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SRI LANKA NATIONAL HYDROGEN ROADMAP

Contents

Messages from GoSL

Hon. President's Message

The climate crisis is the single largest challenge faced by humankind to date, and one that demands a collective resolve. The current multiple ecological crises – spanning from massive forest fires in many parts of the world, record heat waves affecting billions of people and animals, and the extensive loss of Antarctic Sea ice, are reminders of the urgent need to concertedly decarbonize the world.

Disproportionately affected are the countries of the global South, who are the least responsible for universal emissions but the most vulnerable to their impact. Therefore, the climate crisis is not only an ecological issue, but also one of equity. As we transition to a new post-carbon world, global investment and trade flows must address this mounting climate debt.

In this context, Green Hydrogen is an important aspect Sri Lanka envisions to resolutely pursue. The country's abundant wind and solar resources, substantially outweigh its domestic power requirement, leaving the surplus to be utilized for grid-independent export into this fast-growing industry. I have directed the preparation of an investment framework, comprising international standards, by which global capital can be attracted to Sri Lanka, leveraging the country's strategic location to realize its potential as a true energy hub, while delivering value to all our citizens.

Ranil Wickremesinghe
President
Democratic Socialist Republic of Sri Lanka

Minister’s Message

As the world shifts rapidly towards more sustainable energy, green hydrogen is emerging as a promising solution to decarbonisation challenges across many sectors. For Sri Lanka, green hydrogen, producible at scale from our abundant offshore wind and solar, also presents an unparalleled opportunity to accelerate economic growth by converting and exporting energy as green ammonia and methanol without being constrained by domestic demand. It can also substitute fossil fuel and chemical imports by providing a clean, renewable, and versatile energy carrier for many domestic sectors, including transportation, industry, and power generation.

This document, which outlines key steps required for creating an optimal legal, operational, and commercial environment to attract international investment into the sector, done in collaboration with our green hydrogen technology partner, is a declaration of our national resolve to pursue a path of development that is harmonious with both our local environment and our global commitments. President Ranil Wickremesinghe emphasised this in his recent Special Address to the Nation on 01 June 2023, when he said;

“We aim to prioritise modern and sustainable efforts such as renewable energy, green hydrogen, and digitisation. We can draw inspiration from the Andhra region of India, which has excelled in developing these areas. Such modern and sustainable initiatives are vital for the complete transformation of Sri Lanka’s economy. Over the next few months, we will make a special invitation to the private sector to submit their own business proposals that align with our vision of modernisation and sustainability”

The Sri Lanka Green Hydrogen Roadmap is a step in that direction.

Hon. Kanchana Wijesekera MP
Minister of Power & Energy

State Minister's Message

Sri Lanka, like the rest of the world, has experienced the hardships of recent times, and this experience has led us to clearly see the importance of energy security and dependency, as well as explore new sources and forms of energy. Developments in technology clearly indicate that the entire world is now looking at alternative energy sources that will not only contribute to a greener world but will depolarize the energy sector, opening new opportunities to new nations.

Blessed with immense potential for both solar and wind power, under the guidance of his His Excellency the President and the Hon Minister of Power and Energy, we hope to build on these to ensure that we would be self-sufficient in our power generation as well as become one of the regions largest exporters of renewable energy.

While we focus on this goal, our preliminary studies have shown that there remains an even greater potential for us, should we explore the possibilities and opportunities of green hydrogen. While the technology is new and groundbreaking, the interest and potential cannot be ignored. Considering the resources of Sri Lanka and its geographical positioning, we have no doubt of its potential to be a hub for power in this new cleaner, greener world.

We stand by to support the development of this new industry and to assure potential investors that we have done the necessary groundwork to ensure their safety and profitability on the journey to not only a better Sri Lanka but a better world.

Hon. DV Chanaka MP
State Minister of Energy

Executive summary

Global climate change is a significant and pressing issue facing the world today. It is caused by the release of greenhouse gases, such as carbon dioxide, into the atmosphere, which trap heat and cause the Earth's temperature to rise. This can lead to a range of negative impacts, including more frequent and severe weather events, rising sea levels, and loss of biodiversity.

It is the responsibility of all countries to take steps to mitigate climate change and reduce their greenhouse gas emissions. Decarbonizing 80% of the economy is generally considered a feasible task, as relevant technologies are both widely accessible and economically viable. However, decarbonizing the "last mile" and sectors that are difficult to abate presents a more formidable challenge.

Green hydrogen, produced using renewable energy sources like wind and solar power, offers a potential solution for these hard-to-abate sectors. It holds the promise of significantly contributing to the transition towards a low-carbon economy by serving as a clean, efficient, and versatile energy source.

Over the past five years, more than 30 nations have either developed or initiated the preparation of national hydrogen strategies. While climate goals pledged by these countries have been a principal driving force, geopolitical dynamics and unpredictable & fluctuating Fossil fuel (Coal, Oil & Gas) prices have also catalyzed the shift towards greener fuels, particularly green hydrogen.

Countries are investing heavily in the development and deployment of green hydrogen technologies, recognizing the important role that this fuel can play in decarbonizing their economies.

As a recognition of the growing requirements to combat climate change, Sri Lanka has revised its NDCs to meet the global expectations and objectives. To achieve these aggressive targets, rapid renewable energy must be deployed as well as advanced technology to manage the associated intermittencies, ensure grid stability and energy independence. Sri Lanka views green hydrogen as the critical enabler of renewable integration and sustainable energy storage.

In addition to domestic decarbonisation, Sri Lanka has the potential to contribute to global decarbonisation effort by producing green hydrogen from excess renewable energy. The country has an abundance of excess renewable energy, including solar, wind, and hydroelectric power, and it could use this capacity to produce green hydrogen for domestic use and export. By doing so, Sri Lanka could not only reduce its own greenhouse gas emissions, but also support the transition to a cleaner and more sustainable energy system globally.

Sri Lanka's national hydrogen implementation strategy will follow the key themes below:

01.
Case and enablers for a Green Hydrogen economy

02.
Define achievable goals and ambitions over the short, medium and long term

03.
Priority sectors, markets and opportunities

04.
Policy, legal and fiscal framework

05.
Implementation plan

Sri Lanka's NDCs

70% renewable energy generation by 2030

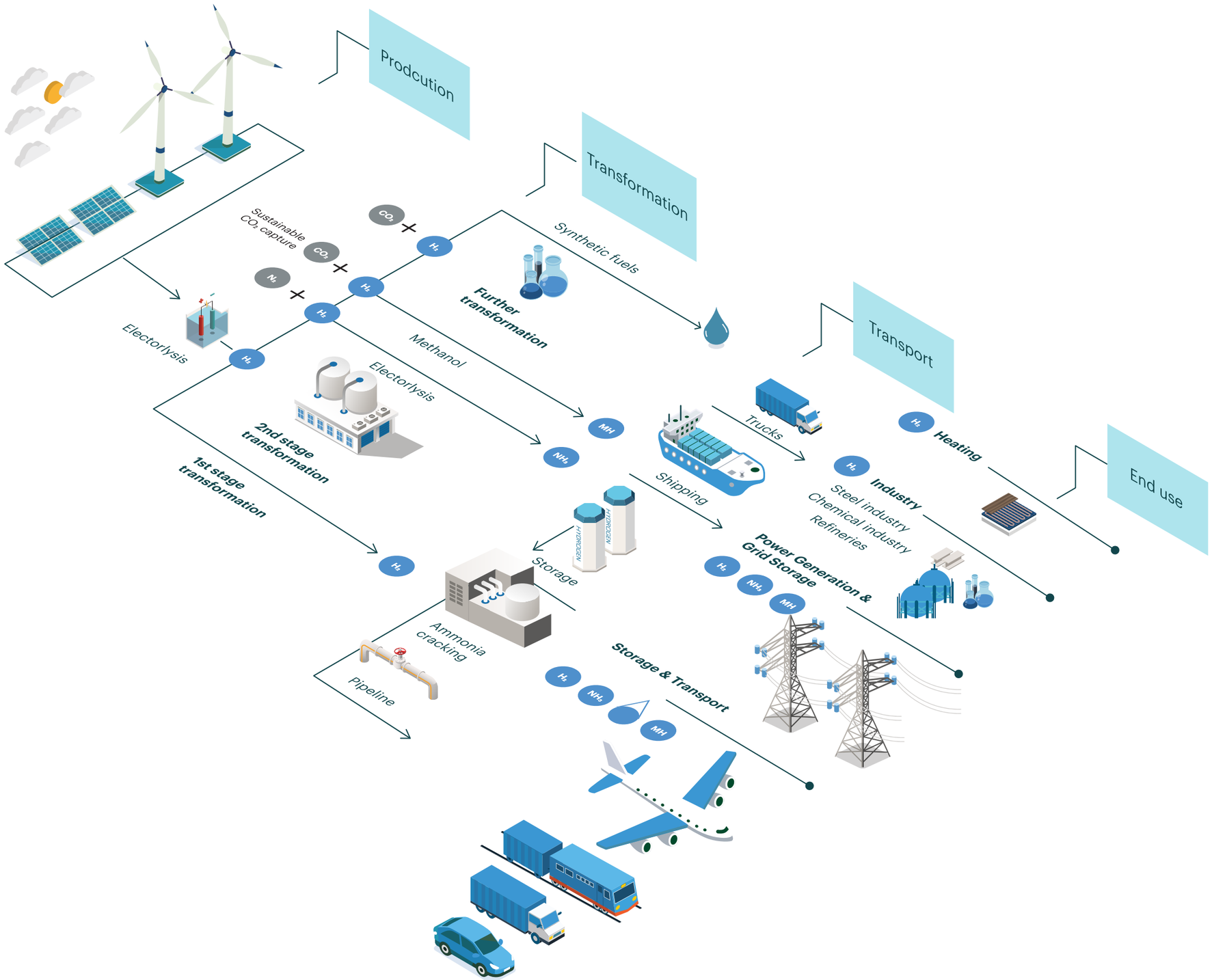
Carbon Neutrality by 2050

0% Coal additions

What is Green Hydrogen?

Green hydrogen, a clean and versatile energy carrier, has emerged as a promising solution in the quest for sustainable energy systems. Produced through the electrolysis of water using electricity generated from renewable sources, green hydrogen is an eco-friendly alternative to conventional hydrogen, which is often derived from fossil fuels. As global efforts to decarbonize energy systems and mitigate climate change continue to gain momentum, green hydrogen has become a key player in the transition to a low-carbon future for applications that cannot be easily electrified.

The production of green hydrogen involves the use of an electrolyzer, a device that separates water (H2O) into its constituent elements, hydrogen (H2) and oxygen (O2), through an electrochemical process. By applying a voltage across an anode and a cathode submerged in an electrolyte, water molecules are split into hydrogen and oxygen gas. The hydrogen produced can then be compressed, stored, and transported for various applications, such as power generation, transportation, and industrial processes. Oxygen produced as a by-product can also be deployed in Industries and medical use.



Green Hydrogen: the Sri Lankan context

Sri Lanka recognizes that green hydrogen offers a unique opportunity to tackle three significant socio-economic challenges: energy security and independence, energy affordability and equity, and environmental sustainability. The National Green Hydrogen Roadmap aims to address these challenges through a flexible and adaptive approach to implementation.

Sri Lanka currently relies heavily on imported hydrocarbon fuels, which poses considerable risks to the nation's electricity generation in terms of supply security and affordability. This risk materialized in 2022 when fuel shortages and high prices occurred. The national energy policy aims to provide universal access to electricity, anticipating that households will transition to clean energy for cooking and adopt domestic technological equipment. In this context, Sri Lanka's energy policy must incorporate provisions to address cooking or other assets that encourage households to transition to cleaner energy sources. Hydrogen has the potential to serve as a clean cooking fuel, especially in communities that rely on biomass and fossil fuels, reducing indoor pollution and associated health effects. However, hydrogen must be produced using sustainable feedstocks and energy sources to ensure that local impacts are not mitigated at the expense of other life cycle impacts.

To address energy volatility and availability issues, Sri Lanka is focusing on indigenous energy sources, particularly renewable energy, while using hydrogen as a storage medium. Green hydrogen is also being utilized to replace fossil fuels for transportation and industrial heat. To meet Sri Lanka's environmental obligations, rapid deployment of renewable energy and advanced technology for managing intermittencies, ensuring grid stability, and achieving energy independence is essential.

In order to tackle challenges related to energy variability, Sri Lanka is prioritizing the development of domestic energy resources, with a special emphasis on renewable energy sources, and employing hydrogen as an effective storage medium. Green hydrogen is also being harnessed as a sustainable alternative to fossil fuels in the transportation and industrial heating sectors. To fulfill Sri Lanka's environmental commitments, it is imperative to expedite the implementation of renewable energy technologies and adopt cutting-edge solutions for managing fluctuations, guaranteeing grid stability, and achieving energy self-sufficiency.

Sri Lanka possesses over 40 GW of offshore wind potential, which greatly surpasses its current and future energy demands. Once the existing energy deficit is met, the country will still have over 35 GW of excess renewable energy, which is difficult to monetize due to its status as an island nation. Green hydrogen and its derivatives represent the most viable option for maximizing the potential of this excess renewable energy. Furthermore, exporting green ammonia will provide significant economic benefits through lease, royalty, and tax revenues from the allocation and commercialization of acreage for offshore wind.

Sri Lanka Hydrogen targets 2030

4,000
jobs created

500 Mn
of export revenue from manufacturing of green energy value chain components

1 Bn
Investment into domestic production and utilisation of green hydrogen and associated technologies

10 Bn
FID for offshore energy production and export

4 GW
of offshore Wind and Hydrogen production infrastructure installed

Objectives and Initiatives

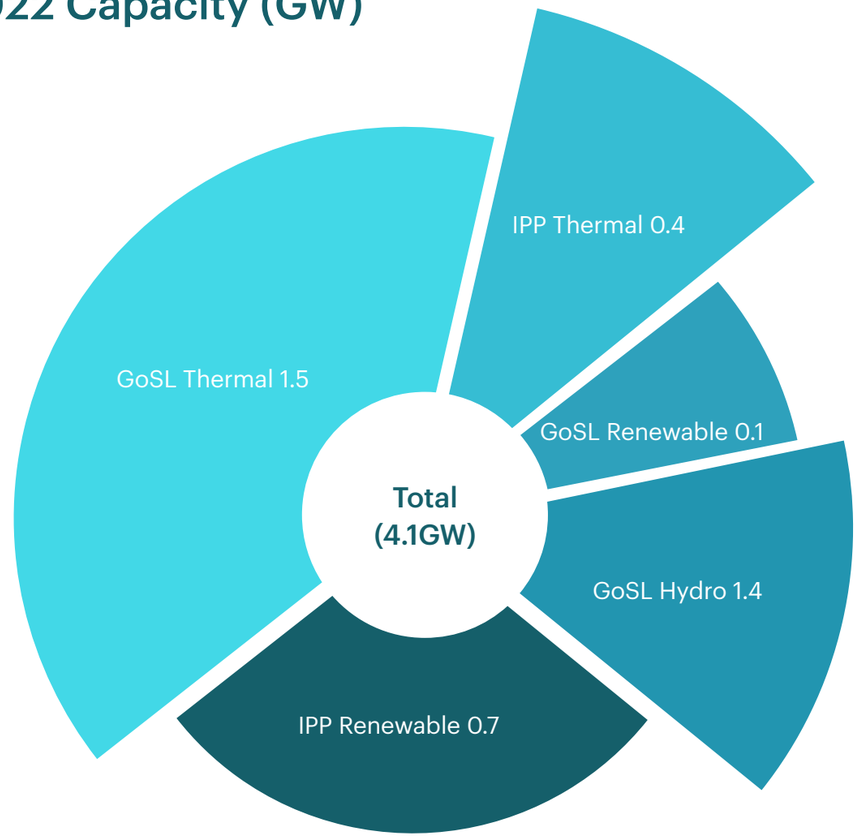
Energy Security

Harnessing low-cost renewable energy is the key to Sri Lanka's energy independence. Integration of green hydrogen will enable Sri Lanka to shift away from the historic narrative of reliance on imported energy through fossil fuels. Sri Lanka's significant renewable surplus provides the opportunity to shift towards a self-sustainable, clean future. Catalysing green hydrogen

Hydrogen provides an avenue towards Sri Lanka's energy independence. Hydrogen fuel cells provide an attractive alternative to larger scale Battery Energy Storage Systems. They provide long term energy storage, do not degrade and require replacement, and do not mandate the same environmental concerns regarding the mining and disposal of toxic metals. As electrolyser technology advances towards eliminating the requirements of precious metals, Sri Lanka believes large scale fuel cell technology will be a viable option to ensuring clean energy integration whilst providing uninterrupted power supply.

In the longer term, Sri Lanka will also explore avenues for hydrogen in both energy storage and power generation. Progressive generation equipment manufacturers already provide the option of co-firing hydrogen in Combine Cycle Natural Gas Turbines with the industry indicating the pure hydrogen as a fuel is a possibility in the future. Sri Lanka's recently discovered Natural Gas reserves are a low-cost energy option that the country must use to decrease domestic energy costs, however this source of energy has associated carbon emissions that the country must abate wherever possible. As a result, Sri Lanka will be seeking to decarbonise any CCGT through the introduction of hydrogen pre combustion and Carbon Capture Utilisation and Storge (CCUS) in the post combustion environment.

2022 Capacity (GW)



Fuel Imports by Type (mt'000s)	
Crude	649
Refined Products	3927
Coal	1707
L.P. Gas	290

Total hydrocarbon Imports (2022) -

USD 5.1 Bn

Energy Export

Sri Lanka's unique geographical advantages, such as the abundance of renewable energy resources and close proximity to the East-West shipping route, provide an exceptional opportunity for the country to establish itself as a green energy producer, exporter, and regional hub. By servicing energy transitions in the Middle East, Africa, and Asia in the short term, and Europe in the long term, Sri Lanka can significantly contribute to the global shift towards sustainable energy.

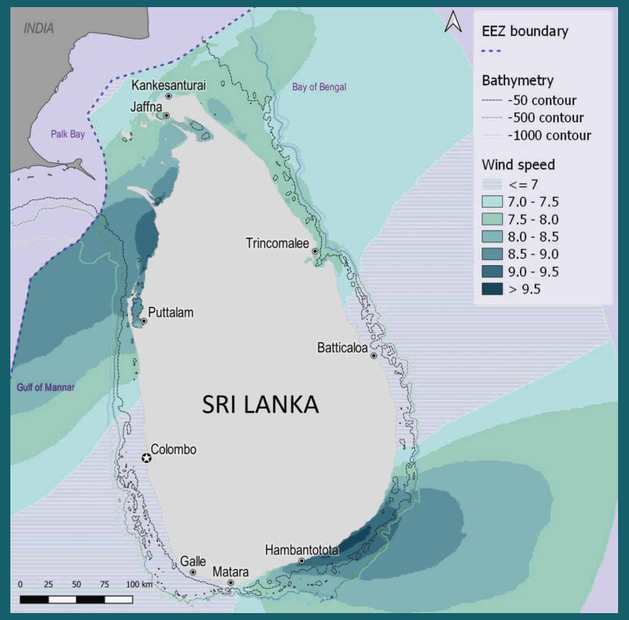
To fully capitalize on these advantages, Sri Lanka recognizes the importance of process efficiency in maintaining competitive costs and ensuring the viability of green energy production. The government has, therefore, initiated the process of identifying optimal locations for grid-independent production, storage, and delivery of hydrogen and its derivative molecules at scale. This strategic approach aims to maximize the country's potential as a green energy powerhouse while minimizing socio-environmental impacts.

A supportive policy environment is essential for encouraging investment and fostering innovation in green energy technologies. The government's commitment to creating a conducive regulatory framework will help attract both domestic and international investors, further strengthening Sri Lanka's position as a green energy hub.

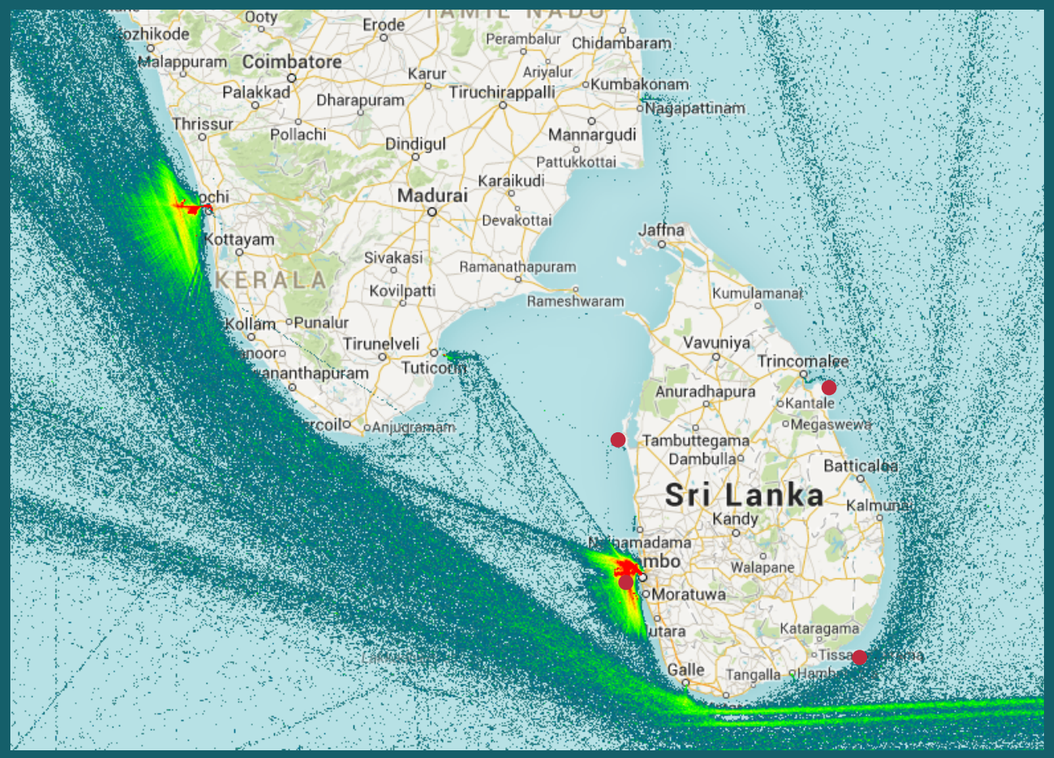
Efficient, off-grid electricity delivery for electrolysis is one of the key considerations in the development of hydrogen production facilities for export. By leveraging the country's renewable energy potential, such as solar, wind, and hydro power, Sri Lanka can ensure a steady and sustainable supply of electricity for green hydrogen production.

Another crucial aspect with respect to Sri Lanka is the minimal deviation of shipping routes, taking into account the needs of potential end customers. By strategically positioning hydrogen production and storage facilities near major shipping lanes, Sri Lanka can minimize transportation costs and streamline the export process. Furthermore, accommodating the growing ship size forecast for hydrogen and its derivatives transport is essential for ensuring the efficient and safe movement of green energy products.

Offshore Wind potential



Shipping traffic

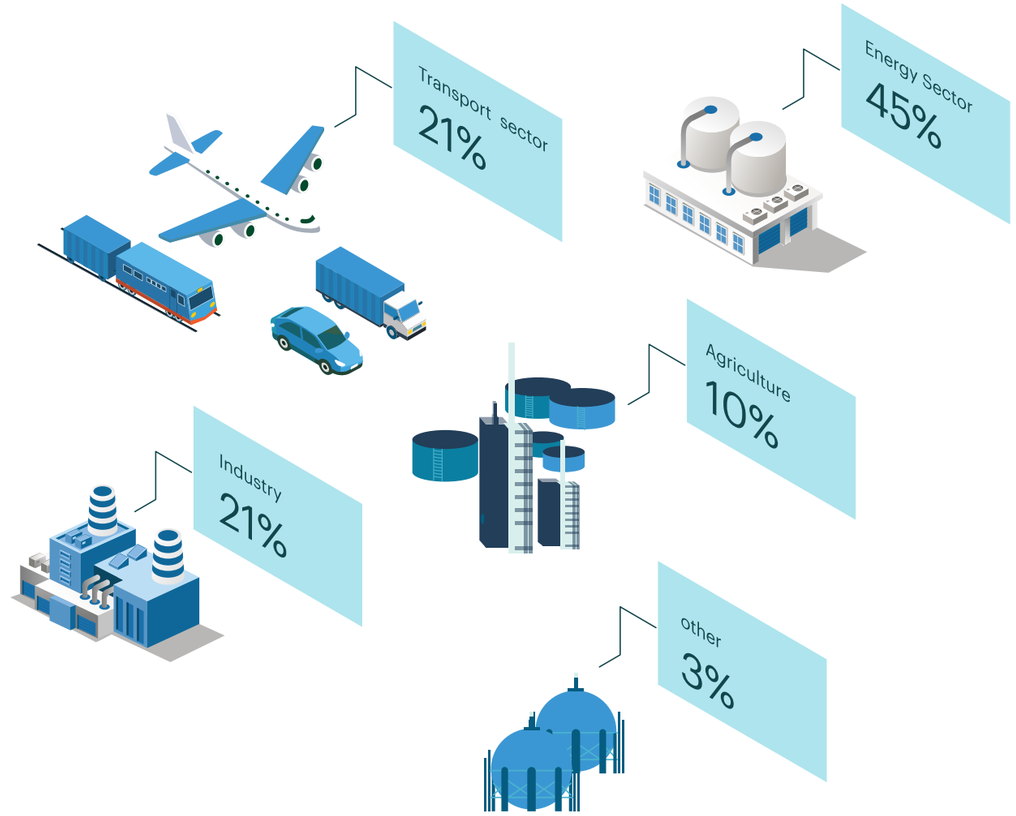


● Identified Locations for Green fuels bunkering and export

Sectoral Decarbonisation and Import Substitution

Sri Lanka total emissions is

43 Mn Tons CO2e



Transport and Logistics

Transport and logistics are responsible for approximately 25% of Sri Lanka's CO2 emissions, making this sector a top priority in the country's national decarbonization strategy. While Sri Lanka has made strides in addressing private transport emissions by promoting the import and adoption of electric vehicles (EVs), the limitations of EVs in long-range travel and heavy goods vehicle (HGV) operations due to the weight of batteries have led the nation to explore alternative solutions for sustainable transportation.

Sri Lanka is, therefore, actively pursuing hydrogen opportunities within the logistics and public transport sectors to drive a shift towards low-carbon transport, ultimately reducing the demand for imported fossil fuels and lowering emissions. Green hydrogen, produced using renewable energy, has the potential to transform the transport and logistics industry by serving as a clean, efficient, and high-energy-density fuel for various modes of transportation, including heavy-duty trucks, buses, and trains.

Investments in the development and deployment of hydrogen fuel cell vehicles (FCVs) can help address the challenges associated with long-range travel and HGV operations, as FCVs can achieve longer driving ranges and faster refueling times compared to EVs. Moreover, the weight of hydrogen fuel cell systems is significantly lower than that of large battery packs, making them a more suitable option for heavy-duty transportation applications.

To successfully implement hydrogen-based solutions in the transport and logistics sectors, Sri Lanka must invest in the necessary infrastructure, such as hydrogen refuelling stations, production facilities, and storage systems. Public-private partnerships and government incentives can be utilized to encourage the development of hydrogen infrastructure and the adoption of hydrogen-powered vehicles.

1.7 Mn
Tons of Fuel

3.5 TWh
of Energy Demand

Shipping

Maritime logistics is a key contributor to the national economy. The Port of Colombo (PoC) was ranked 22nd globally in the World Bank CPPI and was also ranked the most efficient port in South Asia. Sri Lanka has a geographical advantage already exploited by the shipping industry; In combination with Sri Lanka's rich renewable resources, this can be further leveraged for the supply of green shipping fuels at locations requiring minimal route deviation, resulting in a contribution to decarbonising the shipping sector.

PoC's reliance on transhipment business means increased pressure to conform to supply chain environmental standards. The Sri Lanka Ports Authority, private terminal operators and other port stakeholders have committed to a sustainability GHG emission reduction project to align with the National Climate change targets intended addressing the below UN SDGs. By accelerating adoption of advanced low carbon technologies, the Port of Colombo can expedite internal decarbonisation in line with other global ports' leading environmental sustainability initiatives.

3685
ships called at the Port of Colombo

6.8 Mn
TEUs handled in 2022

85%
of TEUs handled as transhipment

120 MW
Port Power consumption

Aviation

Sri Lanka's commitment to decarbonizing the aviation sector aligns with global efforts to mitigate climate change and reduce greenhouse gas emissions. By exploring the financial and technical feasibility of installing storage and delivery infrastructure for sustainable fuels, Sri Lanka aims to position itself as a regional hub for the supply of sustainable aviation fuels (SAF), including green hydrogen-based fuels.

As tourism plays a vital role in Sri Lanka's economy, the country is keen to promote sustainable and low-carbon tourism practices. By adopting green hydrogen-based fuels in the aviation sector, Sri Lanka can effectively reduce the carbon footprint associated with air travel, further enhancing its appeal as an environmentally responsible tourist destination.

Green hydrogen, when combined with captured carbon dioxide, can be converted into synthetic aviation fuels, which have the potential to significantly reduce emissions from the aviation sector. Establishing a local production and supply chain for SAF would not only contribute to the decarbonization of the aviation industry, but also stimulate economic growth and create new job opportunities in the country.

In addition to green hydrogen, other sustainable aviation fuels such as biofuels derived from organic waste, algae, or other renewable sources can be explored as potential low-carbon alternatives. The development and implementation of these fuels would not only contribute to the reduction of greenhouse gas emissions but also support the growth of a circular economy by utilizing waste streams.

38000
aircraft movements at Bandarayake International Airport

900 Mn
litres of fuel supplied

Tourist Arrivals (Million)

2018	2019	2020	2021	2022
2.3	1.9	0.5	0.2	0.7

Manufacturing and Agriculture

Sri Lanka's agriculture manufacturing and industrial sectors play a crucial role in the nation's economic growth, contributing significantly to export revenue. As the world becomes increasingly concerned about climate change and global emissions, countries are placing a higher emphasis on reducing their carbon footprint. To stay competitive in the export market, Sri Lanka recognizes the importance of minimizing supply chain emissions throughout the entire value chain, while also promoting sustainable practices.

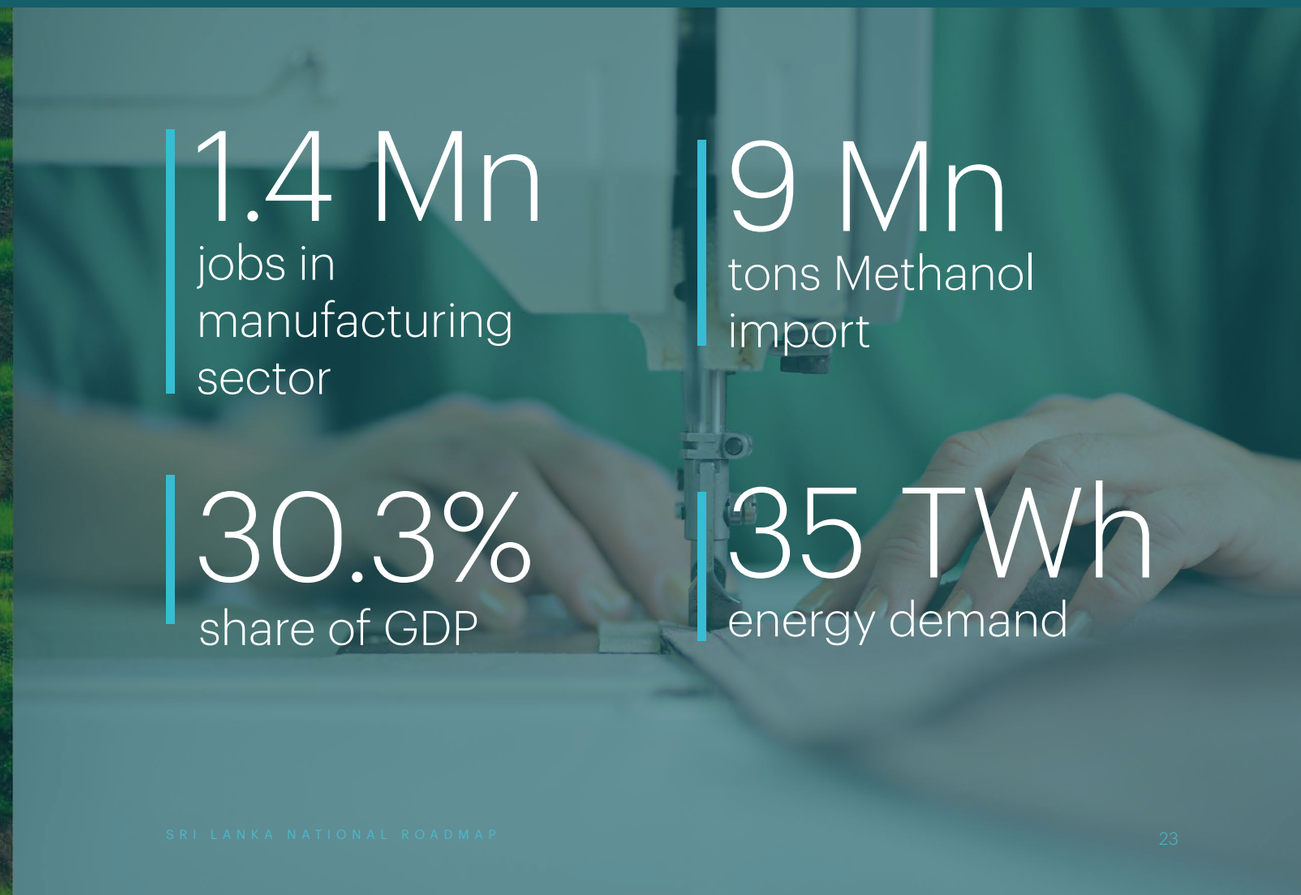
Domestically, Sri Lanka aims to increase the integration of renewable energy sources, such as solar, wind, and hydro power, into its manufacturing and industrial processes. This will not only reduce the country's dependence on fossil fuels, but also create a cleaner, more sustainable energy mix for the future. In addition, energy storage systems will be deployed to further decrease reliance on the grid, ensuring a stable and uninterrupted power supply for the manufacturing sector.

Green hydrogen, produced using renewable energy sources, has immense potential to revolutionize Sri Lanka's manufacturing industry by providing a low-carbon alternative for various industrial processes. By generating green methanol and ammonia using locally sourced green hydrogen, the country can effectively reduce its carbon footprint and enhance the sustainability of its industrial sector. Green methanol can serve as a clean fuel and a raw material for the production of various chemicals, while green ammonia can be utilized as a low-emission fuel and in the manufacturing of fertilizers, chemicals, and polymers.

0.9 Mn
Tons of Fertiliser imports

8.7%
share of GDP

2.1 Mn
Jobs in agricultural sector



1.4 Mn
jobs in manufacturing sector

9 Mn
tons Methanol import

30.3%
share of GDP

35 TWh
energy demand

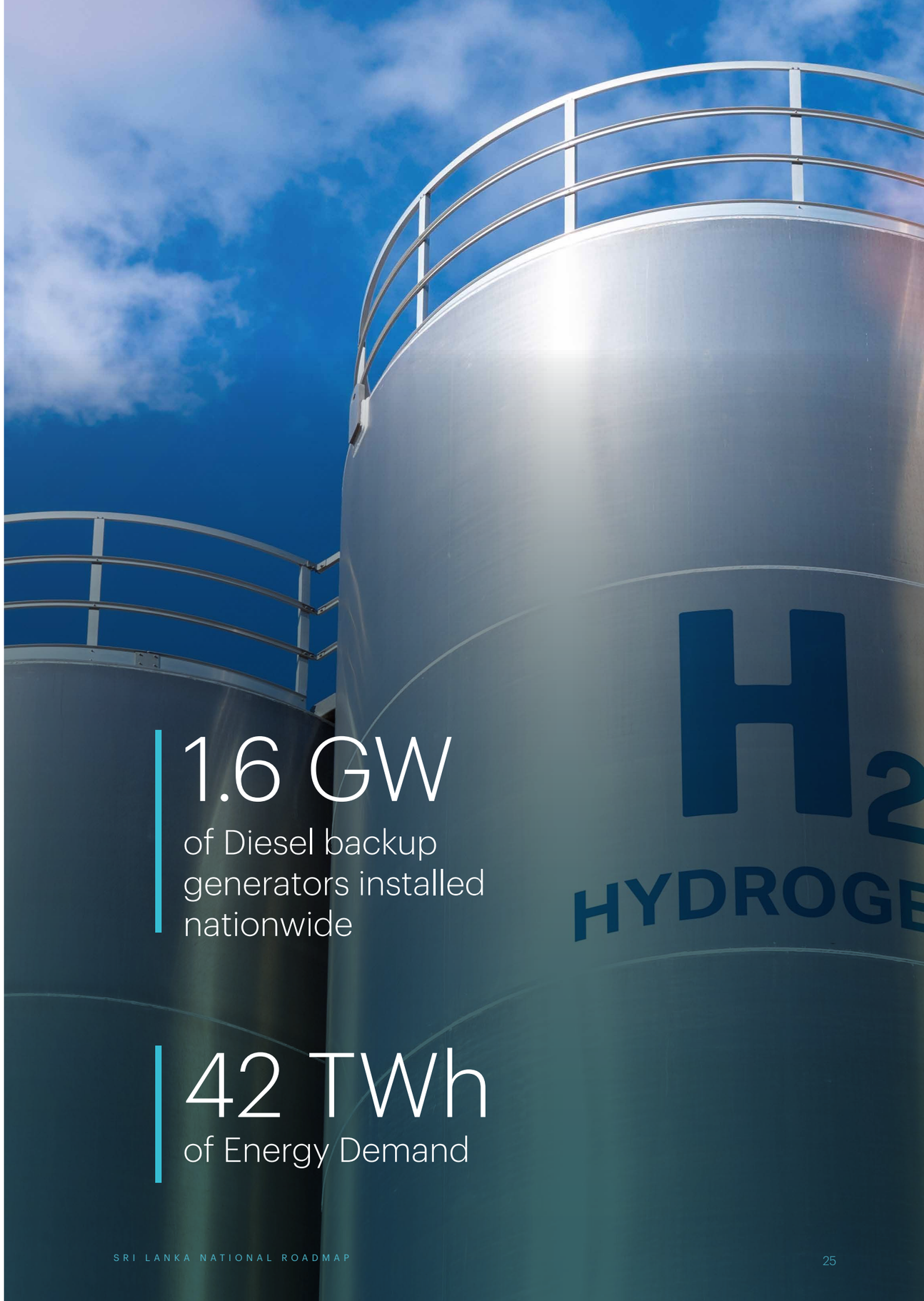
Buildings and Energy

Historic grid instability in Sri Lanka has led to a widespread reliance on diesel-fueled generators as backup power sources for large-scale commercial and residential buildings. This practice not only contributes to the country's greenhouse gas (GHG) emissions but also exacerbates the burden on the government to supply imported energy in the form of fossil fuels during periods of energy scarcity. Moreover, the use of diesel generators in densely populated residential and work areas raises concerns about air quality and public health.

To address these challenges, Sri Lanka is exploring the potential of utilizing hydrogen storage as a viable low-carbon alternative for backup power in high-density areas. This approach would not only help reduce GHG emissions but also minimize distance transport costs, as the demand centers for backup power are typically concentrated in urban areas.

The Sri Lankan government is driving this initiative by conducting life cycle cost analyses to assess the economic feasibility of hydrogen-based static energy storage systems. These analyses aim to demonstrate the long-term cost-effectiveness of hydrogen storage solutions when compared to traditional diesel generators, taking into account factors such as reduced maintenance and replacement costs due to the absence of mechanical and synchronous components in hydrogen storage systems.

Hydrogen storage systems, such as fuel cells and hydrogen-based batteries, have the potential to offer several benefits over diesel generators. For instance, hydrogen-powered systems have fewer moving parts, which results in lower maintenance requirements and a longer operational lifespan. Additionally, hydrogen fuel cells generate electricity with minimal noise and no harmful emissions, making them a more environmentally friendly and health-conscious choice for backup power in densely populated areas.



An Off Grid Shift

The urban representation of Sri Lanka's 22 million population sits at roughly 18%. The remainder of the population is distributed within commuters from semi-rural areas and the permanent rural population. Rural inhabitants have an intrinsically lower energy consumption per capita, yet the right to continuous power is nation-wide and uncompromised. Sri Lanka understands that, with the high upfront capital expenditure and transmission losses, conventional grid connectivity to rural areas may not be the most economical solution. In addition, a large portion of rural areas benefit from high solar irradiation, meaning that energy is available to be utilised in-situ. The government of Sri Lanka will therefore assess the viability of micro grid hybrid energy systems in rural areas utilising photovoltaic cells combined with fuel cells and BESS for uninterrupted power that is not subject to tariff revision or volatility. This will be initiated through small scale pilot projects in selected areas deemed economically. These pilot projects will also be utilised to ascertain the viability of applying the same methodology to communications infrastructure and any other widespread use where grid connectivity is a cost burden to the state.

In addition to off grid energy in rural areas, green hydrogen presents an opportunity to provide a clean cooking alternative, Traditional cooking methods in rural Sri Lanka, such as wood and biomass burning, generate significant amounts of indoor air pollution, which can lead to severe respiratory issues and other health problems. The use of green hydrogen for cooking produces only water vapor as a by-product, thus eliminating harmful emissions and significantly improving indoor air quality. Additionally, green hydrogen eliminates the risk of fire accidents associated with open fires and unsafe cooking practices.

Bankability in Green Hydrogen

Equatorial and sub-equatorial countries, which predominantly consist of lower and middle-income nations, possess a considerable potential for utility-scale renewable energy. These countries, however, often present inherent investment risks to institutional and private investors due to their economic status. Sri Lanka recognizes that accelerating the large-scale commercialization of offshore wind and hydrogen production is contingent upon creating a bankable investment environment, protected from domestic inefficiencies as much as possible.

To achieve this goal, the Government of Sri Lanka has identified the development of a hydrogen implementation framework in collaboration with key industry stakeholders and financiers as a top priority. By adopting a proactive approach that caters to the needs and requirements of investors, Sri Lanka aims to foster an investment climate that is conducive to the rapid deployment of renewable energy projects.

By working hand-in-hand with experienced industry players and financiers, the country intends to develop a comprehensive hydrogen investment framework that addresses potential risks, mitigates uncertainties, and streamlines regulatory processes. This collaborative effort will help ensure that investors have the confidence and security needed to support the growth of Sri Lanka's renewable energy sector.

Sri Lanka as a value chain player

As countries across the globe ramp up renewable energy and hydrogen implementation, lead times and supply for the requisite infrastructure continue to lag demand. Sri Lanka believes that a global push to bolster manufacturing will be required to meet global expectations and environmental obligations. Further utilising Sri Lanka's geographical advantage, the Government will engage key industry players to ascertain the viability of manufacturing or assembly of key components within Sri Lanka and create a favourable investment environment accordingly. Beginning with quay wall load bearing limitations, Sri Lanka has begun to evaluate the technical feasibility of providing heavy engineering locations for players looking to provide large scale renewable and hydrogen infrastructure to the surrounding region. Sri Lanka will also promote local manufacturers to utilise the rich mineral resources available and seek to enter advanced aspects of the growing green hydrogen value chain.

Sri Lanka has identified the following manufacturing opportunities that will be assessed considerate of demand potential and local resources:

01. Electrolyzer production:

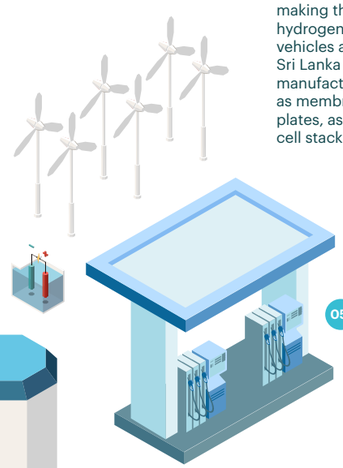
Electrolyzers are essential components in green hydrogen production, as they split water into hydrogen and oxygen using renewable energy. Sri Lanka can establish manufacturing facilities for producing various types of electrolyzers, such as alkaline electrolyzers, proton exchange membrane (PEM) electrolyzers, and solid oxide electrolyzers. This would involve manufacturing core components, such as electrodes, membranes, and catalysts, as well as assembling complete electrolyzer systems.

02. Other Renewable energy equipment & components:

As green hydrogen production relies on renewable energy sources, there is potential for Sri Lanka to manufacture solar panels, wind turbines, and other renewable energy equipment. This would not only support the green hydrogen industry but also contribute to the overall growth of the renewable energy sector in the country and the region.

03. Fuel cell production:

Fuel cells convert hydrogen into electricity, making them a key component in various hydrogen-powered applications, such as vehicles and stationary power systems. Sri Lanka can explore opportunities in manufacturing fuel cell components, such as membranes, catalysts, and bipolar plates, as well as assembling complete fuel cell stacks



04. Hydrogen Storage and transportation equipment:

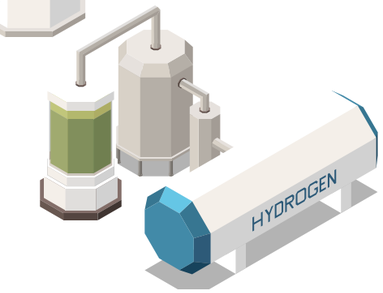
The safe storage and transportation of hydrogen require specialized equipment, such as high-pressure storage tanks, cylinders, and fuel cell containers. Sri Lanka can develop the capacity to manufacture these components, catering to both domestic and international markets.

05. Power electronics and electrical systems:

Electrolyzers and fuel cells require advanced power electronics and electrical systems for efficient energy conversion, transmission, and distribution. Manufacturing opportunities in this area include producing inverters, converters, transformers, and other power electronics components.

06. Gas purification systems:

Producing high-purity hydrogen is crucial for many applications, especially for fuel cell technologies. Manufacturing gas purification systems, such as pressure swing adsorption (PSA) units and membrane separators, can help ensure the efficient removal of impurities and deliver the desired hydrogen purity levels.

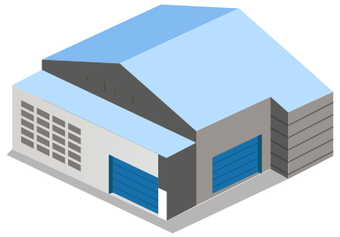


07. Heat exchangers and cooling systems:

Green hydrogen production processes, such as electrolysis, generate significant amounts of heat. Heat exchangers and cooling systems are essential for maintaining optimal operating temperatures and ensuring the longevity of the core components. Manufacturing opportunities in this area include producing various types of heat exchangers, cooling fans, and other thermal management equipment.

08. Piping, valves, and fittings:

The transportation of hydrogen within production facilities and between storage systems requires specialized piping, valves, and fittings designed to handle the unique properties of hydrogen. Manufacturing high-quality, hydrogen-compatible components can help ensure the safe and efficient handling of the gas.



09. Control and monitoring systems:

Efficient and safe operation of green hydrogen facilities relies on advanced control and monitoring systems. Manufacturing opportunities in this segment include producing sensors, controllers, and other instrumentation for process monitoring, automation, and safety.

Support through Policy

For green hydrogen to become competitive with grey hydrogen and be considered a viable energy alternative, regulatory authorities must create an enabling environment that disincentivizes carbon emissions and minimizes the burden on investors taking initial risks to combat climate change. The Sri Lankan government has already embarked on a global benchmarking exercise to determine the key policy and regulatory interventions required to galvanize investment into the nascent hydrogen ecosystem. These will include concessions for green energy infrastructure and other supportive measures to stimulate growth in the sector.

Some of the critical elements of a supportive policy framework for driving the integration of green hydrogen will include:

Carbon pricing

Implementing carbon pricing mechanisms, such as carbon taxes or cap-and-trade systems, can help increase the cost of carbon-intensive energy sources, making green hydrogen more competitive in the market. This, in turn, would encourage businesses and investors to shift towards cleaner energy alternatives.

Financial incentives

Providing tax credits, grants, or low-interest loans to support the development of green hydrogen production facilities, storage systems, and distribution networks can help reduce the initial investment burden on private sector participants. These incentives can catalyze the growth of the green hydrogen industry and drive economies of scale, ultimately lowering the cost of green hydrogen production.

Regulatory support

Streamlining permitting and approval processes for green hydrogen projects, as well as establishing clear technical and safety standards, can help create a conducive environment for investment and innovation in the sector. Regulatory support can also involve setting ambitious targets for green hydrogen adoption in various industries, such as transportation, manufacturing, and power generation.

Infrastructure Planning

The importance of infrastructure planning and investment cannot be overstated when it comes to growing the hydrogen ecosystem in Sri Lanka. A well-designed and robust infrastructure is crucial for the production, storage, distribution, and utilization of green hydrogen across various sectors, such as transportation, manufacturing, and power generation. By investing in infrastructure development, the Sri Lankan government can facilitate the large-scale adoption of hydrogen technologies and create a sustainable energy landscape that supports the country's decarbonization goals. Strategic infrastructure planning ensures that resources are allocated efficiently, minimizing potential bottlenecks and maximizing the benefits of hydrogen integration. Collaborative efforts between the public and private sectors can help mobilize the necessary financial resources and technical expertise to build a comprehensive hydrogen infrastructure network. Ultimately, well-planned infrastructure investments are vital for fostering innovation, driving economic growth, and establishing Sri Lanka as a leading player in the global green hydrogen market.

International collaboration and knowledge transfer

International collaboration is a crucial aspect of growing the hydrogen ecosystem in Sri Lanka, as it enables the country to leverage global expertise, resources, and best practices. The necessity of global collaboration lies in several key areas:

Technology transfer

Partnering with international organizations and countries with advanced hydrogen technologies can facilitate the transfer of cutting-edge solutions and technical know-how to Sri Lanka. This can accelerate the development of a competitive domestic hydrogen industry, as well as enhance the country's capacity to innovate and adapt to new technologies.

Capacity building

International collaboration can help build human capacity by offering opportunities for training, education, and knowledge exchange. By collaborating with global partners, Sri Lanka can ensure that its workforce is equipped with the necessary skills and expertise to effectively manage and operate hydrogen infrastructure and technologies.

Financing and investment

Global partnerships can provide access to international funding sources, such as development banks, climate funds, and private investors, which can significantly contribute to the financing of hydrogen projects and infrastructure development in Sri Lanka. Furthermore, international collaboration can help attract foreign direct investment, thereby stimulating economic growth and job creation.

Policy development

Engaging with international partners can enable Sri Lanka to learn from global best practices in hydrogen policy and regulation, as well as provide insights into successful strategies for incentivizing investment and adoption of hydrogen technologies. This can help the country develop a supportive policy environment that drives the growth of the hydrogen ecosystem.

Standardization and harmonization

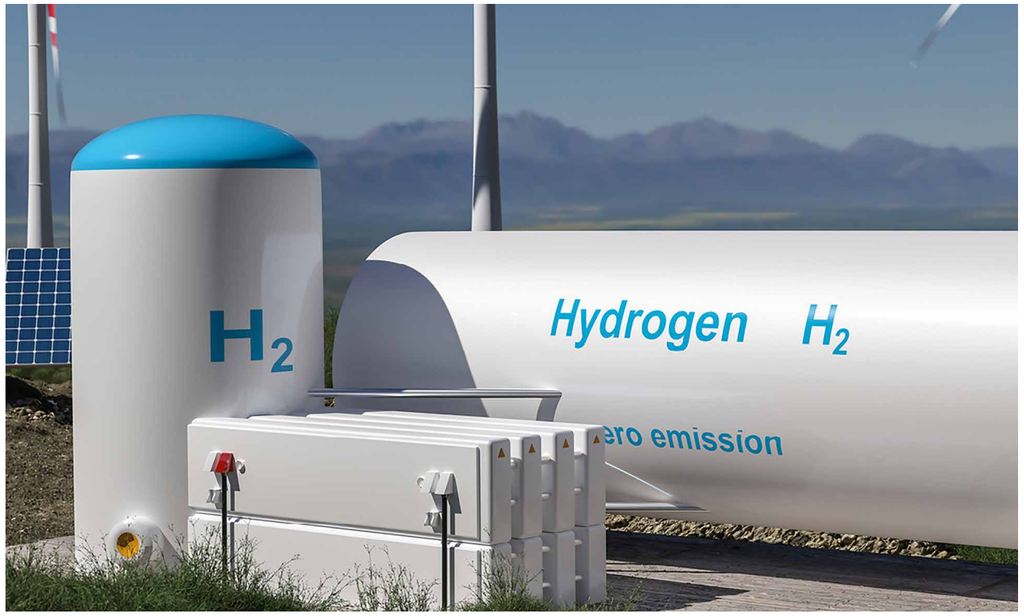
Working with international partners can help Sri Lanka align its hydrogen regulations, standards, and safety protocols with global benchmarks, ensuring that the country's hydrogen infrastructure and technologies are compatible with international norms. This can facilitate cross-border trade and cooperation in the hydrogen sector.

Codes, Safety Standards & Certification

Sri Lanka believes that the key to successfully integrating and implementing a hydrogen economy lies in maintaining unwavering safety standards. To achieve these high standards, the country has initiated collaborations with technology partners who possess extensive experience in the most demanding environments related to hydrogen and molecular safety. As a result, Sri Lanka plans to release its Hydrogen Safety Standards in 2023, which will comprise a robust monitoring and evaluation framework as well as periodic revisions to keep pace with global advancements in the field.

Ensuring that safety standards are not compromised will provide a solid foundation for the growth and success of the hydrogen economy in Sri Lanka.

Sri Lanka is also committed to actively participating in the global push towards standardized green hydrogen certification. By engaging in international collaboration and aligning with global best practices, the country can contribute to the development of a transparent and robust certification system. The following points outline how Sri Lanka plans to participate in this effort:



Collaboration with international organizations and initiatives

Sri Lanka will join forces with global organizations and initiatives that focus on developing standardized green hydrogen certification, such as the International Renewable Energy Agency (IRENA), the International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE)....

Sharing best practices and expertise

Sri Lanka will actively contribute to international dialogues and share its experiences and expertise in green hydrogen production, infrastructure, and safety. By participating in global forums and conferences, Sri Lanka can help shape the development of certification standards and learn from the experiences of other nations.

Adoption of global certification standards

Sri Lanka will align its national policies and regulations with international green hydrogen certification standards as they emerge. By adopting these standards, the country can ensure that its hydrogen industry remains competitive in the global market and adheres to best practices in terms of sustainability and environmental protection.

Monitoring and enforcement

Sri Lanka will establish a robust monitoring and enforcement framework to ensure compliance with international green hydrogen certification standards. This includes setting up a dedicated regulatory body or task force responsible for overseeing the certification process and enforcing penalties for non-compliance

Pilot Projects

The Sri Lankan government is committed to promoting and facilitating the implementation of advanced technologies to assess their technical and commercial viability, particularly in the context of hydrogen solutions. While the government will encourage its participation in these projects wherever feasible, it will prioritize and offer concessions to those willing to assume market risks.

Each project will undergo a thorough evaluation and approval process on an individual basis, ensuring streamlined execution that adheres to the highest environmental and safety standards. This approach to pilot projects will help demonstrate the potential of hydrogen technologies in Sri Lanka while fostering innovation and driving market adoption.

Implementation Strategy

Action Plan: steps necessary for the Sri Lanka National Hydrogen Roadmap to succeed.

A. Introduction

This Action Plan was created in response to Sri Lanka's Green Hydrogen Strategy and aims to identify activities and initiatives to address the country's key energy challenges. The plan will enable the domestic industry to participate in both the supply and demand of Green Hydrogen technologies, as well as focus on developing a long-term export market.

The measures outlined in the Action Plan represent phase one of the National Hydrogen Roadmap, which spans until 2025. During this phase, efforts will be made to create a well-functioning domestic market and address issues such as research and development and international aspects. The next phase, set to begin in 2026, will focus on stabilizing the domestic market and expanding the international dimension of hydrogen, with a particular emphasis on offshore wind development and exports.

The policies and regulatory guidelines included in the plan aim to ensure a level playing field for all market participants and attract global financial investments into Sri Lanka. Safe production and use of hydrogen will be a key pillar in devising these actions.

The plan will also strive to make a realistic assessment of renewable energy sources and demand, prioritizing the optimum utilization of all available resources. Only sectors that are difficult to decarbonize will be identified for demand purposes. In the short to medium term (Phase 1 – 2023 to 2025), priority will be given to identifying high-impact initiatives that are easy to implement. Pilots will be carried out, and based on the lessons learned, a full-scale execution plan will be developed in Phase 2 (2025 to 2028).

Initiatives such as the procurement and manufacturing of electrolysers, hydrogen storage systems, and transport systems will be given priority to meet demand and ensure high efficiency and low cost.

The concerned ministries and stakeholders will be responsible for implementing and financing the measures based on existing budget estimates and financial plans. However, a systemic approach will be adopted in the National Hydrogen Strategy, and cross-cutting dimensions will be emphasized with a focus on both domestic and international markets.

B. Key Stakeholders and Creating enabling environment.

The development of the Sri Lanka hydrogen ecosystem will depend on 6 key groups of stakeholders and the Government will create an enabling environment to the below:

i. Off-taker group: Stakeholders that will diminish the risks of the projects guaranteeing volume demand; could be also co-investors.

ii. Financing investors: Funds or banks willing to invest in the energy market in Sri Lanka

iii. Demand technology developers: Technology developers for different hydrogen applications – Mobility, Industrial Heat, Grid storage solutions, Off-Grid solutions and Cold storage for Agriculture products etc.

iv. Renewable Electricity generation (providers or developers): Current or new Renewable energy generation players that will dedicate resources to hydrogen projects and Off-shore wind developers.

v. Hydrogen production companies: Responsible for technology and infrastructure development for hydrogen production, transportation, and storage

vi. Ecosystem builders: Agencies Responsible for creating the eco system for the hydrogen market like evolving the Policy and establishing Regulatory systems, facilitating international cooperation agreements for export, safety standards, carrying out special studies on infrastructure creation, environment requirements and guidelines, Promoting and coordinating together with universities the research on hydrogen and derivatives.

Coordinated actions of different stakeholder groups will allow to accelerate the growth of the hydrogen market in Sri Lanka by:

- Facilitating the creation of the enabling environment for the market to operate
- Rapidly acquiring and incorporating the hydrogen technology development to boost demand and
- Coordinating financing, energy generation and production promoting the development of new projects

C. High level Roadmap

2022 to 2025

Policy Regulation, Demonstration, Pilots, Off-Shore Studies

- Publish policies and formulate regulations.
- Initiate priority pilots, trials, and demonstration projects, scaling up based on learning.
- Assess domestic demand.
- Publish safety standards.
- Initiate the Climate Change University through the Hydrogen Centre of Excellence.
- Start capacity-building initiatives.
- Conclude offshore energy studies.
- Finalize offshore energy commercial contracts.
- Begin dialogue with Green Ammonia importing countries to assess demand.
- Evaluate supply chain and infrastructure needs.
- Identify opportunities in hydrogen value chain manufacturing, such as Electrolysers and Hydrogen storage equipment.
- Formulate policies and processes to attract investment in Green Hydrogen technologies.

Phase 1

Phase 2

Domestic Ramp-Up, Supply Chains, Offshore Blocks

- Activate the medium-scale market and target demand sectors like Mobility, Industry, Ports, etc.
- Start the development of offshore energy acreage.
- Develop supply chains and domestic infrastructure.
- Manufacture hydrogen-fueled IC engines and Fuel Cell Heavy-duty trucks and long-distance buses on a pilot basis.
- Develop a Hydrogen distribution network.
- Assess demand for price parity.
- Meet domestic demand in selected sectors – Mobility, Industry.
- Start manufacturing of hydrogen value chain equipment.

Offshore Production Capacity

2025 to 2028

2GW

2028 to 2035

Leverage Scale for Expansion in Domestic Consumption and Production Scaling Up, Green Ammonia Manufacturing, and Export of Green Hydrogen and Derivatives

- Develop large-scale Green Hydrogen and increase penetration in Mobility sector and Ports, and initiate SAF in Aviation sector.
- Scale up the manufacturing of Hydrogen-fueled IC engines and Fuel Cell Heavy-duty trucks and long-distance buses.
- Expand the network of Green Hydrogen dispensing stations.
- Assess the usage of Green Hydrogen in Power sector requirements like Storage and Grid balancing.
- Commercialise offshore wind and Green Fuel production to meet export potential.

10GW

Phase 3

Phase 4

30GW

2035 to 2048

Green Hydrogen Market Stabilization and Capitalization of Export Markets

- Stabilise domestic demand, including Rail transport.
- Scale up Green Ammonia volumes.
- Initiate domestic manufacturing of Electrolysers and associated equipment.
- Stabilise Green Ammonia Fuel exports and increase volumes with further offshore wind development.

D. Implementation Plan

I. Creating an Enabling Environment – Policy, Regulatory, Incentives, Markets, and Investments

1. Develop and publish a **Green Hydrogen Mission & Policy.**
2. Design and publish Green Hydrogen **Regulations.**
3. Develop infrastructure studies and coordinate with private organizations for **infrastructure development.**
4. Promote the **adoption** of green hydrogen in industries, Mobility, Storage, Off-grids, Agriculture, etc., by evolving well-structured norms, guidelines, subsidies, and incentive mechanisms.
5. Establish **environmental** requirements and processes for the development of hydrogen projects.
6. Develop **safety standards** and **certification** guidelines.
7. Design **permits** for the operation of hydrogen pilots and coordinate work with companies.
8. Create a conducive **domestic market** by designing transparent procurement practices for both domestic players and global companies.
9. Develop **funding lines** for initial pilots and feasibility studies and promote the country as an investment destination.
10. Formulate **international cooperation** agreements for facilitating exports.

II. Green Hydrogen Production & Supply – Assessment of Potential Based on Renewable Energy (RE) Potential

11. Assess Green **Hydrogen potential** based on Sri Lanka's Renewable Energy resources in a phase-wise and source-wise manner.
12. Conduct geographic zone assessment of onshore and offshore **RE potential**, including offshore wind.
13. Assess the existing transmission system for the **evacuation** of RE.
14. Evaluate environmental and social concerns in realizing the RE potential.
15. Estimate the **cost of RE** source-wise and phase-wise and propose policy and regulatory interventions to optimize RE cost and market development initiatives.
16. Determine the **excess RE** available after meeting domestic demand, which will result in the production of Green Ammonia Fuel.
17. Conduct **Grid Stability** studies due to RE development.
18. Assess Electrolyser capacities in Phase 1 and based on demand.
19. Finalize the import versus **domestic manufacturing** strategy for Electrolysers and other supply chain items like transformers, inverters, compressor systems, storage, and transport.

III. Green Hydrogen Demand

20. Identify the off-takers of Green Hydrogen in the Mobility sector. In Phase 1, pilot projects for the use of Green Hydrogen in Long-distance buses and Heavy-duty trucks will be initiated. Retrofitting of existing Diesel engines with 100% Hydrogen-fueled IC engines will be tested on Buses and Trucks as proof of concept.

21. Based on the outcomes and experience, this initiative will be scaled up to 10% of the fleet in Sri Lanka in Phase 2.

22. In Phase 3, all new long-distance buses and heavy-duty trucks will either be IC engine fuelled by Green Hydrogen or Fuel cell vehicles.

23. Demonstration projects and pilots to test the blending of Green Hydrogen to partially replace heat in Industrial furnaces will be initiated. Industries like Ceramics & Glass manufacturing will be selected in Phase 1.

24. Based on the outcomes, experience, and lessons learned, this initiative will be scaled up to 10% of the Industrial heat replacement in Phase 2.

25. Introduce Green Hydrogen in Ports of Sri Lanka, starting with the Port of Colombo.

26. Study Green Hydrogen dispensation technologies and conduct pilot projects.

27. Study Green Ammonia Fuel bunkering in Ports for export, starting with the Trincomalee port.

28. Implement Fuel Cell technologies for Off-grid solutions in remote villages where grid extensions are challenging or expensive.

29. Implement clean power for tourism-related resorts infrastructure to promote Green & Clean Tourism.

30. In agricultural areas, the concept of fuel cell-based power will be used for cold storage and temperature-sensitive environments for fruits & vegetables. This concept will also be adopted for fisheries and other marine food-based export products which require preservation.

31. To address grid flexibility and integration of large renewable energy sources issues, the energy storage concept of Green Hydrogen will be studied in Phase 1 and implemented in Phase 2.

32. Study the use of SAF in the Aviation sector and its introduction in Colombo International Airport in Phase 1, followed by a pilot plant and scale-up in Phase 2.

IV. Research & Innovation

33. Develop an **exclusive roadmap** for the Sri Lanka hydrogen industry in collaboration with Universities, Colleges, Research I nstitutions, business communities, and civil society.

34. **Allocate funds** for research in domestic manufacturing, efficiency improvement, and research on critical materials.

35. Set up short-term **demonstration projects** on green hydrogen concurrently with research being conducted into international supply chains.

36. Establish a Centre of Excellence **(COE)** in collaboration with a University.

V. Capacity Building and Skill Development

37. Create a **national curriculum** for green hydrogen technologies, with modules and courses for different levels of education. The goal is to build capability in Sri Lanka's Key Government departments, regulators, Industry, Small-to-Medium Enterprises (SMEs), students, and emerging entrepreneurs.

38. Incorporate Green Hydrogen-related areas as a major part of the **curriculum** in courses at the International University on Climate Change.

39. Provide specific training on **safety standards** in design & engineering, installation, commissioning, operation, and usage.

40. Introduce **Masters programs** for mid-career professional development.

41. Include modules in **undergraduate programs**.

42. Offer **micro-credential** programs for industry professionals.

43. Develop customized **community education** programs.

44. Launch **talent attraction** initiatives to the green hydrogen sector.

VI. International Trade

The offshore wind resources of around 40 GW could be developed over a period of 20 to 30 years and considering the domestic demand for energy, there will be a huge surplus which can be exported in the form of Green Ammonia. Sri Lanka will initiate steps and actions to become an energy export hub, thereby improving its economy and addressing its energy security/independence challenges. The action points in relation to offshore wind development are:

45. Start **data acquisition** for denoted offshore energy sites.

46. Publish a policy on **incentives** and **concessions**.

47. Finalize the tender design and bidding strategy for the initial blocks identified for commercialization.

48. Complete technical studies and pre-development activities.

49. **Begin bidding** for selected offshore energy blocks.

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Resources:

- Central Bank of Sri Lanka
- Ceylon Electricity Board
- Sustainable Energy Authority
- Department of Agriculture Peradeniya
- Petroleum Development Authority of Sri Lanka
- Public Utilities Commission Sri Lanka
- World Bank Energy Sector Management Assistance Program
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