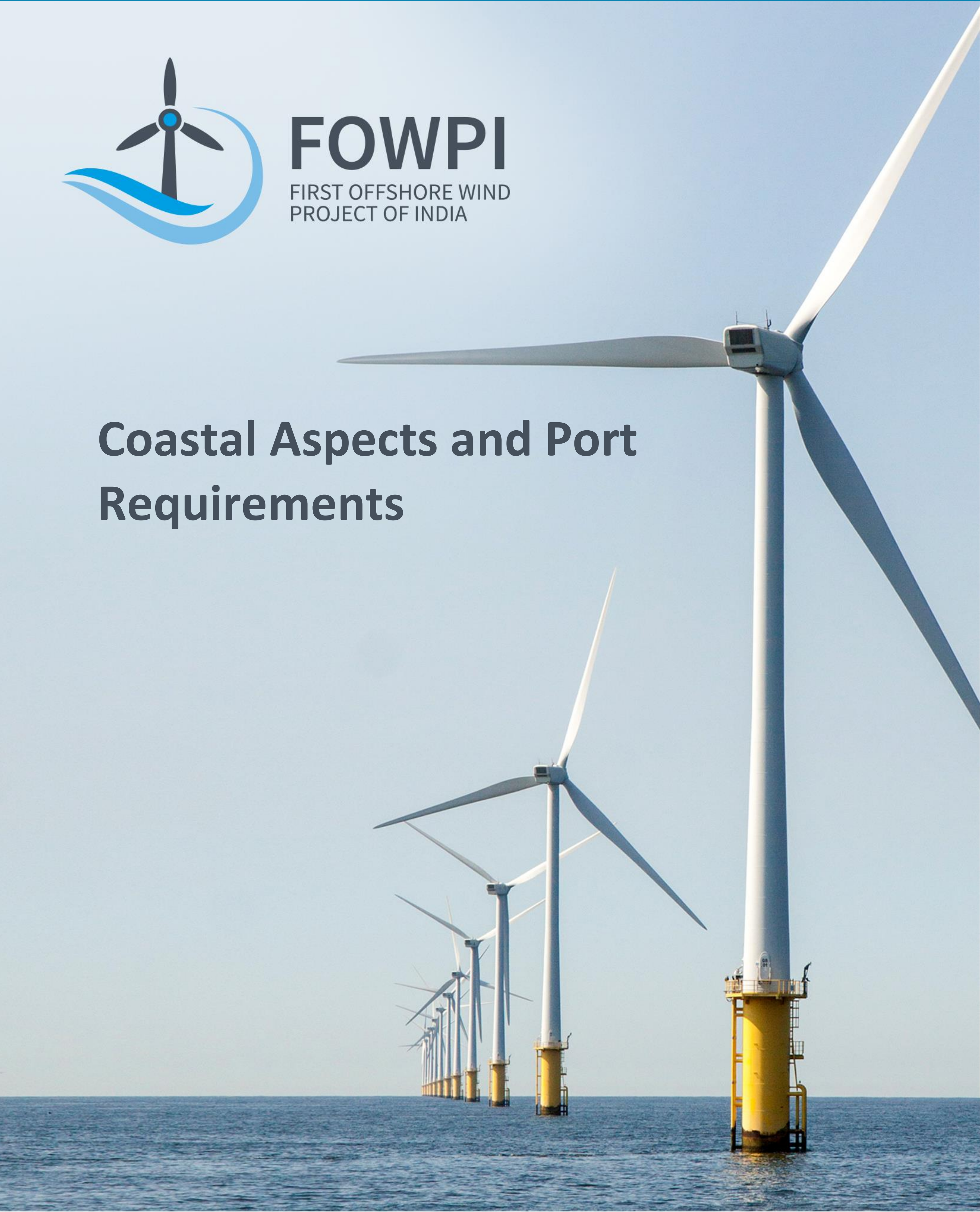
FOWPI

FIRST OFFSHORE WIND PROJECT OF INDIA

Coastal Aspects and Port Requirements



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This Project is funded by The European Union

1 About FOWPI

The First Offshore Wind Project of India (FOWPI) is part of the “Clean Energy Cooperation with India" (CECI) programme, funded by the European Union (EU). The programme aims at enhancing India's capacity to deploy low carbon energy production and improve energy efficiency, thereby contributing to the mitigation of global climate change. Project activities will support India's efforts to secure the energy supply security, within a well-established framework for strategic energy cooperation between the EU and India.

FOWPI is defined as a 200 MW offshore wind farm near the coast of Gujarat, 25 km off Jafarabad. The project scope focus is on preliminary investigations and advisory for the windfarm including wind turbine foundation, electrical network, environmental scoping, financial modelling and other relevant technical studies. FOWPI uses the outputs from Facilitating Offshore Wind in India (FOWIND) project (2013-2018) also supported by the European Union. FOWIND and FOWPI bring the vast experience of European countries in offshore wind, to support India with the creation of a national knowledge centre and with technical support for setting up the first offshore wind-farms.

FOWPI is led by COWI A/S (Denmark) with key support from WindDForce Management Ltd. (India) and COWI Pvt Ltd India. The project is implemented in close collaboration with the European Union, the Ministry of New and Renewable Energy- India (MNRE) and National Institute of Wind Energy- India (NIWE).

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The 14th annual Summit between India and the European Union (EU) was held in New Delhi on 6 October 2017. Both sides adopted a Joint Statement on Clean Energy and Climate Change, reaffirmed their commitments under the 2015 Paris Agreement, and agreed to co-operate further to enhance its implementation. India and the EU noted that addressing climate change and promoting secure, affordable and sustainable supplies of energy are key shared priorities and welcomed the progress on the Clean Energy and Climate Partnership, adopted at the 2016 EU-India Summit, and reiterated their commitment to its implementation and further development. In particular the EU is committed to continue cooperation in view of the cost-effective development of offshore wind in India.

5 Acknowledgements

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APPENDICES

1 Introduction

India has one of the fastest growing economies in the world and, in order to meet with rising energy needs, new generation capacity must be implemented on a regular basis. Renewable energy has for many years been introduced in the Indian energy supply system and specifically onshore wind energy has been playing an important role with over 32 GWs of installed capacity throughout the country i.e. the fourth largest installed wind power capacity in the world. Numbers are quickly rising and by 2022 over 60 GWs of wind energy capacity is targeted to be operational in India.

In Europe, in addition to onshore wind, offshore wind has also become an important contributor to the regional sustainable energy mix. The total offshore wind farm installed capacity in Europe is now close to 20 GWs and many more are expected to be installed within the next years. Given the required infrastructure and various challenges related to the offshore installation and operation, the costs for the first offshore wind farms were relatively high. However, thanks to market maturity and lessons learned in the design, manufacture, installation and O&M, the prices for new offshore wind projects are steeply declining and reaching record low levels. Besides the EU area, other countries that have already installed offshore wind include the USA and Taiwan; whereas countries in which planning activities have been initiated include Australia, Turkey and Japan.

This report extends the FOWPI work by providing i) an overview of existing European practice in offshore wind ports and vessels, ii) a first assessment of the coastal issues around FOWPI and iii) definition of FOWPI port requirements and potential of existing ports in Gujarat to support FOWPI during construction & operation phases.

To support FOWPI installation, port criteria include location/proximity to site, available storage capacity, assembly and lifting/crane specifications for wind turbine components such as towers, internal platforms, rotors as well as offshore foundations and piles. Vessel berthing and access based on typical offshore installation vessels are also considered when selecting an appropriate port.

O&M port requirements are examined to determine a feasible harbour solution for service activity and personnel to and from the wind farm. Where appropriate, the current work outlines improvements to current harbour facilities to help better suit construction and O&M activity at the FOWPI site.

In addition to coastal & harbour solutions, many permits and consents will be required from various government agencies, including for construction activity offshore, but also for construction onshore and in-port. The current study highlights the permits and consents that will be required for the coastal / onshore elements of the project, including cables on- and offshore, substations, and both construction and O&M port facilities.

2 Executive summary

In this study, an overview of port capabilities and associated coastal issues for India's First Offshore Wind Farm Project (FOWPI) in Gujarat have been considered based on the experiences from Offshore Wind Farm (OWF) projects in other countries. Specific local issues and conditions for permitting were explored. The COWI team conducted site-visits to ports as part of the assessment.

2.1 Wind farm site

The conceptual 200 MW FOWPI project is within the offshore Zone B identified by the FOWIND project, Ref /1/. The assumed site location and boundaries are illustrated below in Figure 2-1, along with nearby port locations, and further described in the FOWPI Wind Turbine Layout and AEP report Wind, Ref. /10/.

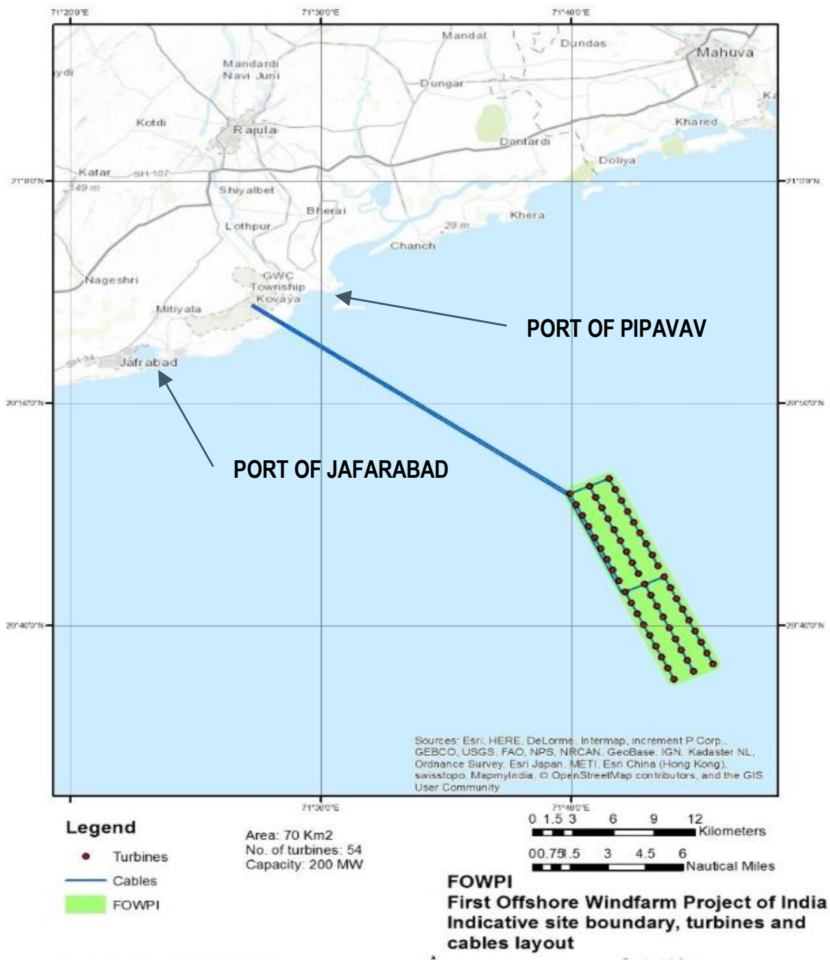

Figure 2-1: Location the FOWPI site and nearby Ports of Pipavav and Jafarabad

2.2 Coastal aspects

Coastal aspects refer to the construction of facilities onshore or nearshore to support windfarm constructions or operation. The coastal OWF issues that are central to FOWPI are outlined below.

2.2.1 Subsea power cables

As per FOWPI Electrical and Grid Study Report, Ref. /12/, targeted for a 200 MW OWF, the optimum configuration for power export to land is based on multiple low/medium voltage subsea cables i.e. without an offshore substation (OSS). However, the use of an OSS should still be of consideration for FOWPI upon detailed design – especially in view of expected project pipeline around FOWPI area.

Depending on the electrical export configuration, i.e. with or without OSS, power would be transmitted from FOWPI with one or more subsea cables. The length of each the subsea cable would be between 22-50 km. FOWPI grid study also provides detailed options for cable trenching and burial, which may be desired to avoid potential damage during operations.

2.2.2 Onshore substation

An area close to the subsea cable landing area is expected to be allocated for an onshore station to collect output from the subsea power export cables, and subsequent connection to the overhead lines. Exact space requirements would depend on final electrical design, but conceptual designs, site visits and meetings with APMT indicate that Pipavav Port has the ability to accommodate such ONSS within the port grounds.

2.2.3 Power transmission on land

Transmission from the ONSS close to the landing point to the grid substation is expected to be made via overhead lines. According to the GETCO study, available at FOWPI Electrical and Grid Study Report, Ref. /12/, several substations with sufficient interconnection capacity are available in the region. However, the preferred (and closest) option would consists of a new, and currently under planning, substation that would accommodate up to 1 GW of offshore wind as indicated in Ref. /12/. To reach such planned substation an overhead line of 3 - 10 km is expected.

N.B. The grid connection/metering point remains to be determined in coordination with Indian authorities and GETCO.

2.3 Port requirements & appraisal

The dimensions of the OWF components are determining factors for port requirements and it is critical that port infrastructure can handle the lifting and storage of these components during OWF construction. To avoid making serial upgrades and improvements to harbour facilities and to optimize workflow and construction activity, future demands and OWF development pipelines should also be taken into consideration when determining port requirements.

Ports in this paper were examined for their capacity to handle the following components of FOWPI 200 MW project:

- Turbines (Nacelle, blades, hub)
- Foundations (Monopile, jacket, gravity base, etc)
- Cables (export, inter-array)
- Offshore substation (OSS)

The storage area requirements were assessed based on logistical requirements for the shipment of components to and from the port and on experience from offshore wind ports world-wide. For FOWPI project, this has been assessed to be in the order of 40 ha, based on a project size of 200-300 MW using 3 to 6 MW wind turbines. This same area could also support additional pipeline, however if more than 200-300 MW of capacity will be simultaneously handled, additional storage would be required. In this case, it is likely that additional berthing would need to be added to support the construction activities as well.

The bearing capacity for wharf decks, retaining structures or other loadout structures must be sufficient for heavy lift activities. A minimum load capacity in the order of 10-15 tonnes/m² is needed for general purpose storage, lifting etc. For heavy lift areas and structures, 25-50 t/m² capacity is recommended based on the preliminary foundation designs for FOWPI.

Subsea and inter-array cables are typically loaded directly onto Cable Lay Vessels (CLV) and not stored at port facilities, however, future requirements may be different. COWI looked for sufficient water depth to accommodate transport and installation vessels, sufficient bearing capacity at the transportation and assembly areas and for proper berthing and load out of for jack-up vessels.

For vessel access, the water depth must be sufficient for Wind Turbine Installation Vessels (WTIV) and other construction and transportation vessels. While each vessel has specific requirements, the suggested mean low water depth range should be in the order of 11-15 m (see Table 6-5). O&M Access to the offshore wind farm is possible with a service vessel, which only requires a water depth of approximately 5 m. Site conditions and bathymetry had been previously assessed in for the FOWPI site as shown in Figure 2-2.

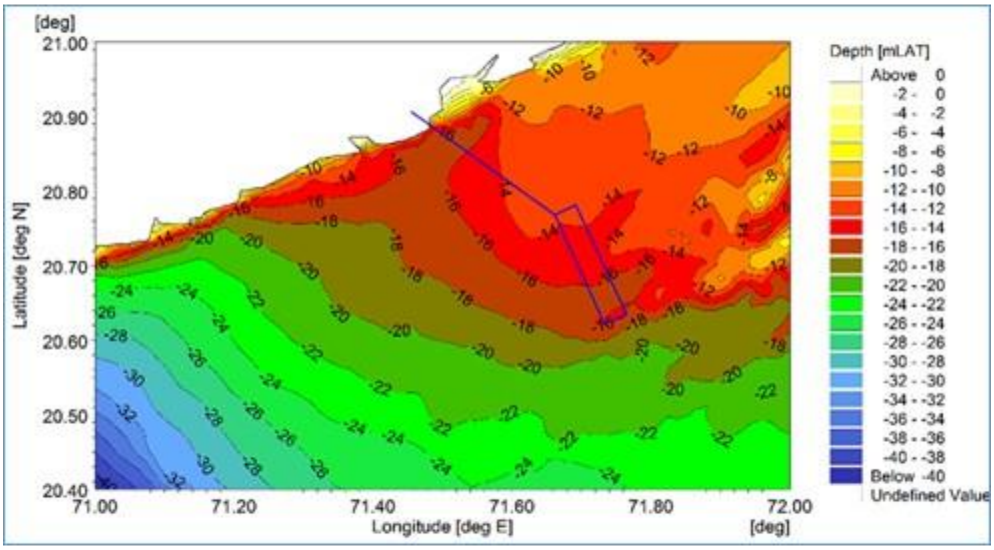

Figure 2-2: Bathymetry around the FOWPI site, Ref. /9/.

The main summary requirements for required ports are shown in Table 2-1.

Type of port	Storage area/ facilities [m²]	Crane capacity [t]	Berth length [m]	Quay side capacity UDL [t/m²]	Heavy load capacity UDL [t/m²]	Storage Area Capacity	Water depth [m]	Air draft [m]	Transport Access
Construction	400.000	1.300	400-500	10-15	25-50	4-8	11-15	100	Rail, Highway
O&M Service	500	-	50-80	-	-	-	5	-	-

Table 2-1: Main port requirements for construction and O&M of FOWPI based on preliminary design data, Ref. /11/, and European experience.

2.3.1 Construction and load out port

None of the ports examined along the coast of Gujarat are found to be completely suitable in their current form for OWF construction activities and will require upgrades or restructuring of existing space and/or shuttering or relocation of existing port and berth activity.

Based on site visits, typical vessel characteristics and construction requirements, the most suitable port to support the construction of FOWPI project was found at Pipavav.

The port is privately owned and operated by APMT, under a time-limited concession agreement, and located 22 km from the FOWPI site. Port of Pipavav meets many requirements needed for India’s first OWF, however upgrades will be needed. The bearing capacity of the quay area is currently insufficient and will need to be upgraded to operate the large cranes needed for preassembly of tower sections, Rotor Nacelle Assembly (RNA), and load-out activities. In addition, the berth flexibility for accommodating Self-Propelled Modular Transporters (SPMTs) and crawler cranes during loadout activities is currently limited due to very narrow access bridges (width=10m) from the hinterland to the berth. Despite these drawbacks, Pipavav port has space for new facilities, and a prime location in relation to the FOWPI site.

The FOWPI team visited Pipavav facilities in January 2018. During the visit the port management expressed interest to service and support the construction and maintenance activity of the FOWPI offshore wind farm.

2.3.2 O&M and service port

During operation, regular planned and unplanned Operations and Maintenance (O&M) activity will take place offshore at wind turbines throughout the wind farm. To reduce fuel and vessel costs, and to improve efficiency and response time, distance between the service port and OWF should be minimised. Two ports were identified, Pipavav and Jafarabad, located approximately 22 km and 33 km from the wind farm, respectively. Either of these ports should be able to accommodate FOWPI O&M related activity. Pipapav is recommended for use as an O&M service port, however, as it will reduce vessel costs significantly due to its better proximity. In addition, infrastructure at Jafarabad is currently very limited, and focused on small fishing vessels.

2.4 Permits

In general, the development of ports to support offshore wind in Gujarat must be made in accordance with the rules and regulations of the local port authorities. Ref. /13/ provides a comprehensive list of required permits related to Pre-construction, Construction, Operations & Decommissioning phases, and a relevant selection of these is given in section 7.

Vessel operation in Indian ports requires License from Directorate General of Shipping, Govt. of India. Operation of vessels in Gujarat maritime areas requires approval by Ministry of Defence and clearance from the Naval Team as well.

Permits and/or no objections are needed for subsea cables, substations, overhead lines, grid connection, among others, all of which must be obtained from various authorities. The authorities overseeing the various planning and consent activities for offshore wind farm development in Gujarat include, but may not be limited to:

- Ministry of Power
- Ministry of Defence
- Ministry of Home Affairs
- Directorate General Shipping
- Gujarat Maritime Board and Environmental Department

- Fisheries Department
- Power transmission company
- Private pipeline and cable owners

NIWE is expected to act as one-stop-shop and facilitate all permitting.

3 References, abbreviations and definitions

3.1 References

Reports and Other References

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Ref. /4/ Douglas Westwood, Assessment of Vessel Requirements for the US Offshore Wind Sector, 2013. Available at: https://www.energy.gov/sites/prod/files/2013/12/f5/assessment_vessel_requirements_US_offshore_wind_report.pdf, Accessed: 05 December 2018.

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Ref. /8/ COWI, FOWPI Geophysical Survey, Version 1.0, June 2018.

Ref. /9/ COWI, FOWPI Metocean Study. Version 1.0 September 2017.

Ref. /10/ COWI, FOWPI Wind Turbine, Layout and AEP. Version 1. September 2018.

Ref. /11/ COWI, FOWPI Advisory Foundation Concept Design. Version 2, June 2018.

Ref. /12/ COWI, FOWPI – Advisory Electrical Concept Design. Version 1, August 2018

Ref. /13/ ERM, FOWPI – Environmental Scoping Report and Consent Register. Version 1, October 2018.

3.2 Abbreviations

Abbreviation	Full form
APMT	APM Terminals Pipavav
CLV	Cable lay vessel
CTV	Crew transfer vessel
FOWIND	Facilitating Offshore Wind in India
FOWPI	First Offshore Wind Project of India
GETCO	Gujarat Energy Transmission Corporation Limited
GoI	Government of India
Govt.	Government
GCZMA	Gujarat Coastal Zone Management Authority
ha	Hectare
km	Kilometer
kV	Kilovolt
LOA	Length overall
Lo-Lo	Lift on/Lift off
m	Meter
MoEF & CC	Ministry of Environment, Forest and Climate Change
MP	Monopile
MRNE	Ministry of Renewable Energy
MT	Metric tonnes
MV	Medium voltage
MW	Megawatt
O&M	Operations and maintenance
ONSS	Onshore substation
OSS	Offshore substation
OSV	Offshore service vessel
OSW	Offshore wind
OWF	Offshore wind farm
PoC	Point of connection (Interconnect point)
RNA	Rotor Nacelle Assembly
Ro-Ro	Roll on/Roll off
SPMT	Self-propelled modular transporter
STATCOM	Static synchronous compensator
t	tonne
TP	Transition piece
TRANSCO	Transmission company
UDL	Uniform distributed load
WTIV	Wind (Turbine) installation vessel
WTG	Wind turbine generator

4 Overview of offshore ports and vessels

European offshore wind boasted almost 16 GW of capacity by the end of 2017, Ref. /7/. Development of this scale would not have been possible without large port and vessel industry devoted to meeting the construction and service needs of OWFs. As FOWPI moves forward from a concept to a reality, it is helpful to consider the European experience in creating the infrastructure necessary to support OWF development.

4.1 European Ports

European ports have been supporting offshore wind projects since early stage demonstration projects. Specifications may considerably vary from one harbour to another, depending on the OWF specification - e.g. targeted WTG/foundation size - and project pipeline that the port must support.

Key data for some of the ports supporting offshore wind in Europe are presented in Table 4-1.

Port	Upland area [m²]	Berth length [m]	Load capacity deck [ton/m²]	Navigable depth [m]	Transportation
Bremerhaven, Germany	1.780.000	3.000	5 to 20	8 to 14	Railway access 2.5 km to highway
Cuxhaven, Germany	2.630.000	1.090	20	6 to 16	Railway access 2 km to highway
Esbjerg, Denmark	4.500.000	10.550	5	10	Railway access Highway access
Grenaa, Denmark	73.000 preassembly area	Unknown	Unknown	11	Highway access
Brest	400.000	400*	10*	12*	Highway Access, Rail station 1km
Lindø, Port of Odense, Denmark	Ca. 400.000*	950	10-15 Extra heavy load area: 15-25 t/m²	Unknown	Unknown
Belfast, UK	Ca. 400.000*	480	50	9.3 to 11.5	Airport access, Highway access, Rail access

*Table 4-1: Key data for some of the offshore wind ports in Europe. * indicates estimated values or planned development.*

In order to to assist the construction of OWFs, various facilities must be built or reinforced at the harbor. These include, for instance, areas for transporting, storing, pre-assembling and exporting OWF components such as foundations, transition pieces (TPs) and wind turbines.

Figure 4-1 and Figure 4-2 provide an illustration of OWF harbour facilities, and a number of other examples are further provided in Appendix C.

Figure 4-1: Photo of offshore terminal in Esbjerg port in Denmark.

Figure 4-2: Overview of Esbjerg port in Denmark.

Wind Europe has also created the Offshore Wind Ports Platform where exchange of best practises and know how are exchanged between European wind ports, see Ref. /6/

4.2 Vessel types

To define the parameters necessary for OSW ports, it is important to understand the operations of the vessels at those ports. Different vessels which are relevant for the FOWPI wind farm are described in this section.

4.2.1 Component transport vessels

The arrival of wind farm components at the offshore wind port may be via sea or via land. In case the components are delivered via sea, this will take place by cargo vessel, including container vessel (e.g., Figure 6-11). Expected cargo vessel dimensions based on European port experience are provided in Table 4-2. Large components such as blades, nacelles, towers and foundations are typically transported on deck while all other smaller equipment is transported in containers.

Characteristic	Dimension/Rating
Length Overall	200 m
Beam	49 m
Loaded Draft	15 m
Cranes	Land-based Gantry 45-72 MT

Table 4-2: Characteristic dimensions of transportation vessels

Figure 4-3: Typical transportation vessel (bulk)

4.2.2 Foundation installation vessel

Foundations (MPs and TPs) are typically installed using a jack-up foundation installation vessel, although derrick barges can also be used in some cases. The jack-up vessel is designed to lift itself out of the water to create a stable platform for heavy lifts and installations. This stability allows for lifting in more various wind and sea state conditions, although exact wind speed and wave height criteria for installations will be vessel dependent and dependent on component weight and crane capacity.

In-harbour load out can be accomplished using a crawler crane, or if this is not possible, the jack-up vessel can be deployed by jacking up adjacent to the wharf/pier and utilizing the WTIV's onboard crane.

Soil preparation or strengthening of seabed at the port may be required to enable repeated jacking operations. Although geotechnical conditions are not known around potential harbours to support FOWPI, NIWE borehole information at the LiDAR position – i.e. close to northwest corner of FOWPI site - shows that thick (~9m) soft clay sediments are present, which could present challenges to jack up operations, see Ref. /8/.

4.2.3 Turbine installation vessel

While derrick barges can be used for installation of foundations, most often WTG components (tower, nacelle and blades) are installed using WTIV, which is a jack-up vessel specifically designed for offshore wind installations (see Table 4-3 for typical dimensions). Jack-ups are required due to the large hub-heights of turbines and in order to maintain stability and control during heavy lift activities over these heights. As WTIVs are jack-up vessels, the same considerations apply as for foundation installation vessels, above.

WTIV Characteristic	Typical Size/Rating
Length overall	50-180m (160-600 ft.)
Beam	20-60m (65-200 ft.)
Loaded draft	6-9m (20-30 ft.)
Crane	Vessel-based heavy lift 540 – 1.500MT (600-1.650 tons)

Table 4-3: WTIV sample dimensions

Figure 4-4: Example of wind turbine installation vessel (WIV)

4.2.4 Cable installation vessel

Cable-lay vessels are typically loaded with their cable reels at the cable manufacturer and thus do not require berthing facilities at staging and fabrication facilities. An example cable lay vessel is shown in Figure 4-5.

Figure 4-5: Cable lay vessel (source: offshore-fleet.com)

4.2.5 Operation and maintenance vessel

Crew and support vessels such as CTVs and OSVs that support O&M activity require smaller port facilities than construction vessels. CTVs and OSVs may transport technicians and equipment, replacement components, and lubricants to and from the wind farm.

European offshore wind farm operators have used a number of different vessel types and sizes, including mono-hulls, catamarans, and small waterplane area twin-hull vessels. High-speed catamarans have become a favoured vessel type by wind farm operators due to their speed, and fuel efficiency as well as their seakeeping ability, cargo capacities, and relative comfort for crew and passengers. This is specially the case if the commute to the OWF becomes too long (i.e. approximately > 2 hours), however high-speed CTVs can cost approximately 4 times more than conventional vessels.

Figure 4-6: High speed service vessel, Ref. /12/.

The number of service vessels required to support an offshore wind farm can vary and may depend on: the number of turbines in the wind farm, turbine models, distance from port, age of the farm, speed of the vessel, carrying capacity and endurance of the service vessel, available weather windows, and available working hours on-site. The number and type of service vessels is a key O&M cost optimization component for the OWF, since service vessels alone can contribute to approx. 30% of the planned OWF O&M costs.

A list of representative service vessel specifications is given in Table 4-4, based on experiences from Europe, with one supporting approximately 30 turbines on average.

Service Vessel Specifications	
Length Overall	15 - 19.7m (50 - 64 ft.)
Beam	6 - 10m (20 - 33 ft.)
Draft	1.5 - 2m (4 - 6 ft.)
Crew	2-3
Passengers	12
Onboard Crane	3 - 4MT (3 - 4 tons)
Cargo Area	12 - 40 m^2 (130 - 425 $ft.^2$)
Service Speed	20 - 25 knots
Endurance (@ Service Speed)	18 - 24 hours
Range	550 - 950 km (300 - 500 nautical miles)

Table 4-4. Representative, high-speed service vessel characteristics

Major unplanned service due to malfunction or failure may require large installation class jack-up vessels, or WTIVs. These vessels are not typically assigned to any particular wind farm and charge daily rates for mobilisation and engagement. Due to their high cost, only major component repairs are typically performed by these vessels such as gearbox, blade, or hub replacement.

5 FOWPI coastal aspects

Coastal issues for the FOWPI project refer to the likely issues that will need to be addressed in construction of facilities onshore or nearshore to support windfarm construction and operations. The coastal OWF issues that are central to FOWPI are hereby discussed and followed by a presentation of port functional requirements.

5.1 Subsea power cables

Proper power transmission infrastructure is critical to the success of FOWPI, which will transmit power to the grid via subsea cables and overhead lines. One option under consideration, for a single 200 MW project, is to connect subsea cables to an onshore substation (ONSS). In this scenario, inter-array cables will connect wind turbines together into strings, whose power would be transmitted via a low/medium voltage export cable to an ONSS substation located both close to the export cable landing and in proximity to the onshore power lines (see Ref. /12/). The ONSS would adjust the power received from the wind farm to match the grid transmission, and then transmit the power further to the location of grid substation. This is illustrated schematically in Figure 5-1.

OWF with MV export cable circuits & onshore substation

- **MV inter-array cables 33(66) kV** connect the WTGs in strings within the wind farm
- **MV export cables** link the wind farm to an onshore substation
- The **ONSS** is situated near the cable landing site and is equipped with MV/HV switchgear, MV/HV power transformers and shunt reactors. The substation is further equipped with harmonic filters and STATCOM for frequency regulation and stability.
- **Onshore cable or overhead lines** transmits the power from the wind farm substation to the grid substation and on to the rest of the grid.

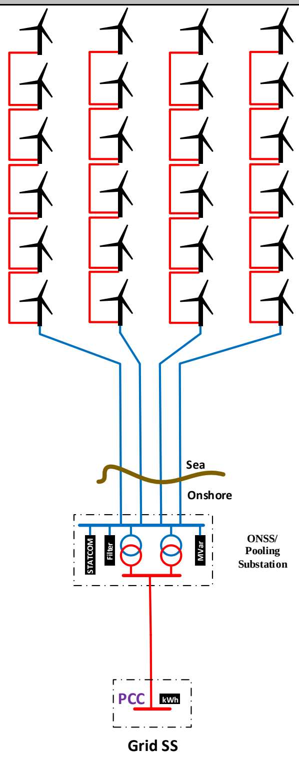

Figure 5-1: Power transmission system

Laying of subsea cables may involve different burial methods depending on local requirements for environmental impact mitigation and design. The cables will be laid with a cable lay vessel, either on top of the sea bed or in a trench and Ref. /12/ presents a full range of options that should be considered for detailed electrical design. Both inter-array and export cables for transmission of the power from the wind farm to the shore will be required.

According to Ref. /5/ export cable failures have been a frequent problem for OWF development in the UK, and proper site investigation and planning is needed to avoid costly repairs. A geophysical study has been performed, Ref. /8/, but the impacts on cable laying activity has not yet been assessed.

Furthermore, the FOWPI power export cabling routing is expected to lay under a number of shipping lanes (see Figure 5-2) and near to an existing oil and gas infrastructure (Figure 5-3) – all of which must be considered for the final electrical design. A full traffic and transportation study has yet to be conducted.

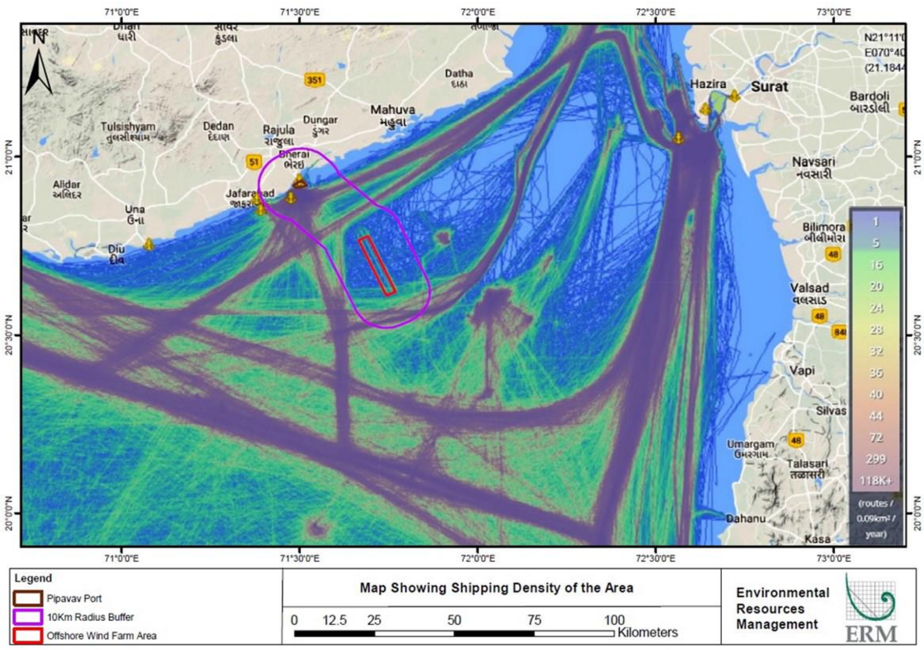

Figure 5-2: Shipping lanes surrounding the FOWPI site, Ref. /12/

The environmental impact of cable lay activities may be significant in some cases, and local soils may present challenges upon detailed survey and require mitigation. The preferred cable landing point is near Pipavav port, so that a cable trench from the nearest point of the wind farm will have a length of approximately 22 km, but proximity to the ONSS is also a major consideration for where to land the cables. Special considerations may be required for cable landing onshore to ensure reliability and lessen environmental impacts on coastal habitats. Modern horizontal drilling methods can be applied to minimize the impact of cable landing activities, if necessary. Selecting a cable landing site with flat topography and few coastal communities is desirable, however in order to avoid the need for horizontal drilling. Pipavav meets most all of these requirements.

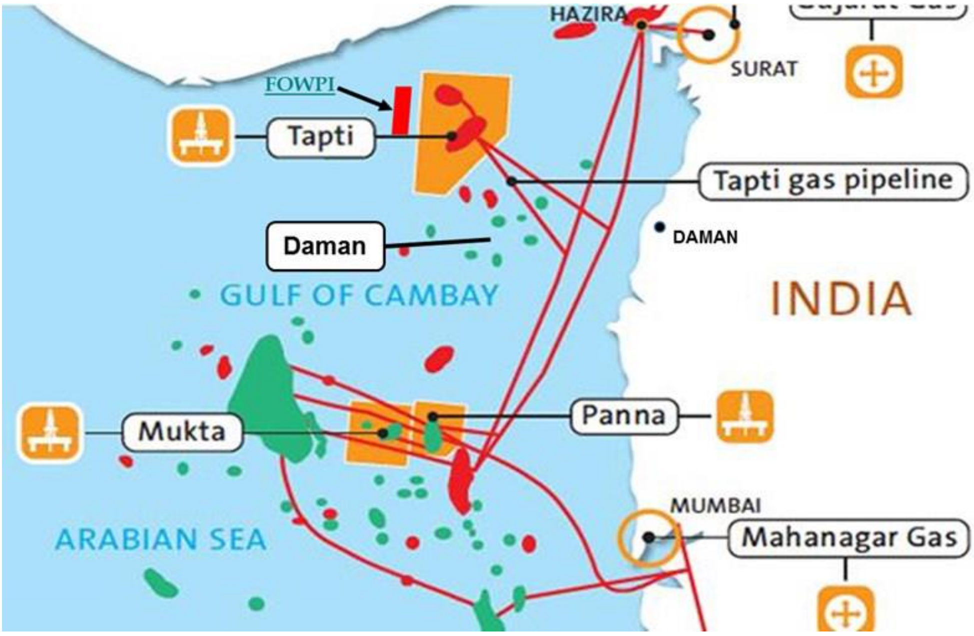

Figure 5-3: Existing oil and gas infrastructure surrounding the FOWPI site, Ref. /12/

The FOWPI wind farm is planned for a location 22 – 40 km from the coastline and power cables shall be placed on the sea bed from six groups of wind turbines to the landing point at the shore. Subsea cables will require a number of permits from various authorities. See section 7 and Ref. /13/ for full details.

5.2 Onshore substation

For FOWPI an onshore substations (ONSS) could be established on the shore near the subsea cable landing site. The ONSS collects all the power from the subsea export string(s) and steps the voltage up to match the voltage needed for further grid transmission. For the FOWPI wind farm, it would be expected to construct the ONSS - with switchgear, compensation rectors, STATCOM, etc - in the vicinity of Pipavav port area. However the exact location has yet to be defined.

If a new station is constructed, the station design will need to consider site flood elevations and other environmental concerns. Depending on the exact location, clearance may need to be obtained from the Gujarat Coastal Zone Management Authority (GCZMA) and Ministry of Environment, Forest and Climate Change. (MoEF & CC).

The power transmission system from the ONSS to the grid would be via onshore transmission cables (likely overhead in India). The final solution will be decided in connection with the detailed design of the wind farm and in accordance with GETCO requirements.

There are five potential sites, listed in Ref. /12/ and illustrated in Figure 5-4, owned and operated by GETCO for the grid connection. Current environmental concerns that have been highlighted in connection with the construction of an ONSS are: changes in land use, soil and land impact, vegetation loss in coastal areas, increased infrastructure, electrocution risk to migratory birds, and disturbance of marine turtle nesting, Ref. /12/.

5.3 Power transmission

Power lines and transmission infrastructure from the ONSS to the substation at the grid connection point will need to be constructed. The possible grid connections points for a 200 MW OWF are seen in Figure 5-4 and the distance between the potential landfall locations and the grid connection point could vary from 3 to 50+ km depending on the selected grid connection point and routing.

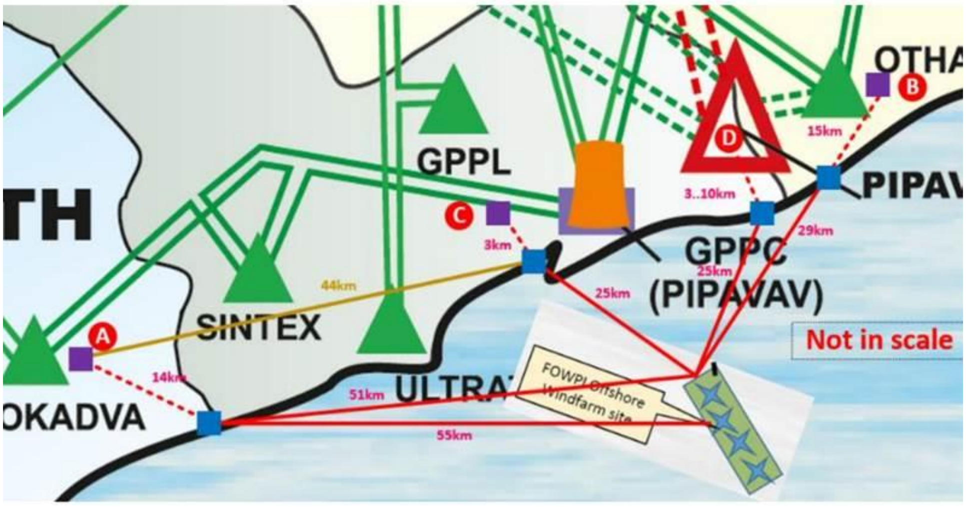

Figure 5-4: 200 MW OWF grid connection options to onshore 220kV network. Option D is 3 – 10 km from expected landfall and represents the planned GETCO 400/222 kV substation in the vicinity of Pipavav port to accommodate large bulk generation from scheduled wind power plants. See Ref. /12/ for further details.

Environmental criteria to be considered in the selection will most likely include avoidance of forests, rivers, eco-sensitive areas, highways, railway lines and villages, Ref. /12/. The power line will likely pass through a number of private plots of land, and contractual agreements and easements with the owners must be obtained as needed, in addition to the permitting requirements outlined in section 7 and in Ref. /13/.

6 Assessment of ports for FOWPI

Based on FOWIND study with the purpose of narrowing the field of suitable ports for OWF development in India, Ref. /1/, two ports were selected to support FOWPI: Pipavav port and Jafarabad port. The port requirements for FOWPI are outlined and compared with the facilities, however the major focus on these two ports is due to their location and proximity to the FOWPI site.

6.1 Port facilities

Due to their size and weight, most offshore wind farm components are manufactured and fabricated at waterfront facilities. At early stages of offshore wind project development in Gujarat, manufacturing is expected to be limited to preassembly activities, such as arrangement of converters, switchgear, etc. on tower internal platforms. This will require adequate covered facilities where such sensitive equipment can be assembled.

Storage and staging areas are also required for loadout and construction. These facilities may consist of a pier or wharf structures, which must be appropriate for the component(s) being manufactured. Generally, storage and staging areas are needed to handle blades, nacelles, hubs, towers, foundations and other components, but also small miscellaneous parts and tools needed for assembly.

Port facilities must be able to accommodate berthing of installation vessels which transport the foundations and the wind turbine components to the site. During the construction period a port with sufficient storage space and crane capacity must be available to handle and move the foundations and the wind turbine components both in upland areas during load-out and transport preparation.

6.1.1 Port functional requirements

An offshore wind farm consists of large components and requires suitable port facilities to handle the components. The main dimensions of the offshore wind farm components for the sizes of turbines considered for the FOWPI wind farm project are presented in the sections below.

Wind Turbines

Two conceptual scenarios for the FOWPI wind farm have been considered. Scenario 1 consists of 66 x 3 MW wind turbines and scenario 2 consists of 33 x 6 MW wind turbines. The dimensions and weight WTGs and their components are shown in Table 6-1.

Turbine Rating	Blade Length	Rotor Diameter	RNA Weight	Blade Weight (3 blades)	Tower Length	Ass. Tower Weight	Tower Bottom Diameter	Nacelle Dimensions Height / Width / Length
3 MW	~ 55m	112m	200 t	25 t	62m	400 t	4.5m	4m /4m /14m
6 MW	~ 75m	154m	410 t	35 t	93m	500 t	6.0m	7m / 7m/ 20m

Table 6-1: Main dimensions for wind turbine components, Ref. /11/

It is noted that the next generation of WTGs will present rated power of more than 12 MW. For a 12 MW turbine, the nacelle weight is estimated to increase to approximately 690 tonnes and the supporting tower to 850 tonnes. However such large turbines are not expected to be deployed in the first Gujarat projects.

Foundations

The foundation type for the FOWPI wind farm will likely be a monopile (MP) solution. A MP consists of a steel tube which is driven into the seabed and are suitable for the soil conditions identified by the FOWPI survey carried out in the wind farm area, Ref. /11/. A transition piece (TP) is placed on top of the MP, and the base of the tubular wind turbine tower is bolted to the TP.

Dimensions for monopile and transition piece for the two-different wind turbines considered by FOWPI are given in Table 6-2. Ranges are presented to indicate that detailed foundation designs have not been performed for FOWPI at this stage. However Table 6-2 is representative of the preliminary designs in Ref. /11/.

Turbine Rating	MP Diameter	MP Length	Typical MP Weight	TP Height	TP Weight	Water Depth
3 MW	4 – 6 m	40 – 60 m	400 – 800 MT	15 – 25 m	100 – 250 MT	15 – 30 m
6 MW	6 – 8 m	50 – 80 m	800 – 1300 MT	15 – 30 m	200 – 400 MT	30 – 40 m

Table 6-2: Typical dimensions of MPs and TPs, Ref. /12/

Cable array & Substation

The total length of each of the power cables connecting the individual turbines in groups and transmission will depend on the final electrical design of the wind farm, and options with and without an OSS are considered in the advisory designs presented in Ref. /12/, and illustrated in Figure 6-1 below. Subsea cables are typically loaded directly onto a cable lay barge or installation vessel, and it is not envisioned that cable storage space will be needed at the marshalling port.

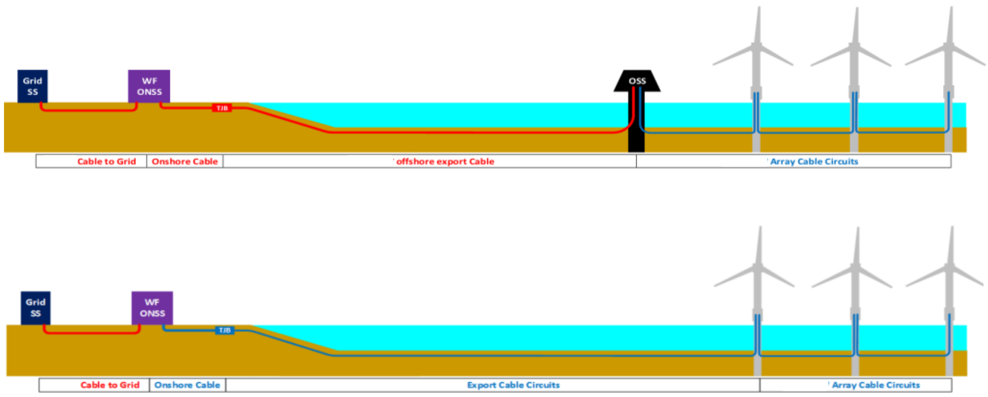

Figure 6-1 Schematic illustration of cable arrangements for FOWPI, Ref. /12/

In this case an offshore substation is deployed, the port should be able to handle the substation structure which may be heavier than any of the wind turbine components.

Note on extreme conditions

Because cyclones are expected in the area, the detailed offshore designs for FOWPI must also properly consider the extreme wind and wave conditions, and onshore project elements must consider storm surge and flooding due to these events.

6.2 Construction and load out port

A construction and load out port for wind farm installation requires several facilities for handling, storage and assembly of wind farm components. The important characteristics needed for these activities are discussed further below.

6.2.1 Loadout and storage area

It is assumed that all WTG and foundation components will be delivered via vessel from different manufacturing plants across the globe to the same load out port in India. Outbound European vessels may have different origin points, as different components such as foundations, TPs and WTG components are often manufactured in disparate areas, however each will arrive and unload their cargo at the selected port in India for construction. A general flow of storage and handling activity that will likely occur is shown in Figure 6-2.

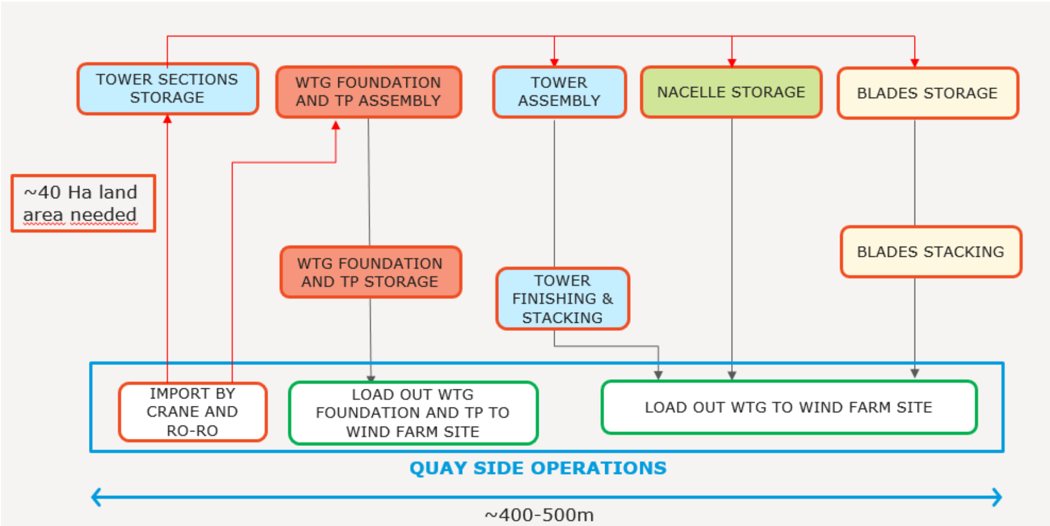

Figure 6-2: Typical flow operations for loadout arrangement

As shown in Figure 6-2, a large area is needed for temporary storage of foundations, wind turbine blades, wind turbine nacelles, wind turbine tower sections and power transmission equipment. Separate piers or wharfs should be considered for large projects or sustained offshore wind farm development activity because easy access and transport from the storage area to the vessel is critical to avoid accidents and delays. Major components (foundations, blade stacks, nacelles, etc.) may require coordinated crawler crane lifting, or the use of SPMTs for very large components. A typical arrangement for staging activities would utilize separate piers or wharfs along the quay for each major component, allowing easy and simultaneous access for WTIV, feeder barges, and other installation vessels.

Tower sections typically arrive prewired, however, tower internal platforms must be preassembled in a sheltered facility at the port to protect sensitive power electronics and other equipment. Completed internal platforms must be stored and sheltered, either in the assembly facility or other location, until they are lifted into place inside the towers and secured. Properly covered and secured tower sections can be stored securely outdoors for later load-out.

Foundations typically arrive preassembled and must be unloaded from vessels. However, MPs and TPs may be assembled offshore depending on the heavy lift capacity of installation vessels.

6.2.2 Indicative storage needs

For FOWPI, the storage area requirements were based on logistical requirements for the shipment of the components to and from the port and on experience from offshore wind ports world-wide. Required land needs for component storage is estimated to be 40 ha, based on a project size of 200-300 MW using 3 to 6 MW wind turbines. This same area could also support additional pipeline, however if more than 200-300 MW of capacity will be simultaneously handled, additional storage will be required above 40 ha. In this case, it is likely that additional berthing would need to be added to support the construction activities as well.

6.2.3 WTG component loads

The expected UDL capacity needed for the WTG components in the port area is listed in Table 6-3, which shows most of the decisive loading situations. Offloading assembled towers and nacelle transport requires approximately 10 t/m², estimated based on the preliminary foundation designs (Ref. /11/) and expected WTG ratings of 3 to 6 MW.

Component	Estimated Load [t]	Estimated UDL [t/m^2]
Tower section (storage)	N/A	4
Tower section (transport)	100	4
Berth offloading (assembled tower)	500	5-10
Nacelle (storage)	200-450	5-8
Blades (stack of 3)	105	<5

Table 6-3: Indicative load values for WTG components (3-6 MW WTG)

An illustration of the arrangement of components for load out is shown in Figure 6-3

Figure 6-3: Assembled towers and blade racks ready for loadout, with tower sections and nacelles visible in the background (East port – Port of Esbjerg).

6.2.4 Crane capacity and SPMTs

The handling of the wind farm components requires crane capacity for unloading/loading of components and preassembly activities. Crawler cranes (e.g. Figure 6-6 and Figure 6-7) and single and twin booms will likely be required for lifting and load out of large components, and gantry cranes will be needed for indoor facilities such as those for preassembly. Crane capacity for unloading requires capacity up to 500-1300 MT for current preliminary design of the monopile foundations, Ref. /11/. The UDL for heavy load crane areas is estimated to be 25 – 50 t/m² based on the experience of European ports, the preliminary design of the foundations and the estimated size of cranes needed. Heavy lift activity can be limited to certain areas at the berth in order to reduce the amount of reinforcements and associated upgrade costs to handle such large UDLs.

In addition to crawler cranes, handling and moving components in the port area via Self Propelled Modular Transporter (SPMT) vehicles is also common (Figure 6-4 and Figure 6-5). Because they are modular, SPMTs can be configured with additional axles to effectively spread loads and UDLs within port, especially for transport of heavy structural components such as nacelles, towers and foundations. This has the potential to reduce UDLs to 10-15 t/m² in heavy transport areas, which can help limit port upgrades.

Figure 6-4: Transportation of Mono-piles with SPMT

Figure 6-5: SPMT for transportation of large heavy components

Figure 6-6: Crawler cranes are used in loadout of many major OWF components.

Figure 6-7: Loading of Mono –pile foundations (MP) and transition pieces (TP)

6.2.5 Quay side length

The quay side length (the linear distance available to vessels) must be sufficient for transport vessels to load and unload components and other cargo. The operations on the quay include unloading and reception of major components from supply vessels, and delivery of foundations, TPs, towers, blades, nacelles etc. to installation vessels for transport to the site. LOA needed for vessel loadout is approximately 150-200 m, based on typical vessel sizes and European experience (Table 6-4).

Best practice observed in Europe is to separate the flow of inbound and outbound vessel traffic at the port. Due in part to the high cost of Wind Turbine Installation Vessels (WTIVs), it is recommended to have exclusive berthing facilities for these vessels. Ideally, one berth should be available for each of the WTG components, foundations and TPs. Based on the particular foundations and turbine sizes for FOWPI, a total length of 400-500m should be available to accommodate all activity, as was depicted in Figure 6-2. A total depth of approximately 70m for the berthing area should be considered, based on the current size of the preliminary foundation designs (Ref /11/).

6.2.6 Quay load capacity

Minimum quay side load capacity is 10t/m² to handle wind turbines up to 6MW. At newer terminals intended for offshore wind farm service for larger wind turbines requires capacities exceeding 20t/m². However, if foundations are to be handled, increased capacity is needed (25-50 t/m²), as discussed in Crane capacity and SPMTs, above. Piers and wharves with a lower-rated deck load may be used, however vessels with a heavy lift crane will be needed, or tracks can be laid down on top of piers for better weight distribution and to prevent damage by crawler cranes and to reinforce transportation pathways.

6.2.7 Quay Water depth

Based on recent project experience in Europe, large transportation vessels are requiring increasing water depths, with recent projects using vessels requiring 15 m for operations. However, even large WTIVs typically can operate in 6-8 m of water when fully loaded (Ref. /2/). Table 6-4 shows the dimensions and characteristics of worldwide offshore wind vessel fleets, including draft, which is used to determine the minimum operational water depth requirements. In addition, allowance for tidal fluctuations at the terminals is needed and it is recommended to have a mean low water level of 11 m at the construction and loadout port.

When utilising jack-up vessel for onloading WTG components it is important to avoid leg penetration into soft and muddy soils. Soil stabilization may be necessary by port authorities as part of the upgrade process.

6.2.8 Navigable depth

For installation offshore and for O&M access during operation, sufficient navigable depth is needed for each vessel type. Site bathymetry has been previously assessed for the FOWPI site as shown in Figure 6-8. Based on the bathymetric data and typical vessel draft requirements (e.g., Table 6-4), no navigable depth issues are expected to be encountered for FOWPI.

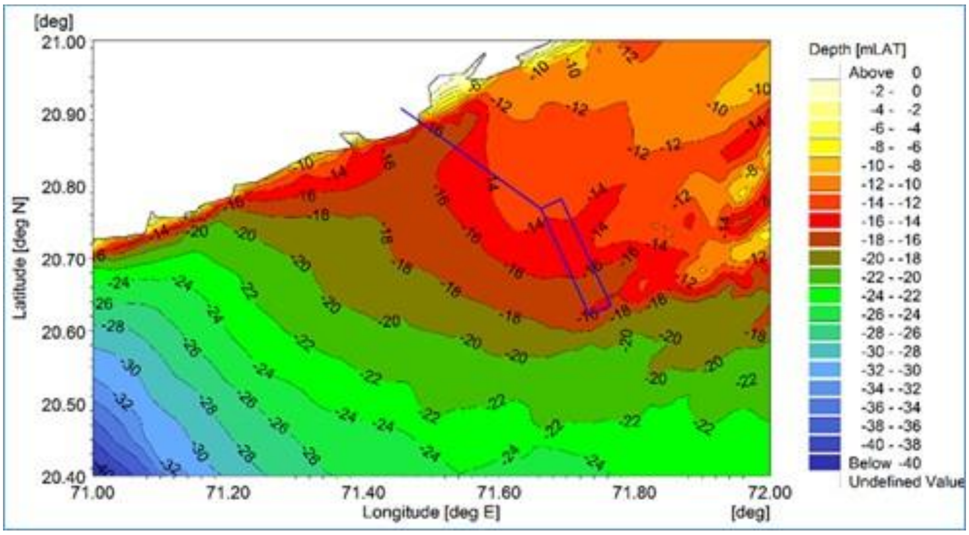

Figure 6-8: Bathymetry around the FOWPI site, Ref. /9/.

Owner	Vessel Name	Vessel Type	Flag	Year Built	Length	Breadth	Draft	Water Depth	Cargo Area	Pay Load	Main Crane Load	Crane Height	Speed	Legs
					(m)	(m)	(m)	(m)	(m2)	(t)	(t @ m)	(m)	(knots)	
A2SEA	Sea Power	Semi-Jackup	Denmark	1991/ 2002	92	22	4.3	24	1,020	2,386	230 t @ 15 m	-	7.8	4
A2SEA	Sea Energy	Semi-Jackup	Denmark	1990/ 2002	92	22	4.3	24	1,020	2,386	110 t @ 20 m	-	7.8	4
A2SEA	Sea Jack	Jackup Barge	Denmark	2003	91	33	5.5	30	2,500	2,500	800 t	-	-	4
A2SEA	Sea Worker	Jackup Barge	Denmark	2008	56	33	3.6	40	750	1,100	400 t @ 17 m	-	-	4
A2SEA	Sea Installer	TIV	Denmark	2012	132	39	5.3	45	3,350	5,000	800 t @ 24 m	102	12.0	4
Bard	Wind Lift 1	Jackup Barge	Germany	2010	102	36	3.5	45	-	2,600	500 t @ 31 m	121	-	4
Besix	Pauline	Jackup Barge	St. Vincent & G.	2002	48	24	2.5	30	-	1,500	200 t	-	-	4
DBB Jack-Up Services	MV Wind	Jackup Barge	Denmark	1995/ 2010	55	18	2.4	25	-	-	1,200 t	100	-	4
Geosea	Neptune	Jackup Barge	Luxembourg	2012	60	38	3.9	52	1,600	1,600	600 t @ 26 m	-	7.7	4
Geosea	Goliath	Jackup Barge	Luxembourg	2008	56	32	3.6	40	1,080	1,600	400 t @ 15 m	-	-	4
Geosea	Vagant	Jackup Barge	Netherlands	2002	44	23	4.2	30	-	1,000	-	-	-	4
Geosea	Buzzard	Jackup Barge	St. Vincent & G.	1982	43	30	3.0	40	-	1,300	-	-	-	4
Gulf Marine Services	GMS Endeavour	Jackup Barge	Panama	2010	76	36	6	65	1,035	1,600	300 t	-	8.0	4
Fugro Seacore	Excalibur	Jackup	Vanuatu	1978	60	32	2.8	40	-	1,352	220 t @ 14 m	64	-	8
HGO InfraSea Solutions	Innovation	TIV	Germany	2012	147	42	7.3	50	-	8,000	1,500 t @ 32 m	120	12.0	4
Hochtief	Thor	Jackup Barge	Germany	2010	70	40	8.3	50	1,850	3,300	500 t @ 20 m	-	-	4
Hochtief	Odin	Jackup Barge	Germany	2004	46	30	5.5	35	-	900	300 t @ 15 m	-	-	4
Jack-Up Barge	JB-114	Jackup/Heavy Lift	Bahamas	2009	56	32	3.0	40	-	1,250	300 t @ 16 m	-	-	4

Owner	Vessel Name	Vessel Type	Flag	Year Built	Length	Breadth	Draft	Water Depth	Cargo Area	Pay Load	Main Crane Load	Crane Height	Speed	Legs
					(m)	(m)	(m)	(m)	(m2)	(t)	(t @ m)	(m)	(knots)	
Jack-Up Barge	JB-115	Jackup/Heavy Lift	Bahamas	2009	56	32	3.0	40	-	1,250	300 t @ 16 m	-	-	4
Jack-Up Barge	JB-117	Jackup/Heavy Lift	Bahamas	2011	76	40	3.9	45		2,250	1,000 t @ 22 m	-	-	4
KS Drilling	Titan 2	Jackup Barge	Panama	2007	52	35	2.9	40	-	-	176 t @ 12 m	-	7.0	3
MCI	LISA A	Jackup	Panama	1977/ 2007	73	40	4.0	33	1,000	950	425 t @ 18 m	80	-	4
Master Marine	NORA	Jackup	Cyprus	2012	118	50	7.4	50	2,500	7,200	750 t @ 29 m	-	8.0	4
Muhibbah Marine	MEB JB1	Jackup Barge	Germany	1960/ 1995	49	31	3.0	ca. 30	748	-	272 t @ 14 m	-	-	8
RWE Innogy	Victoria Mathias	TIV	Germany	2011	100	40	4.5	40	-	4,200	1,000 t @ 21 m	110	7.5	4
RWE Innogy	Friedrich-Ernestine	TIV	Germany	2012	109	40	-	40	-	4,200	1,000 t @ 21 m	110	6.4	4
Seajacks	Seajacks Kraken	TIV	Panama	2009	76	36	3.7	41	900	1,550	300 t @ 16 m	-	8.0	4
Seajacks	Seajacks Leviathan	TIV	Panama	2009	76	36	3.7	41	900	1,550	300 t @ 16 m	-	8.0	4
Seajacks	Seajacks Zaratan	TIV	Panama	2012	81	41	5.3	55	2,000	3,350	800 t @ 24 m	-	9.1	4
Swire Blue Ocean	Pacific Orca	TIV	Cyprus	2012	161	49	6.0	70	4,300	6,600	1,200 t @ 31 m	118	13.0	6
Swire Blue Ocean	Pacific Osprey	TIV	Cyprus	2012	161	49	5.5	70	4,300	6,600	1,200 t @ 31 m	118	13.0	6
Workfox	Seafox 7	TIV	Isle of Man	2008	75	32	3.4	40	700	1,120	280 t @ 22 m	-	-	4
Workfox	Seafox 5	TIV	Isle of Man	2012	151	50	10.9	65	3,750	6,500	1,200 t @ 25 m	-	10.0	4
MPI / Vroon	MPI Resolution	TIV	Netherlands	2003	130	38	4.3	35	3,200	4,875	600 t @ 25 m	95	11.0	6
MPI / Vroon	MPI Adventure	TIV	Netherlands	2011	139	41	5.5	40	3,600	6,000	1,000 t @ 26 m	105	12.5	6

Owner	Vessel Name	Vessel Type	Flag	Year Built	Length	Breadth	Draft	Water Depth	Cargo Area	Pay Load	Main Crane Load	Crane Height	Speed	Legs
					(m)	(m)	(m)	(m)	(m2)	(t)	(t @ m)	(m)	(knots)	
MPI / Vroon	MPI Discovery	TIV	Netherlands	2011	139	41	5.5	40	3,600	6,000	1,000 t @ 26 m	105	12.5	6
Weeks Marine	RD MacDonald	Jackup Barge	US	2012	79	24	4.4	22	955	2,300	680 t @ 43 m	46	-	8
Fred. Olsen Windcarrier	Brave Tern	TIV	Malta	2012	132	39	6.0	45	3,200	5,300	800 t @ 24 m	102	12.0	4
Fred. Olsen Windcarrier	Bold Tern	TIV	Malta	2013	132	39	6.0	45	3,200	5,300	800 t @ 24 m	102	12.0	4
Hochtief	Vidar	TIV	Germany	2013	137	41	6.3	50	3,400	6,500	1,200 t @ 28 m	-	10.0	4
Van Oord	Aeolus	TIV	Netherlands	2013	139	38	5.7	45	-	6,500	900 t @ 30 m	120	12.0	4
Seajacks	Seajacks Hydra	TIV	-	2014	-	-	-	48	900	3,350	400 t	-	-	4
DBB Jack-Up Services	Wind II	TIV	-	2014	80	32	-	45	-	-	-	-	-	4
Inwind	INWIND Installer	TIV	-	-	101	68	4.5	65	3,500	4,500	1,200 t @ 25 m	105	-	3
Gaoh Offshore	Deepwater Installer	TIV	-	-	140	40	6.5	50	6,000	10,450	1,600 t @ 20 m	105	10.0	4

Table 6-4: Offshore installation vessels used in offshore wind farm construction, Ref /5/

6.2.9 Air draft

WTG tower sections are normally transported in a vertical position. For example, WTG installation vessels are most efficient when towers are transported vertically and preassembled. Turbine manufacturers typically do not permit tower sections to be transported horizontally once they have been outfitted with internal platforms. Transporting the towers in shorter vertical sections is possible, but this increases offshore construction time. Jackets may be transported upright to save space on the installation vessel or material barge.

The required air draft depends on the actual length of the monopile and the tower sections. For the FOWPI project the required air draft is expected to be approximately 80–100m.

6.3 O&M port and service facility

For the operational lifetime of the wind farm, it will be necessary to conduct periodic maintenance. This activity can range from regular equipment checks, and the replacement of minor parts, to partial or full replacement of major components such as gearboxes, bearings, blades and electrical equipment. The O&M port and service facilities act as maintenance base for the offshore wind farm and will require storage and staff facilities, as well as a wharf for berthing of service vessels including crew transfer vessels and offshore supply vessel. A major requirement for the O&M port is a suitable location which is in the proximity of the wind farm. This will enable fast access in case of failures or unplanned maintenance activity, thereby reducing fuel, vessel, and personnel costs.

Based on European experience, a building at the port of at least 300 m^2 is needed for storage of spare parts and a small workshop. Spare parts and consumables that need to be stored for O&M activity could include components such as bolts, cables, tools and lubricants, necessary for both scheduled and unscheduled maintenance of the wind farm and substation(s). The workshop should facilitate planned and unplanned maintenance and repair activity of minor components.

A staff office must also be established at the port and should include facilities for incidental office work and accommodation of service personnel during weather days, etc.

A service vessel for wind turbine O&M must be designed and built to service the wind farm. Based on European experience, the length of a typical offshore supply vessel is typically between 40 and 70m. Berth length should be between 50 to 80m for transfer of personnel and supplies offshore to the site.

6.4 Summary port requirements

The overall minimum suggested requirements for the port size and facilities for the FOWPI wind farm are summarised in Table 6-5. Berth load capacity is usually determined by foundations, i.e., the heaviest components.

Type of port	Storage area/ facilities [m²]	Crane capacity [t]	Berth length [m]	Quay side capacity UDL [t/m²]	Heavy load capacity UDL [t/m²]	Storage Area Capacity	Water depth [m]	Air draft [m]	Transport Access
Construction	400.000	1.300	400-500	10-15	25-50	4-8	11-15	100	Rail, Highway
O&M Service	500	-	50-80	-	-	-	5	-	-

Table 6-5: Main port requirements for construction and O&M of FOWPI based on preliminary design data, Ref. /11/, and European experience

6.5 Recommended construction and load out port

Comparing ports at Pipavav and Jafarabad, Pipavav port appears better suited for construction activity in connection with FOWPI. A discussion of the assessment and suitability for OWF construction is given below.

6.5.1 Pipavav port

The port at Pipavav is located in the state of Gujarat and is 22 km from the FOWPI site, giving the port an excellent location to serve as construction port for FOWPI. Figure 6-9 shows the exact wind farm location in relation to the Pipavav port. Meetings held with Pipavav port management indicate that they are strongly interested in making required investments and upgrades to the port in order to support the developing offshore wind industry in India.

Officially, Gujarat Pipavav Ports Ltd. is a public-private partnership port, and the first in India. The port was established in 1998 with a 30-year concession agreement and boasts connectivity and easy access to all international shipping routes as well as highway and rail connectivity.

Current port facilities are designed for the requirements of a multi-cargo port. The port handles shipping containers, liquids, bulk cargo, including Ro-Ro and Lo-Lo cargo. Pipavav port is equipped with modern and efficient container handling equipment and has container yard facilities, including container storage areas. A Bulk cargo handling facility includes a dedicated berth with an alongside draft of 13.5m. Three shore cranes are available for loading and unloading activities. Liquid cargos are handled in a dedicated berth which has an alongside draft of 12 m. The Ro-Ro cargo capacity is currently about 250.000 cars.

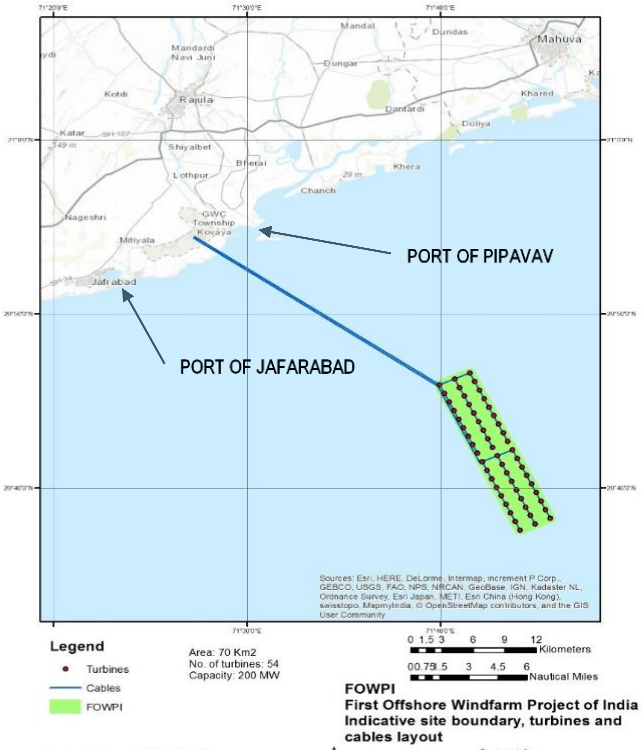

Figure 6-9: Locations of Port of Pipavav and Port of Jafarabad

Pipavav port has a coal yard with conveyer that is currently in use approximately once per month. The conveyer is outfitted with a water curtain, hard curtain and stop operations, and is only used when cars are not being transported at the port. Car manufacturers are one of the port's priority clients and demand strict procedures for reduction of coal dust, which would be vital for handling wind turbine technology as well. According to the port management at the time of COWI's visit, coal handling is not a priority operation and is in decline. Coal handling at Pipavav has faced pressure as India has recently increased its domestic coal production to be less reliant on imports. Current energy policies in India also indicate reductions are likely to continue in future.

Presently, Pipavav port activity occupies only part of the land available to it. The port has the ability to scale up its existing cargo capacity to meet future growth and to add additional types of cargo in the future, such as offshore wind components. A plan of the Pipavav port is shown in Figure 6-10, and further photos of the port can be found in Appendix A.

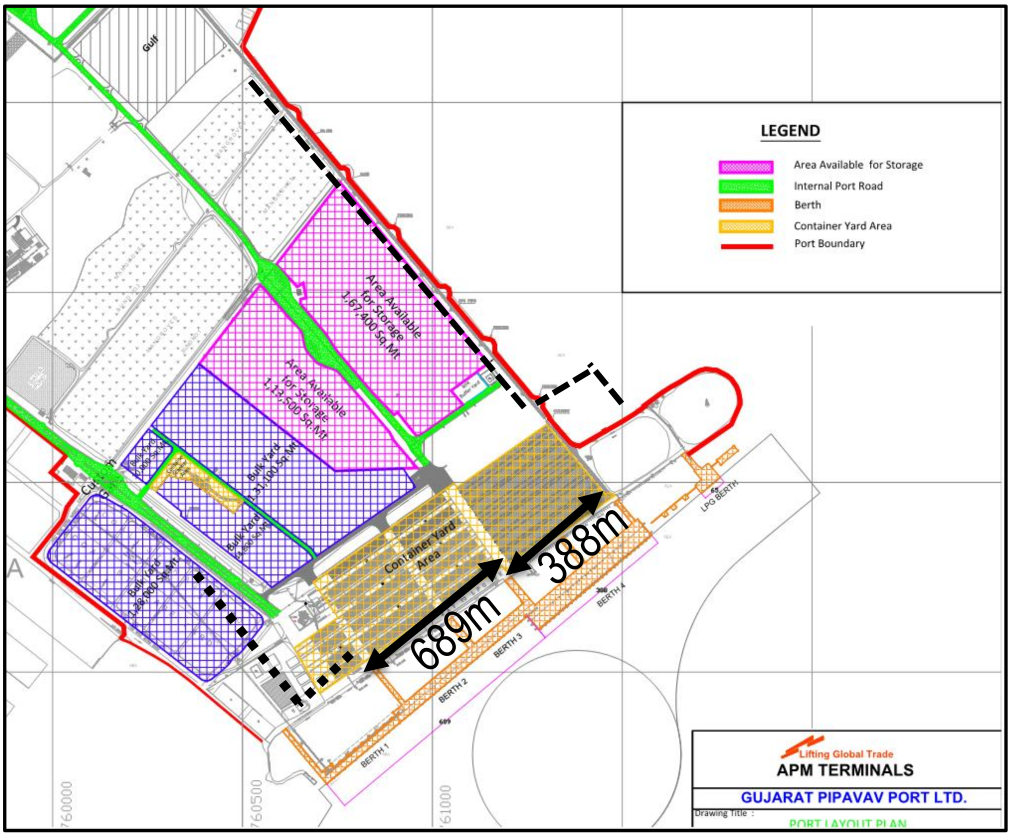

Figure 6-10: Pipavav port plan, courtesy of APM Terminals.

Berth 1 is currently used for coal and berths 2-4 (Figure 6-11) are being used for loading and unloading of containers. There are existing constraints in the coal conveyor system in the southwest area and the liquid pipeline at the northeast area. The quay side structure at Pipavav consists of a concrete suspended pile deck. During a technical meeting with the port staff, it was indicated that the max UDL is 5 t/m², which would mean that berth facilities would need reinforcements for offloading and loading out OWF turbine and foundation components. The management also indicated that berth length could be extended if needed for OWF vessels. The water depth at the berth is 13.5m and the suspended deck structure is connected with the hinterland via access bridges (See Figure 6-11). The access bridges are 10m wide, which limits flexibility for unloading and handling at the berth.

Figure 6-11: Container berth 2-4 with connecting access bridges. In the background is the container stacking area visible.

Landing the OWF export cable was discussed with the technical manager at Pipavav port, who indicated that it could be possible to land the cable on-site. A 33 kV/220 kV substation is located on the premises and is connected to the GETCO transmission grid via a 220 kV overhead line.

Based on the data and information received from port management during meetings with the COWI team, Pipavav port provides sufficient water depth, but would need modifications of both the quay and storage areas to handle offshore wind farm components during construction of FOWPI. As existing berths are in use, they will have to be released for the FOWPI project. If they cannot, the port could be extended to the northeast by moving the existing LPG terminal further to the northeast. Alternatively, due to the decline of coal operations at Berth 1, the coal area could be transformed into a loadout area/storage area. Revetments along the southwest part of the coal area should be investigated for a new loadout berth.

As berth load capacity is usually determined by foundations, quay areas and bridge connections will need to be reinforced to carry loads for FOWPI components, which are expected to need a capacity of 25-50 t/m². However, as Pipapav port has both proximity to the FOWPI site and is a large, functioning, industrial port with available storage and capability for upgrades, it is recommended to use Pipapav as a construction and installation port for FOWPI.

Looking beyond FOWPI, the port will require major upgrades if it is to be used as a main port for the future OWF development in India. New berths with bearing capacity beyond the 25-50 t/m² range given here will likely be required, or existing berths will need to be upgraded. Many large components which cannot be transported to the port by land will require manufacturing and pre-assembly facilities.

Photos taken by the FOWPI team during a visit to Pipavav port are available in Appendix A.

6.5.2 Jafarabad port

The COWI team also visited the Jafarabad port, a fishing port in the Indian state of Jafarabad (see Figure 6-12 for map). After an initial assessment, the water depth berth facilities, crane facilities and storage areas were deemed too limited for OWF construction activity. The port is best suited for small vessel traffic, and could not be utilised effectively as a construction and load out port without performing significant renovations and upgrades that would change the character of the port.

Photos taken by the FOWPI team during a visit to Jafarabad port are available in Appendix B.

Figure 6-12. Jafarabad port location

6.6 Recommended O&M and service port

6.6.1 Pipavav

Pipavav port management expressed interest to act as a service facility and port for FOWPI. Management also indicated that the port could accommodate subsea cable landing and act as a location for a possible ONSS (pooling) station. As vessel fuel costs make up a significant percentage of routine offshore maintenance costs, it is preferable to utilize the Pipavav port as a base for O&M and service activity because it is closer to the FOWPI wind farm.

6.6.2 Jafarabad

Jafarabad port (Figure 6-13) is a fishing port near the FOWPI site, however, at a distance of 33 km, it is not as conveniently located as Pipavav. Jafarabad could act as an O&M and service port, accommodating small service and crew transfer vessels. However, infrastructure is currently rudimentary and berthing facilities and workshop space would need to be built for use by FOWPI. When combined with the longer access times due to the port's location, it is preferable to locate O&M facilities at Pipavav.

Figure 6-13 Jafarabad fishing port has only basic facilities at the current time for supporting the FOWPI site.

7 Permits for coastal activities

Activities in the coastal areas fall under the jurisdiction of various central and state and local government agencies, each having their own approval process. Permits and consents for the projects are expected to be facilitated by NIWE, which is to act as a one-stop-shop.

It is important to emphasize that a clear scope of responsibility - incl. permitting development and ownership of project components - remains to be defined/shared e.g. between the local TSO, in this case GETCO, and the offshore wind project developer.

Expected permits and consents related to coastal activities for FOWPI are listed in Table 7-1. A more comprehensive list of permits, not only related to coastal activities, is presented in Ref. /13/.

Activity	Phase	Offshore/ Onshore	Approval Type	Regulation/ Convention/ Policy	Requirement	Nodal Authority
Health Safety and Environment						
Carrying out Nonexclusive Offshore surveys/studies in waters/ Exclusive Economic Zone of India using vessels	Pre-construction	Offshore	Naval Security Clearance for Vessels to Operate in Maritime Zone of India (MZI)	Same as above	All vessels deployed in the area by contracted companies of the developer shall undergo naval security inspection under the aegis of the FOC-in-C of the concerned Naval Command, Flag Officer, Offshore Defence Advisory Group (FODAG) prior to their deployment. As per norm, one month's notice is to be given to facilitate clearance/ inspection. Please refer to Annexure 1(E) of the NIWE guidelines to this regard.	FODAG
	Pre-construction	Offshore	Security Clearance for Company & Director(s)	Same as above	Necessary security clearance will be required to be obtained for the Company and the Directors to be involved in the development of the proposed project. Please refer to Annexure 1(M) & 1(N) of the NIWE guidelines to this regard.	Ministry of Home Affairs
Construction/operation/decommisioning of offshore wind power installation	Operations	Offshore	Aviation Clearance	National Offshore Wind Energy Policy-2015 issued in Gazette notification dated 07 October 2015	For offshore wind projects located near aviation radars/aerodromes (distance not specified), clearance will be required from Ministry of Civil Aviation. No clearance/NOC required for all other locations.	Ministry of Civil Aviation
	Construction; Operations & Decommissioning	Offshore	Clearance for operating within existing oil and gas blocks	National Offshore Wind Energy Policy-2015 issued in Gazette notification dated 07 October 2015	For offshore wind project proposed in Oil & Gas Blocks, necessary approval is required to be obtained from the Ministry of Petroleum & Natural Gas (MoPNG). NOC is not required for construction undertaken outside the offshore Oil & Gas Blocks. Review of the project design document does not indicate any conflict of the proposed offshore infrastructure with any oil and gas block, with the Tapti Oil Field Development Area located at a distance of 5 km from the project site boundaries. Subsea infrastructure however still remains to be assessed.	Ministry of Petroleum & Natural Gas (MoPNG)
	Construction; Operations & Decommissioning	Offshore	Permission for operating within safety zone of any oil and gas facility	Petroleum and Natural Gas (Safety in Offshore Operations) Rules, 2008	In accordance to the Petroleum and Natural Gas (Safety in Offshore Operations) Rules, 2008 a safety zone of five hundred metres from the extremities of the offshore oil and gas facility is required to be maintained. In case for any unauthorized vessel (including aircraft) to enter, pass, stay or operate in the safety zone, necessary permission is required to be obtained from the operator of the said facility. But it is to be noted that the same applies only for unauthorized vessels.	Operator of oil and gas facility
	Construction & Operations	Offshore	Restriction of operating in close vicinity of offshore windfarm installation	The International Regulation of Offshore Wind Farms under the 1982 Law of the Sea Convention	In accordance to the relevant provision of The International Regulation of Offshore Wind Farms under the 1982 Law of the Sea Convention, coastal States has the power to regulate innocent passage, including in the vicinity of a wind farm, which is not limited only to the operation of 'positive' routing systems', such as Traffic Seperation Schemes (TSS) or sea lanes. This may include "safety zones" or "Areas to be Avoided" (ATBAs), established by the coastal State, which could lead to the result that any activity in fact is banned from these areas. Presently, for the coastal state of Gujarat the demarcation of safety zones or ATBAs around offshore windfarms are yet to be established.	Operator of offshore windfarm installation

Activity	Phase	Offshore/ Onshore	Approval Type	Regulation/ Convention/ Policy	Requirement	Nodal Authority
	Operations	Offshore and Onshore	License for transmission of electricity (both onshore and offshore)	Electricity Act, 2003	The developer is required to obtain transmission licence for construction and maintenance of certain transmission lines and the facilities to be used for evacuation of power from proposed offshore wind energy installation and onshore sub-station.	Central Electricity Regulatory Commission/ Gujarat Energy Transmission Corporation Limited (GETCO)
	Operations	Offshore and Onshore	Power Purchase Agreement & Power Generation License	Electricity Act, 2003	Per provision of Section 49 of the aforesaid Act, any consumer of electricity is required to enter into an agreement with any entity involved in supply of electricity on such terms and conditions (including tariff) as may be agreed upon. All independent power producers, is required to enter into a power purchase agreement (PPA) with the respective State Electricity Boards.	Central Electricity Regulatory Commission/ Gujarat Energy Transmission Corporation Limited (GETCO)
	Construction & Operations	Offshore	Clearance for setting of offshore wind installation near any space station	National Offshore Wind Energy Policy-2015 issued in Gazette notification dated 07 October 2015 Circular No: NIWE/OW&IB/Offshore/2017/01 as issued by National Institute of Wind Energy (NIWE): Detailed Draft Guidelines for Offshore Studies and Surveys by Private sector	Clearance from security angle is required to be obtained with respect to maintenance of minimum safety distance from any nearby space installations.	Department of Space Installation
	Construction; Operations & Decommissioning	Offshore & Onshore	License for performing any operations within any notified ecologically sensitive area	Wild Life Protection Act, 1972 Coastal Regulation Zone (CRZ) Notification, 2011	In accordance to section 28 of the Wild Life Protection Act, 1972, a permit will be required from the Chief Wild Life Warden to enter into notified ecologically protected area viz. sanctuaries, national parks etc., for the purpose of investigation or study of wildlife and purposes ancillary or incidental thereto; photography; scientific research; tourism; and transaction of lawful business with any person residing in the sanctuary. Furthermore, in accordance to section 29 of the aforesaid Act, no person shall destroy or damage the habitat of any wild animal or deprive any wild animal or its habitat within any notified ecologically protected area except under and in accordance with a permit granted by the Chief Wildlife Warden and no such permit shall be granted unless the State Government authorises the issue of such permit. The Coastal Reuglation Zone (CRZ) Notification 2011, restricts the activity within any CRZ-1 areas viz. ecologically sensitive and important such as national parks, Sanctuaries, reserve forests, wildlife habitats, mangroves, corals coral reef areas; areas close to breeding and spawning grounds of fish and other marine life, areas of outstanding beauty/areas rich in genetic diversity, areas likely to be inundated due to rising Sea level consequent upon global warming and such other areas, as may be declared by the Central and State Government at the State or Union territory level from time to time.	Chief Wild Life Warden

Activity	Phase	Offshore/ Onshore	Approval Type	Regulation/ Convention/ Policy	Requirement	Nodal Authority
	Operations	Offshore	Final Approval Certificate	National Offshore Wind Energy Policy-2015 issued in Gazette notification dated 07 October 2015.	Following completion of the project, a certificate for commencement of operation of the windfarm shall be issued by NIWE. This will enable verification of all statuary and regulatory guidelines by the NIWE before commissioning.	NIWE
	Construction & Operations	Offshore	Environmental Clearance (EC) and CRZ Clearance	EIA Notification, 2006 (as amended) and Coastal Regulation Zone Notification, 2011	Offshore windfarms are not covered under the Schedule I of EIA Notification, 2006 which requires an Environmental Clearance (EC) to be obtained. However the offshore windfarm installation based on their distance to the coast (<12nm) may require an CRZ clearance to be obtained from the MoEF &CC and GCZMA.	Gujarat Coastal Zone Management Authority/ Ministry of Environment Forests & Climate Change (MoEF&CC)
Transportation of cargo by vessel during construction/operation/decommissioning phase of the project	Construction; Operations & Decommissioning	Offshore	Cargo Ship Safety Construction Certificate; Cargo Ship Safety Equipment Certificate	SOLAS 1974, regulation I/12, as amended by the GMDSS amendments; 1988 SOLAS Protocol, regulation I/12	For any cargo vessel of 500 gross tonnage and over to be deployed for the proposed project, a Cargo Ship Safety Construction Certificate and Ship Safety Equipment Certificate shall be issued after survey which satisfies the requirements for cargo vessels set out in regulation I/10 of SOLAS 1974.	Directorate General of Shipping (DG Shipping)
	Construction; Operations & Decommissioning	Offshore	Ship Safety Certificate	Merchant Shipping (Safety Convention Certificates) Rules, 1968 International Convention on Safety of Life at Sea (SOLAS), 1974	With respect to the proposed project, all vessels operating within coastal or territorial waters in India is required to obtain an Ship Safety Certificate from the Certifying Authority.	Directorate General of Shipping (DG Shipping)
Laying of sub-sea power transmission lines/cables, onshore cables, O&M building facilities and construction of sub-station for power evacuation.	Construction & Operations	Offshore & Onshore	Coastal Regulation Zone (CRZ) Clearance	Coastal Regulation Zone (CRZ) Notification 2011	Per this notification and with respect to the proposed project all activities pertaining to laying of sub-sea power cables/transmission lines including setting up of sub-station for power evacuation from non-conventional energy sources within the coastal regulation zone (CRZ) will require necessary clearance to be obtained from Gujarat Coastal Zone Management Authority (GCZMA) and Ministry of Environment Forests & Climate Change (MoEF&CC). For the purpose of obtaining the CRZ clearance the following will be required: • Form-1 (Annexure-IV of the CRZ notification); • Rapid EIA Report including marine and terrestrial component; • Comprehensive EIA with cumulative studies for projects in the stretches classified as low and medium eroding by MoEF&CC based on scientific studies and in consultation with the State Governments; • Disaster Management Report, Risk Assessment Report and Management Plan; • CRZ map indicating HTL and LTL demarcated by one of the authorized agency in 1:4000 scale; • Project layout superimposed on the above map; • The CRZ map normally covering 7km radius around the project site. • The CRZ map indicating the CRZ-I, II, III and IV areas including other notified ecologically sensitive areas; and • No Objection Certificate from the concerned State Pollution Control Boards or Union territory Pollution Control Committees for the projects involving discharge of effluents, solid wastes, sewage and the like.;	Gujarat Coastal Zone Management Authority/ Ministry of Environment Forests & Climate Change (MoEF&CC)

Activity	Phase	Offshore/ Onshore	Approval Type	Regulation/ Convention/ Policy	Requirement	Nodal Authority
	Construction & Operations	Onshore	Environmental Clearance (EC)	EIA Notification, 2006 (as amended)	An Environmental Clearance (EC) may get triggered for the onshore structures likley to developed for the proposed project under the following circumstances: • O&M building facilities designed with a total built up-area of >20000 sq.m. and <150000 sq.m. of built up area; and • Onshore cable lines route that passes through any notified ecologically sensitive area.	Ministry of Environment Forests & Climate Change (MoEF&CC)
	Operations	Onshore	Hazardous Waste Authorization	Hazardous and Other Wastes (Management and Transboundary Movement) Rules, 2016	For the project loading and unloading vehicles and other construction equipments will generate hazardous waste in the form of hydraulic and waste fuel, engine oil, spent oil, etc. and will require to obtain authorization from State Pollution Control Board. Hazardous waste also to be disposed of through authorised vendor/ recycler.	Gujarat Pollution Control Board (GPCB)
Laying of onshore cables	Construction & Operations	Onshore	Cable Crossing Agreements	National Offshore Wind Energy Policy-2015 issued in Gazette notification dated 07 October 2015	As discussed in Sl. No. 43 there exists potential for cross cabling during laying of onshore power cables. If such cable crossings are identified then necessary agreement need to be formulated with the concerned owner/developer.	Department of Telecommunic ations (DoT)
Construction of any infrastructure within port limits	Construction	Offshore & Onshore	Permission from Port Authority for development of project related port infrastructure	Gujarat Maritime Board Act, 1981	As per section 35 of the Act, the erection or fixation of any wharf, dock, quay, stage, jetty, and pier, place of anchorage, erection or moorings with respect to the proposed project within the limits of port or port approaches will require prior permission from the Port Authority.	Gujarat Maritime Board (GMB)
	Construction & Operations	Offshore & Onshore	Coastal Regulation Zone (CRZ) Clearance	Coastal Regulation Zone (CRZ) Notification 2011	As discussed in Sl. No. 39, construction of any structures like jetties etc. within the CRZ limits will trigger a CRZ clearance to be obtained from the Gujarat Coastal Zone Management Authority (GCZMA) and MoEF & CC. For the purpose of obtaining clearance, an EIA has to be prepared and submitted to the aforesaid authorities	Gujarat Coastal Zone Management Authority/ Ministry of Environment Forests & Climate Change (MoEF&CC)
Berthing of project vessels at port involved in project offshore surveys, raw material supply and construction, operation and decommissioning activities	Pre-construction; Construction; Operations & Decommissioning	Offshore	Permission from Port Authority for berthing of vessels	Indian Ports Act, 1908	In case berthing of vessel is required at any of the west coast port then accordance to provision of section 43 of the Ports Act necessary port clearance needs to be obtained through payment of port charges as levied by the Central Government.	Gujarat Maritime Board (GMB)
Social						
Engagement of Labour for survey, construction, operations and decommissioning	Pre-construction; Construction; Operations & Decommissioning	Offshore & Onshore	Principal Employers Registration under Contract Labour (Regulation and Abolition) Act, 1971	Contract Labour (Regulation and Abolition) Act, 1970	Principal Employer has to be registered under the act for engaging more than twenty contract labour	Department of Labour
	Pre-construction; Construction; Operations & Decommissioning	Offshore & Onshore	Labour License under Contract Labour (Regulation and Abolition) Act, 1970	Labour License under Contract Labour (Regulation and Abolition) Act, 1970	All contractors have to be registered for engaging labour.	Department of Labour
	Pre-construction; Construction; Operations & Decommissioning	Offshore & Onshore	Principal Employer Registration under Interstate Migrant Worker Act, 1979	Interstate Migrant Worker Act, 1978	Principal Employer Registration under Interstate Migrant Worker Act, 1979 if interstate migrant workers are to be engaged	Department of Labour

Activity	Phase	Offshore/ Onshore	Approval Type	Regulation/ Convention/ Policy	Requirement	Nodal Authority
	Construction, Operations & Decommissioning	Onshore	Registration under Building and Other Construction Works Act, 1996	Building and Other Construction Works Act, 1996	Building and Other Construction Works Act, 1996- registration and payment of BOCW fees (1% of construction cost)	Department of Labour and BOCW Welfare Board
Land Acquisition/ Purchase	Preconstruction	Onshore	For government led acquisition- Right to Fair Compensation and Transparency in Land Acquisition Resettlement and Rehabilitation 2013	Right to Fair Compensation and Transparency in Land Acquisition Resettlement and Rehabilitation 2013	Requirements as stated under the RTFCTLARR Act 2013 will have to be implemented for assessment, valuation and disbursement of compensation and provisions for Resettlement and Rehabilitation	Land Acquisition Officer- District Magistrate/Sub -divisional Magistrate
	Preconstruction	Onshore	Private Purchase- All private /direct land purchase - Gujarat Land Revenue Rules 1972	Gujarat Land Revenue Rules 1972	Direct Purchase of private land will follow the rules as down in Gujarat Land Revenue Rules 1972	Gujarat Revenue Department
	Preconstruction	Onshore	Transmission Line- to follow the guidelines for compensation payment in regard to right of way for transmission line	Guidelines for payment of compensation towards damages in regard to Right of Way for transmission lines. 15th October 2015	Compensation @ 85% of land value as determined by District Magistrate or any other authority based on Circle rate/ Guideline value/ Stamp Act rates for tower base area (between four legs) impacted severely due to installation of tower/pylon structure; Compensation towards diminution of land value in the width of Right of Way (RoW) Corridor due to laying of transmission line and imposing certain restriction would be decided by the States as per categorization/type of land in different places of States, subject to a maximum of 15% of land value as determined based on Circle ratel Guideline valuel Stamp Act rates; For this purpose, the width of RoW corridor shall not be more than that prescribed in Annex 2 of the guidelines	Land Acquisition Officer- District Magistrate/Sub -divisional Magistrate

Table 7-1 Permits required for offshore wind farm development in Gujarat. For a full list of requirements see Ref. /13/.

Appendix A   Photos Pipavav port

Figure A - 1 Storage area

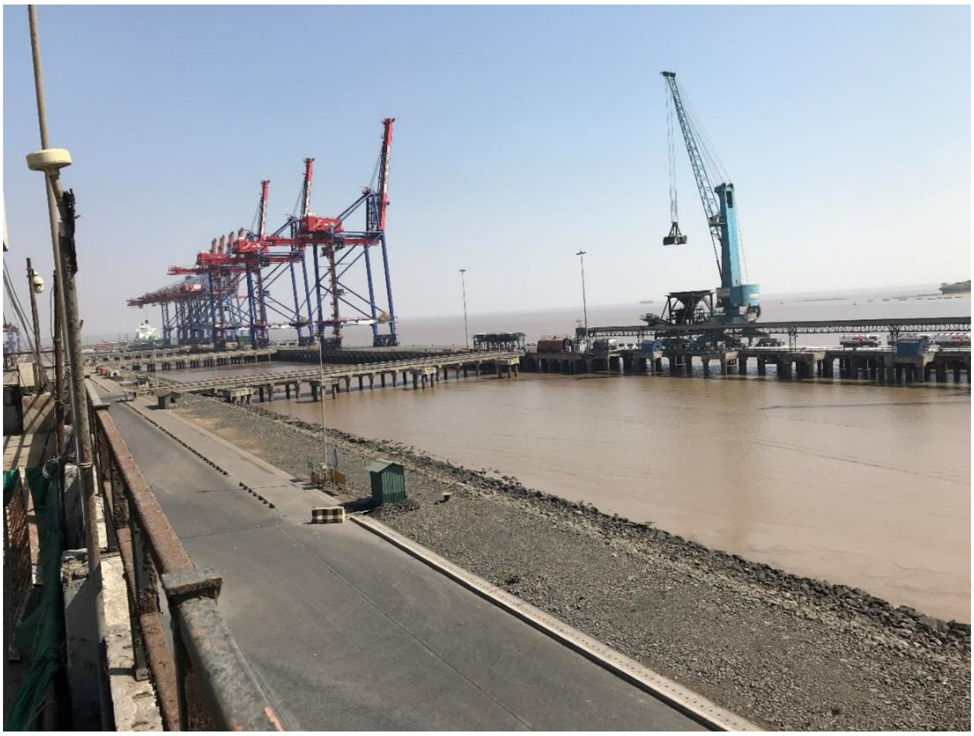

Figure A - 2 View of suspended pile deck and bridge connection to quay side

Figure A - 3 33kV/220kV substation within the port area

Appendix B Photos Jafarabad port

Figure B - 1 Jafarabad port

Figure B - 2 Jafarabad port

Figure B - 3 Jafarabad port

Appendix C Examples of EU offshore wind ports

The rapid development of offshore wind farm projects in Europe has required port facilities for servicing the industry and more than 30 ports in countries surrounding the North Sea have been developed and involved in the offshore activities in Europe.

Figure C - 1 Offshore wind ports in Europe.

Examples of facilities for some of the European offshore wind ports are presented below.

C.1 Port of Bremerhaven, Germany

The Port of Bremerhaven is located in northern Germany at the mouth of the River Weser. The port's infrastructure and proximity to the North Sea have contributed to Bremerhaven's ongoing participation in OSW projects. The Port of Bremerhaven has supported several projects: Germany's first OSW, Alpha Ventus, and the Nordsee Ost OSW farm. The Port of Bremerhaven is a driving factor for the development of OSW in the region. The port has been upgraded during recent years. The port can handle offshore wind turbines with capacities up to 6-10 MW.

Figure C - 2 Overview of Bremerhaven port in Germany.

Figure C - 3 Photo of offshore terminal in Bremerhaven port in Germany.

C.2 Port of Cuxhaven, Germany

The Port of Cuxhaven is located at the mouth of the Elbe River, in northern Germany. The Port, which was not developed as a deep water port until 1997, boasts access to the North Sea and the Baltic Sea through the Kiel Canal. Cuxhaven has provided staging, fabrication, and maintenance facilities for OSW projects in the North Sea. New berthing space of 1340 m and water depths of 11 m is available. Additional facilities have been constructed including an additional area of 85.0000 m² and an additional 290 m of wharf. The port can handle offshore wind turbines with capacities up to 6-10 MW.

Figure C - 4 Overview of Cuxhaven port in Germany.

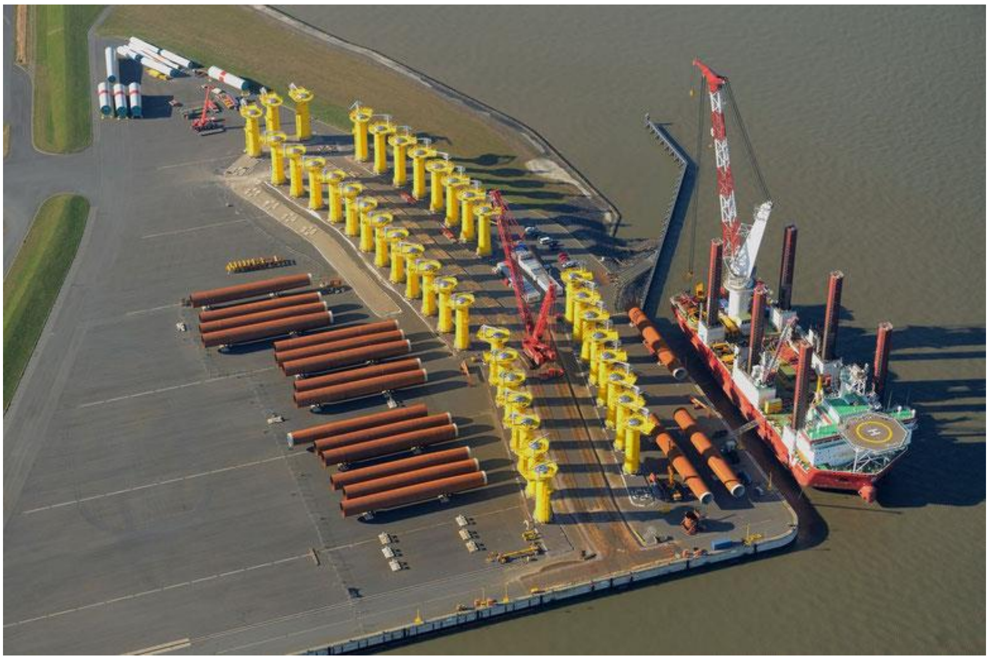

Figure C - 5 Photo of offshore terminal in Cuxhaven port in Germany.

C.3 Port of Esbjerg, Denmark

The Port of Esbjerg is one of the leading ports in Europe in terms of handling and exporting wind power plants. The port played a key role in the rise of Denmark's OSW industry which launched over a decade ago with the installation of the world's first large-scale OSW farm, Horns Rev I. Today the Port of Esbjerg has facilities and areas for transporting, pre-assembling, exporting, and servicing OSW turbines. Due to the significant amount of available space, Siemens Gamesa Renewable Enrgy ships a significant number of offshore turbines through this port. The port is designed to handle offshore wind turbines with capacities up to 6-10 MW.

Figure C - 6 Photo of offshore terminal in Esbjerg port in Denmark.

Figure C - 7 Overview of Esbjerg port in Denmark.

C.4 Port of Brest, France

The port will be expanded to cover an area of 400.000 m² to accommodate space for storage and assembly areas for future offshore wind farms. Presently the port has four terminals with quay length between 310 and 550 m and water depth between 7 and 13 m.

Figure C - 8 Photo of offshore terminal in Brest port in France.

Figure C - 9 Overview of Brest port in France.

C.5 Port of Grenaa, Denmark

The Port of Grenaa is one of the leading industrial ports for offshore wind projects in Denmark. The port has a 73.000 m² storage and assembly area with direct access to the quay. Other facilities include reinforced concrete quay areas with high load-bearing capacity, dedicated areas for installation jack-up ships with reinforced sea bed and good infrastructure to the port with bypass roads close to the port. The water depth is up to 11 m.

Figure C - 10 Overview of Grenaa port in Denmark.

Figure C - 11 Photo of offshore terminal in Grenaa port in Denmark.

FOWPI

FIRST OFFSHORE WIND PROJECT OF INDIA