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ICLEI Local Governments for Sustainability SOUTH ASIA

Roadmap on Offshore Wind Energy for Tamil Nadu

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This document has been prepared by **ICLEI - Local Governments for Sustainability, South Asia** under the **'Development of Roadmap for Offshore Wind in Tamil Nadu'** project.

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Disclaimer

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List of Abbreviations

ADB	Asian Development Bank
CAGR	Compound Annual Growth Rate
CEA	Central Electricity Authority
CERC	Central Electricity Regulatory Commission
CTU	Central Transmission Utility
CUF	Capacity Utilization Factor
DEA	Danish Energy Agency
Discom	Distribution Company
GW	Gigawatt (1 GW = 1,000 MW)
HT	High Tension
IFC	International Finance Corporation (IFC)
IREDA	Indian Renewable Energy Development Agency
IWPA	Indian Wind Power Association
IWTMA	Indian Wind Turbine Manufacturers Association
LCoE	Levelized Cost of Electricity
MNRE	Ministry of New and Renewable Energy
MoEFCC	Ministry of Environment Forest and Climate Change
MoP	Ministry of Power
MW	Megawatt (1 MW = 1,000 kW)
NCCR	National Center for Coastal Research
NIWE	National Institute of Wind Energy
NLDC	National Load Dispatch Centre
NTPC	National Thermal Power Corporation
OEM	Original Equipment Manufacturer
OSW	Offshore Wind
PFC	Power Finance Corporation
PGCIL	Power Grid Corporation of India
PLF	Plant Load Factor
POSOCO	Power System Operation Corporation, Grid India.
RPO	Renewable Purchase Obligation
SECI	Solar Energy Corporation of India

SERC	State Electricity Regulatory Commission
STU	State Transmission Utility
TANGEDCO	Tamil Nadu Generation and Distribution Corporation
TANTRANSCO	Tamil Nadu Transmission Corporation Limited
TANSIDCO	Tamil Nadu Small Industries Development Corporation Limited (TANSIDCO)
TANSI	Tamil Nadu Small Industries Corporation Limited
TEDA	Tamil Nadu Energy Development Agency
TIDCO	Tamil Nadu Industry Development Corporation
TIIC	Tamil Nadu Industrial Investment Corporation
TN	Tamil Nadu
TNERC	Tamil Nadu Electricity Regulatory Commission
TNGCC	Tamil Nadu Green Climate Company
TNSDC	Tamil Nadu Skill Development Corporation
EDII-TN	Tamil Nadu Entrepreneurship Development and Innovation Institute
VGF	Viability Gap Funding
WTG	Wind Turbine Generator
Y-o-Y	Year on year

1 Introduction

Summary:

India holds significant untapped potential for offshore wind (OSW) energy and the journey towards harnessing this potential began with MNRE's draft Offshore Wind Policy of 2012. These efforts gained momentum in the last decade, particularly in Tamil Nadu and Gujarat, due to favourable resource potential and regional advantages for renewable energy generation. This chapter highlights key milestones in India's OSW journey, including technical studies, policy and regulatory actions, and institutional measures such as designation of the National Institute of Wind Energy (NIWE) as the nodal agency for OSW development. Further, MNRE through strategic studies has set an ambitious trajectory of 37 GW of OSW development by 2030 for Gujarat and Tamil Nadu, reflecting India's commitment to expanding its OSW capacity.

Tamil Nadu, a leader in onshore wind energy, is now poised to play a crucial role in India's OSW ambitions. With 46% of its installed capacity already from renewable sources, the state aims to meet 50% of its electricity demand through renewable energy by 2030. This roadmap document on Offshore Wind Energy for Tamil Nadu is prepared to outline a comprehensive strategy and provide key recommendations to support early-stage OSW development and long-term sustainability of OSW projects in the state. The roadmap emphasizes the importance of strategic coordination among state and national agencies, the development of enabling policies, and robust stakeholder engagement to transform Tamil Nadu into a leader in OSW energy in India.

1. Introduction

1.1 Background: India's Offshore Wind Initiatives

India, with a coastline of 7,516 kilometres, has significant untapped offshore wind (OSW) energy potential. Efforts on offshore wind energy in India started taking off in the last decade, with the draft Offshore Wind Policy prepared by the Ministry of New and Renewable Energy (MNRE) in 2012. In the last decade, offshore wind developments in India have gained momentum, particularly in Tamil Nadu and Gujarat, due to their favourable seabed conditions & depth, wind resources, and regional advantages for renewable power generation and its off-take. Several studies involving resource assessments, marine spatial planning, and geotechnical surveys have been conducted in identified offshore areas near these states.

As a first step, the 'Facilitating Offshore Wind in India (FOWIND)' project in 2013 carried out technical assessments, planning, and techno-economic feasibility studies on OSW. This study also identified potential offshore zones in the states of Gujarat and Tamil Nadu. The MNRE has notified 'National Offshore Wind Energy Policy' in 2015. The National Institute of Wind Energy (NIWE) has been designated as India's nodal agency for the development of OSW energy under this policy. Other notable studies including marine spatial planning, grid transmission and port infrastructure readiness, financial modelling, among others have been conducted under COE and other initiatives.

In 2018, NIWE published the guidelines for 'Offshore Wind Power Assessment Studies and Survey' to encourage private sector expertise to undertake accurate wind resource assessments, and fast track OSW development in the country. The Ministry of External Affairs (MEA) notified seabed lease rules in December 2023 to facilitate smooth leasing process for conducting necessary offshore wind surveys and project execution by developers.

Further, MNRE published a strategy paper for the OSW development that has set out a cumulative auction trajectory of 37 GW by 2030 in the states of Gujarat and Tamil Nadu (MNRE, 2023). The maritime spatial planning study conducted under the CoE initiative showcases that Tamil Nadu's coastline offers higher wind resources (9 to 11 m/s) and favourable seabed depths with lower environmental and social conflicts.

Key developments related to OSW power in India over the last decade or so are summarised below.

Table 1: List of key OSW policies and assessments in India

Year	OSW Related Developments / Studies / Guidelines / Policy
2012	MNRE - Draft Offshore Wind Policy
2013 - 2018	FOWIND - Facilitating Offshore Wind in India Project
2015	MNRE - National Offshore Wind Policy
2016 - 2019	FOWPI - First Offshore Wind Project of India
2018	NIWE - Guidelines for OSW Power Assessment Studies and Surveys

Year	OSW Related Developments / Studies / Guidelines / Policy
2020 onwards	MNRE & DEA - Center of Excellence (CoE) for Offshore Wind and Renewable Energy
2022	MNRE - Strategy Paper for Establishment of Offshore Wind Energy Projects
2023	MNRE - Revised Strategy Paper for Establishment of Offshore Wind Energy Projects
2023	MEA - Offshore Wind Energy Lease Rules, 2023
2023	MoPSW (Ministry of Ports, Shipping & Waterways) - 'Harit Sagar' Green Port Guidelines
2024	SECI - Tender for seabed lease rights for 4 GW of OSW along the coast of Tamil Nadu

1.2 Context: Roadmap on Offshore Wind Energy for Tamil Nadu

The state of Tamil Nadu has been at the forefront of decarbonizing its conventional energy supply, with 46% installed capacity being from renewable sources. Tamil Nadu leads in utilisation of onshore wind energy in the country, with its 10,743 MW of wind power capacity as of May 2024, accounting for as much as 24% of India's total wind capacity. **With renewables accounting for 21% of its current generation, the state has set an ambitious target of meeting 50% of its electricity demand by RE by 2030 as part of its climate and energy transition strategy.** Recently in early 2024, the state also set up a special purpose vehicle (SPV) to boost implementation of RE projects.

Considering the resource assessments outcomes and the favourable conditions of Tamil Nadu coastline, MNRE published India's first tender (request for selection) in February 2024, for allocation of the state's seabed areas to project developers towards establishment of OSW projects of 4 GW capacity. Though economic development in the offshore territory is under the purview of national government, and agencies such as NIWE and SECI will govern the tendering and consequent processes, Tamil Nadu will play an active role in strategizing and coordinating a multitude of ecosystem related actions along with national agencies across policy and regulation, development of ports and other infrastructure, manufacturing and allied industries, skilling and capacity building, and stakeholder and community engagement, among others. Global offshore wind market outcomes affirm that the existence of enabling policy regulations along with technical know-how, and robust local supply chain are critical for deploying the complex and resource intensive OSW projects in a time bound manner.

In this regard, ICLEI-Local Governments for Sustainability, South Asia, together with the Planning Department, Government of Tamil Nadu and its Sustainable Development Goals (SDG) Coordinating Centre developed present roadmap for the Government of Tamil Nadu's concerned authorities to steer and support successful early-stage development of offshore wind developments in the state.

The roadmap seeks to

- take stock of Tamil Nadu's current energy transition landscape and review recent studies on OSW

- assess indicative OSW implementation trajectories, investment and infrastructure requirements, readiness and potential benefits
- map potential opportunities and consumer segments for off-take of OSW power
- conduct stakeholders' consultations and elucidate the role of key stakeholders
- provide key recommendations and actions to support the development and growth of the OSW sector in the state and assure its long-term success and sustainability.

The roadmap development was conducted through literature review and analyses coupled with stakeholder consultations by the ICLEI South team and a Senior Renewable Energy Expert, with the Planning Department and the SDG Coordinating Centre of Tamil Government advising and extending necessary support. The following flow chart outlines key activities carried for the development of offshore wind roadmap for Tamil Nadu.

1. **Analyse existing literature and landscape review of existing guiding frameworks, projects, and policies to identify baseline situations, gaps, and opportunities in the OSW sector**
2. **Stakeholder mapping across OSW value chain including key Tamil Nadu state agencies department. Conduct of stakeholder consultations to identify opportunities, key developments, priorities and on-ground challenges for inclusion in OSW roadmap preparation**
3. **Assessment of market potential, and identification of drivers and opportunities for OSW power offtake considering national and state renewable energy targets, enabling policies and regulatory framework**
4. **Prepare draft OSW roadmap with key recommendations and gather inputs from key stakeholders to validate findings through consultations**
5. **Finalise OSW roadmap for Tamil Nadu with key strategies and recommendations to support and fast-track early stage OSW deployment**

2 Overview of the Global Offshore Wind Market and Technology

Summary:

Offshore wind has emerged as a pivotal clean energy technology supporting global sustainable energy transitions and decarbonization efforts. This chapter provides an overview of global offshore wind markets, technological advancements and development trajectory in leading global OSW markets. These markets are shaped by the establishment of robust manufacturing capabilities, supply chains, regulatory frameworks and technological innovations enhancing the efficiency in construction and operation of OSW farms due to reduction in operational challenges and costs. The chapter also discusses the OSW project development lifecycle, emphasizing the importance of effective long-term planning, community engagement, and adherence to country-specific regulations, as these projects typically have longer development timeframes from initial surveys to project execution.

OSW projects are typically capital-intensive in nature and require substantial investments from the early development stages necessitating effective financial planning throughout the project lifecycle. Financing mechanisms must address various risks, including technical, regulatory, and environmental, to secure investment. This chapter highlights examples from global markets, such as syndication, government funding, and tax incentives, that provide insights into potential financing strategies for OSW projects. The chapter also emphasizes the employment opportunities in the OSW value chain spanning design, construction, operation, and maintenance, which emerging markets like India can leverage to develop a skilled local workforce, contributing significantly to local economies and the overall sustainability of OSW projects.

2. Overview of the Global Offshore Wind Market and Technology

Offshore wind has gained increasing prominence and emerged as a key clean energy technology solution to support sustainable energy transition and decarbonization goals across countries. Countries such as South Korea, Belgium, Denmark, France, and Germany have incorporated specific offshore wind targets in their net-zero goals. Globally, total offshore wind installed capacity stood at 75.2 GW by the end of 2023. With 10.8 GW of new OSW capacity addition, the year 2023 witnessed 24% growth compared to the previous year as per the recently launched global offshore wind report (Global Wind Energy Council, 2024).

As seen in Figure 1, OSW projects have had gradual trajectories across markets owing to the timeframe required for establishing ecosystems in terms of manufacturing capabilities, supply chains as well as governing policies and regulations. As the OSW markets have grown, the levelized cost of electricity (LCOE) or the net cost of electricity from OSW has seen significant reductions, by up to 70%, i.e. $3/MWh in the last decade (Global Wind Energy Council, 2023)

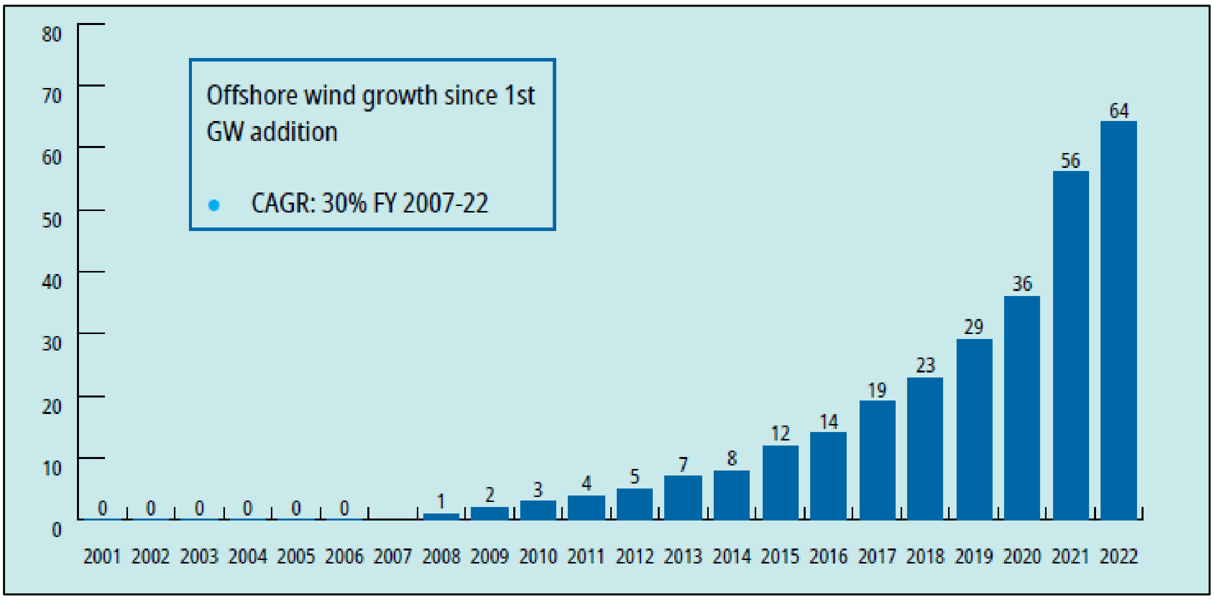


Figure 1: Global annual offshore wind capacity additions

Source: Reproduced from Global Wind Energy Council, 2023

In terms of installed capacity of offshore wind energy at the global scale, China leads the market with 48%, followed by the UK 22%, and Germany 13% (Global Wind Energy Council, 2023), as shown in Figure 2. The Asian market, broadly, is witnessing steady growth as governments are setting-up policy frameworks and concerted efforts related to clear regulations around sea-bed and marine spatial activities, roles of project developers, long-term project planning to ensure economic opportunities, compliances and environmental clearances and effective community engagements. GWEC estimates that global OSW markets to grow at a CAGR of 31% by 2027, with new offshore wind installations up to 50 GW by 2030 (Global Wind Energy Council, 2023).

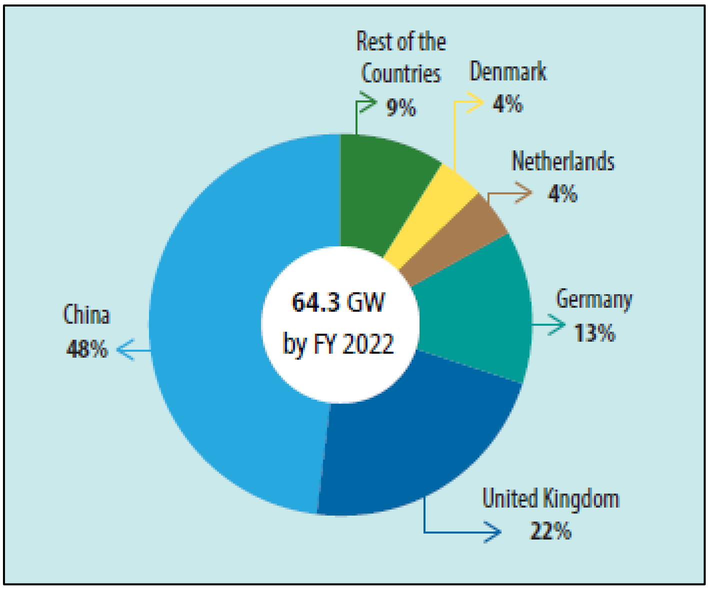


Figure 2: Country-wise share of offshore wind installations

Source: Global Wind Energy Council, 2023

In India, significant progress has been made in the offshore wind space from 2018 onwards. MNRE has mapped a potential of 35 GW for OSW energy along the Tamil Nadu coastline (MNRE, 2023). In 2023, MNRE also published a revised strategy paper for establishment of OSW projects, that outlines three implementation models for different offshore zones, with a potential bidding trajectory of 37 GW by 2030 for the coastlines of Gujarat and Tamil Nadu. Towards fulfilment of this identified trajectory, Solar Energy Corporation of India (SECI), published India's first tender for 4 GW of offshore wind projects in February, 2024. The request for selection tender seeks bids for the allocation of seabed lease rights at identified locations (blocks) along Tamil Nadu's coastline, wherein the successful bidder can carry out studies, surveys, and commission and operate OSW projects of up to 4 GW capacity on a Build Own Operate (BOO) basis.

2.1 Technological Overview of Offshore Wind Projects

The following table provides a summary of main mechanical components and allied infrastructure of offshore wind technology. Few relevant terminologies are added in the Annexure I.

Table 2 : Key OSW technology and project components

Offshore wind turbine components	
Nacelle	The nacelle houses wind turbine's key components- the gearbox, generator, drive train, brake assembly, yaw bearing and yaw system. Considering the remoteness, access concerns, complex operation and maintenance activities for offshore wind nacelle, some manufacturers provide designs which can support allowing service personnel to access directly from hovering helicopters.

Rotor	The rotor is like that of onshore wind and extracts kinetic energy from the air and converters it into rotational energy in the drive train. The rotor assembly consists of a hub, blades, bearing and pitch system. Hub holds the turbine blades and connects them to the main shaft.
Blades	Blades are similar to onshore wind turbines; however, the size, material composition, and structural design differs from the onshore turbines. The material of construction is mainly fiberglass, epoxy resins, and carbon fibres. The aerodynamic surfaces capture wind energy, and cause the rotor to spin. Each blade has its own pitch mechanism to maximise power output.
Tower	Turbine tower supports nacelle and rotor. Tower's height depends on the turbine design and size which varies as per the site. Tower is a steel structure, and typically houses electrical equipment, control system, safety equipment and has an access system (ladder) to reach the nacelle.
Typical Offshore wind turbine foundations	
Monopile	The monopile type foundation consists of a monopile as a column and a transition piece for connection with a tower of the wind turbine. Monopiles and transition pieces are extra-thick, large-diameter, and long, super-heavy objects. The monopile structure is the predominant foundation type for shallow depth (less than 30 to 40 metres) offshore wind sites..
Jacket	This is a lattice-like structure used as a foundation for offshore wind turbines. Such structures are suitable for deep waters (around 40-50 metres of seabed depth). This consists of various small legs connected to each other by the braces.
Tripod	This foundation consists of a three legged pile support that is fixed on seabed foundations. This type of foundation is adopted in offshore oil & gas, but has limited adoption for offshore wind power. The tripod foundation does not require soil bed preparation for installation.
Floating	This is a buoyant structure used for supporting offshore wind turbines in deep water (i.e. where seabed depth is more than 60 meters, and fixed support structures are not feasible). It consists of a floating sub-structure which provides buoyancy to the turbine, and a connected mooring system maintains turbine movements within allowed design ranges.
Gravity	Gravity-based foundations are large concrete structures that sit on the seabed and rely on their weight to provide stability for the wind turbine. They consist of a concrete base into which the shaft of the wind turbine is installed
Electrical infrastructure	
Array Cables	This is also known as inter-array cables. This cable network is used to transfer power from individual offshore wind turbines to the offshore substation.
Offshore	Offshore substations are generally used to combine the power generated

Substation	from various individual offshore wind turbines. This substation can be HVAC or HVDC (High Voltage AC or High Voltage DC) type. HVAC substations typically stabilise power coming from individual wind turbines, and step-up the voltage to desired level for further transmission to onshore substations, and grid connection. This type of offshore substation is typically adopted for near coast installations. HVDC offshore substations are typically used for higher distance from the coast. Most commonly, these substations first upgrade AC power from different wind turbines (for e.g. 33 kV or 66 kV to 132 kV), which will be converted to DC (for e.g. 320 kV). This DC power is transmitted to an onshore substation, which can either convert to AC for HVAC transmission, or upgrade for HVDC transmission.
Export Cables	These cables transmit electricity from offshore substation to onshore substation. This is mostly static cable connected to the seabed. The size and capacity of the cable vary based on HVAC or HVDC, voltage level, and power transmission requirements.
Onshore Substation	Onshore substations receive power from one or multiple offshore substations, and connect with transmission networks with necessary power conditioning. Protection and control systems are used in this substation as per applicable grid code and standard safe practices.

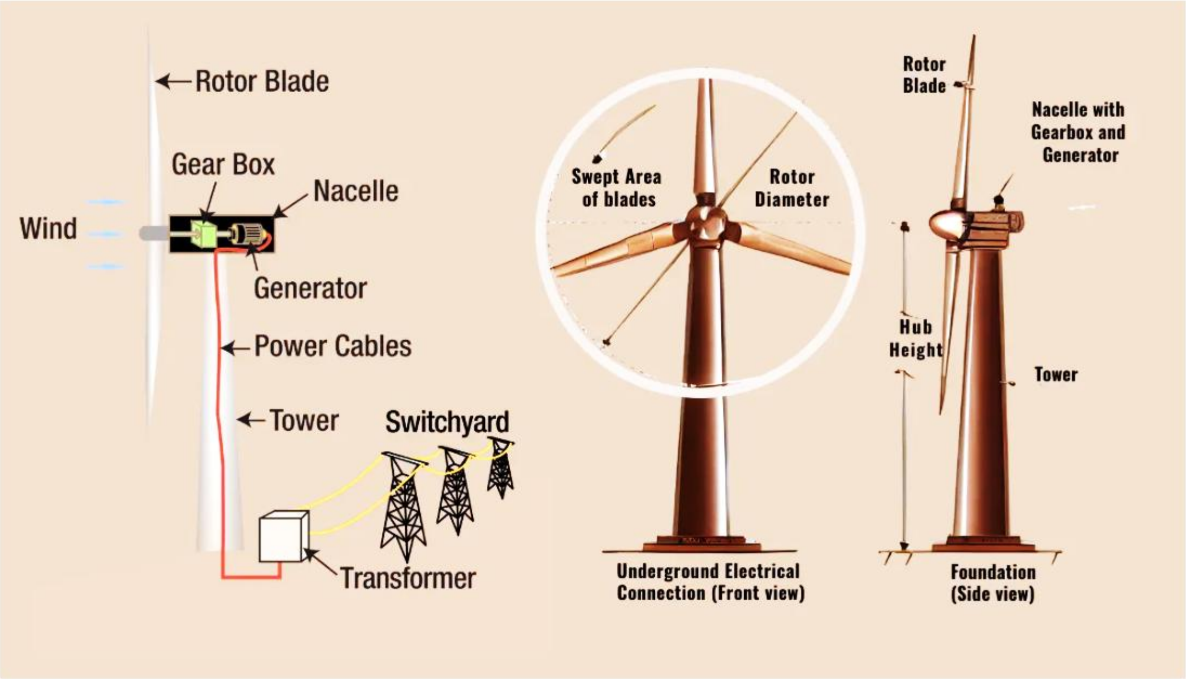


Figure 3: Schematic Diagram of OSW Technology

Source: [Windmills Tech]

Key differences between onshore and offshore wind technology

The turbine technology (nacelle and rotor) used in onshore and offshore wind is similar, however offshore wind requires specialised designs for subsea components (such as foundations, towers, cables) and balance-of-plant infrastructure to withstand a different and harsher marine environment.

The primary advantage and value proposition of offshore wind is that it is able to generate significantly higher volumes of energy due to its higher capacity factor and large power output as compared to onshore wind (see Table 2). Offshore wind turbines can be scaled much larger, helping to capture and produce more energy. Onshore wind turbines are limited up to certain heights given potential interferences and impacts on land. Offshore wind farms benefit from stronger and more consistent wind speeds compared to onshore locations due to less obstructed wind flow or drag caused due to land contours and man-made obstructions in case of onshore wind farms. Offshore wind offers reliable renewable energy to support enhanced energy security and diversification, without competing for limited land areas.

Onshore installations are simpler due to easier access to land-based work for construction and maintenance, unlike offshore farms where skilled workforce and specialised techniques are essential for OSW farms construction and operation and maintenance (O&M) activities. Offshore wind farms are typically located in near-shore or deeper ocean zones up to Exclusive Economic Zone (EEZ) of 200 nautical miles. OSW installations are built on fixed foundations (monopile or jacket) in shallower waters and using floating structures for deeper areas (generally more than 60 m water depth) as shown in Figure 4. Advanced analytical, planning and designing expertise is required for OSW projects that are very site specific, including climate conditions and marine environment for timely execution.

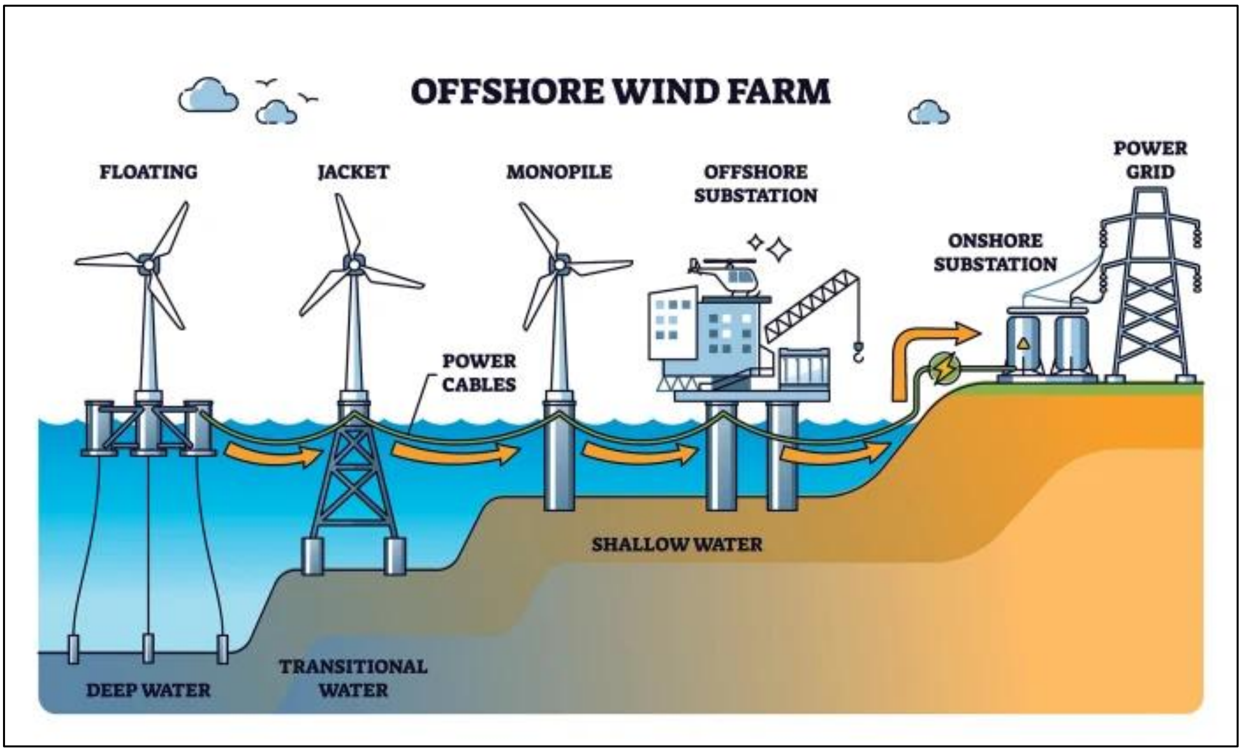


Figure 4: Typical offshore wind farm diagram with illustration for various foundation types

Source: Power & Motoryacht

Table 3: Key differences between onshore and offshore wind projects

Parameter	Onshore Wind	Offshore Wind
Wind Resource	Less wind resource compared to OSW- about 5-7 m/s	Higher wind resource with 8-11 m/s @ 150 meters above ground level
Environmental (and local) Impact	Can impact human activities, local wildlife, land use.	Relatively less impact on human activities with the exception of fisheries and marine ecosystems
Project costs	Lower installation and O&M costs	Higher installation and O&M costs
Wind Turbine Generator (WTG) size	Limited due to logistic, transportation and infrastructure constraints. WTGs up to 5 MW are available	High due to high wind resource and economy of scale considerations. WTGs up to 15 MW have been set up and higher capacities are under development
Scale and Potential	Subject to local land availability, and wind resources	High but subject bathymetry considerations
Capacity Utilisation Factor (CUF)	Lower (Ranging from 18% to 40%)	Higher (Ranging from 35% to 55%)

2.2 Technology Scenario

In terms of technology manufacturing and supply chain scenario, China leads the production of nacelle globally with a capacity of 16 GW per year as well as in terms of supplying components including gearboxes, generators, among others (58 % and 70% of global market share respectively). Europe follows China with 9.5 GW nacelle production capacity, mainly in Denmark, Germany and France, and then Asia Pacific region with 1.9 GW capacity, mainly in Taiwan and South Korea.

With regard to offshore wind turbine blades, international companies such as Siemens, Vestas, LM Wind Power, among others have the capacity to produce blades suitable for offshore plants, with sizes reaching up to 105 m for a 12 MW wind turbine and have planned to graduate to production of blades for 15-16 MW wind turbines by 2024-25 (AEGIR Insights, 2022).

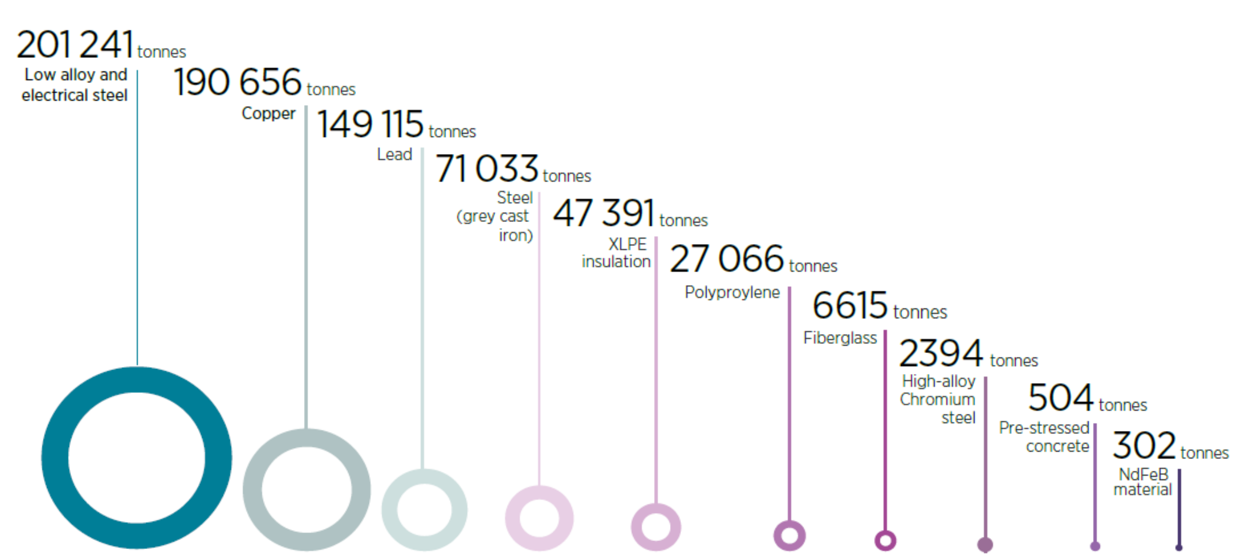
Currently Indian original equipment manufacturers (OEMs) lack capacity to produce such turbines, suitable for OSW, however global OEMs have OSW manufacturing know-how and facilities in India (ORE, Catapult, and mec+, 2023). A list of major offshore wind turbine manufacturers is provided in Annexure II.

In terms of the foundation for OSW installations, monopile and jacket type foundations are prevalent. However, market trends indicate a gradual but growing interest in developing floating foundations given their potential for siting turbines in deeper waters with abundant wind potential. Floating foundations provide scope for faster deployment. A few European countries, the UK and USA have floating foundation-based demonstration projects in place and large-scale projects in the pipeline (Global Wind Energy Council, 2023).

Material requirements for Offshore wind projects

Offshore wind projects due to their exposure to harsh weather conditions and physical interactions with marine environments including saline water, ocean wave impacts, as well as aquatic life, are required to be built with materials having specific properties and strengths. Figure 5 depicts the indicative material requirements for a 500 MW offshore wind project (IRENA, 2018).

Indian industrial ecosystems are equipped to provide main raw materials such as steel alloys, copper and lead, however expertise in terms of developing specified materials for OSW project requirements along with the workforce is lacking. Major global wind energy manufacturing players have their facilities in India, having in-house R&D set-up which is in compliance with international standards and certifications, however these lack capacity to manufacture large size offshore wind project components. Specific material composites required for components such as blades are largely being imported.



Note: NdFeB material (also known as neodymium magnet, NIB or Neo magnet), is a permanent magnet made from an alloy of neodymium, iron and boron.

Figure 5: Material requirements in tonnage for development of 500 MW offshore wind project

Source: Renewable Energy Benefits: Leveraging Local Capacity for Offshore Wind, IRENA, Abu Dhabi, 2018

2.3 Offshore Wind Project Development Cycle

Offshore wind projects globally have a typically longer development time frame of 7 to 10 years, commencing from initial surveys and culminating in project execution. Project timeframes can vary depending on several factors including country-specific regulations and compliance requirements, geographical conditions of the project site, among others.

The figure below summarizes the key stages of an offshore wind project development cycle, along with representative timelines (Global Wind Energy Council, 2024). It is important to note that these timelines exclude the project decommissioning phase, which can take an additional 3 years to complete.

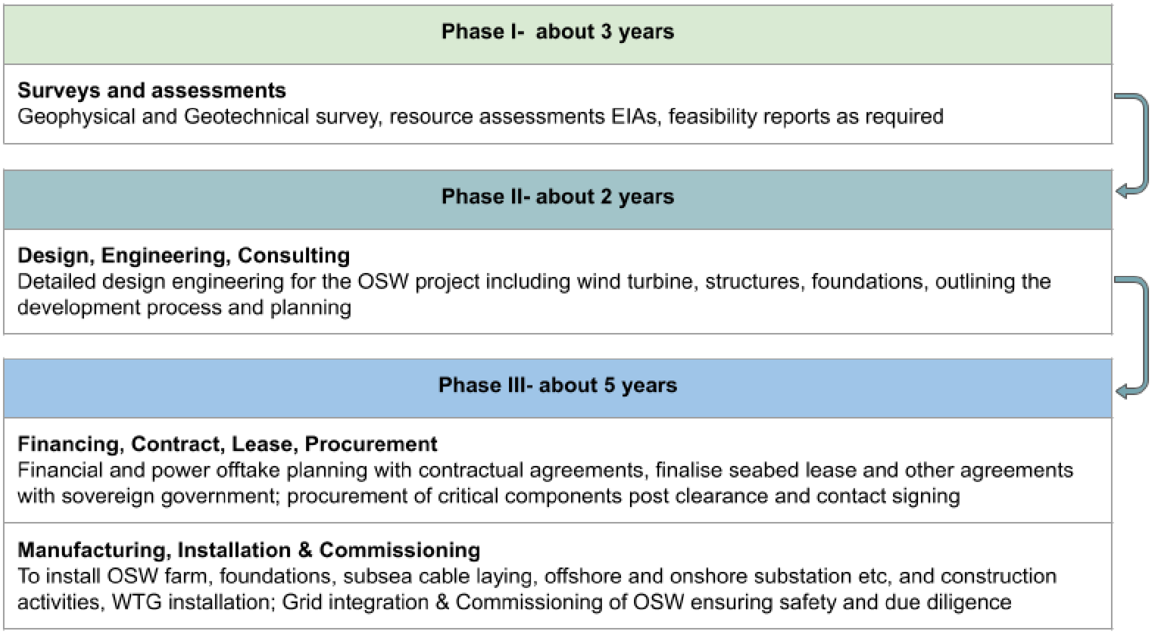


Figure 6 : Offshore Wind Project Development Activities and Timelines

2.4 Financing Considerations for Offshore Wind Projects

OSW projects are highly capital intensive, with CAPEX costs of over INR 20,000 Crore and incurring operating costs of around INR 5,000 Crore for every GW of offshore wind capacity. Given the need for high volume of financial resources and long project development timelines that extend over several years, prudent financial planning is essential for OSW projects from early development stage till project life-cycle, to ensure successful deployment and viable operations.

Financial resources are required in the initial stage (phase I) for resource assessments and surveys, lease of seabed areas, agreements, social and environmental due-diligence, and various clearances. Apart from this, sufficient funds are needed to lock prices of critical components (such as WTG, foundations, transmission assets etc.). Project developers also have to consider currency fluctuations, change in inflation rates, hedging and overheads for storage of project equipment/components at nearby ports. Allied with technical performance, utilisation of appropriate financing mechanisms can help reduce the project LCoE (levelized cost of electricity), which is a measure of the average net present cost of electricity generation for a generator (or developer) over its lifetime.

Offshore wind projects are site dependent and specific, and subjected to various risks associated with aspects such as offshore and submarine engineering, technology, meteorology, policy and regulatory requirements, approvals, liasoning with multiple stakeholders (defence, marine, local-fisheries, port and cargo transport), early stage-market and technology risks, environment clearances, skilled workforce availability, wind farm maintenance, and power evacuation and off-take on a commercial basis.

Even with multiple options of project financing for renewable energy projects in the market, there are limitations with regard to tapping these financial resources for OSW energy at a reasonable cost (debt or equity) due to these associated risks. Apart from this, financing institutions also require expertise to evaluate OSW project proposals with regard to technical, supply chain, policy and regulatory risks. Moreover, since offshore wind farms have longer lead times, capital expenditure is required to be financed well before the project starts generating profit through sale of renewable electricity.

Most financing or lending institutions have their own set of compliance requirements to finance OSW projects. Apart from financial risk assessment, lenders also seek compliance on environmental and social impact assessments. These comprehensive risk management frameworks for project and project related financing, are with a primary focus on environment and social responsibility, such as the Equator Principles[1] and performance standards of institutions such as the International Finance Corporation (IFC). OSW project developers will need to follow such standards and guidelines, particularly when seeking capital borrowings from international banks and financing institutions.

OSW projects involve multiple developers, companies, institutions and financiers in their construction, operations and maintenance. Given the multidisciplinary operational profile of offshore projects, in most cases, risks are shared among various stakeholders such as project developers, financiers, and off takers. While a larger pool of stakeholders can spread the risk, it can pose implementation and coordination challenges.

Considering the nascent stage of development in India, perceived future risk can be reduced with the government's pro-active support or participation in the development process, and enabling financial measures and interventions. Examples of financial mechanisms employed in other countries to support OSW can be seen further in section 6.2.6.

Case Study: Financing of Triton Knoll wind farm in the British North Sea

The Triton Knoll offshore wind farm consists of 90 turbines, having a total installed capacity of 857 MW. This wind farm is located 32 km from the Lincolnshire coast in the North Sea. This farm has installed MHI Vestas v164-9.5 MW turbines. This is one of the largest offshore wind farms in the world. Each turbine is up to 187 meters tall with blades of over 80 meters long.

[1] Equator Principles have garnered significant adoption within the financial sector globally, with over 128 financial institutions signing up and 34 designated countries.

The power is collected via two Offshore Substation Platforms (OSPs), via 66kV array cables and associated equipment. Power is stepped up to 220 kV on the OSPs and is exported to the onshore substation at Bicker Fen, Linconshire, via circa 108 km of offshore and onshore export cables using two circuits. At the onshore substation, the power is stepped up again to 400kV and connected via 2 km of 400 kv cable to the National Grid substation where it joins the National Electricity Transmission System (NETS). Construction and engineering company J Murphy & Sons carried out the 57 km onshore cable installation for this wind farm.

The Triton Knoll offshore wind farm is jointly owned by RWE (59%), J-POWER (25%) and Kansai Electric Power (16%). RWE operates the plant on behalf of partners.

The overall financing amounts to approx. £2 billion (approx. 2.5 billion USD). This financing was secured through a syndicate of international banks, including KfW IPEX-Bank, Sumitomo Mitsui Banking Corporation, ABN AMRO Bank, MUFG Bank, ING Bank, Landesbank Hessen-Thüringen Girozentrale, Natixis, Bayerische Landesbank, National Westminster Bank, Lloyds Bank, Skandinaviska Enskilda Banken, Commerzbank AG, BNP Paribas, Landesbank Baden-Württemberg and Banco Santander S.A.

As per the current UK regulations, post commissioning of offshore wind farms (typically built with the transmission infrastructure), once the wind farm starts to generate electricity, the developer must divest the transmission asset. This is done through Ofgem's OFTO Tender Regime.

UK regulator (Ofgem) through competitive tender, selected ETEPCO (a consortium of Equitix Limited and TEPCO Power Grid Incorporated) to own & operate the Triton Knoll transmission infrastructure for 23 years.

To summarise, OSW financing is a complex process which requires multiple investors, backed by banks syndication. Finance is required for the capital requirements, project approvals and related legal processes, installation and commissioning, and various operation and maintenance activities. With multiple project partners and investors, risks associated with OSW can be shared. Also, additional efforts shall be required to bring all consortium partners in sync.

Key Takeaways:

- Multiple Project Development Partners
- Multiple International Banks Syndication (Debt)
- Active Role of Government and Regulator for various phases of development
- Divestment on Transmission Assets
- Long Term Contracts and Risk Sharing

Reference weblinks:

1. https://www.kfw-ipex-bank.de/Business-sectors/Energy/Wind-power/Offshore-wind-power/
2. https://www.rwe.com/en/press/rwe-offshore-wind-gmbh/2023-12-05-triton-knoll-offshore-wind-farm-sale-of-transmission-assets/

3. https://centrusfinancial.com/credential/consortium-acts-as-financial-adviser-to-ofgem-on-the-573-million-transfer-of-triton-knoll-offshore-wind-farm-transmission-link/

2.5 Employment Opportunities in the Value Chain

Offshore wind projects are starkly different from other renewable energy projects, in terms of technology and costs related requirements across lifecycle stages as well as workforce inputs and expertise required for design, construction, operation and maintenance, considering offshore operations. Additionally, technologies related to wind turbines, use of fixed foundations versus floating turbine foundations are evolving, thereby requiring skilled and adaptable workforce in the value chain.

Emerging markets such as India are more labour intensive than other developed markets of Europe, and therefore offer great opportunity to develop the local workforce for OSW projects where as much as 35% of the total workforce can be employed for installation, operation and maintenance activities, barring the manufacturing segment comprising of 59% of employment opportunities (see Figure 7).

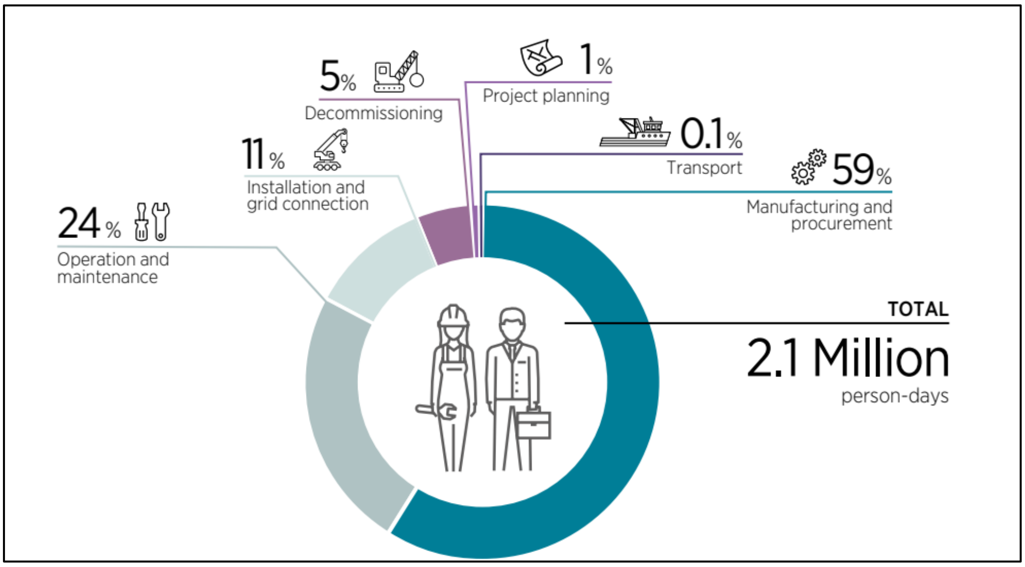


Figure 7: Human resource requirement for the development of a 500 MW OSW project

Source: IRENA (2018), Renewable Energy Benefits: Leveraging Local Capacity for Offshore Wind, IRENA, Abu Dhabi.

3 National Developments and Role of Offshore Wind in Tamil Nadu's Energy Transition

Summary:

This chapter discusses the implementation models proposed by MNRE in its revised strategy paper to facilitate the development of 37 GW of OSW capacity off the coasts of Gujarat and Tamil Nadu by 2030. Three distinct OSW project development models are outlined by MNRE; including a viability gap funding (VGF) based model to assist financial viability of initial OSW projects are discussed. These models are tailored to accommodate the nascent state of India's OSW sector, providing a structured approach to project development while balancing financial viability and regulatory compliance.

Expected timelines and key milestones for OSW project development based on the MNRE's tender for OSW development published in Febrary 2024 are discussed, emphasizing the importance of pre-construction surveys, environmental impact assessments, and resource measurements. With seabed lease auctions planned for FY 2024-25, the first OSW projects in Tamil Nadu are anticipated to be commissioned post-2030, contingent on the successful navigation of regulatory approvals, financing, and infrastructure development. It also includes a review of key policy and regulatory frameworks put in place by national and state institutions to support the development of OSW projects.

The existing energy landscape of Tamil Nadu and its outlook for 2047 is further outlined, rationalizing the need for OSW integration in the state's energy mix in the coming decades to address the growing energy demands and also to meet larger goals of decarbonizing the electricity grid-electricity and sustainable development. Tamil Nadu targets to meet 50% of its electricity demand with renewables by 2030. However, rising energy demands, driven by industrial growth and urbanization, present challenges including gaps between generation and demand that necessitate further expansion of generation capacity. Despite Tamil Nadu's progress in renewable energy, the growth rate of onshore wind capacity has slowed and solar power alone may not suffice to meet the increasing energy demands. OSW offers a promising solution, providing higher and more reliable electricity generation compared to other onshore renewable solutions.

The chapter apprises of the socio-economic benefits of strategic development of OSW in Tamil Nadu, supported by its abundant wind resources, favourable geographical location, and existing expertise in wind energy. The OSW sector promises substantial socio-economic benefits, including job creation, economic growth, technological innovation, and skill development. Additionally, investments in OSW infrastructure, particularly in ports and manufacturing, could stimulate local economies, increase state revenue, and enhance community development. By capitalizing on these advantages, Tamil Nadu is well-positioned to become a leader in OSW, driving both economic prosperity and environmental sustainability.

3 National Developments and Role of Offshore Wind in Tamil Nadu's Energy Transition

India has identified its strategy and implementation models to move ahead with the development of 37 GW of OSW capacity along the coastlines of Gujarat and Tamil Nadu through the MNRE's revised strategy paper for establishment of OSW projects, 2023. Efforts to initiate development of its first offshore wind projects have further gathered pace, with the country's first ever tender floated in February 2024 to allocate seabed sites along the coast of Tamil Nadu for developing 4 GW of offshore wind projects.

3.1 Implementation Models for Offshore Wind Projects by MNRE

MNRE, in its revised strategy paper, has outlined an implementation approach and anticipated auction trajectory to facilitate the development of 37 GW of offshore wind farms off the coasts of Gujarat and Tamil Nadu (MNRE, 2023). This strategy paper is the outcome of multiple stakeholder consultations with private sector, project developers, and central and state government departments and institutions. Considering the nascent state of OSW projects in India, MNRE has outlined three OSW project development models, including a model with necessary financial support (in terms of viability gap funding) to assist financial viability of initial OSW projects. The other two models are proposed without VGF assistance, however the minimum target installation capacities were defined. Key features of the three models of MNRE's strategy paper are summarized in Table 4 below.

Table 4: MNRE revised strategy paper: Proposed OSW project implementation models

	Model A	Model B	Model C
Type of Development	VGF support for demarcated offshore wind zones wherein NIWE has conducted or plans to conduct detailed studies and surveys	Non-VGF model, applicable to sites identified by NIWE, providing exclusivity of seabed lease to selected OSW project developers during survey period of two years	Non-VGF model, where potential project developers can identify any site, excluding the sites considered under Model-A and Model-B), for detailed surveys and studies, in order to submit proposals for OSW project development. This model does not provide non- exclusivity of Seabed lease rights at prospective zones to project developers during survey period
Targeted Installation	1,000 MW	14,000 MW (Minimum)	22,000 MW (Minimum)

	Model A	Model B	Model C
Identified Capacities for Initial Phase of Installations	500 MW in Gujarat 500 MW in Tamil Nadu	First Bid for 4,000 MW in FY 2023-24 Second Bid for 3,000 MW in FY 2024-25	Open to submission of proposals by project developers
Identified Sites	Zone B3, Gulf of Khambhat, Gujarat- 500 MW Site Coordinates identified by NIWE for Tamil Nadu - 500 MW	Site details for Gujarat not declared Total 14 blocks have been identified in Tamil Nadu (sites 2,3,4,7) - 4,000 MW (sites 5,6,8) - 3,000 MW	To be selected by Developer within EEZ of the Country, and sites excluding under identified under Model-A and Model-B
Annual Lease Fee / Bidding Terms	Lease – INR 1 Lakh/sq.km/year	Lease Competitive Bidding - minimum floor price @ INR 1 Lakh/sq.km/year till the Commercial Operation Date Post Commissioning - Rs. 1 Lakh/sq.km/year till lease	Lease / Allocation Fee OR Revenue Sharing (for captive consumption/ third party sale/ sale through exchange under open access)
Survey/Study for Sites	Identified by NIWE	To be done for provisionally allocated sites within 5 years (one year extension on case to case basis)	To be done by Developer and to conclude within 3 years
Sale of Power	Through SECI/ Implementing Agency, Back to back Power Sale Agreement with State Discom	Open Access/ Captive / Third Party Sale After two years, bid from Discom on the basis of Tariff	Open Access/ Captive / Third Party Sale Tariff based bidding for power procurement for Discom or Central or State Government Departments

3.2 Offshore Wind Potential and Developments in Tamil Nadu

In Tamil Nadu's case, resource assessments conducted under FOWIND and FOWPI projects show that state's coastline has higher wind resource, thereby promising higher PLFs, energy generation and improved feasibility for OSW projects. Tamil Nadu coastline is estimated to have an OSW potential of 35 GW based on the resource assessments conducted by NIWE.

As seen in figure 08 below, 8 zones (A to H) suitable for OSW project development have been identified at the Gulf of Munnar off Tamil Nadu's coastline, with areas ranging from 810 to 2,116 square kilometers. These zones are distinguished by mean wind speeds ranging from 7.1 to 8.2 meters per second at 120 meters above ground level (AGL), coupled with water depths varying from 10 to 53 meters below the Lowest Astronomical Tide (LAT). Each of these zones has the capacity to host multiple multi-MW OSW farms, indicating the vast potential for renewable energy generation that lies untapped along the Tamil Nadu coastline.

For Model A (as shown in **Error! Reference source not found.**), the Union Cabinet approved the Viability Gap Funding (VGF) for offshore wind project installation and commissioning (500 MW each off the coast of Gujarat and Tamil Nadu), with an outlay of INR 6,853 Crore and INR 600 Crore for upgradation of two major ports to meet logistics requirement for offshore wind energy projects.

Among these zones, B, D, E, and G have been highlighted as particularly promising for OSW development projects. These zones were selected based on several key factors, including relatively high wind speeds, favorable seabed depths, and minimal conflicts with environmental and social concerns.

SECI in its recent tender has identified specific blocks within Zone B (Block B2, B3, B4 and B7) for leasing of sea-bed areas to project developers. Each site covers an area of about 200 square kilometers and has the potential to generate around 1 GW of power. The selected developers will conduct necessary surveys in these identified blocks and further develop OSW projects of up to 4 GW potential on a Build-Own-Operate basis based on the survey findings and subject to all procurement and implementation clearances.

As part of its renewable energy commitments, the state is willing to off-take electricity generated from offshore power development taking place locally (Tamil Nadu Industries Department Policy Note, 2023).

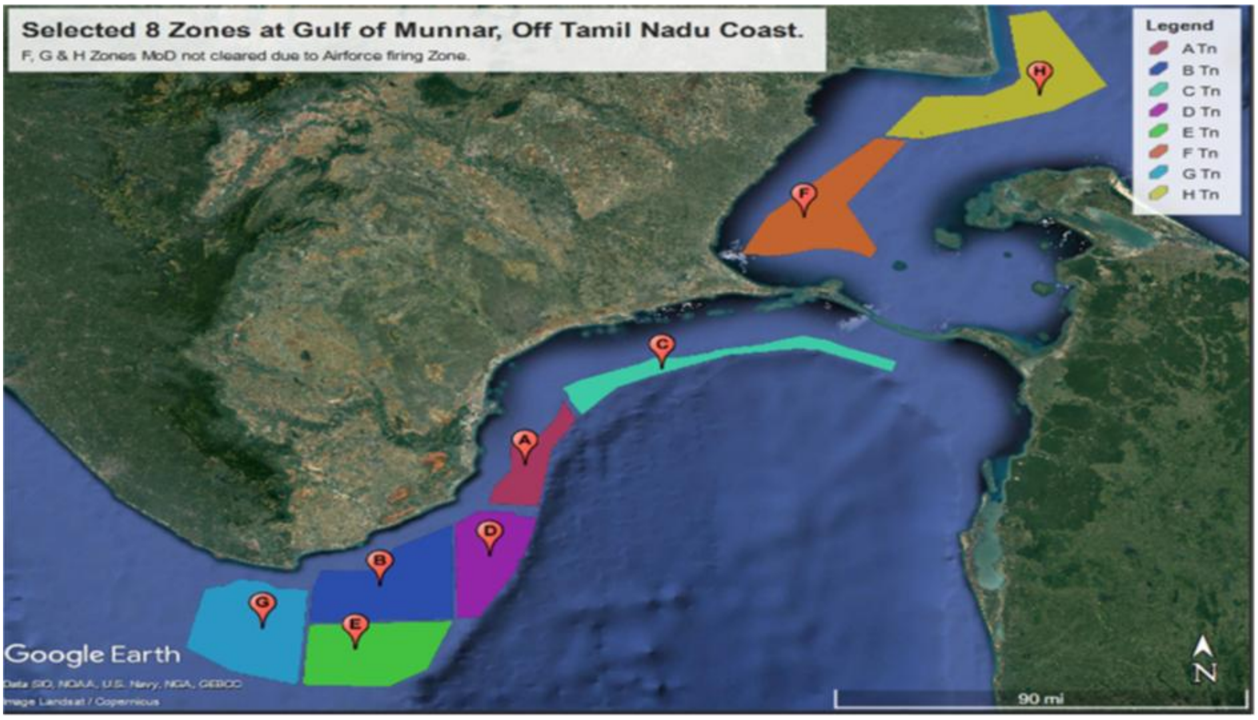


Figure 8: Demarcated Zones identified with high OSW potential in Tamil Nadu

Source: MNRE revised Strategy paper, 2023

3.3 Expected Timelines for OSW Project Development in Tamil Nadu

While the first round of leasing of seabed areas in Tamil Nadu is planned in FY 2024-25, project developers will need to navigate through various stages including the pre-construction surveys and resources assessments, design, engineering, financing, contracts, procurement, installation and commissioning before the first OSW project is in a position to commence full-scale operations. Realisation of project development timelines will be impacted by progress of activities and factors related to award of seabed lease, resource mapping, development approvals, financing aspects, transmission infrastructure availability, project development and commissioning.

OSW project development is segmented into two main phases as per the Offshore Wind Energy Lease Rules, 2023 to be followed by project developers - including Phase I: Resource Measurement (with metocean studies) and Phase II: Project Development, Installation, Commissioning, Operation & Maintenance, Decommissioning) as reflected in Figure 09 below. The first phase lease is focused on the resource measurement and related studies and assessments. The timeline shall be three years, which can be further extended to two years. Post expiry of the five years period, the Lease shall expire; and all clearances to the Lessee (project developer) shall be withdrawn and the Lessee shall have to deposit the study or survey data to NIWE; unless the lessee has started work to set up wind energy capacity as per the terms of the Lease. For the second phase of development, where project developers will construct and operate OSW wind power projects, the lease shall be for a period of 35 years. Further extension shall be based on viability and safety of the project. Also, lessee shall have to complete the decommissioning within two years of termination of the lease and either reuse, recycle or responsibly dispose of all materials removed from the project.

Considering the above guidelines, it is evident that with seabed lease auctions planned in 2024-25, the commissioning of the initial OSW wind project(s) in Tamil Nadu can be expected to be realized sometime after 2030 (in FY 2030-31 or FY 2031-32 considering 5 years for resource measurement, approvals and 1.5 years to 2 years for project development without any delays). Post the offshore project installation, evacuation of power through transmission infrastructure will be managed by state and central transmission utilities. The Central Electricity Authority has already mapped development of 5 GW transmission network development by 2030 in the state of Tamil Nadu by CTU (i.e. PGCIL), which is crucial for offshore wind power development (Central Electricity Authority, 2022).

Phase I	Resource Measurement	3 Yrs.	
Phase I (Extension)	Resource Measurement	2 Yrs.	
Phase II	Project Development -Installation, Commissioning,O&M	Up to 35 Yrs.	
Phase II	Decommissioning	Within 2 Yrs. of lease termination	

Figure 9: OSW Development Phases proposed in the Seabed Lease Rules

Key milestones of SECI's 4 GW OSW Tender

SECI's tender outlines key milestones that project developers are expected to adhere to. The key steps, as per the RfS tender document, are highlighted below.

Table 5: List of project milestones as per the SECI's 4 GW tender document

No	Milestone	Description	Envisaged timeline
1	Request for Selection (RfS) of bidder	SECI published tender in February 2024 for selection of bidder (Offshore Wind Power Developer- OWPD) for selected blocks at Tamil Nadu coastline	Day 0
2	Agreement to Lease (AtL)	SECI provides letter of award (LOA) to the selected bidder	90 days from LOA
3	Stage II project clearances + survey	Post AtL, bidder to obtain stage II clearances and survey commencement approvals as specified in RfS documents	6 months from the AtL signing for securing project clearances

No	Milestone	Description	Envisaged timeline
4	Seabed Lease Deed	To be signed between MNRE and OWPD for exclusive seabed block allocation for conducting surveys, and development activities for detailed project report (DPR) preparation including project financing aspects	Subject to project clearances, survey results and compliances as per RfS document terms
5	Concession agreement	To be signed between NIWE and OWPD- Sets procedures and timelines for OWPD to design, build, finance, construct, commission, operate and maintain the project	Post DPR submission and in-compliance with seabed lease agreement for 35 years and extendable

As described in step 3 in the Table above, detailed surveys are expected to be conducted by the selected project developers before signing the seabed lease deed. These surveys are noted in Table 6 below.

Table 6: Description of surveys to be conducted by the selected project developer

Milestones	Description
Geophysical and geotechnical surveys	To study subsea bed environment such as water column, subsoil and overall seabed conditions to prepare geological spatial maps to validate suitability for wind turbine foundations considering the load bearing capacity of subsea soil and other geological characteristics
EIA (Environment Impact Assessment)	To study potential impact on environment (air, water, biodiversity, land use, socio-economic impact)
Environmental Surveys (Benthic, Ornithological, Marine, Onshore)	To study impact on habitat and species living on the sea and in sediment; impact with birds, impact on marine mammals, impact of OSW development onshore etc.
Resource Assessment including metocean assessments	To evaluate wind resources, weather and operating conditions for designing a wind farm. Metocean conditions refer to the combined wind, wave, and climate (etc.) conditions as found on a certain location.

3.4 Tamil Nadu's Renewable Energy Transition

Tamil Nadu has been at the forefront of decarbonizing its conventional energy supply, supported by encouraging state level policies and leveraging national frameworks for renewables. Renewable energy sources accounted for half of the state's installed power generation capacity of 40.5 GW as of June 2024 (see Figure 10). The renewable installed in the state (excluding large hydro), contributed around 33% of Tamil Nadu's electricity demand (10,850 Million units (MU)) in July 2024.

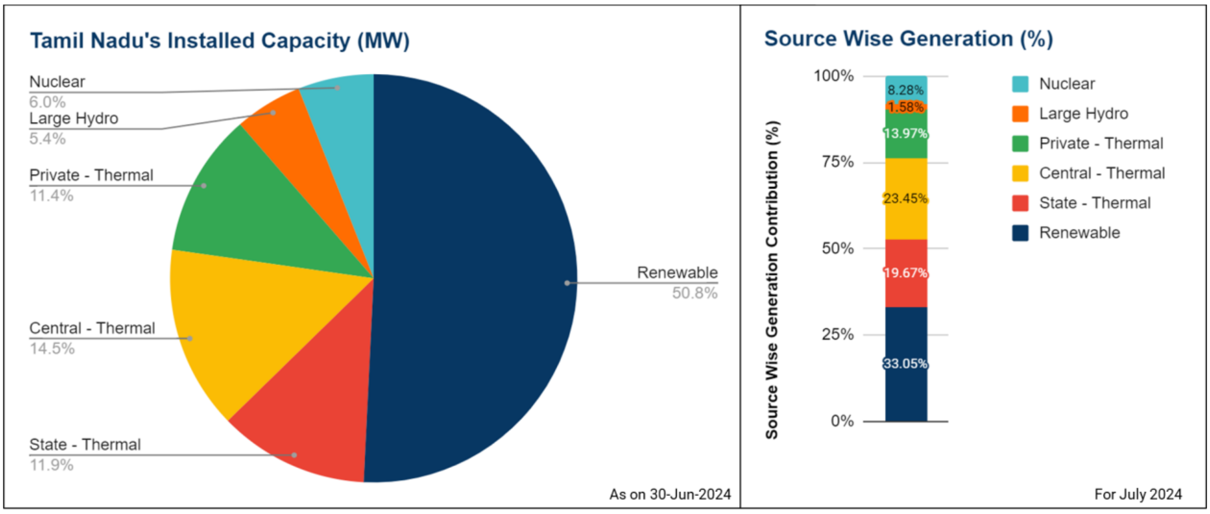


Figure 10: Tamil Nadu's Source wise Installed Capacity & Electricity Generation (July,2024)

Source: Central Electricity Authority (CEA), Ministry of New and Renewable Energy (MNRE)

Over the last five years, wind energy installations in Tamil Nadu grew at 3.1% CAGR, while solar energy installations are rising at 26.5% CAGR. The state has an installed capacity of 10,789 MW of wind power, 8,617 MW of solar power, and 1,045 MW of bio power as on June, 2024. To further drive renewable energy integration, Tamil Nadu has set an ambitious target of meeting 50% of its electricity demand by RE by 2030.

The state government is also focusing on establishing green hydrogen manufacturing locally. TIDCO, in partnership with IIT Madras, is planning to develop a green hydrogen cluster at the Tuticorin Port. Additionally, the V.O. Chidambaranar Port and Tuticorin Port have significant potential for green hydrogen production (MNRE, 2024). These ports shall enhance opportunities for domestic manufacturing and green hydrogen facilities across India under the Green Hydrogen Transition (SIGHT) Programme, with proposals invited by SECI.

While Tamil Nadu has achieved notable progress in renewable energy installations, its rising energy demand is a challenge. Tamil Nadu ranks fourth across India in peak energy demand owing to its enabling policies for easy-of-doing-business, well-established and diverse industrial and commercial belts, and urbanization (Energy Dept., Govt. of Tamil Nadu, 2023). The highest peak power demand recorded in the state was 18,048 MW for FY 2022-23, while it was 19,409 MW for FY 2023-24, which was 8.91% higher than the previous year. To meet its peak demand, especially during the months of January to March, Tamil Nadu has established intra-day energy swapping arrangements with state utilities from Madhya Pradesh and Rajasthan state. The state's generation and distribution utility, TANGEDCO has put in place long-term contracts with the power exchange to address peak demand requirements. To manage peak demand and absorb intermittency of wind and solar resources, the state government is investing in energy storage solutions. The state has planned to commission 500 MW of pumped hydro storage by 2024-25 and further identified locations for a pumped hydro storage pipeline of 14,500 MW.

While Tamil Nadu has deployed renewable energy to half of its total installed capacity, these variable renewable energy sources are only able to contribute to about one-third of the state's total electricity generation. The pace of wind capacity addition in the state has slowed down in recent years. Therefore, offshore wind can offer significant opportunities and benefits to support Tamil Nadu's energy transition and diversification. Due to its capability to deliver higher electricity generation and reliable green power for longer durations as compared to solar and onshore wind, offshore wind energy can help address the state's rising energy demand and dependency on other power sources and mechanisms (intra-day and long term procurements) for managing peak demands.

3.4.1 Energy Outlook for Tamil Nadu

As part of this roadmap, potential targets for installation of OSW power in Tamil Nadu have been delineated until 2047 in section 5.1 to align with India's energy security scenarios 2047 targets. This trajectory serves as a reference point for anticipated OSW development that will take place in the state.

In alignment with this timeframe, this section includes an assessment of Tamil Nadu's energy basket for 2047, including projected electricity demand and power generation from renewable and non-renewable sources, to have a better understanding of potential opportunities for integration of OSW energy.

Tamil Nadu has witnessed an increase of 8.91% in its electricity demand in FY 2023-24 than the previous year, surpassing CEA's forecast of 5.4% annual increase in demand for the same period. If the growth in demand continues as per trends estimated in Ministry of Power's 20th Electrical Power Survey of India, Tamil Nadu's electricity demand is expected to increase to more than 183,000 million kWh in FY 2030-31 from 126,598 million kWh recorded for FY 2023-24, rising further to about 335,500 million kWh by year 2047.

With regard to power generation, as of June 2024, Tamil Nadu had a total installed power capacity of 40.5 GW, making it the third-largest power generating capacity state in India, after Maharashtra and Gujarat. The state has deployed more than 20.5 GW of renewable energy technologies (10.7 GW of wind, 8.6 GW of solar, and 1.2 GW of other renewable energy technologies – biomass, bagasse, waste to energy). The state also has 2.1 GW of large hydro power generation and 2.4 GW of nuclear power generation capacity in place.

A prospective scenario of Tamil Nadu's energy mix and generation from non-renewable and renewable resources by 2047 has been analysed to help understand the potential role that OSW that can play in the state's future power supply to meet its rising energy demand. This analysis takes into account the state's current and expected power generation capacity from thermal, large hydro, nuclear as well as onshore wind, solar, biomass and waste-to-energy sources **(excluding offshore wind)**. Considerations include the age of current power generation fleet of thermal and hydro power plants and their expected decommissioning, trend of installation or capacity addition of these resources, and their expected power generation (i.e. PLF)[2]. Based on the state's policy to transition to renewable energy, it is considered that no new capacity addition of thermal power will take place.

It is estimated that Tamil Nadu's total power generation capacity will stand at about 146 GW by 2047 (see Figure 11). Considering the anticipated reduction in thermal power plant capacities[3], Tamil Nadu is expected to require a significant ramp-up in the deployment of renewable energy technologies (solar, onshore wind, biomass, small hydro, and waste to energy) by 2047 in order to meet its rising electricity demand. It is estimated that renewable energy capacity will increase by 9.5 times from 2024 to 2047, given current and expected patterns of renewable deployment in the state. The thermal power capacity will be reduced by 18.5% by 2047, resulting in available thermal capacity of 13.5 GW[4]. Further, it is assumed that 1 GW of nuclear plant (Kudankulam U-6) will be integrated into the state's installed generation capacities. Moreover, around 1.4 GW of currently installed large hydro capacity will be non-operational by 2047, considering non-utilization of hydropower plants with lifetime of more than 60 years.

Based on the forecasts and corresponding PLF values of the different energy sources, it is estimated that Tamil Nadu's installed power capacity by 2047 will be able to generate about 257,300 million kWh of electricity as shown in Figure 12. The state is expected to transition towards renewables as the major source of electricity generation in the next two decades, corresponding to the forecasts of large-scale increase in renewable energy capacity including solar, onshore wind, biomass, small hydro, and waste to energy. Renewables (excluding offshore wind) are estimated to account for 68% of the state's total electricity generation in 2047 as compared to 27% in 2024 as seen in Figure 13.

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[2] Key considerations/assumptions: a) Onshore wind power installation year-on-year growth rate assumed: 3% till year 2034 (i.e. average of four year period from FY 2020-21 to FY 2023-24) and 2% from 2035 to 2047 – considering occupancy of existing onshore wind resource sites and old wind plants under repowering; b) Solar power installation year-on-year growth rate assumed: 20% till year 2034 (i.e. average of four year period from FY 2020-21 to FY 2023-24) and 6% from 2035 to 2047 – considering land/space occupancy by solar, and old plants under repowering; c) Average onshore wind CUF assumed: 18%, and solar CUF assumed as 15% (based on generation data of FY 2023-24 for Tamil Nadu); d) Thermal PLF assumed: 55%, with a reduction of 1% PLF every six years; e) Large Hydro PLF assumed: 18% till 2031-32, a PLF of 17% from FY 2032-33 to 2047; f) Nuclear PLF assumed: 69% till 2031-32, PLF of 68% assumed from FY 2032-33 to FY 2039-40, and PLF of 67% assumed from FY 2040-41 to 2047; g) State's annual average PLF is considered for thermal (coal, lignite, gas) power plant (including State, Central and Private owned plants), large hydro, nuclear based on actual installed and generation with data from National Power Portal, MNRE, and CEA.

[3] With increasing clean energy adoption and supporting policy mechanisms, the thermal power plants PLFs have been reducing over the years in India. Stringent environmental policies, regulations, adherence to efficiency benchmarks (like PAT - perform, achieve, and trade mechanism of Bureau of Energy Efficiency), coal availability and quality concerns, volatility of coal prices shall result in decommissioning of older and inefficient thermal power plants. Additionally, reducing PLFs shall increase the fixed cost recovery gap, which will catalyse to increase the rate of decommissioning further.

[4] Out of existing thermal power plants in the Tamil Nadu state, total 19 thermal power plants having cumulative capacity of 3.5 GW are more than 30 years old. Present analysis considers average thermal plant design life of 25 years; and average useful life of thermal power plant of 40 years including various repairs/renovation/modernisation measures. This analysis has also considered cumulative thermal capacity addition of 3.4 GW from new thermal power plants – North Chennai TPP ST-III, Ennore SCTPP U-12, and Udangudi SPP Unit -12.

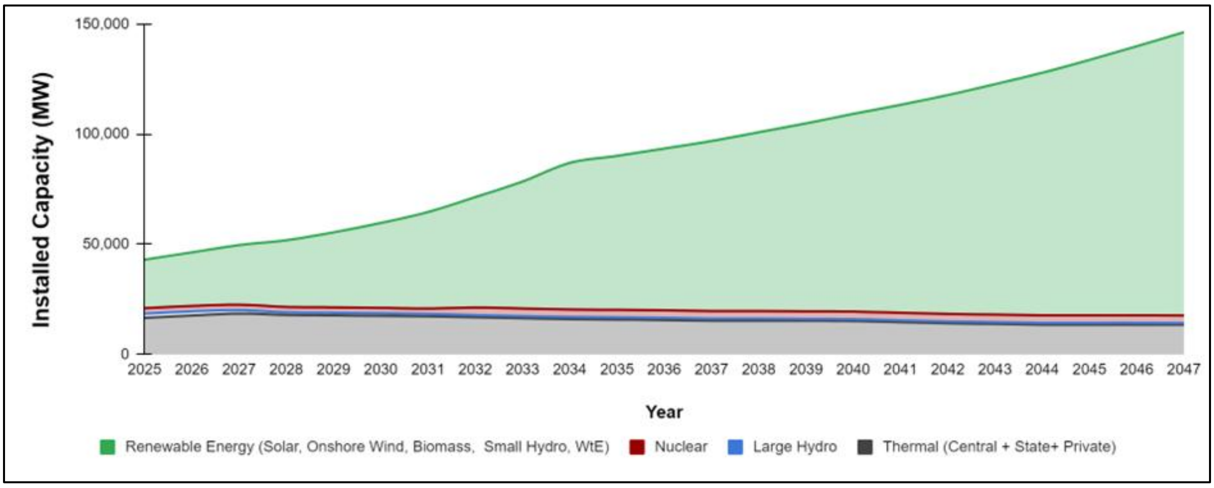


Figure 11: Forecast of Installed Capacity in Tamil Nadu by 2047

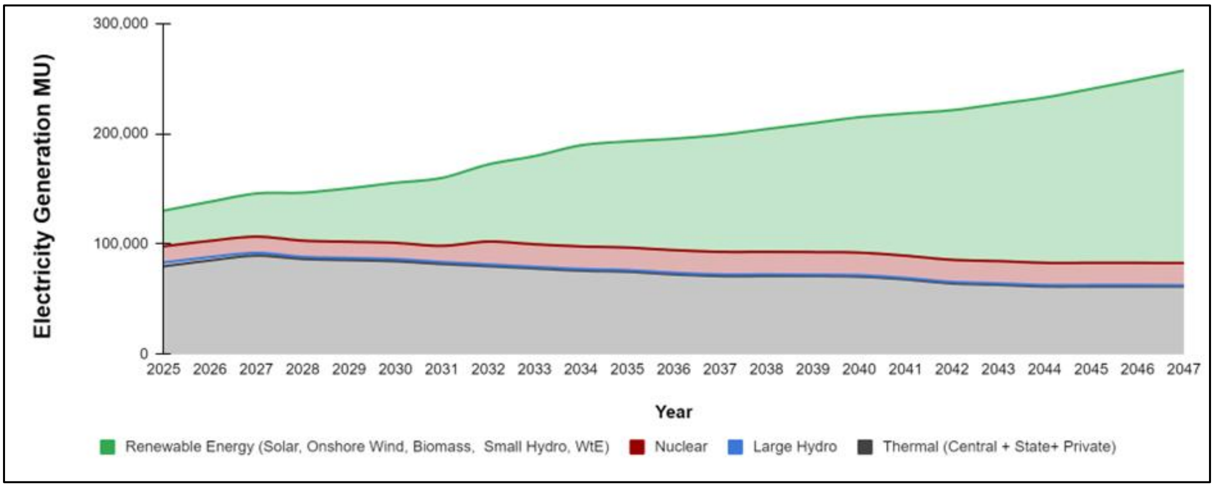


Figure 12: Forecast of Electricity Generation for Tamil Nadu by 2047

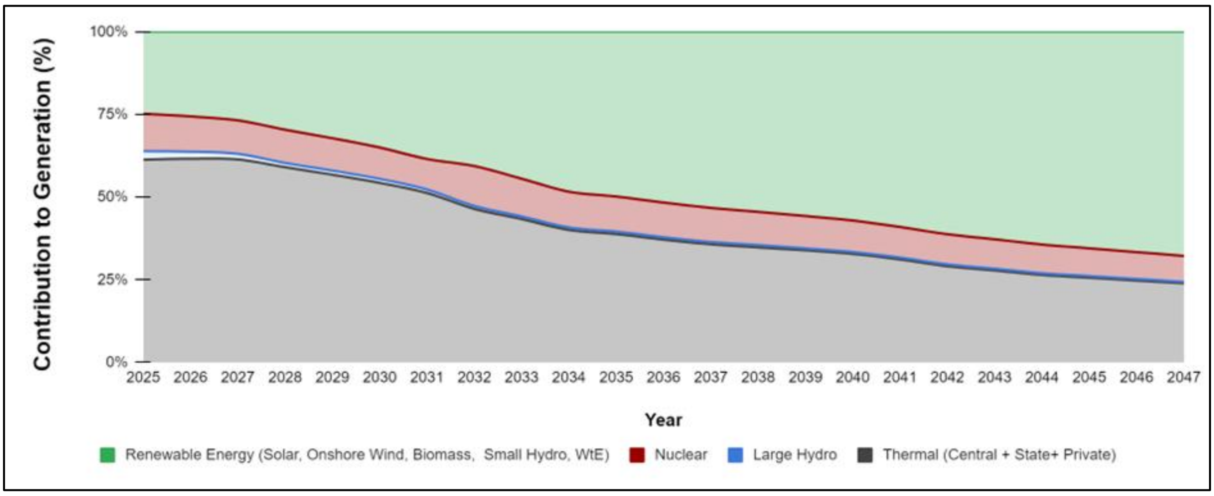


Figure 13: Estimated Resource-wise share of Electricity Generation for Tamil Nadu by 2047

Source: ICLEI South Asia analysis based on data from CEA, MNRE, MoP

3.4.2 Bridging Electricity Supply Gaps and Renewable Purchase Obligation Targets through OSW Energy

Based on the forecasts of state-level electricity requirement and its future power generation based on the currently prevalent energy resources in its energy mix (conventional and renewable energy sources, excluding off-shore wind), it is observed Tamil Nadu will potentially not be able to generate sufficient electricity to meet its demand in the next two decades. Significant electricity shortfall is noticeable from year 2028 onwards, rising further until 2047 based on the above analysis (see Figure 14).

Tamil Nadu is estimated to have a potential electricity shortfall of 20,500 million kWh by 2032; 33,000 million kWh by 2037, and further rising up to as much as 78,000 million kWh by 2047. In order to meet this gap, the state may need to resort to short-term power procurement and energy exchange mechanisms[5].

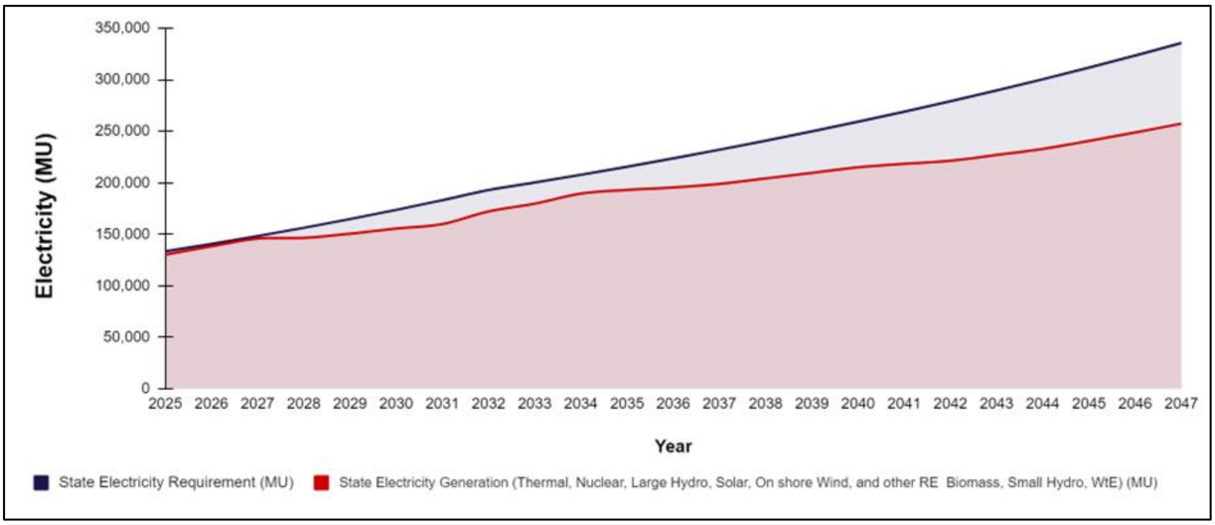


Figure 14: Forecast of Electricity Demand and Generation for Tamil Nadu by 2047

Source: ICLEI South Asia analysis based on data from CEA, MNRE, load dispatch center

The offshore wind potential along the coast of Tamil Nadu presents a significant opportunity to enhance the state's energy security and supply. Ensuring timely deployment of offshore wind energy projects to tap this resource potential can play a crucial role in fulfilling Tamil Nadu's electricity needs post 2030, while supporting its transition to a more sustainable energy mix.

Renewable Purchase Obligation (RPO) Targets

The Tamil Nadu government has announced a target of sourcing 50% of energy from RE. The TNERC has set a RPO target of 43.33% by 2030. To achieve this RPO, Tamil Nadu requires the following additional capacities to be put in place by 2029-30 (Energy Dept., Govt. of Tamil Nadu, 2023):

- Wind: 3,368 MW
- Solar and other renewables: 20,568 MW
- Hydro: 2,273 MW

[5] While the power demand-supply gap may reduce around the year 2032 with the expected addition of 1 GW nuclear plant (Kudankulam Unit 6), it is expected to continue to increase till 2047.

Despite significant existing and forthcoming installation of onshore wind and solar power in the state, the escalating electricity demand along with challenges such as limited land availability and lower generation for onshore renewables will pose challenges to meet RPO targets solely through solar and wind in the long term. Based on the forecasts of renewable based generation and electricity requirement, Tamil Nadu is likely to have a shortfall in meeting its RPO targets as per the analysis in the section above. It is estimated that Tamil Nadu may be able to achieve 32% of renewable based generation by 2030 based on current trends, thereby potentially falling short of its RPO target by 11% as shown in Figure 15. While Tamil Nadu's first OSW installations are expected to come online only after 2030, OSW energy, with its higher reliability and power generation potential compared to solar and onshore wind, can help address the state's RPO requirements, rising energy demand and dependency on conventional power sources.

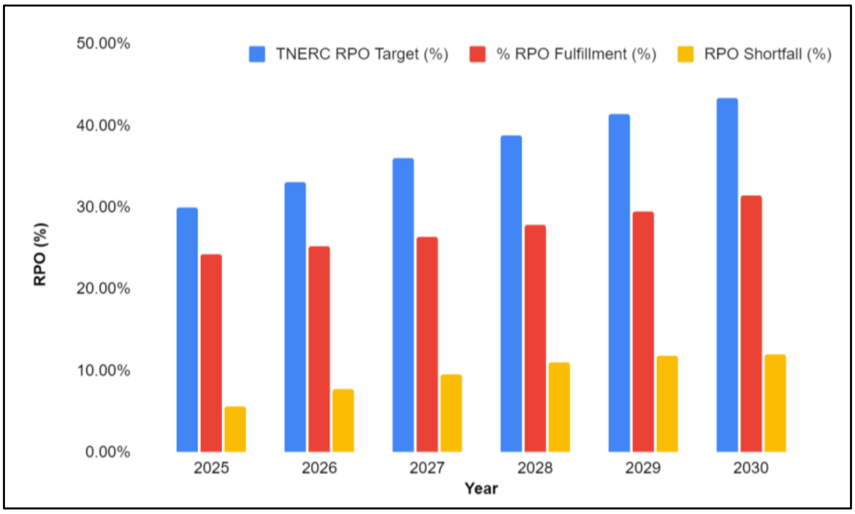


Figure 15: RPO forecast for Tamil Nadu by 2030

Source: ICLEI South Asia analysis based on various data (from CEA, MNRE, load dispatch center)

3.5 Strategic Benefits of Offshore Wind Development in Tamil Nadu

By capitalizing on its favorable location, prior experience with wind manufacturing and deployments, strategic goals for energy transition and supportive policy environment, Tamil Nadu is well-positioned to become a leader in offshore wind energy in India. The development of the OSW sector can deliver substantial economic, environmental, and social benefits, contributing to the state's sustainable development goals.

Figure 16: Rationale for OSW Development in Tamil Nadu

Technical and Strategic Drivers:

- Abundant Offshore Wind Resource: Tamil Nadu, with its extensive 1,076 km coastline offers high wind speeds and vast offshore areas suitable for wind farm development.

- Energy Security and Diversification: Developing OSW projects in Tamil Nadu will diversify the state's energy mix, reducing its reliance on coal and other fossil fuels. OSW, with its higher capacity factor compared to onshore wind, can provide a stable and reliable source of electricity, enhancing energy security.

Socio-Economic Benefits:

- Job Creation: OSW projects can generate substantial employment opportunities across the value chain. In the near term, OSW projects of 4.5 GW capacity in the state are estimated to require a workforce of over 40,000 full-time employees by 2032, with additional OSW installations thereafter driving a multi-fold increase in employment opportunities (200,000+ FTE jobs by 2037) (see section 5.7.1 for further details).

- Economic Growth: Investment in OSW infrastructure can stimulate local economies. As the OSW sector develops in the state, it will bring forth opportunities in value chain and infrastructure areas including materials, manufacturing, and port development that can result in a substantial economic impact, driving growth in local businesses and industries, and enhancing the state's economic profile.

- Increased Revenue: OSW projects can generate substantial revenue through taxes, such as the Goods and Services Tax (GST), and through lease payments. For Tamil Nadu, these revenues can be reinvested into improving public welfare, developing infrastructure, and enhancing social services, thereby further driving socio-economic development and growth.

- Technological and Skill Development: The OSW industry can foster technological innovation and skill development. Collaboration with global OSW leaders can promote knowledge transfer and capacity building and establish Tamil Nadu as a leader in OSW technology.

Cascading Benefits

- Enhanced Shipping and Port Activities: The development of OSW projects necessitates robust port facilities, which can yield substantial economic benefits. Enhancing port infrastructure to accommodate larger vessels, increase cargo handling capacities, and improve trade efficiency can significantly strengthen the state's trade networks. This development not only supports the OSW industry but also boosts overall maritime commerce, driving economic growth and integration with global markets.

- Community Development: OSW projects can catalyze the development of coastal communities by enhancing infrastructure, education, and healthcare services. The economic activities generated by these projects can elevate living standards, reduce poverty levels, and improve the overall quality of life for residents.

Environmental Benefits

- Decarbonization and Environmental Benefits: The IEA estimates that each GW of OSW can avoid approximately 3.5 million tonnes of CO_2 emissions annually. For Tamil Nadu, harnessing its OSW potential could contribute significantly to greenhouse gas emissions reduction, climate mitigation efforts and net-zero ambitions. This initiative aligns with broader environmental goals and supports Tamil Nadu’s commitment to sustainable development.

3.6 Review of Policy and Regulatory Framework for Offshore Wind

National and state nodal institutes such as MNRE, NIWE, SECI, Tamil Nadu Energy Department, TNERC have developed policies and regulation for faster uptake of renewable energy projects including OSW. Relevant policies and regulatory framework and initiatives that have implications on OSW development in the state, including mandates such as renewable purchase obligations (RPOs) and provision of incentives such as waiver of inter-state transmission charges have been reviewed and summarized below.

Table 7: Key enabling national and state policies and regulations related to OSW sector

Enabling policy/regulation	Summary
National Offshore Wind Energy Policy-2015	• Established the framework for OSW development in India

Enabling policy/regulation	Summary
	• Facilitates the development of OSW projects up to seaward distance of 200 nautical miles from the baseline, within the Exclusive Economic Zone (EEZ) • National Institute of Wind Energy (NIWE) designated as the nodal agency responsible for OSW development in India
Revised Strategy Paper for Establishment of OSW Projects- 2023	• The strategy paper proposes three models for the development of OSW projects: Model-A (VGF Model), Model-B (Non-VGF but with exclusivity over seabed during the study/survey period), and Model-C (Non-VGF and without exclusivity over seabed during the study/survey period). • Sets out a cumulative auction trajectory of 37 GW by 2030 for the states of Gujarat and Tamil Nadu
Offshore Wind Energy lease Rules-2023	• These lease rules regulate the grant of leases for OSW based power and transmission projects within India's Exclusive Economic Zone • MNRE will identify the sea bed lease area for OSW project development based on wind resource assessment and marine spatial planning • Clearances from various ministries and departments are required before granting the lease, including ministries of Defense, Home Affairs, External Affairs, Environment, Forest and Climate Change, Space, and Ports, Shipping, and Waterways.

TNERC RPO Regulations-2023 (Draft)	• These regulations require distribution licensees, consumers with captive generating plants, and open access consumers to fulfill a minimum percentage of their energy consumption from renewable sources.
	• Obligated entities must comply with RPO targets mentioned below:
	  ○ 2023-24: Wind RPO: 1.60% | Total RPO: 27.08%
	  ○ 2029-30: Wind RPO: 6.94% | Total RPO: 43.33%

Electricity (Promoting Renewable Energy Through Green Energy Open Access) Rules, (Second Amendment) Rules, 2023	For OSW, the Electricity (Promoting Renewable Energy through Green Energy Open Access) Amendment Rules, 2023 state that additional surcharge shall not be applicable if electricity produced from offshore wind projects that are commissioned until December 2032, is supplied to open access consumers.
ISTS Waiver of charges on transmission of the electricity generated from	As per the notification issued by the Ministry of Power, OSW projects that are commissioned on or before December 31, 2032, will be exempt from Inter-State Transmission System (ISTS) charges for a period of 25 years from their commissioning date. Projects commissioned from January 1, 2033, onwards will be subject to incremental ISTS charges.

Enabling policy/regulation	Summary
solar and wind sources of energy	
Draft Renewable Generation Obligation, 2023	The draft notification focuses on designated consumers with coal/lignite-based generating stations and sets minimum renewable generation obligations (RGO) for them. RGO targets are determined based on the commercial operation date of coal/lignite-based generating stations, as follows: ● For stations operational on or before March 31, 2023: Minimum RGO target is 6%, with compliance due by April 1, 2026 ● For stations operational between April 1, 2023, and March 31, 2025: Minimum RGO target is 10%, with compliance due by April 1, 2028 ● For stations operational from April 1, 2025, onwards: Minimum RGO target is 10% from commercial operation date of the generating station

4 Stakeholder Mapping and Insights from Consultations

Summary:

Offshore wind projects are inherently complex and technologically demanding, necessitating the establishment of infrastructure and operations both on land and in the offshore marine environment. This includes the seabed, thereby requiring a diverse range of stakeholders to collaborate effectively. Early identification and engagement with all relevant private and public stakeholders in the OSW value chain are crucial for effective and timely coordination and project implementation. The chapter underscores the importance of such collaboration for the successful deployment of OSW projects in Tamil Nadu.

As part of the roadmap development, a comprehensive stakeholder mapping was conducted at both the regional and national levels, encompassing government institutions, grid operators, port authorities, potential power buyers, corporates, developers, financial institutions, and local communities. This chapter outlines the key roles of the mapped stakeholders in OSW project administration, execution, and management, ensuring structured stakeholder engagement. This chapter also includes insights from stakeholder consultations that highlighted the need for dedicated institutional setups, demonstration projects, clear roles, and financial mechanisms. The key insights from stakeholder consultations also inform recommendations for regulatory frameworks, infrastructure development, financing, and capacity building to ensure the successful implementation and long-term viability of OSW projects in Tamil Nadu.

4. Stakeholder Mapping and Insights from Consultations

Offshore wind projects are complex and technologically demanding as they involve establishment of infrastructure and operations on land as well as in the offshore marine environment including the seabed, thereby requiring a diverse range of stakeholders to collaborate effectively. It is essential to identify and engage with all relevant private and public stakeholders in the OSW value chain at an early stage for effective and timely coordination and project implementation.

4.1 Mapping of Key Stakeholders in the OSW value chain

Stakeholders relevant to the OSW sector have been mapped within the Tamil Nadu region as well as at the national level. These stakeholders include government institutions, national, state and local electricity grid operators (planning authorities, generators, and distributors), port and industry authorities, potential off-takers or buyers of OSW power, Indian corporates and independent power producers, global project developers and manufacturers, financial institutions as well as local community representatives.

Major stakeholders across the offshore wind energy value chain can be classified as follows:

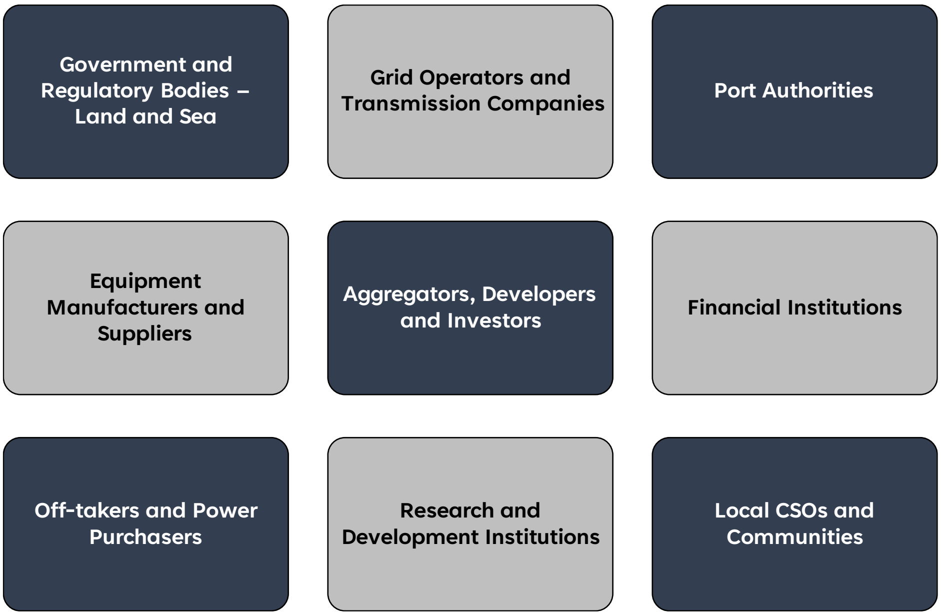


Figure 17: Key stakeholder categories across offshore wind value chain

Stakeholders across these categories in Tamil Nadu's OSW value chain are mapped in Table 8.

Table 8: Mapping of key stakeholders in Tamil Nadu's OSW value chain

Category	Stakeholder
National level stakeholders	MNRE, Grid India (POSOCO), CEA, PGCIL, CTU, MoEFCC, MoD, NTPC, SECI. NCCR
State level stakeholders	State Planning Commission, Planning Department, Energy and fisheries department, TEDA, TNERC, TANGEDCO, TANTRANSCO, TIIC, TIDCO, Tamil Nadu Maritime Board, TNSDC, TNGCC, Guidance Tamil Nadu, MSME Department, Industries and Commerce Commissionerate
Independent Power Producers	Alfanar, Ayana Renewables, Adani Green Energy, Renew Power, Reliance, ONGC, Sembcorp, Suzlon.
Onshore wind developers	Everrenew Energy, KP Group, Suzlon
Port authorities	V.O Chidambaranar Port Authority (Tuticorin Port), Indian Ports Association, Chennai Port Trust
Equipment Manufacturers and Associations	Envision, Gamesa, LM Wind Power, Suzlon, Vestas, IWPA, IWTMA, Senvion.
Financial Institutions	ADB, IFC, IREDA, SBI, PFC, World Bank,
Potential Off-takers	Energy authorities, automotive, cement and textile industries and IT companies operating in Tamil Nadu coast and region.
Project Developers and Investors	British Petroleum, RWE, EDF. Equinor, Orsted. WPD Offshore
International Agencies	European Union, British High Commission, IEA, Danish Ministry of Climate, Energy and Utilities

Based on the stakeholder mapping across the OSW value chain, key stakeholders and their potential roles in terms of administration, execution, and management of OSW projects have been outlined in Table 9 below.

Table 9: Roles of key stakeholders identified in the OSW value chain

Stakeholder - (Influencing and contributing to OSW uptake in the region)	Description/ Role of the stakeholder
State Planning Commission	The State Planning Commission serves as an apex advisory body to the Government of Tamil Nadu. The Commission actively engages in the formulation, implementation, and

Stakeholder - (Influencing and contributing to OSW uptake in the region)	Description/ Role of the stakeholder
	evaluation of policies, with a specific focus on development, economic growth, social welfare and innovation. It works closely alongside sectoral government departments, promotes knowledge sharing and facilitates collaborative initiatives for the state's holistic progress.
Planning Department, Government of Tamil Nadu	The Planning & Development Department coordinates the preparation and monitoring of development plans and policies in Tamil Nadu. It engages with various government departments to achieve sustainable development goals (SDGs), facilitates strategic planning for large-scale transport, energy, infrastructure and oversees major projects. It supports evidence-based policy-making, administers the Tamil Nadu Innovation Initiatives (TANII), and ensures balanced regional development through the State Balanced Growth Fund and other programs.
Tamil Nadu Generation and Distribution Corporation Limited (TANGEDCO)	Coordination and seeking regulatory guidance from TNERC, identify use cases/business models to purchase and promote offshore wind energy
Tamil Nadu Electricity Regulatory Commission (TNERC)	Independent state regulator, coordination and seeking guidance from CERC, ensure tariff setting, grid infrastructure connectivity, and other suitable regulations for OSW while maintaining financial health of state utilities
Tamil Nadu Energy Development Agency (TEDA)	Support and streamline OSW project implementation through state's green energy SPV to increase renewable energy mix in the grid
Tamil Nadu Green Energy Corporation Limited (TNGECL)	State's newly formed SPV to streamline and fast-track RE project implementation in the Tamil Nadu state
Tamil Nadu Transmission Corporation Limited (TANTRANSCO)	Provide adequate and reliable transmission infrastructure and services in the state for OSW projects
National Institute of Wind Energy (NIWE)	Nodal agency for OSW projects. Undertake due diligence as per MNRE's guidelines for OSW projects. Ensure state of the art R&D efforts, resource assessments, standards and testing and skill development to streamline and fast track OSW projects

Stakeholder - (Influencing and contributing to OSW uptake in the region)	Description/ Role of the stakeholder
Tamil Nadu Industry Agencies – TIDCO, TIIC	Ensure conducive policies, mechanisms and investment avenues for establishing OSW ecosystem in the state and strengthen the supply chain
Tamil Nadu Environment and Fishery Department	Coordinate as necessary with MoEFCC, state's coastal regulation zone (CRZ) authority and relevant agencies for EIAs and other required clearances for OSW projects including coordination with local communities.
Tamil Nadu Skill Development Corporation (TNSDC)	State Nodal Agency for skill development to transform the state into skill hub by skilling the youth to enhance their employability and match the industry expectations.
Research and Development Institutions	Support Centre and State to develop OSW ecosystem in the region- indigenization of technology and resources
Project Developers and Investors	Project development, securing financing, conducting feasibility studies, obtaining necessary permits, procurement, and overseeing construction and operation of OSW projects.
Financial Institutions	Provision of project financing through loans, investment, and financial advisory services to support the OSW projects. Ensure robust and inclusive models for financing and cost recovery.
Local CSOs and communities	Understand project nuances and benefits for the local community

4.2 Insights from Stakeholder Consultations

For the development of Tamil Nadu's OSW roadmap, consultations were carried out with identified key stakeholders to understand the existing situation, identify OSW specific developments and priorities, opportunities and gaps, and gather related data and information. Key insights gathered through in-person and virtual stakeholder consultations are summarised below.

Table 10: Insights from stakeholder consultations

Stakeholders	Key Discussions
State Planning Commission	• Intends to work on innovative policies and projects while proactively engaging with relevant Tamil Nadu state departments

Stakeholders	Key Discussions
	• OSW can be one of the regional growth factors, linked with skilling, technology development, just transition / green economy / blue economy, and vision 2047 • Need of aligning OSW projects with Just Transition and map potential benefits covering social and economic aspects.
Planning Department, Govt. of Tamil Nadu	• Need of state level SPV dedicated to OSW and RE projects with clear roles and authority • Need of demonstration project for price discovery of OSW energy tariff and for developing required regulations for the long-term viability RE intermittency and rising power demand has led to state's reliance on pumped hydro storage for peak demand management
National Institute of Wind Energy (NIWE)	• Tamil Nadu is the priority area considering the wind resource potential available for 8-9 months at TN coastline with potential PLF of about 50%. Demonstration OSW project of 16 MW capacity underway at Dhanushkodi • A centralised digital portal is under development for developers to seek project clearances and administration processes. NIWE is the nodal agency to facilitate the clearance processes • A dedicated task-force is established comprising of state and national stakeholders to streamline the OSW uptake • Detailed assessment of ports infrastructure is in underway to study ports readiness for OSW projects • Need of capacity building for NIWE's experts for GIS, and data analytics using AI and ML techniques for accurate resource assessments, project performance monitoring, and informed operation and maintenance for maintaining CUFs. • Results of pilot projects will help in deciding local content regulations as well as support local supply chain ecosystem.
MSME Department, Industries and Commerce Commissionerate	• Digital database of MSME clusters of Tamil Nadu is underway. Database will assist identifying industries relevant to wind sector value chain. • Dedicated programs can be designed based on the needs assessment of the mapped MSME industries including upgradation and upskilling.
Energy Department, Govt. of Tamil Nadu	• Need clarity on state energy department's role for OSW projects • Assurance of fishing communities' livelihoods and upskilling without job guarantees
Fisheries Department, Govt. of Tamil Nadu	• Involvement of fishing communities from the project planning stage • Department will support to provide site specific insights/challenges based on the OSW projects maps

Stakeholders	Key Discussions
TN Skill Development Corporation	• Department needs support on analyzing market trends and gaps such as skillsets required for OSW projects. • Department has various on-going schemes such as 'Naan Mudhalvan' through which dedicated programs can be designed as well as collaborations can be done based on the needs assessment for OSW value chain.
Tamil Nadu Energy Regulatory Commission	• Need to assess OSW energy supply and state's energy demand patterns to develop case for Tamil Nadu • Promote OSW captive consumption, considering the financial implications on TANGEDCO • Central support in terms of VGF and relaxation in wheeling charges can help at the early-stage • Need lower OSW power purchase costs to attract off takers. E.g., OSW cost of around INR 6/kWh compared to conventional 7-7.5 INR/kWh on average.
TANGEDCO	• Similar to other RE projects, Government of Tamil Nadu maybe allocated 50% of generated power Willing to procure initial 2 GW power at INR 4/unit
POSOCO- GRID INDIA	• OSW is an additional asset for resource adequacy to meet peak demand • No grid code modification is required for integrating OSW projects. The existing provisions of Grid Code are sufficient.
Tamil Nadu Industrial Investment Corporation (TIIC) and Tamil Nadu Industrial Development Corporation (TIDCO), Govt. of Tamil Nadu	• Need plans for round the clock (RTC) power supply to handle the RE intermittency • No OSW related activities through TIDCO yet- potential sector to incorporate under Green Hydrogen cluster development project being planned at Tuticorin port • Need of state level SPV to drive OSW projects in the state
SDG Coordination Centre (SDGCC), Govt. of Tamil Nadu	• Need a framework to address bottlenecks at OSW projects value chain considering all stakeholders • Enabling strategies and solutions to be identified considering each stakeholders' interest as well as benefits envisaged through the OSW projects
British High Commission (BHC)	• Need of a platform for collaboration among stakeholders across OSW value chain • Capacity building for TANGEDCO officials on OSW technology and projects • Enabling policies, interventions, mechanisms and innovative solutions to resolve environmental conflicts

Stakeholders	Key Discussions
	• Frequent engagements and dialogues between local communities such as fishermen and state authorities to capture their feedback and inputs
Private developers	• Relaxation in soft components such as certification fees for improving OSW projects financial viability • Partnerships with neighbouring countries to tap into regional capacities and supply chain can help improve cost efficiencies, bringing down 30-40% of project costs incurred during project construction activities • Development of OSW supply chain ecosystem and R&D expertise to reduce dependence on imports and project costs, attract potential investments, and job creation
Financing institution	• Thorough financial due diligence is necessary for lending to OSW projects, given the significant capital requirements and project timelines involved • OSW projects for captive consumption in commercial and industrial sectors can be more viable compared to DISCOM energy procurement, considering financial stability • Streamlining the standardization of balance of system components and necessary compliances for OSW plants will help facilitate ecosystem development and project implementation • Borrowers/project developers must comply with robust international market-standard financing frameworks and due diligence guidelines, performance standards, EHS guidelines to avail high volume finance required
Joint Industry Consultation	• Opportunity to cater to growing energy demand: India's electricity use is lower than global average however is rising owing to economic growth. OSW has potential to provide clean, large-scale reliable power. • Investments: OSW projects take longer to build (about 7 years) than project investors typically prefer. Need of enabling financial instruments or incentives to attract long-term investments. • Policy and Permits: Clarity on detailed EIAs and approvals along with government support such as VGF and long term RPOs is crucial • Workforce Training: OSW project needs skilled workforce across the value chain (about 10,000/GW). Repurposing and upskilling existing oil & gas workers can help address this gap • Operational Challenges: Reducing certification and testing costs and addressing community concerns (fisheries) are important for smooth operations. CSR initiatives can help.

Stakeholders	Key Discussions
	• Manufacturing Opportunity: Indian companies have capacity to indigenize 60-70% OSW value chain and hence should aim to graduate and serve the global OSW market

4.3 Key Takeaways: Opportunities and Challenges for OSW Development in Tamil Nadu

Key takeaways of stakeholder consultations have been summarised below across ecosystem aspects such as finance and economic benefits, regulation and governance, infrastructure and capacity building. The stakeholder insights and takeaways have been used to inform the recommendations identified to support OSW development in Tamil Nadu.

Challenges/ Opportunities	Proposed Action
Regulation and Governance	
Inadequate Regulatory Framework for OSW Integration: The current regulatory framework lacks clarity, for the integration of intermittent OSW energy into the grid.	Develop a stable and clear regulatory framework for OSW integration can create a predictable environment for investors and developers. The TNERC can develop these regulations that addresses energy intermittency and grid stability, promotes OSW power offtake, and provides financial incentives, fostering a supportive environment for OSW projects.
Need to Operationalize a Dedicated Institutional Setup: While a task force for OSW has been established at the state-level, a dedicated institutional setup needs to be fully operationalized to facilitate effective coordination between private stakeholders and government bodies, to streamline project development and address regulatory challenges.	Operationalize the specialized task force that has been established at the state level or setup a special purpose vehicle (SPV) as a joint venture between MNRE, Government of India, (represented by NIWE) that takes charge of the procurement, development, and construction of OSW power projects in the state in collaboration with NIWE.
Absence of Stakeholder Advisory Committees: The lack of formal advisory bodies hinders the inclusion of industry perspectives in policy and regulatory framework.	Create Stakeholder Advisory Committees with representatives from the OSW industry to provide valuable insights and address sector-specific challenges, ensuring regulations are practical and industry-aligned.
Complex Project Approval Processes: Ambiguities and complexities in the project approval process, including environmental and social assessments.	Develop a clear and efficient project approval process with defined environmental and social assessment standards.

Challenges/ Opportunities	Proposed Action
Financing of OSW projects	
Absence of Cost-Benefit Analysis for OSW Projects: The absence of comprehensive cost-benefit analyses tailored to the Indian context can undermine financial viability.	Conduct detailed cost-benefit analyses to assess project feasibility and attract investment. Support from TANGEDCO and TNGECL will be essential for identifying viable business models.
Ambiguity in OSW Power Off-take and Tariff Structure: Project developers face uncertainty due to the absence of long-term assurances for energy off-take and suitable tariff structure which can facilitate the integration of OSW energy into the grid while ensuring financial sustainability.	Defining long-term RPOs specifically for OSW, would establish clear commitments for both project developers and state Discom. TNERC can develop a tariff structure that balances compensation for OSW energy with the financial health of utilities.
Limited Funding Mechanisms for OSW Projects: There is a lack of adequate funding mechanisms to support OSW project implementation.	Establish funding programs and financial instruments to support OSW projects, engaging with financial institutions to develop inclusive financing models.
Power off-take	
Opportunity to meet growing energy demand in India’s states through clean and reliable OSW power - With India's electricity consumption on the rise due to economic growth, there is a significant opportunity to meet this growing demand through clean and reliable OSW power. The current per capita electricity use in India is lower than the global average, highlighting the potential for expansion.	Coordination with national and state electricity authorities and power system operators especially Grid-India, will be essential to ensure the smooth integration of OSW with the national grid and facilitate the export of surplus power to other states. This will optimize the use of generated OSW energy across Indian states.
Infrastructure and Supply Chain	
High Costs in Component Testing and Certification	Establish local testing and certification facilities to streamline processes and reduce associated expenses, supported by the National Institute of Wind Energy (NIWE).
Inadequate Infrastructure and Logistics for OSW Components - There is a lack of dedicated infrastructure and logistical expertise for handling OSW turbines and components	Invest in dedicated terminals and port facilities, and develop logistical expertise to manage OSW components effectively. The Ministry of Ports, Shipping, and Waterways and Tamil Nadu Maritime Board should support this infrastructure development.

Challenges/ Opportunities	Proposed Action
Advancing Local Manufacturing Capabilities: Opportunity for Tamil Nadu to develop its manufacturing sector to not only meet domestic OSW needs but also to position itself as a key player in the global OSW market.	By focusing on local production of OSW components such as turbines, nacelles, and blades, Tamil Nadu can stimulate economic growth, create jobs, and reduce dependence on imports. Develop policies and incentives that encourage local manufacturing. Establishing specialized industrial zones for OSW component manufacturing, providing financial support for R&D, and creating training programs to build a skilled workforce will be crucial.
Capacity Building and Stakeholder Engagement	
Gaps in Knowledge and Capacity Building for OSW Technologies: Decision-makers and technical professionals lack sufficient knowledge of OSW technologies and best practices.	Partner with the Tamil Nadu Skill Development Corporation (TNSDC) to implement targeted training programs to build technical skills and leverage expertise from research institutions and related sectors.

5 Offshore Wind Scenario, Opportunities and Readiness in Tamil Nadu

Summary:

Tamil Nadu is poised to become a major player in the OSW energy sector, with the MNRE outlining a strategic plan for seabed area auctions along the state's coast from untilyear 2028. This chapter highlights opportunities for OSW development in Tamil Nadu given the anticipated substantial OSW energy development. A deployment trajectory for OSW in Tamil Nadu has been outlined until 2047. The cumulative OSW installation in Tamil Nadu is projected to reach 4.5 GW by 2032, 24.4 GW by 2037, and up to 63.4 GW by 2047. This expected growth in OSW deployment will lead to significant economic benefits, including employment opportunities and investment potential, contributing to Tamil Nadu's goal of becoming a $1 trillion economy.

The chapter also emphasizes the crucial role of ports in enabling OSW project deployment and operations. Preliminary high-level suitability to support OSW activities has been checked for Tamil Nadu's ports, including major ports like Tuticorin and minor ports such as Kudankulam, Udangudi, Chinnamuttom, and Colachel. Tuticorin port is found to be highly suitable for both construction and O&M activities due to its advanced infrastructure and strategic location near several OSW zones, while other minor ports in the region show potential to become viable OSW hubs for O&M of OSW projects with further infrastructure development and investments. Furthermore, the chapter outlines the importance of grid infrastructure readiness to support the integration of OSW energy. The Central Transmission Utility and Tamil Nadu's State Transmission Utility are planning significant upgrades and expansions including the development of pooling stations and interconnection infrastructure to ensure efficient power transmission from OSW sites. The long-term success of OSW in Tamil Nadu will also require significant efforts in developing human resources with the right skills, by leveraging existing experience of workers with onshore wind and Oil & Gas sectors to meet employment opportunities across the OSW value chain the state.

A readiness assessment is included to assess the suitability of conditions and preparedness in Tamil Nadu to support the early-stage development for the forthcoming 4 GW of OSW projects and better understand areas where interventions are required.

5. Offshore Wind Scenario, Opportunities, and Readiness in Tamil Nadu

MNRE's revised strategy paper outlines seabed area auction trajectories for the coast of Tamil Nadu from FY 2023-24 to FY 2027-28, which is expected to set the pace for OSW energy development in the state. These auctions will result in lease of 3,409 square km of seabed area out of total 10,560 sq. km blocks with high offshore potential identified in the off coast of Tamil Nadu (see Figure 18) (MNRE, 2023). The strategy paper also proposes development of 500 MW of VGF-supported OSW projects in the state.

In June 2024, India's Union Cabinet approved the Viability Gap Funding (VGF) scheme for OSW projects at a total outlay of INR 74.5 billion, including an outlay of INR 68.5 billion for installation and commissioning of 1 GW of offshore wind energy project as per the VGF supported Model A suggested in MNRE's strategy paper. Out of this 1 GW capacity targeted under Model A, 500 MW of offshore wind project will be installed in Tamil Nadu. These initial offshore wind projects will kick-start offshore wind deployment in India.

To guide and regulate the leasing, installation, operation and maintenance of OSW energy projects at the offshore sites, the Ministry of External Affairs (MEA) published the 'Offshore Wind Energy Lease Rules, 2023, which are to be followed by project developers (MEA, 2023). As noted earlier, a tender for sea lease of 4 GW of offshore wind has already been floated in February 2024 under Model B (non-VGF model providing exclusivity of seabed lease at identified sites to selected project developers during survey period of two years) (SECI, 2024). The proposed auctions (till FY 2027-28) can be expected to result in offshore wind power installations with a potential capacity between 15 to 20.5 GW, based on wind power capacity densities ranging from 4.5 MW/sq.km to 6 MW/sq.km (see Figure 19).

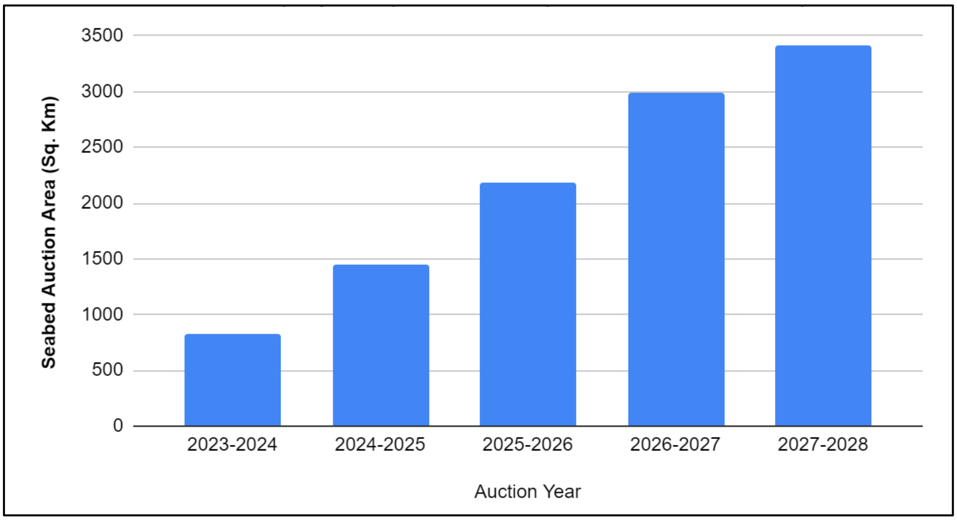


Figure 18: Total seabed auction areas (sq.km) planned for offshore wind in Tamil Nadu

Source: MNRE revised strategy paper, 2023

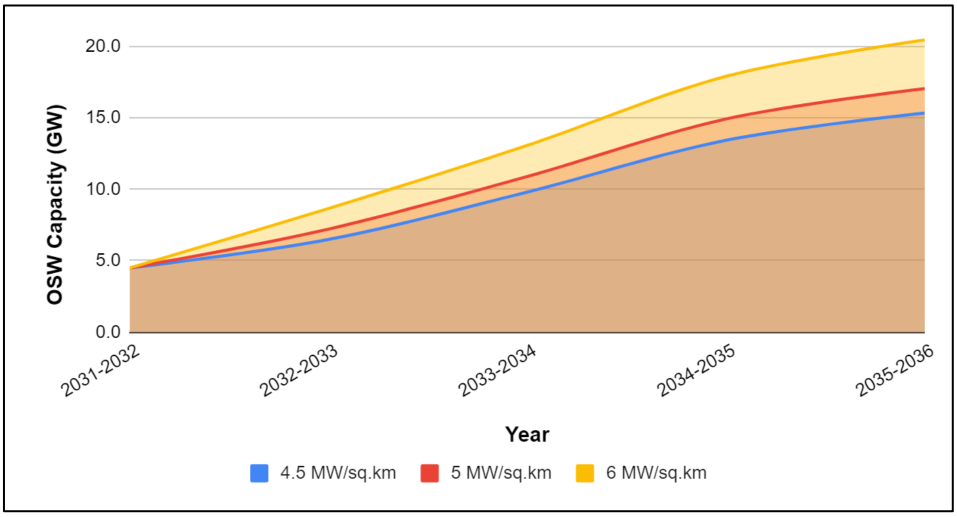


Figure 19: Potential offshore wind capacities from proposed seabed auctions in Tamil Nadu

Source: ICLEI South Asia analysis based on MNRE revised strategy paper for establishment of OSW energy projects 2023

5.1 Tamil Nadu's Offshore Wind Deployment Trajectory

A trajectory for the offshore wind power installation in Tamil Nadu is forecasted to serve as a reference point for prospective OSW development. This indicative trajectory helps to provide an understanding of the expected scale of OSW deployment, project infrastructure implications, investment potential and benefits such as employment opportunities.

Potential targets for installation of OSW power in Tamil Nadu have been delineated until 2047 to align with India's energy security scenarios 2047 targets. Given the existing auction plans, the OSW installation trajectory is mapped for Tamil Nadu from 2032 to 2047, assuming a lead time of 7 years for project commissioning from seabed lease tender award. The estimation is based on an extrapolation of MNRE's auction trajectory and incorporates growth rates based on the auction trajectory as well as the global market.

The first tranche of the offshore wind deployment until 2032 will be driven by 500 MW of VGF supported project (Model A) and the recently initiated 4,000 MW seabed lease auction. Based on different average wind power densities outlined in MNRE's strategy paper and blocks with OSW potential identified in Tamil Nadu, the total capacity of offshore wind installation is estimated to range from 47.5 GW to 63.4 GW by 2047 (see Figure 20).

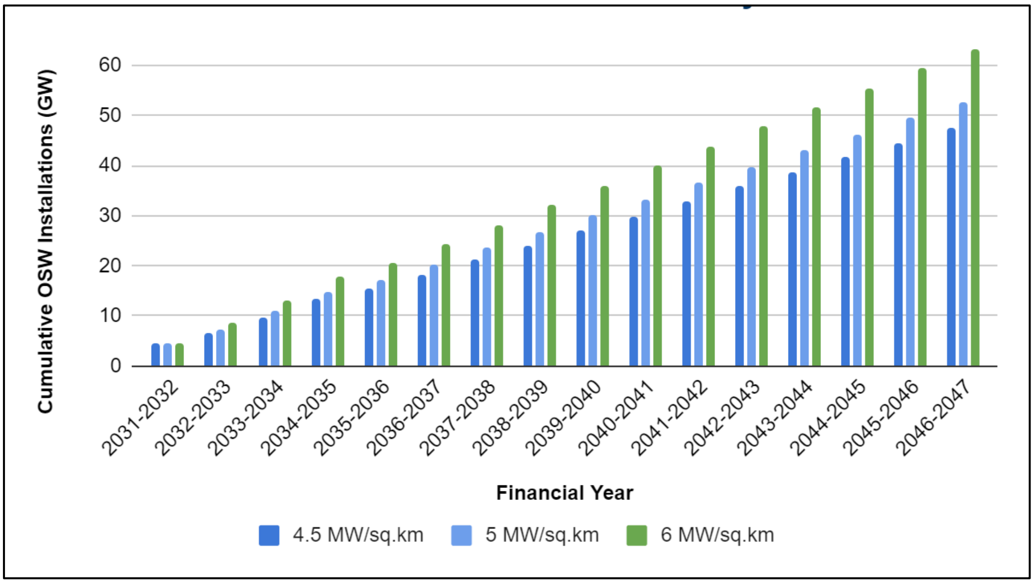


Figure 20: OSW Installation Scenarios based on wind power densities, 2032-2047

Source: ICLEI South Asia analysis

Based on this analysis, the potential OSW targets have been outlined by assuming a power density of 6 MW/sq. km which is deemed to be achievable based on existing technology and projects in emerging markets. Thus, potential cumulative OSW installation in Tamil Nadu is expected to be 4.5 GW by 2032, 24.4 GW by 2037 and going up to 63.4 GW by 2047.

Table 11: Potential Offshore Wind Targets for Tamil Nadu

Potential OSW Trajectory	2032	2037	2047
OSW cumulative installed capacity (GW)	4.5	24.4	63.4

5.2 Offtake Opportunities and Drivers in Tamil Nadu and beyond

Tamil Nadu ranks second in India's states in terms of economy, with a GDP of INR 23.64 lakh crore, and is poised for significant growth. The state aspires to become a $1 trillion economy, fuelled by investments in sectors like textile parks, food parks, EV manufacturing, green hydrogen, and data centers. This economic expansion, supported by favourable policy frameworks and investments, will drive electricity demand not only in Tamil Nadu but also in other states in the region.

The state's power demand is projected to increase at a CAGR of 6% over the coming decade, with peak demand expected to grow by around 30% by 2027 (GWEC, 2022). The rapid proliferation of EVs in recent years, with Tamil Nadu aiming for 30% EVs in total vehicle sales by 2030, will further contribute to electricity demand. The state's manufacturing sector, contributing 33% of the Gross State Value Added (GSVA) in 2020-21, has been consistently growing over the past decade. Tamil Nadu aims to achieve a 15% growth rate in the manufacturing sector by 2025. This sector includes highly energy-intensive industries such as textiles, iron and steel, paper, cement, plastic, and fertilizer.

As seen in section in 3.2.1, forecasts of electricity requirement and future power generation indicate a potential gap between electricity demand and supply in Tamil Nadu, starting from 2028 onwards and rising until 2047. The potential shortall in state's electricity generation is estimated to be 20,500 million kWh by 2032, 33,000 million kWh by 2037, and go up to as 78,000 million kWh by 2047. Meeting this shortfall may require the state to depend on options such as short-term power procurement and energy exchange mechanisms, which will increase the cost of supply and impact energy security. Based on the state's projected trajectory of OSW deployment as outlined in section 5.1, corresponding electricity generation is estimated to be 18,900 million kWh from 4.5 GW of capacity by 2032, 102,600 million kWh from 24.4 GW by 2047, and 266,600 million kWh from 63.4 GW by 2047[6]. Thereby, power generation from OSW projects installed off the coast of Tamil Nadu can help the state to bridge its supply-demand gap and fulfil energy requirements beyond the state as well (see Figure 21).

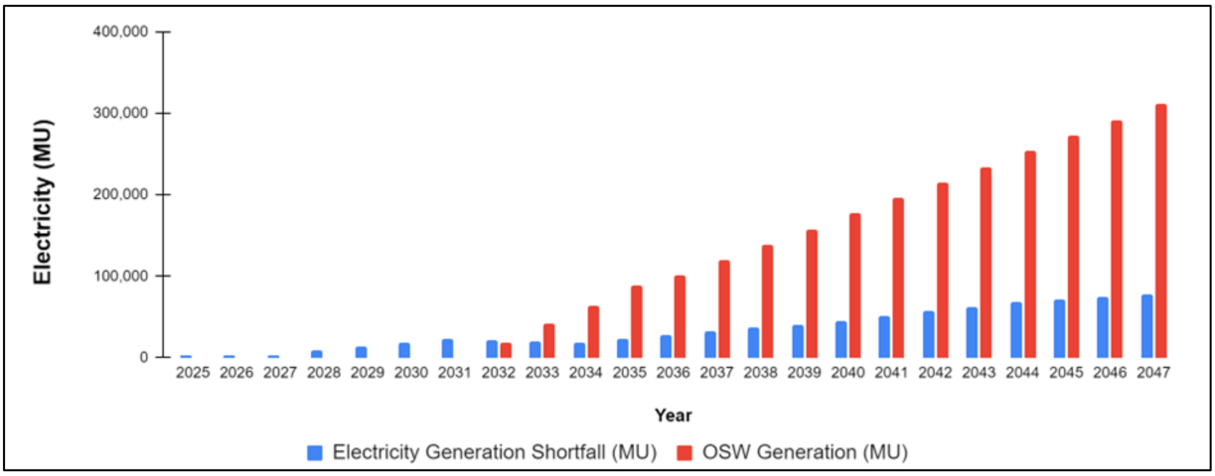


Figure 21: Tamil Nadu's Electricity Generation Shortfall versus projected OSW based generation until 2047

Source: ICLEI South Asia analysis based on datasets from CEA, MNRE, load dispatch center

Decarbonization is crucial for Tamil Nadu's industries to reduce their carbon footprint and enhance sustainability. The state has committed to no new unabated coal investments and has set up a Green Climate Fund to mobilize 1,000 crores for climate change mitigation and adaptation (DIPR, 2023). These steps align with Tamil Nadu's commitment to achieve net zero well before 2070.

It is observed that industrial captive power plants (having demand of 0.5 MW and above), primarily based on hydro, steam, diesel, gas (accounting for over 90% of capacity) and renewable sources (solar, wind, biomass) have relatively low PLF as per information reported in the All India Electricity Statistics 2024 by CEA. Average annual PLF of captive power plants across different industry sectors in Tamil Nadu are shown in Figure 22. This presents potential opportunities for industries to shift to offshore wind power from such captive units with low PLFs, offering benefits of deferred capital investment, operation & maintenance costs, and freeing up space utilised by captive power plant in the Industrial premises for other productive purposes. Moreover, offshore wind power can support industries to achieve significant increase

[6] Average CUF of 48% has been considered to estimate electricity generation from OSW

in renewable integration, offering benefits to industries for regulatory provisions such as PAT mechanism, carbon trading, and the Carbon Border Adjustment Mechanism (CBAM).

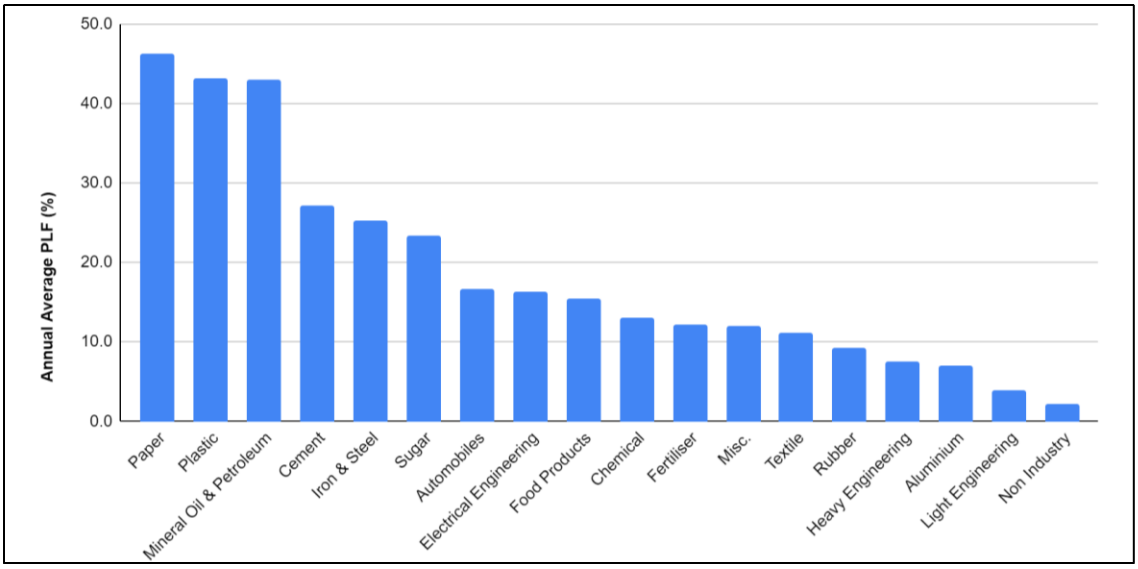


Figure 22: Annual Average PLF of Captive Power Plants installed by Industries in Tamil Nadu, FY 2022-23

Source: CEA, All India Electricity Statistics 2024

Tamil Nadu is also focusing on harnessing the hydrogen economy to mitigate emissions in hard-to-abate sectors such as oil and gas, cement, steel, and fertilizer. Substantial electricity input, equating to nearly 50 kWh per kg, is required to produce green hydrogen. India's hydrogen demand is projected to be 10 metric tonnes (MT) by 2030, with Tamil Nadu expected to contribute roughly 10% of this demand, necessitating around 5 GW of RE capacity for green hydrogen production.

Energy transition and decarbonization goals at state, sectoral, and corporate levels present opportunities for OSW energy to cater to rising energy demand across various sectors and consumers in Tamil Nadu and beyond. Additionally, benefits such as the ISTS waiver and exemption of additional surcharge for OSW projects commissioned by December 2032 make OSW an attractive proposition.

Key segments and drivers for potential utilisation of OSW generated power include:

Manufacturing and Industrial Growth:

- As of 2023, the manufacturing sector accounted for 17% of the GDP. The government has set an ambitious goal to increase the manufacturing sector's share of the economy to 25% by 2025 (Invest India, 2024).
- In the fiscal year 2020-21, the industrial sector accounted for the largest share of electricity consumption at 41.09% (Ministry of Statistics and Programme Implementation, n.d.)
- Tamil Nadu's manufacturing sector contributed 25% to the state's Gross State Value Addition (GSVA) in FY20 and aims for 15% annual growth until 2025, with plans to attract INR 1,000 billion in investments by 2025 under its Industrial Policy (GWEC, 2022). The

state dominates with approximately 45% of India's auto exports and about 35% of auto component exports (Tamil Nadu Infrastructure Development Board, 2024).

E-Mobility:

- Government of India's target of 30% EV market share by 2030 (NITI Aayog, 2023)
- EV adoption expected to grow at a CAGR of 49% till 2030 in India (PIB, Govt. of India, 2023)
- The electricity consumption attributed to EV charging stations operated by DISCOMs in the FY 2023-24 amounted to 445.97 MU (CEA, 2024)
- The government of Tamil Nadu also introduced its EV policy, in line with the National Policy, aiming to achieve a 30% share of EVs in total vehicle sales by 2030. Tamil Nadu has registered a cumulative EV sale of 5.60% as of FY2024 (JMK Research, 2024).
- As of February, 2024, Tamil Nadu has 643 operational public EV charging stations (PIB, 2024).

Green Hydrogen Production:

- The National Green Hydrogen Mission aims to achieve 5 million tonnes of green hydrogen production capacity by 2030, with intent to cater to the international market (MNRE, 2023)
- India will need 125 GW of renewable energy by 2030 to achieve its green hydrogen target (MNRE, 2023). Potential to explore green hydrogen production using OSW power.
- Tamil Nadu will require 5 GW of renewable energy dedicated to Green Hydrogen production, considering that the state will meet around 10% of India's projected hydrogen demand of 10 million tonnes by 2030 through green hydrogen production (GWEC, 2022). Potential to explore green hydrogen production using OSW power
- Neighbouring states such as Andhra Pradesh also targets green hydrogen production up to 0.5 MTPA and green ammonia production up to 2.0 MTPA in the next five years through its Green Hydrogen and Green Ammonia Policy 2023 (NREDCAP, 2023).

Data Centres and Global Capability Centres:

- India is a hub for data centers and Global Capability Centers (GCC) (offshore units of multinational corporations that provide support and IT services), given its lower costs, improved digital infrastructure, and availability of power for operating these centers
- Data centers in India will cross 2,000 MW demand by 2026 (CareEdge Ratings, 2024)
- Global commitments by IT companies to adopt renewable energy for GCC & data centers will increase the renewable electricity demand further
- Bengaluru, in the neighbouring Karnataka state, is a key data center market in India, housing 15% of the country's existing capacity with 96 MW demand (Department of Electronics, IT, Bt and S&T, Government of Karnataka, 2022).
- Tamil Nadu currently has a data center capacity of 57 MW. The state has signed MoUs worth INR 89 billion for the phased development of additional data centers (GWEC, 2022)

One Sun, One World, One Grid (OSOWOG):

- India aims to increase cross border electricity transactions through the One Sun, One World, One grid initiative under the International Solar Alliance, with the intent to connect different regional grids through a common grid that will be used to transfer renewable energy power and help realize the potential of renewable energy sources, especially solar energy.
- India aims to become a catalyst for supplying renewable energy in the cross-border electricity exchanges under this initiative (Ministry of Power, 2023)
- OSW power can potentially complement large scale solar PV to enhance overall grid operations, integration and reliability of round-the-clock renewable power

5.3 Cost Analysis for Potential Off-takers

To further examine offtake opportunity, a cost analysis has been undertaken for procurement of offshore wind power for (i) State discom, i.e. TANGEDCO and (ii) high-tension (HT) consumers primarily representing the Commercial and Industrial (C&I) segment.

The analysis is based on prevailing power purchase cost of TANGEDCO and average electricity cost for HT consumers from TNERC's latest tariff order and weighted average offshore wind LCOE[7] from FIMOI II (CoE for Offshore Wind and Renewable Energy, 2022) and IRENA (IRENA, 2023). These cost data points have been forecasted to FY 2031-32 to FY 2036-37, when the first offshore wind project in Tamil Nadu is expected to come online. Further details of the analysis are provided in Annexure III.

It is found that offshore wind power is an attractive proposition for both TANGEDCO and HT C&I consumers in the state. As the domestic offshore wind market evolves with on-ground project deployment, and with technology and infrastructure developments, the LCOE of offshore wind power will further reduce, as seen in other markets. This will increase the viability of offshore wind power offtake in the mid to long-term.

Table 12: Comparison of electricity costs for TANGEDCO and HT consumers as against OSW LCOE values

Electricity cost (INR/kWh)	2031-32	2032-33	2033-34	2034-35	2035-36	2036-2037
Offshore wind (LCOE)	7.4	7.1	6.9	6.7	6.4	6.2
TANGEDCO (power purchase)	6.8	7.1	7.4	7.8	8.2	8.5
HT Consumer	13.0	13.4	13.9	14.4	14.9	15.5

[7]LCOE is the ratio of lifetime costs to lifetime electricity generation, both of which are discounted back to a common year using a discount rate that reflects the average cost of capital. This includes total installation costs including project development costs, grid connection, equipment, installation, civil engineering, contingency, etc.

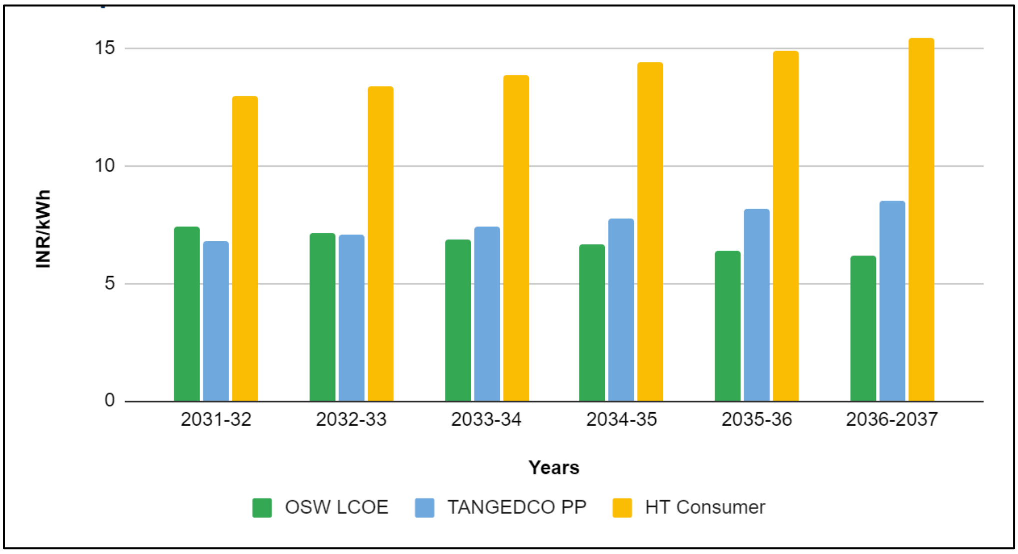


Figure 23: OSW Power Offtake Opportunity for TANGEDCO, HT Consumers in Tamil Nadu

Source: ICLEI South Asia analysis based on TNERC regulatory orders, IRENA and FIMOI study

Opportunity for Tamil Nadu DISCOM:

TANGEDCO's power purchase cost is estimated to rise by 4.75% year-on-year, from INR 5.43/kWh in 2027 (as forecasted in the tariff order) to INR 6.8/kWh by 2031. The power purchase cost is influenced by long term power purchase contracts with power producers (thermal, solar, onshore wind, hydro, biomass), short term power procurements, fuel costs, among others. Offtake of OSW power offers a renewable, reliable and cost-effective source of power, making it an attractive opportunity for TANGEDCO in the long-term.

The Tamil Nadu government has shown its willingness to offtake power generated from OSW Plants to meet its increasing energy demand, driven by industrial growth in southern Tamil Nadu (Tamil Nadu Industries Department Policy Note, 2023). This will give a supportive push to TANGEDCO's proposition for OSW power offtake. Further, offshore wind power procurement will contribute to fulfilling RPO targets. It will also reduce dependency on availability and price fluctuations of fuels and on the volatility of the short-term power market.

Opportunity for HT Consumers in Tamil Nadu:

The average billing rate or cost of electricity for HT consumers in the state is estimated to increase from INR 9.43/kWh in 2022 to INR 13/kWh by 2031, rising by around 3.59% year-on-year. Given this rising cost of electricity, offshore wind power is a viable proposition for HT consumers.

HT consumers can avail various regulatory and policy mechanisms such as open access and green energy open access. By using the high voltage transmission network (central or state operated), HT consumers can take advantage of lower technical losses, which will further optimize cost of offshore wind offtake. Moreover, HT consumers will be able to fulfill renewable energy procurement requirements as mandated by the government or international business procurement guidelines such as CBAM and also claim carbon offset benefits (European Commission, 2023).

5.4 Implications: OSW Infrastructure, Investment and Benefits

OSW projects are capital intensive and have long project development cycles spanning over 7 to 10 years. They involve inherent engineering complexity and higher cost implications due to their unique installation, foundation, subsea cables, offshore substations, and operations and maintenance activities, all of which have a bearing on economic viability of OSW projects. Based on estimates prepared under this study, indicative CAPEX and OPEX costs are provided below as a reference point for initial OSW projects to come up in Tamil Nadu. These cost estimates reflected on a per MW basis have been arrived at based on global installation prices, previous datasets and information from multilateral development banks, and previous studies on OSW in India such as FIMOI to provide a more up-to-date and context-specific understanding of potential costs.

Cumulative CAPEX costs are estimated to be about INR 207.66 million per MW of OSW installed, with turbine costs alone accounting for over 40% of CAPEX (see Table 13). Infrastructure such as foundation, array and export cables and offshore substation account for a third of the unit CAPEX cost while installation costs are also significant. While substantially lower than the capital outlay, operation and maintenance costs of OSW projects are estimated to be about 5.21 million per MW per year. It should be noted that OSW markets that have matured over time, have been able to optimize project costs and reduce cost of energy from OSW projects through a steady rate of project delivery, improved learning and efficiency, and expansion of supply chain. Further details of the cost estimations are provided in Annexure IV.

Table 13: OSW project cost estimates

Cost Components	Approx. Cost (INR/MW)	Share of CAPEX
Development Cost (INR/MW)	7.55 million	3.6%
Project Execution Cost (INR/MW)	3.83 million	1.8%
Turbine Cost (8 MW wind turbine generator) (INR/MW)	92.25 million	44.4%
Foundation Cost (INR/MW)	23.12 million	11.1%
Array Cables (INR/MW)	16.11 million	7.8%
Export Cables (INR/MW)	16.86 million	8.1%
Onshore Substation (INR/MW)	4.91 million	2.4%
Offshore Substation (INR/MW)	15.42 million	7.4%
Installation Cost (INR/MW)	27.6 million	13.3%
Total CAPEX (INR/MW)	**207.66 million**	
Total OPEX (INR/MW/year)	**5.21 million**	

Source: ICLEI South Asia analysis based on global OSW cost estimates by World Bank, NREL, IRENA and estimates by FIMOI for India

The anticipated OSW deployment in Tamil Nadu by 2047, noted earlier in this chapter, will entail significant financial and infrastructure requirements while delivering socio-economic and climate benefits as outlined in the Table 14 below. Based on the expected scale of infrastructure development, investment potential and multidisciplinary nature of OSW, there is a need for Tamil Nadu to initiate strategic action that puts in place building blocks that help to develop and support an ecosystem for OSW development. This will help to realize the potential and drive significant social and economic benefits and industrial growth in the state.

Table 14: OSW related Infrastructure requirements, investment potential and employment opportunities in Tamil Nadu

Parameter	2032	2037	2047
Installed OSW capacity (GW)	4.5	24.4	63.4
Number of turbines, nacelles, towers, foundations (1 each) (Wind turbine generator - 8 MW)	563	3,044	7,919
Number of blades	1,689	9,132	23,757
Cumulative capital investments (billion INR)	934	4,662	10,273
Cumulative operation and maintenance investments (billion INR)	23	388	4,212
Full time employment potential (jobs)	42,570	230,824	599,764
GHG emission reduction (Million tonnes of CO_2e) per year	15	70	205

Source: ICLEI South Asia analysis

Potential Opportunities in the OSW value chain in Tamil Nadu

As the OSW sector develops in the state, it will bring forth opportunities in value chain and infrastructure areas including materials, manufacturing, and port development that can deliver local benefits and build an ecosystem. Such development will create numerous diversification, expansion and employment opportunities across various sectors, ranging from manufacturing, engineering, logistics to maintenance, among others.

The existing mineral resources, MSMEs, industrial units, and manufacturing infrastructure in Tamil Nadu lends the state a unique position for facilitating offshore wind manufacturing and development (Govt. of Tamil Nadu, 2022). Typical material required for 1 MW of OSW installation is shown in Table 15. Potential opportunities include sourcing and supply of raw materials, use of recycled materials extracted from mines and material management. Tamil Nadu state is endowed with major minerals such as Limestone, Magnesite, Graphite, Bauxite, Iron Ore that form key materials used in manufacturing of offshore wind turbine generators, construction work with steel & cement, and manufacturing of components such as tower, substation, cables and sub structures. Significant volumes of materials such as aluminum, carbon fiber, steel, manganese and nickel will be required to install 24.4 GW of OSW by 2037 in Tamil Nadu.

Table 15: Approximate material requirements for 1 MW OSW project

Material	Unit material requirements (kg per MW of OSW)
Aluminum	922
Carbon Fiber	580
Steel	2,800
Manganese	4,671
Nickel	3,592

Source: NREL, 2023

Tamil Nadu is a leading manufacturing and industrial hub for automobiles, space sector, renewable energy, electrical vehicles, electronics, heavy engineering equipment, pharmaceuticals, and textiles (Invest India, 2023) (MSME - Development Institute, 2015). The adoption of OSW power offers opportunities to significantly enhance and expand the state's existing onshore wind manufacturing capacity to accommodate OSW related manufacturing, fostering increased investment and local economic growth. Tamil Nadu houses six to eight major onshore wind turbine manufacturers, (included in MNRE's Revised List of Models and Manufacturers, including foreign companies like Vestas, Siemens Gamesa (having offshore wind experience in other countries (MNRE, 2024). Also, gear box manufacturers and tower builders are well entrenched in the state. Collaboration with original equipment manufacturers (OEMs) is essential for the manufacturing of critical components used in offshore substations, cables, and wind turbine generators.

Additionally, the focus on blade recycling and sustainable material management will contribute to a more circular economy, aligning with environmental goals and advancing the state's renewable energy capabilities (Saur Energy International, 2023). Recycling industries can play an important role in repurposing blade and tower materials from onshore turbines for use in offshore wind turbine production. Additionally, developing new ports for offshore installation, storage, and handling cargo is crucial to support the growing offshore wind sector. These infrastructural and industrial opportunities will enhance the state's capacity to support and grow its offshore wind industry while leading to socio-economic benefits.

5.5 Suitability of Ports in Tamil Nadu for OSW

Ports play a crucial role in enabling the deployments and operations of offshore wind (OSW) projects. Tamil Nadu, with its extensive 1,076 km coastline and numerous ports, requires strategic action and timely attention to support the initial 4.5 GW of OSW projects in the near term, as well as the projected OSW capacity in the long term. Ensuring the availability and readiness of port infrastructure is essential, as gaps can negatively impact the cost, timelines, and efficiencies of early-stage OSW projects.

Major upgrades to port infrastructure typically require a minimum of two years, often more, depending on factors such as permitting procedures. Therefore, it is imperative that relevant state departments and decision-makers, in collaboration with port owners, operators, and central government institutions, plan and implement the necessary upgrades and expansions to support OSW development in a timely manner.

Port infrastructure requirements for OSW projects vary at different stages of their lifecycle. For instance, large ports are necessary for the construction phase including component storage, and assembly phases before OSW installation, while smaller ports are better suited for operations and maintenance activities. The proximity of ports to project sites can optimize transit time and costs, further enhancing efficiency.

Investments in port infrastructure for OSW should also consider accommodating future technological developments, such as the expected increase in turbine sizes. By proactively addressing these needs, Tamil Nadu can ensure the successful implementation and long-term sustainability of its OSW projects.

Tamil Nadu has 3 major ports managed by individual port trusts, 17 minor ports managed by the Tamil Nadu Maritime Board, and 9 fishing harbours managed by the Tamil Nadu Fisheries Department. To check the suitability of using seaports and harbours for OSW energy deployment in the identified OSW zones off the coast of southern Tamil Nadu, the following ports and harbours existing between Rameswaram and Kanyakumari were considered.

Table 16: Summary of Tamil Nadu ports and their suitability to support OSW sector

Name of Port	Potential Port Suitability for OSW	Ownership / Management	Remarks
Rameswaram (Minor Port)	Suitable to develop as O&M port with minor upgrades	Tamil Nadu Maritime Board	Handling fishing activities, connectivity to NH 87

Name of Port	Potential Port Suitability for OSW	Ownership / Management	Remarks
Pamban (Minor port)	Not suitable	Tamil Nadu Maritime Board	Can handle only small vessels passing through, needs significant developments
Vallinokkam (Minor port)	Not suitable	Tamil Nadu Maritime Board	Coral reefs and turtle breeding points nearby, potential biodiversity conflicts. Ship breaking work previously carried out at this location is suspended.
Tuticorin (Major Port)	Suitable to develop as construction and O&M port with minor upgrades	V.O Chidambaranar Port Authority	Existing major port, most suitable for use as OSW construction port for deployments in zones A, B, C, D, E, and G
Punnaikayal (Captive Minor port)	Not suitable	Tamil Nadu Maritime Board - Captive use by Dharangadara Chemical Works Ltd.	Declared for supply of raw materials to DCW Ltd.
Manappad (Captive Minor port)	Not suitable	Tamil Nadu Maritime Board - Captive use by Indian Gas Ltd.	Declared for handling of LNG import for use in Gas turbine power plants, limited space and potential disturbances to LNG handling operations.
Udangudi (Minor Port)	Suitable to develop as O&M port with major upgrades	Tamil Nadu Maritime Board - Captive use by TANGEDCO	Proposed to be developed as an open sea jetty to receive coal for TANGEDCO's 1600MW Udangudi super critical thermal power project. Feasibility of OSW O&M operations at the port can be explored in collaboration with TANGEDCO
Kudankulam (Minor Port)	Suitable to develop as O&M port with minor upgrades	Tamil Nadu Maritime Board - Captive use by Kudankulam Nuclear Power Plant	Can handle loading and unloading of over dimensional cargo and heavy lift cargo through barge, Lift-on/Lift-off (LoLo) and Roll-on/Roll-off (RoRo) operations. Well connected to National and State Highway roads.

Name of Port	Potential Port Suitability for OSW	Ownership / Management	Remarks
			Within 50 km radius of zones A, B, D and E, suitable for O&M of offshore WTGs
Chinnamuttom (Fishing Harbour)	Suitable to develop as O&M port with major upgrades	Tamil Nadu Fisheries Department	Handling fishing activities. Space limitations exist, but will be suitable for O&M operations. Has access to NH 66 and 44 and is closer to OSW zones (within 50 km radius)
Muttom (Fishing Harbour)	Not Suitable	Tamil Nadu Fisheries Department	N.A.
Kanyakumari (Minor port)	Not suitable	Tamil Nadu Maritime Board – Kanyakumari Boat Jetty	Handles small ferries for tourism, limited space availability, and integration of OSW operations will have impact on tourism activities.
Colachel (Minor Port)	Suitable to develop as O&M port with major upgrades	Tamil Nadu Maritime Board	Handling fishing activities at present. Limitations in road connectivity and located beyond 50 km radius of OSW zones Natural harbour with deep waters, and potential for development as deep-sea trans-shipment port

Potential Ports in Southern Tamil Nadu to Support OSW Construction and O&M

Tuticorin Port (For Construction and O&M):

Tuticorin Port, operated by V.O. Chidambaranar Port Trust, is an all-weather port designated as a major port in India and is potentially well-suited for supporting OSW projects due to its advanced port infrastructure, logistical capabilities, and strategic location. The port is located strategically within 50 to 120 km distance from the offshore wind zones A, B, C, D, E, and G identified along the southern coast of Tamil Nadu, of which B, D, E and G are prioritised for OSW farm development, making it an ideal hub for OSW development in Tamil Nadu. The port has good road accessibility through National Highways 38 and 138, enabling potential transfer of wind turbine generators components and crew and is also connected via a broad-gauge rail network and a regional airport.

The port can handle the demands of the intensive schedule of offshore wind turbine generator installation during the construction phase and the critical nature of O&M activities owing to the existing port facilities such as storage area for pre-assembly of wind turbine components for load-out, heavy lift equipment, and adequate berthing facilities for handling of heavy and over dimensional cargo. Notably, Tuticorin port is already handling import and export of wind turbine blades and towers, demonstrating its capability to handle over dimensional cargo.

The port has a harbour entrance width of about 150 m and a depth of 9.3 to 14.2 m. The existing berthing facilities at the port range from 140 to 370 m. This enables accessibility of specialized vessels such as wind turbine installation vessels, heavy lift vessel, crane vessels, and other component transfer vessels. The coal jetty at Tuticorin port where coal handling is being phased out can be utilised for OSW activities, with upgrades such as seabed strengthening, or alternatively a dedicated OSW terminal can be developed at the port for the construction and O&M activities (CoE for Offshore wind and RE, 2023).

It is to be noted that careful planning and coordination with port authorities and stakeholders will be essential to address any logistical challenges as delays in pre-assembly and loadout of wind turbine components from the port for installation can prove to be expensive owing to the high chartering charges to be paid for the specialized vessels such as the wind turbine installation vessel and other vessels that will be handling installation of the wind turbine generators in the designated offshore wind farm locations.

Kudankulam Port (For O&M):

Kudankulam port has strategic advantages to act as a potential O&M hub for OSW energy projects due to its proximity to potential offshore wind sites and existing infrastructure. The port was developed as part of the Kudankulam Nuclear Power Project (KKNPP) to support its logistical needs and is used to transfer over dimensional and heavy lift cargo from Tuticorin port to KKNPP site. Utilizing the Kudankulam port for OSW O&M activities presents significant security and regulatory challenges due to its vicinity to the strategic nuclear power plant, and the existing port facilities limit the O&M activities that can be undertaken from the port.

The port has a Lift-on/Lift-off (LoLo) jetty and a Roll-on/Roll-off (RoRo) jetty to handle Ro-Ro and Lo-Lo operations from barges that carry heavy and over-dimensional cargo. The artificial harbour was dredged and blasted up to 4 m throughout the harbour basin to enable barging operations. Due to its strategic location, this port can potentially be used for crew transfer through crew transfer vessels (CTVs) and possibly allow transfer of heavy lift cargo that may be required for replacement of minor wind turbine generator components and repair of major components from the port to offshore sites using barges. The components can then be repaired/replaced using specialized vessels such as crane vessels or smaller wind turbine installation vessels that can be chartered for major maintenance activities and overhaul of critical equipment.

Deploying specialized offshore wind Service Operation Vessels (SOVs) increases the efficiency of O&M activities in the offshore wind farm sites, and availability of a port dedicated for O&M within 50 km radius and ability to handle SOVs reduces crew transfer time and loading/ unloading of fuel, materials and minor wind turbine generator components. The breakwater entrance width of the port is 100m and the overall jetty length of 120m (including both Lo-Lo and Ro-Ro jetties) is adequate for handling of SOVs, however, the port requires further dredging to increase basin depth to 9m to enable docking of SOVs that require higher draft than barges.

Thus, substantial investment and careful planning would be required to develop Kudankulam as a viable hub for O&M of OSW energy projects including repair/replacement of minor components. The road infrastructure connecting the KKNPP site to the NH 44 also needs to be augmented to enable seamless transport of personnel and spares for regular maintenance.

The benefits of leveraging existing infrastructure must be weighed against the costs and challenges of developing new port facilities and meeting the regulatory requirements owing to the presence of a nuclear facility in the vicinity. A detailed feasibility study on utilizing the port as a hub for offshore wind O&M activities needs to be undertaken in comparison with potentially developing a dedicated terminal for OSW activities at the Udangudi port which is under development by TANGEDCO for their captive use.

Udangudi Port (For O&M):

Udangudi is an emerging minor port in Tamil Nadu and has the potential to be developed as an O&M port for offshore wind O&M activities given its strategic location near potential offshore wind sites and planned infrastructure development associated with the 1600 MW Udangudi Super Critical Thermal Power Project. TANGEDCO is developing the port with an open sea coal jetty to handle coal shipments for its captive use in the thermal power project. Leveraging the synergy with the thermal power project’s infrastructure can be advantageous, but thorough planning and coordination with TANGEDCO, that operates the port, and with other stakeholders are essential to address logistical challenges.

The port can be potentially suitable for handling Crew Transfer Vessels (CTVs) for personnel transport to wind turbine generator locations for periodic monitoring and maintenance activities, and minor repair works. However, handling of more complicated O&M activities such as replacement of minor and major wind turbine generator components requires significant investment in developing specialised port facilities, marine services, and logistics. A detailed study is required to explore the feasibility of developing the port as a dedicated O&M port for OSW.

Chinnamuttom Fishing Harbour (For O&M):

Chinnamuttom is a fishing harbour located in Kanyakumari district which was expanded in the recent years under the 'Sagarmala' program of the Ministry of Ports, Shipping and Waterways where additional infrastructures such as "L" Jetty, auction hall, net mending shed, administrative office, utilities, and parking area was developed. Although the current infrastructure is limited and tailored to the fishing industry, this harbour can potentially be developed further to support O&M activities of OSW projects by building additional facilities within the existing harbour site and through minimal port development activities.

The key advantages of this fishing harbour with respect to OSW energy development lie in its strategic location within 50 km of the identified OSW zones A, B, D & E and easy access to NH 66 and NH 44. Although availability of space in the existing harbour complex is limited, developing a crew-transfer station, training facilities, and a small storage area for minor wind turbine components can potentially be undertaken at the existing harbour complex and will enable day-to-day O&M operations from this location without the security and regulatory challenges posed by Kudankulam port.

To transform Chinnamuttom Harbour into a viable port for offshore wind O&M activities, it is crucial to ensure support and cooperation of the local fishermen community as this location will continue to be focused on fishing activities while OSW can be of value to the existing infrastructure developed as part of the Chinnamuttom harbour complex.

Colachel Port (For O&M):

Colachel is a minor port in Tamil Nadu with an active fishing harbour but without other significant commercial activities. The port was identified to be a natural harbour with deep waters that can safely anchor large vessels and was proposed to be developed as an international deep seaport for trans-shipment operations. But no further developments have taken place due to disagreements with the local fishermen community and need for enhanced support.

The Colachel port has the potential to support offshore wind O&M activities due to its strategic coastal location offering proximity to potential offshore wind sites and international shipping lanes, and its natural geographic feature offering. However, the current infrastructure is limited and focused on fishing activities, necessitating significant investment and port development activities to potentially accommodate the needs of OSW projects.

For developing the port as a viable hub for offshore wind O&M activities with ability to handle CTVs and SOVs, careful planning and engagement with relevant stakeholders to address environmental and regulatory concerns, community engagement to ensure the support and cooperation of the local fishing community, and substantial infrastructure developments will be crucial. At the existing levels of infrastructure, the port can potentially only act as a hub for crew-transfer operations using CTVs for daily monitoring activities which do not require significant port facilities and can be accommodated in the existing fishing harbour.

Summary of suitability of seaports in Southern Tamil Nadu for potential development as OSW enabled ports

Tuticorin Port is highly suitable for both construction and O&M activities due to its advanced infrastructure and strategic location in close vicinity to several identified OSW zones. It boasts well-developed facilities capable of handling heavy and over-dimensional cargo and has existing experience in handling wind turbine components. However, it requires careful logistical planning to avoid delays and additional costs.

Kudankulam Port is potentially suitable for O&M activities, leveraging existing infrastructure developed for the Kudankulam Nuclear Power Project. Its strengths include proximity to OSW sites and existing facilities for heavy and over-dimensional cargo. Nonetheless, it faces security and regulatory concerns due to the nearby nuclear facility and requires substantial investment for further development as a key hub for O&M activities with adequate facilities at the port to handle OSW SOVs.

Udangudi Port is an emerging port that has the potential to be developed as an O&M port due to planned infrastructure associated with the Udangudi Thermal Power Project. It benefits from a strategic location near OSW sites and potential synergy with thermal power project infrastructure. However, it needs significant investment and detailed planning to handle complex O&M activities.

Chinnamuttom Fishing Harbour can support day-to-day O&M operations with additional minimal infrastructure development. Its strengths lie in its proximity to OSW zones and recent expansions under the 'Sagarmala' program. The challenges include limited space and the need for cooperation from the local fishing community.

The Colachel port offers potential for OSW O&M activities with substantial investment and development. It has a strategic coastal location, proximity to OSW sites and shipping lanes, and natural deep waters. However, the existing infrastructure is focused on fishing, necessitating significant investment and port development activities including addressing the local community and environmental concerns. Also, Colachel port lacks adequate road connectivity and is more than 50 km away from OSW zones except B and G.

Countries such as Scotland are strategizing to develop infrastructure and supporting systems for a cluster of ports in order to support 40GW+ pipeline of projects. To successfully support the initial 5 GW and future OSW capacity, Tamil Nadu must prioritize strategic upgradation of its ports to develop a cluster of ports enabled for handling OSW activities around Tuticorin port, which is by far the most developed port and stands ready for immediate OSW construction albeit with minor upgrades and development of OSW specific facilities.

Many of the large components required for both fixed and floating wind projects will have to be manufactured near port facilities and these manufacturing opportunities will need to be matched to existing port infrastructure developments. Other port sites will have to be expanded to meet the requirements of such OSW component manufacturing and especially for the largest of these components, the substructures required for floating wind. Significant investment in a number of port sites will be required to deliver and the Collaborative Framework's aim is to match industry and public funding to accelerate these port infrastructure projects.

While Udangudi and Kudankulam present opportunities with further development, only Kudankulam is close enough to most of the OSW zones to be developed as a viable O&M hub. Chinnamuttom and Colachel ports require significant investment and community engagement to become viable O&M ports for OSW sector. Coordinated efforts among state departments, port authorities, and stakeholders are crucial to address port infrastructure gaps, regulatory requirements, and environmental impacts, ensuring the efficient and sustainable growth of OSW projects in Tamil Nadu.

5.6 Grid Infrastructure for OSW Energy Integration

As part of its ambitious energy transition and net-zero goals, India announced at the 26th Conference of Parties (COP26) at Glasgow in 2021 its commitment to have 500 GW non-fossil energy capacity in place by 2030 (PIB, Govt. of India, 2021). The Central Electricity Authority (CEA) has recognized the need to ensure commensurate transmission infrastructure requirements are in place to accommodate the anticipated volumes of renewable power. Tuticorin and Karur region in Tamil Nadu have been designated as potential renewable energy zones by the CEA for transmission system planning owing to their high potential for solar and wind energy projects.

As part of the Green Energy Corridor (GEC) Phase I scheme of Ministry of Power, the Tuticorin Pooling Station (PS)[8] with a rated voltage of 765 kV/400 kV, currently charged at 400 kW/230 kV, was developed by POWERGRID as an Air Insulated Substation (AIS) near Ettayapuram, Tuticorin district, Tamil Nadu. POWERGRID has also deployed another Pooling Station as a Gas Insulated Substation (GIS), the Tuticorin-II PS, interconnected with the Tuticorin PS located around 12 km away through 400 kV 2xD/c (quad) lines. These pooling stations are aimed at facilitating interstate transmission system (ISTS) interconnection of RE power projects in the region and transfer of the green power to beneficiaries in the Tirunelveli region of Tamil Nadu.

As part of this transmission network planning, CEA has considered deployment of 5 GW of OSW power by 2030 along the coastal region of southern districts Tuticorin, Tirunelveli and Kanyakumari in Tamil Nadu. The OSW power will be connected to the existing ISTS network in the Tuticorin and Tirunelveli region and additional infrastructure required will be developed with funding assistance from the central government and multilateral agencies.

The additional grid infrastructure required for ISTS interconnection of OSW projects includes a 12 X 500 MVA capacity onshore pooling station with rated voltage of 400/230 kV, which is proposed to be developed near Avaraikulam, Tirunelveli district along with offshore substations with cumulative capacity of 5 GW for interconnection of the offshore wind turbine generators to be developed in the OSW zones B and G. The Avaraikulam pooling station will be connected via 400 kV d/c lines to the existing 765/400 kV rated ISTS pooling stations near Pugalur, Karur

[8]**Pooling Station:** The substation where pooling of generation of individual wind generators or solar generators is done for interfacing with the next higher voltage level substation. This shall be the first interface point with DISCOM/STU/CTU network (CERC, 2013)

district and Ettayapuram, Tuticorin district. Figure 15 shows the transmission network planning by CTU for OSW in Tamil Nadu.

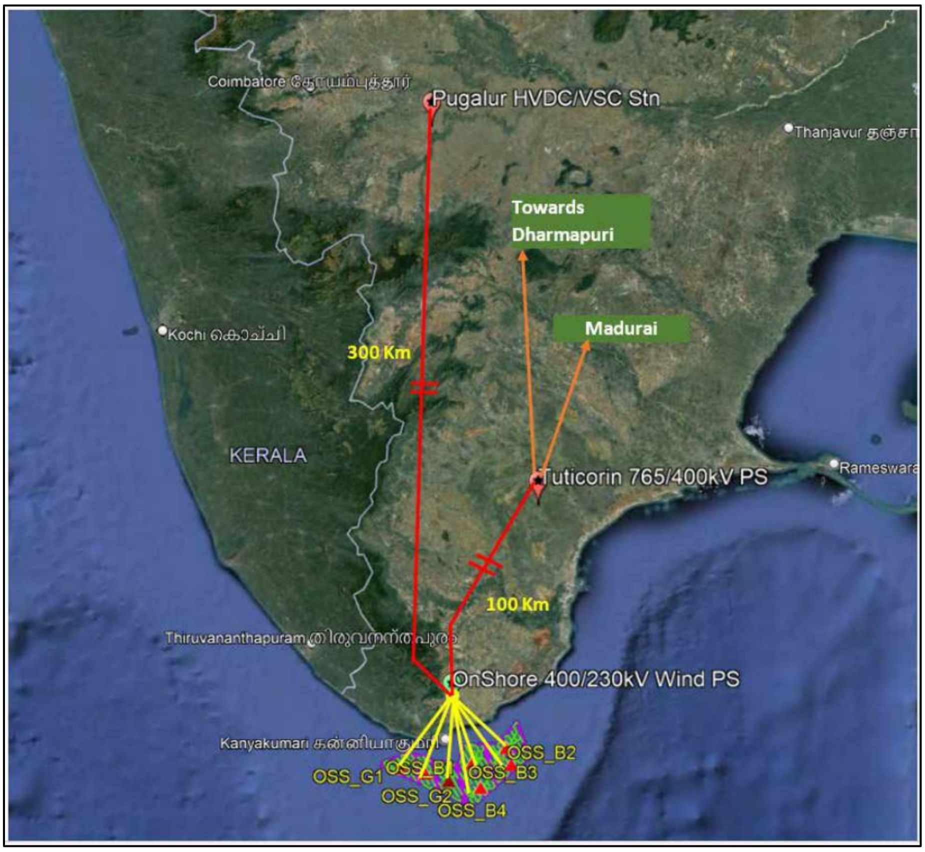


Figure 24: Transmission Network (CTU) Planning for OSW in Tamil Nadu

Source: Central Electricity Authority

Along with the central government's planning for developing the CTU network, Tamil Nadu can also develop the state transmission unit (STU) network connected to ISTS network to enable utilisation of OSW power within Tamil Nadu state. Intra-state network augmentation planned by TANTRANSCO in the region, through augmentation of substations at Ottapidaram, Udangudi and Sagarengapuram to handle 400 kV/230 kV connected by a 400 kV HVDC transmission line, will enable offtake of offshore wind power.

Further, as the offshore wind power market becomes mature in Tamil Nadu, the state government can also plan specifically for infrastructure such as offshore substations and dedicated network for OSW power. Overall, for the effective transmission of OSW power, long term planning shall be essential, with specific investment plans.

5.7 Skill Requirements and Employment Opportunities

As per the IEA's World Energy Employment Report, 2022, the wind power sector employed 1.2 million people in both onshore and offshore wind projects, wherein about 210,000 jobs were in the offshore wind sector, primarily in Europe and China. India's onshore wind industry has witnessed significant growth, with about 44 GW installed capacity as of mid-2023, and has a robust supply chain and expertise in place for project planning, design, manufacturing, logistics installation, operations, and maintenance. However, the offshore wind industry requires additional specific skill sets that differ from onshore renewable solutions. Thereby, given the anticipated trajectory of OSW power in the country and Tamil Nadu, a workforce with specialised skill sets will be needed to build, commission, operate and maintain OSW projects. This also presents a greater opportunity for developing regional technical capabilities and potential for socio-economic growth at the state and national level.

OSW projects encompass sectors and stakeholders that operate on-shore as well as off-shore. They require a well-established industrial ecosystem including local equipment manufacturers, skilled labourers, technicians and professionals to successfully deliver and operate projects on-ground. This section provides information on key aspects of the OSW value chain and the opportunities in terms of employment and skills.

The following table highlights the key phases of typical offshore wind project development cycle and the relevant activities and skills required.

Table 17: Skillsets requirements across OSW project cycle

Project Planning
Development and Project Management • Project development, liaisoning, and approvals from concerned authorities • Marine environmental surveys, wildlife surveys, wind resource assessment, geo-technical and geo-physical surveys, environmental impact assessments • Application of GIS, data analytics, and other relevant tools • Project financing and modeling, risk assessment and mitigation • Understanding of power market including exchanges, third party sale, grid infrastructure assessment, intra and, interstate and national level regulations and policies • Project consultancy and management for data collection, analysis and reporting
Component Manufacturing
Wind turbine component manufacturing and assembly (mainly - blades, towers, and nacelles) • Expertise in material engineering, equipment/component manufacturing, understanding of relevant product standards and testing and quality assurance • Design and draughtsmanship capability for detailed component designs and CNC machine operators, heat treatment, sheet-metal and press operators • Capital goods and heavy duty engineering, process control, equipment handling, and management • Operators and Engineers in managing rotor blade manufacturing • Experts in localization of the immersed submarine foundation and implementing different types of offshore foundations such as jacket, floating and monopile • Experts in executing the foundations
Supply Chain and Logistics

• Expertise in supply chain management, procurement and associated logistics • Expertise in building access ways, storage yards, operation and maintenance berths • Development of suitable transport vehicles and accessories to handle large sized wind turbines and components
Offshore Wind Project Construction Phase
Onshore Infrastructure including ports, grid infrastructure, and ancillary services • Civil and mechanical works at the port, loading, unloading, and assembling and dis-assembling of components. • Fabrication and machine work including welding, offshore submarine welding, fabrication, galvanizing/ coating/ painting, and quality control of these processes. • Design and construction of offshore substations, export cable laying, and power evacuation works. • Foundation expertise with structural engineering, rigger for safe lifting and movements of large structures. • Environment, Health & Safety (EHS) expertise for onshore and offshore operations
Submarine operations and offshore activities • Inter-array cable laying, offshore substation installation including HT feeder, switchgear and relevant safety equipment. Cable jointing, termination and testing. • Fiber-optic communication cable laying and testing, and cable protection expertise. Expertise in remotely operated vehicles (ROVs) for submarine inspections for cable laying and relevant activities • Operating robotic machines in submarine environment including activities such as part welding and fixing of turbine tower to the foundation • Jack ship maneuvering and crane operations, ship and vessel operators and related marine engineering work and maintenance. Guard vessel operators and management for safe and efficient offshore operations. • Wind turbine assembly and installation work at offshore foundation • Training and expertise for executing operations for extended time period including long-term stay at offshore service stations • Lighting and Navigation for safe and guided movement of goods and personnel • Expertise in oil spill clean-up operations to restrict sea pollution. Emergency cleanup operations including techniques such as burning, dispersion, or skimming as suitable.
Operation and Maintenance Phase
Offshore wind farm operations and maintenance: • Warehouse and inventory management with an understanding of the Offshore wind operations and requirements • Control room engineers to monitor and manage offshore wind farm operations • SCADA development and data analytics expertise for OSW plant troubleshooting and improving plant performance. Communication network operations expertise • Expertise in OSW plant decommissioning, component removal, repair, refit, and maintenance using port facilities.

• Turbine blade inspection and onsite repair through manual intervention or unmanned aerial vehicles. Expertise in electrical and mechanical faults troubleshooting, inspection and maintenance at the farm or on the turbine. • Regular maintenance activities for equipment such as cranes, personnel lifts, component lifting equipment, fire and safety equipment, among others. Foundation cleaning. Vessels' operation and maintenance.
Financing and Risk Mitigation: Project due diligence and certified project financing experts having RE project experience considering the risks involved
Miscellaneous services: Offshore wind plant related insurance, legal and other relevant services

Given the activities and expertise required for the development of OSW projects, it is essential to understand that many of the skillsets highlighted in the table above are highly transferable with upskilling. For instance, workforce from the Oil and Gas industry that handles offshore operations and operates cranes for off-shore operations can be employed in OSW projects with relatively low efforts. Similarly, the workforce involved in logistics, ports, and warehousing is suitable for OSW projects.

5.7.1 Potential Employment Benefits in Tamil Nadu

This section provides an overview of employment opportunities, considering the different phases of OSW project development cycle that span across multiple years and in the context of Tamil Nadu's existing industrial expertise of SME manufacturing, supply chain and labour inputs.

To estimate potential direct employment opportunities that can result from OSW in Tamil Nadu, baseline assumptions are informed from a study undertaken by the Danish government agency for the French OSW market (Ministry Of Foreign Affairs, Denmark, 2023). This reference study primarily takes into account IRENA's assessment (IRENA, 2018), where only direct job opportunities are estimated and does not include indirect jobs that emerged due to allied economic activities in the value chain. It provides full-time employment equivalent (FTE) estimates for development of a 1 GW OSW project using fixed foundation, which is the technology expected to be used in initial OSW projects in India and is thereby used as a basis (see Table 18). As per the study, OSW projects with floating foundations require about twice the workforce needed for projects with fixed foundations, consequently leading to more employment opportunities as the OSW market in state evolves and transitions to advanced technology.

Thereby, anticipated future OSW installations for Tamil Nadu, can potentially bring employ 42,570 persons by 2032 for the initial 4.5 GW uptake, 230,824 persons by 2037, and rising up to 599,764 full-time jobs by 2047 (refer to Table 18 for details).

Table 18: Employment opportunities for 1 GW OSW project

Employment opportunities for 1 GW OSW project with fixed foundation, FY 2022	
Employment category	**Full-time employment (FTE) potential**
Project design and planning	130
Wind turbine manufacturing and balance of plant components	5,280
Offshore wind farm construction	1,000
Operation and Maintenance	2,640
Decommissioning	410
Total	**9,460**

Source: Ministry of Foreign Affairs, Denmark

While the employment opportunities shown are based on the global experiences, it is important to note that the OSW market is still at a nascent stage in India, wherein the components and technology know-how possibly will be sourced from international markets in the near-term. Regulations on domestic content, wherein project developers are required to utilise locally manufactured goods and services, may come in place in a gradual progressive manner. Accurate employment opportunities need to be assessed considering India’s labour input statistics and multipliers. It is also to be noted that considering technological advancements and productivity improvements, FTE per unit of installation intend to reduce gradually.

5.8 Readiness Assessment for upcoming 4 GW of OSW Development in Tamil Nadu

The early-stage development of OSW projects off the coast of Tamil Nadu is imminent, with the tender for 4 GW of OSW development floated by SECI in February 2024. Thereby, it is important to assess the suitability of conditions in Tamil Nadu for such early-stage development and better understand areas where actions are required to improve the conditions.

A readiness assessment has been undertaken in this section to understand where the state stands to support and realize the initial 4 GW of OSW projects that are in the pipeline through the recent SECI tender. This readiness matrix, presented in Table 19, provides a structured evaluation of key parameters essential for the successful implementation of OSW projects. Each parameter is assessed across three stages—Early Stage, Partially Developed, and Developed—reflecting the current level of preparedness and identifying areas that require further development. This matrix serves as a strategic tool to guide project stakeholders in prioritizing actions and resources to ensure the efficient and timely execution of OSW projects.

Readiness Scale	Early Stage	Partially Developed	Developed
	Early stages of development	Partially developed, with some foundational elements in place	Well-developed and largely ready for project implementation

Table 19: Readiness Assessment for the Initial 4 GW OSW Development in Tamil Nadu

Parameters	Early Stage	Partially Developed	Developed	Key Aspects
Governance, Policy, and Regulatory Framework				
Governance and Institutional Framework				Coordination between central and state governments, as well as among various regulatory bodies, is crucial to streamline processes and reduce bureaucratic hurdles. While the NIWE serves as the nodal agency for OSW development at the national level and a specialized task force has been established to coordinate OSW development at the state level, but it still needs to be fully operationalized to provide effective support and enhance collaboration with stakeholders across multiple levels of governance.
Policy & Regulatory Framework				While national level policies, guidelines and strategic documents such as MNRE's strategy paper for OSW establishment do exist, there is a need for a comprehensive policy framework dedicated to OSW at the state level to promote OSW power offtake, provide financial incentive and stimulate early-stage development and investments. Notably, GoI has provided ISTS charges and Additional Surcharge waiver for OSW projects commissioned on or before 31st December 2032.
Implementation Planning and Resource Assessment				
Streamlined Implementation Process				Applicable clearances from various Central/State Ministries/Departments with responsibilities of the bidder and NIWE is well defined in the RFP document.

Parameters	Early Stage	Partially Developed	Developed	Key Aspects
Site Identification and Resource Assessment				NIWE has identified potential sites with high wind potential off the Tamil Nadu coast. Preliminary wind resource assessments and geotechnical surveys have been conducted. However, detailed resource assessments and environmental and social impact studies are needed.
Infrastructure and Supply Chain Readiness				
Supply Chain and Local Manufacturing				Though Tamil Nadu has a matured onshore wind industry and supply chain, but offshore wind requires specialized equipment, including turbines, foundations, and installation vessels, which are not yet fully developed in India. In the short term, reliance on imported components will be necessary to meet the project timelines.
Port Infrastructure				Tamil Nadu's port infrastructure, is currently not fully equipped to handle the specific demands of OSW projects. Handling large and heavy components such as turbine blades, nacelles, and towers requires specialized infrastructure, which is limited at present. In April, 2024, the Union Shipping Ministry announced development of an OSW terminal at VOC Port in Thoothukudi. Also minor ports like Udangudi and Kudankulam will be crucial for the O&M of OSW projects, offering logistical support, storage, and handling of maintenance equipment.
Grid Connectivity and Infrastructure				OSW will require significant upgrades and new infrastructure, including grid substations, and integration with the state's transmission network. The Central Electricity Authority has already mapped development of 5 GW transmission network development by 2030 in Tamil Nadu.
Demand for OSW Offtake				

Parameters	Early Stage	Partially Developed	Developed	Key Aspects
Offtake Assurance				The responsibility for securing offtake agreements has been delegated to the bidders/developers. Developers are required to independently arrange for the sale of the generated electricity, often through open access mechanisms.
Technical Capability and Workforce Preparedness				
Technical Expertise and Workforce Development				Offshore wind requires specialized skills in marine engineering, offshore construction, and operations with the Indian workforce lacking such experience and expertise. While India has a solid foundation in wind energy expertise, the transition to offshore wind requires further development of specialized skills.Targeted training and capacity-building initiatives are needed to develop the workforce for offshore wind. For the early stage development of OSW projects, developers must address technical knowledge gaps through strategic collaborations with international private sector companies along with experts to acquire the necessary skills and expertise for successful implementation.
Investment Readiness				
Project Financing				OSW projects are highly capital-intensive, requiring substantial upfront investment. Securing project financing remains a significant challenge, particularly in a market where OSW is relatively nascent. There is a lack of established financial models tailored to the unique risks and rewards of offshore wind in India.
Stakeholder and Community Engagement				

Parameters	Early Stage	Partially Developed	Developed	Key Aspects
Stakeholder Engagement and Community Involvement				Stakeholder engagement, particularly with local communities and industries, is in the early stages. Fishermen, coastal residents, and local governments are key stakeholders who need to be consulted. Community involvement is critical for the success of the project, and more comprehensive engagement strategies are needed to address local concerns.

6 Strategies and Recommendations to Support Offshore Wind Development in Tamil Nadu

Summary:

This chapter outlines a comprehensive set of strategies and recommendations covering various critical aspects, including policy and regulatory frameworks, governance structures, supply chain development, technology and innovation, finance, skill and capacity building, and stakeholder engagement, aimed at fostering the sustained development of OSW energy in Tamil Nadu. Given the nascent state of OSW development, a robust policy and regulatory framework are essential to integrate OSW energy into state's long-term energy planning and implementation. This involves establishing and operationalising a dedicated state-level nodal agency to streamline governance and facilitate coordination among various stakeholders, including government bodies, developers, and local communities to help in simplifying regulatory processes, expediting project approvals, and ensuring the timely implementation of OSW projects. Additionally, developing financial incentives and support mechanisms, such as production-linked incentives and tax rebates, is crucial to attract investments and reduce the financial risks associated with early-stage OSW projects.

Enhancing the local supply chain and fostering innovation in OSW technology are also vital components of the recommended strategies. This includes investing in infrastructure upgrades at strategic ports, developing specialized training programs to upskill the workforce, and promoting research and development to address technical and operational challenges. Engaging with local communities and stakeholders through transparent communication and consultation processes is equally important to build trust, address concerns, and ensure the successful integration of OSW projects into the state's socio-economic landscape. By implementing these comprehensive recommendations, Tamil Nadu can position itself as a leader in the OSW energy sector, contributing to sustainable development and economic growth.

6. Strategies and Recommendations to Support Offshore Wind Development in Tamil Nadu

An assessment of the OSW trajectory, offtake opportunities, investment potential, existing policy and regulatory landscape, and readiness of the existing ecosystem and infrastructure was carried out in the previous chapters. Informed by this assessment, strategies and recommendations are suggested in this chapter to support sustained development of the OSW energy sector in Tamil Nadu. The recommendations address key aspects including policy and regulatory framework, governance and institutional framework, demand creation, supply chain, technology and innovation, finance, skill and capacity building, and stakeholder engagement.

6.1 Enabling Strategies to Support Offshore Wind

The key strategies to enable proliferation of OSW in Tamil Nadu, along with an indicative implementation framework, are presented below. A list of recommendations for each thematic area follows. The recommendations address various challenges and opportunities envisaged while developing the OSW energy sector, sustained by a robust local ecosystem including auxiliary industries, skilled personnel and increasing demand for OSW energy owing to right market, policy and regulatory signals.

I. Integration of Offshore Wind in Energy Planning, Policy and Regulatory Frameworks:
For offshore wind energy to contribute significantly to the energy mix, its integration into state and national energy planning, policy and regulatory frameworks is essential.

The integration of offshore wind energy into Tamil Nadu's energy planning, policy and regulatory frameworks is a strategic imperative. This will help to harness the state's significant OSW potential and to meet its growing energy demands through diversified clean energy resources. The state's long-term power system planning necessitates diversification of its energy mix, reducing dependence on conventional fossil fuels, and addressing the challenges of energy access, affordability, and environmental sustainability (NREL, 2021). OSW can complement the existing renewable energy efforts especially on higher integration of solar power into the grid and can stimulate economic growth in the relatively less developed Southern coastal region of the state, where the immense potential for OSW exists, by fostering technological advancements, industrial development and job creation.

Sustained deployment of OSW projects in Tamil Nadu requires addressing several technical and logistical challenges, including inadequate road facilities, port development and electricity grid capabilities. Regulatory complexities can arise from the necessity to integrate intermittent wind power into the grid while ensuring stability. The environmental considerations, high capital requirements and financing hurdles further complicate the feasibility and execution of OSW projects in the region. Developing a robust policy and regulatory framework is crucial to overcoming these obstacles, supporting the transition towards a low-carbon economy, enhancing energy security, and fostering economic development within the state.

Input	Activity	Expected Output	Anticipated Impact
Strategic Planning: Assess OSW resource potential, environmental impacts, grid integration capabilities, and economic feasibility, informing realistic and ambitious OSW targets	Coordinate with energy regulators and policymakers to update existing frameworks and policies to explicitly include targets and incentives for OSW energy. This involves incorporating OSW renewable purchase obligations (RPOs)	A policy environment that fully supports and promotes the development of OSW energy as a key component of the renewable energy portfolio in Tamil Nadu and a robust local ecosystem to support it in the long-term	Accelerated deployment of OSW projects and supporting the transition towards a sustainable and diversified energy mix.

II. Establishment and Operationalization of a Dedicated State-level Nodal Agency for OSW Development

The complexity and multi-disciplinary nature of OSW projects necessitate a streamlined and

The need for establishing and operationalizing a dedicated nodal agency for OSW development at the state level stems from the complex regulatory and operational landscape of OSW projects. These projects are inherently multi-dimensional, involving technical, environmental, and socio-economic considerations. This necessitates permissions and approvals from various central government ministries, and agencies, such as the Ministry of Ports, Shipping and Waterways, Ministry of Defence, Ministry of Civil Aviation, Ministry of Fisheries, and Ministry of Environment, Forests and Climate Change, among others.

OSW projects also require several regulatory and environmental clearances from state level departments and agencies such as the TNERC, TANGEDCO, Tamil Nadu Coastal Zone Management Authority, and Tamil Nadu Pollution Control Board. Notably, several approvals from the central agencies are streamlined with recommendations and clearances from state level counterparts. Each of the departments or agencies, both at the central and state level, have their own set of regulations and concerns, ranging from navigational safety and national security to protection of environment and fishermen's livelihoods. Obtaining approvals from the multitude of agencies and stakeholders could be challenging at times, given the potential for overlapping jurisdictions and the diversity of concerns that need to be addressed.

NIWE serves as the nodal agency for OSW development at the national level and a state-level task force has been established for state-level coordination. However, the challenges noted above underscore the necessity to fully operationalize a dedicated state-level entity that can support NIWE on aspects such as procurement, streamlining the approval process, and navigating the regulatory landscape of Government of Tamil Nadu. This will ensure that OSW projects are developed in a timely and environmentally sustainable manner, similar to the strategic approach adopted by the Government of Tamil Nadu for development of Chennai Metro Rail. The Government of Tamil Nadu created a SPV, Chennai Metro Rail Limited, a joint venture between the Government of India and the Government of Tamil Nadu.

The primary objectives of such a state-level nodal agency for OSW would be to:

- Simplify and expedite the regulatory processes for OSW projects in the state
- Serve as the point of contact for investors, developers, and other stakeholders
- Facilitate approvals and clearances for developers from central and state level agencies
- Drive policy development and implementation tailored to the unique needs and opportunities of the OSW sector
- Facilitate synchronization of OSW development activities between ports, marine services and other stakeholders
- Facilitate research and development efforts in OSW technology and practices
- Promote skill development and capacity building within the sector
- Collaboration with stakeholders to develop a local ecosystem of auxiliary industries and services for OSW activities
- Coordinate with state level agencies in Gujarat and relevant national stakeholders to foster knowledge sharing and cross learning on experiences from early-stage OSW projects in Gujarat and Tamil Nadu.

Activity	Expected Output	Anticipated Impact
• Establish a state-level nodal agency to provide support on local coordination, decision-making, approvals, stakeholder engagement. Clearly define its roles and responsibilities	• Identifying potential OSW sites, conducting feasibility studies, and managing the allocation of sites to developers through transparent bidding processes. • Primary liaison between government, OSW developers, grid operators, port authorities, financial institutions, and local communities. • Facilitation of approvals & clearances from multiple stakeholder departments • R&D and Innovation Support	• Enhanced investor confidence leading to increased domestic and international investments in OSW projects • Accelerated Project Development • Significant contribution to Tamil Nadu's renewable energy targets • Cross learning from OSW experiences between Gujarat and Tamil Nadu

III. Local Demand Creation for Offshore Wind Energy:

A strategic approach to demand creation such as green hydrogen production through OSW power, powering electric vehicle charging stations through renewables, and creating national level RPOs for offshore wind ensures stable market growth, encouraging continuous investment and development in the sector.

Adopting a comprehensive approach to demand creation that includes the high-opportunity Commercial and Industrial (C&I) sector, emerging end-uses like green hydrogen production and charging of electric vehicles, and establishing long-term RPOs for offshore wind, will help advance OSW sector in Tamil Nadu. Green hydrogen production represents a significant opportunity for creating demand for OSW energy. Countries like Netherlands are investing in green hydrogen as a storage solution to store and use renewable energy. Tamil Nadu, with its considerable OSW potential, could pioneer green hydrogen production facilities powered by OSW, establishing a new industry that enhances the viability and demand for OSW energy.

Notably, consultations with stakeholders, including TIDCO, have highlighted the development of a proposed hydrogen cluster in the Tuticorin region of Tamil Nadu. As per GWEC Roadmap on Wind Energy, Tamil Nadu will require 5 GW of renewable energy dedicated for Green Hydrogen production, considering Tamil Nadu will meet around 10% of India's projected hydrogen demand of 10 MT by 2030 through green hydrogen production (GWEC, 2022). With its higher capacity factor and large power outputs, offshore wind is able to deliver significantly high volumes of energy to meet the substantial electricity input required for green hydrogen production.

The analysis on offtake of OSW power, presented in section 5.3, underscores its potential benefits for the State DISCOM and HT Commercial & Industrial consumers. Also, from a nationwide perspective, OSW power presents significant opportunities across various sectors in India. It supports the expanding manufacturing sector by providing reliable and sustainable energy, meets the increasing electricity demand from EVs as adoption rates surge, and enhances cross-border electricity transactions while strengthening grid operations through integrated renewable energy sources.

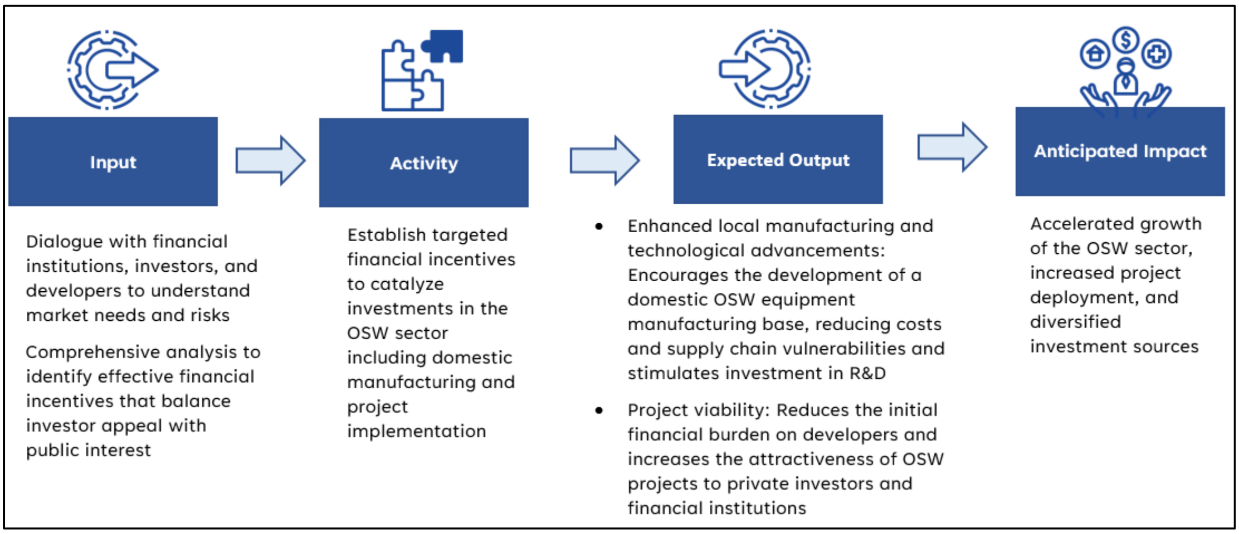
Input	Activity	Expected Output	Anticipated Impact
Analysis of potential demand sectors, including large C&I consumers, and innovative uses like green hydrogen production, charging of EVs, certainty of power offtake including long term Power purchase Agreements (PPA), Market competitiveness and long-term energy demand Evaluate mandates, attractive pricing models and incentives for green energy adoption among large consumers	Evaluating policies and market demand to foster a robust and enduring demand for OSW energy	Sustainable demand for OSW energy, characterized by committed off-take agreements and a broad base of energy consumers participating in green energy initiatives.	Stabilization of the market for OSW, incentivization of further investments in the sector, and acceleration towards achieving Tamil Nadu's renewable energy targets.

IV. Financial Incentive Schemes to Catalyse Investments

Design and implement financial incentives that enhance the economic viability of OSW projects, especially in early-stage development

Financial incentives are pivotal for reducing the investment risk and enhancing the financial viability of OSW projects, especially in early-stage developments. By reducing upfront costs and ensuring competitive returns, such schemes can attract a broader spectrum of investors and developers to the OSW sector. Examples such as the production linked Incentive scheme, generation based incentives, tax rebates, and viability gap funding have demonstrated success in other RE sectors and can be tailored to meet the unique needs of OSW projects in Tamil Nadu.

Potential capital investments of INR 934 billion are expected to deliver 4.5 GW capacity in the state by 2032, further rising up to as much as INR 10,273 for 63 GW capacity by 2047 (see section 5.4 for further details). The Government of Tamil Nadu can facilitate investments including from foreign direct investments from global OSW developers through dedicated platforms and events like the Tamil Nadu Global Investors Meet and Tamil Nadu Climate Summit.

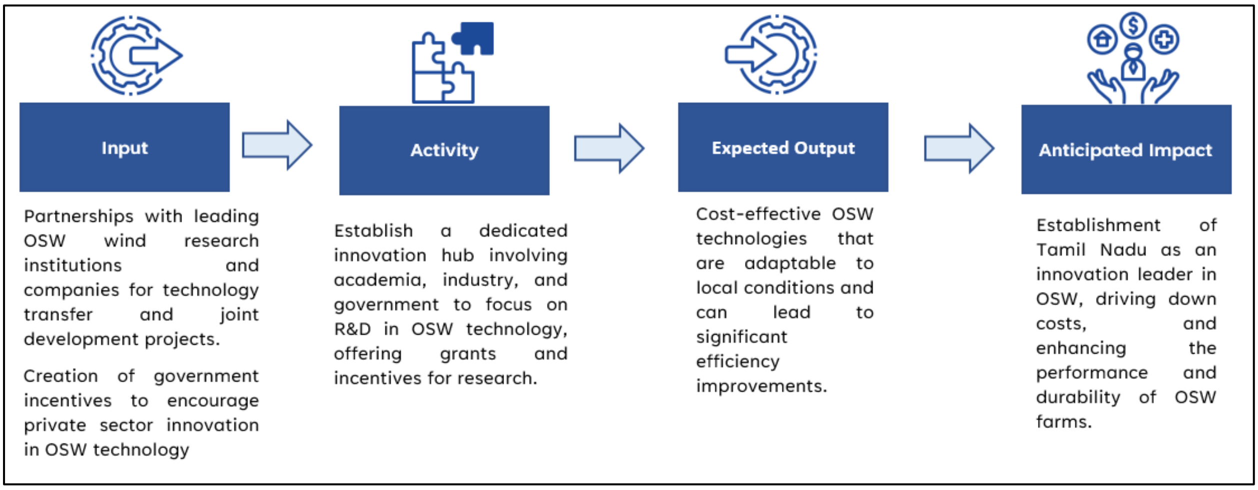


V. Innovation-Driven Approach to Offshore Wind Technology

The dynamic nature of offshore environments demands continuous innovation (research and development) to improve efficiency, resilience, and cost-effectiveness.

The imperative for an innovation-driven approach in OSW technology emerges from the complex challenges and unique opportunities presented by the marine environment, alongside the global mandate for sustainable and renewable energy sources. This approach not only aims to enhance the efficiency and output of OSW farms but also to make offshore wind a more competitive and reliable energy source.

By fostering advancements in turbine design, foundation technologies, installation methods, and digital integration, innovation can address technical barriers and operational efficiencies, thereby ensuring the viability and scalability of OSW projects in diverse marine conditions.

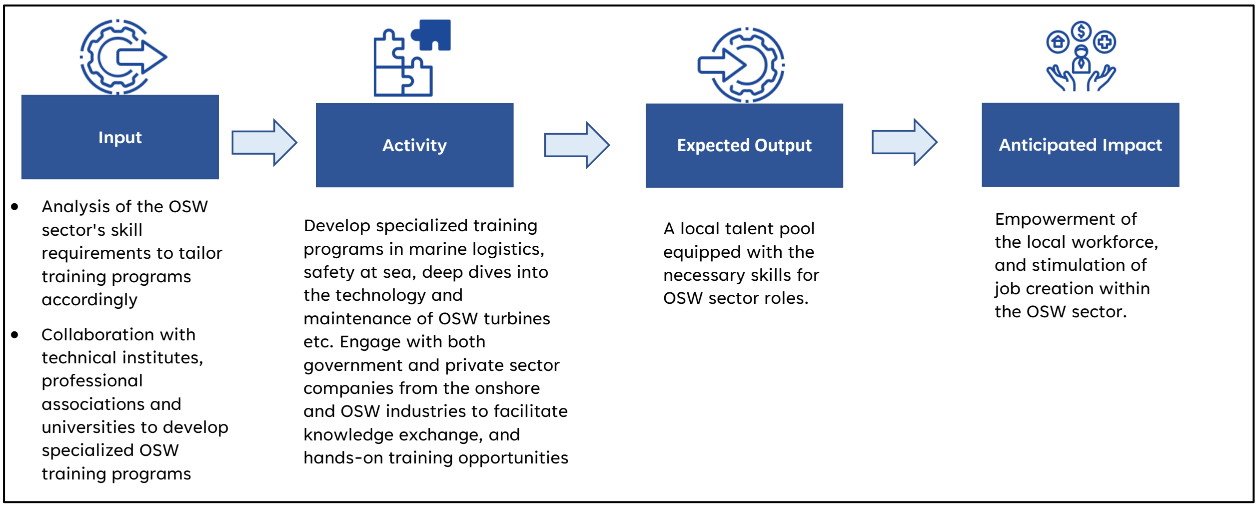


VI. Capacity Building and Up/Reskilling through targeted training programs

By building a skilled local workforce, the state not only enhances its competitiveness in the offshore wind market but also contributes to job creation, sustainable economic development and fosters OSW deployments.

Installation of the OSW wind farms require specialized skill sets compared to other sectors, including the erection of turbines, assembling, and transporting materials (which require specialized equipment). The transition towards a more substantial OSW capacity necessitates a concerted effort in capacity building and local workforce development, integrating the valuable insights and technical skills of professionals from the existing onshore wind sector. In the near term, OSW projects of 4.5 GW capacity in the state are estimated to require a workforce of over 40,000 full-time employees by 2032, with additional OSW installations thereafter driving a multi-fold increase in employment opportunities (200,000+ FTE jobs by 2037) (see section 5.7.1 for further details).

The transition from onshore to offshore wind projects involves unique challenges, including marine operations, deeper technical complexity, and stricter safety protocols. To bridge this skill gap, targeted training programs must be designed to upskill onshore wind professionals and technicians for OSW deployments. Migration of skilled personnel from related fields such as oil and gas industry with extensive maritime experience can be targeted for OSW related trainings to bridge knowledge gaps between onshore and offshore wind industry.



6.2 Key Recommendations

This section offers a comprehensive list of recommendations across thematic areas: Governance and Institutional Framework, Policy and Regulatory Framework, Technology and Supply Chain Development, Finance and Investments, Skill and Capacity building, and Stakeholder Engagement.

6.2.1 Governance and Institutional Framework

Due to the large scale of OSW projects, associated technological complexities, and substantial pre-construction investments required, they often face significantly higher investment risks. These risks stem from the complexity involved in planning and developing an offshore wind farm, the engineering rigour and technology involved, and coordination between multitude of stakeholders across the energy and maritime infrastructure value chain which can lead to unforeseen technical difficulties and delays. Any such delays can further magnify the financial uncertainties of OSW projects that require appreciable upfront capital even for planning, permitting, and preliminary infrastructure development.

Therefore, OSW energy development in Tamil Nadu necessitates a coordinated approach to the development of supporting infrastructure and auxiliary industries for OSW project development, regulatory and environmental compliance, stakeholder and community engagement, and the synchronisation of ports, terminals, and marine support services that is crucial to ensure the efficient and timely delivery of equipment, materials, and personnel required for the construction, operation, and maintenance of OSW farms.

A coordinated approach to the OSW development process necessitates development of a centralized single-window clearance system hosted by a nodal agency, preferably, a state level entity dedicated to OSW development. Although NIWE is designated as the nodal agency at the national level to facilitate OSW development in the country, the presence of a dedicated state-level institution can lend much needed operational support and capacity to collaborate with various stakeholders across multiple levels of governance.

Thus, Government of Tamil Nadu should strive to establish a special purpose vehicle (SPV) as a joint venture between MNRE, Government of India, (represented by NIWE) that takes charge of the procurement, development, and construction of OSW power projects in the state in collaboration with NIWE. This intervention will provide a key strategic push for enhanced coordination and support to OSW in the state as it has done in the transport sector through the Chennai Metro Rail Limited. This dedicated agency, acting as the nodal entity for OSW energy development in Tamil Nadu, will benefit from having procurement capabilities such as SECI to be able to support developing OSW farms and enabling power infrastructure such as energy storage in Tamil Nadu. TNGECL, the proposed nodal agency in the state for proliferation of non-conventional energy sources can be the joint venture partner to NIWE as a representative of the Government of Tamil Nadu.

Notably, many of the older low-capacity onshore wind plants in the region are in the last stages of their life cycle or becoming obsolete and will be replaced with new high-capacity wind towers adding to the increased generation of intermittent wind power in the region. The dedicated agency can partner with local DISCOM or CTU to develop energy storage solutions or procure energy storage plants to support both onshore and offshore wind project developers to enhance the reliability of renewable power generated by their assets.

The dedicated nodal agency should also coordinate with nodal industrial agencies in the state such as the Tamil Nadu Industrial Development Corporation Limited (TIDCO) and Tamil Nadu Infra Industrial Investment Corporation (TIIIC) to secure funding and develop supporting infrastructure and service industries required to cater to the operational needs of OSW farms and future expansion of the projects. The agency should also encourage collaboration between the government and private sector under PPP models for funding and development of the infrastructure required.

Key aspects of OSW energy development where the dedicated agency or SPV can take on coordinated efforts and specific roles include:

Strategic Planning and Collaboration:

- NIWE serves as the nodal agency for OSW development at the national level and a specialized task force has been established to coordinate OSW development at the state level. It is suggested that this Task Force should be fully operationalized and should includes representatives from the Port Trust Boards, Tamil Nadu Maritime Board, OSW project developers, TANGEDCO, TIDCO and relevant government bodies to enhance coordination and expedite project timelines by ensuring that all regulatory, logistical, and technical aspects of OSW projects are addressed promptly and efficiently.
- Establishing Memorandum of Understanding (MoU) between the Port Trust and OSW project developers to outline roles, responsibilities, and collaboration frameworks.
- Drafting comprehensive Contractual Agreements for port development and construction activities to ensure alignment with OSW project phases by clearly defining the timelines, milestones, and penalties involved.
- Evaluating the port infrastructure through feasibility studies and assessments to identify existing strengths and capabilities, and to determine OSW project specific upgrade requirements.

- Identifying optimal locations for substations, cable routes, and grid connection points through joint feasibility studies with TANGEDCO.

Regulatory and Environmental Compliance:

- Employing technical experts to conduct comprehensive EIAs to minimise the environmental impact of port development activities and OSW farm development.
- Coordinating with multiple stakeholders from the Government of Tamil Nadu to facilitate necessary permits and approvals, especially for permissions from environmental authorities, seaport and power grid accessibility, and for operational clearances.
- Establishing a single-window clearance system to streamline all permissions and clearances to avoid unnecessary procedural delays involved in large-scale projects.

Port Development and Terminal Upgrades

- Infrastructure enhancement of ports and terminals to enable handling of large and heavy components of OSW projects such as turbine blades, nacelles, and towers. This includes reinforcing quay walls, expanding storage areas, and installing heavy-lift cranes of appropriate capacity at the ports, if not available already.
- Establishing specialized and dedicated facilities at ports for assembly, storage, and pre-commissioning of OSW components to streamline logistics and minimize technical delays.
- Ensuring that port construction and upgrades align with the delivery and installation schedules of OSW project components.

Logistics and Supply Chain Management

- Developing an integrated logistics plan that aligns the schedules of manufacturers, transport providers, and installation teams to ensure that all components arrive on time and are ready for pre-commissioning test, approvals, and deployment to offshore sites.
- Implementation of robust inventory management systems and practices specialised to track the movement of OSW project components from various production facilities across the state to ports, and further on to offshore sites.
- Coordinating with wind energy plant equipment manufacturers and relevant government agencies such as the TIDCO on development of manufacturing or assembly facilities closer to the construction port to enable long-term support to operation and maintenance of the OSW farms and their future expansion.

Marine Support Services:

- Engaging with port authorities and installation support teams to ensure the availability and coordination of specialised vessels, including installation ships, crew transfer vessels (CTVs), and service operation vessels (SOVs) that are critical for transporting personnel and components to offshore sites, and construction OSW towers.

  Utilization of advanced weather forecasting and sea state monitoring systems to optimize the timing of transport and installation activities, reducing the risk of weather-related delays.

Grid Integration and Infrastructure development:

- Collaborating with CERC and TNERC for regulations on offtake of OSW generated power, tariffs, and deviation settlements with RLDCs and SLDCs.
- Engaging with industrial HT consumers in the southern districts of Tamil Nadu to offtake wind power under corporate PPAs with the OSW power developers to reduce dependency on ISTS for offtake of power generated.
- Collaborating with CTU for implementation of envisaged onshore and offshore substations by 2028-29 to support at least 1 GW of OSW energy deployments.

Workforce Training and Safety:

- Providing technical training for handling specialized equipment and infrastructure in collaboration with NIWE and the Tamil Nadu Skill Development Corporation, to enhance the skilled workforce trained in OSW project installation and maintenance.
- Establishing health and safety regulations for the workforce employed in the OSW sector and providing training on safety aspects for working at offshore sites with harsh marine environments.
- Implementing stringent safety protocols as part of Standard Operating Procedures (SOPs) to protect workers during transport and installation activities, including emergency response plans and safety drills.
- Providing targeted training to skilled personnel from related fields such as onshore wind, oil and gas to bridge skill gaps in OSW workforce requirements.

Stakeholder Engagement:

- Fostering collaboration between key stakeholders, including port authorities, OSW project developers, equipment manufacturers, and local communities. Dedicated communication mechanisms and cooperation between multiple levels of governance are essential for addressing challenges and ensuring project success.
- Engaging with local coastal communities to address concerns regarding development of OSW farms through various communication channels.
- Conducting public outreach programs to transparently inform local communities about the benefits and impacts of OSW development, including development of associated port facilities, grid and road infrastructure, and the advent of auxiliary industries supporting the OSW farms bringing employment opportunities and enhancing local economy.
- Holding periodic meetings with key stakeholders including representatives from local communities to update on progress of OSW development and involve them in decision-making processes.

6.2.2 Policy and Regulatory Framework

Early-stage development of OSW energy in Tamil Nadu presents several policy and regulatory opportunities and challenges that need careful consideration and strategic intervention. While national level policies, guidelines and strategic documents such as MNRE's strategy paper for OSW establishment do exist, there is a need for a comprehensive policy framework dedicated to OSW at the state level. Such tailored state-specific policy and regulations provides clarity and stimulates early-stage development and investments.

Financial incentives and support mechanisms such as subsidies, tax incentives, and favourable tariff structures are critical to improve viability of early-stage OSW projects. Developing a comprehensive financial support mechanism that includes risk mitigation instruments and long-term PPAs can attract investments and reduce the perceived risks associated with OSW projects.

Development of OSW projects involves securing statutory clearances from multiple regulatory bodies at the state and national level, including maritime authorities, environmental agencies, and nodal agencies. The permitting process is often lengthy and complex and may lead to delays in project approvals and implementation. Streamlining the regulatory process through a single-window clearance system could significantly enhance efficiency and reduce administrative burdens.

To overcome the existing challenges in OSW development, Tamil Nadu should implement a comprehensive policy and regulatory framework that streamlines regulatory processes and OSW development activities, enhances infrastructure, promotes OSW power offtake, and provides financial incentives.

This following section outlines specific policy and regulatory recommendations, to adequately support OSW development in Tamil Nadu:

Streamlining the Regulatory Processes:

- Establish a single-window clearance system, coordinated by NIWE[9] and the proposed state level OSW nodal agency, to streamline the permitting process for OSW projects. Roles and timelines of different agencies and stakeholders, across multiple levels of governance, should be clearly defined and documented. The proposed state-level OSW nodal agency can support NIWE to streamline and facilitate approvals from relevant state-level authorities such as the Tamil Nadu State Disaster Management Authority (TNSDMA), Tamil Nadu Environmental Impact Assessment Authority (EIAA), Tamil Nadu Coastal Zone Management Authority (TNCZMA), Tamil Nadu Pollution Control Board (TNPCB), Tamil Nadu Maritime Board or other respective port trust of major ports and their national counterparts. Such a centralized and collaborative permitting process will facilitate timely and efficient development of OSW projects.
- Given that OSW projects fall under the Coastal Regulation Zone (CRZ-IV) category, a national level environmental clearance for implementing the project is required based on recommendations and other relevant statutory approvals from state level agencies. Development of standardized Environmental Impact Assessments (EIA protocols, procedures and formats tailored to OSW projects, addressing specific concerns such as impact on marine life, habitat alteration, and impacts on coastal communities will make the EIAs process efficient and less time-consuming.

Case Study: Offshore Wind Development in Netherlands

[9] As outlined in the National Offshore Wind Energy Policy, 2015, NIWE serves as the national-level nodal agency for OSW development. Its responsibilities include managing bidding processes, contracting with developers, conducting resource assessments and surveys, demarcating development blocks, facilitating clearances from relevant ministries, monitoring project activities, and other related mandates.

The Netherlands has set a goal to transition entirely to sustainable energy sources by 2050, with OSW energy being a pivotal element in this strategy. The country is well-suited for OSW energy generation due to its relatively shallow waters, favourable wind resource, and proximity to ports and energy consumers.

The government has set targets to have 4.5 GW of OSW operational by 2023, catering to 3.3% of the nation's energy needs. By 2030, the goal is to have 21 GW of OSW farms in operation, thereby meeting 16% of the country's energy demand. The government has developed an Offshore Wind Energy Road Map to provide clarity and ensure certainty for wind farm developers. This document outlines the planned construction schedule and locations for development of 21 GW OSW farms in the Netherlands.

Other factors that have supported the growth of OSW in the Netherlands include implementation of a one-stop shop system. This system streamlines the process for stakeholders by consolidating all preparatory efforts undertaken by the government, such as the OSW wind farm site decisions, site studies, and grid connections. Consequently, tenders for OSW farms in the Netherlands are made accessible to all interested parties and thereby mitigating risks for applicants seeking permits for OSW implementation.

Financial Incentives

- Extending the waiver of Inter-State Transmission System (ISTS) charges offered to OSW project to a longer timeline would provide project developers a more realistic timeframe to utilise this benefit for a larger pipeline of projects. At present, ISTS waiver is offered to OSW projects commissioned before December 31st, 2032. This condition does not provide sufficient time to complete a substantial number of OSW projects, given the project development timelines and trajectory planned. On similar lines, waivers and incentives can be put in place by Government of Tamil Nadu for transmission of offshore power through its transmission network managed by TANTRANSCO.
- By offering a predictable and attractive price for OSW-generated electricity, a Feed-in-Tariff (FiT) mechanism would reduce financial risk for developers and stimulate private investment for early-stage projects in the sector. The feasibility to structure the mechanism to have a higher FiT in the initial years, with a subsequent decrease over time can be assessed, in order to offer better financial support to OSW projects upfront. High FiTs, energy banking, tax rebates and other such interventions supported early-stage onshore wind development in Tamil Nadu. Replicating this strategy for OSW can attract similar levels of investment and development.

Regulatory mandates and protocols:

- Defining long-term Renewable Purchase Obligations (RPOs) specifically for OSW, as done previously for solar power and through the recently published Energy Storage Obligations, would establish clear commitments for both project developers and TANGEDCO. For developers, RPOs ensure a stable demand, reduce financing risks, and encourage technological advancements. For TANGEDCO, the long-term RPOs secure a reliable supply of energy, aid in regulatory compliance, stabilise energy costs, and contribute to grid stability.
- Minimize curtailment of OSW generation by developing clear protocols and compensation mechanisms for managing potential curtailment of OSW generation,

considering factors such as must-run requirements for RE based on national or regional dispatch instructions. About 4.3% of wind and solar generation is curtailed annually in the state (NREL, 2022). To manage potential curtailment of RE generation, the TNERC has developed comprehensive draft guidelines (TNERC, 2024), released in February 2024. Implementing TNERC's guidelines will help minimize curtailment of OSW generation, which can negatively impact developers during early stages of OSW development. These guidelines classify curtailment situations into grid security and operational categories. Operational curtailment may occur due to factors like transmission congestion, low demand periods coinciding with high renewable generation, and state under-drawl beyond volume limits allowed by central regulators. The guidelines provide detailed curtailment protocols for scenarios such as high grid frequency, congestion on specific transmission lines, and state under-drawl exceeding 200 MW.

- Facilitate open access OSW projects by developing a standardized power purchase agreement (PPA) template to streamline negotiations between project developers and high-tariff industries. TNERC has announced its draft Regulations for Green Energy Open Access, 2024. These regulations focus on ensuring non-discriminatory green energy open access (GEOA) through the intra-state transmission systems and the distribution system of state licensees. As per the regulations, all GEOA applications must be submitted to the portal set up by the Central Nodal Agency (CNA), the National Load Dispatch Centre. The CNA will route applications to the State Nodal Agency (SNA). The Tamil Nadu State Load Dispatch Centre will serve as the SNA for granting Short-Term Green Energy Open Access, while the State Transmission Utility (STU) will be the SNA for granting Long-Term and Medium-Term Green Energy Open Access.

Comprehensive OSW Health and Safety Regulations:

- The MNRE, in collaboration with the NIWE and Directorate of Industrial Safety and Health under the Labour Welfare and Skill Development Department, Government of Tamil Nadu, should establish a robust framework for health and safety (H&S) regulations that address all lifecycle stages of OSW projects. This framework can be aligned with international guidelines and best practices, such as those established by the Global Wind Organisation (GWO), International Maritime Organization (IMO) and International Finance Corporation (IFC). Onshore wind sector in Tamil Nadu has witnessed negligence of safety regulations by labour working on the ground leading to severe health hazards including deaths. The H&S regulations should outline steps to be taken by stakeholders to avoid on ground negligence towards safety aspects as OSW projects carry higher threats for workers.

Decommissioning Guidelines:

- Develop decommissioning guidelines outlining the procedures, responsibilities, and timelines for decommissioning OSW projects. Ensure alignment with international best practices and regulatory standards to facilitate safe and environmentally responsible decommissioning processes. Develop specific protocols and standards for managing hazardous materials and waste generated during decommissioning activities, particularly with relevance to seabed clearance.

Tamil Nadu can adopt the following best practices from around the world to prevent defaults on decommissioning obligations for OSW projects:

Japan: Developers must outline decommissioning methods in their leasing plans under the Marine Renewable Energy Act and secure funds for decommissioning through financial guarantees or protected accounts.

Netherlands: The leasing process requires developers to provide a bank guarantee of €120,000 per MW upon permit issuance to cover future decommissioning costs. This amount is indexed annually at 2% and reviewed after 12 years of operation. Developers must submit a full decommissioning plan for approval before decommissioning.

United Kingdom: Developers are legally responsible for decommissioning under the Energy Act 2004, requiring them to provide financial security and submit a decommissioning programme. The Secretary of State approves decommissioning programme.

6.2.3 Local Demand Creation for OSW Offtake

The Tamil Nadu government can become a catalyst for strengthening the OSW development through supportive policies and regulatory directives to stimulate demand creation with long-term sustainability in Tamil Nadu. Promoting the use of offshore wind power within the state for industrial clusters and commercial hubs can drive demand and bring economic growth.

For example, integrating OSW power into the energy mix for major industrial zones such as the Chennai-Kanyakumari Industrial Corridor can enhance the competitiveness of local industries by providing access to clean and reliable energy.

The state can also support emerging end-uses such as green hydrogen production and electric vehicle charging, and defining specific long-term RPOs for OSW power. Such initiatives will help build demand for OSW while decarbonizing electricity consumption. Financial support, such as waiving State Transmission Utility (STU) charges on OSW power offtake within the state, can further incentivize development.

Key recommendations to accelerate demand for OSW energy in Tamil Nadu are:

Facilitate offtake by Local Commercial and Industrial Consumers:

- C&I consumers stand to benefit from the adoption of OSW energy in Tamil Nadu. With increasing grid tariffs for conventional electricity sources, transitioning to OSW presents a viable opportunity for these consumers to mitigate rising energy costs as reflected in the offtake analysis in Chapter 5. Open access consumers, like large industries, benefit from OSW's competitive pricing and stable supply, reducing grid dependence. OSW also offers environmental benefits such as reduced greenhouse gas emissions, aligning with corporate sustainability goals. To capitalize on these advantages, it's imperative to sensitize the C&I consumers about the potential cost savings and environmental benefits associated with OSW.
- Integrating OSW power into green hydrogen hub ports (e.g., V. O. Chidambaranar Port) can create a unique proposition, setting a model for replication across India. Developing green hydrogen facilities can drive innovation and create new markets for OSW power,

further enhancing the state's renewable energy portfolio. The state government can also combine the benefits of OSW power with developments in Round-The-Clock (RTC) renewable power plants and battery storage projects. This integrated approach will optimize grid infrastructure utilization and enhance financial returns on infrastructure investments. By providing comprehensive support, the state government can create a catalyst effect, driving the growth of the OSW sector and positioning Tamil Nadu as a leader in renewable energy development.

Collaborate with TIDCO, SIPCOT and SIDCO to utilize OSW energy for emerging industrial clusters in the region:

- TIDCO, responsible for overseeing medium and large-scale industrial development, and the State Industries Promotion Corporation of Tamil Nadu Limited (SIPCOT), which manages industrial parks across the state, play crucial roles in enabling large C&I consumers to offtake power locally. Leveraging their strategic position and expertise, TIDCO and SIPCOT can identify suitable industrial estates and hubs within their network to facilitate OSW offtake among industrial consumers.
- Facilitate long-term PPAs with the energy intensive consumers in the emerging industrial landscape of Southern Tamil Nadu which includes an industrial ecosystem surrounding the ISRO Lauch Pad at Kulasekharapattinam, and new manufacturing facilities for emerging technologies and sectors such as electric vehicles, battery manufacturing, renewable energy components, and more. SIPCOT also serves as a nodal agency for the Tamil Nadu government, responsible for approving and disbursing the structured package of incentives to large industrial units, which can be leveraged to incentivize green power purchase by new commercial and industrial consumers.

Regulatory mandate for OSW power purchase by DISCOMs:

- Off-shore specific RPOs ensure a stable revenue for developers through PPAs with DISCOMs, creating demand for OSW power as they signal clear commitments from TANGEDCO. Owing to reduced financing risks, this encourages developers to continue investments in OSW that is crucial for long-term sustainability of the sector and encourage technological advancements. TNERC, in 2023, has updated RPO targets for the state, setting up cumulative wind RPO of 6.94% by FY 2029-30.

6.2.4 Technology and Domestic Supply Chain Development

Globally, the offshore wind industry is undergoing transformation in terms of underlying technology and components as well as integration of advanced systems such as artificial intelligence and computation techniques to optimise project planning, execution, operation and maintenance. It is crucial for Tamil Nadu's existing industrial ecosystem to integrate such global best practices at an early stage to achieve the OSW milestones set by MNRE. Though Tamil Nadu has a matured onshore wind industry and supply chain, these industries need to upgrade their expertise and manufacturing capabilities to cater to the offshore wind market.

Developing a resilient OSW supply chain in Tamil Nadu requires leveraging the state's past successes in onshore wind energy through strategic planning. According to the Global Wind Report 2022 published by GWEC, India holds an 8.5% share in the global supply chain, while the worldwide wind energy installations crossed 1000 GW. Establishing dedicated industrial estates through the Tamil Nadu Small Industries Development Corporation will support MSMEs in OSW component manufacturing. Promoting domestic manufacturing with financial incentives, including capital subsidies, concessional financing, tax benefits, and R&D support, alongside facilitating strategic public-private partnerships (PPPs), will strengthen local capabilities and drive expertise development.

Investments from Indian OEMs are needed to match OSW requirements in terms of design, materials and processes to bring down project costs while delivering envisaged energy production. For instance, OSW wind turbine blades being of large size, also require dedicated transportation and logistics systems for safe and uninterrupted supply to the respective ports, where such facilities are currently lacking in Tamil Nadu. Respective planning and industrial departments such as MSME department under the Commissionerate of Industries and Commerce, Planning & Special Initiatives, and TIDCO need to layout detailed guidelines, infrastructure programs and concrete infrastructure investment plans. These measures need to be supplement with necessary long term contract assurance through existing schemes for SMEs to produce quality products and sustain.

This section highlights the key interventions and case studies for strengthening Tamil Nadu's offshore wind industry.

Leverage Tamil Nadu's onshore wind ecosystem:

- The SME industry ecosystem of TN state can be targeted to be customised for manufacturing primary and ancillary components of OSW to reduce imports and build resilience around global supply chain and logistics challenges. For instance, 10 Indian OEMs have the expertise in the nacelle assembly of onshore wind turbines, wherein strong local manufacturing know-how of gearbox assemblies exists.
- Global major offshore wind blade manufacturers are present in India, catering to onshore wind industry. However, they currently do not have manufacturing capacities to produce larger OSW turbines blades and need support from state level agencies to setup such facilities near suitable ports for delivering turbine blades and components in economic and timely manner (ORE Catapult and mec+, 2023). TIDCO and MSME department can conduct stakeholder consultations to map challenges and opportunities for establishing local OSW supply chain, such as dedicated guidelines and programs for establishing OSW facilities near ports of interest.
- Periodic local content targets can then be set in phased manner by MSME, TIDCO and relevant state nodal agencies to boost indigenous component manufacturing, through the support of central government programs such as production linked schemes. The state currently provides capital subsidy up to INR 150 lakh for select thrust areas and stakeholders, wherein OSW can be added as a dedicated category.

Promote research and innovation for OSW key components:

- Establish technology innovation hub for continued research on critical components such as turbine blade, nacelle, tower, foundation, offshore substations, and other balance of plant elements considering component reliability, quality, and circularity (end of life).

- Tamil Nadu Industries Department's R&D Policy 2022 can be appropriately leveraged. The Policy aims at providing incentives and regulatory support to establish centre of excellence, and draw on linkages with existing research facilities and industries to promote and scale emerging technologies and solutions in the state (Tamil Nadu Industries Department Policy Note, 2023). Missions such as Tamil Nadu Startup and Innovation Mission (TANSIM) can be promoted to encourage and enable innovation across the OSW value chain in the state.
- Collaboration between public institutions such as NIWE, NIOT and IITs along with private institutions shall be strengthened through dedicated funding avenues to develop research laboratories and testing facilities.
- Development of sustainable materials shall be prioritised for turbine blades and other key elements that are hard to recycle. The efficient materials can also enable large capacity wind turbine manufacturing with optimised size or capacity to weight ratios and their deployment to reduce effective project costs as well as the environmental impacts.

Promote establishment of domestic manufacturing facilities for OSW components:

- In the short-term, reliance on foreign expertise and advanced technology is necessary to bridge the knowledge gap and kickstart OSW projects in Tamil Nadu. However, in mid-term, strategic cooperation and partnerships with established foreign OSW component manufacturers can facilitate knowledge transfer and technology acquisition. Government incentives and investments will play a crucial role in this transition.
- Local manufacturers and service providers should be encouraged to establish partnerships with global OEMs. This will be critical to improve local technology know-how and capabilities. Industries and MSME departments of Tamil Nadu will need to facilitate such technology and knowledge transfer as global OEMs would rely on their existing R&D and testing facilities located outside India. Manufacturing expertise for offshore wind sub-components such as generators and control systems is lacking domestically given the nascent market. Global partnerships will allow local manufacturing of sub-components and can also enable export of manufactured components to existing OSW markets as well as emerging markets in the Asia Pacific region.
- Building on Tamil Nadu's successful establishment of manufacturing hubs for onshore wind components, local production of OSW components can be fostered through targeted subsidy programs. These programs can include capital subsidies, low-interest loans, and tax incentives. Similarly, local entrepreneurial efforts can be supported through Tamil Nadu Startup and Innovation Mission (TANSIM) and financial incentives. By providing upfront financial assistance, this approach delivers a two-fold benefit: reducing costs for OSW projects and creating an indigenous manufacturing and supply chain base.
- For instance, TIDCO can utilize existing joint venture mechanisms of equity participation and other financing schemes to support setting-up the MSME base for OSW industries. Similarly, capital subsidy programs being run by the MSME Department for promotion of clean energy technologies, setting-up micro manufacturing enterprises, entrepreneurship and industry scale-up can be leveraged to promote local OSW industry.

- Establishment of a dedicated industrial estate for MSMEs by SIDCO and promotion of industrial development by TIDCO along the southern coast under larger programs such as the Chennai Kanyakumari Industrial Corridor Project (CKICP) can help develop a local ecosystem with domestic manufacturing capabilities and ability to provide other supporting services, especially in the areas closer to envisaged OSW deployments.

Promote local content requirements for OSW projects:

- Mandating local content requirements will ensure a certain percentage of OSW components are sourced locally and stimulate the growth of the domestic manufacturing sector. This will not only create jobs and boost the local economy but also enhance the reliability and self-sufficiency of the supply chain, thereby increasing investor confidence in the OSW projects.
- The central government would play a pivotal role in implementing local content requirements and domestic manufacturing through policy impetus such as the Aatmanirbhar Bharat. This can be achieved through enacting legislation and developing regulations specifying these requirements, providing financial incentives such as subsidies, grants, and tax benefit to enhance local manufacturing capabilities.

Promotion of innovative technologies for faster and resource efficient feasibility assessments and monitoring:

- Material components and activities such as sub-sea cables with various joineries are evacuated from OSW farm till onshore substation, as well as vessels operations continuously interact with ocean floor and shallow waters. NIOT with their R&D expertise can undertake detailed surveys using autonomous monitoring vehicles to effectively monitor such assets for fault monitoring as well as undertake regular preventive check-ups. Such technology may assist in mapping suitable sites for OSW wind farms by analysing soil and geological properties remotely. Technical personnel from respective state agencies such as Tamil Nadu port authorities, coast guards, pollution control boards, coastal authorities, NIWE, among others shall be trained for such emerging technologies for informed project planning and implementation.

Initiate assessments and community dialogues for biodiversity and ecosystems conservation:

- Tamil Nadu coastline is one of the oldest biodiversity rich marine areas globally. In-depth environmental surveys with the help of sub-sea remote monitoring robots or other relevant technologies can be deployed to understand the intricate ecosystems thriving in the region. This will help to design and implement conservation measures along with informed planning of offshore wind farms to minimise environmental impacts.
- Extensive on-ground dialogues with local communities shall be conducted to understand the native ecosystems as well as disseminate outcomes of scientific assessments and knowledge to resolve conflicts that are being raised due to the absence of the robust data and studies. For instance, France Renewables Association has prepared easy to understand booklets giving overview of anticipated impacts of OSW farms on the environment in the region along with solutions and case studies for avoiding, reducing and compensating the impacts.

Initiate assessments for floating foundations and innovation in the fixed foundations:

- Evacuation of fixed foundations in the sea-beds is a cost and material intensive process. Established OSW markets such as Europe are now increasingly shifting towards use of floating foundation structures. This helps to reduce impact on marine environment caused due to subsea construction work, achieving cost reductions, better suitability with local ocean conditions and structural stability with faster deployment. Different techniques such as spar-buoy, tension leg platform, barge, semi-submersible are being demonstrated globally. NIWE and NIOT in partnership with relevant experts shall undertake potential assessments in deep ocean areas for the floating foundation deployment in a phased manner.
- Indian manufacturers have the expertise from the other offshore sectors such as oil and gas to build OSW fixed OSW foundations (including monopile and jacket), however, they depend on neighbouring countries for fabrication facilities. TIDCO can engage with key private players to assess the requirements for setting up facilities for foundation manufacturing along with required skill sets and specifications such as material specifications, welding processes, among others to promote local manufacturing. R&D efforts can be strengthened to build the projects for Tamil Nadu's sea-bed conditions, ecosystems, and dependent communities. For instance, Chinese wind turbine manufacturer Mingyang Smart Energy has developed the world's first 'Fish Farm-Equipped Offshore Wind Jacket Foundation' wherein the jacket foundation is typhoon resistant and is able to raise up to 150,000 fish in 5,000 cubic metres of water, with remote functions such as automated feeding, monitoring, detection, and collection.

Research and enabling regulations on OSW farm decommissioning:

- In India's case, while decommissioning of OSW projects will happen further down the line, it provides an opportunity for decarbonising supply chain as well as job creation. Timely research on the recyclability of wind turbine blades along with buildout of OSW farm components and their repurposing would play a critical role considering OSW farm's embodied lifecycle emissions and their mitigation through innovative approaches and enabling regulations.
- Several local stakeholders would play active role in the decommissioning phase. For instance, Port Authorities in providing necessary infrastructure for OSW plant decommissioning, State's Skills departments and missions such as TANSIM and WorkLabs and key research institutions would provide essential workforce for skills such as parts dismantling, scientists and seafarers. Industry departments including TIDCO, and TN Pollution Control Board will need to lay out guidelines for reverse supply chain of dismantled parts along with scientific disposal of dismantled parts of OSW projects.

Development of Indian standards and protocols:

- Stakeholder interactions with Indian manufacturing and EPC companies as well as the literature review recommend establishing national component manufacturing and safety standards for ensuring quality long-lasting products for Indian emerging offshore wind industry and would help reduce associated testing and certification expenses which are higher in the global market. Bureau of Indian Standards (BIS) in collaboration with NIWE, and global agencies can consider development of standards suitable for Indian industry and geographical conditions.

Case study: UK's Offshore Wind Innovation Hub

UK's OSW innovation hub aims at reducing offshore wind energy cost through innovation and maximising economic impact for the UK. The hub coordinates with UK's offshore wind stakeholders to fast-track supply chain innovation and identify financing opportunities. The hub regularly convenes industrial stakeholders and informs government agencies on the upcoming technological innovations for financing as well as prioritising market transformation.

Success story:
Innovative remote condition monitoring technology for bolted assets: UK-based Smart Component Technologies (SCT) is the Smart Washer, a wireless sensor node for the local and remote monitoring of a bolted joint. The technology has the potential to reduce O&M costs by 15%, eliminate the need for bolting inspection and therefore, reduce the scheduled downtime of a turbine and lower the risk to personnel by reducing manned surface vessel trips for inspection.

Digital Solutions to Optimise Offshore Windfarm Consenting Timelines: OSW projects face challenges such as EIAs with time-intensive preparation and review. The hub is attempting to transform the project consenting through solutions such as Digital EIAs, data capture, storage and analysis.

Source: UK's Offshore Wind Innovation Hub

6.2.5 Skill Development and Capacity Building

The OSW sector is at very nascent stage in India with limited OSW specific design and development expertise. As elaborated in the section on skill requirements in Chapter 5, OSW farm development involves cross-sectoral operations that have high inter-dependency and impacts on the overall project cycle, necessitating availability of skilled workforce for timely project execution. Specific skills such as operating OSW vessels, installation and repair of turbines at heights in the seabed are unique, with the Indian workforce lacking such experience and expertise. Adopting specific guidelines and an action plan based on an assessment of the current expertise and gaps of the domestic workforce is very critical considering the timelines of the on-going 4 GW OSW tender.

As per the IRENA's analysis significant workforce can be trained locally for OSW component manufacturing (59% of total person-days requirement) and commissioning, especially the foundation (36% of the total person-days requirement) (IRENA, 2018).

Tamil Nadu presents significant potential to leverage its onshore wind workforce expertise and re-skill or upskill it for offshore wind industrial ecosystem. A study conducted by the Tamil Nadu Skill Development Corporation (TNSDC) also highlights that southern Tamil Nadu districts have labour available with required educational levels and skill sets and are willing to work within the state. Leveraging such local skilled labour, through upskilling, for OSW component manufacturing and plant evacuation will be beneficial for integrating the potential of unused workforce thereby improving employment and economy in the region. This section provides key recommendations for enhancing local skillsets and capacities in the state for OSW project deployment.

Leverage existing institutional set-up for development of professional skilling programs and creation of knowledge portal:

- The state government can collaborate with dedicated institutions such as NIWE through its 'Naan Mudhalvan Skill development scheme' and portals such as 'WorkLabs' in order to create curated programs for different qualification/professional levels in the OSW industry value chain to improve institutional as well as individual capacity for establishing robust local workforce. Through WorkLabs, collaboration can be extended to educational institutes of vocational training, environment, health and safety, engineering, financing and management to integrate necessary skill sets required for OSW industry as part of the curriculum.
- Establish partnerships with local training and educational institutes, and industry leaders in the region to develop targeted training programs for OSW jobs. The high availability of skilled labour from the region can be leveraged to develop both permanent and contractual labourers of different skill levels to support OSW development.

Continued peer-to-peer learning and knowledge exchange:

- Tamil Nadu state industries department can utilize platforms such as 'Advanced Manufacturing Hub (AMHUB)', and Centre of Excellence (CoE), to develop peer-to-peer learning and knowledge exchange programs with established offshore wind markets, including study tours having exposure to R&D facilities. Joint stakeholder consultations and dialogues can be conducted to improve technical know-how, and to streamline and optimize offshore wind value chain in Tamil Nadu and India.

Reskilling and livelihood improvement programs for project associated communities:

- Socio-economic welfare is always prioritized when national governments initiate major development programs including renewable energy projects such as utility scale solar and wind power plants. The emerging offshore wind field offers high potential to transition skilled workers from fossil-fuel based industries to OSW industry. Similarly at local level, based on social impact assessments results, concerned state level social-reform departments, for instance Industrial Co-operatives Wing being operated by MSME department, can strategize livelihood improvement programs for communities dependent on sea-bed sites for activities such as fishing. Retaining the existing livelihood means must be prioritized first.

Policy interventions to utilize oil and gas industry expertise and workforce for the offshore wind industry:

- Skillsets and activities from sunset industries of oil and gas such as geotechnical studies, EIAs, plant/structural design engineering, building platforms in seabed, drilling in the subsea floor, nearshore infrastructure development such as port and harbour, sea and sub-sea operation and maintenance activities; are common to offshore wind industry as well. The proposed state-level nodal agency can establish partnerships with Indian PSUs such as ONGC and with private companies to transfer or train the local workforce for the OSW industry.

- The proposed state-level nodal agency can design skill-bridge programs in collaboration with relevant stakeholders such as the Tamil Nadu Skill Development Corporation (TNSDC) to help existing workers in related fields transition into the OSW sector.

Case study: Scottish government's 'Energy Skills Passport' initiative

The Scottish government, under the North Sea Transition Deal and 'Just Transition' agenda, earmarked € 5 million for creating innovative digital solutions and pathways for workers to shift from offshore energy sectors such as oil & gas to offshore wind. OPITO- is an industry owned organisation, the grantee of the passport initiative, engages with global government agencies and industries to provide required qualified workforce certified through their centres. Employees can avail tailor made trainings and employers can access the skill assessment tools and other products to identify suitable workforce.

The focus of the passport project is on the alignment of technical qualifications and the mapping of safety standards, the creation of career pathways for relevant roles, and a mechanism for employers and employees to understand recognised standards. It has resulted in the creation of career pathway information for over thirty oil and gas roles and entry routes into the wind industry leading to roles such as maintenance technician, commissioning technician, senior high-voltage technicians and authorised personnel and troubleshooting technicians.

Source:

1. https://opito.com/news/opito-awarded-5-million-through-just-transition-fund-to-deliver-energy-skills-passport
2. https://oeuk.org.uk/roadmap-for-energy-skills-transition-secures-backing-from-wind-oil-and-gas-sectors/

6.2.6 Finance and Investment

Finance and investments are crucial to realize OSW development in Tamil Nadu, considering the substantial costs associated with resource assessment, pre-feasibility studies, high initial capital outlays, extensive infrastructure requirements, and multi-year project timelines. Decision-makers must ensure adequate financing for OSW farm expenses, including planning, construction, and maintenance, as well as long-term investments in the state to develop supporting ecosystems such as manufacturing and skill development and infrastructure like ports, roads, and electrical grids.

Investing in the OSW ecosystem is not just a financial decision, but a strategic move that aligns with the Tamil Nadu state government's objective to become a US$ 1 trillion economy by 2030, which also highlights OSW as one of the five key areas for growth in the energy sector (TNIDB, 2024). Such investments will not only support the OSW sector but also contribute significantly to the broader economic growth and sustainability goals of the state, making investors feel that their contributions are part of a larger cause.

Clear and favourable financial and investment guidelines and active government support and participation are essential to accelerate the uptake of OSW in Tamil Nadu. These measures will help mitigate the risks associated with the high volume of investments required, making the state a more attractive destination for both domestic and international investors in the OSW sector as well as for mitigating risks associated with policy and regulatory changes, ensuring timely project implementation, and driving local economic growth and job creation.

The state government can play a pivotal role by facilitating cross-departmental coordination, streamlining approval processes, and ensuring transparent communication with stakeholders. By actively engaging in the OSW sector, the government can help align the interests of private developers, public agencies, and local communities, fostering a collaborative environment that supports sustainable development. Additionally, government participation can help address challenges related to land acquisition, environmental clearances, and community engagement, ensuring that projects progress smoothly and meet all regulatory requirements.

Following strategies can be adopted for financing of offshore wind in Tamil Nadu:

- **Shared Investment:** Tamil Nadu state government departments such as TIDCO, TANGEDCO, TRANTRANSCO, and the TNGECL can explore joint equity partnerships with private OSW developers to share benefits and create a ripple effect in state's economy. These partnerships can distribute the financial burden and risks, making large-scale projects more feasible and attractive to investors. By leveraging the financial resources and expertise of private developers and also from MDBs, the state can accelerate the development of OSW projects. Additionally, the government can secure low-cost debt finance or financial assistance for TANTRANSCO to build the necessary transmission infrastructure, facilitating the utilization of OSW power within the state.
- For instance, developing an integrated transmission network that connects OSW farms with industrial clusters and urban centres can enhance energy security and reliability. Furthermore, shared investments can help build local supply chains, promote the growth of ancillary industries, and create job opportunities in manufacturing, construction, and maintenance. Tamil Nadu can ensure a more resilient and dynamic OSW sector by undertaking these collaborative investments, driving economic growth and advancing its renewable energy goals. These measures will also ensure that the TN economy grows, thereby creating long-term financial stability.
- **Facilitating Finance and Investment:** Streamlined regulatory process can reduce bureaucratic delays and simplify regulatory compliance, encouraging more investors to enter the OSW sector. 'Guidance Tamil Nadu' can leverage equity support from TIDCO and lead the expansion of the onshore ecosystem to encompass offshore investments, with support and coordination from the central government and multilateral partners. This coordinated effort can attract foreign direct investment and international expertise, further strengthening the state's OSW capabilities.
- Additionally, attracting new investments from global OSW developers can be facilitated through platforms and events like the Tamil Nadu Global Investors Meet, TN Startup and Innovation Mission, TNAMHUB, Guidance Tamil Nadu, Worklabs and Investor Meets, where potential investors can learn about the state's favourable policies, available incentives, and investment opportunities. At such platforms, the state government can organized focused business meetings for OSW developers, while facilitating

participation of and matchmaking with domestic and international financing institutions and banks (public, private, multilateral).

- The state can build a strong pipeline of projects that contribute to its renewable energy goals by showcasing Tamil Nadu as a premier destination for OSW investments. Possibilities of financing institutions and lenders coming together to jointly finance OSW power projects can be explored. Pooling financial resources through such syndication can help distribute financing risk among multiple lenders and limit cash outflows of participating lenders while making low-cost finance available for OSW projects.
- Furthermore, the involvement of institutions like the Tamil Nadu Infrastructure Fund Management Corporation (TNIFMC) and the TNIDB can provide additional financial instruments and incentives to attract investment. Additionally, collaborating with international financial institutions such as the World Bank and the Asian Development Bank (ADB) can bring in technical expertise and concessional funding, further lowering the financial barriers to OSW projects. By facilitating and creating a conducive environment for financing and investments in the OSW sector, Tamil Nadu can attract greater interest from OSW manufacturers, OEMs, and project developers, thereby stimulating the local economy and positioning itself as a leader in the market.

Regulatory Shield and Purchase Guarantee:

- Stable, clear and encouraging policy & regulatory environment in the state shall increase the confidence of financial lenders. The state can also explore mechanisms such as feed-in tariffs, renewable energy certificates, and long-term power purchase agreements (PPAs) to provide additional financial incentives and stability to OSW projects. By ensuring a secure and predictable revenue stream, Tamil Nadu can attract more developers and investors to the OSW sector, driving sustainable growth and development.
- **Prioritised OSW Power:** For early-stage initial OSW development projects approved by 2030, the TNERC can include priority to OSW power transmission in the STU network over other renewable energy power. This will lead to lesser curtailments and increased confidence for developers & lenders.
- **Assured Returns:** The state government can support OSW developers, while confirming assured power purchase from the state government backed industrial parks. Further, regulatory support for assured contractual OSW power purchase for its off takers for initial OSW development projects (approved till 2030), shall ensure steady utilization and returns to the developers. Further, TNERC can decide charges for OSW power offtake deferral from commitment for these initial projects.

Global Cases of Financial Support Mechanisms for Offshore Wind:

- **Syndication:** In 2023, the Kitakyushu-Hibikina offshore wind farm project (in Japan) was financed by three large banks, and a syndicate of 34 other lenders.
- **Government Funding:** The state of Victoria in Australia has funded three offshore wind farm projects, through funding of AUD 37.9 million under the 'Energy Innovation Fund', which was created to support innovative renewable energy technologies.
- **Sovereign Wealth Funds:** Norway's central bank, which manages the sovereign wealth fund, plans to acquire a 50% stake in the Borssele offshore wind farm in the

Netherlands. Moreover, Norway's sovereign wealth fund has acquired 16.6% stake in German offshore wind farm. UAE's state-backed renewable energy firms have invested in offshore wind projects through sovereign wealth funds.

- **Flexible Financing Approaches:** In the Netherlands, an international consortium of lenders that is facilitated by the European Investment Bank, provides flexible financing mechanisms for developers of offshore wind projects, including non-recourse financing, loan, bond, equity investment, and various mix of financing instruments.
- **Bonds:** Denmark has used instruments such as 'Green Bonds' and 'Blue Bonds' to finance offshore wind power projects.
- **Tax Credits:** In the US state of New York, offshore wind projects are eligible for Investment Tax Credits, under the inflation reduction act.
- **Consistency of Cash-Flow:** The Contracts for Difference (CfD) mechanism in the UK ensures revenue certainty over the debt tenure of offshore wind farms.

Case Study: Government support scheme to reduce financial risk for OSW project developers

The CfD (Contract for Difference) mechanism in the UK provides a robust financial framework to support offshore wind development. Under this mechanism, the government compensates developers if the market price falls below a fixed strike price, ensuring stable revenue. Conversely, if the market price exceeds the strike price, developers pay the excess back to the government. This structure offers developers predictable and stable income while mitigating associated market risks. Additionally, CfD agreements typically span 15 years, offering long-term financial security for project developers and fostering a conducive environment for investment in large-scale renewable energy projects.

Reference Link:

1. https://www.gov.uk/government/collections/contracts-for-difference
- https://www.great.gov.uk/international/content/investment/sectors/offshore-wind/#:~:text=CfDs%20incentivise%20investment%20in%20renewable,project%20development%20in%20the%20UK.

Prioritising Developer Credibility for early-stage projects:

- Technical credentials, including a track record of successful offshore projects and strong credit ratings, significantly increase the chances of project success and reduce risks for investors and financiers and is crucial for the growth of the OSW sector in Tamil Nadu. It is important that credible and experienced project developers and suppliers with proven technical expertise and financial stability are prioritized and engaged in early-stage projects, as was done for the auctioning of the seabed leasing in Tamil Nadu by SECI.
- Furthermore, similar priorities should be applied in tendering and contracting processes when employing private sector firms for the holistic and synchronized development of allied infrastructure such as ports, grid infrastructure, and roads. These infrastructures are critical for OSW logistics and project costs. By ensuring that only reputable firms with demonstrated capabilities are involved, Tamil Nadu can minimize delays, cost overruns,

and operational challenges, thereby enhancing the overall feasibility and attractiveness of OSW projects.

- Additionally, involving organizations such as the Tamil Nadu Maritime Board and Tamil Nadu Transmission Corporation (TANTRANSCO) in the selection process can ensure that the infrastructure development aligns with the specific needs of OSW projects. This coordinated effort will help create a robust support system for OSW development, reducing logistical bottlenecks and optimizing project costs.
- By prioritizing developer credibility and ensuring the involvement of experienced and financially stable firms, Tamil Nadu can set a strong foundation for its OSW sector. This emphasis on credibility will not only drive successful project outcomes but also foster sustainable economic growth, providing a secure foundation for the OSW sector's future.

6.2.7 Communication and Stakeholder Engagement

Effective communication and stakeholder engagement are crucial for successfully developing OSW projects in Tamil Nadu. Involving local communities, mainly fishermen and other affected groups, from the preliminary stages of project planning can help build trust, address concerns, and ensure that the benefits of OSW projects are shared equitably. Transparent and ongoing communication can mitigate potential conflicts, enhance community support, and facilitate smoother project implementation.

The Tamil Nadu state government, developers, and relevant agencies should establish a comprehensive stakeholder engagement strategy. This strategy should include regular consultations, public meetings, and informational workshops to inform and involve fishermen and other affected communities. Providing clear information about the project’s scope, potential impacts, and benefits is essential. This includes explaining how OSW projects can create job opportunities, contribute to local economic development, and provide clean energy. Specific measures to address the concerns of fishermen should be a key component of this strategy. This might include assessing and minimizing the impact of OSW infrastructure on fishing activities, ensuring access to fishing grounds, and possibly providing compensation or alternative livelihoods if necessary. The Tamil Nadu Fisheries Department, with its expertise and commitment, can play a pivotal role in facilitating these discussions and ensuring that the voices of the fishing community are heard, and their concerns are addressed.

Moreover, establishing grievance redress mechanisms can provide a formal process for stakeholders to raise concerns and seek resolutions. This can help address issues promptly and maintain a positive relationship between developers and the community. Collaborative efforts with local non-governmental organizations (NGOs) and community leaders are crucial. They can enhance the effectiveness of engagement activities, ensuring that the process is inclusive and culturally sensitive, respecting the diversity and unique needs of the local communities.

By prioritizing communication and stakeholder engagement, Tamil Nadu can foster a supportive environment for OSW projects, ensuring that development is both socially responsible and sustainable. This approach mitigates risks associated with social conflicts and contributes to the long-term success and acceptance of OSW initiatives in the region.

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8 Annexures

8.1 Annexure I: List of key terminologies used in the offshore wind projects

Technical Terminologies	
Capacity (MW) or Turbine Rated Power	The rated capacity of an offshore wind turbine is the maximum output possible from a wind turbine at rated wind speed (declared by turbine manufacturers). The rated wind speed is the wind speed at which the turbine reaches its maximum power output.
Capacity Factor	This is the ratio of annual energy production by offshore wind turbines to the maximum energy production possible at rated capacity for a year.
Annual Energy Production (AEP)	Gross AEP is the predicted annual energy production based on offshore wind turbine power curve, excluding losses. The Net AEP is metered annual energy production at the substation. This considers the effect of offshore wind turbine downtime, grid curtailments, wake losses, electrical and other losses. (Net AEP = AEP - losses of power due to various factors)
Cut-in Wind Speed (m/s)	This is the minimum wind speed at which offshore wind turbines start producing power.
Cut-out Wind Speed (m/s)	This is the maximum wind speed at which offshore wind turbines stop producing power to prevent damages (due to high wind).
Other Terminologies	
Availability (%)	This is the percentage of time the offshore wind turbine generator is available to produce power if the wind speed is within the operational range (i.e. between cut-in and cut-off wind speed) of the turbine.
LCoE	The Levelized Cost of Energy (LCoE) is a widely used metric that measures the cost of producing electricity over the entire operational life of a power plant. For an offshore wind power plant, the LCoE represents the average revenue per unit of electricity generation needed to cover all costs associated with the plant (i.e. all capital, operation and maintenance, and decommissioning costs). The LCoE is calculated by converting all costs to a single present value using the weighted average cost of capital (WACC) over the wind farm's operational lifetime.
MSP	Marine Spatial Planning (MSP) is a process developed to manage marine environments, i.e. direct human activity in the ocean to various uses and economic activities. MSP guides to reduce potential conflicts, and impact on the environment.

8.2 Annexure II: Major Offshore Wind Turbine Manufacturers

The major offshore wind turbine suppliers are given in the following table

Supplier/ Manufacturer	Model	Capacity (MW)	Rotor Diameter (m)	Country
Vestas	V236-15.0MWTM	15	236	Denmark
	V174-9.5 MWTM	9.5	174	US
	V164-10.0 MWTM	10	164	
	V164-9.5 MWTM	9.5	164	
Siemens Gamesa Renewable Energy	SG 8.0 - 167DD	8	167	Spain
	SG 11.0 - 200 DD	11	200	
	SG 15 - 222 DD	14	222	
	SG 14 - 236 DD	14	236	
GE VERNOVA	Haliade - X 14 MW	12	220	US
	Haliade 150 - 6MW	6	150.95	
Areva	Multibird M5000	5	116	France
Mingyang Smart Energy	MySE 8-10 MW	8.5-11	230-25X	China
	MySE 11-12 MW	11-1	230-242	
	MySE 14-16 MW	14-16		
	MySE 22MW	18-20+		
Seawind Ocean Technology	Seawind 6-126	6.2	126	Netherland
	Seawind 12-225	12.2	225	
Envision	EN 226 - 8.5	8.5	226	China
	EN 252 - 14	14	252	
Goldwind Science & Technology Co., Ltd.	GW 165-5.2/5.6/6/7/8/13 MW	5.2 / 5.6 / 6	165	China

8.3 Annexure III: Analysis on Offshore Wind Installation and Power Offtake Opportunity for Tamil Nadu

Multifactorial analysis has been conducted for the derivation of the offshore wind potential for the Tamil Nadu state, and its power offtake opportunities within the state. This analysis considers the impact of historical installations of onshore wind power, solar power (rooftop, ground mount) within the Tamil Nadu state, yearly RE generation patterns & CUF, state's electricity demand, power purchase cost of discom (i.e. TENGEDCO), average billing rate to HT consumers, offshore wind LCOE for Tamil Nadu and inflation factors etc. The historical reference data have been used for formulating a forecast model with combination with other influencing factors.

Historical Solar & Onshore Wind Installations in Tamil Nadu:

Tamil Nadu state has been early adopter to tap wind power due presence of high wind resources. Further, with supportive policies from central and state governments, solar power installation momentum gained in the last decade (2014-2024) (MNRE, 2024). By leveraging its renewable resources like solar & wind, the Tamil Nadu state is one of the top renewable energy adoption state in the India. The installation of (onshore) wind and solar power is shown in following figure A.

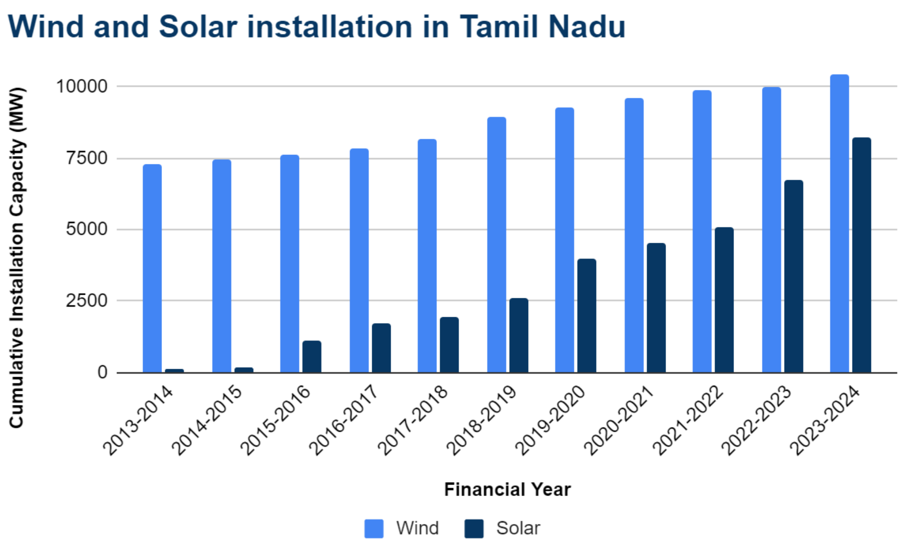

Figure A: Historical Solar and Onshore Wind Installations in Tamil Nadu

Annual Electricity Generation Profile from Renewable Energy:

The month wise renewable electricity generation profile from onshore wind power and solar installations in the Tamil Nadu state for year 2023-24 is shown in figure B. This figure reflects higher wind power generation during June to September months. Also, wind power generation is typically higher than solar wind power due to i) higher installed capacity, and ii) higher CUF. Based on actual generation, the wind power CUF is 18%, while solar power CUF is 15% for year 2023-24 (CEA, 2024)

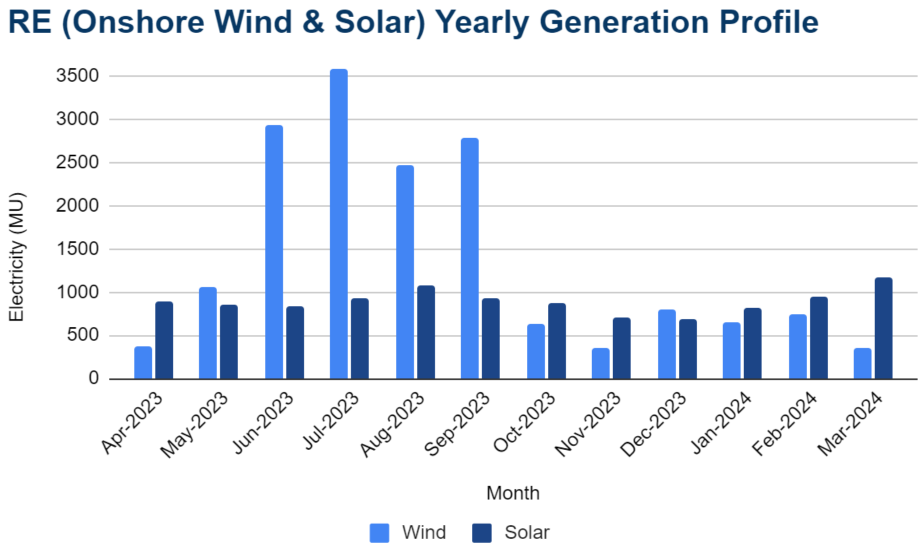

Figure B: Monthly Renewable Electricity Generation Profile for Tamil Nadu (FY 2023-24)

The historical trend of renewable energy (onshore wind and solar) installations and its generation profile were used for the prediction of future RE installations and generation in Tamil Nadu state.

Forecasts of Renewable Energy Installation & Generation and State Electricity Demand:
Apart from historical data points, following factors considered for the forecasting of renewable energy (onshore wind, offshore wind, and solar) installations & generation, and State's Electricity Demand.

Considerations for Analysis:

- Average OSW Output Power Density for the coast of Tamil Nadu: 6 MW/sq.km
- Seven Years Commissioning Time after Seabed Lease auctioned by MNRE (i.e. Seabed lease auctioned in 2023-24 will be commissioned by 2031-32)
- OSW Installations as per MNRE Auction Plan (MNRE Strategy Paper), and FoWIND study (FOWIND, 2018)
- OSW Capacity Factor: 48%
- Total Seabed in the coast of Tamil Nadu: 10,560 sq.km. (FOWIND, 2018)
- Onshore Wind Power Installation Growth rate in Tamil Nadu: 3% Y-o-Y (MNRE Data, last four year average) till 2023-34, afterwards 2% Y-o-Y growth rate (considering occupancy of existing onshore wind resource sites, and old plants under repowering)
- Solar Power Installation Growth rate in Tamil Nadu: 20% Y-o-Y (MNRE Data, last four year average) till 2023-34, afterwards 6% Y-o-Y growth rate (considering land occupancy by solar, and old plants under repowering) (MNRE, 2024)
- Onshore Wind CUF: 18% (based on FY 2023-24 data) (CEA, 2024)
- Solar CUF: 15% (based on FY 2023-24 data) (CEA, 2024)
- Tamil Nadu Average Energy Demand Rise: 4.39% (TNERC, 2022)

The forecasted deployment of RE installations, generation, and state electricity demand for the Tamil Nadu state is shown in Table A. With the consideration of current growth rate and forecast, the renewable energy generation will surge from FY 2031-32 with the installation of offshore wind, which will bring significant OSW power offtake opportunity for Tamil Nadu state afterwards.

Table A: Forecast of RE Installation & Generation, and State Electricity Demand

	2031-32	2036-37	2046-47
Tamil Nadu Electricity Demand (MU)	192,966	232,077	335,684
Installed OSW (GW)	4.5	20.5	63.4
Installed Onshore Wind (GW)	13.4	15.1	18.4
Installed Solar (GW)	35.3	60.5	108.4
OSW (MU)	18,922	102,404	266,391
Onshore Wind (MU)	21,171	23,835	29,054
Total Solar (MU)	46,174	79,192	141,821

Electricity Cost Forecast:
As above analysis shows the positive impact of OSW power adoption to realize renewable energy transition in the Tamil Nadu state. Energy cost economics analysis for Tamil Nadu state shall bring insights for the OSW power offtake opportunity within the state. As there is no previous OSW installation in the state, global weighted average OSW LCoE (2020-2022) compiled by IRENA has been considered for this analysis (IRENA, 2023). The weighted average OSW LCoE compiled by IRENA is shown in figure – C.

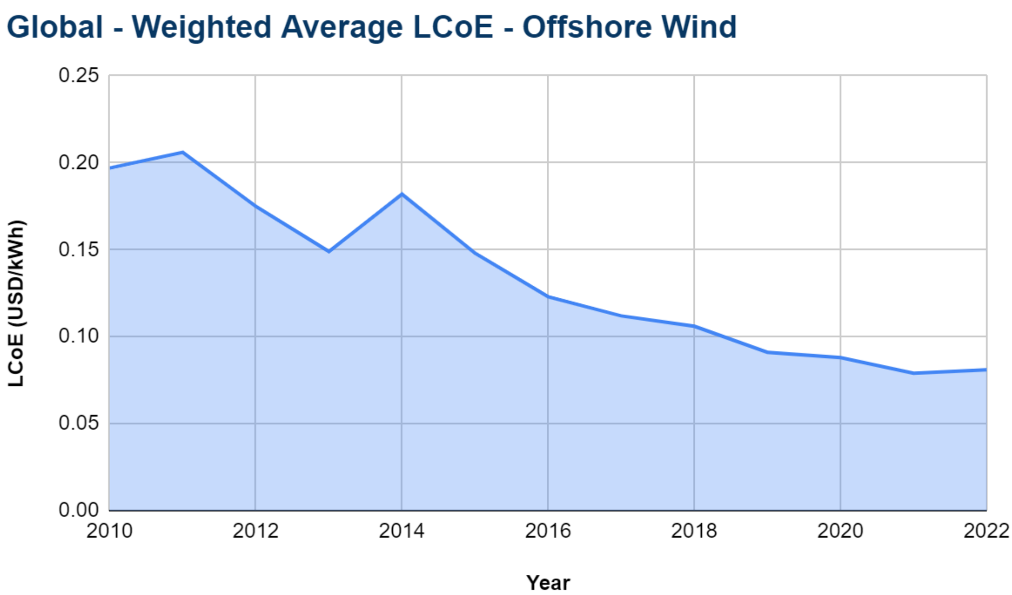

Figure C - Trend of Global weighted average LCoE for OSW power

The global weighted average OSW LCoE shall reflect the trend of future LCoE changes. Further, FIMOI version-2 cost estimates for FY 2025 has been considered for first offshore wind power, which shall result into its commissioning by 2031-32 (CoE for Offshore Wind and Renewable

Energy, 2022). The inflation rate of India has been adjusted with weighted average OSW LCoE change.

For assessing the offshore wind power offtake opportunities, TANGEDCO and HT consumers has been considered. The approved average billing rate (ABR) by TNERC for HT consumers for same financial years is shown in Table B. Considering volume of sales to respective HT consumer categories shown in Table B, and respective ABR has been converted to weighted average billing rate for HT consumers for representing overall HT consumer category. The forecasted power purchase cost has been derived from approved true-up from FY 2016-17 to FY 2019-20 calculated by TNERC (TNERC, 2022).

Table B- Average Billing Rate for HT Consumers in Tamil Nadu (INR/kWh)

Category \ Year	2022-23	2023-24	2024-25	2025-26	2026-27
HT IA: HT-Industry	8.96	9.28	9.61	9.96	10.31
HT IIA: Govt. educational institute	9.73	10.12	10.53	10.93	11.39
HT IIB: Pvt Educational Institute	10.93	11.36	11.81	12.28	12.77
HT III - HT commercial	11.67	12.06	12.47	12.87	13.28
Weighted Average - ABR (INR/kWh)	**9.43**	**9.77**	**10.12**	**10.49**	**10.86**

Table C- TANGEDCO Power Purchase Cost Forecast (INR/kWh)

Category \ Year	2027-28	2028-29	2029-30	2030-31	2031-32	2032-33	2033-34	2034-35	2035-36	2036-37
TANGEDCO - Power Purchase Cost (INR/kWh)	5.63	5.89	6.17	6.47	6.77	7.10	7.43	7.79	8.16	8.54

Considerations for Analysis:

- OSW Year on Year LCOE Reduction: -3.66 % (based on global weighted average LCoE from 2020-2022 compiled by IRENA (IRENA, 2023)
- Average Adjusted OSW LCoE Cost Reduction: -3.48% Y-o-Y considering Inflation in India (MacroTrends, 2022)
- Weighted Average Billing Rate for HT Consumers in Tamil Nadu: 9.43 INR/kWh for FY 2022-23, Y-o-Y rise: 3.59%
- TANGEDCO Power Purchase Cost FY 2020-21: 4.06 INR/kWh, Y-o-Y rise: 4.75%

The forecasted power purchase cost for TANGEDCO, Electricity cost to HT consumer and OSW LCoE is summarized in Table E. For this estimation, the first offshore wind power project is assumed to be commissioned by 2031-32. This LCOE forecast for future projects was refined using two factors: the historical OSW trend and the inflation factor.

Year-on-year changes in OSW LCOE were derived from the historical trend of the global weighted average OSW LCOE, as compiled by IRENA (IRENA, 2023). The inflation rates for India were then adjusted with these weighted average OSW LCOE change factors (MacroTrends, 2023). This adjusted weighted factor was used to forecast future OSW LCOE projections for Tamil Nadu.

The electricity purchase of both TANGEDCO and HT consumers, the approved true-up (for FY 2016-17 to FY 2020-21), and approved tariff (for FY 2022-23 to FY 2026-27) by TNERC has been taken as a reference (TNERC, 2022). This reference values have been used to forecast the future power purchase cost for TANGEDCO, and electricity cost for HT consumers in Tamil Nadu.

Table D - Electricity Cost Forecast till 2037 (INR/kWh)

Category \ Year	2027-28	2028-29	2029-30	2030-31	2031-32	2032-33	2033-34	2034-35	2035-36	2036-37
TANGEDCO - Power Purchase Cost (INR/kWh)	5.63	5.89	6.17	6.47	6.77	7.10	7.43	7.79	8.16	8.54
HT Consumer Electricity Cost (INR/kWh)	11.25	11.66	12.07	12.51	12.96	13.42	13.91	14.41	14.92	15.46
OSW LCoE (INR/kWh)					7.4	7.1	6.9	6.7	6.4	6.2

8.4 Annexure IV: Offshore Wind Cost Estimates for Tamil Nadu

Considerations:

- USD to INR Rates: 83 INR/1 USD
- Considered 'Zero' for Non-available information
- Compiled Cost Distributed to Relevant Categories for referred USA location report
- Weightage factor derived based on report year, forecast year, location proximity (to Tamil Nadu)

Derivation of Weightage Factor								
Report Year	2022	2022	2022	2022	2022	2022	2022	Considerations
Projection Year	2020	2025	2020	2025	2028	2028	2022	
Location	Tamil Nadu	Tamil Nadu	Gujarat	Gujarat	Market Rates	Philippines	USA	
Weightage Scale								
Report Year (Two Year) / Estimation Year (latest figures)								
2019-2020	1	1	1	1	1	1	1	More weightage for recent information
2021-2022	2	2	2		2	2	2	
2023-2024	3	3	3	3	3	3	3	
Forecasted Year (Two Year) (Inflation, Developments)								
2019-2020	0.5	0.5	0.5	0.5	0.5	0.5	0.5	More weightage for nearby year to 2024 (consideration of inflation, reduction in cost due to technology development etc)
2021-2022	1	1	1	1	1	1	1	
2023-2024	2	2	2	2	2	2	2	
2025-2026	2	2	2	2	2	2	2	
2027-2028	1	1	1	1	1	1	1	
Location (Proximity)								

Derivation of Weightage Factor								
Within India / Market Rates	2	2	2	2	2	2	2	More Weightage to Developed Market Rates and Nearby Proximity to TN (as technology will be imported in India)
Tamil Nadu	1	1	1	1	1	1	1	
Within 5,000 KM	1	1	1	1	1	1	1	
Above 10,000 KM	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	
Weightage Factor	**6.5**	**8**	**5.5**	**7**	**5**	**4**	**3.5**	

Capex & Opex Requirement Cost Estimates for Offshore Wind Farm at Tamil Nadu (INR/MW)								
Report Year	2022	2022	2022	2022	2022	2022	2022	
Projection Year	2020	2025	2020	2025	2028	2028	2022	
Location	Tamil Nadu	Tamil Nadu	Gujarat	Gujarat	Market Rates	Philippines	USA	
Derived Weightage Factor (for TN)	**6.5**	**8**	**5.5**	**7**	**5**	**4**	**3.5**	
Cost Components \ Reference Report	**FIMOI**	**FIMOI**	**FIMOI**	**FIMOI**	**World Bank**	**World Bank**	**NREL**	**Weighted Avg. Cost**
Development Cost (INR/MW)	68,00,000	58,00,000	57,00,000	58,00,000	1,09,24,875	1,31,55,998	81,34,000	75,51,073
Project Execution Cost (INR/MW)	64,00,000	54,00,000	29,00,000	54,00,000	0	0	36,52,000	38,31,190
Turbine Cost (8 MW WTG) (INR/MW)	10,97,00,000	9,33,00,000	9,61,00,000	9,33,00,000	10,86,40,111	11,48,72,913	0	9,22,47,904
Foundation Cost (INR/MW)	1,50,00,000	1,27,00,000	3,66,00,000	1,27,00,000	2,78,41,935	2,69,59,728	5,05,47,000	2,31,20,584
Array Cables (INR/MW)	2,41,00,000	2,05,00,000	1,00,00,000	2,05,00,000	31,62,881	30,16,884	2,55,72,300	1,61,14,810
Export Cables (INR/MW)	1,83,00,000	1,55,00,000	2,65,00,000	1,55,00,000	1,16,25,727	53,11,253	2,55,72,300	1,68,62,701

Capex & Opex Requirement Cost Estimates for Offshore Wind Farm at Tamil Nadu (INR/MW)								
Onshore s/s (INR/MW)	66,00,000	56,00,000	68,00,000	56,00,000	0	0	85,24,100	49,14,794
Offshore s/s (INR/MW)	1,75,00,000	1,49,00,000	1,82,00,000	1,49,00,000	90,75,220	92,00,052	2,55,72,300	1,54,18,465
Installation Cost (INR/MW)	3,97,00,000	3,37,00,000	4,73,00,000	3,37,00,000	0	0	1,90,07,000	2,76,00,620
Total CAPEX (INR/MW)	24,41,00,000	20,74,00,000	25,01,00,000	20,74,00,000	19,83,34,393	20,98,12,463	30,41,12,000	20,76,62,141
Total OPEX (INR/MW)	71,40,000	46,40,000	71,40,000	46,40,000	59,01,217	52,64,690	-	52,11,262
Reference Report Links	https://coe-osw.org/the-fimoi-report/				https://documents1.worldbank.org/curated/en/099225004192234223/pdf/P1750040b777da0c30935a0e2aa346f4e26.pdf		https://www.nrel.gov/docs/fy24osti/88335.pdf	