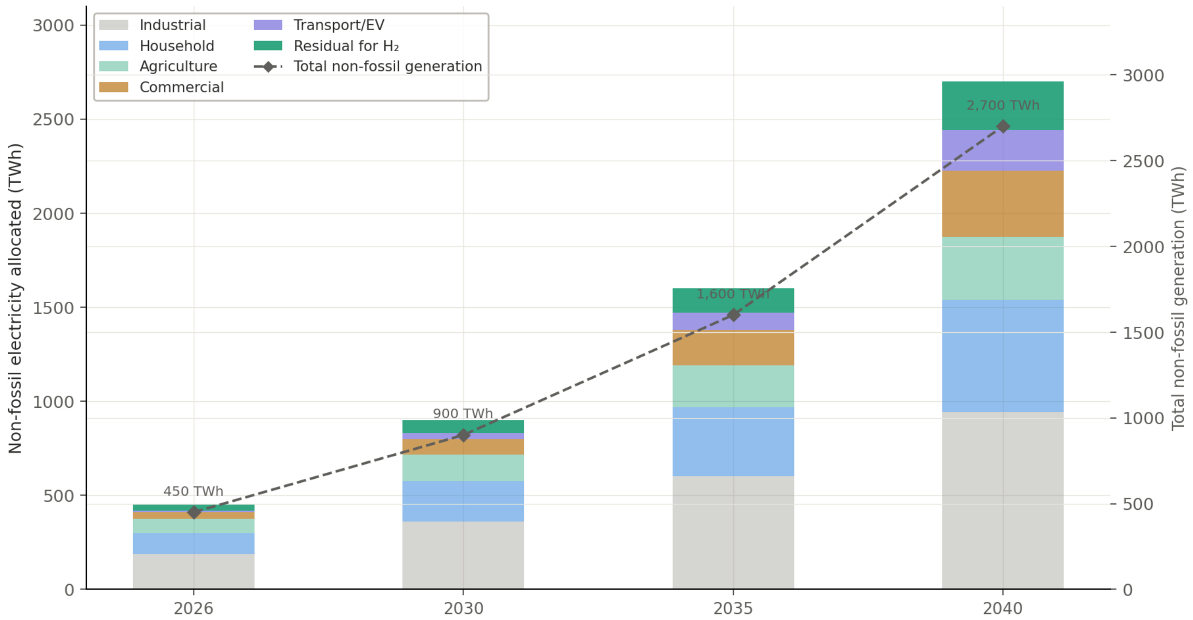
- **Transport** - The burgeoning EV fleet and the fully electrified railway network
- **Agriculture** - Irrigation, pumping, and rural electrification
- **Commercial/ Services** - Urban infrastructure and data centres
- **Industrial loads** - Baseline and heavy manufacturing
- **Residential loads** - Cooling and household appliances
- **Miscellaneous** - Public water works, street lighting, and industrial estates

As shown in *Appendix 2* , these sectors collectively command **over 90%** of projected non-fossil generation. This leaves a ‘Residual Pool’ of **under 10% for green hydrogen**. The percentage of non-fossil share allocated to the above sectors are based on a pro-rata basis. This is to ensure that these priority sectors are decarbonised before ‘residual electricity’ is diverted to hydrogen production.

Elevating hydrogen production to priority status is something to be discussed both from a political and environmental point of view

Green hydrogen production is not considered a priority sector in the above analysis and modelling. Therefore, green hydrogen production potential is analysed solely from the residual non-fossil electricity made available after allocation to priority sectors and also considering any curtailment of non-fossil generation.

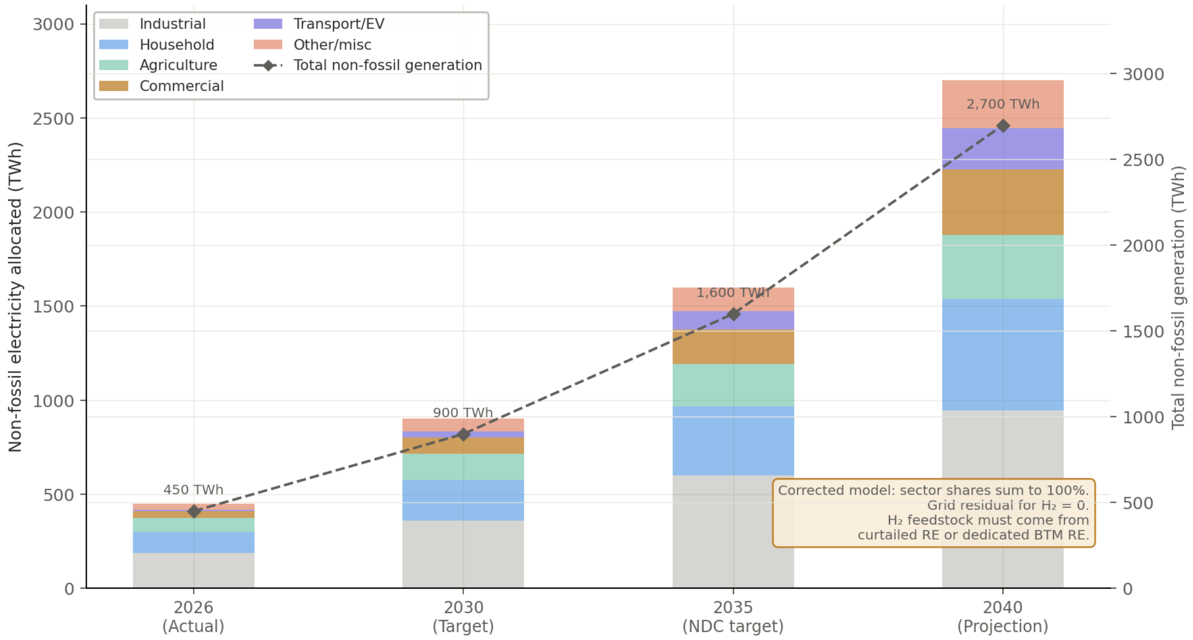
India non-fossil generation — sector allocation & residual for green hydrogen, 2026–2040



Methodology: Non-fossil generation allocated pro-rata across sectors based on each sector's share of total electricity demand.
Residual = non-fossil generation − sector allocations. H_2 yield = residual TWh ÷ 57.9 kWh/kg (55 kWh/kg electrolyzer + 5% system losses).
Sector shares: industry 42→35%, household 24→22%, agriculture 17→12.5%, commercial 8→13%, transport 1.5→8% by 2040.

Fig 3: Allocation of non-fossil electrical generation to different sector - India (Without ‘Miscellaneous’ category)

India non-fossil generation — full sector allocation (corrected to 100%), 2026–2040



Corrected model: sector shares sum to 100%.
Grid residual for H_2 = 0.
H_2 feedstock must come from
curtailed RE or dedicated BTM RE.

Sector shares sum to 100% at each year. Pro-rata allocation: each sector receives NF generation × its share of total demand.
Industry 42→35%, Household 24→22%, Agriculture 17→12.5%, Commercial 8→13%, Transport 1.5→8%, Other/misc 6.9→9.5%.

Fig 4: Allocation of non-fossil electrical generation to different sector - India (With ‘Miscellaneous’ category)

If hydrogen were elevated to a priority status, it would **necessitate keeping other vital sectors on fossil-fuel power**, a move that would be politically and environmentally counter-productive or at least subject to intense scrutiny and analysis.

The stacked bar chart in Fig 3 shows the total non-fossil generation allocated to different priority sectors and the residual electricity left after allocation to these priority sectors. This actually is quite an optimistic scenario because the 'dark green' stack of the bar chart will actually be consumed by another sector which falls under the category of '**Miscellaneous**' , which includes - **Public water works (2.21%), street lighting (0.61%) and captive generation + construction + industrial estates (4%)** in which case there is almost zero non-fossil electricity left for green hydrogen production. The same stacked bar chart in the modified case including this 'Miscellaneous' category is shown in Fig 4. But to present an optimistic scenario, the 'Miscellaneous' category is neglected for further analysis.

The pro-rata model shows that as long as non-fossil generation's share of total electricity remains below 100%, the residual electricity for hydrogen generation is structurally limited because every priority sector gets a slice of non-fossil power proportional to its size.

Total electricity demand = Non-fossil generation + Fossil generation

The Residual Analysis: A 2030 Reality Check

Table 2 provides the 'Supply Ceiling' for grid-connected green hydrogen. It accounts for the rising priority demand and excludes the 'Miscellaneous' category to present an optimistic baseline.

Year	Non-fossil generation (TWh)	Priority sector allocation (TWh)	Residual electricity available for H_2 production (TWh)	Residual electricity for H_2 as % of non-fossil generation	H_2 production potential (MT)
2026	450	~419	~31	~7%	0.54
2030	900	~833	~67	~7.4%	1.17
2035	1600	~1472	~128	~8%	2.21
2040	2700	~2444	~257	~9.5%	4.43

Table 2: Hydrogen production in MT from residual non-fossil electricity (Without 'Miscellaneous' category)

The H_2 conversion arithmetic in MT from the TWh available is straightforward:

$$H_2\ (\text{MT}) = \text{Residual (TWh)} \times 10^9\ \text{Wh/TWh} \div 57{,}900\ \text{Wh/kg} \div 10^6\ \text{kg/MT}$$

The 2030 Target Gap: India's **National Green Hydrogen Mission (NGHM)** targets 5 MT of green hydrogen production by 2030. However, the grid-available ceiling is only **1.17 MT** - less than 25% of the target. To bridge this **3.8 MT gap**, India would require massive 'behind-the-meter' (BTM) dedicated plants. Without them, the shortfall must be met by grey hydrogen, which invalidates the 'Green' mission.

The Supply-Demand Divergence:

India's current hydrogen demand (as on 2026) is ~7 MT [10]. This is what is the need in industries - mainly **refineries**, **fertiliser**, and **ammonia**. Total unconstrained H_2 demand in 2030 is projected at ~11 MT and ~24 MT by 2040. This represents a CAGR of ~9.8 % per year. This data is shown in Table 3.

Year	Total H2 demand (MT)	Green H2 production* (MT)	Coverage of green hydrogen with total demand
2026	~6.5 to 7	0.54	~8%
2030	~11	1.17	~11%
2035	~16 to 18	2.21	~12.3%
2040	~24	4.43	~18%

Table 3: Percentage of Green H_2 coverage of the total hydrogen demand (Without 'Miscellaneous' category)
* From grid residual electricity

Fig 5 is a visual representation of Table 3, where one can see that green hydrogen production from residual non-fossil electricity does not even meet 25% of the total hydrogen demand even until 2040. The **green hydrogen part will not even be present** in Fig 5 if the **'Miscellaneous' category for the priority sectors is included** in the calculation.

Therefore the structural message is stark - **grid residual green hydrogen alone can never meet total hydrogen demand** across this entire horizon. Even by 2040, it covers less than 25% of the total demand. The rest must come from:

- Dedicated behind-the-meter Renewable Energy wired directly to electrolysers (not grid-dispatched). **India would need ~1065 TWh of behind-the-meter non-fossil generation by 2040** to meet the hydrogen demand which is practically unfeasible.
- Blue hydrogen (natural gas + CCS) as a transitional bridge
- Continued grey hydrogen (SMR/coal gasification) for the uncovered balance

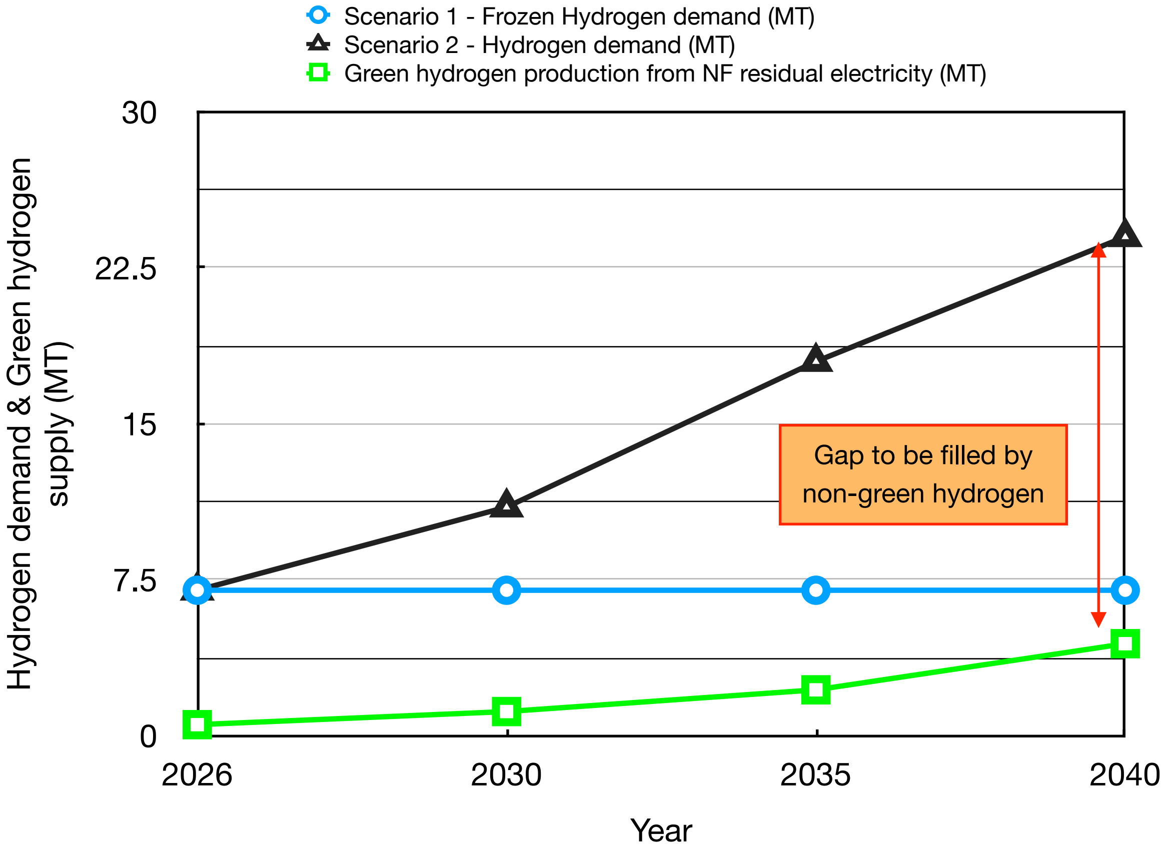


Fig 5: Green Hydrogen supply vs Hydrogen demand - 2026 till 2040
(Without ‘Miscellaneous’ category)

This is arguably the most important insight for policy realism - as of August 2025, 94% of India’s announced green hydrogen capacity had not moved beyond the announcement stage, with only 2.8% operational [11], and this statistic aligns perfectly with what the electricity residual match tells us. The grid simply doesn’t have the surplus yet to support anything close to the ambition.

The core fallacy in India’s green hydrogen narrative:

The policy framing (in India and elsewhere in the world) assumes green hydrogen can be additively scaled on top of everything else India needs electricity for. But it’s a zero-sum competition for the same electrons.There are three points which need to be unpacked.

- **The ‘Dedicated RE’ Fiction**: Behind-the-meter RE wired to an electrolyzer sounds clean in a project proposal but ignores the economic gravity issue. The moment that plant sits next to a grid-connected region, which every industrial electrolyzer will, the economics pull against exclusivity. A project developer who locks 500 MW of solar exclusively to hydrogen production at ~$3–4/kg will soon realise that the **revenue generated is forgoing grid merchant revenue, RECs, and industrial supply contracts which operate at higher margins** and at some stage will be tempted to arbitrage that power into the grid. No rational developer holds that discipline at scale. The RE gets arbitraged into the grid the moment spot prices are attractive.

- **The Demand Crowding Problem**: Every GW of new RE added behind the meter is a GW that EVs, data centres, green steel, and residential cooling, all of which are growing explosively, will lobby to access. India's per capita electricity consumption is still only ~1,460 kWh/yr [12, 13] vs China's ~6,000 and the OECD average of ~8,000. The headroom for competing demand is enormous, and those competing uses will always have a stronger political constituency than hydrogen, because they deliver immediate, visible welfare gains.

- **The Energy Hierarchy Problem**: Hydrogen via electrolysis is fundamentally a **tertiary use of electricity** - one is converting a high-grade energy carrier (electricity) into a lower-grade one (hydrogen, with 30–40% round-trip losses) to then burn, electrochemically convert or reconvert it. Every sector that can use electricity directly - industry, transport, heating - will be driven by basic economic logic to electrify directly rather than electrolize-then-use. Green hydrogen only makes sense where direct electrification is physically impossible: high-temperature industrial heat above 1000°C, long-haul shipping, aviation, and certain chemical feedstocks as mentioned in Table 4. For the long-haul shipping and aviation applications, it won’t be directly used as a fuel but rather be used to generate syngas which will then be used to produce liquid fuels for use in those applications.

Sector	Common narrative	Reality	Verdict
Steel (DRI)	Green H_2 replaces coking coal	Direct electrolytic steel (molten oxide electrolysis) emerging; H_2 is one path, not the only	Yes
Trucks/Buses	Fuel Cell vehicles	Battery trucks already cheaper per km in India's duty	No
Refineries	Green H_2 replaces grey	Genuine need - but requires H_2 at < $2/kg, not $ 4-6/kg	Yes
Fertilizers (ammonia)	Green ammonia	One of the few legitimate use cases - no electrical alternative	Yes
Heating	H_2 blending in gas grids	Direct heat pumps are 3-4 times more efficient	No

Table 4: Sectoral Viability (Hydrogen vs Direct Electrification)

India needs to add roughly **1,500–2,000 TWh of new non-fossil generation by 2040** just to electrify its existing energy demands — industry, EVs, cooling. The projected range of non-fossil generation is between 2200 and 3200 TWh, as mentioned in Table 1. That is the primary claim on every solar panel and wind turbine that gets built. **Green hydrogen for industrial substitution is competing against this primary claim with an inherently inefficient conversion process**. Green hydrogen would need an additional 1065 TWh (behind-the-meter) just for its production. The residual after meeting those primary claims as the model shows caps out at ~4.4 MT by 2040, against a projected demand of ~24 MT.

The math and the engineering model say the same thing:

India's green hydrogen ambition for industrial decarbonisation is structurally over-promised and under-scrutinised.

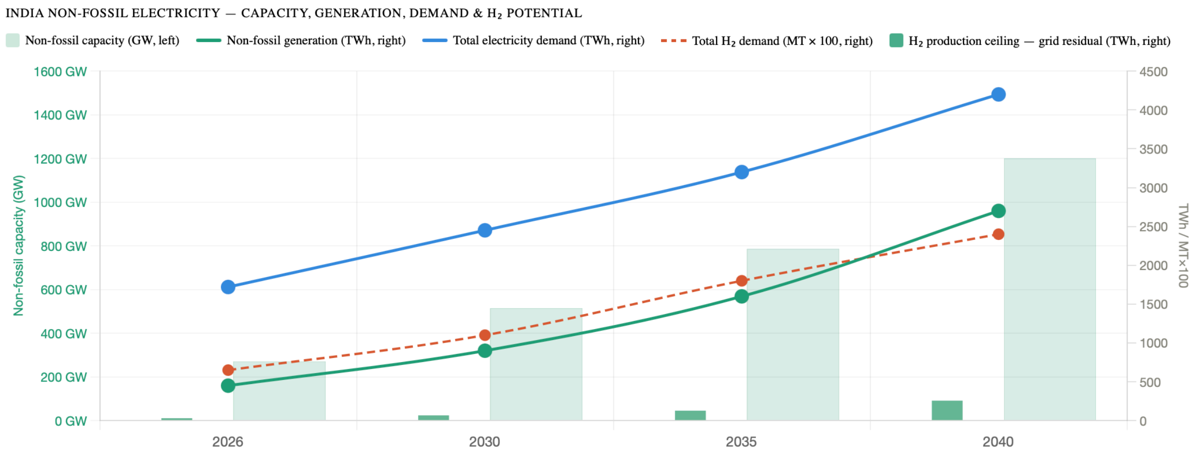
IV. The Supply Ceiling & 2070 Stress-Testing

The central fallacy of the National Green Hydrogen Mission (NGHM) is the assumption that green hydrogen supply and total hydrogen demand will naturally converge at some point in time and thus the urgency and need for investing in electrolyser technology. As shown in Figure 6, the ‘Green hydrogen Ceiling’ (from grid residual supply) and the projected demand are actually on diverging trajectories.

The 2040 Horizon: Arithmetic of a Net Deficit

By 2040, India’s electricity demand is projected to reach **~4200 TWh**, while non-fossil generation lags at **~2700 TWh**. This 1500 TWh gap must be filled by fossil fuels, meaning the grid remains in a structural deficit.

The chart in Fig 6. makes the supply-demand gap viscerally obvious - the total H_2 demand line (dashed orange) runs far above the green H_2 ceiling (dark green residual bars) throughout the entire horizon. Even in 2040, the grid-residual ceiling of ~4.4 MT covers less than 25% of projected demand of ~24 MT, and that is before any competing sectors arbitrage the surplus away. Fig 6. is a complex chart which warrants a detailed explanation.



Capacity (GW, left axis) vs generation & demand (TWh, right axis). H_2 demand plotted as MT × 100 for scale comparability. Electrolyzer assumption: 55 kWh/kg + 5% system losses = 57.9 kWh/kg net. Sector allocation pro-rata on non-fossil generation share.

Fig 6: India non-fossil electricity - capacity, generation, total demand & green hydrogen potential (2026-2040)

- **The capacity bar (pale green bars, left Y-axis) - Capacity Illusion**

  Non-fossil capacity grows from 272 GW in 2026 to 1,200 GW by 2040, a near 4.5× expansion. It looks impressive in isolation. But the bar's relationship to everything else on the right axis is the first warning sign. A lot of installed capacity does not automatically mean a lot of usable electricity let alone for green hydrogen production.

- **The capacity-generation gap**

  The solid green line (non-fossil generation, right axis) sits at only 450 TWh in 2026 against 272 GW of capacity. That implies an average capacity utilisation of roughly 19%, entirely consistent with solar running at 18–22% and wind at 25–35%. This gap narrows only modestly over time. By 2040, 1,200 GW of capacity yields ~2,700 TWh, still only a ~26% utilisation factor. The physical intermittency of solar and wind is baked in permanently. No amount of policy ambition can change this arithmetic.

- **The primary demand claim (blue line, right Y-axis)**

  Total electricity demand stands at 1,720 TWh in 2026 and climbs to 4,200 TWh by 2040. Critically, it is always substantially larger than non-fossil generation throughout the entire horizon. This means **non-fossil electricity never produces a structural surplus over total demand**. The grid is always in a net deficit that fossil generation must fill. Green hydrogen is therefore always competing against unmet primary demand, not feeding off genuine excess as the theory of green hydrogen is supposed to mean.

- **Non-fossil electrical energy for green hydrogen (dark green bars, right Y-axis)**

  These are the most important and most sobering element of the chart. The residual available for hydrogen production after pro-rata sector allocations is barely visible in 2026, amounting to just 31 TWh, grows to 67.5 TWh by 2030, and **reaches 257 TWh by 2040**. The smallness of these values relative to everything else is the central visual message: the slice left over for hydrogen is structurally thin for the entire foreseeable future.

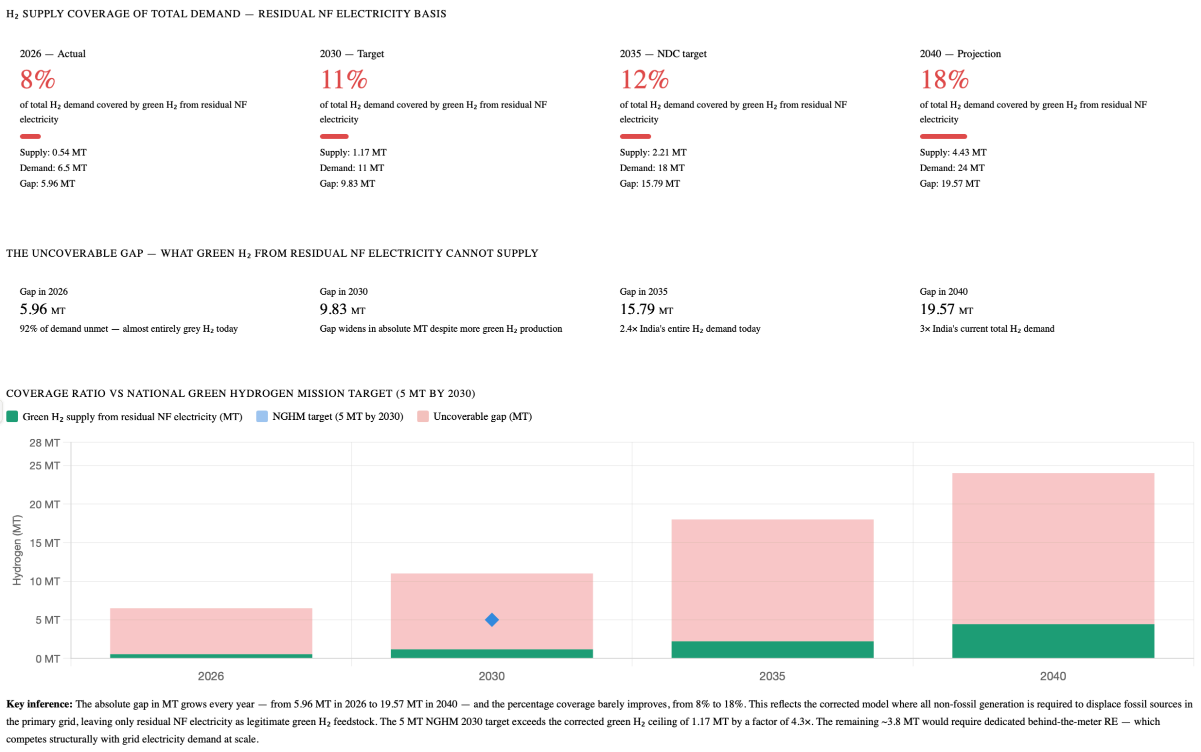
- **The total H_2 demand line (dashed orange, right Y-axis)**

  Plotted at MT × 100 for scale comparability, this runs from 650 (= 6.5 MT) in 2026 to 2,400 (= 24 MT) in 2040. It consistently sits far above the dark green residual bars and even well above the solid green line (non-fossil generation) until the year 2037. The gap between the dashed orange line and the dark green residual bars is the hydrogen supply deficit that cannot be closed by grid-residual electricity alone and must come somewhere else.

The single most important inference

The chart shows **three lines and two bar series all moving upward, which can superficially look like a story of progress**. The real story is in the ratios that do not converge. **Total electricity demand grows faster than non-fossil generation. H_2 demand grows faster than the residual non-fossil electricity available for hydrogen**. The two gaps - between fossil and non-fossil generation, and between total H_2 demand and H_2 supply (via non-fossil electricity) do not close by 2040 under any realistic scenario modelled here. India's green hydrogen ambition is structurally racing ahead of the electricity system that is supposed to power it.

Fig 7. shows the demand growth for hydrogen from 2026 until 2040 and it also shows the percentage of this demand that can practically be met by green hydrogen from residual non-fossil electricity.



H_2 SUPPLY COVERAGE OF TOTAL DEMAND — RESIDUAL NF ELECTRICITY BASIS

2026 — Actual
8%
of total H_2 demand covered by green H_2 from residual NF electricity
Supply: 0.54 MT
Demand: 6.5 MT
Gap: 5.96 MT

2030 — Target
11%
of total H_2 demand covered by green H_2 from residual NF electricity
Supply: 1.17 MT
Demand: 11 MT
Gap: 9.83 MT

2035 — NDC target
12%
of total H_2 demand covered by green H_2 from residual NF electricity
Supply: 2.21 MT
Demand: 18 MT
Gap: 15.79 MT

2040 — Projection
18%
of total H_2 demand covered by green H_2 from residual NF electricity
Supply: 4.43 MT
Demand: 24 MT
Gap: 19.57 MT

THE UNCOVERABLE GAP — WHAT GREEN H_2 FROM RESIDUAL NF ELECTRICITY CANNOT SUPPLY

Gap in 2026
5.96 MT
92% of demand unmet — almost entirely grey H_2 today

Gap in 2030
9.83 MT
Gap widens in absolute MT despite more green H_2 production

Gap in 2035
15.79 MT
2.4× India's entire H_2 demand today

Gap in 2040
19.57 MT
3× India's current total H_2 demand

COVERAGE RATIO VS NATIONAL GREEN HYDROGEN MISSION TARGET (5 MT BY 2030)

Key inference: The absolute gap in MT grows every year — from 5.96 MT in 2026 to 19.57 MT in 2040 — and the percentage coverage barely improves, from 8% to 18%. This reflects the corrected model where all non-fossil generation is required to displace fossil sources in the primary grid, leaving only residual NF electricity as legitimate green H_2 feedstock. The 5 MT NGHM 2030 target exceeds the corrected green H_2 ceiling of 1.17 MT by a factor of 4.3×. The remaining ~3.8 MT would require dedicated behind-the-meter RE — which competes structurally with grid electricity demand at scale.

Fig 7: India Green Hydrogen - supply coverage & demand gap (2026-2040)

The three panels in Fig 7 together make the above argument watertight.

The **coverage cards** on the top show the percentage improving, from 8% in 2026 to 18% in 2040, which is the number most policy documents will cite. But the **gap cards** immediately beneath, show the absolute MT deficit growing in the same period from 5.96 MT to 19.57 MT. These two facts are simultaneously true and point in opposite directions, which is exactly the sleight of hand in most green hydrogen narratives: **percentage progress masking absolute deterioration**.

The stacked bar chart, at the bottom, makes the most damaging single point: the light red uncoverable gap is always the dominant portion of the bar. Even in 2040, after 14 years of the most aggressive RE buildout India has ever attempted, the green slice is less than a quarter of the total bar. And the NGHM’s (National Green hydrogen Mission) own 5 MT target for 2030 sits more than twice the height of the green supply bar for that year.

The most uncomfortable number in the entire panel is the 2040 gap: 19.57 MT. That is nearly triple India's entire hydrogen consumption today, and it is the volume that would still need to come from grey or blue hydrogen or simply not exist even under the most optimistic trajectory. That is the number that should be at the centre of every policy conversation about India's hydrogen mission.

Stress testing the model from 2040-2070:

To see if a ‘Crossover Point’, where green hydrogen supply finally meets total demand, is possible, the model was extended and applied to four post-2040 demand scenarios against two non-fossil growth trajectories (4% vs 8% CAGR)

Scanario	Demand CAGR	Narrative
1. Frozen	0%	Hydrogen demand stops growing at 2026 levels (unrealistic)
2. Moderate	3.0%	Steady industrial expansion and substitution
3. Low	2.0%	Aggressive direct electrification displaces H_2 use cases
4. High	4.5%	Aggressive adoption in steel, shipping, and aviation

Table 5: Hydrogen demand scenarios (post 2040)

The growth in non-fossil capacity addition and generation is shown in Fig 8.

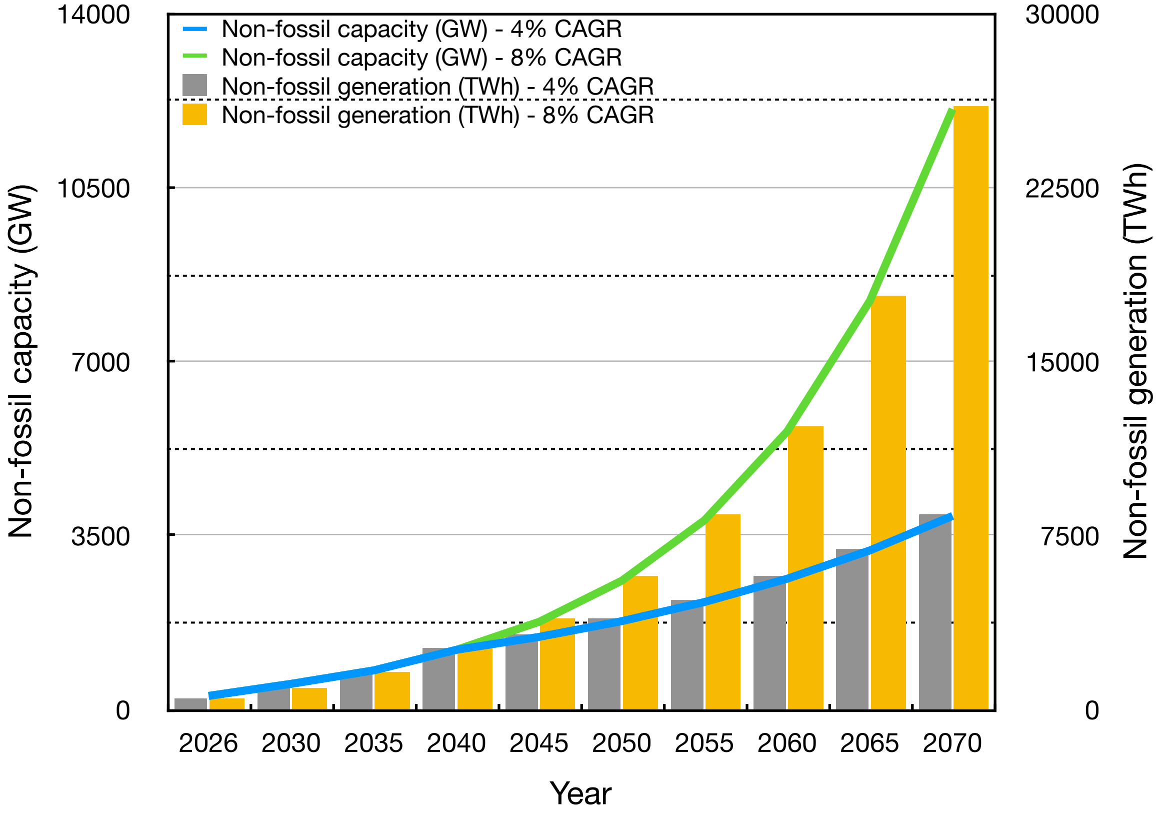


Fig 8: Non-fossil capacity addition & generation (2026-2070) - India

Results of the Stress Test:

The model reveals that for nearly all realistic scenarios, **there is no cross over in sight before 2070**. The hydrogen demand from all four scenarios and the ‘green hydrogen’ production potential (from residual non-fossil electricity) under the 4% & 8% non-fossil capacity growth is shown in Fig 9.

- **Scenarios 2,3, & 4**: Irrespective of whether non-fossil capacity grows at 4% or 8%, the ‘Green Ceiling’ never catches up to the demand line.
- **The ‘Unicorn’ Scenario, Scenario 1**: A crossover only occurs if we freeze hydrogen demand at today’s levels (~7 MT) AND maintain aggressive 8% non-fossil capacity growth. Even then the crossover is delayed until 2045.

India’s current 6.5 MT is almost entirely grey hydrogen locked into two captive cases - **refineries and fertilisers**. Both of these sectors are structurally growing. Refinery throughput is expanding as vehicle ownership rises.

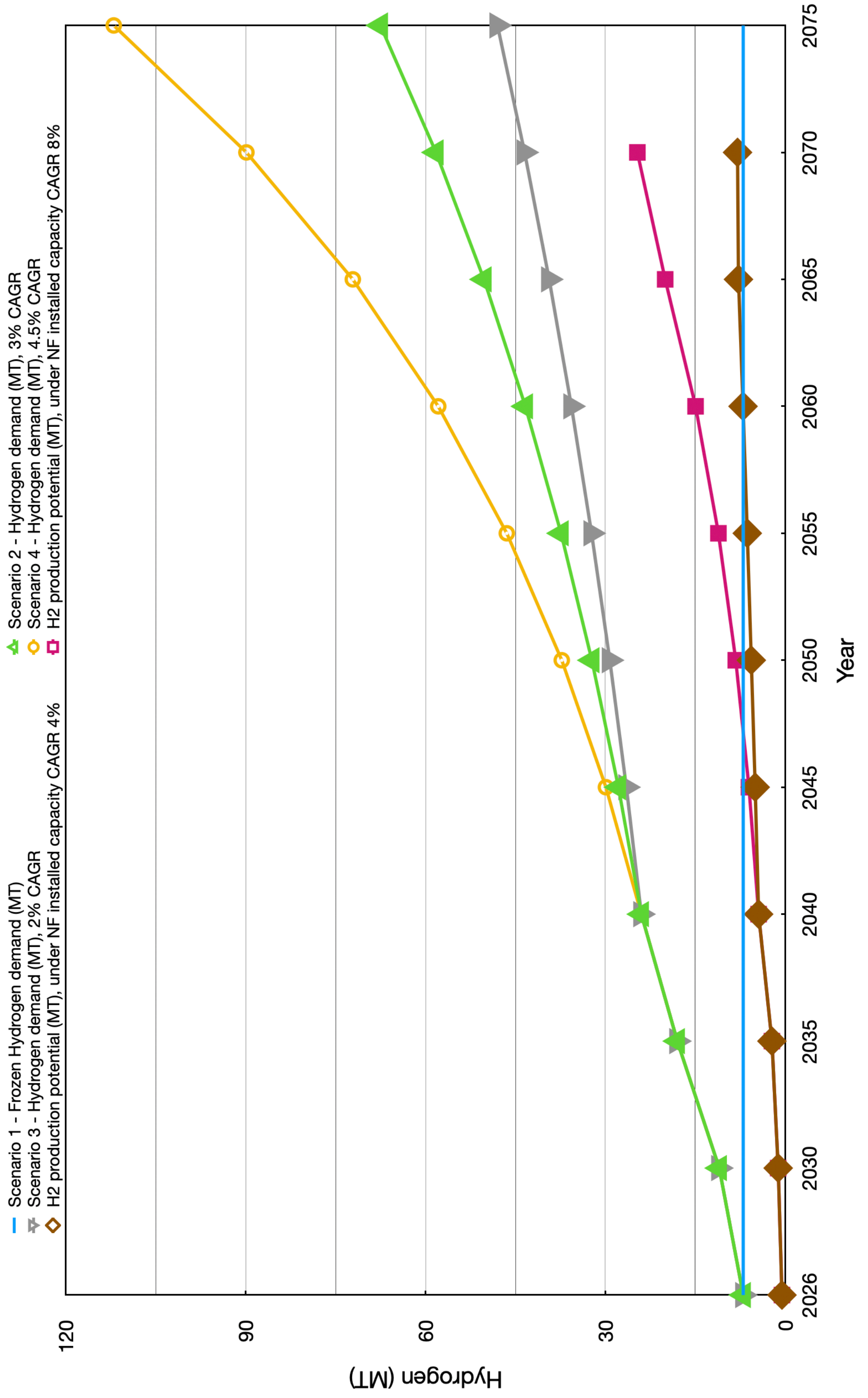


Fig 9. India Green Hydrogen production from residual NF electricity (2026-2070) - Stress testing against three demand scenarios

Fertiliser demand tracks agricultural intensification and population. Even in a world where no new hydrogen applications emerge - no green steel, no fuel cells, no blending - the existing base grows. Realistically, scenario 1 collapses under stringent scrutiny.

Note: The above scenarios were modelled under the assumption that the multiplier (TWh/GW) which is the ratio of non-fossil generation to non-fossil capacity addition is moderate. Even with an aggressive multiplier, the **non-fossil generation capacity doesn't shift too much to alter the outcomes**. The respective multipliers shown in Table 6.

Year	Multiplier moderate (TWh/GW)	Multiplier aggressive (TWh/GW)
2040	2.25	2.25
2045	2.23	2.4
2050	2.22	2.55
2055	2.2	2.7
2060	2.18	2.85
2065	2.17	3
2070	2.15	3.15

Table 6: Multiplier used for non-fossil generation prediction (2040-2070)

For a genuine crossover to occur **there must be continued non-fossil installed capacity acceleration and demand moderation**. These two things need to happen simultaneously, and each of which is uncertain independently. Currently, the crossover point is less of a target and more of a morale under the current grid-residual logic.

The 'Global Scale' sanity check

The hydrogen demand CAGR for the pre-2040 period and for the post-2040 period is shown in Table 7.

All three post-2040 demand scenarios assume a sharp deceleration from the 9.8% pre-2040 pace which is usually the right engineering assumption since:

a. The 2026-2040 growth is driven by new policy rush, green hydrogen missions and aggressive targets that front load demand.

b. Post 2040, the easy substitution opportunities are exhausted and demand growth naturally moderates.

c. Direct electrification progressively displaces hydrogen in marginal use cases.

Period	Demand CAGR
2026 - 2040	9.8% (implied 6.5 → 24 MT)
2040 - 2070 (Scenario 2)	3%
2040 - 2070 (Scenario 3)	2%
2040 - 2070 (Scenario 4)	4.5%

Table 7: Hydrogen demand for pre-2040 period and for post-2040 period

Proponents of the 8% CAGR trajectory, for non-fossil capacity addition, may argue that India can simply build more. However, the model exposes this as a physical impossibility.

- The Numbers: An 8% CAGR results in **~26000 TWh** of non-fossil generation by 2070.
- The Comparison: This single-nation figure would be close to **today's entire global electricity consumption which is ~29000 TWh**.
- The Constraint: At this scale, the non-fossil build out must saturate relative to India's land area, grid capacity, and demand ceiling let alone the large quantities of water (equivalent to major national river system) needed for electrolysis systems. For e.g. solar needs roughly 4 to 5 acres of land per MW and when one does the math for the 26000 TWh, the number will be truly astonishing.

The 8% 'Aggressive' scenario is a mathematical fiction. The **4% CAGR (~8400 TWh by 2070)** is the only credible baseline for national planning. Under this credible baseline, 'Green Hydrogen' remains a niche residual fuel or feedstock rather than an economic backbone.

V. The Curtailment Paradox - Is ‘Free’ electricity the answer?

Curtailment is often framed as the ‘gold mine’ of the energy transition: zero cost, surplus electrons that would otherwise be wasted. However, transforming these wasted electrons into affordable hydrogen requires more than just an electrolyser system; it requires solving an economic paradox and before arriving at the economic paradox one has to evaluate if it is even possible and the if the numbers make sense.

The Growing Tsunami of Curtailment

India’s grid is already showing signs of structural strain. In the second half of 2025, **India lost 2.3 TWh** of solar generation due to emergency grid measures [14]. In high renewable states like Rajasthan and Gujarat, **curtailment levels have already reached 10-30%** [15] during peak hours due to a combination of transmission unavailability and inflexible coal plants that cannot ramp down fast enough.

The curtailment projections until 2040 is given in Table 8 below.

Year	Non-fossil generation (TWh)	Electricity curtailed (TWh)	Curtailment Rate (%)	Green H_2 production from curtailed electricity (MT)
2026	450	8.1	1.8	0.14
2030	900	33	3.6	0.57
2035	1600	132	8.25	2.28
2040	2700	324	12	5.6

Table 8: Projected non-fossil electricity curtailment and H_2 potential (2026-2040)

Now if all of this curtailed electricity is somehow not curtailed but stored or channelled effectively and used for green hydrogen production, how will the numbers play out? As one can see from Table 8, the numbers from curtailed electricity are slightly better than that from residual non-fossil electricity. The comparison between green hydrogen production from residual electricity and curtailed electricity is shown in Fig 10 in order to make this difference stark. As one can see, **even using curtailed electricity to the full extent possible does not make a major dent to the production volumes of green hydrogen**.

This production of green hydrogen from curtailed electricity faces a massive physical hurdle: the **transmission lag**. Central Electricity Authority (CEA) reports indicate that while generation capacity can be added in 18 months, the Inter-State Transmission System (ISTS) often lags by **3-5 years** [16]. This mismatch makes high curtailment rates a mathematical certainty rather than a policy choice.

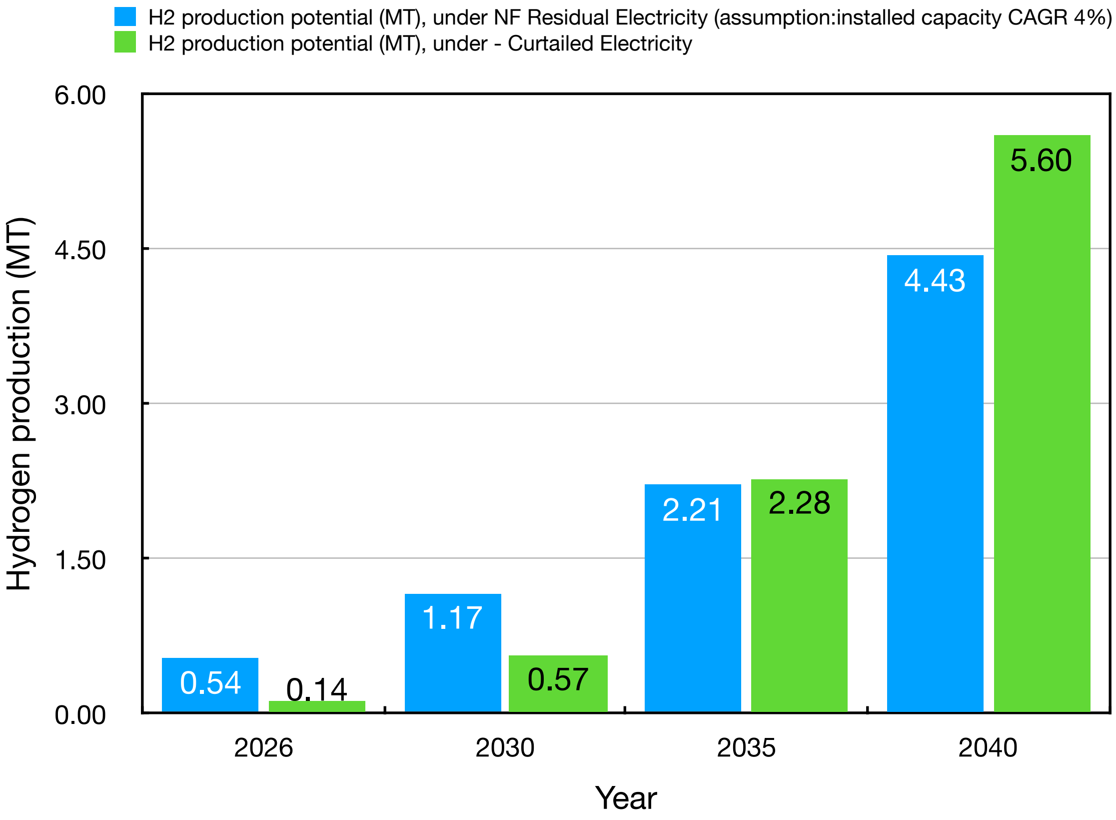


Fig 10: Comparison of green hydrogen production potential from residual NF electricity & curtailed electricity
(NF = Non-Fossil)

Note: The Blue bars in Fig 10 won't even exist if the 'Miscellaneous' category from the priority sectors is included. The **green hydrogen production from residual non-fossil electricity excluding the 'Miscellaneous' category is the most optimistic case**.

The 2030 curtailment estimate deserves explanation. According to developers, nearly 4 GW of commissioned renewable capacity was being curtailed during peak solar hours even as of early 2026 due to inadequate transmission margins [17]. With 300 GW of additional non-fossil capacity coming in by 2030 and transmission infrastructure lagging by 3-5 years behind generation commissioning, curtailment in absolute TWh terms could reach upto 4% of the 900 TWh non-fossil generation base.

The Economic Trap: Why ‘Free’ power is expensive

Curtailed electricity is fundamentally different from residual grid electricity in one important way - **it has zero opportunity cost**. It is being wasted. This is the narrative one often hears. The most dangerous misconception in green hydrogen narratives is also that **zero-cost electricity equals low-cost hydrogen**. For e.g. An electrolyzer co-located at a solar park in Rajasthan consuming curtailed midday power does not compete with any other sector's demand, because that electricity was going to be thrown away anyway. This makes curtailment-fed hydrogen the one genuinely additive, non-competing source of green H_2 feedstock in the entire model.

However, and this is where the engineering realism bites again. In reality, the **Levelised Cost of Hydrogen (LCOH) is highly sensitive to the Capacity Factor (CF)** of the electrolyser. Curtailment is intermittent by nature. It happens for 4-6 hours around solar noon on days when demand is low.

- **The CAPEX Penalty**: An electrolyser running only on curtailed power would have very low capacity factor perhaps 10-15% which dramatically increases the capital cost per kg of hydrogen produced.

- **The non-fossil electricity consumer**: Now if the same electrolyser is not only running on curtailed power but also from non-fossil electricity, then it is competing with other priority sectors for the same electrons. Detailed discussions on this were done in Section III - The Resource Competition Framework.

- **Cost Amortisation**: One would need roughly 6 to 8 times more electrolyser capacity to produce the same annual output compared to a unit running at 80% capacity factor on dedicated non-fossil electricity. That means to produce 1 kg of hydrogen at a 15% CF, the fixed capital costs (CAPEX) must be amortised over 80% fewer units of output.

Therefore, even if the electricity is free, the high CAPEX-per-kg often makes ‘curtailed hydrogen’ more expensive than hydrogen produced using more expensive, steady grid power and the moment one connects the electrolyser to the grid, it is competing with the priority sectors for the ‘green electrons’.

The Curtailment Volume Gap

A common rebuttal to the ‘Resource Competition’ argument is that India can simply use curtailed electricity - power that the grid cannot absorb - to produce green hydrogen. This section stress tests that assumption by calculating the maximum theoretical hydrogen yield from projected curtailment, assuming 100% of wasted electrons are diverted to electrolysers.

The plot of potential green hydrogen production from curtailed electricity against the three demand scenarios (mentioned in Section IV.) makes the volume gap viscerally clear. This plot is shown Fig 11. Even under this idealised scenario where hydrogen faces zero competition for wasted electrons:

- **Scenario 3 (2% CAGR)**: Green hydrogen from curtailment only meets demand in 2060.
- **Scenario 2 (3% CAGR)**: The crossover point is delayed further to 2066.
- **Scenario 4 (4.5% CAGR)**: Curtailed electricity never catches up demand within the 2070 horizon.

While the National Green hydrogen Mission views curtailment as a low-cost feedstock, this accounting ignores the **Decarbonisation Deficit** it creates elsewhere in the economy. When non-fossil electricity is curtailed, the total pool of green electrons available to the nation shrinks. By diverting the curtailed electricity specifically for hydrogen production, the green-energy targets of priority sectors is being delayed due to non-availability of green electrons. Fig 12 captures this essence and complements Fig 11. The main takeaways from Fig 12 are as follows:

- **Gross Demand**: The amount of non-fossil power these sectors should have received (blue bar + grey bar) based on their pro-rata share of total gross generation.
- **Net Allocation**: The actual amount (blue bar) they actually receive after curtailment is removed from the pool.
- **The Deficit**: The green-energy gap (grey bars) that must now be filled by fossil fuels.

The above data reveals that curtailed electricity creates a massive compounding deficit for the rest of India's sectors. By 2070, the deficit grows to a staggering number ~3500 TWh and that means in order to produce green hydrogen, India must force its priority sectors to remain dependent on fossil sources that could have been decarbonised if that curtailment were solved through better grid management or storage instead.

Curtailed electricity projections until 2070 under a non-optimal grid infrastructure is given in Appendix 3.

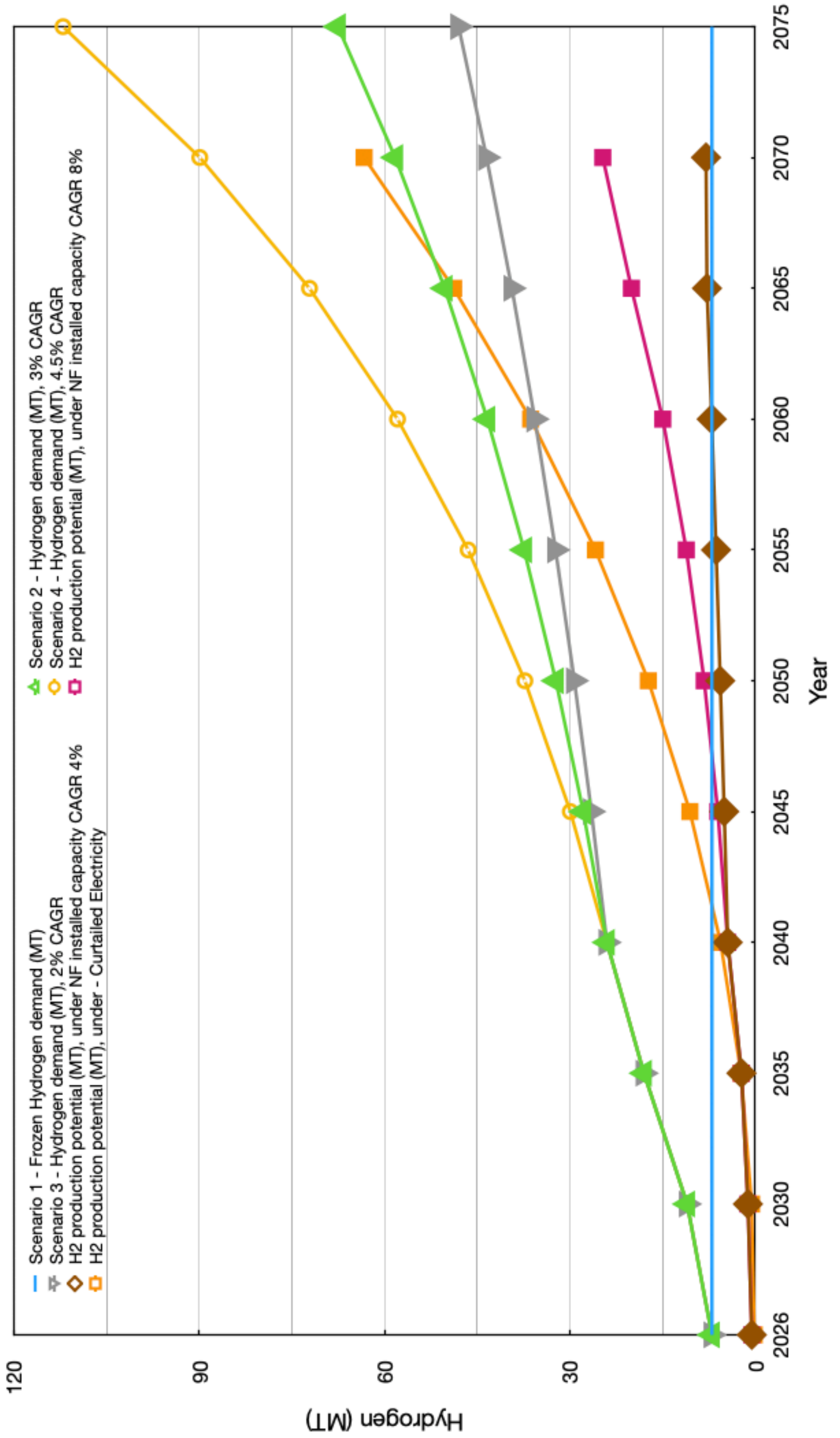


Fig 11: India Green Hydrogen production from curtailed electricity (2026-2070) - Stress testing against three demand scenarios

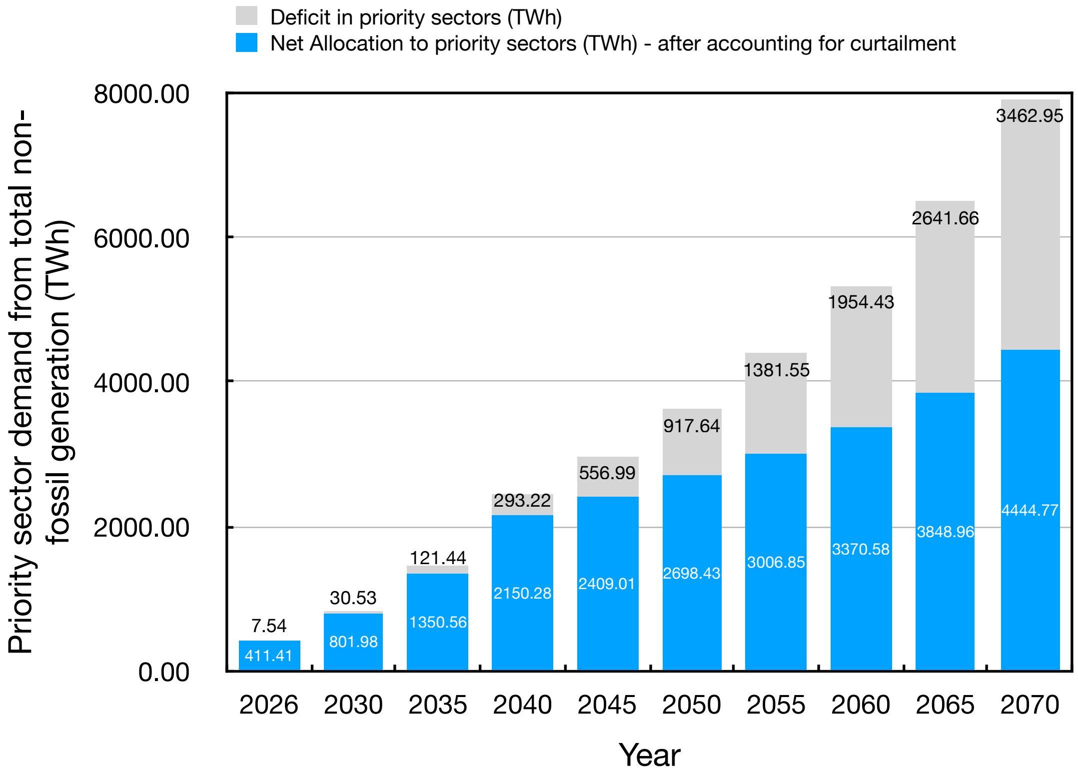


Fig 12: Visualisation of the deficit in priority sectors due to curtailment

The most critical takeaway is not that green hydrogen from curtailed electricity eventually crosses the demand curve, but the area between the curves for the next 40 years.

- Between 2026 and 2060, India faces a cumulative supply-demand gap of **tens of million of tonnes.**
- For the prime years of India's industrial transformation (2026-2050), the 'free' curtailed energy provides less than 20% of what the economy requires.

Physical Limits to Curtailment Growth

The model assumes curtailment reaches 12% by 2040 and continues to scale. The scaled-up data for curtailment until 2070 is given in Appendix 3. However, a grid that operates with persistent, double-digit curtailment is a grid in structural failure. As transmission infrastructure (ISTS) improves and grid management becomes more sophisticated, **the total pool of curtailed energy is actually likely to shrink**, not grow. This in turn will reduce the share of curtailed electricity going into green hydrogen production and thus bringing down the volume of potential hydrogen production.

Now the problem with analysing the green hydrogen production potential solely with curtailed electricity is as follows:

- Assumes entire curtailed electricity goes into hydrogen production.
- Assumes demands for priority sectors are already met which is not the case.
- Assumes BESS and other long term storage technologies do not progress with time.

Therefore, if the best-case scenario for green hydrogen relies on energy that won't be sufficient for another 35 years, then curtailment is not a bridge to a hydrogen economy, it is a marginal supplement that arrived four decades too late.

The 'Two-Plate' feeding model: Residual and curtailed non-fossil electricity

To understand the physical limits of green hydrogen, we must distinguish between the **Theoretical Maximum** (the policy-maker's view) and the **Conservative Baseline** (the engineer's view)

A. In the idealised scenario (zero curtailment)

$$\text{Gross Generation} - \text{Priority Demand} = E_{\text{residual},H2}$$

$E_{\text{residual,H2}}$ = Residual electricity (for green hydrogen production)

The above equation **is applicable in a perfect world** where the grid is a giant, infinite battery, and the transmission is perfect. Whatever the priority sectors don't consume, the electrolysers can feed on it. This is the 'theoretical maximum' possible for green hydrogen production. While useful for high-level modelling, as used in Sections III. and IV, it assumes every green electron generated can be physically delivered to an electrolyser.

B. In the real-world scenario (with curtailment)

$$\text{True Residual Electricity} = (\text{Gross Generation} - \text{Curtailment}) - \text{Priority Demand}$$

In reality, grid congestion and technical ramping floors for coal plants lead to curtailment.

In this scenario, there is a **net grid surplus**. This is the electricity that survived the grid constraints and is still available for green hydrogen production. Now if curtailment is first subtracted and then the need of the priority sectors fulfilled, then hydrogen is competing for ‘usable’ grid power. This is the most conservative and safest way of modelling the energy needed for electrolysis plants for green hydrogen production. In this case, the electrolysis plants enjoy the double benefit - curtailed power and net grid surplus. However, in the present Indian electricity system context, this is not practically feasible.

The Dual-feed capability of Hydrogen

Often in energy modelling, curtailment and hydrogen are treated differently than other sectors. This is because hydrogen electrolysers don’t need a steady 24/7 schedule to operate (OPEX is another issue to be dealt with and not in the scope of this report) and this is an unique advantage of hydrogen.

- **Priority sectors**: They must be fed from Net Generation (Gross minus Curtailment). They cannot be fed curtailed power because they need power when they want it.
- **Hydrogen production**: It can actually be fed on both
    - Residual non-fossil electricity (or left over usable grid power) or
    - Curtailment. If one puts the electrolyser right next to the solar farm, it can use the electricity that the grid refused to take.

While curtailment-fed hydrogen is "genuinely additive" and does not compete with other sectors, it is an economic outlier. It can support small-scale, co-located pilot projects in Rajasthan or Tamil Nadu, but it cannot be the foundation of a 24 MT green hydrogen 2040 national mandate. Any mission that relies on "waste" electrons as its primary feedstock is essentially building its foundation on a resource that the grid is actively trying to eliminate through better storage and transmission. The government of India is spending billions on other technologies as well such as BESS, Pumped hydro, and ISTS transmission lines, specifically to eliminate curtailment.

The Ethical and Policy Conflict

This modelling exposes a fundamental policy contradiction. The government is essentially:

a. Setting decarbonisation targets for the grid and priority sectors

b. Allowing curtailment due to infrastructure lags

c. Diverting that curtailment to a new sector - Green hydrogen

There is no such thing as ‘Surplus’ green energy in a grid that is still burning coal to meet base demand (of priority sectors). Any electron diverted to hydrogen is an electron stolen from one of the priority sector’s green quota. As Fig 9 and 11 clearly demonstrate, the deficit created by this choice grows exponentially, reaching catastrophic levels by mid-century.

VI. Conclusions and the reality check

India's **green hydrogen ambition is bold, well-intentioned, and politically compelling**. The National Green Hydrogen Mission's target of 5 million tonnes per annum by 2030 has generated significant investor interest and policy momentum. This analysis, however, subjects that ambition to a rigorous engineering and electricity systems lens, and the findings are sobering. The current trajectory of India's Green Hydrogen mission suggests a **fundamental misalignment between industrial policy and grid reality**. India cannot reach its Green Hydrogen ambitions if it treats H_2 as a "by-product" of grid decarbonization.

The electricity arithmetic does not support the ambition:

India's non-fossil installed capacity is projected to grow from 272 GW in 2026 to 1,200 GW by 2040 - a near five-fold expansion that represents one of the most aggressive renewable energy buildouts in history. Yet installed capacity is not the same as usable electricity. With solar and wind capacity utilisation factors of 19–26%, this translates to non-fossil generation of only 450 TWh in 2026, rising to 2,700 TWh by 2040. Throughout this entire period, total electricity demand - growing from 1,720 TWh to 4,200 TWh - consistently and substantially exceeds non-fossil generation. Fossil generation remains indispensable to fill the gap. There is **no structural electricity surplus from which green hydrogen can be drawn**.

The pro-rata allocation reveals a harder truth:

When India's electricity demand is allocated across all consuming sectors — industry, households, agriculture, commercial, transport and miscellaneous — using the CEA's own sectoral breakdown that sums to 100%, the residual available for green hydrogen electrolysis from the grid is effectively zero. Every unit of non-fossil electricity generated is needed to reduce fossil consumption in the primary grid. Diverting it to electrolyzers instead means burning more coal elsewhere - which defeats the purpose of green hydrogen entirely.

The only legitimate feedstock sources are structurally limited:

The only non-competing electricity available for green hydrogen production is curtailed non-fossil electricity that the grid physically cannot absorb. Residual non-fossil electricity is literally not available when the ‘Miscellaneous’ category is also included in the list of priority sectors. Based on current and projected curtailment data, this yields a green hydrogen production ceiling of approximately 0.14 MT in 2026, rising to 5.56 MT by 2040. Against a total hydrogen demand growing from 6.5 MT to 24 MT over the same period, **neither curtailed electricity nor residual non-fossil electricity is able to meet even 25% of the total demand**. The absolute gap widens from 5.96 MT to 19.57 MT. The NGHM's 5 MT target for 2030 exceeds this corrected ceiling by a factor of 4.3 times (when considering residual non-fossil electricity) and 8.8 times (when considering curtailed electricity).

The crossover horizon is distant and conditional:

Extending the analysis to 2070 under multiple demand scenarios, a genuine crossover - where green hydrogen supply meets total hydrogen demand - does not occur before 2060 even under optimistic assumptions. The crossover only occurs under the assumption that curtailed electricity grows exponentially, any other assumption prevents even that crossover to occur. The crossover requires the simultaneous occurrence of two conditions: steady non-fossil capacity growth (4% CAGR) and a sharp deceleration in hydrogen demand growth to either 2% or 3% CAGR (scenarios 3 and 2 respectively in Fig 9 and 11 respectively) as direct electrification displaces hydrogen in substitutable applications. Under the base case demand trajectory of 4.5% CAGR, no crossover occurs within the modelled horizon of 2075.

An aggressive non-fossil capacity addition of 8% CAGR post 2040 is practically impossible because of the constraints in land area, grid capacity and demand ceiling. Hence, although a crossover (of green hydrogen with demand) is mathematically feasible on an earlier timeframe, with an aggressive 8%CAGR build-out, this cannot be achieved practically and therefore less credible for any planning.

Relying on "waste" electrons (curtails electricity) is a strategy of planned obsolescence. As BESS and Inter State Transmission Infrastructure (ISTS) improve, the very resource this strategy relies on - curtailment - will actively shrink.

The Decarbonisation Trilemma

To reach its targets and 2040 goals, India faces three mutually exclusive paths, each with a profound ‘Carbon Opportunity Cost’:

- **The Over-Build path:** Meeting the 2040 deficit would require an additional 300-400 GW of dedicated RE capacity purely for electrolysis, over and above the existing 1200 GW grid target. This number is quite critical and must be considered in future policy framings.

- **The Grid Conflict:** Every 1 TWh of solar diverted to an electrolyser instead of the grid keeps ~800 tonnes of CO_2 active in the system via coal-fired base load. If that 1 TWh goes to H_2 production, it only displaces the carbon from "Grey Hydrogen" (natural gas). If the grid is still 40% fossil-based in 2040, using green electrons for H_2 while coal still powers homes is, from a purely atmospheric perspective, inefficient decarbonisation.
- **The Import Reality:** If domestic production cannot scale due to land or grid constraints, India must prepare for a future of 'Green Imports' (Ammonia from Australia or Africa) to avoid stalling its industrial growth.

Strategic Alternatives: Bridges or Traps?

The Pink hydrogen Pivot (Nuclear)

The Nuclear Energy Mission launched in 2025 (with a ₹ 20,000 crore outlay) [18] provides a critical alternative.

- **Small Modular Reactors (SMRs)** offer always-on power that can keep electrolysers running at **>90% capacity factors**, solving the CAPEX amortisation problem that cripples solar-powered units.
- Unlike solar, which requires massive land footprints (projected at 2% of India's total area by 2070), SMRs can be co-located at retired coal plants, utilising existing water and transmission infrastructure.

The Blue Hydrogen 'Gas Deficit'

While used as a bridge in the EU, Blue Hydrogen (Gas + Carbon Capture) remains a niche for India. With over 50% of natural gas imported, the added cost of **Carbon Capture and Storage (CCS)** often makes it more expensive than the current domestic green hydrogen price of **\$3.5 - \$4.0 /kg**.

Geological Storage: India's proven capacity for large-scale CO_2 sequestration (depleted oil/gas fields) is limited compared to the US or North Sea, making the "S" in CCS a logistical nightmare.

The Carbon Wall: CBAM and Sectoral Mandates

By 2026, the Carbon Border Adjustment Mechanism (CBAM) [19] has become a definitive phase of global trade.

- **Export Risk:** Indian steel (emitting ~2.1 tCO_2/tonne) faces an immediate carbon duty of €65-70 per tonne when entering the EU.
- **Sectoral Mandates:** Because the economics do not favour green hydrogen over grey hydrogen, the only path forward is **Sectoral Purchase Obligations**. However, mandating consumption without fixing the 'Green Ceiling' in production risks creating a market of 'pseudo-green' accounting rather than actual molecular decarbonisation.

Domestic Cost: As India potentially implements its own carbon credit trading system (CCTS), the "cheapness" of Grey Hydrogen will evaporate.

What will be India's choice?

Is India's priority to have a clean grid by 2040 or a clean industrial sector? **Data suggests that India might not be able to have both**. India's electricity system will remain in structural deficit relative to demand well past 2040. In that context, every unit of renewable energy built has a higher-value use than electrolysis — directly powering homes, factories, electric vehicles and cooling systems that currently run on fossil fuels. Green hydrogen earns its place only where no direct electrical alternative exists. That is a significantly narrower mandate than current policy envisions, but it is the one the physics and the electricity numbers consistently support. When one moves past the policy rhetoric and audits the electrons, one finds that green hydrogen is not a plug-and-play solution for the existing grid, but a competitor for a finite and already strained resource. Data suggests that without dedicated, non-grid generation and transitional blue/grey support, the industrial sector will face a massive energy deficit that could stall GDP growth.

A Roadmap Beyond the Mirage

The findings are conclusive. India cannot reach its Green hydrogen ambitions if it treats H_2 as a byproduct of grid decarbonisation.

- **Accept the 2060 timeline**: Policy must pivot from a '2030 Production Goal' to a '2060 Scale-Up Goal'. The intervening decades must be treated as a pilot phase focused on technical efficiency rather than volume.

- **Sovereign Energy Islands**: To avoid the ‘decarbonisation deficit’ (for meeting hydrogen demand), India must move exclusively toward Behind-the-Meter dedicated energy parks. Only by decoupling hydrogen from the civil grid can India ensure that the electricity is genuinely additive. However, there is a conflict here which must be addressed - If India uses its best high-yield solar land in Rajasthan or wind sites in Tamil Nadu specifically for hydrogen, those "prime" electrons are not helping to shut down coal plants.

- **Prioritise Grid Stability**: Curtailed electricity should be viewed as a resource for BESS (Battery Energy Storage) first. Using it for hydrogen (~40% round-trip efficiency) while the grid needs storage (at ~85% round-trip efficiency) is an engineering inefficiency India cannot afford.

Green hydrogen is not a missing link, it is a luxury molecule. Data suggests that without dedicated, non-grid generation, the pursuit of mass-scale green hydrogen will create an energy deficit that stalls national decarbonisation rather than accelerating it.

Disclaimer:

This article has been written by Dr. Vikrant Venkataraman, Director & Founder of VenkaCon Consulting (www.venkacon.com). The analysis and data are based on pure facts that is available on the internet and the views and opinions expressed are solely meant for providing a practical and holistic view on the topic of Electrolysis and Green Hydrogen which has become an important topic in India's decarbonisation journey.

List of Abbreviations

Abbreviation	Expansion
BESS	Battery Energy Storage System
BTM	Behind The Meter
CAGR	Compounded Annual Growth Rate
CAPEX	Capital Expenditure
CEA	Central Electricity Authority
CCS	Carbon Capture & Storage
CUF	Capacity Utilisation factor
DRI	Direct Reduced Iron
EV	Electric Vehicle
GW	Giga Watt
ISTS	Inter State Transmission System
LCOH	Levelised Cost of Hydrogen
MMT	Million Metric Tonnes
MT	Million Tonnes
NDC	Nationally Determined Contribution
NF	Non-Fossil
NGHM	National Green Hydrogen Mission
OPEX	Operating Expenditure
PV	Photo Voltaic
RE	Renewable Energy
SMR	Steam Methane Reforming
TPA	Tonnes per Annum
TWh	Terra Watt hours

Appendix 1 - CUF of other non-fossil sources

1. Nuclear (The High-CUF Hero)

CUF: 80–85%

Likelihood of Dominance: Low.

Reason: Nuclear has a massive "Multiplier" effect, but in India, the gestation period (time to build) is 10–15 years. While India has ambitious nuclear plans, it is a "slow and steady" builder. It cannot keep up with the 4–8% CAGR required for the 2070 goal. It will remain a "supporting actor" (~5–8% of the mix), not the lead.

2. Offshore Wind (The Night-Shift Hero)

CUF: 40–50%

Likelihood of Dominance: Moderate.

Reason: Offshore wind is more consistent than onshore. However, it is significantly more expensive per MW. India is just beginning its offshore journey in Gujarat and Tamil Nadu. Even if it grows, it likely won't "dominate" because solar is just so much cheaper.

3. Hydro and Pumped Hydro (The Battery Hero)

CUF: 35–45%

Likelihood of Dominance: High as a stabilizer, Low as a primary source.

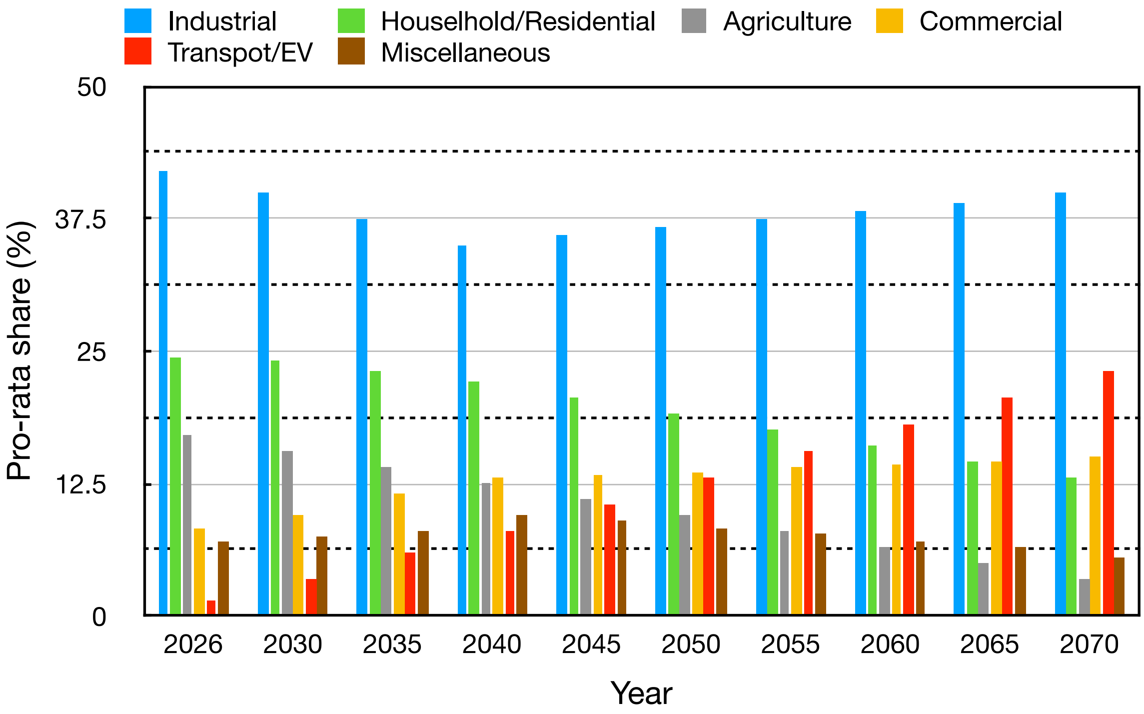
Reason: Large hydro has environmental and "human cost" (resettlement) hurdles. Its role in 2070 won't be to generate the bulk of the TWh, but to act as a giant battery to manage the solar peaks.

The "Solar Gravity" Problem

The reason solar will continue to dominate (and thus pull the average CUF down) is pure **Economics**. Solar is currently the cheapest way to add a "Green Watt" to the system. In a free market or a government-tender system, 10 GW of Solar will always be built faster and cheaper than 2 GW of Nuclear or Wind. As a result even if we add Nuclear and Wind, the sheer volume of Solar capacity being added will be so high that it will dilute the total system efficiency.

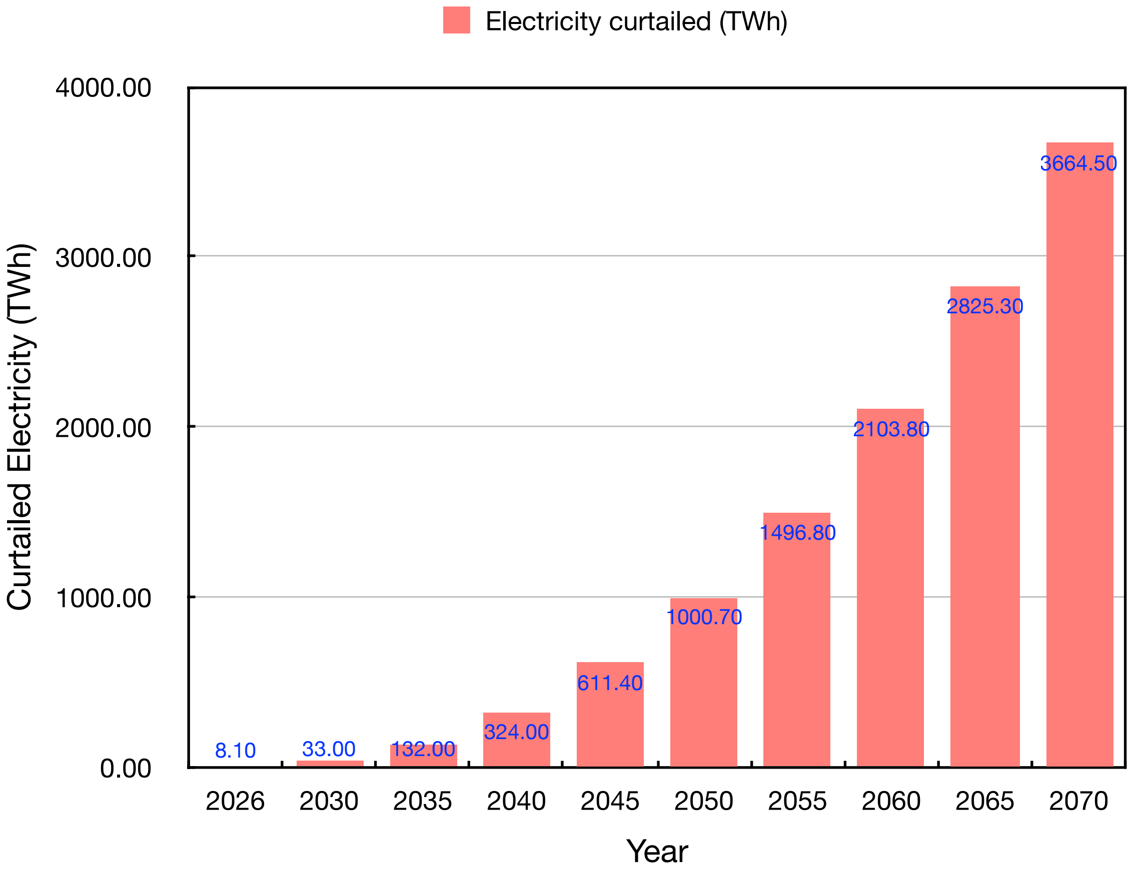
Appendix 2 - Pro-rata share of different priority sectors

The pro-rata allocation share of the different priority sectors.



Appendix 3 - Curtailed Electricity estimates & projections (2026-2070)

Growth in curtailed electricity as non-fossil capacity and generation grow. The chart below assumes a non-optimised grid infrastructure, leading to massive curtailment. This curtailment data has been projected for non-fossil capacity addition of 4% CAGR.



References:

[1] https://fuelengineering.in/india-green-hydrogen-projects-2026/

[2] https://www.pib.gov.in/PressReleasePage.aspx?PRID=2245157&reg=3&lang=1#:~:text=India Commissions 8,000 TPA Green,and Hindustan Petroleum Corporation Limited.

[3] https://gh2.org/countries/india

[4] https://www.pib.gov.in/PressNoteDetails.aspx?id=155990&NoteId=155990&ModuleId=3&reg=3&lang=2

[5] https://fuelcellsworks.com/2025/11/11/green-investment/jsw-commissions-green-hydrogen-plant-to-decarbonize-dri-steelmaking-in-karnataka

[6] https://www.solarmango.com/dictionary/capacity-utilization-factor/

[7] https://en.wikipedia.org/wiki/Capacity_factor

[8] https://renewablewatch.in/2026/03/25/cea-issues-transmission-plan-to-integrate-over-900-gw-non-fossil-fuel-capacity-by-2035-36/

[9] https://www.pib.gov.in/PressReleasePage.aspx?PRID=2120729&reg=3&lang=2

[10] https://www.crfindia.org/publications/issue-brief/the-missing-half-of-indias-green--hydrogen-strategy

[11] https://ieefa.org/resources/enabling-sustainable-demand-green-hydrogen-india

[12] https://www.pib.gov.in/PressReleasePage.aspx?PRID=2215187&reg=3&lang=2#:~:text=1.,November 2025 is 55.57 GW.

[13] https://www.iea.org/countries/india/electricity

[14] https://ember-energy.org/app/uploads/2026/01/EMBER-Report-Beyond-capacity-why-Indias-power-system-must-get-flexible-PDF.pdf

[15] https://www.thecore.in/economy/india-solar-energy-renewable-net-zero-rajasthan-gujarat-859376

[16] https://openthemagazine.com/india/why-indias-power-equipment-sector-could-see-5-years-of-strong-growth

[17] https://www.mercomindia.com/rajasthan-curtails-4-gw-of-renewables-as-transmission-delays-mount

[18] https://orfme.org/research/big-aspirations-for-small-modular-reactors-understanding-indias-strategy-on-smrs/

[19] https://eurometal.net/cbam-reshapes-indias-steel-access-to-europe-webinar/