Domestic Market Pathways and Carbon Abatement Economics of Green Ammonia in India

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Abstract

India's growing ammonia demand, historically dominated by the fertilizer sector, creates a significant opportunity to establish a large-scale domestic green ammonia industry. This paper examines how strategically leveraging domestic demand can position India as a globally competitive producer. Using evidence from the Solar Energy Corporation of India's Tranche I auction, which discovered tariffs between ₹49.75/kg and ₹64.74/kg (≈USD 570–740/t), the analysis shows that green ammonia is approaching cost parity with grey ammonia derived from imported natural gas. Under favorable gas price conditions, the implied carbon abatement cost falls as low as USD 30–40 per tonne of CO_2, underscoring the economic viability of green ammonia for decarbonization. Anchoring early production in the fertilizer sector, followed by gradual expansion into steel, refining, and shipping, provides investment certainty, drives economies of scale, and strengthens the domestic supply chain. The findings highlight India's domestic-first strategy as a replicable model for other emerging economies, where competitive auctions can bridge the green premium, secure initial demand, and prepare the foundation for export competitiveness. Policy implications include the phased introduction of blending mandates, establishment of certification frameworks, and investment in export infrastructure, positioning India both as a low-cost decarbonizer for domestic industries and as a credible supplier in global green value chains.

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Keywords

Green ammonia; Reverse auctions; Carbon abatement cost; Fertilizer sector; Hydrogen derivatives; Industrial decarbonization

Highlights

- SECI auction shows green ammonia nearing parity with grey ammonia in India.
- Carbon abatement cost as low as USD 30–40/tCO_2 under favorable gas prices.
- Fertilizer demand provides stable anchor for large-scale green ammonia projects.
- India's domestic-first model offers replicable lessons for emerging economies.
- Policy on blending, certification, and ports is vital for global competitiveness.

1.0 Introduction

Mitigating climate change requires rapid decarbonization across all sectors, with particular urgency in hard-to-abate industries such as steel, refining, chemicals, and maritime shipping [12,15]. While renewable electricity has transformed the power sector, industrial processes and long-distance transport remain predominantly fossil fuel–dependent [21]. In this context, green ammonia (NH_3), synthesized from renewable hydrogen and atmospheric nitrogen, has emerged as a pivotal hydrogen derivative and zero-carbon fuel. Its high energy density, tradability through existing ammonia infrastructure, and dual role as both a feedstock and fuel position it as a cornerstone of the global energy transition [3,2]. Critically, green ammonia enables the cost-effective transport of renewable energy from resource-rich regions to demand centers worldwide [17].

India is the world's second-largest ammonia consumer, with demand anchored by the fertilizer sector, which accounts for over 60% of the country's ammonia consumption [10]. The current demand is estimated at 18–19 million tonnes per annum (Mtpa) and is projected to rise modestly at a ~1% CAGR, reaching ~20 Mtpa by 2040 [13]. Beyond fertilizers, additional demand is expected from emerging industrial applications in green steel, refining, and chemicals, alongside the maritime shipping sector, where ammonia-fueled engines are projected to be commercialized by 2028–2030 [4,6]. This combination of stable baseline demand and high growth potential provides a unique platform for scaling the domestic green ammonia industry.

This study argues that cultivating strong domestic demand is the most effective and resilient strategy for India to establish cost leadership and global competitiveness in green ammonia. Anchoring initial large-scale production to assured domestic offtake—particularly in fertilizers—reduces investment risk, accelerates learning-by-doing, and unlocks economies of scale [16,22]. A domestic-first approach strengthens industrial resilience and enhances supply-side credibility, positioning India as a reliable and low-cost supplier to international markets, such as the European Union, Japan, South Korea, and Southeast Asia [14,11].

The remainder of this paper is organized as follows. Section 2 details the techno-economic methodology used for demand and cost modelling. Section 3 presents the results on cost competitiveness, carbon abatement economics, and domestic demand scenarios. Section 4 interprets the findings and highlights the implications for policy and industrial strategy. Section 5 benchmarks India's position relative to its international peers. Section 6 concludes with policy insights for advancing a domestic-first strategy that anchors India's role in global decarbonization.

2.0 Methodology

2.1 Analytical Framework

This study employed a techno-economic framework to evaluate the market viability and carbon abatement potential of green ammonia in India. The analysis integrated three components:

- Demand projection: A bottom-up projection of domestic demand through 2035 [13].
- Cost modelling: Estimation of the Levelized Cost of Ammonia (LCOA) for both green and grey ammonia, validated against empirical auction data [22,15].
- Abatement economics: Calculation of the Carbon Cost of Abatement (CCA) to assess the relative competitiveness of green ammonia under climate policy scenarios [21].

2.2 Demand Projection Framework

The domestic demand for green ammonia is projected to 2035 based on the substitution potential in established industries and adoption timelines in emerging sectors. The key assumptions are as follows:

- Fertilizers: Current demand of ~18 Mtpa, growing at ~1% CAGR. A substitution potential of up to 20% is assumed for existing urea plants and up to 100% for complex fertilizers (DAP/NPK) without major retrofitting [10].
- Industrial applications: Gradual uptake in refining and chemical manufacturing, contingent on the scaling of pilot projects and supportive policy mandates [17,18].
- Maritime shipping: Significant demand is expected post-2030, following the anticipated commercialization of ammonia-fuelled engines (2028–2030) [5,1].

2.3 Levelized Cost of Ammonia (LCOA) Modelling

The LCOA was estimated for a representative utility-scale green ammonia plant in India, with grey ammonia costs modelled on the delivered price of natural gas. Core parameters are drawn from recent techno-economic literature and industry reports [16,9].

Table 1: Key techno-economic parameters used for Levelized Cost of Ammonia (LCOA) modelling in India.

Source: Author's compilation based on [16,9].

Parameter	Value Range
Renewable electricity cost	USD 30–60 / MWh
Electrolyzer CAPEX	USD 600–800 / kW
Electrolyzer efficiency	68–75%
Ammonia plant CAPEX	USD 900–1500 / annual tonne
Weighted Average Cost of Capital (WACC)	8–10%
Delivered natural gas price (grey ammonia)	USD 10–12 / MMBTU

2.4 Carbon Cost of Abatement (CCA) Calculation

The CCA quantifies the cost of avoiding one tonne of CO_2 emissions by substituting gray ammonia with green ammonia. It is calculated as:

$$\mathrm{CCA} = \frac{LCOA_{\mathrm{green}} - Cost_{\mathrm{grey}}}{Emissions_{\mathrm{grey}} - Emissions_{\mathrm{green}}}$$

For this analysis, the emissions differential reflects the displacement of natural gas–based ammonia production, with an emissions intensity of approximately 2.3–2.5 tCO_2 per tonne of ammonia [12,21].

This methodological framework provides an integrated basis for assessing India's green ammonia potential across three dimensions: cost-competitiveness, demand trajectory, and abatement economics. The results of this analysis are presented in Section 3.0.

3.0 Results

3.1 Summary of Key Findings

The analysis shows that green ammonia in India is on the cusp of commercial viability, a conclusion strongly validated by recent large-scale public auction results. The discovered tariffs confirm that production costs are approaching parity with conventional grey ammonia, thereby establishing a competitive carbon abatement cost and strengthening the economic rationale for accelerated adoption [22,15].

3.2 Cost Competitiveness Analysis

Our LCOA model projects a base case production cost for green ammonia in the range of ₹52–56/kg (USD 630–680/t). This is close to the prevailing cost of grey ammonia, estimated at ₹46–48/kg (USD 540–570/t), assuming a delivered natural gas price of USD 10–12/MMBTU [12,21].

These modeled costs were empirically validated by the first tranche of auctions conducted by the Solar Energy Corporation of India (SECI). The auctions contracted a total of 724,000 tonnes per annum of supply for the fertilizer sector, with discovered tariffs spanning ₹49.75–64.74/kg [22].

Table 2: Summary of SECI Green Ammonia Auction Outcomes (Tranche I). Source: Author's compilation based on [22].

Offtaker & Location	Contracted Capacity (tpa)	Winning Developer	Discovered Tariff (₹/kg)	Equivalent Tariff (USD/t)*
IFFCO – Paradeep, Odisha	100,000	ACME Cleantech	49.75	570
Madras Fertilizers – Chennai, TN	4,000	Suryam International	50.00	567
Coromandel International – Kakinada, AP	85,000	Jakson Green	50.75	583
Krishna Phoschem – Madhya Pradesh	70,000	NTPC Renewable Energy	51.80	595
Coromandel International – Vizag, AP	50,000	ACME Cleantech	51.89	596

MB Agro Products – MP	60,000	Oriana Power	52.25	600
GNFC – Bharuch, Gujarat	50,000	Onix Renewable	52.50	603
MB Agro Products – Maharashtra	70,000	SCC Infrastructure	53.05	609
IFFCO – Kandla, Gujarat	100,000	ACME Cleantech	54.73	629
Paradeep Phosphates – Odisha	75,000	ACME Cleantech	55.75	640
Mangalore Chemicals – Karnataka	15,000	SCC Infrastructure	57.65	658
Paradeep Phosphates – Goa	25,000	ACME Cleantech	62.84	720
Indorama India – Haldia, WB	20,000	ACME Cleantech	64.74	739

**USD conversions assume an exchange rate of USD 1 = ₹87.5 (as used in SECI's forward-looking analysis).*

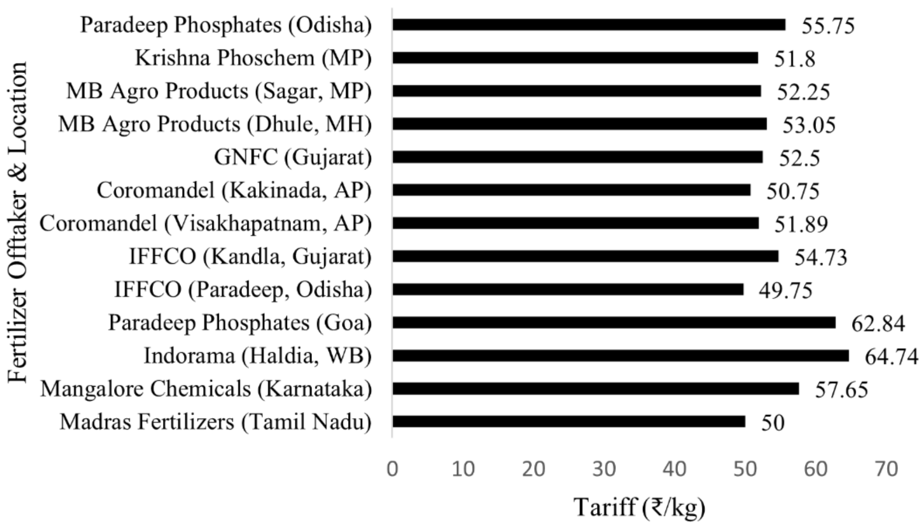

Figure 1: Tariff spread across winning bids in SECI's Tranche I green ammonia auction (₹/kg). Source: Author's analysis based on SECI auction data [14,15].

3.3 Carbon Abatement Economics

The narrow cost differential between green and grey ammonia translates into a calculated Carbon Cost of Abatement (CCA) in the range of USD 30–40 per tonne of CO_2. This positions green ammonia among the most cost-effective decarbonization pathways, particularly when benchmarked against prevailing international carbon market prices [12,9].

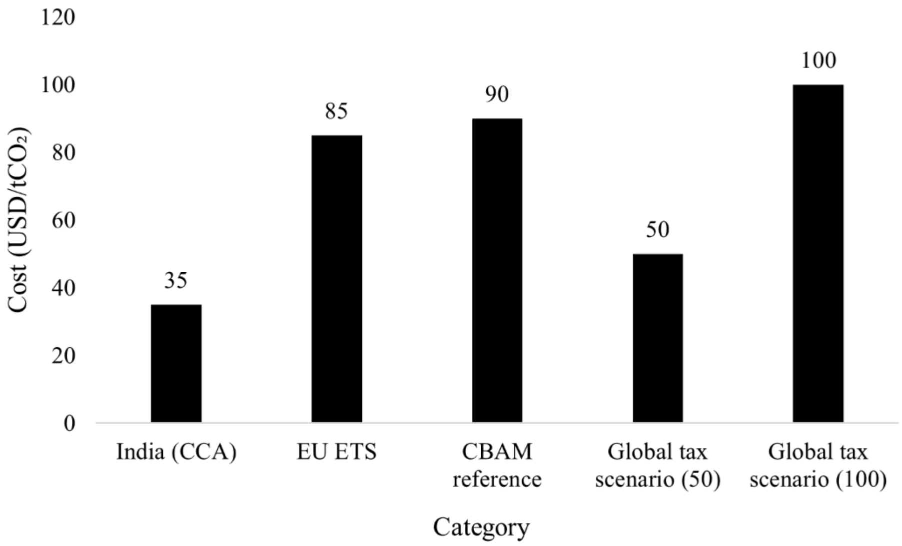

Figure 2: Comparison of India's carbon cost of abatement (CCA) with international carbon price benchmarks. Source: Author's analysis based on [12,13,9].

3.4 Domestic Market Trajectory

Sectoral substitution modelling suggests that India's domestic green ammonia market could expand rapidly over the next decade. Under a moderate adoption scenario, demand may reach ~4 Mtpa by 2035, with a high adoption pathway enabling up to 6 Mtpa [17,10].

Table 3: Projected domestic green ammonia demand in India (million tonnes per annum). Source: Author's modelling based on [17,10].

Year	Low Adoption Scenario	Moderate Adoption Scenario	High Adoption Scenario
2028	0.5	0.8	1.0
2030	1.0	1.8	2.5
2032	2.0	2.9	4.0
2035	3.0	4.0	6.0

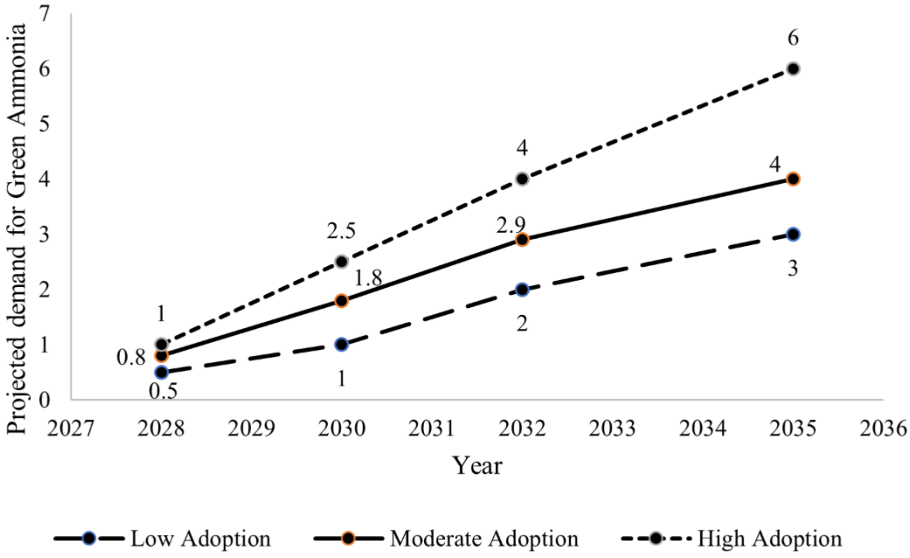

Figure 3: Projected domestic demand for green ammonia in India under low, moderate, and high adoption scenarios (2028–2035). Source: Author's modelling based on [17,10].

The results demonstrate a strong economic case for scaling green ammonia in India. The combination of near-term cost parity and low abatement costs provides compelling justification for policymakers and industry stakeholders to accelerate market creation, which is explored in the following discussion section.

4.0 Discussion

4.1 Interpreting the Significance of the Results

The results mark a pivotal inflection point for India's industrial decarbonization pathway. Achieving near-cost parity for green ammonia—validated by transparent reverse auction outcomes (Table 2; Figure 1)—reframes the transition from a long-term aspiration to an immediate opportunity. The implied carbon abatement cost of USD 30–40/tCO_2 (Figure 2) demonstrates that green ammonia is not only a climate-aligned option but also an economically rational one in markets exposed to moderate carbon pricing [12,21]. This strengthens the case for targeted policy interventions to accelerate demand creation, positioning green ammonia as a viable tool for near-term industrial transition.

4.2 Evaluating Critical Policy Levers

India's progress has been anchored by a supportive policy ecosystem, though several gaps remain.

- National Green Hydrogen Mission (NGHM). The NGHM has created a favourable environment, with provisions such as a 25-year waiver of inter-state transmission system (ISTS) charges that substantially lower renewable power costs—the largest cost component of green ammonia [10].
- SECI's Reverse Auction Model. The Tranche I auction demonstrated the effectiveness of market-based instruments in de-risking early-stage investments. By linking production directly to fertilizer offtakers, SECI reduced counterparty risk, ensured credible demand, and enabled competitive yet realistic bidding [22,15].
- Policy Gaps. Despite progress, the absence of blending mandates for green ammonia in fertilizer, refining, and chemicals creates demand uncertainty beyond initial auction volumes. Likewise, the lack of an internationally aligned certification framework and a national registry for guarantees of origin risks limiting Indian producers' access to premium markets [19]. Closing these gaps will be critical to secure investor confidence and expand market reach.

4.3 The Strategic Importance of Industrial Clustering

The auction results also reveal the decisive role of geography and logistics in cost competitiveness. The lowest tariffs were achieved for projects co-located with offtakers, such as Paradeep, Odisha (₹49.75/kg), while higher tariffs were observed for distant supply chains, such as delivery to Haldia, West Bengal (₹64.74/kg) (Table 2). This underscores the importance of developing integrated green ammonia hubs in coastal states like Odisha, Gujarat, and Andhra Pradesh, where strong industrial demand, robust port infrastructure, and high renewable energy potential converge [14,13]. Such clusters can reduce logistics costs, enable shared infrastructure, and unlock economies of scale.

4.4 The Reinforcing Pull of Global Market Drivers

Global trade policies amplify the domestic rationale for green ammonia adoption. The European Union's Carbon Border Adjustment Mechanism (CBAM) will impose levies on carbon-intensive imports such as fertilizers and steel, creating direct risks for Indian exporters reliant on grey ammonia inputs [14,11]. By substituting green ammonia in domestic production, Indian industry can mitigate these risks and capture "green premiums" in carbon-conscious markets. Aligning domestic decarbonization strategies with international compliance frameworks thus transforms potential liabilities into competitive advantages in global supply chains.

4.5 Synthesis

This discussion highlights three strategic imperatives:

1. Reinforce successful mechanisms such as SECI's reverse auctions to drive transparent price discovery.
2. Address demand uncertainty by introducing blending mandates and internationally recognized certification systems.
3. Prioritize the development of coastal industrial clusters that integrate renewable resources, port infrastructure, and industrial offtakers.

Together, these measures can consolidate India's domestic foundation while positioning the country as a cost-competitive and reliable supplier in the global green ammonia economy.

5.0 International Benchmarking

5.1 Establishing India's Competitive Position

The techno-economic evidence indicates that India’s green ammonia pathway is not only viable for domestic substitution but also competitive on a global scale. India’s structural advantage lies in the convergence of three factors: low-cost renewable electricity, a large and stable domestic demand base, and a supportive policy framework [10,15]. Together, these elements position India to emerge as a leading global supplier of low-carbon ammonia, comparable to resource-rich regions such as the Middle East, North Africa, and Chile [2,9].

5.2 Carbon Abatement Cost vs. Global Carbon Prices

India’s calculated Carbon Cost of Abatement (CCA) of USD 30–40/tCO_2 provides a critical benchmark of competitiveness. When compared with international carbon price trajectories—commonly modelled at USD 50/tCO_2 and USD 100/tCO_2 [12,13]—it becomes clear that green ammonia adoption in India is economically rational under both moderate and stringent carbon pricing regimes. As illustrated in Figure 2, India’s CCA falls well within the compliance range for mechanisms such as the EU Emissions Trading System (ETS) and the Carbon Border Adjustment Mechanism (CBAM) [14]. This alignment implies that Indian-produced fertilizers, steel, and chemicals could remain competitive in export markets exposed to carbon regulation, turning compliance obligations into strategic advantages.

5.3 Production Cost (LCOA) Comparison

Benchmarking India’s modelled Levelized Cost of Ammonia (LCOA) against peer regions further underscores its competitiveness. India’s estimated LCOA of USD 630–680/t is broadly aligned with renewable-rich geographies such as MENA and Chile, though these benefit from superior solar and wind resources [21]. India’s domestic demand anchor and policy-driven scaling reduce financing risks, enhance economies of scale, and improve resilience.

Table 4 summarizes international cost comparisons. While the United States enjoys a subsidy-driven cost advantage under the Inflation Reduction Act (IRA), which offers a USD 3/kg production tax credit for hydrogen [11], India stands out as one of the most competitive unsubsidized producers globally. This strengthens the durability of India's business case even in the absence of large fiscal outlays, highlighting its structural cost advantage relative to most peers.

Table 4: Comparative LCOA of green ammonia (USD/t, unsubsidized basis unless noted). Source: Schmidt et al. [21], Breyer et al. [2], H2Global [11].

Region/Country	Estimated LCOA (USD/t)	Key Competitive Factors
India	630–680	Low-cost solar; large domestic demand anchor; proactive policy support.
MENA	720–750	Excellent solar irradiance; established export infrastructure.
Australia	900–950	Abundant solar/wind; proximity to Asian markets; higher EPC costs.
Chile	750–800	World-class solar in Atacama Desert; export-focused.
USA (with IRA subsidies)	500–550	Significant cost advantage from IRA's $3/kg H_2 production tax credit.

The international benchmarking analysis confirms that India is positioned at the frontline of global green ammonia competitiveness. Its low abatement costs align with emerging global carbon pricing regimes, while its unsubsidized production costs compare favourably with most peers. Together, these advantages underpin India's dual strategy: advancing domestic decarbonization while building a credible long-term export role in low-carbon global value chains.

6.0 Implications for India's Role in Global Decarbonization

6.1 The Domestic Anchor for Global Ambition

The convergence of cost competitiveness, market scalability, and enabling policy support highlights a central strategic insight: India’s most credible pathway to global leadership in the hydrogen economy lies in cultivating a large-scale, stable domestic market for green ammonia [10,15]. Anchoring the transition in robust domestic demand provides price stability, fosters innovation, and shields producers from international market volatility. Unlike export-centric models, which remain vulnerable to fluctuating demand and geopolitical risk [14], a domestic-first strategy positions India as a reliable, resilient, and long-term partner in global low-carbon supply chains.

6.2 A Decarbonization Engine for Itself and the World

India’s domestic-first strategy creates a dual opportunity—enabling it to act as both a low-cost decarbonizer at home and a credible supplier abroad:

1. Low-cost decarbonizer for domestic industries. Scaling green ammonia offers a direct abatement pathway for key sectors such as fertilizers, steel, and chemicals. In fertilizers, it reduces reliance on volatile natural gas imports while supporting food security [12]. In steel and chemicals, it enables the production of “green commodities,” insulating exports from instruments such as the EU Carbon Border Adjustment Mechanism (CBAM) while improving competitiveness in carbon-regulated markets [14]. This domestic decarbonization drive simultaneously advances India’s energy security and strengthens industrial competitiveness.

2. Credible supplier to global markets. A strong domestic base functions as a supply buffer, enhancing India’s credibility as an exporter. This reduces dependence on

uncertain early-stage international offtake while enabling gradual and sustainable scaling [16]. From this foundation, export corridors to the European Union, Japan, South Korea, and Southeast Asia can be developed more resiliently. Coastal states such as Gujarat, Odisha, and Andhra Pradesh—with strong industrial clusters and port capacity—are particularly well-positioned to serve as strategic gateways for these flows [19].

6.3 The "Renewables Pull" Effect

Large-scale, low-cost green ammonia deployment could generate a broader "renewables pull" effect, wherein global energy-intensive industries relocate or expand production in regions with competitive renewable feedstocks [2]. By establishing itself as a hub for affordable green ammonia, India could attract foreign direct investment in green steel, chemicals, and advanced materials. This dynamic would accelerate domestic industrial upgrading while embedding India more deeply in high-value segments of international trade [20].

6.4 Synthesis

By strategically cultivating a resilient domestic market, India can unlock a dual advantage: advancing industrial decarbonization and energy security at home while simultaneously becoming a trusted node in global low-carbon trade. A domestic-first strategy therefore offers the most resilient and credible pathway for India to achieve long-term leadership in the hydrogen and green ammonia economy.

7.0 Conclusion

7.1 Reiteration of the Central Thesis

This study has demonstrated that anchoring India's green ammonia transition in strong domestic market pathways provides the most effective and resilient strategy for achieving industrial scale, cost leadership, and long-term stability. By leveraging its substantial internal demand base—particularly in fertilizers—India can establish a virtuous cycle of investment, cost reduction, and technological innovation, positioning itself as a globally competitive supplier of low-carbon ammonia [14,16].

7.2 Summary of Key Findings

The analysis, supported by techno-economic modelling and validated through auction outcomes, yields three central insights:

- Validated cost competitiveness. SECI auction–discovered tariffs of ₹49.75–64.74/kg confirm that green ammonia is rapidly converging toward parity with fossil-based grey ammonia [10].
- Favourable abatement economics. A carbon abatement cost of USD 30–40/tCO_2 makes green ammonia an economically rational choice in the context of emerging global carbon pricing regimes and compliance instruments such as the EU Carbon Border Adjustment Mechanism [14].
- Substantial domestic potential. Demand modelling indicates a credible pathway for 3–6 million tonnes of domestic green ammonia consumption by 2035, spanning fertilizers, industrial applications, and maritime shipping [1,20].

7.3 Concluding Policy Insight

India's strategy—centered on reverse auctions linked to guaranteed industrial offtake—offers more than a national blueprint. It provides a replicable model for other emerging economies, illustrating how transparent, competitive mechanisms can de-risk private investment while driving down costs. If scaled effectively, this approach can accelerate India's industrial decarbonization while simultaneously advancing the global hydrogen transition in a manner that is both economically viable and strategically resilient [7,21].

Note: While this study used a conservative grey ammonia benchmark of USD 540–570/t (based on delivered natural gas costs), other analyses place unsubsidized costs in India closer to USD 640–660/t. This narrower "green premium" further strengthens the case for accelerated adoption [12].

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Declaration of Competing Interest

The author declares no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability Statement

The data supporting the findings of this study were derived from publicly available sources, including reports by SECI, IRENA, the International Energy Agency (IEA), and the Government of India. All datasets used are cited in the References section of this paper.

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