Embedded Selforganizing Systems

Issue Topic: "Artificial Intelligence & Machine Learning in Computer Vision Applications "

Harnessing Sri Lanka's Offshore Wind Energy for Net Zero and Regional Carbon Neutrality

Vidya Amarapala
School of Engineering
University of Bolton
Boston, United Kingdom
vda1res@bolton.ac.uk

Abdul Salam Darwish
School of Civil Engineering and Built Environment
University of Bolton
Boston, United Kingdom
a.darwish@bolton.ac.uk

Kais Muhammed Fasel
School of Civil Engineering and Built Environment
University of Bolton
Boston, United Kingdom
kk1res@bolton.ac.uk

Peter Farrell
School of Civil Engineering and Built Environment
University of Bolton
Boston, United Kingdom
p.farrell@bolton.ac.uk

Abstract **— Sri Lanka has approximately 22 million citizens, making it the only country in South Asia with complete electricity grid penetration throughout the nation and uninterrupted service. Despite renewable energy sources, including significant hydropower potential, the reliance on imported fossil fuels remains a significant concern. It should be noted that Sri Lanka possesses an estimated untapped offshore wind potential of approximately 92 GW, which presents both an opportunity and a challenge. This study's problem is identifying and navigating the technical challenges associated with evacuating and using such a large amount of offshore wind energy. Due to the excess energy generated, the existing grid capacity is insufficient to handle the surplus energy. Therefore, leveraging Sri Lanka's abundant wind energy resources is critical to help it reach its Net Zero targets while reducing foreign exchange expenditures on fossil fuel imports and generating revenue from surplus energy sales. This study examines alternative options for harnessing offshore wind energy in Sri Lanka, considering battery storage and hydrogen. A comparison has been performed for the two types of storage. The paper favoured green hydrogen, a burgeoning commodity on the global market, and exports surplus energy to India via a DC link. Wind energy potential has been revised, and a wind farm of 100 MW capacity has worked as a case of a pilot project. To make offshore wind energy more efficient, the authors recommend further exploration of several scenarios. It could include selling offshore wind potential to select decision-makers, extracting enough energy to meet national demands, and harnessing a significant portion of the estimated 92 GW offshore wind energy potential by 2023. The goal is to achieve net-zero emissions and adopt green hydrogen production towards the energy transition.**

Keywords-- Offshore wind energy, Renewable energy, DC link, Technical Challenges, Green Hydrogen, SAARC regional grid.

I. INTRODUCTION

The world is at a critical juncture due to climate change and global warming. COP28 recommended that we stick to 1.5° C to be sustainable, and if not irreversible, catastrophic effects may not tunnel the planet Earth to another mass extinction. However, the World Health Organisation says, "Climate change is impacting health in a myriad of ways, including by leading to death and illness from increasingly frequent extreme weather events, such as heatwaves, storms and floods, the disruption of food systems, increases in zoonoses and food-, water- and vector-borne diseases, and mental health issues." [1]. Hence, bringing our carbon footprint individually, nationally, and globally is essential. Therefore, the content of this article is of paramount importance, and the will to implement it is critical at this juncture for a sustainable future of our mere existence. Sri Lanka has 92 GW of offshore wind energy [2]. It can drive Sri Lanka to its carbon neutrality and Net Zero with a practical and pragmatic roadmap, progressively achieving the action plan to reach the final target. However, the potential of 92 GW [2] is excessively high for the Sri Lankan national grid, as shown in Fig. 1. As such, several options will be deliberated in this article for managing the available quantity of energy, including regional carbon neutrality. Therefore, the grid connectivity between Sri Lanka and India will be critically important, as will the regional grid connectivity. From the point of view of regional development, it is critically vital to eradicate energy poverty. It is accepted that energy directly relates to the economy and economic growth [3]. Hence, if this program could help eradicate energy poverty, it would elevate the living standard of those in the energy poverty bracket. Further, they will be part of the big economy and the GDP. Moreover, they will be able to expand the Public-Private Partnership (PPP), which will positively impact the respective country's economy and the region at large. For example, SAARC's energy poverty figures were 34% [4].

Little literature covers some sections of this article, especially Net Zero Sri Lanka [5], [6], [7]. While logistical gaps have been addressed, there seems to be a lack of attention to knowledge gaps.

Notably, there appears to be a lack of explicit commitment to fully harnessing offshore wind energy potential to support Sri Lanka's Net Zero target and regional carbon neutrality. Additionally, there is a recognised need for a comprehensive environmental impact assessment, particularly concerning environmentally sensitive areas between Sri Lanka and India, particularly in the context of grid connectivity [8].

The vast offshore wind energy capacity in Sri Lanka presents a significant opportunity to achieve much-needed carbon neutrality. Moreover, strategic utilisation of the entire wind energy potential can facilitate the production of green hydrogen from surplus wind energy. The total recorded offshore wind energy potential stands at 92GW [2], a substantial portion of which must be exported as electrical energy or green hydrogen. However, The World Bank Groupe (2023) has developed a road map to develop the total offshore wind potential of only 56 GW. It is a significant loss from the original 92GW due to the restricted areas and realistic implementation of the system for financial and technical reasons. Further, it notes that this estimate is based on high-level analysis using existing spatial data and acknowledges significant gaps in the available data. Therefore, it emphasises the need for future studies and research to better understand the feasibility of offshore wind development and fill these data gaps. These studies must use real-time data collected from environmental stations installed at selected areas around the country's coastal areas. It also mentions that not all identified resources may be economically feasible, particularly in areas with lower wind speeds and deeper waters. In this respect, the road map forecasts a mere 500-1000MW of offshore wind projects to be commissioned by 2030. This indicates the importance of considering economic viability when planning offshore wind projects [8]. Despite the World Bank Groupe recommendations and findings, fresh studies must be undertaken to utilise as much as possible from Sri Lanka's offshore wind potential of 92GW.

Therefore, the authors are willing to conduct detailed research to assess the potential of offshore wind energy, utilising available wind speed data from near-shore wind masts in high-wind areas of Sri Lanka. The dataset underwent thorough analysis, including cleaning and testing using Microsoft Excel to develop numerous histograms based on mean, median, and mode. Subsequently, the Ryleigh and Weibull Distribution functions were employed to determine wind density probability throughout the year following the methodology of Darwish (1988).

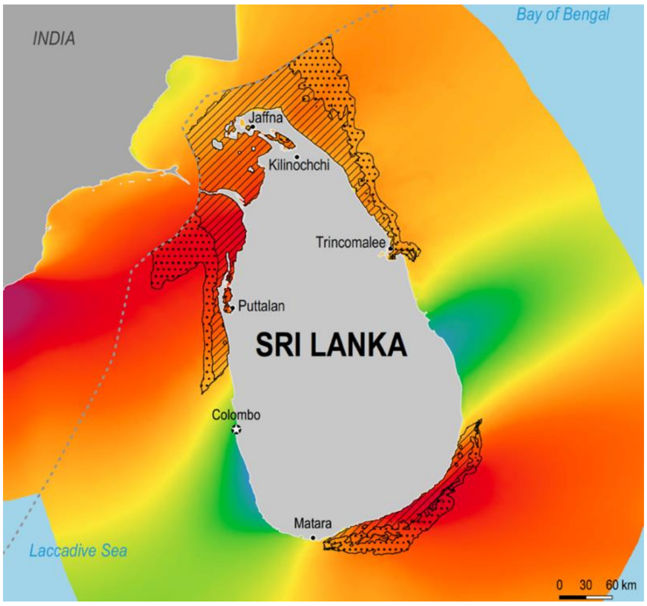

Fig. 1. The offshore wind energy potential [2]

Looking at the roadmap suggested by the World Bank discussed earlier. The authors believe that some scenarios could be taken for further discussion to enhance the efforts towards a perfect energy transition and extract the maximum possible potential of offshore wind energy for Sri Lanka. Some of these thoughts are drawn and exposed for future considerations as follows:

- Develop a plan to sell the offshore wind potential resource to a third party for the personal benefit of a few so-called "decision-makers.
- Develop a road map to extract just enough offshore wind energy to match the national energy requirement.
- Develop a road map to extract the 56 GW of the 92 GW available wind energy potential estimated by the World Bank (2023) so that Net Zero is achieved and green hydrogen is produced with the surplus energy.
- Develop a detailed road map to extract the maximum potential with connectivity to India and the SAARC/BIMSTEC grid and generate green hydrogen.

The fourth option is the most pragmatic of all the options listed above and must be implemented with a very transparent methodology. To be nationally and socially responsible, it may be essential to study some road maps for developing offshore wind potential in Europe, the UK, and India, extract the most appropriate sections, and develop the most advantageous way forward for the country and its citizens, [9]. To ensure the collaborative use of energy transition, energy transportation should focus on how logistically viable it is. This can be viewed by considering sharing some parts of the produced power with the nearest neighbours to avoid energy loss. Fig. 2 shows the proposed grid connectivity between Sri Lanka and India for the expected projects near the borders.

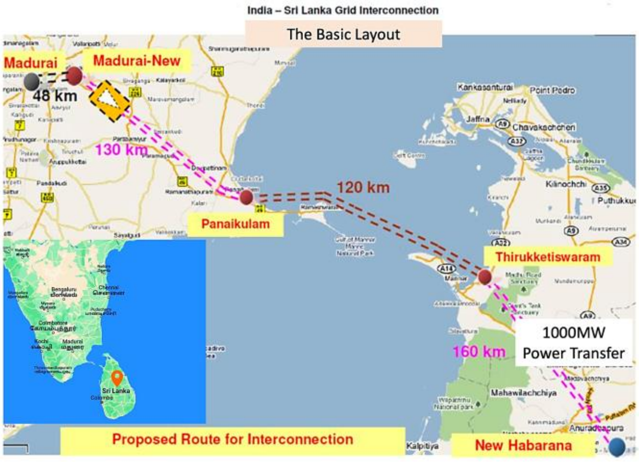

Fig 2. Proposed grid connectivity between India and `Sri Lanka [10]

This research aims to assess Sri Lanka's energy landscape in terms of production and demand to identify the wind projects necessary for achieving Net Zero by 2050. This involves developing a pilot wind energy project tailored to Sri Lanka's available wind energy potential. Additionally, the objective is to evaluate the viability of different energy storage technologies, including batteries and hydrogen, to ensure grid energy continuity. Drawing from the comprehensive analysis conducted by Amarapala et al. (2023), another objective is to determine the most feasible storage options for offshore wind energy, focusing on endorsing green hydrogen due to its compelling advantages.

II. Sri Lankan Energy Status

Therefore, the RE installed capacity should be around 5GW by 2030, with a 10 % increase until 2050. However, based on the energy demand and the forecasted growth, the rate of increase should be 0.24 % of renewable sources to achieve Net Zero by 2050, which is not a difficult task at all with a proper road map and development plan. The generation data released by the Public Utility Commission of Sri Lanka in March 2024, Fig. 3, indicates a notable drop and a stagnation in energy demand over the past couple of years, which can be primarily attributed to the economic crisis experienced by the country. Furthermore, a discernible dip in demand was observed in 2023, particularly around September, potentially influenced by the impact of electricity tariff increases. However, this situation is expected to change starting from March 2024, following an overall price reduction in electricity by 21.9% [11]. Based on the available data, the monthly average generation has consistently hovered marginally above 50GWh and below 55GWh over the past six years, extending to the first quarter of 2024.

Considering the peak energy demand depicted in Fig. 4, Table I provides forecasts for 2030 and 2050. Consequently, Sri Lanka should increase investment in renewable energy by 1.67% annually to achieve Net Zero by 2050, with a target capacity of 71,565 GWh. In terms of GWh, this translates into an annual increase of 0.8333 GWh. A target of 1 GWh per year has been set to ensure safety.

As a result, to add 1 GWh of additional wind energy capacity, it is necessary to develop the following project capacities:

$$Windfa\ Capacity\ (MW) = \frac{\text{Energy Required}\left(\frac{\text{MWh}}{\text{year}}\right)}{\text{Capacity Factor x Number of Hours in a year}} \quad (1)$$

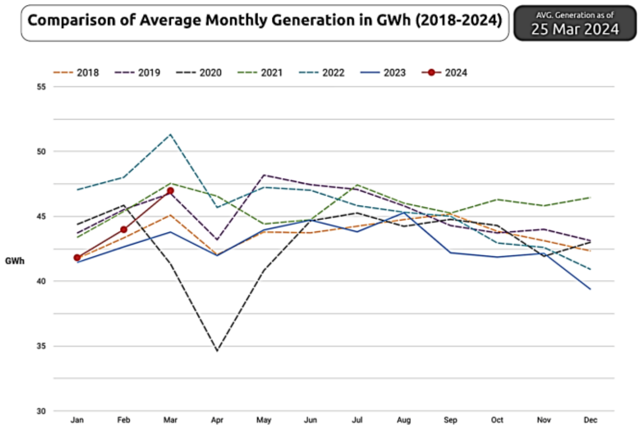

Fig 3. Comparison of average monthly generation in GWh [11]

Assuming a daily operating duration of 17 hours, the yearly increase in investment amounts to 315.038 MW. Additionally, Sri Lanka is equipped with various renewable energy resources, including solar and hydropower, that can assist in meeting this requirement.

TABLE I. Peak Demand In GWh

Year	*Peak Demand in GWh*
2020	46
2021	47.5
2022	52
2023	47
2024	50
2030	55
2050	71.565

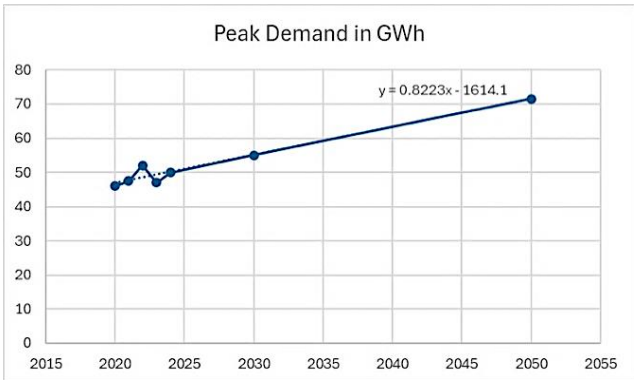

Fig 4. The energy demand and forecast for Sri Lanka (created by the authors)

The optimal forecasted dispatch energy demand is shown in Fig. 5. Historically, it was recorded that March had the lowest wind potential in Sri Lanka [12].

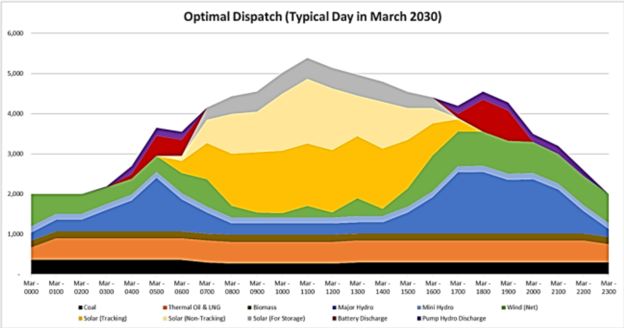

Fig. 5. The optimal dispatch demand on a day in March 2030 [12]

III. THE STATUS OF RENEWABLE ENERGY

The current installed capacity of renewable energy is shown in Table II. It is clear from the table that Wind Energy will be utilised at 148MW in 2021[15]. In this respect, it is required to commission 10 GW of offshore wind by 2050, leaving Solar to share some of the day load and leaving present hydro to do the peak load management and the frequency stability for Sri Lanka to meet Net Zero as planned. According to the Ceylon Electricity Board, in the long-term generation expansion plan (2023-2042), only 1723MW by 2030 and 3573MW by 2042 have been identified from wind energy. As such, it is important to revisit these plans and develop a robust road map for offshore wind development by an independent body.

TABLE II. CURRENT INSTALLED CAPACITY OF RENEWABLE ENERGY [13], [14], [15], [11]

Year	*Wind (GW)*	*Solar (GW)*	*Hydro (GW)*	*Biomass (GW)*	*Municipal Waste (GW)*
2019	0.128	0.057 + 0.217	13.98 + 0.41	0.04	0.01
2020	0.148	0.075 + 0.275	13.98 + 0.41	0.04	0.01
2021	0.148	0.10 + 0.415	13.98 + 0.41	0.04	0.01
2022	0.248	0.110 + 0.535	13.98 + 0.416	0.04	0.01
2023	0.263	0.137 + 0.652	13.98 + 0.422	0.044	0.01

IV. DATA ANALYSIS AND WEIBULL FUNCTIONS

Wind data analysis follows the methodology presented by Darwish (2019). This is to analyse the wind data collected from Mannar City northwest of Sri Lanka and estimate the Weibull parameters according to those data. Weibull distribution functions were, therefore, possible to generate. These functions showed high potential to fit the actual data and present them in mathematical form for further analysis, such as energy calculations and the proposed wind turbine capacity factor for selecting the suitable wind energy conversion system for this city to develop a pilot wind energy project. Fig. 6 shows the results. In this figure, different plots for the Weibull function are compared with the Raleigh distribution, a special case of the Weibull distribution having a shape factor equal to 2. The data were considered at 50 m height.

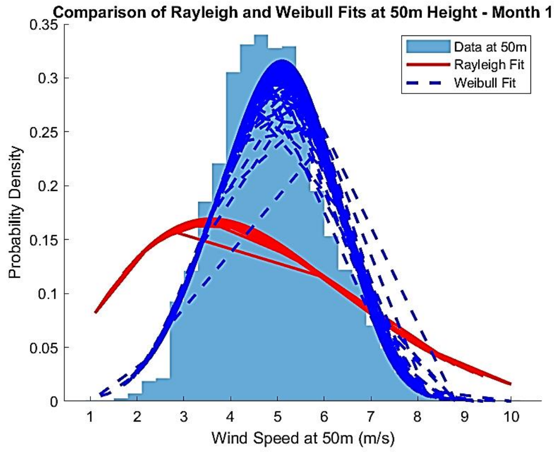

Fig. 6. Wind density is plotted using the Weibull distribution function based on one month of wind data.

A suitable wind turbine was selected using the methodology of Darwish et al. (2019). The turbine power curve is shown in Fig. 7, where three commercially available wind turbine data, for example, were matched with the wind speed of the identified area of Sri Lanka. Of the three models, Nordex N100/2500 performed best with the wind speed data of Mannar at 50m high.

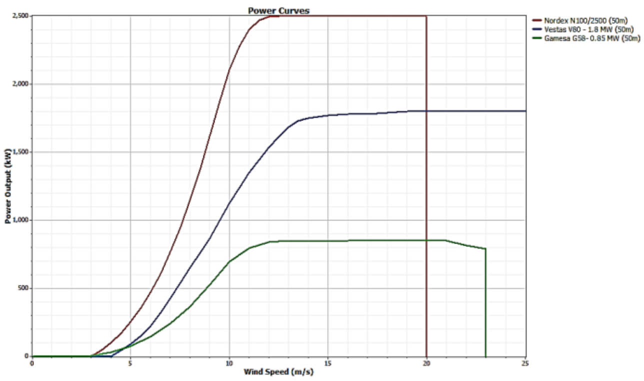

Fig. 7. Power curves of 3 types of wind turbines available in the market (created by authors)

V. SUGGESTED PILOT WIND FARM

A 100 MW wind farm can be formed using the previously chosen turbine model. This would require the deployment of 40 turbines with a capacity of 2.5 MW each. These turbines are suggested to have a rotor diameter of 116 meters and a hub height of 100 meters. A fixed-foundation type is recommended since the water depth is less than 50 meters. Following a seabed survey, the type (monopile, jacket, etc.) will be determined to assess the most suitable option.

VI. ENERGY STORAGE

Lithium-ion batteries most commonly used are adept at offering short to medium-term energy storage solutions, effectively addressing challenges such as managing fluctuations in renewable energy generation and ensuring backup power availability during outages. Their capability to swiftly discharge stored energy makes them valuable assets in maintaining grid stability and reliability. Conversely, lithium-ion batteries are better suited for applications where space constraints are a concern, such as residential or small-scale commercial energy storage solutions. Their compact nature and versatility make them ideal for these scenarios. In comparison, liquid-metal batteries (LMBs) exhibit highly appealing characteristics, even though they have yet to undergo real-world testing scenarios. However, hydrogen boasts a higher energy density per unit mass than batteries, rendering it particularly advantageous for endeavours necessitating substantial energy within limited spatial confines [16]. Examples include heavy-duty transportation modes like trucks and ships and industrial processes requiring significant energy input [17]. Green hydrogen stands out due to its versatility in efficiently converting it to other energy forms. Moreover, its commercial demand surpasses other options, and its flexibility in transportation makes it easily tradable. Green hydrogen is the most viable storage option as it can convert to electricity and power for multiple industries such as manufacturing, air, sea, and land transportation. The key factors between Battery storage and H2 are compared to assess the viability of proper storage. Based on the comparison made on this aspect by Amarapala et al. (2023) and considering two technologies, further comparisons are made in Table III.

TABLE III. COMPARISONS BETWEEN BATTERY STORAGE AND H2 [20, 17].

Feature	Battery Storage	H2 Storage
Maturity	Mature technology	Less mature technology
Round-trip efficiency	High (80-95%)	Low (20-30%)
Response time	Faster	Slower
Maintenance cost	Lower	Higher
Storage capacity	Limited	Large
Environmental impact	Higher	Lower
Leakages	N/A	It can leak, leading to safety issues
Existing infrastructure use	It can be integrated with a grid	Requires new infrastructure
Potential for other sectors	Limited	It can be used in transportation and industrial applications
Economic	No trading	Can be traded
Cost per kWh of storage capacity	High	Lower
Best for	Short-term storage, grid balancing	Long-term storage, seasonal variations

Compared to lithium batteries, hydrogen fuel cells are more energy efficient but less convenient. Due to its faster response and higher efficiency, battery storage is currently the best option for short-term storage and grid balancing. However, H2 storage has the potential for long-term storage but needs further development to make it cost-competitive. The H2 fuel offers clean emissions (water vapour) and fast refuelling for long-range travel. It is a sustainable energy carrier due to its high energy density and future cost reduction.

VII. REGIONAL CARBON NEUTRALITY

The carbon footprint is a significant concern for wellbeing of humankind and the planet Earth. Sustainability, the environment, global warming, etc., are often debated topics at every conference. At the recently concluded COP28, it was deliberated and agreed that "In early 2025, countries must deliver new nationally determined contributions. Every commitment – on finance, adaptation, and mitigation – must bring us in line with a 1.5-degree world." Sri Lanka still has under 1ton CO2 emission per capita. However, it is impossible to emit any further as the developed countries, the Global North, have already consumed the carbon quota of the developing countries, which is called the Global South [18]. However, human progress has been revolving around energy. The world needs a lot of energy to sustain and further development, and as such, it has become our collective social and environmental responsibility to curtail carbon emissions and achieve carbon neutrality, not only as an individual nation but as a whole region. Hence, moving away from fossil fuels and all activities that emit greenhouse gases is important. The first step of the process is to move to the energy transition. It can be done with the help of surplus offshore wind energy from Sri Lanka and other renewable energy sources in the region [2]. It has been suggested that the current offshore wind energy development plans in Sri Lanka, as outlined by [19], [8], are very conservative and insufficient to achieve the Net Zero emission goal. A new offshore wind energy development roadmap is needed to overcome natural and other obstacles and fully harness the energy potential. This new roadmap includes conducting a comprehensive environmental impact assessment across the entire area under the patronage of the Government of Sri Lanka. Furthermore, efforts should be made to actively pursue the India-Sri Lanka DC link and connectivity to facilitate energy trading across borders. Incorporating hydrogen into the project from its inception is also recommended. A comprehensive roadmap accompanied by detailed reports such as Environmental Impact Assessments (EIA), feasibility studies of offshore wind potential, and transparent project management practices will help attract investments.

To encourage investor confidence, the government must prioritise transparency in dealing with offshore wind energy projects. This approach will foster sustainable energy development and contribute significantly to achieving Sri Lanka's energy goals. It is also noted that, due to the excess energy generated, the existing grid capacity is insufficient to handle the surplus energy. To examine the energy landscape (production versus demand), secondary data can be obtained from the Ceylon Electricity Board and the Public Utilities Service Commission of Sri Lanka.

VIII. CONCLUSION

Ultimately, Sri Lanka's efforts to achieve carbon neutrality will be significantly enhanced by optimising and expanding its offshore wind capacity. Consequently, the existing offshore wind roadmap must be critically reassessed and refined, particularly regarding strategic adjustments to exclusion and restricted zones established by the World Bank Group. A key component of optimising offshore wind resources is maximising their potential. Establishing robust grid connectivity with India is also a cornerstone for improving energy security and fostering a sustainable energy exchange ecosystem in the region. These initiatives represent a comprehensive approach to decarbonising the national grid, transportation sectors, and other critical industries. Increasing the amount of energy stored over time can be achieved through the strategic adoption of green hydrogen production for long-term energy storage and lithium-ion batteries for short-term power storage. The purpose of this endeavour is not only to generate foreign exchange through energy trading but also to contribute significantly to environmental conservation and sustainable development. Despite the challenge of achieving a sustainable and carbon-neutral future, the strategic deployment of offshore wind energy, backed by strong political will and international cooperation, is crucial to this goal. Sri Lanka can achieve its decarbonisation targets and set an exemplary environmental stewardship and sustainable development standard by advocating innovative solutions and fostering regional partnerships. To secure a resilient, prosperous, and sustainable future for Sri Lanka and beyond, forward-looking policies and investments in renewable energy technologies are essential.

REFERENCES

[1] W.H.O. (2023 October) "Climate Change". [Online]: https://www.who.int/news-room/fact-sheets/detail/climate-change-and-health#:~:text=Climate%20change%20is%20impacting%20health,diseases%2C%20and%20mental%20health%20issues

[2] World Bank Groupe. (2019) Expanding Offshore Wind to Emerging Markets. https://www.worldbank.org/en/topic/energy/publication/expanding-offshore-wind-in-emerging-markets

[3] Zhang. Z, et al. (2011) Causal Relationships between Energy Consumption and Economic Growth. [Online]:https://www.sciencedirect.com/science/article/pii/S1876610211012926

[4] ADB (2023) "Asia In The Global Transition To Net Zero". [Online]: https://www.adb.org/sites/default/files/publication/876891/ado-2023-thematic-report.pdf

[5] Shah, S.A.A., Zhou, P., Walasai, G.D. and Mohsin, M. (2019) Energy security and environmental sustainability index of South Asian countries: A composite index approach. Ecological Indicators, [Online] 106 ( ), pp. 105507 https://www.sciencedirect.com/science/article/pii/S1470160X19304923.

[6] Fernando, L., Liyanage, H.M., Anandarajah, G. and Attalage, R.A. (2023) "Achieving near-zero carbon dioxide emissions from energy use: The case of Sri Lanka" [Online]: https://pdf.sciencedirectassets.com/312218/1-s2.0-S2352550923X00050/1-

[7] Ranasinghe, H. (2022) "Carbon Net-Zero by 2050: Benefits, Challenges and Way Forward" Journal of Tropical Forestry and Environment Vol. 12, No. 01 (2022) 1-9.

[8] World Bank Groupe. (2023) Offshore Wind Road Map for Sri Lanka. [Online]: https://documents1.worldbank.org/curated/en/099082123192513217/pdf/P17530502c20a50b30bfcd0db467e71bf0d.pdf

[9] Skjølsvold, T.M., Heidenreich, S., Henriksen, I.M., Vasconcellos Oliveira, R., Dankel, D.J., Lahuerta, J., Linnerud, K., Moe, E., Nygaard, B., Richter, I., Skjærseth, J.B., Suboticki, I. & Vasstrøm, M. 2024, "Conditions for just offshore wind energy: Addressing the societal challenges of the North Sea wind industry", Energy research & social science, vol. 107, pp. 103334.

[10] Weerasinghe, L. (2023) India –Sri Lanka Cross Border Electricity Network Interconnection "The History and the Way Forward". [Online]: https://sarepenergy.net/wp-content/uploads/2023/02/6.-Sri-Lanka-Country-Update-Mr.-M.-Lakshitha-Weerasinghe-11th-Meeting-of-TF-2-SAREP-Kathmandu-Nepal.pdf

[11] PUC SL (Public Utility Commission of Sri Lanka). Electricity tariff (2024) [Online]: https://www.pucsl.gov.lk/

[12] Kulatunga, A. Ralapanawe, V. Sepala, R. Gajanayake, S. and Talagalla, S. (2020) Sri Lanka, Achieving of 80 Percent Renewable by 2030.

[13] CEB (Ceylon Electricity Board), annual report (2019). [Online]: https://www.ceb.lk/publication-media/annual-reports/94/en

[14] CEB (Ceylon Electricity Board), annual report (2020). [Online]: https://www.ceb.lk/publication-media/annual-reports/108/en

[15] CEB (Ceylon Electricity Board) annual report (2021). [Online]: https://www.ceb.lk/publication-media/annual-reports/123/en

[16] Boretti, A. (2020) Production of Hydrogen for export from wind and solar energy, natural gas, and coal in Australia. International Journal of Hydrogen Energy, 45 (7), pp. 3899-3904

[17] Amarapala, V., Darwish, A.S., Farrell, P. (2023) Storage of wind power energy: main facts and feasibility hydrogen as an option. Renewable Energy and Environmental Sustainability. EDP sciences. 8.16. [Online]: https://www.rees-journal.org/articles/rees/full_html/2023/01/rees220022/rees220022.html

[18] Wrigley. J, (July 2022) "It is time for the Global North to take responsibility for climate change". [Online]: https://sites.manchester.ac.uk/global-social-challenges/2022/07/16/its-time-for-the-global-north-to-take-responsibly-for-climate-change/

[19] Economy Next. (August 2023) " Sri Lanka eyes 500 to 1000MW of offshore wind by 2030 in roadmap" [Online]: https://economynext.com/sri-lanka-eyes-500-to-1000mw-of-offshore-wind-by-2030-in-roadmap-129247/

[20] Jacobson, M.Z. 2024, "Batteries or hydrogen or both for grid electricity storage upon full electrification of 145 countries with wind-water-solar?", iScience, vol. 27, no. 2, pp. 108988-108988.

[21] Darwish. A, (2019) "A methodology for improving wind energy production in low wind speed regions, with a case study application in Iraq" [Online]: www.sciencedirect.com

[22] Darwish, A. S. K. Sayigh, A.A.M. (1988). Wind energy potential in Iraq, Solar & Wind Technology, Volume 5, Issue 3, Pages 215-222. ISSN 0741-983X.

[23] Amarapala, V., Darwish, A.S., Farrell, P. (2022) Energy status and the importance of wind energy resources in Sri Lanka, Springer. Sustainable Energy Development and Innovation. Springer International Publishing. [Online]: https://www.springerprofessional.de/en/energy-status-and-the-importance-of-wind-energy-resources-in-sri/20166484