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Green Hydrogen Technologies for Systems Transformation: Building a compilation of national strategies, plans and projects

2024

Preface

In 2023, the Climate Technology Centre and Network (CTCN) compiled 10 Green Hydrogen Technology strategies, plans and projects under preparation and/or implementation worldwide. As a continuation to the region-tailored capacity building program on Green Hydrogen, which benefits country focal points of UN Climate Change Convention Technology Mechanism (UNFCCC TM), CTCN's curation of 10 global green hydrogen cases intends to inspire developing countries in researching, developing, and disseminating system-changing climate technology solutions.

This year, four country cases are added to the curation and compilation in collaboration with UNEP Copenhagen Climate Centre (CCC). We hope the added cases of Paraguay, Malaysia, Mauritania, and Jordan will provide countries with information to accelerate their climate action through climate technology.

Acknowledgement

This piece was drafted with and reviewed by the UNEP CCC Green Hydrogen expert, Dr. Romanas Savickas, and reviewed by the Green Energy Institution, Network Member of the CTCN. We sincerely thank them for their collaboration in disseminating such a timely knowledge piece.

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Paraguay is a country with a large supply of hydroelectric plants, placing the country at an advantage for green hydrogen production. In their 2019-2023 National Energy Agenda (AEN[1]), the government of Paraguay mentions hydrogen in a significant number places, identifying green hydrogen as essential to increase national energy security, decarbonize energy areas such as transportation, and becoming a Logistics and Renewable Energy Hub in the region. Therefore, it can be presumed that hydrogen will play a key role in meeting Paraguay's international commitment to the Paris Agreement and the 2030 Sustainable Development Goals (SDGs).

As stated in Paraguay's 'National Development Plan Paraguay 2030', their objective is to reduce 20% of fossil fuel consumption and increase the consumption of renewable energy by 60% by 2030.

In the National Energy Policy 2040, the government committed to promoting the substitution of imported fossil fuels with energy sources of national origin. The government has developed an Electromobility Strategy and the Guide for the Standardization of Electric Mobility. Furthermore, the Ministry of Public Works expressed an interest in the transition to clean mobility using hydrogen. Also, the Ministry of Industry and Commerce set as a priority to assess the potential of using hydrogen in industry, aiming to replace the unsustainable use of biomass.

Key strategies

The country has abundant water and renewable energy resources, and it has the third-largest barge fleet in the world. Its strategic geographic location in the centre of South America positions the country as a possible leading green hydrogen producer for its use in the transport, industry, and clean fuel sectors.

The government of Paraguay and the Vice Ministry of Mines and Energy have set as a priority to use hydrogen to be used as a fuel for long-distance transportation both in the land and river transport sectors.

Paraguay produces 71% of its electricity using hydroelectric power plants, allowing for a strong renewable energy generation matrix. However, the country still has a noticeable 41% of imported fossil fuels (petroleum and diesel) in the final national energy balance. This is mainly responsible for supplying the transport sector and accounts for around 93% of transport sector demand. It provides a main niche for the introduction of hydrogen into the national energy matrix.

The Paraguayan electrical system holds 8,810 MW capacity of hydroelectricity power plants targeted to reach 11,541.86 MW by 2030. A major part of the produced hydroelectricity is exported to other countries. Yet, there are significant electricity resources left for hydrogen production and utilisation with the intent to decarbonize other sectors besides mobility.

In the overall electricity system, hydrogen in Paraguay could contribute to the peak hour surplus electricity storage, and its generation via fuel cells could be used to balance electricity grids and for frequency regulation. Together, hydrogen is playing a critical role in increasing the national energy security of Paraguay.

Furthermore, hydrogen in Paraguay can be used in industry, green chemistry, and agriculture for fertiliser production and clean synthetic fuels such as methane, methanol, and ammonia production and domestic use, replacing gasoline

[1] SUSTAINABLE ENERGY FOR PARAGUAY 2019-2023. Ministry of Public Works & Communications. Vice-Ministry of Mines & Energy. https://www.ssme.gov.py/vmme/pdf/agenda/AgendaEnerdelParaguay-VEnglish_compressed.pdf.

and diesel, producing solvents and antifreeze. For example, in the agriculture sector, the annual demand for nitrogen fertilizers in 2019 was 150,075 tonnes. Hydrogen was also identified as a raw material in the hydrogenation of vegetable oils to produce margarine.

Hydrogen in Paraguay could also replace the biomass and firewood currently used in high temperature industries.

Projects

Reducing 20% of fossil fuel consumption in Paraguay by 2030 would cut 429.04 ktoe of petroleum derivatives. Installing a 600 MW capacity hydrogen plant with an annual production and utilisation of 90.000 tonnes of H_2 as a fuel in the land and river transport sector by 2030 could avoid the equivalent of 1.3 million tonnes of CO_2 emissions. This environmental benefit supports the goal of including hydrogen in the National Strategy for Sustainable Mobility, through a demonstration pilot.

A number of concrete projects are in the pipeline. For example, hydrogen can be used to promote the energy transition of the transport sector from land to maritime. A potential new route for cargo and public transport could be built from Asunción to the Brazilian border.

Also, in 2022, Atome Energy's Green Ammonia announced a 120 MW green hydrogen and ammonia production facility in Villeta Paraguay with 100,000 metric tonnes of green ammonia produced annually. IDB Invest, a member of the Inter-American Development Bank Group, announced on June 2, 2024 a USD $125,000,000 greenfield green hydrogen project near Villeta, helping Paraguay to develop, design, construct and operate green hydrogen production. In 2021 an agreement was signed for the construction of a green hydrogen and ammonia production plant situated within the Itaipu Technology Park on the border with Brazil. By the end of 2024, the plant will be producing 50MW and gradually increase production up to 250MW.

Massive Itaipu hydroelectric dam on the Parana River located on the border between Brazil and Paraguay[2]

[2] Reference: https://www.freepik.com/premium-photo/massive-itaipu-hydroelectric-dam-parana-river-located-border-brazil-paraguay_37959373.htm.

Green Hydrogen Technology Application Asia and the Pacific Region

Malaysia

Green Hydrogen Technology Application
Asia and the Pacific Region
Malaysia

National plans

The Malaysia Ministry of Science, Technology and Innovation have published the "Hydrogen Economy and Technology Roadmap" which aligns with the National Science, Technology and Innovation Policy 2021-2030 and National Energy Policy 2022-2040.

With the intent to provide a secure, affordable, and sustainable alternative source of fuel, Malaysia plans to contribute to each dimension of the so-called energy trilemma.[3] To scale up the hydrogen ecosystem, Malaysia is setting priorities to invest in the development of a new hydrogen infrastructure, and supports transforming 'just technology users' into innovators, technology producers, and new talent cultivators.

Malaysia is positioning itself as a leading nation among ASEAN[4] countries in the hydrogen economy by 2050. With hydrogen as a cornerstone of this new energy economy, Malaysia intends to export hydrogen to Japan, China, South Korea, and other economies. Malaysia in a short, medium, and long-term perspective focuses on shifting from a moderate to highly significant hydrogen trading hub.

Nationwide, Malaysia aims to achieve a sustainable energy mix using increased clean energy sources. In the long-term, there will be a 2,066,667 tonnes (equivalent to 68.2 TWh) of annual hydrogen demand for energy storage and as a fuel for combined-cycle gas turbines. Malaysia will prioritise investment in hydrogen technologies to reflect the demand for domestic hydrogen consumption, stability, security of energy, sustaining international energy trading and decarbonisation.

The 12th Malaysia NDC Plan 2021-2025 aims to achieve net zero emissions by 2050. Low-Carbon Nation status could be achieved using hydrogen in the transportation sector. In the long-term, a wider mobility ecosystem is projected to be developed with 924,242 tonnes (equivalent to 30.5 TWh) annual hydrogen production demand in the transport sector.

Key strategies

The Ministry of Economy and the Ministry of Energy and Natural Resources are the federal ministries responsible for energy in Malaysia. The government of Malaysia focuses on measures to stimulate the adoption of green energy, and various ministries have published roadmaps with strategic plans to achieve net zero greenhouse gas emissions by as early as 2050.

Back in 2018, the largest primary energy sources in Malaysia were natural gas (41%), crude oil and petroleum (30%), coal/coke (22%), and only 7% hydropower and other renewable energy.

In 2020, renewable energy amounted to 8,450 MW, from which 5,692 MW from hydro, 1,534 MW from solar PV and biomass, 507 MW from small hydro and 123 MW from biogas. The hydrogen production from non-renewable and renewable sources are natural gas to produce blue hydrogen, and solid biomass, solar, hydropower, and ocean thermal energy conversion. Green hydrogen produced from only renewable energy sources remains a strategic goal in the long term.

By identifying gaps in hydrogen policy, standards and regulation, the National Energy Transition Roadmap proposes establishing hydrogen regulation, guarantee of hydrogen origin certification of importing countries, and improving the permitting process for hydrogen projects.

[3] Trilemma refers to energy security, affordability, and sustainability.
[4] Brunei, Burma (Myanmar), Cambodia, Timor-Leste, Indonesia, Laos, Malaysia, the Philippines, Singapore, Thailand and Vietnam.

Malaysia aims to be a technology-driven and high-tech nation by 2030. In the context of hydrogen, it has three objectives: to institutionalise and strengthen the national hydrogen governance and ecosystem, to accelerate hydrogen economy adoption by industry, and to use hydrogen to contribute to the country's GHG mitigation strategies.

The Hydrogen Economy and Technology Roadmap 2023 proposes five strategic action plans to strengthen the governance system and regulatory framework, facilitate an enabling environment for the hydrogen economy growth, commercialise the technology for hydrogen production and infrastructure, invest in research and development, and develop the workforce capacity of the hydrogen ecosystem.

Projects

Various hydrogen projects are in the process of being developed. In May 2019, an Integrated Hydrogen Production Plant and Refuelling Station for hydrogen fuel cell buses and cars was developed and completed. Sarawak is planning to build six multi-fuel refuelling stations with conventional fuels, electric charging, and hydrogen refuelling.

Malaysia is also supporting three projects to produce green hydrogen with a focus on hydrogen and ammonia for export and domestic use in East Malaysia, intending to be completed by 2027. It is expected that green hydrogen, as a clean energy carrier, can be used in the transport sector, allowing for a phase-out of grey hydrogen by 2050, and producing 3.75 Mton/year of green hydrogen by 2050 from renewables.

Another green hydrogen and ammonia project in Malaysia aims to produce 7,000 ton/year of green hydrogen for Sarawak's local use, 600,000 ton/year of blue ammonia, 630,000 ton/year of green ammonia and 460,000 ton/year of green methanol.

The Sarawak project for hydrogen production via electrolysis will use hydropower and produce around 90,000 tonnes per year of green hydrogen, from which 2,000-3,000 tonnes will be dedicated to local consumption. The rest of the hydrogen will be converted to methylcyclohexane (MCH), a liquid hydrogen carrier, which will be exported to Japan. The dedicated project site is located at a large petrochemical industrial park that already has shipping and port facilities.[5]

A schematic for the H2biscus project in Sarawak, Malaysia[6]

[5] Reference: https://bimp-eaga.asia/article/sarawak-export-green-hydrogen-2030.
[6] Reference: https://www.hydrogeninsight.com/production/green-hydrogen-projects-in-malaysia-worth-billions-of-dollars-to-be-signed-off-this-week-report/2-1-1603550.

Green Hydrogen Technology Application

Africa Region

Mauritania

Green Hydrogen Technology Application
Africa Region
Mauritania

National plans

Mauritania, as a part of the African Green Hydrogen Alliance, is taking steps to position itself as a key player in Africa's transition to sustainable energy in the green hydrogen space. Mauritania's 2022 green hydrogen roadmap explores opportunities and outlines future steps. Following Mauritania's transformational energy sector vision to increase the share of renewables to 60% and reduce greenhouse gas emissions by 92% by 2030, green hydrogen is projected as one of the key energy vectors. Mauritania will allocate 5% of its coastal territory to renewable energy to be able to produce hydrogen via electrolysis to meet 14% (or 12 Mt/year) hydrogen demand. Mauritania plans to expand the green hydrogen export potential to Europe, and this way increase the country's GDP by 50-60% by 2035.

The Mauritanian government plans to create four new entities related to hydrogen. The first one is the Hydrogen Directorate which is to be responsible for the strategic, political, legal, contractual and diplomatic aspects of the hydrogen sector. Secondly, a Hydrogen Agency is a new state entity responsible for operational functions such as monitoring and execution of projects, and developing feasibility studies. Thirdly, a Hydrogen company will be responsible for the financial aspects. Lastly, Hydrogen Departments (integrated into Mauritanian universities and schools) will be responsible for higher education, R&D activities, and technological development.

Mauritania has the largest pipeline of renewable hydrogen projects by 2030 in sub-Saharan Africa. Derisking is required to secure the off-takers and attract sufficient investment. To raise the appetite for a large investment, the cooperation between both domestic and international stakeholders should be increased.

Key strategies

In the field of green hydrogen, Mauritania puts its strategic focus on sustainable energy, economic growth, and global environmental goals with a major focus on green hydrogen export. It focuses on export by shipping hydrogen in the form of ammonia, coupling existing iron ore mining with renewable hydrogen to produce direct reduced iron, and transporting hydrogen to Europe via the Maghreb natural gas pipeline. To achieve this, Mauritania needs to enhance its cooperation between government agencies, donors, private partners, and developmental institutions.

In the hydrogen sector, Mauritania foresees green steel, methanol, fertilizers, electricity production, hydrogen for mining machines, and heavy transport, for which deep-dive studies need to be developed. For now, the priority is placed on the production of liquid hydrogen, ammonia, ammonium nitrate, green steel, and methanol for which intermediate-sized pilot installations need to be built, to later be transitioned to large-scale production units. The pilots should start with the construction of sites for solar and wind electricity-based electrolysis production, connected to desalination of water from the Atlantic Ocean. Installed on the coast, port infrastructure will have to be developed to export hydrogen, ammonia, and other "green" derivatives.

In the context of regulation, Mauritania needs to reform the Electricity Code and to identify a normative hydrogen safety system for the production, storage and transport of hydrogen and its by-products. This should follow strict international standards through the classification of risky installations and management of the certification of infrastructure across the entire value chain.

A standard contract for the hydrogen industry must be developed to define a type of contract between the government and hydrogen developers. What is also needed is the development, clarification and simplification of the contractual framework by providing simplified rules, procedures and decision-making algorithms for hydrogen related projects such as the call for tender procedures and tax benefits helps to foster and expand the projects pipeline.

Mauritania also needs to update the National Water Plan to develop a master plan for hydraulic infrastructure and identify investment needs as well as to identify the water needs for areas with water stress and in mining sites. Strategically, it is important to establish an institutional framework of the Hydrogen Directorate, Hydrogen Agency and Departments of Hydrogen, which will ensure effective collaboration with relevant state bodies, industry and other stakeholders. To enhance the local capacities and reflect a demand for hydrogen professionals, training and higher education programs should be opened to a wider public. Mauritania also needs to strengthen its infrastructure – such as ports and railways – to reflect a growing hydrogen demand and production, and in order to avoid possible delays due to under-sizing.

Projects

Various projects are underway. In 2022, the Ministry of Petroleum, Energy, and Mines signed three projects:

- The 40 billion USD project called 'AMAN' aims to construct a 30 GW combined wind and solar energy generation plant for the 1.7 million tonnes green hydrogen and 10 million tonnes of green ammonia annual production facility in Mauritania's northern desert and coastal regions.
- A 10 GW capacity electrolysis production project powered by solar and wind resources in Nour, which aims to be one the largest green hydrogen projects globally by 2030.
- Mauritania's state-owned company has partnered with ArcelorMittal aiming to produce 2.5 million tonnes of green steel per year.

Green hydrogen production and storage in Mauritania[7]

[7] Reference: https://oilreviewafrica.com/exploration/industry/project-nour-mauritania-paves-way-to-become-world-class-green-hydrogen-initiative.

Green Hydrogen Technology Application

Middle East Region

Jordan

Green Hydrogen Technology Application
Middle East Region
Jordan

National plans

Jordan plans to create a local green hydrogen economy and position itself as a regional centre supplying green hydrogen and Power-to-X (PtX) products. In the short term, it plans to enhance domestic use and supply a modest export, while scaling up in the long term.

Jordan has significant low-cost renewable energy resources and the ability to convert them into chemical energy, green hydrogen, and its derivative products via Power-to-X. This makes Jordan attractive for green hydrogen production. It would reduce costly fossil fuel imports, improve energy security, enhance export competitiveness, and transition the country to a more prosperous, equitable, and sustainable economy.

Even small-scale action on domestic use and export would significantly contribute to a greener future. Jordan plans to produce 591,000 metric tonnes of green hydrogen annually by 2030, 1.5 million metric tonnes by 2040, and 3.4 million metric tonnes by 2050. Additionally, the export in the form of green ammonia is projected as 2.3 million metric tonnes. These activities will require a mobilisation of 175 billion USD of investment.

Key strategies

The Jordan green hydrogen strategy has five strategic priorities: 1) strengthening production measures, 2) supporting hydrogen investments, 3) stimulating market demand, 4) facilitating low-cost supply, 5) leveraging existing leadership in renewable energy and strengthening the enabling environment. An assessment needs to be developed to identify and address the regulatory requirements, and ensure that health and safety standards are in line with evolving international standards.

Jordan plans to employ an already mature hydrogen production technology and equipment to kickstart local hydrogen demand for the offtake in municipal bus transportation, hydrogen blending with natural gas for power generation, and heavy-duty trucks. The hydrogen ecosystem development relies on private investors. However, government support is needed to remove barriers related to regulatory, land and water availability, as well as infrastructure.

In the short term, the financing can be ensured via incentives developed in Jordan's Investment Environment Law, facilitating a low-cost hydrogen supply. The green hydrogen production expansion should go together with a growing renewable power generation as green hydrogen production expansion will facilitate the integration of higher shares of renewable power in the grid through electricity balancing and storage.

The Draft Green Hydrogen Strategy presented recommendations that need to be incorporated into Jordan's National Energy Sector Strategy. For example, the strategy calls for establishment of a cross-ministerial green hydrogen steering committee chaired by the Ministry of Energy and Mineral Resources. Also, within the Ministry of Energy and Mineral Resources, a unit to coordinate a green hydrogen initiative is needed, as well as facilitating investor engagement, collect and maintain data, conducting further studies.

The Ministry of Energy and Mineral Resources together with the Ministry of Investments can provide support to interested investors by signing a Memorandum of Understanding and feasibility studies and maintaining an investment pipeline by screening and prioritizing potential projects.

Projects

Jordan is already starting a number of hydrogen projects, and has the potential to become a global powerhouse in domestic and global green energy transition.

Near the port of Aqaba many end-users are located, including fertilizer producers and exporters. Therefore, concentrating green hydrogen production there would reduce transport costs and facilitate innovation and ecosystem growth, improving competitiveness.

Furthermore, Jordan is planning to develop a Green Hydrogen Industrial Hub located 7 km from the seaside, in the Aseza area.

By 2030, Masdar targets to produce 1 million metric tonnes of green hydrogen. To this end, Masdar signed a joint development agreement for 1GW wind project and battery energy storage system and announced a separate Memorandum of Understanding for a green hydrogen plant feasibility study in Jordan. The feasibility study will assess the potential to establish a green hydrogen project near the Port of Aqaba to produce cost-competitive hydrogen from desalinated seawater and renewable power.

Aseza green ammonia plant in Jordan[8]

[8] Reference: https://www.barracudaservice.com/projects/jod-02-bam-anp-1-copy/.

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