OFFSHORE WIND TECHNICAL ASSISTANCE FOR SRI LANKA

EXECUTIVE SUMMARY

Study to expedite the development of offshore wind in two high potential areas off the coast of Mannar and Puttalam

FEBRUARY 2026

WORLD BANK GROUP

ESMAP
Energy Sector Management Assistance Program

UK Government

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Consortium

Pondera
Amsterdamseweg 13
6814 CM Arnhem
The Netherlands

https://ponderaconsult.com/

RMA Energy
27, Palmyrah Avenue
Colombo 3
Sri Lanka

http://rmaenergy.lk/

Title
Offshore Wind Phase II Technical Assistance for Sri Lanka

Type of document
Study to expedite the development of wind energy in two high potential areas of the coast of Mannar and Puttalam

Date
21-11-2025

Internal project number
723176

Client
World Bank Group, ESMAP and UK Government

Authors
Pondera: Wouter Pustjens, Linh Dong, Truc Le, Janno Heger, Joost Starmans, Suzanne Klerx

RMA: Swetha Perera, Tilak Siyambalapitiya, Lakmali Liyanage, Thirasara Gunaruwan, Amila Wickramasinghe, B Singhakumara

Reviewed by
Pondera: Eric Arends

Executive summary

Brief overview of the study

The Consortium, consisting of RMA Energy and Pondera Consult, has been executing an extensive study for offshore wind under a Technical Assistance (TA) Support Program of the World Bank Group to the government of Sri Lanka. It is funded by the UK Government with support from the World Bank Group's Energy Sector Management Assistance Program (ESMAP).

This study (under Phase 2 TA) is intended to build further on the main findings from the Offshore Wind Roadmap (under Phase 1 TA). It focuses on conducting a pre-feasibility study for two high-potential areas for wind power development off the coast of Puttalam and Mannar provinces. **The main objective of this study is to create attractive market conditions for investors and advance the development of the first offshore wind projects in Sri Lanka.** The technical assistance also aims to: 1) to de-risk future project development activities, 2) to engage stakeholders and build capacity to create widespread support, and 3) to increase general knowledge of offshore wind in Sri Lanka.

The technical assistance consists of several integrated assessments as follows. A constraint assessment (Chapter 2) was carried out to identify potential risks and barriers for offshore wind energy, and to identify the best potential locations for development projects. This information, along with other aspects such as realistic scales and local context, was used to develop project concepts (Chapter 3). These project concepts include information about infrastructure characteristics such as turbines, foundations, layout and the grid. Several variations were made to conduct a comparative assessment on factors such as energy yield and (economic) feasibility.

Additionally, several more nationwide building blocks for offshore wind development were investigated. A port appraisal study (Chapter 4) was conducted to determine the readiness and required upgrades of Sri Lankan and nearby Indian ports, including an outlook on potential socio-economic opportunities. The electrical system of Sri Lanka was also analysed (Chapter 5) to obtain insights on how to integrate the power from offshore wind projects into the grid, including an overview of potential grid development and including power flow modelling. An assessment of favourable market conditions (Chapter 6) was conducted, including mitigation and solution measures for commercial risks and bankability issues. Finally, stakeholder engagement and capacity building activities (Chapter 7) were conducted throughout the entire duration of the study.

The summary of each chapter, corresponding to the six main tasks of this study, briefly covers the objectives, methods, findings, and recommendations, is provided below.

This study reaffirms the conclusion of the Roadmap that the offshore areas in Puttalam and Mannar have significant potential for offshore wind projects. Among them, Mannar appears to have the greatest potential due to a combination of favourable factors. The study also highlights the need for Sri Lanka to continue building on the progress already made in developing key building blocks for offshore wind, including port and grid infrastructure, supply chain development, setting favourable market conditions, continuing stakeholder engagement and capacity building, and execute further studies to mitigate risks and uncertainties. With the right efforts, the first offshore wind projects could be tendered in the next 2 to 3 years and commissioned by the mid-2030s. The report confirms that Sri Lanka's offshore wind development potential will be heavily influenced by, and dependent on, the progress of offshore wind deployment in neighbouring Tamil Nadu, India.

The findings of this study, particularly the identified information gaps and uncertainties, combined with knowledge from offshore wind development in comparable markets, will form the basis for the subsequent Phase 3 Technical Assistance. This next phase will focus on site-specific surveys to generate evidence-based data that will further de-risk development and advance offshore wind deployment. Specific recommendations for the surveys under Phase 3 Technical Assistance will be captured in a separate document in due course (Text box 1 provides suggestions based on this study).

Text box 1 Suggested priority surveys for site suitability

The study highlights the need for a deeper understanding of biodiversity, particularly marine mammals, birds, and bats, and the characterization of geotechnical and geophysical conditions, including sea depths and seabed composition. Moreover, local fishers actively use the Mannar and Puttalam coasts, raising concerns about offshore wind development and underscoring the need for further study and coordination.

The geotechnical and geophysical survey should capture bathymetric variability and provide a general understanding of subsurface conditions and soil properties at key locations to support site selection and feasibility assessment.

Similarly, the ecological characterization survey should assess potential project areas by identifying present species, understanding their seasonal distribution, frequency, and migration routes, and determining overall suitability for development.

To maximize efficiency, it is strongly encouraged to combine survey efforts—for example, conducting marine mammal observations alongside geophysical surveys. Sri Lankan entities should take the lead in these efforts to build local capacity, with international experts providing technical support and strengthening offshore wind survey practices.

Summary of the six tasks of this study

Constraint Assessment

The Constraint Assessment evaluated the feasibility of offshore wind energy development in the offshore areas of Mannar and Puttalam by identifying and assessing key offshore constraints. It also helped identify mitigation measures to reduce risks and uncertainties while outlining potential suitable areas for offshore wind development.

A comprehensive assessment framework was established, encompassing technical, environmental, social, and safety considerations. Data from diverse sources, including global datasets, online literature, local expertise, site visits, and stakeholder consultations, were analysed. The main analyses were carried out using a Geographic Information System (GIS) as a mapping tool.

Several key constraints were identified, each varying in significance. The primary risks and uncertainties affecting offshore wind feasibility, along with potential mitigation measures, are summarized below in order of highest to medium risk:

- **Ecological (high risk):** The project areas are located in a wider region known as a biodiversity hotspot, particularly for avifauna (birds and bats) and marine mammals. However, there is limited knowledge regarding the presence, distribution of species, and the dynamics of nearby migration routes. Further research and on-site surveys are needed, with priority actions to be captured in a separate document during the Phase 3 Technical Assistance in due course.
- **Fishing (high risk):** The entire coastal area of Mannar and Puttalam is actively used by local fishers, with fishing hotspots located near the project boundaries. Local fishers have expressed concerns about offshore wind development. Additionally, illegal fishing activities by Indian fishermen also take place in Sri Lankan waters. Close coordination with local fisheries and aligned development efforts could help mitigate potential disturbances.

- **Wind speed (medium/high risk):** Both areas exhibit favourable wind speeds for offshore wind development. In Mannar, the mean wind speed at the proposed project site is 8.4 m/s at a 150 m Mean Sea Level (MSL) hub height. In the Puttalam area, slightly lower mean wind speeds of 7.7 m/s are observed at the same hub height. However, there is uncertainty regarding the wind speed gradient offshore in Puttalam, where wind speed variations appear to be more pronounced, potentially affecting the accuracy of wind resource estimates and layout design. Additional wind assessments are currently being conducted as part of a parallel study by the World Bank. Seasonal variation is high, which is an important consideration for offshore wind system integration. However, daily variation is low, with modelled wind speeds higher during non-daylight hours, which can be highly complementary to Solar PV.
- **Water depth (medium/high risk):** Generally, both areas are relatively shallow and offer a suitable depth range for fixed-foundation offshore wind technology, with many areas ranging between 10 and 30 meters in depth. However, there is some uncertainty regarding the presence of shallow waters, particularly due to presumed sandbanks in Puttalam. Further bathymetric surveys are needed for precise siting, with priority actions to be captured in a separate document during the Phase 3 Technical Assistance in due course.
- **Seabed characteristics (medium risk):** Although no seabed conditions are expected to negatively impact the foundation design options, data, particularly on the spatial variation of seabed conditions, are limited. Geotechnical and geophysical surveys are therefore essential to assess soil properties, sediment types, and potential constraints, with priority actions to be captured in a separate document during the Phase 3 Technical Assistance in due course.
- **Shipping (medium risk):** Although the project areas are located outside major international shipping lanes, local shipping activities are present in Puttalam. Strong future coordination and alignment with the maritime sector, along with potential zoning and marking/lighting systems, could help mitigate potential disturbances.
- **Tourism (medium risk):** Although not a primary tourism destination, coastal tourism activities do take place near both project sites. Ongoing stakeholder engagement throughout the planning process is essential.
- **Military (medium risk):** Military activities overlap with the project areas, although there are no dedicated military zones within them. Close engagement with the Ministry of Defence and the Navy is necessary to establish operational agreements.
- **Mining activities (medium risk):** The project areas are subject to hydrocarbon exploration activities; however, no active mining operations have been identified within them. Continuous dialogue with the Ministry of Energy and the Petroleum Development Authority should be maintained.
- **Coastal residents (medium risk):** While the project areas are not located near the most densely populated coastal areas, there could be opposition from residents along the adjacent coastline due to the potential visibility of the wind farm from shore. Informing residents, addressing their concerns, conducting thorough impact assessments during the Environmental and Social Impact Assessment (ESIA), and holding public awareness campaigns can help reduce opposition and build local support.
- **Culturally sensitive areas (medium risk):** Similarly, potential visual interference is a key consideration, as the offshore wind farm may be visible from culturally sensitive areas along the coast. Stakeholders from these areas should be actively engaged throughout the process to address concerns and ensure their perspectives are considered.
- **Other wind projects (medium risk)**: Several onshore wind projects are located near the coast. Although a 5 km exclusion zone to the coast is applied in this study, potential wake effects may still reduce energy yield and increase fatigue for downwind existing onshore wind farms. Wind resource modelling will help improve the understanding of wake effects and, consequently, inform mitigation measures such as optimal siting (since wake effects typically decrease with distance) and the design of offshore wind projects (which can be optimized to reduce or withstand wake effects).

A spatial analysis incorporating all identified constraints was conducted, mapping out exclusion zones and suitable areas for offshore wind deployment. The following exclusion zones are proposed:

- Water depths shallower than 10 meters and deeper than 50 meters to enable cost-effective foundation structures and installation methods;
- A 5-kilometer safety / precautionary buffer zone from Adam's Bridge National Park is proposed to minimize potential negative effects on ecological values;
- A 5-kilometer distance from the coastline is proposed to minimize potential negative effects on ecological values, coastal activities, and people;
- A 1-kilometer distance from the marine border (EEZ) with India is proposed to avoid any potential border issues.

It is important to emphasize that while these exclusion zones are proposed, no definitive obstacles have been identified within the project areas at this stage that would entirely preclude offshore wind development. The suggested exclusion zones and the preliminary available areas for offshore wind are shown in Figure 1 and Figure 2 (i.e., colour-blocked areas). Notably, relatively large areas remain potentially available for offshore wind development (i.e., areas with parallel diagonal stripes), which, in theory, could accommodate multi-GW projects in both regions. However, further research is required to confirm their suitability. These areas were considered for the design of the reference projects (see next task).

Figure 1 High-priority offshore wind areas with exclusion zones (Mannar)

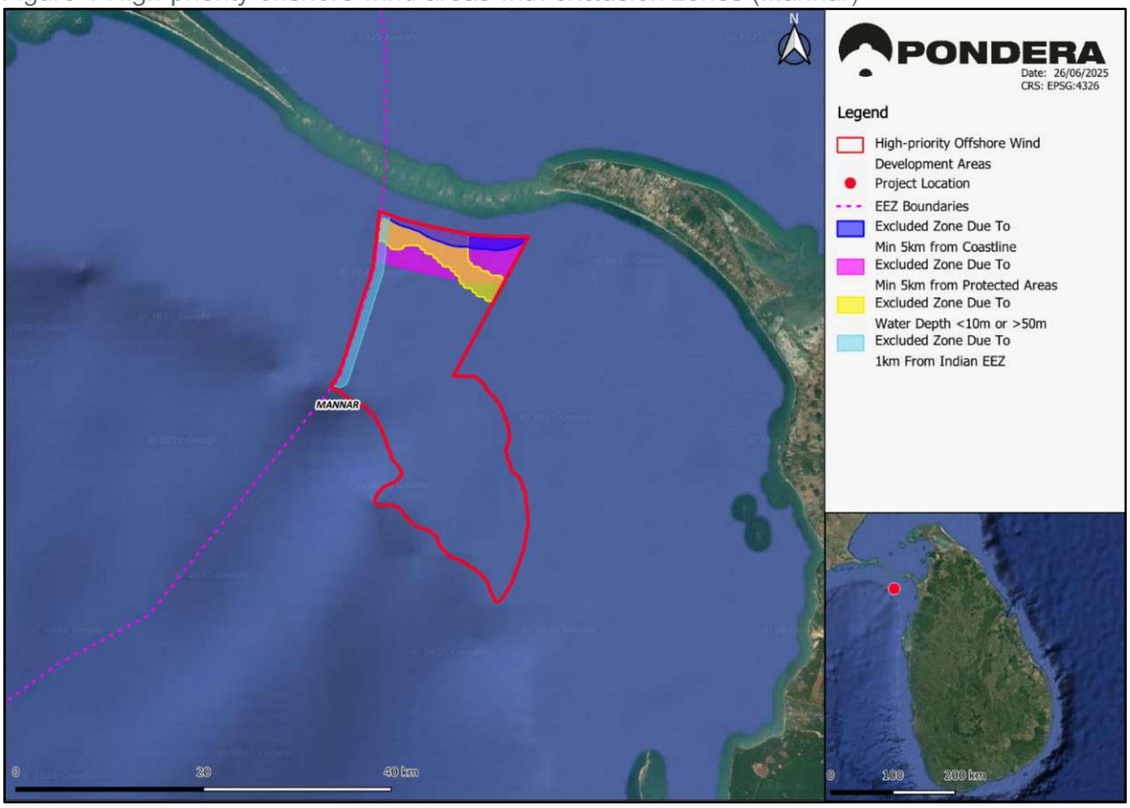
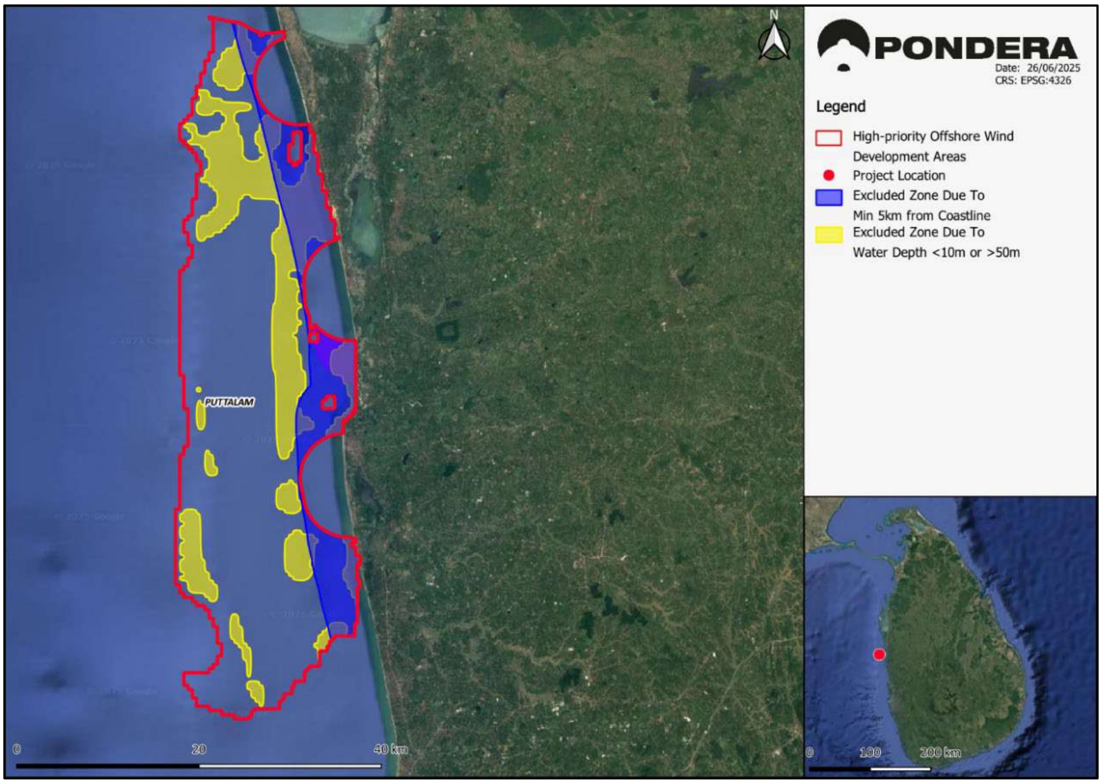


Figure 2 High-priority offshore wind areas with exclusion zones (Puttalam)



Project concept

Building on insights from other tasks in this study, this chapter develops reference wind farm layouts, considering wind climate, various constraints and technology options.

Wind data from the Everoze report[1], calibrated using Vortex data and validated against ERA5 data, formed the basis for the wind climate assessment. While data validation showed a reasonable correlation, it also underscored the need for on-site wind measurement campaigns to reduce uncertainty.

A 500 MW project concept was developed for each area, utilizing 34 benchmark IEA-15 MW turbines with a 240 m rotor diameter and a 150 m hub height on monopile foundations. Layouts were designed as regular rectangular grids, accounting for prevailing wind directions and wake effects. The electrical system designs incorporate 132 kV array cables and onshore substations (further described in the Task Electrical System). The reference projects are shown in Figure 3.

[1] Vortex FDC. (2023, March 17). *Sri Lanka offshore wind – Wind resource and mapping* (Report No. VORTEX017-R-01-B). A report for the World Bank under MSA with Vortex.

Figure 3 Reference project (left Mannar, right Puttalam)

Energy yield modelling, conducted using WindPRO 4.0, revealed a significantly higher Annual Energy Production (AEP) in Mannar compared with Puttalam (see Figure 4), primarily due to higher mean wind speeds and lower wake losses.

Several alternatives were developed and compared, focussing on performance, energy yield and Levelised Cost of Energy (LCoE).

For Mannar, the following alternative project concepts were developed:

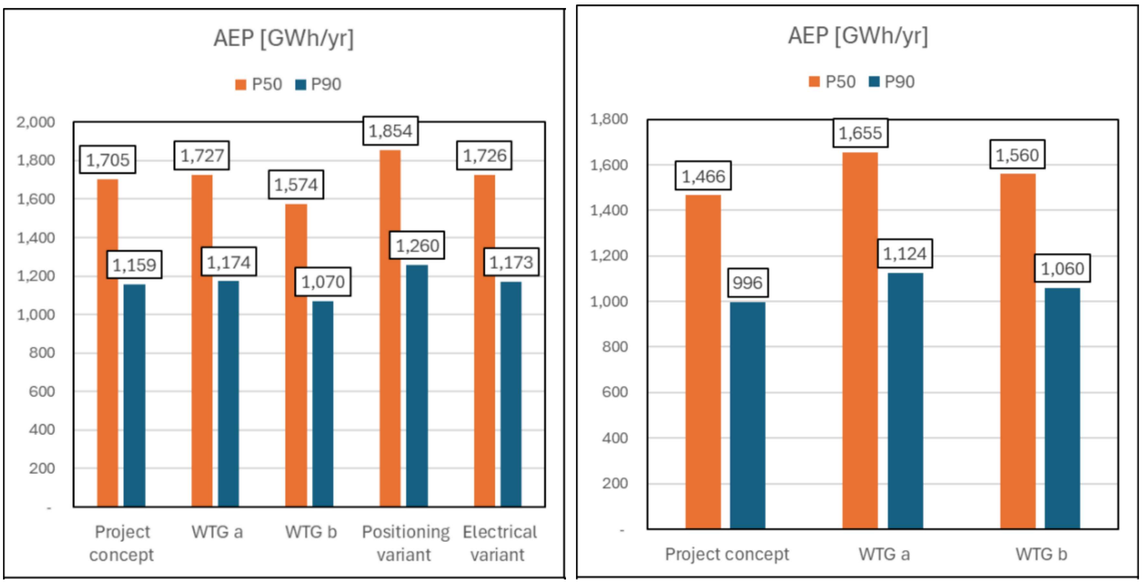
- WTG a = smaller wind turbine with lower power-to-rotor ratio, suitable for lower wind speeds (type: WB-8.6-200);
- WTG b = larger wind turbine (type: WB-18-250);
- Positioning Variant = layout optimized to reduce wake losses, featuring two longer rows of wind turbines;
- Electrical = includes an offshore substation.

For Puttalam, the following alternative project concepts were developed:

- WTG a = smaller wind turbine (type: WB-8.6-200);
- WTG c = lower power-to-rotor ratio, suitable for lower wind speeds (type: GW184/6.45MW).

The results of the AEP for the concept variants are visible in Figure 4. The positioning variant in Mannar has the highest AEP, but due its layout (spread perpendicular to the prevailing wind) reduces opportunities for phased development for OWP.

Figure 4 Results P50 and P90 AEP calculation of various project alternatives (left Mannar, right Puttalam)

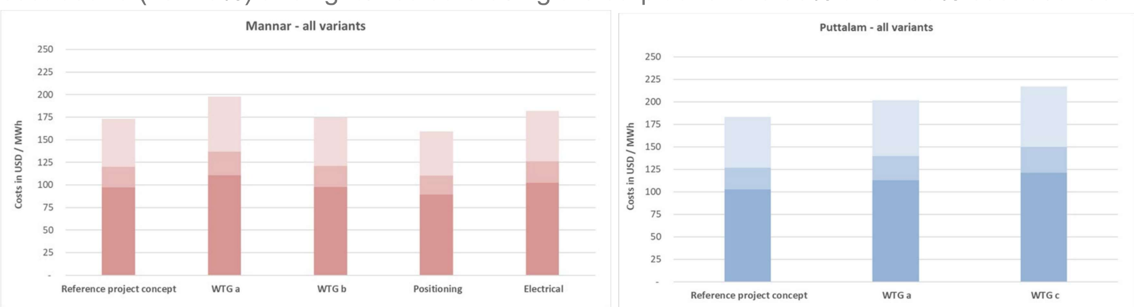


The LCoE was calculated for the concept variants using inputs such as the project timeline, costs (investment costs, i.e., CAPEX, and annual O&M costs, i.e., OPEX), discount rate or WACC, and AEP under three cost scenarios:

1. The relatively high price levels of 2024 will remain unchanged in the coming years (100%);
2. Current prices will drop back to the 'regular' 2019 price levels (80%);
3. The price level based on a projected local supply chain (economies of scale due to rapid APAC development and relatively cheap local labour) (70%).

The result of the LCoE calculation (see Figure 5) showed a wide range of outcomes, from 102-217 USD/MWh (Puttalam) to 89-189 USD/MWh (Mannar). In general, Mannar appears more attractive from a financial viability perspective. The LCoE for the reference project is higher than in the Roadmap, due to increased CAPEX (from 2.5 to 3.5-4.0 million USD/MW). It is important to note that there are significant variations and uncertainties in the LCoE calculations. This highlights the need for future work to narrow down the bandwidth of variants and create more certainty about the factors that strongly influence the LCoE. The 'value' of offshore wind in the electricity mix is still to be determined via dispatch modelling (as a post-project activity).

Figure 5 LCoE results for variants (Mannar=left, Puttalam=right). Darker colours being the lower cost bound (i.e. 70%) and lighter colours being the surplus for the 80% and 100% cost bounds



Port appraisal
The port appraisal assessed the readiness of Sri Lankan ports for offshore wind development and determined whether port upgrades are necessary. Data from the World of Ports database, field trips to port facilities, and publicly available sources such as the Ceylon Fishery Harbours Corporation website were used as inputs for the assessment.

The appraisal examined three types of offshore wind ports: 1) fabrication ports, 2) marshalling ports, and 3) O&M ports (SOV-based and CTV-based O&M ports). The ports assessed for their suitability to support offshore wind are shown in Figure 6. Given India's proximity to Sri Lanka and the expectation that offshore wind development will begin there earlier than in Sri Lanka, ports in India have also been evaluated for offshore wind development in Sri Lanka.

Figure 6 also shows the preferred ports for offshore wind development in Mannar and Puttalam, along with the necessary future upgrades.

Tuticorin port is recommended to support both fabrication and marshalling activities. Indian ports (like Tuticorin) are likely to lead regional offshore wind development while also servicing offshore projects in Sri Lanka (for manufacturing and marshalling). We analysed that Colombo port also has the potential to become a marshalling port, but significant upgrades would be necessary, including relocation of locks and gates and the procurement and installation of specialized equipment. In addition, the limited offshore wind project pipeline along Sri Lanka's west coast raises concerns about the economic viability of investing in Colombo port's development solely for marshalling activities. Given that marshalling operations occur for only a limited duration within the project lifecycle, the investment required for Colombo may not be justified. In contrast, upgrading Tuticorin for both fabrication and marshalling purposes represents a more strategic and cost-effective option for supporting offshore wind development in the region. Additionally, India's substantial offshore wind ambitions make it likely that large-scale ports like Tuticorin will be prioritized for regional projects.

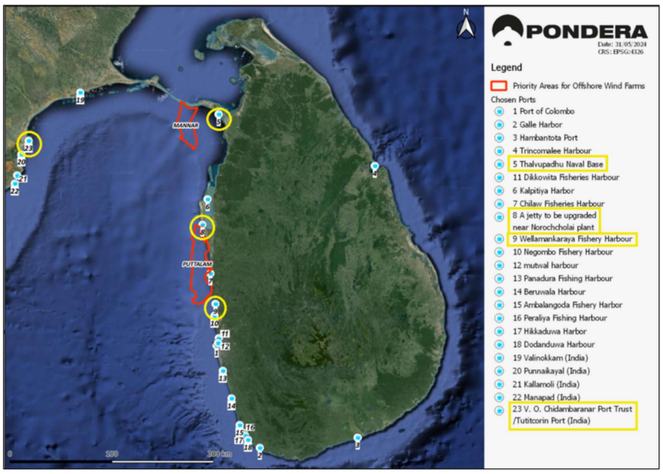
Nevertheless, the port appraisal indicated that Tuticorin requires extensive upgrades, including dredging, breakwater widening, quay length expansion, and the procurement and installation of equipment to function as a fabrication port. Minor modifications, such as breakwater widening and equipment procurement, are also necessary for its development as a marshalling port.

Regarding port development, Sri Lanka could focus on O&M ports. Several ports along the west coast have been identified as potentially suitable, with the following preferred options:
- For SOV O&M activities, Wellamankaraya is selected as the most promising port, only requiring dredging to become feasible. Wellamankaraya could potentially also serve future Indian offshore wind projects in the region.
- For CTV O&M activities jetty development near Thalvupadhu Naval Base and the Norochcholai Coal Power Plant are selected as the most suitable options for Mannar and Puttalam, respectively.

Development of O&M ports could contribute to economic growth in Sri Lanka, potentially creating an estimated 800 to 1,600 full-time jobs over 25 years for O&M activities.

An important takeaway from the analysis is that port development in Sri Lanka should be considered in the regional context of developments and opportunities in India.

Figure 6 Preferred ports for offshore wind in Mannar and Puttalam. Left: all ports considered (preferred in yellow). Top right: selected ports. Bottom right: required upgrades.



Type of Port	Mannar	Puttalam
Fabrication	Tuticorin	Tuticorin
Marshalling	Tuticorin	Tuticorin
SOV-based O&M	Wellamankaraya	(Wellamankaraya)
CTV-based O&M	A jetty to be upgraded near Thalvupadhu Naval Base	A jetty to be upgraded near Norochcholai Coal Power Plant

Type of port	Name of port	Major upgrades needed
Fabrication port	Turicorin	Dredging, breakwater widening, quay length expansion and equipment procurement, and equipment procurement and installation
Marshalling port	Tuticorin	Breakwater widening and equipment procurement and installation
SOV-based O&M port	Wellamankaraya	Dredging of at least 3 m
CTV-based O&M port	A jetty to be upgraded near Thalvupadhu Naval Base	Yard expansion
	A jetty to be upgraded near Norochcholai Coal Power Plant	Yard and quay length expansion
	Mutwal	No major technical upgrades
	Wellamankaraya	Dredging of at least 1 m
	Colombo	No major technical upgrades

Electrical system of the Offshore Wind Farms and grid integration

The Sri Lankan electrical system was analysed to integrate power from offshore wind projects into the grid. Building on the Offshore Wind Roadmap, the study assessed site-specific grid connection topologies, including voltage levels, maximum capacity, and connection points. It also reviewed power flow potential and contingency scenarios. Studies were conducted for the milestone year 2035, focusing on the proposed electrical system configurations for offshore wind farms in Puttalam and Mannar and evaluating the capability of the existing and planned transmission network.

The high-level configuration of the electrical system, including array strings, submarine cables, and onshore substations, for the project concepts is shown Figure 3.

To integrate the proposed 500 MW Puttalam offshore wind farm into the Sri Lankan grid, the following electrical system and grid connection arrangement is proposed:

- Four 132 kV submarine cables will each connect 8–9 wind turbines and transmit the generated power to a new onshore substation.
- At the onshore substation, the voltage will be stepped up to 220 kV.
- A new 220 kV double-circuit overhead transmission line of approximately 50 km will be constructed from the Puttalam onshore substation to the Wariyapola grid substation.
- At the Wariyapola grid substation, the 500 MW Puttalam offshore wind farm will be integrated into the national grid.

To integrate the proposed 500 MW Mannar offshore wind farm into the Sri Lankan grid, the following electrical system and grid connection arrangement is proposed:

- Four 132 kV submarine cables will each connect 8–9 wind turbines and transmit the generated power to the existing Mannar grid substation over an average distance of approximately 53 km.
- At the Mannar grid substation, the voltage will be stepped up to 220 kV using transformers installed as part of the project, as the substation currently lacks 132/220 kV step-up transformers.
- Since the capacity of the existing 220 kV transmission line from Mannar grid substation to New Anuradhapura grid substation (via Vavuniya) is already allocated to other onshore wind farms, the construction of a 15 km 220 kV double-circuit overhead transmission line between Mannar grid substation and the HVDC substation is essential for power evacuation.

- To accommodate the offshore wind farm, the planned capacity of the transmission line between Mannar grid substation and the HVDC substation will be enhanced as part of the project.

Table 1 presents a summary of the identified offshore wind farm capacities that can be connected with the grid under different network upgrading scenarios. As summarized in the table, without additional network upgrades, only a limited capacity can be connected. Existing and planned upgrades in the network are not sufficient to interconnect large scale offshore wind in Puttalam and Mannar.

According to the CEB LTGEP 2023-2042, by 2035, 2,090 MW of wind power plants can be connected to the national grid, but with additional network upgrades. Studies and system stability analyses indicated that the power system can accommodate up to 1,000 MW of offshore wind capacity by 2035 (for both wind farms). Planned network upgrades include new transmission lines and substations to improve grid connectivity and manage power flows. Additional network capacity will be required to support these connections to ensure system stability and efficiency.

The planned interconnector with India potentially increases the capacity of the Mannar project. With planned and additional upgrades, combined with the interconnector, approximately 1,000 MW of offshore wind could be possible in Mannar by 2035.

Table 1 Offshore wind farm capacities possible to be grid connected by 2035 under different conditions

	Offshore wind farm capacity possible for grid connection	**Mannar**	**Puttalam**	**Remarks**
1	With the planned upgrades	250 MW	200 MW	Upgrading of the transmission network infrastructure is planned for Mannar in parallel with the ongoing onshore wind development in Mannar. However, only limited capacity is uncommitted. No substantial transmission network upgrades planned in Puttalam area.
2	With additional upgrades of the grid	500 MW	500 MW	Further upgrading of the transmission network in Mannar and Puttalam is possible to accommodate offshore wind.
3	With 1 and 2 above, in combination with the interconnector with India	1,000 MW	500 MW	500 MW of India-Sri Lanka interconnection capacity is assumed to be allocated to export wind power generated in Mannar to India. Offshore wind farm in Puttalam will still have transmission constraints, preventing export of generation by an offshore wind farm in Puttalam to India.

While Table 1 presents the offshore wind farm capacities that can be grid connected by 2035, this capacity can be further increased with increasing electricity demand in the system. For example, based on the current demand forecasts, by 2040, the capacity that can be connected in Mannar can be increased to 1,500 MW.

The grid analysis was completed in summer 2024. At the beginning of 2025, news emerged that the large-scale Adani project (250MW) was withdrawn, potentially making more network capacity for offshore wind available. This should be re-investigated, but it is outside the scope of this study.

Favourable market conditions
The favourable market conditions for offshore wind projects in Sri Lanka were assessed, including Sri Lankan macroeconomics, procurement options, and commercial risk and bankability considerations. Mitigation measures were proposed, where relevant. The assessment employed a secondary research method, synthesising existing data from research studies, articles, and in-house expert knowledge to derive findings and recommendations. An alignment exercise was conducted with a parallel WB study into the regulatory environment to ensure consistency in findings and recommendations.

The key insights regarding Sri Lanka's macroeconomic indicators related to offshore wind are provided in Table 2, with policy recommendations for improved conditions outside the scope of this study.

Table 2 Key insights on Sri Lanka macro-economics

Indicators	Key insights
GDP	• A growing GDP indicates economic strength, providing a stable environment for investments in offshore wind projects. • Although GDP growth levels have been fluctuating in recent years, even showing declines in economic activity, near term prognoses predict growth.
Currency Reserves	• Sufficient currency reserves improve financial stability, ensuring the country can meet financial obligations. • Sri Lanka's foreign currency reserves have fluctuated significantly over the last decade, hampering the ability to manage external shocks and meet its international financial obligations. More recently, reserves have increased to $5.4 billion, with no future targets set.
Inflation	• Low and stable inflation helps maintain predictable costs and financial stability, benefiting the economic viability of offshore wind projects. • During the 2022 economic crisis, Sri Lanka experienced a sharp increase in inflation, which was subsequently managed through rigorous monetary policies. Recently inflation levels have stabilized.
Foreign exchange rate	• A stable foreign exchange rate reduces currency risk for international investors and ensures predictable costs for imports. • The volatility of the USD/LKR exchange rate, especially in 2022, raises concerns for investor sentiment and foreign investment. Currency volatility adds uncertainty, potentially deterring new

Indicators	Key insights
	investments. The exchange rate improved and stabilised throughout 2023 and 2024.
Financial stability	• A stable financial environment attracts investment by reducing the risk of volatility in the offshore wind market. • Sri Lanka has recently faced financial stability challenges amid economic contraction, high inflation, and increased interest rates. Despite this, improvements in financial markets, foreign exchange liquidity, and IMF support suggest signs of stabilization and potential economic recovery.
Power Sector	• A well-developed and reliable power sector, with sufficient demand, provides the necessary infrastructure and grid capacity to support the integration of offshore wind energy into the national grid. • For Sri Lanka, although there has been some reduction between 2019 and 2022, electricity demand is projected to grow in the coming period, increasing the need to diversify into new generating sources including offshore wind. • Financial challenges persist within Sri Lanka's power sector, where state-owned utilities frequently incur losses. Due to tariff measures implemented since 2022, the situation has improved. • Gradual liberalisation of the power market and recently approved legal provisions toward market mechanisms are expected to increase competition and (foreign) investments.

Regarding procurement systems for offshore wind, this study builds on the recommendations from the Roadmap and assumes that the government-led pathway towards offshore wind will be followed. This assumption is based on the relatively small market size of offshore wind in Sri Lanka, links to the Tamil Nadu offshore wind market, the lack of developer appetite for risk in new markets and the absence of sufficient market competition. It is an important assumption, as the choice of procurement system influences the content and recommendations regarding favourable market conditions.

The key insights regarding commercial risks and bankability considerations related to offshore wind in Sri Lanka (split into technical, financial and environmental categories) are provided in Table 3.

Table 3 Key insights on commercial risks and bankability considerations

Section	Sub sections	Key insights
Technical	Supply chain	• Offshore wind projects in Sri Lanka face significant supply chain challenges due to competition for global resources and existing supply chain issues. • Aligning with India's offshore wind development could create a larger, more attractive market and foster a stronger regional supply chain (potentially leading to lower costs), leveraging established trade relationships.

Section	Sub sections	Key insights
		• Sri Lanka's existing maritime infrastructure and local engineering expertise offer potential for developing localized supply chain elements, supporting project construction and maintenance.
	Ports	• Current port capabilities insufficient for offshore wind development. • Chapter 4 provides an extensive port appraisal and recommendations on port usage and development. • Government and/or private investment in port facilities for offshore wind projects is essential.
	Grid	• Ensuring efficient integration of offshore wind power (OWP) into Sri Lanka's grid requires expanding both regional and national capacities. • Chapter 5 provides an extensive grid connection assessment and recommendations on required grid upgrades. • The planned interconnector with India holds potential to significantly enhance grid absorption capabilities in the Mannar area. • Current financial constraints challenge CEB's capacity to fund necessary grid upgrades. • Clarifying responsibilities between developers and CEB regarding infrastructure development is crucial, weighing the advantages of streamlined project management against potential financial burdens and public sector investments.
	Compliance with standards	• Sri Lanka faces potential risks without national standards, including regulatory uncertainties and market limitations. • Developing standards can enhance project quality, competitiveness, risk management, environmental responsibility, and regulatory alignment, crucial for efficient project development and global market access.

Financial	Financial support mechanisms (FSMs)	• FSMs are essential for offshore wind development as they help to offer investors a more stable return and de-risk projects for lenders resulting in reduced financing costs and lower cost of energy.
		• There are generally three pricing mechanisms that can be adopted:
		  o Fixed Pricing: Ensures stable and predictable revenue but may not capitalize on potential wholesale electricity market price increases.
		  o Premium Pricing: Offers potential for higher revenue when market prices rise but includes risk if market prices fall (apply for Feed-in Premium and one-way CfD).
		  o Competitive Pricing: Can drive down costs through competition but may result in lower margins for suppliers.

Section	Sub sections	Key insights
	Electricity price	• Electricity market price fluctuations pose a significant risk for offshore wind projects (not supported by FSMs), impacting revenue due to factors like market demand and government policies. • Sri Lanka, previously with the highest prices in South Asia, has seen reductions since October 2023. • Fixed price mechanisms such as FITs provide stable revenue, while premium pricing adds a buffer against market fluctuations. Although competitive bidding introduces some risk, this is typically managed through long-term PPAs with fixed tariffs and flexible terms. • Future offshore wind contracts in Sri Lanka are expected to move towards competitive bidding under the Electricity Act of 2024. However, rather than exposing projects to the free-floating wholesale market, the competitive bidding process will likely allocate long-term PPAs with fixed tariffs, ensuring predictable revenue with a designated public counterpart.
	Grants	• There are currently no national government funds available for offshore wind. • Two examples of funds for energy efficiency projects are the Sustainable Guarantee Fund managed by SLSEA and the (to be opened) Sustainable Energy Guarantee Fund
	Costs	• Offshore wind projects are very costly, with 500 MW installations running into billions, increasing financial risk and deterring investors. • The cost estimations for the LCoE in Chapter 3 have a high uncertainty, compounded by the lack of regional benchmarks. This is addressed by using various cost scenarios and a sensitivity analyses. • Sri Lanka's proximity to Tamil Nadu offers a potential cost advantage, as developers may integrate Sri Lankan projects with India's offshore wind market, sharing resources and procurement. This could reduce costs and is factored into the LCoE analysis in Chapter 3.
	Taxation and profit repatriation	• Currently, there are no corporate tax concessions, though imported equipment for power projects is exempt from customs duty and VAT. • To attract investors, it is advisable to establish favourable tax regimes and set clear arrangements for profit repatriation.
	PPA	• The PPA in Sri Lanka relies on CEB, historically reliable in payments despite recent financial challenges. It has a typical 20-year term, with recent PPAs about 10 MW projects coming with USD denomination, providing revenue stability.

Section	Sub sections	Key insights
		• For a bankable PPA, it is crucial to clearly define the responsibilities of both parties, particularly regarding grid connection. However, with the ongoing unbundling of the energy sector, it's unlikely that the PPA will address grid investment responsibilities, as this would fall outside the scope of the agreement between the developer and the off taker. • The Sri Lankan PPA should include clear curtailment compensation mechanisms, defined limits on curtailment duration, and risk-sharing provisions. • Comprehensive insurance coverage in the Sri Lankan PPA meet the essential requirements, although political risk insurance is not explicitly detailed. • There are ambiguities in defining default events and force majeure conditions • The Sri Lankan PPA's dispute resolution process involves a tiered approach starting with mutual discussions and potentially escalating to higher-level representatives or an Expert, but lacks clarity in Schedule 15, creating uncertainties. • Additionally, the PPA is governed by Sri Lankan law, which may be less appealing to international investors preferring a globally recognized legal system.
	Financing	• Offshore wind projects are typically financed through a mix of debt and equity, using a non-recourse structure to limit risk to the project itself. • Key factors include: ○ interest rates, which affects borrowing costs and is better managed through international funding; ○ maturity, which determines repayment timelines and influences total interest costs; ○ gearing, which impacts financial stability by balancing debt and equity levels, with higher gearing increasing risk and lower gearing requiring more initial investment.
	Domestic financial support mechanisms	• Financing offshore wind projects in Sri Lanka will rely heavily on international capital, but local banks are essential for managing currency risk by providing loans in LKR, aligning with local revenue streams and enhancing stability. These banks' local market expertise also improves financing solutions. • Grants and funds are examples of domestic financial support mechanisms, but none are currently available for offshore wind projects.
	International financial support mechanisms	There are various international financial support mechanisms: • ECA-backed loans: ECA-backed loans require projects to meet strict risk criteria, including rigorous due diligence and reporting, more demanding than those of commercial financiers.

Section	Sub sections	Key insights
		Transactions with OECD Arrangement-covered ECAs must strictly comply with their additional regulations. • IFI guarantees: Guarantees can pose challenges due to complex accounting and approval processes for contingent liabilities, potentially leading to overuse for political reasons. • IFI insurance: Insurance requires advanced financial markets and historical project data to effectively manage risks across the renewable energy sector. In Sri Lanka, the CEB's comprehensive report on sales and generation data for renewable energy projects serves as a valuable tool for insurers, offering insights that can aid in evaluating and pricing insurance for these projects. • Blended finance: 1) Determining optimal timing and duration for concessional funds in blended finance is challenging. 2) Local financial markets must align with international standards for projects to sustain themselves post-intervention. 3) Government-set prices and market monopolies can distort signals, risking viability despite concessional support. Sri Lanka's fixed-price PPAs and the "must-run, must-take" policy ensure revenue stability, aiding blended finance. However, regulated tariffs may deter self-sustaining market after blended finance intervention. • A/B loan: Structuring A/B loans is complex due to splitting the loan into two parts with differing requirements, risk assessments, and expectations. Coordination challenges arise in aligning interests and managing relationships effectively. • Green bonds: 1) Green bonds don't offer financial advantages over conventional bonds as interest rates are based on the issuer's credit rating, not the funds' purpose. 2) There is no guarantee proceeds will be used as intended, potentially diverted to other areas. 3) Committing funds to specific expenditures may force cutbacks elsewhere due to fiscal constraints. 4) Measuring their impact is complex and uncertain, posing challenges in proving additional spending achieves desired outcomes, which can deter future investments.
Environmental and social	Sharing Maritime Space	• Offshore wind projects face risks from competing interests, for the potential projects in Mannar and Puttalam mostly related to fishing, ecology, shipping, military, and tourism. • In Chapter 2 an extensive constraint assessment has been carried out, highlighting the key risks from competing interests and potential mitigation measures. Competing interests could lead to delays, increased costs or reduced energy yield. • Competing interests are best managed during the planning stage through strategic assessments such as MSP and subsequently with ESIA, both of which involve extensive stakeholder engagement.

<table>
<tr><th>Section</th><th>Sub sections</th><th>Key insights</th></tr>
<tr><td></td><td>Lender E&S safeguard requirements</td><td>Lender E&S safeguard requirements can be split into several categories, the below table indicates which are covered by various leading institutions on this topic.
<table>
<tr><th></th><th>Equator Principles</th><th>IFC</th><th>EHS Guidelines</th><th>ADB</th></tr>
<tr><td>ESIA</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td></tr>
<tr><td>Biodiversity and marine conservation</td><td>✓</td><td>✓</td><td></td><td></td></tr>
<tr><td>Pollution prevention and control</td><td>✓</td><td>✓</td><td></td><td></td></tr>
<tr><td>Climate change adaption and mitigation</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td></tr>
<tr><td>Social engagement</td><td>✓</td><td>✓</td><td></td><td></td></tr>
<tr><td>Cultural heritage</td><td>✓</td><td>✓</td><td></td><td></td></tr>
<tr><td>Labour and working conditions</td><td>✓</td><td>✓</td><td>✓</td><td></td></tr>
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From Table 3 it is evident that many factors are required to create favourable market conditions for offshore wind in Sri Lanka. This study makes an initial attempt to provide an overview and recommendations. Further work and research are needed to support the rollout of offshore wind. Valuable lessons can be learned from offshore wind development in mature markets.

Stakeholder Engagement and capacity building

The primary goals of stakeholder engagement were to raise awareness, collect feedback, build capacity, and generate support for offshore wind projects. Offshore wind development is a new concept for the Sri Lankan community and, therefore, requires early and continuous stakeholder involvement, including government organizations and local communities. Moreover, long-term engagement is essential, particularly in the Mannar and Puttalam regions, where existing onshore wind projects and those currently in planning may have influenced perceptions of offshore wind initiatives.

A qualitative primary research approach was employed for the stakeholder engagement, gathering firsthand information through field trips, workshops, and online meetings to provide direct insights and contextual understanding.

Stakeholders were classified at three levels:

1. <u>National-Level Stakeholders:</u> Government and private organizations crucial for offshore wind development.
2. <u>Regional-Level Stakeholders:</u> The prominent regional-level government stakeholders are District Secretaries, Divisional Secretaries and representatives of local authorities. In addition, there are also non-government organizations (NGOs) working on environmental and social safeguards and NGOs working in the fisheries sector.
3. <u>Project-Affected Stakeholders:</u> Communities, organizations, and individuals who may be directly impacted by the project, including religious groups, fishing communities and tourism-related entities.

The following stakeholder engagement activities were performed as part of the study:

- Inception Mission: Held in November 2023, the project team (Pondera and RMA Energy) and World Bank had various one-on-one discussions with identified stakeholder organizations, making stakeholders aware of the offshore wind development activities.
- Workshops: After the inception mission, RMA Energy continued discussions with the executing agency, the Ministry of Power and Energy (MoPE). In January 2024, the ministry sent introductory letters to District Secretary Mannar, District Secretary Puttalam, coastal Divisional Secretaries of Mannar and Puttalam districts and 17 identified government organizations to request their assistance for future activities. Capacity-building workshops were arranged for regional and national stakeholder organizations. A series of workshops were held in Mannar (37 participants), Puttalam (32 participants) and Colombo (75 participants) between 26 February and 5 March, 2024. Additional efforts were made to increase the participation of women.
- Online Meetings with NGOs: An online meeting was arranged on the 13th of June 2024 with the relevant environment and social NGOs to inform them about the ongoing pre-feasibility study, to get their feedback, and to obtain relevant data for the analyses.
- Final workshops: A final series of workshops was held in Mannar (36 participants), Puttalam (33 participants) and Colombo (62 participants) from 17 – 21 March 2025 to present the findings of the pre-feasibility study and gather the final feedback. This helped refine the project conceptual design and ensured that the final report reflects the input of stakeholders.

Stakeholder engagement and capacity building should remain a priority effort in subsequent phases of offshore wind development, building on the achievements of this study.