SEAS AT RISK

Green Hydrogen and Shipping

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Lesson from India for a Just Maritime Transition

Executive Summary

Shipping's transition to zero and near-zero emissions fuels is often framed as a question of which fuel will dominate. This brief argues that the more important question is how the transition is structured. India's emerging green hydrogen landscape provides a valuable lens through which to assess this, illustrating both the potential and the limits of hydrogen-derived fuels for maritime decarbonisation in fast-growing, resource-constrained economies.

India combines strong policy ambition, large renewable energy potential, and a strategic port geography. At the same time, analysis of production costs and system conditions shows that this potential is highly dependant on context. At the time of the study, green hydrogen costs in India remain relatively high, generally ranging from around $6 to $10 per kilogram.

More optimistic scenarios approaching $4 per kilogram as scale increases and electrolyser costs fall. Wind and hybrid renewable systems consistently outperform solar-only configurations in many industrial-port regions, due to higher utilisation rates of electrolysers. These findings suggest that hydrogen viability is not universal.

It is contingent on specific geographic, technical, and economic conditions. Hydrogen should therefore be treated as a constrained and context-dependent option, rather than a default pathway for maritime decarbonisation.

For the maritime sector, the most credible pathways emerge where production, storage, and use are co-located around port and industrial clusters. Such configurations can reduce logistical complexity, enable early bunkering solutions, and support domestic coastal shipping decarbonisation. However, these opportunities must be weighed against significant constraints. Green hydrogen production is resource-intensive.

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It raises critical questions around water availability, land use, community impacts, and infrastructure readiness. Financing risks and uncertain demand further complicate deployment, alongside the need for robust certification and safety frameworks. Left unaddressed, these factors risk reproducing extractive development patterns, particularly if export-led models are prioritised over domestic decarbonisation. As such, countries in the Global South, in their heterogeneity, complexity and uniqueness, may not only be sites of deployment. They can also be leaders in shaping alternative transition pathways. With the right policy frameworks, they can define models that prioritise domestic value creation, energy sovereignty, and equitable development, rather than replicating extractive export-oriented systems. Rather, they highlight broader dynamics that will shape the role of hydrogen in global shipping. As recent disruptions around key maritime chokepoints such as the Strait of Hormuz have underscored, the energy transition must also be assessed through the lens of resilience and security. In this context, fuel choices cannot be considered in isolation from wider system design, including trade patterns, infrastructure dependencies, and resource allocation. Recent disruptions around key maritime chokepoints have further underscored the need to assess fuel pathways through the lens of resilience and geopolitical dependency. A transition centred only on scaling new fuels risks increasing complexity, cost, and vulnerability.

This is especially true if it is not combined with measures that reduce energy demand.
The evidence presented in this brief therefore supports a sequenced and strategic approach to maritime decarbonisation. Hydrogen and its derivatives may play a role, particularly in hard-to-abate segments of shipping, but they should not be treated as a universal solution. Instead, they should be deployed in a way that complements, rather than displaces, more immediate and cost-effective measures.
In particular, five priorities emerge:

First, wind propulsion should be scaled as a first-order transition tool and deployed across the existing fleet as a priority measure. Wind-assisted propulsion technologies are already available, can be deployed across a wide share of the existing fleet, and directly reduce fuel consumption. This is not a competing pathway to alternative fuels, but a foundational measure that reduces the scale, cost, and infrastructure burden of the entire fuel transition.. By lowering total energy demand, wind propulsion reduces the scale, cost, and infrastructure burden associated with the production and use of hydrogen and other e-fuels.

Second, shipping’s overall energy demand should be reduced through strengthened efficiency measures. Operational improvements, optimised routing, and tighter efficiency standards can significantly cut fuel use across the fleet, lowering both emissions and the volume of alternative fuels required.This is particularly important from an equity perspective, as reducing overall energy demand lowers pressure on land, water, and energy resources in producing countries.

Third, hydrogen-derived fuels should be used strategically, not indiscriminately. Given their cost, infrastructure requirements, and resource implications, they should be prioritised for segments of maritime transport where direct electrification, efficiency, and wind cannot deliver sufficient emissions reductions.

Fourth, deployment should prioritise domestic, port-based models with strong social and environmental safeguards, and explicit alignment with principles of equity, environmental justice, and inclusive development.

Fifth, the transition must be supported by stable and equitable financing mechanisms. Instruments such as an ambitious global levy on shipping emissions, combined with targeted public finance, can help de-risk early investments, support fuel-saving technologies, and ensure that the costs and benefits of the transition are distributed fairly, particularly for vulnerable economies.

Taken together, these findings suggest that India is not simply an opportunity story for green hydrogen in shipping, but a test case for how the transition will unfold globally. The choices made today, on sequencing, resource use, infrastructure, and policy design, will determine whether hydrogen contributes to a maritime transition that is efficient, resilient, and just, or one that is more costly, more complex, and uneven in its impacts.

This brief draws on SAR analysis of green hydrogen production economics in India conducted in late 2025. Cost estimates should be understood as indicative and scenario-based, given rapid changes in technology costs, policy frameworks, and global energy markets.

Introduction

The race to produce green hydrogen cost-effectively is often presented as central to global decarbonisation strategies. However, for the maritime sector, the more critical question is under what conditions hydrogen can realistically contribute to emissions reductions. Hydrogen produced using renewable energy instead of fossil fuels or 'Green' Hydrogen, presents a significant opportunity for the maritime sector to reduce the carbon intensity of global trade. However, the answer to whether a country or sector can fuel itself using green hydrogen significantly depends on the costs of its production.

SAR Shipping examined the economics of green hydrogen production in India to understand the most viable technical options, market conditions, and cost drivers. The study highlights key policy actions—such as strengthening safety standards and aligning green fuel production with the maritime sector—that can help India build a competitive edge. These findings may also offer useful lessons for other rapidly developing economies aiming to support clean energy transitions.

With this foundation, the next section provides an overview of India's growing green hydrogen landscape and the opportunities it presents.

A Snapshot of India’s Green Hydrogen Landscape:

The National Green Hydrogen Mission sets ambitious production and capacity targets including producing at least 5 million metric tonnes (MMT) of green hydrogen per year by 2030.

These efforts are engendered by India’s push towards securing more self-reliance in the energy space. As a result of this positive national policy push, we see multiple pilot projects being announced and being developed across the country. SAR, at the time of this study, recognised 17 such sites across promising regions including Odisha, Tamil Nadu, Gujarat, Madhya Pradesh, Rajasthan, Andhra Pradesh to mention a few. These regions have several large scale projects in the pipeline with million tonne ambitions from Andhra Pradesh2 and other regions attracting global investment, indicating India’s potential to export green hydrogen after meeting domestic demand.

Deep diving analytically into the economics of green hydrogen production across India, the study reaffirms how the country’s large coastal landbase and renewable energy generation potential enable gigawatt scale green hydrogen and ammonia hubs. The key findings of the study are shared below.

Costs are currently high, but not uncompetitive:

The study finds India’s green hydrogen costs currently range from $6–10/kg, with optimistic scenarios, driven by scale and cheaper electrolysers, lowering this to about $4/kg. Although these figures suggest potential in some contexts, they also underline that green hydrogen remains costly and highly sensitive to technology and scale. With rapid technology development, global cost reductions, and major investments under the National Green Hydrogen Mission, India is well placed to move toward long-term international targets of $1–2/kg by 2030.

Valuable Insights on Price Sensitivity

Electrolyser costs are crucial:

Electrolyser prices are the main component of green hydrogen projects and make up 70-80% of the entire capital cost. Therefore, costs must fall significantly to make the process affordable. If electrolyser prices fall by 50%-75%, LCOH also falls at nearly the same rate bringing values down to the $4-5 range from the $9-10 mark for most sites.

Economies of scale have a significant positive impact on affordability:

Moving from small to large-scale projects significantly reduces LCOH (Levelized Cost of Hydrogen) in optimistic scenarios, highlighting the importance of scale for improving cost competitiveness. Wind system oversizing3 (300%) yields LCOH of $6.06/kg.

Wind and Hybrid systems prove to be better in most industrial port clusters:

The choice and quality of renewable resources shape cost-competitiveness. The analysis shows that wind and hybrid (wind + solar) systems consistently deliver lower green hydrogen costs across India’s major port and industrial clusters. This is largely because hydrogen costs fall when electrolysers can operate at higher utilisation rates, which depends directly on the availability of steady renewable power. These findings suggest that hydrogen viability is context-specific rather than universal, and that system design matters as much as headline ambition.

In India, while solar varies sharply by region, wind resources are generally more reliable. As a result, wind and hybrid setups produce hydrogen more efficiently and at lower cost, while solar-only configurations face higher intermittency and cost challenges.

This production potential at industrial-port locations creates a natural opportunity for integration with the maritime sector. The next section looks at what opportunities this brings for the shipping sector and its decarbonisation.

Unlocking Maritime Opportunities With Green Hydrogen

ZNZ fuels produced from renewable electricity not only enable export revenue streams, attract foreign investment, enhance resilience against fluctuating global fossil fuel prices, but also help flourish downstream industries like fertilisers, chemicals and the maritime sector. Since the maritime sector plays such a crucial role in an economy and will need to be at the heart of a sustainable trade transition, exploring industry synergies at ports unlocks many useful insights.

Ports act as industrial anchors for hydrogen deployment. Several regions across India show strong potential for integrated green energy hubs, particularly where renewable resources, industrial demand, and port infrastructure converge.

Co-located integrated green energy hubs, storage and bunkering near major ports creates logistics economies of scale and new port revenue streams (through storage, handling, exports).
India’s geographic position and existing trade routes create potential for both regional and long-haul hydrogen-derived fuel supply, particularly toward Asia and Europe. However, export-oriented models must be carefully balanced with domestic decarbonisation priorities to avoid reinforcing extractive energy patterns.

While these routes are a potential way to export green hydrogen, it is important to pay primary importance to catering domestic demand and decarbonising the national economy. reimagined non-extractive development models that prioritise domestic decarbonisation, local value creation, and equitable benefit-sharing, rather than export-oriented energy systems that externalise environmental and social costs.

Prioritising domestic models:

Building a green hydrogen value chain starts with and impacts the domestic routes.

Bunkering transition & coastal shipping: Green ammonia, methanol provide a pathway to clean coastal and short-sea shipping first (lower refit complexity), enabling ports to become integrated green energy hubs and stimulating shipyards for retrofits and newbuilds5. This could be initiated by conducting short sea pilots across the country through potential routes (including but not limited to Mumbai–Mundra–Kandla, Chennai–Kolkata; Tuticorin–Kochi) for green hydrogen pilot bunkering and coastal fleet decarbonisation.

Challenges to plan for:

1. **Conversion and total costs:** A key challenge is the added cost of hydrogen storage and conversion to ammonia and other useful fuels. The lower the costs, the stronger the case for the economy to find ways to adopt sustainable options..
2. **Port infrastructure & bunkering readiness**: Fuel operations are complex and require expensive investments and long permitting timelines to ensure due diligence to safety protocols. Retrofits, dedicated storage tanks, trained labour are just a few steps in the list required to turn the clean fuel dream to reality.
3. **Offtake and financing risk:** A lack of dedicated demand6 poses a major challenge and weakens industry confidence.. Large integrated green energy hubs need long-term offtake agreements or policy support (like guaranteed tenders) to attract finance and is highlighted by policy research on other countries with aligning ambitions.7
4. **Certification and lifecycle rules**: export markets demand strict sustainability evidence (Additionality, Chain of Custody, Life Cycle Analysis, etc.). India must establish credible certification and tracking. The Green Hydrogen Certification Scheme 8 is an excellent initiative in this direction and the actual progress is yet to be seen post proper implementation.
5. **Environmental and social impacts:** : coastal land use, water availability and desalination needs, biodiversity impacts, fisheries displacement, and community consent are critical considerations. These pressures are particularly acute in regions already facing environmental stress9, finding balance between managing timelines and rigorous impact assessment studies is challenging yet necessary.
6. **Skill & supply chain gaps:** need for ship retrofits, new bunkering tech, and domestic manufacturing of electrolysers and storage equipment. Significant investments have been made by the central government to mobilise these areas however national and international value chains are yet to be adopted by businesses.
7. **Port proximity to densely populated cities:** As discussed in other work on e-fuel safety before, bunkering operations are advised not to be conducted near populated communities, which is unfortunately the case with most of India's ports. An alternate solution ensuring maximum safety and public health measures are a must before establishing any large scale bunkering operations for green hydrogen and green ammonia.

Welcoming Synergies with India's Evolving Maritime Policy:

Maritime India Vision 2030 and recent reforms in modernising maritime policy (including the Coastal Shipping Bill, streamlined Merchant Shipping Bill) pave the way to a bright future for the national shipping sector. This is evident in the increasing international interest in maritime India in the form of partnerships and global foreign investment inflow10. It is also a foundational step towards aligning shipping with a sustainable hydrogen oriented economy.

Appreciable maritime policy improvements:

Financial Support under the National Green Hydrogen Mission and Maritime Vision 2030
The government has committed ₹115 crore for green-hydrogen-related pilot projects in shipping by 2025–26, supporting demonstrations in green bunkering, vessel retrofitting, and port refuelling systems. Alongside this, the new ₹25,000-crore Maritime Development Fund (MDF)11 provides long-term capital to expand India's shipping tonnage and strengthen shipbuilding capacity. Together, these measures lower the financial barriers for hydrogen-ready ships, coastal movement of green fuels, and port-side storage or processing facilities.

Strengthening Certification Standards

Under the Green Hydrogen Certification Scheme, clarity on the definition of “green” hydrogen is provided , requiring mandatory clear rules on lifecycle emissions, renewable energy sourcing, and independent verification. This aligns domestic producers with international markets that demand transparent carbon accounting. In parallel, Maritime India Vision 2030 promotes certification for green shipping and green ports, including standards for low-emission vessels, hydrogen-ready or ammonia-ready ship designs, renewable-powered port operations, and safety protocols for handling alternative fuels. Together, these certification schemes help create a trusted ecosystem.

Goal to become a “Top Seafaring Nation”

This goal covers expanding high-quality training, opening more opportunities for women, and building a globally competitive workforce. Such development is essential for handling new fuel technologies, hydrogen safety protocols, and green port operations, making India capable of providing skilled maritime services. Notable international collaborations include shared plans to develop shared training & safety standards, Certifications of Competency for seafarers with Denmark, UAE, South Korea, Singapore, South Korea.

Push for sustainable and safe maritime systems. Ports are encouraged to adopt renewable electricity, electrify cargo-handling equipment, and invest in clean-fuel infrastructure. Real-time monitoring, enhanced safety training and modernised digital systems further strengthen readiness for low-carbon logistics and green-fuel handling.

Additionally, Green hydrogen offers strategic value not only to domestic decarbonisation but also to maritime fuel transportation under the IMO’s Net Zero Framework. India’s policy and industrial leadership in hydrogen production can help meet zero and net-zero fuel targets outlined in the framework, while enabling Indian ports to emerge as advanced green bunkering hubs.

Why India’s case matters — lessons for similar, fast-growing economies

India is a useful case not because it offers a simple hydrogen success story, but because it reveals the real choices that will shape maritime decarbonisation in fast-growing economies. Its experience shows that scale, policy alignment and port geography can create opportunity, but that delivered viability depends on sequencing, safeguards, and governance. In that sense, India is a test case for whether hydrogen contributes to a transition that is efficient, resilient and just, rather than one that is more extractive, more costly and more uneven in its impacts.

Beyond technical and economic considerations, the deployment of green hydrogen infrastructure raises fundamental questions of environmental justice and political economy. Large-scale hydrogen production is resource-intensive, requiring significant volumes of water, land, and renewable energy, often in regions already facing environmental stress. Without strong governance, this risks reinforcing extractive development models, where resources are mobilised for export-oriented energy systems while local communities bear the environmental and social costs.

A just maritime transition must therefore explicitly avoid reproducing patterns historically associated with colonial and unequal economic systems. This includes ensuring public accountability, meaningful community participation, equitable distribution of benefits, and strict safeguards on land use, water access, and environmental integrity. Hydrogen deployment should not replicate extractivist dynamics under a “green” label. It should instead contribute to a transition that is equitable, locally beneficial, and socially accountable.

Conclusion:

This brief draws on SAR analysis of green hydrogen production economics in India conducted in late 2025. Cost estimates should be understood as indicative and scenario-based, given rapid changes in technology costs, policy frameworks and energy markets.

Further work is needed on full value-chain costs and on the wider social and environmental conditions for deployment, including water availability, land use, biodiversity impacts, and public accountability, particularly in regions where resource pressures are already high.