APCTT
Asian and Pacific Centre for Transfer of Technology
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Consolidated Reply

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Query 7 -

Green Hydrogen Technologies and Pathways for a Low-Carbon Asia-Pacific

Community of Practice (CoP) on Climate Technologies

APCTT
COMMUNITY OF PRACTICE
ON CLIMATE TECHNOLOGIES

Community of Practice (CoP) on Climate Technologies

Shared Experiences, Smarter Solutions for Climate Action and Resilience

The Community of Practice (CoP) on Climate Technologies launched by the Asian and Pacific Centre for Transfer of Technology (APCTT) is dedicated to addressing the multifaceted challenges posed by climate change in the Asia-Pacific region through technology solutions. By leveraging the region's rich innovation capacities and good practices, the CoP aims to enhance access to critical knowledge on climate technologies. The Community connects professionals engaged in delivering technological solutions to climate change.

The objective of this Community of Practice is to:

- Promote collaborative problem-solving and policy-relevant dialogue
- Support the localization and transfer of innovations suited to national priorities
- Enhance institutional capacities for climate technology governance
- Enable matchmaking between solution providers and implementers

The Community is driven by a participatory and adaptive model that combines knowledge generation, engagement, and access to resources through the following mechanisms: monthly Query-Response Consolidated Reply (CR) cycle, webinars and interactive discussions, knowledge repository and much more.

Original Query by: Dr. Md Abdus Salam, Bangladesh

16th March 2026

Posted: 13th January 2026

Green hydrogen emerges as a critical clean energy carrier for decarbonizing hard-to-abate sectors, such as industry, heavy transport, and power storage, in the Asia-Pacific region[1], where demand for low-carbon fuels is projected to reach 80 million tonnes annually by 2050[2], amid rising energy needs. However, scaling production faces challenges, including high electrolysis costs (currently USD 3-6/kg), limited renewable energy integration, and infrastructure gaps, despite pilot projects in Australia, India, and Japan adding over 10 GW capacity since 2023[3].

In this context, we invite members to share their knowledge and lived experiences on the following questions:

1. From your direct experience and knowledge, please provide examples of proven technological solutions[4] have been successfully deployed at scale in Asia-Pacific countries to reduce green hydrogen costs for commercialization?

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[1] International Renewable Energy Agency (IRENA). "Green Hydrogen Cost Reduction" https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Dec/IRENA_Green_hydrogen_cost_2020.pdf

[2] International Energy Agency (IEA). "Asia Pacific Energy Outlook 2025" https://www.iea.org/reports/world-energy-outlook-2025

[3] Asian and Pacific Centre for Transfer of Technology (APCTT). "Green Hydrogen Technologies" https://apctt.org/sites/default/files/2024-10/Green%20Hydrogen%20technologies%20April-June%202024%20for%20Web_0.pdf

[4] For example - advanced electrolyzers, renewable-powered production hubs, or hydrogen storage innovations

2. What policies, finance models, collaborations accelerated adoption of above green hydrogen technologies, and what barriers (if any) remain?

Your insights will contribute to regional knowledge sharing and inform inclusive strategies for advancing green hydrogen deployment in the Asia-Pacific region and would be greatly appreciated.

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Contents

1. Summary of Responses

The Asia Pacific region's transition to green hydrogen, driven by need to decarbonise heavy industry, was the subject of the query by Dr. Md Abdus Salam, evoking several responses from regional experts.

On the technological front**,** developing nations view Green Hydrogen as a Strategic Development Pathway **for technological leapfrogging** and a shift from commodity exporters to **strategic partners in the digital economy** and act as a power-to-X business proposition.

Wide-spread deployment of Polymer Electrolyte Membrane (PEM) and Alkaline electrolysers with localized manufacturing and the rise of g**igafactory-scale electrolyzer production and standardization** (Engr. Md. Selim Reza) is reported. These interventions, in addition to domestic supply chains, has helped nations like China to achieve **system costs 40–50% lower than early 2020 benchmarks** (Rohit Raj). **Modular architectures and simplified balance-of-plant designs** (Żaneta Kłostowska) are shortening build timelines and improve reliability.

Interest is also growing in **Anion Exchange Membrane (AEM) electrolyzers** (Wasswa Shafik) for lower cost, high-efficiency production. The **Green Hydrogen Pilot Plant at Jorhat, India** (Neeraj Mathur) using AEM and solar is a notable example. **AI-enabled energy management systems** (Irum Tariq) **(EMS) and AI-driven optimization tools** (Żaneta Kłostowska) are being used to synchronise renewables and cut OPEX by 10–15%.

Placing hydrogen hubs near large solar and wind parks also (Engr. Md. Selim Reza) reduces electricity costs, e.g. in western Australia and India. Such **hybrid portfolios** (Żaneta Kłostowska) increase

capacity factors to 45–60% (Irum Tariq), and help push production costs to USD 2/kg. Using **surplus renewable energy during off-peak hours** (Engr. Md. Selim Reza) further lowers marginal costs.

Logistical innovations include **ammonia-based hydrogen carriers** (Engr. Md. Selim Reza) and **Liquid Organic Hydrogen Carriers (LOHCs)** (Wasswa Shafik). The **Brunei and Kawasaki LOHC** (Wasswa Shafik) supply chain demonstrated long-distance feasibility. Converting hydrogen to **green ammonia or green methanol** (Irum Tariq) for industrial and sea based trade could be an intermediate solution before widespread pipelines are available. By-products – most notably the higher oxygen yield (8:1 O2:H2 ration) – can improve project economics (Dan Millison).

National strategies and programmes (Engr. Md. Selim Reza) (e.g. **India's National Green Hydrogen Mission; Australia's Hydrogen Headstart)** (Rohit Raj) are credited with boosting investor confidence. Demand-side measures **– e.g. mandates and offtake assurance** (Irum Tariq) – help bridge early "green premium". Examples are **India's 10% green hydrogen target for steel** (APCTT) and Korea's shipping **blend quotas** (APCTT). **Sovereign guarantees and public offtake commitments** (Sukriti Sharma), strengthen bankability.

Blended finance **– mixing concessional public capital with private equity** (Sukriti Sharma), **Contracts for Difference (CfD) and Carbon Contracts for Difference (CCfD)** (Żaneta Kłostowska) all reduce risks. Institutions such as the **Clean Energy Finance Corporation in Australia** (Irum Tariq) and the **Asian Development Bank** (APCTT) provide concessional debt and risk-sharing. These interventions **reduce the Weighted Average Cost of Capital (WACC)** (Żaneta Kłostowska) and the levelized cost of hydrogen.

Cross-border hydrogen trade **(e.g. Australia–Japan corridor)** (Mahadi Sabdow) and platforms like **APEC and Asia Pacific Green Hydrogen Alliance** (Wasswa Shafik) help harmonise standards and create markets. **South–South and Triangular cooperation supports technology transfer** (and localisation (Engr. Md. Selim Reza).

Green ammonia production for fertiliser (Paul McCormack) provides **climate-smart farming and food security benefits** (Paul McCormack). **Linking hydrogen production with bio-feedstocks in bio-refineries** (Paul McCormack) can support circular supply chains and resilience. Green hydrogen could thus help accelerate **global equity and equality of access to resources** (Paul McCormack) across the region.

Despite the afore-mentioned momentum, several barriers stifle the rapid upscaling of green hydrogen. The **lack of regional "greenness"** certification (APCTT) and absence of harmonised **international standards** (Engr. Md. Selim Reza) impede access to strict markets. **Regulatory fragmentation** (Akhil Katiyar) also creates legal and financial risk.

Insufficient pipelines and port terminals are critical bottlenecks (Mahadi Sabdow). About **5,000 km of pipelines will be needed by 2030** (APCTT) in South East. **Blending hydrogen with natural gas** (Neeraj Mathur) pilots show short-term potential but wider high-pressure storage and cryogenic transport would require major investments. **Grid constraints and limited renewable penetration** (Engr. Md. Selim Reza) also reduce access to low-cost electricity.

In arid regions, electrolyzers water needs **(9–10 litres/kg H2)** risk aquifer depletion or demand energy-intensive desalination. Competition between large **solar arrays and food production** could cause land-use concerns. L**ife cycle and water usage audits** (APCTT) could prevent greenwashing and enhance sustainability (APCTT).

Delays by buyers and sellers is creating market paralysis, while **commercial banks show limited appetite** (Sukriti Sharma) and **institutional skills gaps** (Engr. Md. Selim Reza). Skills and institutional capacity gaps are slowing delivery. A **phased approach – using hydrogen first for fertilizers** and later scaling industry uptake (Engr. Md. Selim Reza) – is suggested for countries like Bangladesh. Bridging the above **policy, institutional and regulatory gaps** (Irum Tariq) through sustained action and regional cooperation could be the deciding factors for the Asia-Pacific region to move to mass commercial adoption.

2. Relevant Experiences

Australia

Australia is scaling green hydrogen under its National Hydrogen Strategy through large renewable-powered hubs targeting domestic use and exports. Major projects include the Western Green Energy Hub and the Asian Renewable Energy Hub, supported by funding from the Australian Renewable Energy Agency (ARENA) and the Hydrogen Headstart programme to bridge cost gaps. Companies such as Fortescue and Woodside are developing large-scale hydrogen and ammonia facilities linked to wind and solar resources.

China

China has commissioned large-scale renewable hydrogen projects, including Sinopec's Kuqa facility in Xinjiang with a capacity of about 20,000 tonnes per year using renewable-powered alkaline electrolysers. National hydrogen plans (2021–2035) promote deployment in refining, chemicals, transport, and energy storage, supported by provincial incentives and demonstration clusters. State-owned enterprises lead development, while grid operators integrate renewable balancing and digital monitoring systems.

India

India's National Green Hydrogen Mission targets production of 5 million tonnes per year by 2030 through production-linked incentives and competitive SIGHT tenders for electrolyser capacity. Public sector entities such as NTPC and private developers including Adani and Reliance are developing integrated hydrogen and ammonia projects in renewable energy zones such as Kutch and Jamnagar. The Council of Scientific and Industrial Research is supporting localisation of electrolyser technologies to reduce costs. Financial instruments such as viability gap funding and green bonds are being used to mobilize large-scale private investment.

Indonesia

Indonesia is developing its hydrogen roadmap as part of its long-term energy transition, with feasibility studies and pilot concepts led by state utility PLN and energy company Pertamina. The country is assessing renewable-based hydrogen production for use in refining, fertilizers, and future exports. Engagement with international partners and regional alliances focuses on resource assessment, infrastructure planning, and investment mobilisation.

Japan

Japan's revised Basic Hydrogen Strategy outlines long-term demand expansion supported by large public investment under the Green Innovation Fund. Demonstration projects include the Fukushima Hydrogen Energy Research Field (FH2R), a large-scale renewable-powered electrolysis facility. The Ministry of Economy, Trade and Industry (METI) is introducing price support mechanisms and market incentives to reduce costs and stimulate demand.

Malaysia

Malaysia is positioning green hydrogen within its energy transition strategy, with PETRONAS leading feasibility studies and early project development, particularly in Sabah and Sarawak. Planned projects focus on renewable-powered hydrogen and ammonia production for domestic industry and potential export within ASEAN markets. Government agencies are working on policy frameworks and infrastructure planning to support future hydrogen hubs.

Mongolia

Mongolia is exploring renewable hydrogen as part of its net-zero pathway, supported by analytical work from the OECD and regional partners. Studies highlight the country's significant wind and solar resources and their potential for large-scale, export-oriented hydrogen production. Policy work is focused on strategy development, regulatory design, and identification of suitable locations for demonstration zones.

Pakistan

Pakistan is assessing green hydrogen opportunities through early private sector initiatives and policy discussions led by the Power Division and energy authorities. It is part of the UNIDO's Global Clean Hydrogen Programme. Potential applications include renewable-powered hydrogen for fertilizer production and industrial decarbonization. Resource mapping and site identification are being explored using satellite and renewable potential assessments.

Philippines

The Philippines Department of Energy is preparing a national hydrogen roadmap, with a focus on industrial use, transport, and power applications. The strategy aims to leverage the country's renewable potential, including offshore wind, to support future hydrogen production. Private developers such as ACEN have proposed large-scale green hydrogen and ammonia projects to serve domestic demand and potential exports. Public–private partnerships are expected to play a central role in early deployment.

Republic of Korea

The Republic of Korea is implementing a national Hydrogen Economy Roadmap that promotes large-scale production and use across industry, transport, and power generation. Industrial groups such as POSCO and Hyosung are developing hydrogen hubs in locations including Ulsan and Gunsan, supported by government financing and green bond mechanisms. The Ministry of Trade, Industry and Energy is introducing market support schemes and infrastructure planning to reduce production costs. Hydrogen is a key component of Korea's long-term industrial decarbonization strategy.

Singapore

Singapore is pursuing hydrogen as a future low-carbon energy source, with a focus on imports and downstream applications rather than domestic large-scale production. Companies such as Sembcorp are studying hydrogen and ammonia use for power generation and sustainable fuels, while research agencies including A*STAR support system integration and safety research. National policy emphasizes regional supply chains, infrastructure readiness, and international partnerships, particularly with Australia.

Sri Lanka

Sri Lanka is evaluating renewable hydrogen to reduce dependence on imported fossil fuels and support industrial decarbonization. The Ceylon Electricity Board and national research institutions are studying production options using solar and wind resources. Early concepts include pilot-scale projects and potential integration with distributed renewable systems. Development is currently at the feasibility and exploratory stage with support from international partners.

Thailand

Thailand is promoting hydrogen under its long-term energy transition plans, with pilot projects led by the Electricity Generating Authority of Thailand (EGAT) and major energy companies such as PTT and Bangchak. Demonstrations combine renewable power with electrolysis for industrial use and future mobility applications. The government is supporting research, tax incentives, and infrastructure planning to enable market development. Current efforts focus on demonstration projects and early demand creation in refining and transport.

Vietnam

Vietnam is preparing a national hydrogen strategy aligned with its power development plans and industrial decarbonization goals. The government is identifying high-potential wind and solar regions for future hydrogen and ammonia production. Private developers, including T&T Group and other investors, have proposed large-scale projects for domestic use and export. International partnerships and Just Energy Transition Partnership (JETP) financing are expected to support early deployment.

3. Related Resources

Relevant Documentation

APCTT- Green Hydrogen Technologies: Opportunities and Challenges (2024)
This technology brief analyzes the status of green hydrogen development across the Asia-Pacific region. It reviews national strategies and investment plans in countries such as Japan, Australia, and the Republic of Korea. It examines policy frameworks, regional cooperation efforts, and key challenges such as infrastructure gaps, high costs, and the need for technology transfer to support commercialization in hard-to-abate sectors.
https://apctt.org/techmonitor/green-hydrogen-technologies-opportunities-and-challenges-asia-pacific-region

APEC – Exchange of Best Practices for Green Hydrogen Roadmaps (2025)
This study compiles hydrogen strategies and policy approaches from APEC member economies. It compares national roadmaps and identifies priorities such as renewable-based production, industrial use, and export development. The report highlights the importance of locating hydrogen hubs near demand centers and renewable resources.
https://www.apec.org/publications/2025/08/exchange-of-best-practices-for-the-development-of-green-hydrogen-roadmaps-in-the-asia-pacific-region

APERC Hydrogen Report 2024
This report provides a comprehensive assessment of clean hydrogen development across APEC economies. It reviews national strategies, policy frameworks, and investment priorities supporting production and end-use expansion. The analysis highlights major projects, infrastructure planning, and regional cooperation needs. It also presents recommended actions to accelerate commercialization and market creation in the Asia-Pacific region.
https://aperc.or.jp/file/2025/3/18/APERC_Hydrogen_Report_2024_final.pdf

BloombergNEF – New Energy Outlook 2025

BloombergNEF's New Energy Outlook presents long-term energy transition scenarios to 2050, with detailed analysis of renewable expansion and emerging low-carbon technologies. The report examines the role of green hydrogen in decarbonizing hard-to-abate sectors such as industry and heavy transport. It assesses investment needs, policy influences, and financing trends that will shape electrolyzer deployment and hydrogen market growth. The outlook also highlights key risks, including infrastructure constraints, policy uncertainty, and slower-than-expected clean energy transitions in some Asia-Pacific economies.
https://about.bnef.com/insights/clean-energy/new-energy-outlook/

Clean Hydrogen in Asia Pacific: Fuel for Thought (Deloitte, 2024)

This analysis examines the outlook for clean hydrogen development across major Asia-Pacific economies. It reviews national targets, incentive schemes, and investment plans that support large-scale deployment. The report discusses project pipelines, infrastructure requirements, and emerging financing models. It also highlights risks related to grid capacity, transport infrastructure, and demand uncertainty.
https://www.deloitte.com/ap/en/perspectives/clean-hydrogen-in-asia-pacific.html

Global Hydrogen Review 2024 (IEA)

This report provides a comprehensive overview of global hydrogen market developments, including production capacity, electrolyzer deployment, project pipelines, and investment trends. It analyzes cost trajectories, policy developments, and progress toward commercialization across major regions, including Asia-Pacific. The review also highlights gaps between announced projects and expected demand, as well as infrastructure and financing challenges affecting large-scale deployment. It serves as a key reference for tracking global progress and identifying priorities for accelerating green hydrogen scale-up.
https://www.iea.org/reports/global-hydrogen-review-2024

Global Hydrogen Trade to Meet the 1.5°C Climate Goal (IRENA, 2022)

This study explores the potential for international hydrogen trade and the development of export-import value chains. It identifies regions with strong renewable resources and analyzes infrastructure requirements for transport and storage. The report discusses policy frameworks, certification systems, and market mechanisms needed to enable cross-border trade.

https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2022/Jul/IRENA_Global_hydrogen_trade_part_1_2022_.pdf

Global Hydrogen Outlook (IRENA)

This report assesses the long-term role of green hydrogen in the global energy transition, with analysis of cost reduction pathways, renewable resource potential, and international trade opportunities. It identifies regions with competitive production potential and examines infrastructure, investment, and policy requirements for large-scale deployment. The outlook highlights the importance of renewable electricity availability, electrolyzer manufacturing scale, and cross-border value chains.

https://www.irena.org/Energy-Transition/Technology/Hydrogen/Global-hydrogen-trade#:~:text=By%202050%20in%20the%201.5,be%20domestically%20produced%20and%20consumed.

Green Hydrogen Cost Reduction (IRENA, 2020)

This report analyzes pathways to reduce green hydrogen production costs through scale, technology improvements, and low-cost renewable electricity. It presents cost projections and key drivers such as electrolyzer manufacturing expansion and higher utilization rates. The study also examines policy measures, financing support, and infrastructure needs. It provides guidance for governments planning large-scale deployment. https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Dec/IRENA_Green_hydrogen_cost_2020.pdf

Green Hydrogen in Asia: A Brief Survey of Existing Programmes and Projects (Orrick, 2023)
This survey provides an overview of green hydrogen policies, targets, and major projects across key Asian economies. It summarizes national programmes, funding mechanisms, and private sector investments supporting market development. The report highlights early commercial projects and emerging export initiatives.
https://www.orrick.com/en/Insights/2023/07/Green-Hydrogen-in-Asia-A-Brief-Survey-of-Existing-Programmes-and-Projects

Harnessing Green Hydrogen (NITI Aayog, 2022)
This report outlines India's strategic approach to developing a domestic green hydrogen ecosystem. It examines production potential, demand sectors, and opportunities for cost reduction through renewable integration and manufacturing localization. It provides foundational analysis that informed the National Green Hydrogen Mission.
https://www.niti.gov.in/sites/default/files/2022-06/Harnessing_Green_Hydrogen_V21_DIGITAL_29062022.pdf

Japan Hydrogen Strategy – Market Intelligence Report (MFAT, 2023)
This report outlines Japan's long-term targets for expanding hydrogen supply, reducing costs, and developing large-scale import supply chains. The analysis highlights major public and private investment commitments, producer support mechanisms, and cluster development initiatives
https://www.mfat.govt.nz/en/trade/mfat-market-reports/japan-hydrogen-strategy-november-2023

Path to Hydrogen Competitiveness: A Cost Perspective
This report analyzes the cost trajectory of hydrogen technologies and the conditions required to reach price competitiveness. It examines economies of scale, technology learning, and demand aggregation. The study highlights policy tools, financing mechanisms, and infrastructure investments needed to accelerate deployment. Industry case examples illustrate pathways for large-scale adoption.
https://hydrogencouncil.com/en/path-to-hydrogen-competitiveness-a-cost-perspective/

The Future of Hydrogen (IEA, 2019)
This comprehensive study assesses hydrogen's role in the global energy transition. It examines production pathways, infrastructure needs, and applications across industry, transport, and power. The report identifies key policy actions required to scale low-carbon hydrogen and reduce costs. It remains a foundational reference for national strategies and investment planning.
https://www.iea.org/reports/the-future-of-hydrogen

World Energy Outlook 2025 (IEA)
The World Energy Outlook provides long-term energy transition scenarios, including projections for low-carbon hydrogen demand. It analyzes investment requirements, regional outlooks, and policy needs relevant to Asia-Pacific economies. The report highlights the importance of scaling electrolysis capacity and renewable energy supply. It also assesses infrastructure and market development challenges.
https://www.iea.org/reports/world-energy-outlook-2025

Relevant Organizations

Adani Green Energy (India)
Adani Green Energy has developed large-scale green hydrogen ecosystems using advanced electrolyzers, with over 80% of components localized to reduce production costs and support commercialization in steel and fertilizers. A key initiative is the 1 GW green hydrogen hub in Kutch, supported by India's Production Linked Incentive (PLI) scheme and financing through green bonds.
https://www.adanigreenenergy.com/

Asian Development Bank (ADB)
The organization plays a key role in financing electrolyzer projects and renewable integration hubs across India, Indonesia, and Vietnam. It supports cost reduction through blended finance and technical assistance. It has also helped advance national programmes such as India's Green Hydrogen Mission by supporting multi-GW pilot projects since 2023 and encouraging public–private partnerships. https://www.adb.org/

Australian Renewable Energy Agency (ARENA)

ARENA supports the scale-up of renewable hydrogen by funding large-scale electrolyzer projects powered by solar and wind. Through programmes such as Hydrogen Headstart, it provides financial support to accelerate commercial deployment and reduce production costs. The agency enables public–private partnerships and supports projects that position Australia for future hydrogen exports in the Asia-Pacific region. Improving grid integration and supporting enabling infrastructure remain key priorities.

https://arena.gov.au/

Clean Energy Finance Corporation (CEFC)

CEFC provides financing to accelerate large-scale clean energy and low-emissions infrastructure, including renewable hydrogen projects linked to wind and solar. It invests in production facilities, supporting infrastructure, and export-oriented supply chains to strengthen Australia's role in emerging hydrogen markets. The corporation works with industry partners and co-investors to mobilize private capital and enable commercial scale. Its investments focus on building integrated value chains, supporting industrial decarbonization, and strengthening critical supply and infrastructure capacity.

https://www.cefc.com.au/

Council of Scientific and Industrial Research (CSIR)

CSIR develops indigenous hydrogen technologies to support domestic manufacturing and reduce reliance on imports. Its laboratories work on alkaline electrolyzer development and system integration for deployment in industrial and energy applications. CSIR also advances high-efficiency hydrogen production technologies and collaborates with industry partners for pilot projects and field validation. Technology transfer and industry partnerships remain central to its efforts to lower costs and support national hydrogen deployment.

https://www.csir.res.in/

Fortescue Future Industries (Australia)

Fortescue Future Industries is developing large-scale green hydrogen and ammonia projects powered by wind and solar resources, with a major focus on the Pilbara region. The company is also building manufacturing capacity for electrolyzers to support global deployment and reduce costs through scale. Its projects target export markets and industrial decarbonization, supported by a mix of private investment, government support, and commercial partnerships. Addressing transmission, infrastructure, and storage needs remains central to project development.
https://www.fortescue.com/en

Hydrogen Council

The Hydrogen Council is a global industry initiative that develops roadmaps and analysis to guide the scale-up of hydrogen across sectors such as industry, transport, and energy. It brings together companies and governments to identify financing models, policy enablers, and measures to address market and infrastructure barriers. The Council supports demand creation by encouraging corporate offtake commitments and cross-border market development, including in key Asia-Pacific economies. It also highlights the need for secure supply chains for critical materials and for timely investment in transport, storage, and distribution infrastructure.
https://hydrogencouncil.com/

HD Hyundai Heavy Industries (South Korea)

HD Hyundai Heavy Industries is advancing hydrogen and fuel cell solutions to support clean shipping and industrial decarbonization. The company is involved in hydrogen initiatives in industrial hubs such as Ulsan, with a focus on fuel cell systems for maritime applications and offshore energy use. It also works with industry partners on pilot projects aimed at reducing emissions in steel and other hard-to-abate sectors. Strengthening the integration of hydrogen with domestic renewable energy supply remains an important focus.
https://www.hd-hhi.com/

Indian Oil Corporation Limited (India)

Indian Oil Corporation is deploying green hydrogen projects for use in its refineries and is piloting applications in the transport sector. The company is integrating electrolyzer-based production at selected locations and using the hydrogen for mobility demonstrations such as fuel cell buses. It is also working on energy storage and hybrid power solutions to manage renewable variability and grid constraints. Current efforts focus on scaling up projects through partnerships and new financing models while building reliable demand within its core operations.
https://iocl.com/

Ministry of Economy, Trade and Industry (Japan)

The Ministry of Economy, Trade and Industry leads Japan's national hydrogen strategy through funding support, market incentives, and large-scale demonstration projects. It supports renewable hydrogen production facilities such as the Fukushima Hydrogen Energy Research Field and promotes the integration of hydrogen with offshore wind and other clean power sources. The ministry is advancing cost reduction through domestic technology development and market support measures, including contract-based price support mechanisms. Its policies focus on early commercialization, supply chain development, and demand creation, while grid capacity and infrastructure expansion remain ongoing challenges.
https://www.meti.go.jp/english/

Japan Organization for Metals and Energy Security (JOGMEC)

The Japan Organization for Metals and Energy Security supports overseas investment and infrastructure development to secure stable hydrogen and energy supply for Japan. It funds demonstration projects on hydrogen production, transport, and storage, including work on carrier technologies such as liquid organic hydrogen carriers. The organization also supports international partnerships, including projects with Australia, to develop import supply chains and long-term procurement pathways. Expanding receiving terminals and related import infrastructure remains a key challenge for large-scale deployment.
https://www.jogmec.go.jp/english/

Kawasaki Heavy Industries (Japan)
Kawasaki Heavy Industries is developing large-scale hydrogen supply chain solutions, including production, liquefaction, transport, and storage. The company is advancing projects such as the Kobe hydrogen import terminal and has developed liquefied hydrogen carrier technology for international transport. It is also working on hydrogen production systems linked to renewable energy and participates in government-supported demonstration projects. Current efforts focus on scaling commercial operations, expanding carrier technologies, and strengthening long-term demand to support market growth.
https://global.kawasaki.com/

Korea Institute of Energy Research (South Korea)
The Korea Institute of Energy Research conducts research and development on advanced hydrogen production technologies to improve efficiency and reduce costs. Its work includes next-generation electrolyzer systems, system optimization using digital tools, and integration of hydrogen production with renewable energy sources. The institute supports pilot and demonstration projects linked to industrial clusters and renewable energy hubs. Government subsidies support technology deployment, while limited renewable energy availability remains a key constraint for large-scale expansion.
https://www.kier.re.kr/eng/

Ministry of New and Renewable Energy (India)
The Ministry of New and Renewable Energy leads the implementation of the National Green Hydrogen Mission to scale up domestic production and manufacturing. The mission includes production-linked incentives to support electrolyzer manufacturing and reduce costs through localization. The ministry also provides funding support for large-scale green hydrogen projects and integrated production hubs through dedicated schemes. Its approach focuses on building a domestic ecosystem, mobilizing public and private investment, and enabling long-term market development through demand creation and procurement frameworks.
https://mnre.gov.in/

National Thermal Power Corporation Limited (India)
NTPC is developing green hydrogen projects to support decarbonization in sectors such as fertilizers, refining, and steel. The company is setting up hydrogen production facilities at multiple locations using electrolyzer-based systems and renewable energy integration. Its initiatives include pilot projects for green hydrogen blending, green ammonia production, and mobility applications in partnership with research institutions and industry. Current efforts focus on scaling domestic manufacturing, building reliable offtake through industrial use, and addressing challenges related to renewable power availability and grid integration.
https://www.ntpc.co.in/

New Energy and Industrial Technology Development Organization (Japan)
The New Energy and Industrial Technology Development Organization funds research, demonstration, and early deployment of advanced energy technologies, including hydrogen production, storage, and utilization systems. It supports large-scale pilot projects and field installations to improve system performance and reduce costs through innovation and digital optimization. The organization also promotes industry collaboration and workforce development to support technology commercialization. Moving from aging demonstration assets to fully commercial systems remains an ongoing challenge.
https://www.nedo.go.jp/english/

Pertamina (Indonesia)
Pertamina is developing green hydrogen and green ammonia projects as part of Indonesia's energy transition strategy. The company is piloting renewable-based hydrogen production at refinery sites and is exploring export opportunities linked to emerging regional demand. Its initiatives focus on integrating hydrogen into refining operations and building partnerships to support future industrial and maritime applications. https://www.pertamina.com/

PETRONAS (Malaysia)
PETRONAS is developing green hydrogen and low-carbon energy solutions as part of its broader energy transition strategy. The company is exploring renewable-powered hydrogen projects, including initiatives in Sabah, to support future export and industrial applications. It is also working with regional partners to develop cross-border value chains and emerging hydrogen trade opportunities within ASEAN. These efforts aim to position Malaysia as a competitive supplier in the regional clean energy market. https://www.petronas.com/

PetroVietnam (Vietnam)
PetroVietnam is exploring green hydrogen and ammonia development as part of Vietnam's net-zero and energy transition plans. The group is assessing renewable-powered production for use in refining, power generation, and potential export markets. Its strategy focuses on integrating hydrogen into existing energy infrastructure and partnering with international developers to scale deployment. https://www.pvn.vn/

POSCO Holdings (South Korea)
POSCO Holdings is advancing hydrogen-based solutions to support the decarbonization of steel production under its HyREX hydrogen steelmaking initiative. The company is developing green hydrogen supply projects and investing in renewable-linked production to replace coal-based processes. Its transition efforts are supported through green financing and partnerships across the hydrogen value chain, including collaboration with industrial and mobility sectors to build future demand. https://www.posco-inc.com/en/

PT PLN (Perusahaan Listrik Negara) (Indonesia)
PLN is advancing green hydrogen production using surplus renewable and low-carbon power at multiple generation sites. The utility has launched pilot hydrogen plants and is developing a national roadmap to support industrial use and future mobility applications. Its efforts aim to utilize excess electricity, support grid flexibility, and build a domestic hydrogen ecosystem. https://www.pln.co.id/

PTT Public Company Limited (Thailand)
PTT is investing in hydrogen and low-carbon fuels to support Thailand's industrial decarbonization and clean mobility goals. The company is developing pilot projects for hydrogen production and fuel cell applications while working with partners to build future supply chains
https://www.pttplc.com/

Reliance Industries Limited (India)
Reliance Industries is developing integrated green hydrogen projects at its Jamnagar energy complex as part of its New Energy strategy. Its approach focuses on large-scale, renewable-powered production supported by investments in solar, storage, and local manufacturing to reduce costs. These initiatives are backed by long-term capital commitments and green financing to build a fully integrated clean energy ecosystem.
https://www.ril.com/

Saudi Aramco
Saudi Aramco is advancing low-carbon hydrogen and ammonia projects as part of its strategy to supply clean fuels to international markets, including the Asia-Pacific region. The company is developing blue hydrogen and ammonia using carbon capture and storage. Its initiatives focus on large-scale production, international collaboration, and long-term supply agreements to support emerging regional hydrogen markets.
https://www.aramco.com/

Sembcorp Industries (Singapore)
Sembcorp is exploring green hydrogen production, import pathways, and downstream applications including power, industry, and sustainable fuels. It is also working with partners to develop cross-border supply corridors, including renewable energy and hydrogen imports from Australia to support Singapore's future demand. These initiatives are supported by national policy frameworks and focus on building scalable regional supply chains.
https://www.sembcorp.com/

Sinopec (China Petroleum & Chemical Corporation)
Sinopec is developing large-scale green hydrogen projects powered by renewable energy to support industrial decarbonization, particularly in refining and chemical operations. The company has commissioned major renewable-based hydrogen plants and is integrating digital monitoring and system optimization to improve efficiency and scale operations. Its projects focus on linking hydrogen production with renewable power resources and expanding deployment across multiple industrial sites as part of China's national hydrogen strategy.
https://www.sinopecgroup.com/group/en/

State Grid Corporation of China
State Grid Corporation of China supports the development of hydrogen infrastructure by integrating renewable power, grid management, and digital monitoring systems. The company is deploying smart grid technologies, including IoT-based monitoring and energy management platforms, to enable efficient operation of distributed energy and hydrogen projects. Its work focuses on improving renewable integration, system reliability, and coordinated operation of electricity and emerging hydrogen networks at regional and industrial cluster levels.
https://www.sgcc.com.cn/ywlm/index.shtml

Woodside Energy (Australia)
Woodside Energy is developing large-scale renewable hydrogen and ammonia projects in the Pilbara, including the H2Perth and H2TAS initiatives, to support future export markets and industrial decarbonization. The company is advancing integrated projects that combine renewable power, hydrogen production, and storage through partnerships with government and industry. Its strategy focuses on building export-oriented supply chains and securing long-term commercial agreements with customers in key markets such as Japan.
https://www.woodside.com/

Relevant Websites

APEC – Energy Working Group
The APEC Energy Working Group platform supports regional cooperation on clean energy transition across member economies. It provides policy dialogue outputs, project reports, and knowledge exchange relevant to low-carbon technologies including hydrogen. The portal highlights initiatives on energy security, market development, and cross-border collaboration. It serves as a resource for understanding regional policy coordination and capacity building in emerging hydrogen markets.
https://www.apec.org/groups/som-steering-committee-on-economic-and-technical-cooperation/working-groups/energy

ASEAN Centre for Energy
The ASEAN Centre for Energy portal provides regional analysis, policy studies, and strategic initiatives on energy transition in Southeast Asia. It includes research on emerging technologies, renewable integration, and regional energy planning, with growing attention to hydrogen development. The platform supports member states through data resources, roadmaps, and capacity-building activities. It also facilitates regional cooperation and investment dialogue.
https://aseanenergy.org

Asian Infrastructure Investment Bank – Energy
AIIB’s energy portal outlines its financing priorities for sustainable infrastructure across Asia. It includes project information, sector strategies, and investment frameworks that support renewable energy and emerging low-carbon solutions such as hydrogen. The platform highlights approaches to risk mitigation, private sector participation, and blended finance. It provides insight into financing models for large-scale clean energy infrastructure.
https://www.aiib.org/en/policies-strategies/strategies/sustainable-energy-for-tomorrow.html

Australia Department of Climate Change, Energy, the Environment and Water – Hydrogen
This official portal presents Australia's national hydrogen strategy, policy framework, and funding programmes to support large-scale project development. The site outlines export opportunities to key markets in Asia, renewable energy integration, and regulatory measures to enable infrastructure and market growth. It also provides updates on policy development, investment support, and Australia's progress toward becoming a major clean hydrogen exporter.
https://www.dcceew.gov.au/energy/hydrogen

BloombergNEF Hydrogen Hurdle Insights
Podcast hub from Switched On series analyzing global hydrogen progress, noting APAC trends like China's green push and India's low-cost emergence amid stalled 2030 forecasts. Discusses policy hurdles, blue/green mixes, and hard-to-abate gains in shipping/aviation. Links to reports like Hydrogen Supply Outlook 2025 on tenders/blue lead; complements cost/policy trackers for commercialization insights.
https://about.bnef.com/insights/clean-energy/the-hydrogen-hurdle-costs-policy-and-progress/

ERIA – Energy Programme
ERIA's energy programme provides research and policy analysis to support energy transition across ASEAN and East Asia. It includes studies on hydrogen strategies, infrastructure needs, and regional market development. The portal features reports, event materials, and policy recommendations for scaling low-carbon technologies.
https://www.eria.org/research/topic/energy

Energy Market Authority (Singapore) – Hydrogen
EMA's hydrogen page outlines Singapore's strategy to explore low-carbon hydrogen as a future energy source. It provides information on import pathways, technology trials, regulatory considerations, and system integration. The platform highlights national planning efforts to support infrastructure development and market readiness.
https://www.ema.gov.sg/news-events/news?id=feature-stories

Global Renewables Alliance – APAC Green Hydrogen

This platform presents insights on the role of renewable energy in scaling green hydrogen across Asia-Pacific. It highlights policy recommendations, investment needs, and enabling measures to support large-scale deployment. The page summarizes COP outcomes, regional initiatives, and project examples that demonstrate renewable-hydrogen integration.
https://globalrenewablesalliance.org/cop28-/powering-apac-with-renewables-and-green-hydrogen/

H2 View – Asia-Pacific

H2 View provides regular news and analysis on hydrogen developments across the Asia-Pacific region. The platform covers project announcements, policy updates, investments, and technology progress across the hydrogen value chain. It includes expert interviews, market insights, and information on cost reduction, partnerships, and commercialization trends. The site serves as a current information source on regional progress and emerging opportunities.
https://www.h2-view.com/news/asia-pacific

IPHE – Resources

The IPHE resource hub provides international guidance on hydrogen policies, standards, and sustainability frameworks. It includes analytical reports, methodology documents, and tools related to production emissions, safety, and certification. The platform supports member countries in developing harmonized approaches to hydrogen deployment.
https://www.iphe.net/resources

Ministry of Trade, Industry and Energy (South Korea) – Energy

The MOTIE portal provides official information on South Korea's energy policies and industrial strategies. It includes announcements, policy updates, and programme information related to the national hydrogen economy initiative. The platform highlights government support measures, infrastructure development, and industry partnerships. It serves as a primary source for regulatory and policy developments.
https://english.motie.go.kr

National Green Hydrogen Mission – India

This official portal serves as the central platform for India's National Green Hydrogen Mission. It provides information on production targets, incentive schemes such as SIGHT and PLI, and support for domestic electrolyzer manufacturing. The site outlines project tenders, funding mechanisms, and policy guidelines for commercialization and offtake. It also tracks mission implementation and investment progress.
https://nghm.mnre.gov.in

New Zealand Hydrogen Council

The New Zealand Hydrogen Council website provides information on national hydrogen initiatives and industry collaboration. It highlights project developments, policy discussions, and opportunities for low-carbon hydrogen deployment. The platform also shares research insights and stakeholder perspectives on market development. It supports coordination between government, industry, and investors.
https://www.nzhydrogen.org

UNESCAP – Energy Division

UNESCAP's Energy Division portal provides regional analysis, policy resources, and data on energy transition across Asia and the Pacific. It includes publications, project information, and capacity-building initiatives related to renewable energy and emerging clean fuels such as hydrogen.
https://www.unescap.org/our-work/energy

World Bank – Hydrogen for Development

The World Bank's Hydrogen for Development page outlines its work to support low-carbon hydrogen in emerging economies. It provides analytical resources, project examples, and guidance on infrastructure planning, financing, and policy design. The platform highlights approaches to risk reduction, market creation, and integration with renewable energy. It supports governments and investors in scaling hydrogen projects.
https://www.worldbank.org/en/topic/energy/brief/hydrogen-for-development

1. Responses in Full

1. Engr. Md. Selim Reza, ICT & Sustainable Energy Policy Practitioner, Government of Bangladesh
2. Wasswa Shafik, Dig Connectivity Research Laboratory, Canada
3. Mahadi Sabdow, Visionary Technologist and Youth Advocate, Ethiopia
4. Sohail Akhtar, Senior Scientist, Pakistan Council of Scientific & Industrial Research (PCSIR) Lab Complex, Karachi, Pakistan
5. Paul McCormack, CEO, Hydrogen Ireland Association, Ireland
6. Rohit Raj, Research Trainee, Plant Science, BITS Pilani, India
7. Irum Tariq, Member Standing Committee (SC) for Smog and Climate Lahore Chamber of Commerce and Industry (LCCI), CEO at Exodus Green Pvt. Ltd., Pakistan
8. Żaneta Kłostowska, Expert for Innovation and Development of Hydrogen Technologies, TÜV SÜD Polska Sp. z o.o., Poland
9. Paul McCormack, CEO, Hydrogen Ireland Association, Ireland
10. Dan Millison, Manager, Planet Sea, LLC, United States
11. Neeraj Mathur, Individual Consultant, India
12. Akhil Katiyar, Green Hydrogen Specialist, NRDC India Pvt. Ltd
13. Sukriti Sharma, National Coordinator, SAF Association, India
14. Engr. Md. Selim Reza, ICT & Sustainable Energy Policy Practitioner, Government of Bangladesh
15. Inputs from APCTT

Responses:

1. Engr. Md. Selim Reza, ICT & Sustainable Energy Policy Practitioner, Government of Bangladesh

Thank you, Respected Sir Dr. Md Abdus Salam, for raising this timely and highly relevant query. Based on regional observations, policy engagement, and technology assessments in the Asia-Pacific, I would like to share the following insights:

<u>1. Proven Technological Solutions Reducing Green Hydrogen Cost:</u>

Several **scalable technological pathways** have already demonstrated cost-reduction potential in the Asia-Pacific region:

-**Advanced Electrolyzer Technologies:** Large-scale deployment of **PEM and Alkaline electrolyzers** with localized manufacturing has reduced CAPEX significantly, particularly in **Australia** and **India**. Gigafactory-scale electrolyzer production and standardization have proven effective.
-**Renewable-Powered Hydrogen Hubs:** Co-locating electrolysis plants with solar and wind parks (renewable-hydrogen hubs) has reduced electricity costs—the dominant cost component—especially in resource-rich regions of Australia and India.
-**Grid-Integrated & Curtailment-Based Production:** Utilizing surplus renewable energy during off-peak hours has lowered marginal hydrogen production costs, as demonstrated in pilot-to-commercial transitions in **Japan**.
-**Improved Storage & Transport Solutions:** Deployment of **ammonia-based hydrogen carriers** and compressed hydrogen storage has reduced logistical costs for export-oriented hydrogen economies.

<u>2. Policies, Finance Models & Collaboration Enablers:</u>

Key accelerators include:

-Clear National Hydrogen Strategies: Long-term hydrogen roadmaps with demand guarantees (e.g., steel, fertilizer, shipping) created investor confidence.
-Blended Finance & Public Risk-Sharing: Use of concessional finance, green bonds, and sovereign-backed offtake agreements reduced project risk and attracted private capital.
-International Collaboration & Technology Transfer: South–South and Triangular cooperation (e.g., Asia–Pacific knowledge platforms, joint R&D programs) accelerated learning curves and localized innovation.
-Carbon Pricing & Green Procurement Policies: Carbon markets and green public procurement helped narrow the price gap between green and grey hydrogen.

3. Remaining Barriers:

-Despite progress, challenges remain:
-High upfront capital costs for electrolyzers in least-developed countries
-Grid constraints and limited renewable penetration in emerging economies
-Lack of regional hydrogen certification and interoperability standards
-Skills and institutional capacity gaps for large-scale hydrogen systems

- ◇ Way Forward (Regional Perspective):

For countries like **Bangladesh**, a **phased approach**—starting with green hydrogen for fertilizer, backup power, and port-based industrial use—combined with regional cooperation and concessional finance, could make green hydrogen both feasible and affordable.
Green hydrogen is not only a technology transition but also a **governance, finance, and justice transition** for a low-carbon Asia-Pacific.

Thank you for the opportunity to contribute.

2. Wasswa Shafik, Dig Connectivity Research Laboratory, Canada

While green hydrogen adoption in the Asia-Pacific faces cost, infrastructure, and policy challenges, the region's renewable potential, market size, and collaborative initiatives position it to lead in developing a low-carbon hydrogen economy. Strategic investments, aligned standards, and regional cooperation can unlock significant decarbonization and economic opportunities on the pathway to net-zero by mid-century.

Green hydrogen—produced by electrolyzing water using renewable electricity—is increasingly viewed as a cornerstone of the Asia-Pacific's energy transition and a critical tool to decarbonize "hard-to-abate" sectors such as heavy industry, shipping, aviation, and steel production. The Asia-Pacific region, home to some of the world's largest industrial economies and energy consumers, is both a major driver of hydrogen demand and a potential global exporter of low-carbon energy carriers.

1. Core Production Technologies

At the heart of the green hydrogen economy are electrolyzers—devices that split water into hydrogen and oxygen using electricity. The main electrolyzer technologies relevant to the region include:

Proton Exchange Membrane (PEM) Electrolyzers: Offer fast response and flexibility, making them suitable for pairing with variable renewable energy sources.

Alkaline Electrolyzers: A more mature and lower-cost option, though with slightly less operational flexibility.

Anion Exchange Membrane (AEM) Electrolyzers: A promising hybrid technology that combines the low cost of alkaline systems with enhanced efficiency. For example, Singapore-headquartered HYDGEN has raised significant capital to scale AEM electrolyzers that aim to produce ultra-pure hydrogen efficiently and cost-effectively at point-of-use, reducing logistical stresses.

Beyond conventional electrolysis, research continues into innovative processes that could reduce energy inputs and improve scalability, though most are still in early stages.

2. Storage and Distribution Innovations

Hydrogen's low volumetric density requires specialised storage and logistics. Key approaches include:

Compressed and Liquefied Hydrogen Storage: High-pressure tanks and cryogenic systems are widely used but require significant energy for compression or cooling.

Liquid Organic Hydrogen Carriers (LOHCs): These chemical carriers allow hydrogen to be bound to organic molecules for safer, more energy-efficient transport and storage. The first international hydrogen supply chain using LOHC technology was established between Brunei and Kawasaki, Japan.

Pipeline Networks and Deep Storage: Emerging hydrogen pipeline projects (e.g., hydrogen "towns" like Ulsan in South Korea) aim to build hydrogen distribution infrastructure that integrates production, storage, and end-use.

3. Policy, Standards, and Regional Cooperation

A major challenge for scaling green hydrogen lies in policy harmonization and standards, which are still evolving in the Asia-Pacific. The lack of an internationally agreed definition and certification scheme for green hydrogen has led to fragmented approaches, complicating cross-border trade and investment.

At the regional level, institutions such as APEC are actively advancing policy frameworks to foster a coordinated hydrogen transition. Policy dialogues emphasize the need for incentives, standardized regulations, and shared best practices to stimulate market development and decarbonization.

Similarly, the Asia Pacific Green Hydrogen Alliance—supported by public and private stakeholders—focuses on catalysing policy leadership, financing, and trade corridors across advanced hydrogen economies like Australia, Indonesia, Japan, Singapore, and South Korea.

4. Economic and Market Pathways

One of the biggest barriers to green hydrogen in the Asia-Pacific is cost. Green hydrogen remains more expensive than conventional fossil-based hydrogen due to the high cost of renewable electricity and electrolyzers. However, costs are projected to fall significantly through economies of scale, technology improvements, and supportive policy incentives between 2030–2050.

Regional hydrogen markets also stand to create substantial economic value. Independent analyses suggest that clean fuels like hydrogen and ammonia could deliver over a quarter of emissions reductions in the Asia-Pacific by 2050, with nearly USD 1.1 trillion per year in new energy commodity markets and significant cross-border trade.

5. Strategic Sector Integration

Green hydrogen offers a pathway to decarbonize critical sectors including:

<u>Industrial Manufacturing:</u> Steel, chemicals, and refining industries increasingly integrate hydrogen and its derivatives (e.g., green ammonia, methanol) to replace fossil feedstocks.

<u>Transport and Shipping:</u> Hydrogen fuel cells and e-fuels (hydrogen-derived synthetic fuels) are promising alternatives for heavy transport and maritime sectors, which are difficult to electrify directly.

<u>Power Sector Flexibility:</u> When integrated with renewable systems, green hydrogen can address variability in solar and wind generation, serving as long-duration energy storage.

6. Future Pathways and Recommendations

To accelerate the transition toward a robust low-carbon hydrogen economy, the Asia-Pacific needs concerted action on several fronts:

Scale Renewable Capacity: Expand wind, solar, and other renewables to supply both grid decarbonization and electrolyzer feedstock.

Harmonize Standards: Develop regionally aligned definitions and certification schemes to facilitate trade and investment.

Invest in Infrastructure: Build pipelines, storage hubs, and regional distribution networks.

Mobilize Finance: Leverage public and private capital to bridge early-stage cost barriers and support large-scale projects.

Foster Regional Trade: Create export/import corridors to match production centers (e.g., Australia, Middle East) with demand hubs in industrialised economies.

3. Mahadi Sabdow, Visionary Technologist and Youth Advocate, Ethiopia

1. Proven Technological Solutions in Asia-Pacific

Large-scale renewable integration: Countries like Australia and Japan are coupling solar and wind farms directly with electrolysis, lowering electricity input costs for hydrogen production.

Electrolyzer efficiency improvements: Deployment of advanced PEM (Proton Exchange Membrane) and alkaline electrolyzers in China and Korea has reduced operational costs and improved scalability.

Hydrogen blending in industry: Blending hydrogen with natural gas in industrial processes (e.g., steelmaking in Japan, chemical plants in Korea) has proven cost-effective while reducing emissions.

Storage and transport innovations: Liquid organic hydrogen carriers (LOHCs) and ammonia-based storage are being piloted in Singapore and Japan to reduce logistics costs.

2. Policies, Finance Models, and Collaborations

APEC policy frameworks: The APEC Energy Ministerial Meetings (EMM14) endorsed clean hydrogen as a key energy vector, encouraging member economies to adopt roadmaps and regulatory frameworks.

Public-private partnerships: Japan's Green Innovation Fund and Australia's Hydrogen Hubs demonstrate how government seed funding catalyzes private investment.

Regional collaborations: Cross-border hydrogen trade agreements (e.g., Australia–Japan, Korea–Singapore) are accelerating commercialization by pooling resources and demand.

Innovative finance models: Blended finance combining concessional loans, green bonds, and carbon credits has reduced upfront risks for investors.

3. Remaining Barriers

High capital costs: Electrolyzer and infrastructure investments remain expensive, limiting rapid scale-up.

Infrastructure gaps: Hydrogen pipelines, storage facilities, and port terminals are insufficient in many Asia-Pacific economies.

Regulatory fragmentation: Lack of harmonized safety standards and certification schemes across countries slows cross-border trade.

Market uncertainty: Fluctuating renewable energy prices and unclear long-term demand projections hinder investor confidence.

4. Sohail Akhtar, Senior Scientist, Pakistan Council of Scientific & Industrial Research (PCSIR) Lab Complex, Karachi, Pakistan

Energy utilization increases with advancing human knowledge sharing, societal progress, and rising personal demands for comfort and modesty. Energy consumption varies widely by country, directly correlating with cultural and living standards. Global energy use at a particular region ties closely to land population size. Rising CO2 emissions are projected to hit alarming levels in coming years due to surging power sector demand. Climate change challenge requires clean energy tech, efficiency in production, and reliable projects/investment to meet global growing targets, while communities seek cheap local energy methods, and innovations form scientists to provide efficient cost-effective production and storage. Todays, worldwide struggle is on advancing renewable energy for a sustainable low carbon industry and transportation method. The renewable energy methods have enthusiasm for Green Hydrogen against other energy storage systems (much like batteries, which store & deliver power). Green hydrogen technologies primarily rely on renewable-powered electrolysis to split water into hydrogen and oxygen, offering a clean alternative to fossil-fuel-based hydrogen. Here production is made by electricity from renewable sources to power an electrolyzer that separates water into hydrogen and oxygen. The resulting hydrogen can be stored and transported, making it a versatile and reliable energy carrier. This process emits no greenhouse gases, making it a sustainable and clean fuel. The Green Hydrogen is playing a fundamental role in industrial scale and approximately in vehicles transportation. The energy shortage demand of the country can be handling suitably if efficient hydrogen storage and transportation is available.

The Green Hydrogen production as alternative fuel gets promotes in Asia-Pacific region. The China and India jointly accounted above 25% of hydrogen market share, as it is a green energy solution, secondly it liberates the public from the dependency over fossil fuel. While, this struggle has great motivation, but the green hydrogen is not yet matured to assume this crucial task. If we called Car manufacturers to build the Hydrogen generators in their cars because it will make them much cheaper for users, the car required new developments, which make cars more expensive. Accelerated advancement in this sector requires robust scientific and engineering programs that leverage prevailing expertise while maintaining a keen eye on shifting global trends.

Finaly, to acquired/achieved an outlined for CO2 emission as under IPCC guidelines, the safe and efficient Hydrogen production models and methods are needed for the global transition to a low-carbon future. The guide line required as used for renewable energy projects (solar, wind turbine etc.) or Energy-efficient public transportation systems (EV) in urban areas, where fossil fuels utilization in a specific region is replaced by smart energy methods amid in contributing to GHG reductions as well as Carbon reduction.

5. Paul McCormack, CEO, Hydrogen Ireland Association, Ireland

Green Hydrogen is far more than a decarbonisation tool for hard-to-abate sectors. For developing countries, it represents a once-in-a-generation economic development strategy, one that unlocks access to advanced technologies, new industrial capabilities, and global investment flows.

At its core, Green Hydrogen is a platform for technological leapfrogging. Countries rich in renewable resources can convert that natural advantage into clean molecules, clean electrons, and critically clean economic opportunity. By coupling hydrogen production with emerging demand from data centres, AI clusters, and digital infrastructure, nations can position themselves not just as energy exporters, but as strategic partners in the global digital economy.

Data centres and AI supercomputing hubs are rapidly becoming the world's fastest-growing energy consumers. Their need for 24/7 clean power, long-duration storage, and firm, dispatchable energy aligns perfectly with the capabilities of hydrogen. This creates a new class of anchor offtakers, stable, creditworthy, and long-term, capable of underpinning entire hydrogen economies.

Hydrogen is much more than a molecule it is the bridge between natural resource wealth and technical capability. It enables countries to move from being commodity exporters to knowledge economy participants, hosting data centres, AI training facilities, and innovation clusters powered by their own renewable-hydrogen systems.

I passionately believe that Green Hydrogen must be understood not as a niche climate solution, but as a strategic development pathway, one that integrates energy, digitalisation, industrial policy, and global competitiveness. It is a catalyst for new industries, new skills, and new forms of international cooperation.

Especially in the Asia Pacific region, clean hydrogen is not just about decarbonising the old economy, it is the foundation for building a new one.

6. Rohit Raj, Research Trainee, Plant Science, BITS Pilani

Green hydrogen deployment in the Asia-Pacific region has moved beyond pilot demonstrations in several countries, with a few technological and institutional approaches already showing cost-reduction potential at near-commercial scale. Based on regional evidence and practical experience, the following situation- and example-based insights are offered.

1. Proven technological solutions deployed at scale to reduce green hydrogen costs

a) Large-scale renewable-integrated electrolysis (Australia & India)
Australia has demonstrated one of the most effective cost-reduction pathways by co-locating gigawatt-scale solar and wind farms with centralized alkaline and PEM electrolyzers. Projects in Western Australia

and Queensland (e.g., Asian Renewable Energy Hub–linked developments) have achieved significant cost declines through economies of scale, shared infrastructure, and high renewable capacity factors (>55%). These projects reduce electricity input costs—the dominant contributor to hydrogen price—by long-term power purchase agreements (PPAs) with renewable generators.

Similarly, India's National Green Hydrogen Mission has supported deployment of multi-hundred-MW electrolyzer clusters integrated with low-cost solar (₹2–2.5/kWh). Pilot industrial projects in refineries and fertilizer plants have already demonstrated production costs below USD 3/kg under favorable renewable tariffs, primarily using alkaline electrolysis optimized for baseload industrial demand.

b) Electrolyzer manufacturing localization (China & India)
China's rapid scale-up of domestic alkaline electrolyzer manufacturing has substantially reduced capital expenditure (CAPEX), with system costs reported to be 40–50% lower than early 2020 benchmarks. Large deployments linked to renewable-powered ammonia and methanol production have proven technical reliability at scale. India has followed a similar pathway by incentivizing domestic electrolyzer manufacturing under production-linked incentive (PLI) schemes, reducing import dependency and improving supply chain resilience.

c) Industrial off-take–driven hydrogen hubs (Japan & Korea)
Japan and the Republic of Korea have successfully piloted hydrogen hubs anchored by guaranteed industrial off-take (steel, chemicals, and mobility). Although initially reliant on public subsidies, these hubs demonstrated reduced levelized hydrogen costs through high utilization rates of electrolyzers, shared storage, and optimized compression/liquefaction systems. Integration with existing industrial hydrogen pipelines further reduced balance-of-plant costs.

2. Policies, finance models, collaborations, and remaining barriers

a) Enabling policies and market signals

Clear national strategies have been decisive. Australia's Hydrogen Headstart Program, India's National Green Hydrogen Mission, and Japan's Basic Hydrogen Strategy provided long-term demand visibility, production incentives, and regulatory clarity. In India, mandates for green hydrogen use in refineries and fertilizers created assured demand, directly improving project bankability.

b) Innovative finance models

Blended finance mechanisms—combining public grants, concessional loans, and private equity—have been critical. Australia and Japan leveraged contracts for difference (CfD)–like mechanisms to bridge the cost gap between green and fossil-based hydrogen. Multilateral development banks and green climate funds reduced risk premiums by supporting early projects, particularly for electrolyzer deployment and storage infrastructure.

c) International and regional collaborations

Cross-border collaborations (e.g., Australia–Japan, Australia–Korea, and India–EU technology partnerships) accelerated learning curves through shared standards, joint R&D, and harmonization of certification schemes. These collaborations reduced technology uncertainty and supported export-oriented hydrogen value chains.

d) Remaining barriers

Despite progress, barriers remain. Grid integration constraints limit access to low-cost renewable electricity in several developing Asia-Pacific countries. Water availability and desalination costs are emerging concerns in arid regions. Infrastructure gaps—particularly for hydrogen transport, storage, and end-use retrofitting—continue to raise system-level costs. Finally, the absence of universally accepted green hydrogen certification frameworks still restricts cross-border trade and investor confidence.

Concluding Perspective

The Asia-Pacific experience demonstrates that green hydrogen cost reduction is achievable when technological scale-up is matched with strong policy alignment, industrial demand anchoring, and coordinated financing. While advanced economies have led early deployment, the lessons are transferable to emerging economies through regional cooperation, targeted subsidies, and localized manufacturing. Continued focus on grid integration, infrastructure development, and harmonized standards will be essential to move from early commercialization toward full market competitiveness across the region.

7. Irum Tariq, Member Standing Committee (SC) for Smog and Climate Lahore Chamber of Commerce and Industry (LCCI), CEO at Exodus Green Pvt. Ltd., Pakistan

1. Technological solutions- Proven technologies deployed at scale in Asia-Pacific to reduce green hydrogen costs

a) Large-scale alkaline and PEM electrolysis linked to renewables

Where deployed: Australia, China, India, Japan

Alkaline electrolysers (AEL) manufactured at scale in **China** and increasingly in **India** have reduced CAPEX through local supply chains, standardization, and modular design. **PEM electrolysers** in **Japan and Australia** have been deployed where flexibility and rapid ramping are needed to match variable solar and wind generation.

Cost reduction is achieved through:
1. MW- to GW-scale projects
2. Localization of stacks and balance-of-plant
3. Long-term renewable PPAs at very low tariffs (especially solar and wind)

Impact: China's domestically produced electrolysers are already reported at **30–50% lower capital cost** than imported systems, directly lowering levelized hydrogen costs.

b) Co-location of electrolysers with ultra-low-cost renewable energy

Where deployed: Australia (WA, SA), India (Rajasthan, Gujarat), China (Inner Mongolia)

Co-locating electrolysers with **solar and wind farms** avoids grid congestion charges and reduces curtailment. Hybrid renewable systems (solar + wind) improve electrolyser utilization factors, spreading fixed costs over higher output.

Impact: Projects in Australia and India have demonstrated **higher capacity factors (45–60%)**, which is critical for pushing hydrogen costs toward **USD 2/kg**.

c) Industrial-cluster-based hydrogen production and use

Where deployed: Japan, China, South Korea

Hydrogen hubs linked to **steel, refining, chemicals, and ports** reduce transport and storage costs. Hydrogen is consumed close to production points, lowering logistics complexity.

Impact: Japan's industrial hydrogen hubs have shown faster commercialization by anchoring demand in **existing industrial offtakers**, reducing market risk.

d) Ammonia and methanol as hydrogen carriers

Where deployed: Australia–Japan, Australia–Korea, China

Converting green hydrogen into **green ammonia** enables long-distance transport using existing infrastructure. Australia has advanced ammonia export projects linked to renewables.

Impact: This approach lowers **storage and shipping costs**, making regional trade in green hydrogen feasible before pure hydrogen pipelines mature.

e) Digital optimization and modularization

Where deployed: Japan, Australia, China

AI-enabled energy management systems optimize electrolyser operation based on renewable availability and price signals. Modular electrolyser skids reduce installation time and EPC costs.

Impact: Operational expenditure (OPEX) reductions of **10–15%** have been reported in commercial projects using smart dispatch and predictive maintenance.

2. Enabling ecosystem- Policies, finance models, collaborations and remaining barriers

a) Policies that accelerated adoption

Clear national hydrogen strategies: Japan, Australia, India, and China have adopted national hydrogen roadmaps with defined targets and demand sectors. These strategies reduce investor uncertainty and support long-term planning.

Demand-side mandates and offtake assurance: Japan's support for hydrogen use in power and industry. India's **Green Hydrogen Mission** with refinery and fertilizer blending mandates

Carbon pricing and standards: Emissions intensity benchmarks and clean fuel standards improve green hydrogen competitiveness against fossil-based hydrogen.

b) Financing mechanisms and business models

Public capital de-risking: Grants, viability gap funding, and concessional loans from governments and development banks. Australia's Clean Energy Finance Corporation and similar institutions in Japan and Korea played a catalytic role.

Long-term offtake agreements: Take-or-pay contracts with utilities, steelmakers, and chemical producers reduced revenue risk.

Public–private partnerships (PPPs): Governments provided land, infrastructure, and policy support. Private sector led technology deployment and operations.

Industrial anchor-offtaker model: Large industrial users commit to early demand, allowing projects to reach bankability faster.

c) Regional and cross-border collaboration

- Australia–Japan and Australia–Korea hydrogen supply chains
- Technology transfer from Japan and Korea to emerging markets
- Regional platforms for standards, certification, and guarantees of origin

d) Key barriers that still remain

Technical

1. Limited electrolyser lifetimes at high utilization
2. Water availability constraints in arid regions
3. Lack of mature hydrogen storage at scale

Financial

1. High upfront CAPEX despite falling costs
2. Limited access to low-cost, long-tenor finance in developing Asia

Regulatory

1. Absence of harmonized hydrogen standards and certification
2. Unclear rules for hydrogen blending in gas networks

Institutional

1. Weak coordination between energy, industry, water, and transport ministries
2. Skills gaps in hydrogen project development and operations

Asia-Pacific experience shows that **cost reduction in green hydrogen is already happening** through scale, localization, industrial clustering, and renewable integration. However, sustained commercialization depends less on technology alone and more on **policy certainty, demand creation, financial de-risking, and regional cooperation**. Bridging remaining institutional and regulatory gaps will be decisive for moving from early deployment to mass adoption

8. Żaneta Kłostowska, Expert for Innovation and Development of Hydrogen Technologies, TÜV SÜD Polska Sp. z o.o., Poland

From my perspective - combining experience in developing hydrogen ecosystems, collaborating with industry, and working within regulatory and market frameworks- the most effective ways to reduce the cost of green hydrogen in the Asia-Pacific region do not come from a single “miracle” innovation. Instead, they result from a comprehensive package of solutions: scale, low-cost renewable energy, high electrolyzer utilization, efficient infrastructure, and stable demand-side instruments.

1. From your direct experience and knowledge, please provide examples of proven technological solutions have been successfully deployed at scale in Asia-Pacific countries to reduce green hydrogen costs for commercialization?

A. Scaling Electrolyzers: Industrialization, Standardization, and the Learning Curve

The most demonstrably effective cost lever in green hydrogen production has been the rapid transition from small demonstration units to large-scale installations - typically in the range of tens to hundreds of megawatts. Projects that adopt modular architectures, simplified balance-of-plant designs, and standardized grid and process interfaces achieve significantly stronger cost performance.

Scaling drives down CAPEX through bulk procurement, standardized manufacturing processes, and shorter construction timelines. Larger order volumes improve supplier pricing, while repetition reduces engineering uncertainty and installation complexity. At the same time, service contracts benefit from clearer performance benchmarks and stronger warranty structures. This industrialization process activates the learning curve effect: each additional deployment reduces unit costs, improves reliability, and enhances operational efficiency. In the Asia-Pacific region, where manufacturing capacity and supply chain integration can be scaled rapidly, this approach has proven particularly effective.

B. Integration with Renewables Under a High-Utilization Model

Where green hydrogen begins to approach cost competitiveness, a consistent factor is not simply access to renewable energy - but achieving high annual operating hours for the electrolyzer. The economics of hydrogen production are highly sensitive to utilization rates. Low load factors significantly increase the Levelized Cost of Hydrogen because fixed capital costs are distributed across lower output volumes.

Successful projects in Asia-Pacific increasingly rely on hybrid renewable portfolios (e.g., solar PV combined with wind) to smooth intermittency and extend operating hours. In some cases, grid access complemented by Guarantees of Origin or credible certification frameworks enables additional flexibility. Advanced dispatching strategies and energy price forecasting allow operators to optimize production during favorable price windows. This combination - diversified renewable input, intelligent grid interaction, and operational optimization - maximizes asset productivity and reduces overall production cost.

C. System Optimization Through Digitalization and Advanced Control (EMS/SCADA/AI)

Commercially mature projects increasingly integrate advanced Energy Management Systems (EMS), SCADA platforms, and AI-driven optimization tools. These systems synchronize renewable generation profiles, grid constraints, electricity price signals, water parameters, and real-time industrial demand (e.g., refineries, ammonia plants, or steel facilities).

The cost impact of digital optimization is often underestimated because it does not require breakthrough hardware innovation. However, it significantly improves asset utilization, reduces curtailment losses, minimizes downtime, and enhances process stability. Improved forecasting and automated control also contribute to consistent hydrogen quality and lower maintenance requirements. Compared to major infrastructure investments, digital optimization is a relatively low-cost intervention with high systemic return.

D. Shortening the Value Chain: On-Site or Near-Site Production

A substantial portion of hydrogen costs can accumulate in logistics rather than production. Compression, liquefaction, transport, and reconversion processes add both capital and operational expenditure. Projects that locate hydrogen production directly on-site or near-site - particularly within ports or industrial clusters - significantly reduce these downstream costs.

Short pipeline connections, localized hubs, and direct integration with industrial processes eliminate unnecessary transport steps. Avoiding costly stages such as liquefaction or long-distance compression - where not technically required - can materially improve project economics. In Asia-Pacific's emerging hydrogen hubs, proximity between production and consumption has proven to be one of the most practical cost-reduction strategies.

E. Aligning Product Specifications with End-Use Requirements

Some hydrogen projects inadvertently overspecify product quality parameters - such as purity levels or dew point thresholds - beyond what the end-use process actually requires. While safety and technological compatibility remain non-negotiable, aligning hydrogen specifications more precisely with industrial application needs can reduce both CAPEX and OPEX.

Lower purification requirements may reduce equipment complexity, energy consumption, and maintenance needs. In certain industrial applications, ultra-high purity hydrogen is unnecessary, and overengineering the system increases costs without delivering proportional value. Rational specification management is therefore an important - though often overlooked - lever for cost optimization.

F. Efficient Water and Heat Management (Especially in Water-Scarce Regions)

In several Asia-Pacific jurisdictions, particularly those with arid or semi-arid climates, water management becomes a critical enabling factor. While water costs are typically not the dominant component of hydrogen production economics, inefficient water use can create permitting challenges, social opposition, and operational risks.

Effective solutions include water recovery systems, minimizing process losses, integrating desalination only when required, and utilizing waste heat where a thermal off-taker exists. Waste heat integration can improve overall system efficiency and reduce auxiliary energy demand. Although these measures may not represent the largest direct cost savings per kilogram of hydrogen, they often determine project feasibility, regulatory approval timelines, and long-term operational stability.

2. What policies, finance models, collaborations accelerated adoption of above green hydrogen technologies, and what barriers (if any) remain?

The most decisive acceleration in hydrogen deployment occurs when projects are underpinned by predictable and contractually secured revenue streams. Renewable and low-carbon hydrogen remains structurally more expensive than fossil-based alternatives in most markets, which means that without mechanisms stabilizing revenues, projects tend to remain confined to pilot or demonstration scale. The turning point typically comes when policy frameworks introduce demand-side instruments that reduce uncertainty and provide long-term visibility.

Long-term offtake agreements - often spanning 10 to 20 years - create revenue stability that significantly improves project bankability. Contracts for Difference (CfD) and Carbon Contracts for Difference (CCfD) bridge the cost gap between hydrogen and fossil-based alternatives, effectively compensating for the green premium during the early market phase. Similarly, auctions for green end-products such as green steel or green ammonia establish price discovery mechanisms while guaranteeing demand. Premium support schemes that compensate for the cost differential further strengthen the commercial case. These instruments directly reduce the Weighted Average Cost of Capital (WACC). In capital-intensive infrastructure projects, even a reduction of 2–3 percentage points in WACC can translate into double-digit reductions in the Levelized Cost of Hydrogen (LCOH). Financial institutions ultimately finance cash-flow stability rather than technological ambition. Once revenues are secured through contracts or public mechanisms, projects move from being technically promising to financially bankable.

Hydrogen deployment also accelerates significantly when projects are embedded within cluster-based development models rather than developed as isolated installations. Ports, industrial hubs, special economic zones, and hydrogen valleys provide integrated environments where infrastructure, demand, and logistics evolve simultaneously. In such ecosystems, renewable energy infrastructure, grid connections, water sourcing and treatment systems, storage facilities, safety systems, and port logistics are developed in a coordinated manner.

Successful clusters are typically anchored by two or three large industrial offtakers - such as a steel producer, a chemical plant, or a mobility operator - which secure baseline demand and reduce volumetric risk. These anchor customers enable economies of scale and improve the predictability of cash flows. Scale is not only economically advantageous; it strengthens political and regulatory legitimacy. Larger, integrated projects are easier to align with national industrial policy, energy security strategies, and employment objectives, which in turn improves access to public funding and regulatory support.

Another critical enabling factor is blended finance combined with structured risk mitigation mechanisms. In practice, hydrogen projects tend to reach Final Investment Decision (FID) only when supported by a carefully engineered mix of public and private capital. This typically includes CAPEX grants or investment subsidies, tax incentives or accelerated depreciatio mechanisms, concessional loans from development banks, credit guarantees, technology risk insurance, and public co-financing of shared infrastructure

Such arrangements should not be viewed as simple subsidization but rather as structured risk-sharing during the early market transition phase. Public participation in grid reinforcement, hydrogen pipelines, or storage facilities often becomes a prerequisite for lowering hydrogen production costs to levels acceptable for heavy industry. Without this financial engineering, even highly efficient electrolyzer technologies cannot compensate for high electricity prices and elevated capital costs. The financial structure, therefore, becomes as important as technological performance.

Time efficiency in permitting and regulatory clarity further determines the pace of deployment. Lengthy approval processes increase capital exposure, delay revenue generation, and elevate regulatory risk. Efficient permitting systems, clearly defined safety standards, and stable regulatory frameworks can shorten development timelines by several years, substantially improving project economics. Every additional year of delay increases financing costs and erodes competitiveness.

Equally important is credible, internationally recognized certification of green or low-carbon hydrogen. Investors and lenders require legal certainty regarding compliance with taxonomy regulations, climate policies, and ESG reporting standards. For export-oriented projects, the bankability of sustainability credentials can be as decisive as technological performance. If sustainability classification remains jurisdiction-dependent or politically uncertain, financing becomes more expensive and more complex.

Barriers That Continue to Constrain Deployment

Despite accelerating policy frameworks and technological progress, several structural barriers remain.

The most fundamental constraint is the cost and availability of electricity. Hydrogen competitiveness is intrinsically tied to renewable energy pricing and grid accessibility. If renewable power is not genuinely low-cost and available in sufficient hourly profiles, or if grid infrastructure is congested, subject to curtailment, or delayed in connection approvals, hydrogen production costs remain elevated regardless of improvements in electrolyzer efficiency. In several markets, grid bottlenecks effectively neutralize otherwise promising offshore wind or large-scale solar opportunities. Without parallel grid expansion and market reform, hydrogen cost reductions remain limited.

Demand risk continues to represent a core investment challenge. The central question for financiers remains whether durable and creditworthy demand exists. Without firm long-term offtake agreements or cost-differential support mechanisms, industrial buyers hesitate to commit to price premiums, while banks are unwilling to provide project financing without predictable revenue streams. The hydrogen sector remains caught in a structural “chicken-and-egg” equilibrium: buyers wait for prices to fall, and producers wait for guaranteed demand. Absent targeted policy intervention, this equilibrium slows commercialization.

Infrastructure and midstream gaps also constrain deployment. Hydrogen production is only one component of a broader value chain that includes transport, storage, conversion, and safety infrastructure. Pipelines, ammonia conversion facilities, liquid organic hydrogen carriers, compressed or liquefied storage solutions, salt cavern storage, and port handling infrastructure remain underdeveloped or insufficiently standardized in many regions. The lack of scalable and interoperable midstream solutions increases transaction costs, operational risk, and logistical complexity, limiting the formation of international hydrogen trade corridors.

Regulatory inconsistency and certification fragmentation further elevate uncertainty. Divergent definitions of green hydrogen, inconsistent rules on additionality, and varying requirements for temporal and geographical correlation of renewable electricity sourcing create legal and financial risk. Export-oriented projects require long-term assurance that hydrogen will remain recognized under foreign regulatory regimes over asset lifetimes of 15 to 20 years. Without international harmonization, cross-border trade remains exposed to policy volatility, which directly translates into higher capital costs.

Finally, human capital and industrial capacity constraints remain underestimated barriers. Rapid deployment requires specialized engineering expertise, local maintenance and service capabilities, reliable access to key components such as electrolyzers and compression systems, and resilient manufacturing supply chains. Without these elements, project costs increase, implementation timelines extend, and operational risks intensify. Hydrogen deployment today competes not only for financial capital but also for skilled labor, industrial manufacturing capacity, and critical materials.

9. Paul McCormack, CEO, Hydrogen Ireland Association, Ireland

Following the bio-based outcomes of COP30, we in Hydrogen Ireland have been reflecting on how green hydrogen can serve not only as a clean energy vector, and decarbonise dirty industries but how it can serve as a catalyst for transformation across agriculture, food security, and economic resilience specifically in developing countries. Fertilisers are a critical part of this story. Through sustainable green ammonia production, we can ensure affordable access to fertilisers that boost agricultural productivity, enable climate-smart farming, and strengthen food sovereignty specifically in countries in the Asia-Pacific region.

What makes this compelling is that with the systems coupling research we are working on, bio-refineries integrated with hydrogen production can form the backbone of a new clean fertiliser supply chain. By harnessing renewable-powered electrolysis, we can produce hydrogen that feeds directly into green ammonia pathways, while also unlocking synergies with bio-based feedstocks. This creates a circular, resilient model where clean hydrogen, bioeconomy resources, and fertiliser production are aligned to deliver both climate and development outcomes.

In this way, fertilisers are not separate from the green hydrogen agenda, they are embedded within it. Clean hydrogen enables the transition to sustainable fertiliser production, while bio-refineries and agrifood systems provide the context for coupling energy, water, and food security. Together, these innovations can reduce dependency on fossil-based inputs, stabilise rural economies, and empower smallholder farmers with tools to adapt to climate volatility.

Clean hydrogen production is not just an energy solution; it is a lever for global equity. By unlocking energy sources for countries that have long been energy poor because of lack of fossil fuels, it redistributes opportunity and rebalances the energy world. In doing so, it ensures equality of access to resources, equality of participation in the clean economy, and equality of outcome in shared prosperity. This is the promise of hydrogen, a pathway where every nation, community, and farmer can stand as an equal partner in shaping a resilient and sustainable future.

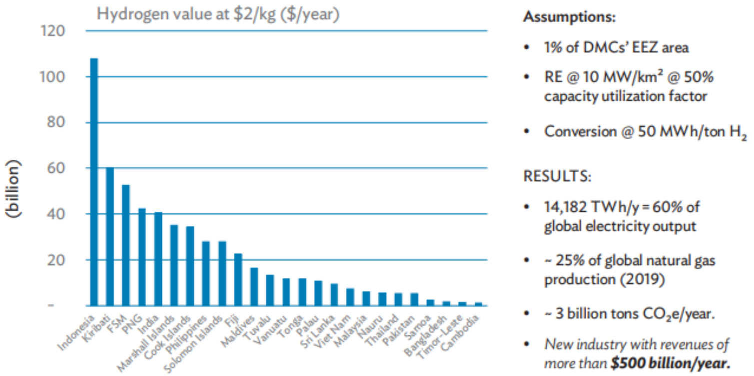
As the world looks to clean energy we must widen the lens and focus beyond just energy use, we see a unique opportunity to broadcast this integrated message, that clean hydrogen is not only about energy, but about building resilient supply chains for fertilisers, food, and water. We would welcome continuing this dialogue with you and exploring how our shared focus on fertilisers can be advanced through the lens of hydrogen-powered systems coupling.

10. Dan Millison, Manager, Planet Sea, LLC, United States

The big picture: what is hydrogen, and what is it good for?

Green hydrogen is a scalable and flexible energy carrier produced by converting renewable electricity (electrons) to split water into hydrogen (protons) and oxygen, which can be stored indefinitely or converted into other molecules. The oxygen by-product can be sold into existing markets depending on local demand. Hydrogen-derived chemicals (molecules) can be transported in bulk as is the case for crude oil, natural gas, refined petroleum products, and other chemicals. Like fossil fuels—which are formed by a combination of solar, biomass, geothermal energy, and geologic time—hydrogen is an energy carrier. Specifically, solar-to-hydrogen mimics the natural processes that create fossil fuels, and potential uses of green hydrogen mimic the existing global hydrocarbons business. The scalability of intermittent solar and wind resources is limited by the ability to time-shift renewable energy output to match demand, and hydrogen appears to be a scalable solution for both time-shifting and location-shifting of renewable energy. A key point that is rarely mentioned: for each ton of H2 produced from water, we get 8 tons of oxygen. Who cares? The average person can survive for 3 minutes without oxygen. More than ½ the oxygen in the atmosphere comes from the ocean, so the ocean (SDG 14) deserves a lot more attention. Most approaches to commercial green H2 is focused only on the H2. What if we work from the oxygen markets back to producing oxygen with H2 as a by-product? More comments to come - thanks! From a policy perspective, green hydrogen is energy-intensive and commercial viability is likely to be location-specific.

Figure 22: Offshore Renewable Energy to Hydrogen Potential in Select ADB Developing Member Countries



ADB = Asian Development Bank, CO_2e = carbon dioxide equivalent, DMC = developing member country, EEZ = exclusive economic zone, FSM = Federated States of Micronesia, H_2 = hydrogen, km² = square kilometer, MW = megawatt, MWh = megawatt-hour, PNG = Papua New Guinea, RE = renewable energy, TWh = terawatt-hour, y = year.

Source: D. Millison. [5]

Green hydrogen is a "power-to-X" business proposition based on selling molecules rather than selling electrons via power purchase agreements. Today there is no global hydrogen market analogous to global crude oil and other hydrocarbons. Therefore, the viability of green hydrogen production depends primarily on electrolyzer costs, local energy costs, specific end-use applications, and willingness of hydrogen buyers to commit to long-term offtake agreements (not unlike traditional liquefied natural gas export projects). Hydrogen supply chain development is

[5] Asian Development Bank (2024). *Emerging Hydrogen Energy Technology and Global Market Study*. Sustainable Development Working Paper No. 96, **p. 44**. https://www.adb.org/sites/default/files/publication/996296/sdwp-096-hydrogen-energy-technology.pdf

expected to continue globally, and as global electrolyzer manufacturing capacity increases, a virtuous cycle of development may emerge. Others have noted the activity in China, and I believe we will see electrolyzer cost reductions similar to what has happened with solar and batteries largely due to the massive brute force investment in China. Green H2 may still look "expensive" today, but we should ask ourselves "expensive compared to what?" Producing H2 from renewable electricity has embedded cost certainty versus cost and price volatility associated with producing H2 from natural gas.

Analogous to stranded gas, we have enormous renewable energy resources waiting to be harvested / monetized, e.g., offshore wind resources which may be too far offshore to justify a transmission connection back to shore. Our business model is "power to X" rather than a power purchase agreement. The graphic above illustrates the theoretical potential in the developing member countries (DMCs) of the Asian Development Bank (ADB). The potential illustrated is quite theoretical in that liquefying and transporting the H2 is not commercial today and may never be: the commercial pathway is more likely to be conversion to methanol or ammonia which can be sold into existing markets.

11. Neeraj Mathur, Individual Consultant, India

Oil India Limited (OIL), Government of India company, has set up Green Hydrogen Pilot Plant at Jorhat in Northeast India. The plant has been set up in collaboration with a private company. The plant is based on Anion Exchange Membrane Electrolysis Technology. It has a capacity to produce 16m3/h of 99.999% green hydrogen using 100 KW of renewable solar power. There are plans to blend the hydrogen with natural gas so that it can be utilized, after blending, in domestic piped natural gas network, natural gas-based burners used by tea gardens for drying of tea leaves and for internal combustion engine. A study undertaken by OIL has shown that natural gas blended with small quantities of hydrogen can be transported through existing pipeline infrastructure without causing any embrittlement.

OIL is also supporting a hydrogen fuel cell electric vehicle through its start-up program.

Government of India policies have supported the adoption of green hydrogen by energy companies at a fast pace as they are in a position to finance alternate energy projects. However, partnerships with private companies are essential for adoption of these technologies. One of the barriers for faster adoption of hydrogen in mass transport system is related to safety which has to be adequately addressed.

12. Akhil Katiyar, Green Hydrogen Specialist, NRDC India Pvt. Ltd

India has set a target of 5 MMTPA of annual green hydrogen production by 2030. The majority of projects expected to be commissioned by 2030 are likely to be based on alkaline electrolyser technology due to its cost competitiveness. The recent bid of ₹279 ($3.08) per kilogram to supply 10,000 tonnes of green hydrogen per year to Numaligarh Refinery Ltd., majority owned by state-run Oil India Ltd., in the northeastern state of Assam, demonstrates the government's strong commitment to achieving this target. Several states have also released their Green Hydrogen Policies; for instance, Gujarat has set a target of 3 MMTPA of green hydrogen production by 2035.

While the government's focus is evident, key challenges must be addressed, particularly securing long-term offtake agreements to ensure demand certainty. Additionally, India needs to align its green hydrogen regulatory framework with EU and U.S. standards to facilitate exports of green hydrogen and its derivatives. This would require compliance with guardrails such as additionality, deliverability, and temporal matching.

13. Sukriti Sharma, National Coordinator, SAF Association, India

Based on my experience working in an industry body, focused on industry decarbonization, and engaging with project developers, technology providers, financiers, and policymakers across the Asia-Pacific region, the following factors have emerged as key accelerators and constraints influencing green hydrogen deployment from an industry perspective,

What has accelerated adoption:

- **Clear national hydrogen roadmaps and long-term demand signals creating investment visibility:** India's National Green Hydrogen Mission has provided long-term clarity on production targets, priority end-use sectors (refineries, fertilizers, steel, Sustainable Aviation Fuel), and export intent, enabling developers to plan integrated hydrogen–SAF projects with greater confidence.
- **Production-linked incentives, viability gap funding, and CapEX subsidies reducing early-stage project risk:** Incentive schemes for electrolyzer manufacturing and green hydrogen production have helped offset first-mover costs, particularly for integrated hydrogen-to-Sustainable Aviation Fuel (SAF) and hydrogen-to-ammonia pathways.
- **Blended finance models combining concessional public capital with private equity and debt to lower the weighted average cost of capital:** Public finance institutions and multilateral development banks have played a catalytic role by offering concessional debt and risk-sharing instruments alongside private capital for early hydrogen projects.
- **Sovereign-backed guarantees and public sector off-take commitments improving project bankability:** Commitments from public sector refineries and fertilizer companies to gradually substitute grey hydrogen with green hydrogen have strengthened long-term demand visibility and supported bankability.
- **Public–private partnerships enabling industrial cluster development and shared infrastructure:** Hydrogen and SAF hubs

emerging in regions such as Gujarat and Maharashtra, which are anchored around refineries, ports, and renewable energy zones, demonstrate how PPP-led cluster development can lower logistics, storage, and infrastructure costs.

- **International collaborations and hydrogen export partnerships enhancing technology access and scale confidence:** India's bilateral cooperation with countries in Europe and Asia-Pacific is increasingly aligned with Article 6 mechanisms, enabling future transfer of mitigation outcomes through green hydrogen and e-fuels while supporting export-oriented SAF supply chains.

Barriers that remain:

- **High renewable electricity costs and grid access constraints limiting cost competitiveness:** Despite declining tariffs, round-the-clock renewable power for electrolyzers remains expensive due to balancing, storage, and grid charges, particularly for high-capacity-factor hydrogen production.

- **Inadequate hydrogen transport, storage, and port infrastructure:** Absence of dedicated hydrogen pipelines, limited high-pressure storage facilities, and lack of hydrogen-ready port infrastructure constrain large-scale hydrogen and SAF export ambitions.

- **Policy and certification uncertainty around "green" hydrogen definitions affecting trade and financing:** Evolving standards for additionality, temporal matching, and carbon intensity create uncertainty for international off-take, SAF eligibility, and carbon market participation.

- **Limited commercial bank appetite for first-of-a-kind projects due to perceived technology and policy risk:** Banks remain cautious on integrated hydrogen–SAF projects given technology novelty, evolving policy frameworks, and unclear long-term price signals.

- **Misalignment between policy timelines and industry investment cycles:** Hydrogen mandates, SAF blending expectations, and incentive durations are not always synchronized with the long gestation periods required for large-scale infrastructure investment.

- **Lack of firm, long-term off-take contracts to support project financing and scale-up:** Absence of binding SAF purchase agreements from airlines limits developers' ability to lock in hydrogen supply contracts and achieve financial closure.

14. Engr. Md. Selim Reza, ICT & Sustainable Energy Policy Practitioner, Government of Bangladesh

The Community of Practice (CoP) on Climate Technologies extends its sincere appreciation to members for their thoughtful and experience-based contributions to Query 7. The responses collectively highlight both the strategic opportunity and the practical complexities of scaling green hydrogen across the Asia-Pacific region.

Below is a synthesis of the key insights shared:

1. Green Hydrogen as a Strategic Energy Carrier:
Several members emphasized that green hydrogen should be viewed not merely as a fuel, but as a flexible **energy carrier** that enables renewable energy monetization, industrial decarbonization, and energy trade.

Drawing an analogy to LNG export models, green hydrogen projects may similarly depend on:

a) Long-term offtake agreements
b) Firm pricing structures
c) Government-enabled permitting and licensing

d) Infrastructure investment mobilized after demand certainty

Like stranded natural gas resources underpinning LNG projects, the Asia-Pacific region possesses vast underutilized renewable resources (e.g., offshore wind and solar) that could be monetized through "power-to-X" pathways.

However, members noted that large-scale liquefied hydrogen trade remains commercially uncertain. More viable near-term pathways include conversion into:

1. Ammonia
2. Methanol
3. Sustainable aviation fuels (SAF)

These derivatives benefit from existing markets and transport infrastructure.

2. Technology Pathways and Demonstration Projects:

India's Pilot Experience

The example shared by **Oil India Limited (OIL)** demonstrates how pilot-scale deployment is advancing technical confidence. Key highlights include:

1. Green hydrogen pilot plant in Jorhat, Northeast India
2. Anion Exchange Membrane (AEM) electrolysis
3. 100 kW solar-powered system
4. 16 m^3/h production capacity
5. 99.999% purity hydrogen

Blending hydrogen with natural gas for use in:

a) Domestic piped gas networks
b) Tea garden burners
c) Internal combustion engines

Importantly, studies indicated that limited blending can occur without pipeline embrittlement risks.

OIL is also supporting hydrogen fuel cell electric mobility initiatives.
These demonstrations reinforce the importance of:

- Early-stage pilots
- Infrastructure compatibility testing
- Public–private collaboration

3. National Targets and Policy Signals:
India's ambition of 5 million metric tonnes per annum (MMTPA) of green hydrogen production by 2030 reflects growing regional commitment. Alkaline electrolyzer technology is currently expected to dominate early deployments due to cost competitiveness.
State-level initiatives, such as Gujarat's green hydrogen policy and targets, further demonstrate subnational leadership.

Clear national roadmaps—such as India's National Green Hydrogen Mission—have provided:

a) Production targets
b) Priority end-use sectors (refineries, fertilizers, steel, SAF)
c) Export orientation
d) Manufacturing incentives

These policy signals are accelerating private investment planning.

4. Financing Models and Market Enablers:
Members highlighted several emerging enablers:

- Accelerators
- Production-linked incentives and capex subsidies
- Viability gap funding mechanisms
- Blended finance combining concessional and private capital
- Sovereign-backed guarantees
- Public-sector offtake commitments
- Industrial cluster development (e.g., hydrogen hubs near ports and refineries)
- Bilateral cooperation aligned with international carbon market mechanisms

Public financial institutions and multilateral development banks are playing catalytic roles in de-risking first-of-a-kind projects.

5. Persistent Barriers and Structural Constraints:

Despite strong policy momentum, several systemic challenges remain:

1. Cost and Infrastructure
2. High round-the-clock renewable electricity costs
3. Grid access and balancing constraints
4. Lack of hydrogen pipelines and storage facilities
5. Insufficient hydrogen-ready port infrastructure
6. Market and Regulatory Uncertainty
7. Evolving definitions of "green hydrogen"
8. Uncertainty around additionality, temporal matching, and carbon intensity standards
9. Need for regulatory alignment with EU and U.S. frameworks for export competitiveness
10. Financing and Bankability
11. Limited commercial bank appetite for first-of-a-kind projects
12. Technology novelty risks
13. Policy timeline misalignment
14. Lack of firm long-term offtake agreements

In particular, the absence of binding purchase agreements—especially for SAF—remains a critical bottleneck for financial closure.

6. Strategic Implications for Asia-Pacific:

From the collective responses, several overarching themes emerge:

Demand certainty is paramount. Long-term offtake agreements remain the cornerstone of project bankability.

Hydrogen derivatives may lead early trade flows. Ammonia, methanol, and SAF offer more practical near-term export pathways.

Cluster-based development lowers system costs. Co-locating renewable generation, hydrogen production, refining, and port infrastructure improves economics.

Public–private collaboration is essential. Governments provide policy direction and risk mitigation; private actors deliver innovation and scale.
Standards alignment will determine export competitiveness. Regulatory harmonization is critical for participation in global hydrogen markets.

Conclusion: The Asia-Pacific region possesses substantial renewable resource potential and emerging policy momentum to position itself as a major green hydrogen producer and exporter.
However, translating ambition into scaled deployment will require:

- Stronger demand-side commitments
- Infrastructure buildout
- Financial de-risking mechanisms
- Certification clarity
- Coordinated industrial ecosystem development

I thank all contributors for sharing practical insights from project development, policy formulation, industry engagement, and financing perspectives. These shared experiences strengthen collective understanding and support smarter pathways toward a low-carbon and climate-resilient Asia-Pacific.

15. Inputs from APCTT

Many Thanks to Dr. Md Abdus Salam, for kicking off this amazing discussion—it's really enlightening to see all the developments in pilots and policies in the Asia-Pacific region. I've been reading through the responses, and while there's good coverage of electrolyzers, hubs, and basic finance, a few key pieces seem to be missing to me. From my experience in policy analysis here in Delhi, I'd like to add to these missing pieces with some down-to-earth ideas and examples.

First, the side effects of environmental issues aren't getting much exmphasis. Green H2 is great-sounding, but electrolyzers are water-hungry—9-10 litres per kg in arid areas like Rajasthan or Gujarat. These could lead to possible aquifer depletion or desalination plants that hike energy consumption up 20-30%. This has happened in India-based projects that turned to wastewater recycling or dry cooling to mitigate this, but without initial LCA (life cycle analysis), we would be vulnerable to greenwashing complaints down the road. Huge solar arrays for H2 hubs are also devouring agricultural land, conflicting with food security in countries like Indonesia. More thinking on this trade-off is needed.

Regarding standards, there is much discussion about fragmentation, but barely any solutions. We do not have a regional certification scheme for "greenness" – things like additionality (no theft of grid power), time matching (Renewable Energy used in same hour), and location. The EU has strict certification requirements; without APAC harmonization through APEC or IPHE, exports face major challenges. Japan is advancing Guarantees of Origin (GOs), but India and Vietnam lag behind. Developer feedback indicates this undermines bankability—addressing it via a straightforward ASEAN+3 protocol could help.

Demand creation remains a critical bottleneck, with discussions rarely moving beyond vague offtake commitments. Effective mandates could address this: for instance, India is targeting 10% green hydrogen use in steel production by 2030, while Korea has introduced blending quotas for shipping. Airlines could secure long-term sustainable aviation fuel (SAF) contracts linked to hydrogen, as seen in Air India's pilot initiatives. Without binding agreements, developers risk stranded assets—global data shows only 7% of announced capacity has materialized, highlighting the need for firm demand signals.

On financing, blended models are noted, but unaddressed risks—such as policy uncertainty driving weighted average cost of capital (WACC) to 12-

15% against the required 8%—undermine viability. Sovereign guarantees or carbon contracts for difference (CCfDs), like Australia's Hydrogen Headstart program, are essential. Banks remain cautious on first-of-a-kind projects without such mechanisms; the Asian Development Bank (ADB) could lead by quantifying risks in large-scale funds.

Infrastructure receives limited attention. Dedicated pipelines are scarce beyond Japan's Kobe terminal, while Southeast Asia requires around 5,000 km by 2030 for regional hubs, alongside port upgrades for liquid hydrogen (LH2) and ammonia. Grid constraints currently waste up to 20% of renewable energy—deploying smart grids and hydrogen production from curtailment could mitigate this.

In summary, these gaps are addressable with focused action. For Bangladesh, a practical entry point could involve hydrogen for fertilizers, financed by ADB and linked to certification and water usage audits. I welcome further discussion or sharing relevant contacts to advance Asia-Pacific leadership in green hydrogen.

Many thanks to all who contributed to this query!

The Community of Practice on Climate Technologies aims to foster technology cooperation and transfer through enhanced knowledge exchange and cross-border collaboration in Asia Pacific.

If you have further information to share on this topic, please send it at apctt@un.org.

This Consolidated Reply is a systematic compilation of all responses received and additional desk research. It has been compiled by the Research Team at APCTT: Pankaj Kumar Shrivastav, Programme Management Officer, APCTT and Jigya, Intern, APCTT.

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