Green Hydrogen Roadmap for Sri Lanka

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1 Introduction

1.1 Objectives

This report functions as a comprehensive set of guidelines for overseeing and assessing green hydrogen initiatives which are about to begin in Sri Lankan context. The National green Hydrogen Roadmap offers guidance on policy implementation, infrastructure development, market expansion, research advancement, and international alliances in order to facilitate the widespread integration of green hydrogen in Sri Lanka's energy sector[1]. Its objective is to promote a sustainable economy based on green hydrogen, with a focus on both economic development and environmental responsibility. In order to enable the smooth transfer of infrastructure and technology, the project also looks at green hydrogen technological processes, storage, transportation, and evaluation of Sri Lanka's renewable energy sector's preparedness[2].

1.2 Literature Survey

The production of green hydrogen using water electrolysis with renewable electricity presents a viable energy solution that is less harmful to the environment than hydrogen generated traditionally. Driven by pro-environment regulations and growing environmental concerns, the global market for green hydrogen reached USD 3.2 billion in 2021 and is expected to grow at a compound annual growth rate (CAGR) of 39.5% from 2022 to 2030[3]. Green hydrogen is acknowledged in Sri Lanka for its capacity to tackle issues related to affordability, environmental sustainability, and energy security. To address these issues, the National Green Hydrogen Roadmap proposes an adaptable strategy[2]. Different manufacturing techniques, each with unique benefits and uses, include biomass gasification, direct water splitting by photoelectrochemical processes, and industrial electrolysis. Different types of electrolyzers, including solid oxide, alkaline, PEM, and HTPEM, are used in industrial electrolysis. Each type has advantages and disadvantages that affect scalability, durability, cost, and efficiency. Direct water splitting also uses solar energy, and biomass gasification produces hydrogen that is carbon neutral, which helps remove carbon dioxide from the atmosphere[4].

Hydrogen storing method

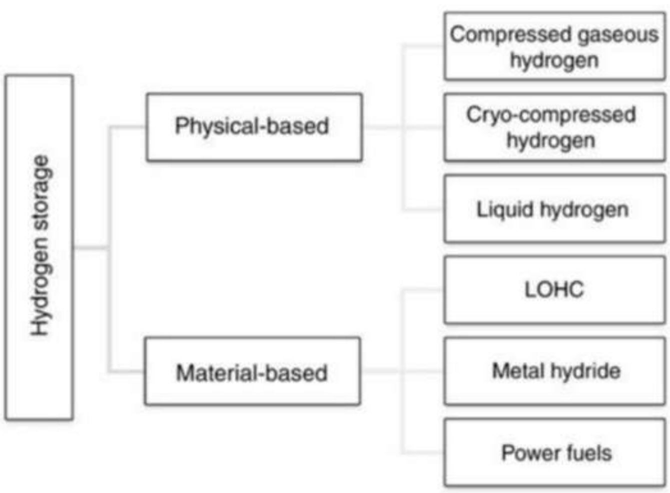

Fig. 1. Techniques to store hydrogen

Hydrogen production technologies

Hydrocarbon Reforming - Hydrocarbon reforming is a widely used method for hydrogen production, particularly through Methane Steam Reforming (MSR). MSR involves a catalytic reaction between methane and steam, producing hydrogen, carbon monoxide, and a smaller amount of carbon dioxide. This endothermic process requires high temperatures (700-1000°C). Another method, Autothermal Reforming (ATR), combines partial oxidation and steam reforming in a single reactor. ATR utilizes the exothermic heat generated from the partial oxidation of methane to drive the endothermic steam reforming reaction, reducing the need for external energy input.

Water Splitting - Water splitting encompasses several techniques, most notably electrolysis. Electrolysis involves using an electric current to split water into hydrogen and oxygen. Proton Exchange Membrane (PEM) electrolysis and Alkaline Water Electrolysis (AWE) are common methods, with PEM using a solid polymer electrolyte and AWE using a liquid alkaline electrolyte. Solid Oxide Electrolysis (SOE) operates at elevated temperatures (800-1000°C) and uses a solid oxide electrolyte. Thermolysis involves direct thermal decomposition of water at very high temperatures (>2500 K), while photolysis uses light energy to split water molecules, often enhanced by chemical catalysts.

Biological Production - Biological methods utilize microorganisms to produce hydrogen. Bio-photolysis mimics photosynthesis in algae and plants, using light energy to split water into hydrogen and oxygen. This process relies on enzymes like hydrogenases. Dark fermentation involves anaerobic bacteria breaking down organic material in the absence of light, producing hydrogen as a byproduct. This method can use various carbohydrate-rich substrates. Photo fermentation employs photosynthetic bacteria that convert organic substrates into hydrogen using light, without evolving oxygen, thereby avoiding competitive reactions and improving yield.

Thermochemical Production - Thermochemical production methods include pyrolysis and gasification. Pyrolysis involves heating organic material in the absence of air, breaking it down into hydrogen, carbon monoxide, and other byproducts. This process occurs at moderate temperatures (500-900°C) and pressures (0.1- 0.5 MPa). Gasification, on the other hand, involves high-temperature partial oxidation of biomass, converting it into a mixture of hydrogen, carbon monoxide, methane, and other gases. Combustion of biomass, while primarily used for energy production, can also produce hydrogen, though it is less efficient and results in significant CO_2 emissions.

Comparison of Hydrogen Production Technologies

Technology	Efficiency (%)	Cost ($/kg H_2)	Scalability
Methane Steam Reforming	65 - 75	1 - 2	High
Autothermal Reforming	70	1.5 - 2.5	Moderate to High
PEM Electrolysis	50 - 70	3 - 7	High
Alkaline Water Electrolysis	60 - 70	2 - 6	High
Solid Oxide Electrolysis	Up to 80	3 - 8	Moderate
Thermolysis	Varies	Experimental	Low (experimental)
Photolysis	Varies	Experimental	Low (experimental)
Bio-Photolysis	Moderate	High (experimental)	Low (experimental)
Dark Fermentation	Moderate	2 - 4	Moderate
Photo Fermentation	Moderate to High	2 - 5	Low to Moderate
Pyrolysis	Up to 60	1.5 - 3	Moderate
Gasification	70 - 80	1 - 2	High
Combustion	Low	High	Low

Extend and reach of renewable energy in Sri Lanka

By 2020, 39% of the energy supply came from renewable sources, producing 162,464 TJ in total energy output. In 2021, the nation produced 16,770 GWh of power, of which 51% came from renewable sources. Of the total electricity generated, 43% came from hydro and marine sources, and the remaining 4% and 3% came from solar and wind energy, respectively. Geothermal and bioenergy sources also had a small impact. The utilization rates of capacity varied, with wind energy exhibiting a strong usage rate of 34% and fossil fuels at 45%. 15,684.783 GWh from hydro and marine sources, 4,641.667 GWh from solar, 1,897.059 GWh from wind, and 397.561 GWh from bioenergy make up the total theoretical potential of renewable sources[5].

Table 1. Renewable energy availability for green Hydrogen production in Sri Lanka.

Energy source	Total consumption (GWh)	Total potential (GWh)	Available energy for green hydrogen production (GWh)
Hydro and marine	7215	15684.783	8469.783
Solar energy	557	4641.667	4084.667
Wind energy	645	1897.059	1252.059
Bioenergy	163	397.561	234.561

Impact of green Hydrogen for National Determined Contributions

1. Diversification - Green hydrogen enhances energy security and aligns with the goals of the Energy Policy by reducing reliance on coal and oil-based thermal power.
2. Growth of Renewable Energy - It promotes technological maturity by acting as a catalyst for the development of domestic renewable energy sources, especially offshore wind.
3. Reduction of Emissions - Sustainable and climate-resilient production is in line with emission reduction objectives.
4. Electricity Targets - By guaranteeing stability from sporadic sources, green hydrogen helps achieve the aim of 70% renewable electricity generation by 2030.
5. Potential for Energy Export - By exporting excess green hydrogen, carbon emissions can be decreased, and regional energy cooperation can be fostered.
6. Decreased Reliance on Imported Fossil Fuels - Increasing output reduces dependency on imported fossil fuels, promoting self-sufficiency and reducing trade imbalances.
7. Remote Energy Access - It makes renewable energy options available to isolated areas without access to power[6].

2 Methodology

2.1 Appraising existing infrastructure and expansion projects.

For Sri Lanka to make the switch to a hydrogen-based energy system, a thorough evaluation of the country's current infrastructure and future growth opportunities is necessary. Power plants, electrical grids, and substations make up the majority of the nation's infrastructure, so it must be evaluated for possible integration into a green hydrogen-based system[7]. Modifications to conventional power plants may be necessary to facilitate the blending or conversion of hydrogen. It is essential to invest in electrolysis plants that produce hydrogen using renewable energy sources such as hydro, wind, or solar power. Solid-state storage, metal-organic frameworks (MOFs), liquid hydrogen storage, and high-pressure gas storage are all essential components of the storage infrastructure. Pipelines and refueling stations are examples of distribution and transportation infrastructure that needs to adhere to safety and legal requirements. Upgrades to the grid's integration are necessary to smoothly integrate hydrogen-based power generation. The future of expansion depends on utilizing the wealth of renewable resources available, which calls for strategic energy planning, international cooperation, and safety precautions in order to win over the public and attract funding[8].

2.2 Green Hydrogen utilizing methods in Sri Lanka.

Sri Lanka is ideally situated to take advantage of green hydrogen to power an offshore wind and solar-powered sustainable economy. Energy storage, transit, industrial heating, export, and bunkering are examples of utilization techniques. In order to maintain grid stability and energy independence, green hydrogen plays a critical role as an energy storage medium. It provides a fossil fuel-free, sustainable transportation option that lowers emissions and encourages environmentally friendly mobility. Industrial heating can contribute to global decarbonization efforts by reducing carbon footprints significantly. Exporting green energy goods, like green ammonia, can boost the country's economy and establish Sri Lanka as a leader in the world green energy industry. Particularly in the maritime industry, hydrogen bunkering provides an environmentally friendly way to power ships and cut emissions, supporting international efforts to decarbonize shipping[9].

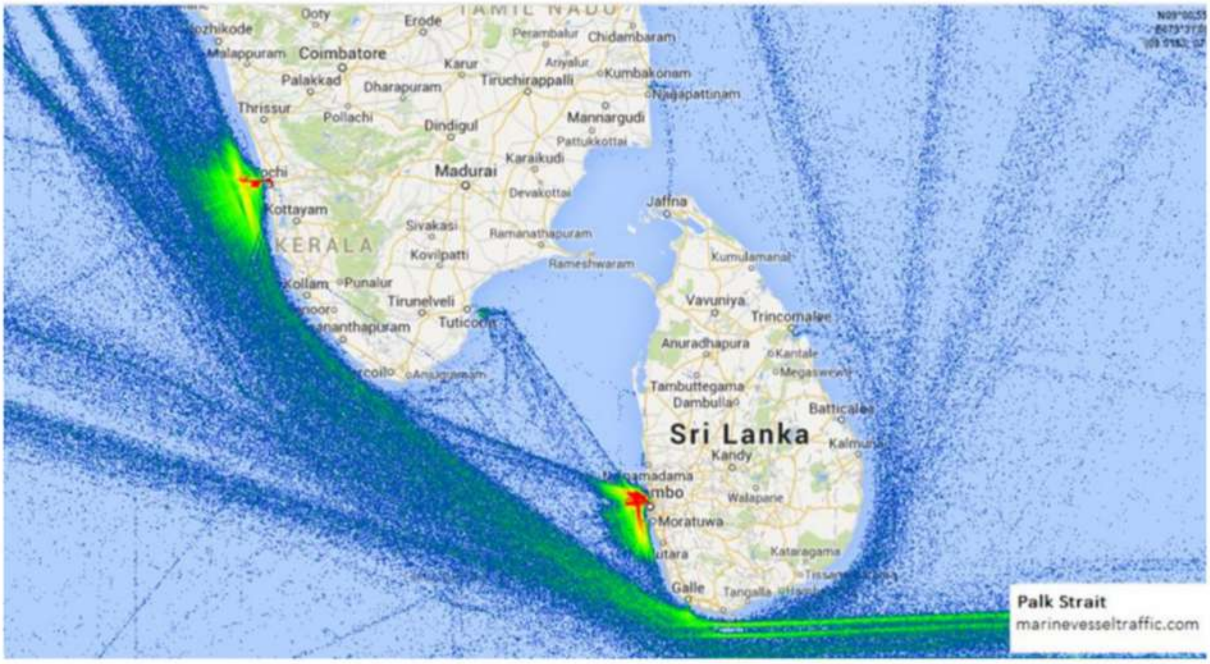

Fig. 2 . Palk straight ship traffic around Sri Lanka

3 Results and Discussion

3.1 Identification of optimal renewable energy source for green Hydrogen production in Sri Lanka.

To determine the best choice for Sri Lanka's transition to green hydrogen generation, it is crucial to assess renewable energy sources according to important criteria. Utilization of available resources, environmental impact, development potential, economic viability, sustainability, and technological maturity level are all considered in the effectiveness evaluation matrix. Using this methodology, wind energy comes out on top as the best option for producing green hydrogen in Sri Lanka, with the highest rating out of all the sources assessed.

Table 2. Evaluation matrix for each renewable source.

Parameter	Hydro and marine energy	Wind energy	Solar energy	Bioenergy
Capacity Utilization	8	7	5	6
Resource Availability	8	9	6	8
Environmental Impact	8	9	9	7
Development Potential	7	8	9	7
Economic Viability	7	8	6	6
Sustainability	8	8	9	8
Technology Maturity Level	8	7	9	7

Wind energy is the most desired renewable energy source according to the scoring method provided in the table because of its high-capacity utilization, abundance, low environmental impact, large development potential, economic feasibility, sustainability, and reasonable level of technological maturity. Sri Lanka has more than 40 GW of offshore wind potential, which means it can produce more green hydrogen than it needs while meeting its electricity needs.

3.2 Green Hydrogen bunkering methods

Green hydrogen bunkering offers a clean energy source for ships and lessens the environmental impact of the shipping industry, making it a crucial step in the worldwide maritime decarbonization efforts. In line with the goals of its Green Hydrogen Roadmap, Sri Lanka is ideally situated to lead the region in green hydrogen bunkering due to its strategic location along important shipping routes.

There are several bunkering techniques, each with special benefits and difficulties. A number of potential solutions for bunkering exist, including compressed hydrogen, liquefied hydrogen, ammonia, and liquid organic hydrogen carriers (LOHCs). These options vary based on energy density, availability of infrastructure, safety concerns, and technological development[10].

Although liquefied and compressed hydrogen have advantages in terms of energy density, they also have drawbacks because of specialized infrastructure and energy-intensive operations. Ammonia bunkering makes use of the infrastructure already in place, but treating it safely is necessary because of its toxicity. Although they are still in the preliminary stages of development, LOHCs offer a potentially safer and more practical alternative.

Investing in innovative bunkering technologies is essential to expediting the maritime industry's shift to environmentally friendly practices. Every bunkering technique advances the use of green hydrogen as a clean energy source in the maritime sector and lowers emissions.

3.3 Green Hydrogen bunkering delivery methods

The development of effective and flexible bunkering supply techniques is important for Sri Lanka to fulfill its ambition of becoming a pioneer in green hydrogen. There are several ways to supply green hydrogen to ships, including ship-to-ship bunkering, barge-to-ship bunkering, mobile bunkering units, and hydrogen filling stations.

While mobile bunkering units offer flexibility in serving smaller ports or vessels without set infrastructure, onshore bunkering facilities offer specialized terminals for refueling at ports. Marine bunkering could make use of hydrogen filling stations, mostly for land-based vehicles. Flexibility is provided by barging to ship and ship to ship bunkering, especially for smaller boats or in isolated areas.

The best way to provide bunkering relies on several variables, including the amount of hydrogen, the distance to be transported, the infrastructure that is available, and technical developments. The pace of maritime decarbonization will be impacted by Sri Lanka's choice of bunkering delivery infrastructure, which might make its ports stand out as regional leaders in sustainable shipping.

Conclusion

In summary, Sri Lanka's development of green hydrogen programs has great potential to promote an energy landscape that is both ecologically conscious and sustainable. Utilizing renewable energy sources, especially wind energy, the country may lower its carbon footprint and promote economic growth. Moreover, implementing cutting-edge green hydrogen bunkering techniques in the maritime industry not only advances worldwide decarbonization initiatives but also establishes Sri Lanka as a pioneer in environmentally friendly shipping. Sri Lanka is positioned to make major progress toward a cleaner, greener future through the development of vital infrastructure and international partnerships, in line with the goals of its National Green Hydrogen Roadmap and supporting international efforts to mitigate climate change.

Keywords: Sri Lanka, Green Hydrogen, Sustainability, Renewable Energy, Maritime transportation

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