Facilitating Offshore Wind in India

Project Inception Report

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FACILITATING OFFSHORE WIND IN INDIA

A baseline assessment of conditions for offshore wind in India

Covering Project related activities from 13th December 2013 to 12th March 2018

This Project is Funded by The European Union


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Foreword

On behalf of the FOWIND Consortium, we are pleased to present this Project Inception Report, which is an assessment of the status of the major factors that will influence the development of offshore wind in India.

The FOWIND project has now been operational for over six months, and together with our Consortium Partners (C-STEP, DNV GL, WISE, GPCL and IEDCL) we have built on the work we put in on the original proposal to come up with this report. In it you will find fully fleshed out analysis which will serve as a baseline against which we measure our own progress, as well as that of the private sector and government as we move towards the creation of a flourishing offshore wind industry, bringing large quantities of clean and affordable energy to a growing nation to power its continued and accelerated economic growth, as well as contributing to its industrial development and energy security.

The report outlines many challenges which will need to be faced and overcome in the coming years: to develop the necessary policy and regulatory frameworks across many government departments at both central and state levels; to attract both public and private investment in the necessary infrastructure to facilitate the development of the industry, particularly when it comes to ports and grids; and finally, to ensure that the conditions are created to leverage India's natural advantages to contain costs in the first instance, and continually lower them over the medium to longer term.

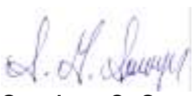
Offshore wind technology has come a long way in the past several years, with the industry reaching critical mass in Europe, while just getting underway in earnest in China, Japan, Korea and in the United States. While costs are still high, there are clear indications that they can be brought down substantially through experience and economies of scale – indeed they must do so if they are to compete with other renewable technologies whose costs are dropping fast. But the rewards are great – a strong, steady resource that can play a major role in supplying clean indigenous energy at modest costs close to the major load centers in coastal cities and industrial areas.

We are living in an exciting time of rapid change in the energy industry, in India, and globally. Renewables penetration rates that were unheard of some 5 or more years ago are now becoming quite common, and at the most recent climate negotiation session, more than 60 countries spoke of their vision for a carbon-free energy sector by the middle of this century.

'Disruptive' technologies like wind and solar PV which are decentralized, modular and quick to install are rapidly making the old utility models unsustainable, and the search is on for new market designs which accommodate large quantities of variable renewables whose marginal cost of generation approaches zero.

We hope that you find the Project Inception Report a useful reference document, and one that we can revisit in the coming years to see just how far we have come towards realizing a prospering offshore wind energy sector in India.

(On behalf of the FOWIND Project Executive Committee)



Stephen G. Sawyer
Chair
FOWIND Project Executive Committee
And Secretary General
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Abbreviations

A

AMSL – Above Mean Sea Level

ASAR - Advanced Synthetic Aperture Radar (ASAR)

B

BESCOM - Bangalore Electricity Supply Company Limited

BOO - Build, Own and Operate

BOOT - Build Own Operate Transfer

C

CEA - Central Electricity Authority

CERC - Central Electricity Regulatory Commission

CESC - Calcutta Electricity Supply Company Limited

COE - Cost of Energy

CSIR - Council of Scientific & Industrial Research

CSO - Civil Society Organizations

CSTEP - Center for Study of Science Technology and Policy

CTU - Central Transmission Utility

CUF - Capacity Utilization Factor

C-WET - Centre for Wind Energy Technology

CWP - Centre for Wind Power

D

DC - District Collector office

DISCOMs - Power Distribution Companies

DoEF - Department of Environment & Forest

DSS - Decision Support System

DTU - Technical University of Denmark

E

EEZ - Exclusive Economic Zone

EHT - Extra High Tension

EIA - Environmental Impact Assessment

ETOPO5 - Global 5' Elevation NOAA product - from ship and satellite data

EWEA - European Wind Energy Association

G

GEGC - Gujarat Electricity Grid Code

GEOSS - Global Earth Observation System of Systems

GESCOM - Gulbarga Electricity Supply Company Limited

GETCO - Gujarat Energy Transmission Corporation Limited

GHG - Greenhouse Gas

GIS - Geographical Information System

GMB - Gujarat Maritime Board

GPCL - Gujarat Power Corporation Limited

GWEC – Global Wind Energy Council

H

HESCOM - Hubli Electricity Supply Company Limited

HT - High Tension

HV - High Voltage

HVAC - High Voltage Alternating Current

HVDC - High Voltage Direct Current

I

IB - Information Bureau

IEA - International Energy Agency

IEGC - Indian Electricity Grid Code

INCOIS - Indian National Centre for Ocean Information Services

IPCC - Intergovernmental Panel on Climate Change

IPPs - Independent Power Producers

IUCN – International Union for Conservation of Nature

L

LDC- Load Despatch Centre

LiDAR - Light Detection and Ranging

LT – Low Transmission

LTA - Long Term Access

M

MEDA - Maharashtra Energy Development Agency

MERRA - Modern-Era Retrospective Analysis for Research and Applications

MESCOM - Mangalore Electricity Supply Company Limited

MMTPA – Million Metric Tones Per Annum

MNRE - Ministry of New and Renewable Energy

MoD - Ministry of Defense

MoEF - Ministry of Environment & Forest

MoF - Ministry of Finance

MHA - Ministry of Home Affairs

MoM - Ministry of Mines

MoP - Ministry of Power

MoPNG - Ministry of Petroleum and Natural Gas

MoS - Ministry of Shipping

N

NAPCC - National Action Plan on Climate Change

NCAR - National Center for Atmospheric Research

NCEF - National Clean Energy Fund

NCEP - National Centers for Environmental Protection

NIO - National Institute of Oceanography

NIOT - National Institute of Ocean Technology

NLDC - National Load Dispatch Centre

NOAA - National Oceanic and Atmospheric Administration

NOWA - National Offshore Wind Energy Agency

NREL - National Renewable Energy Laboratory

NSM - National Solar Mission

NWEM - National Wind Energy Mission

O

O&M - Operations and Maintenance

OW - Offshore Wind

OWESC - Offshore Wind Energy Steering Committee

P

PAB - Project Advisory Board

PDPU –Pandit Deendayal Petroleum University

PEC - Project Executive Committee

PGCIL - Power Grid Corporation of India Ltd.

PMG - Project Management Group

PMU - Project Management Unit

POSOCO - Power System Operation Corporation

Q

QuikSCAT - Quick Scatterometer

R

R&D - Research and Development

RE - Renewable Energy

REC - Renewable Energy Certificate

RLDCs - Regional Load Despatch Centres

ROW - Right of Way

RPO - Renewable Purchase Obligation

RPS - Renewable Portfolio Standard

RRF - Renewable Regulatory Fund

S

SAR - Synthetic Aperture Radar

SCAT - Scatterometer

SEBs - State Electricity Boards

SERC - State Electricity Regulatory Commission

SFD - State Fisheries Department

SLDC - State Load Dispatch Centre

SMB - State Maritime Board

SNAs - State Nodal Agencies

STU- State Transmission Utility

T

TERI - The Energy and Resources Institute

TIV - Turbine Installation Vessels

TNEB - Tamil Nadu Electricity Board

TNMB - Tamil Nadu Maritime Board

U

UI - Unscheduled Interchange

UNEP - United Nations Environment Program

W

WAsP - Wind Atlas Analysis and Application Program

WindSAT - Wind Satellite

WISE - World Institute of Sustainable Energy

WPD - Wind Power Density

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1 Introduction

1. Introduction

BACKGROUND

The EU Delegation to India granted the Facilitating Offshore Wind in India (FOWIND) project to the consortium led by the Global Wind Energy Council (GWEC) in June 2013. The formal contract between the EU Delegation to India and the FOWIND project consortium was signed in December 2013. Project consortium partners include Center for Study of Science, Technology and Policy (CSTEP), Garrad Hassan India Private Limited (trading as DNV GL), Gujarat Power Corporation Limited (GPCL) and World Institute of Sustainable Energy (WISE). IL&FS Energy Development Company Limited (IEDCL) joined the consortium as a Strategic Partner in April 2014.

The FOWIND consortium will undertake actions to assess and promote offshore wind power development in India and to help facilitate India's transition towards a low carbon energy future. The scope of the project is limited to the states of Gujarat and Tamil Nadu. This project is supported by a grant of EUR 4 million from the EU. Further a contribution of EUR 500,000 and INR 20 million (approximately EUR 250,000) is provided by GPCL and IEDCL respectively, as co-financing for the project.

INCEPTION REPORT

This report builds upon the technical proposal submitted in April 2013, based on which the project was awarded to the consortium. The project's inception phase ran from the end of December 2013 to middle of June 2014. It involved a range of activities including preliminary assessments, outreach activities, launch of the project portal (www.fowind.in), raising awareness regarding offshore wind energy and detailed project planning over the first six months. The technical work helped to reinforce the project's context. Meanwhile, the FOWIND project management - and operational structure was also formalized.

The initial Work Packages (see Section: 2.2) and actions as envisioned in the technical proposal are largely retained with minor adaptations to reflect the findings of the Inception Phase. The project implementation plan aims at making tangible contributions towards achieving the project objectives.

The consortium will seek to actively position FOWIND as a valuable resource for all offshore wind stakeholders in India through its project activities. These activities will include preliminary assessment and deepening of understanding on key technical, economic, and environmental opportunities and challenges for offshore wind, training and capacity building activities, and a range of communication as well as outreach activities.

The Section 2 discusses the project objectives, project framework including a detailed discussion on Work Packages 1 to 7. A detailed methodology is discussed under each of the Work Package sub-sections. Section 3 undertakes a thorough review of the existing baseline conditions in India with a view towards facilitating offshore wind development up to 2032 (end of 15th Plan Period in India) These baseline conditions include a preliminary analysis of existing wind resource assessments, grid integration issues and other supporting infrastructure necessary for establishing a viable offshore wind sector in India.

The Section 4 provides a detailed summary of the role of offshore wind in facilitating India's low carbon development. India is an emerging economy with over a billion people and one of the youngest population profiles globally. India's energy choices will have a significant impact on its ability to meet its commitments domestically and internationally[1] towards providing clean, low carbon and sustainable energy future that meets the country's development needs. However the global offshore wind sector is very different from the onshore wind sector, particularly from the construction and O&M (Operations and Maintenance) angle. This mandates that offshore wind (OW) specific support structures and relevant stakeholders are identified and assessed for the success of this project.

Section 5 provides an update on the state of the wind sector globally and in India. It discusses the state of India's established onshore wind industry, the incentive structures available for wind power, and the state of the global offshore industry. This discussion helps to complete the picture on how other renewable sectors (especially onshore wind) have grown and whether any lessons can be drawn for the offshore wind sector in particular.

At a time when significant positive changes are taking place in the global renewable energy sector, India too is grappling with the choice of making a timely transition towards a low carbon future[2]. To further facilitate this transition with the best available information, FOWIND consortium partners will undertake project actions in close collaboration with key national, state and local actors/stakeholders to promote the development of offshore wind in India.

Section 6 summarises the conclusion of the report. India's experience in OW, with the right planning and information could provide regulatory certainty and a long-term signal necessary to make investment decisions.

FOWIND project actions will actively seek to bring forth aspects that would specifically benefit and those that could adversely impact the future of an OW sector in India.

[1]India's commitment and plan towards providing clean, low carbon and sustainable energy is enunciated in the National Action Plan for Climate Change (2008). For more details http://www.moef.nic.in/downloads/home/Pg01-52.pdf

[2]*The Final Report of the Expert Group on Low Carbon Strategies for Inclusive Growth; Planning Commission, Government of India (April 2014). For details* http://planningcommission.nic.in/reports/genrep/rep_carbon2005.pdf

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FOWIND - Facilitating Offshore Wind in India

2. FOWIND - Facilitating Offshore Wind in India

PROJECT OBJECTIVES

Actions under the FOWIND project will seek to promote offshore wind power development to facilitate India's transition towards a low carbon energy future. The project focuses on the States of Gujarat and Tamil Nadu for identification of potential zones for offshore wind (OW) developments through preliminary resource assessment and techno-commercial analysis. The project during the course of 51 months will particularly seek to meet the following objectives:

- Create an enabling environment for offshore wind through preliminary resource mapping, policy guidance and capacity building measures to unlock the offshore wind potential of India
- Utilize European learning in the offshore wind sector to reduce technical barriers and financial risks for subsequent offshore wind developments in India
- Undertake preliminary techno-commercial studies to showcase the potential of offshore wind, especially along the coasts of Gujarat and Tamil Nadu
- Foster strategic partnerships between Indian and European counterparts (public and private sector stakeholders) that enhance knowledge exchange and awareness of latest aspects of offshore wind technology and industry practices
- Develop an Offshore Wind Outlook and Development Pathway for India up to 2032 in the last year of the project

2.1 PROJECT FRAMEWORK

2.1.1 SUMMARY OF PROJECT ACTIONS

Over a period of 51 months the FOWIND project partners will undertake a wide variety of activities to deliver on the objectives outlined in the previous section. All actions will be implemented in consultation with the Ministry of New and Renewable Energy (MNRE).

In the first year this includes a detailed baseline assessment that will be undertaken with a focus on the two key states of Gujarat and Tamil Nadu. Herein the implementing partners will assess the status of various existing regulatory, policy, infrastructural and resource assessments available for facilitating OW developments.

The project will also seek to establish a structural co-operation between the Research and Development (R&D) Institutes and private sector stakeholders relevant to the offshore wind power industry in India and their European counterparts.

The consortium will work closely with the MNRE and the Centre for Wind Energy Technology (C-WET) to develop the modalities for an Offshore Wind related R&D forum over the project duration with the expectation that this forum or platform will become self-sustaining after the end of FOWIND's implementation period. The first meeting of this platform is planned in Year 1 in Germany. At this meeting, GWEC will facilitate interaction among key Offshore R&D institutes in Europe and India.

Given the highly positive response to the launch of the FOWIND project by various industry players in and outside India, the consortium will also seek to establish a formal forum for taking timely and constructive feedback from the stakeholders who have an interest in the offshore wind sector in India. The consortium will utilize GWEC's global industry expertise to design a FOWIND Industry Working Group. This will help the FOWIND consortium to ensure that the project outcomes continue to add value to the Industry's efforts towards investing in the OW sector in the future. The first such outreach is likely to take place in Year 2.

Year 1: Baseline Scenarios and Knowledge Gap Analysis

Project partners including GWEC, CSTEP, DNV GL and WISE worked together to identify various baseline conditions and undertook a desk-based preliminary assessment of publicly available technical studies and infrastructure in the key states of Gujarat and Tamil Nadu.

Actions in Year 1 would help to determine the knowledge gap and preliminary constraint analysis for OW development in India with specifics pertaining to the states of Gujarat and Tamil Nadu. This analysis would help to undertake the prefeasibility study for identification of potential zones based on GIS mapping.

CSTEP and WISE will lead in conducting review of existing studies and collection of constraint data for the states of Tamil Nadu and Gujarat respectively. These data sets will be integrated with DNV GL's Geographical Information System (GIS) that will include preparing a preliminary offshore wind resource map.

Based on the interaction of these data sets a high level scoring will be undertaken to identify areas of interest along the coasts of Gujarat and Tamil Nadu. These areas of interest will be further assessed in consultation with the central and state ministries and agencies.

The constraint data and collected information will be used for the pre-feasibility study that is to be carried out and published in the second half of year 1. This will include a preliminary analysis of techno-commercial, infrastructural, and regulatory constraints. Thereafter the most suitable zones would be studied in further detail over the following years.

In addition, GWEC and DNV GL will conduct a global review of policies, regulations and incentives for offshore wind across key markets to provide a detailed picture of lessons learnt in the OW sector.

GWEC will also facilitate a knowledge exchange study trip to a European member state that is an established player in the offshore wind sector. This study trip will seek active participation from key stakeholders including the Indian Research and Development (R&D) institutes active in various fields relevant to the OW sector. The participants will be identified in consultation with the MNRE.

In addition, CSTEP will conduct sensitization workshop in Tamil Nadu and WISE will conduct sensitization workshops in Gujarat and Delhi. These are likely to be held in September 2014.

As the activities in the first year progress there will be regular information dissemination about the project through the dedicated project website (www.fowind.in). The project website was launched by Dr. Alok Srivastava, Joint Secretary, MNRE on 25th April 2014 in New Delhi.

Year 2: Feasibility and Validation

In Year 2 various technical studies including supply chain, grid infrastructure, logistics (ports and vessels) will be conducted and published. This infrastructure assessment for both Gujarat and Tamil Nadu will help to ascertain the gaps and requirements for OW related developments in the future.

A unique aspect of this project will be Light Detection and Ranging (LiDAR) installation (s) at suitable site(s), identified through the prefeasibility study in Year 1, for measurement of actual wind data. Year 2 will see the acquisition and installation of the LiDAR at a suitable site to reliably measure wind data that will provide more accurate information than existing offshore wind studies in India.

Year 2 will see further strengthening of the R&D platform through an inception workshop in India. The research platform is expected to evolve into a formal forum for promoting best-practice and technical R&D discussions. There will be a follow-up workshop for cross-study training in Europe for the EU-India offshore research platform during the year. Also there will be a field visit of key Indian stakeholders to EU member states to further strengthen the cooperation between key actors on both sides.

Year 3: Capacity Building, Training and Resource Analysis

The wind measurement campaigns will continue into the third year and DNV GL will work on the resource analysis based on the LiDAR data sets. Consequently, the consortium will undertake techno-commercial analysis for a hypothetical 100 MW project for one site in Gujarat and one site in Tamil Nadu.

A report for Gujarat and Tamil Nadu with model guidelines for procedures and documentation required for obtaining clearances/approvals for an offshore wind farm will be developed in Year 3.

The consortium will prepare a model offshore project facilitation guideline including a draft for a Request for Proposal (RFP) for the development of a pilot offshore wind project[3]. This will serve as a reference tool for the relevant policy makers and ministries when a formal Request for Proposal is invited for an Offshore Project in the future. This action will begin in Year 3 and is expected to conclude in the first half of Year 4.

Moreover in Year 3 a final roundtable workshop for R&D and standardization institutes in India for EU India offshore research platform will be held.

Consultation and outreach with local communities will be undertaken in both the states, especially along the zones where wind measurements would be undertaken through LiDAR installation (s). This feedback will help the consortium when developing an Environmental Impact Assessment (EIA) guideline for any potential OW projects.

Year 4: Decision Support System, 2032 Outlook and Stakeholder Outreach

Consolidation of wind data and LiDAR validation report for Gujarat and Tamil Nadu will mark the beginning of the fourth year. This data will be used to update the wind resource map and subsequently a cost of energy (COE) map will be generated. These maps can further facilitate offshore wind spatial planning. The wind data acquired under the project will be disseminated in to the public domain to promote further bankable and detailed resource assessments for OW. The consortium will also work towards issuing a report on OW technology adoption guidelines for Indian conditions.

A high-level roundtable on market mechanisms and policy and regulatory framework for Offshore Wind will be held in New Delhi. CSTEP in Tamil Nadu and WISE in Gujarat will conduct two technical training workshops for State utilities' engineers respectively.

GWEC will lead the preparation of the Offshore Wind Outlook 2032 for India.

Further the consortium will petition the Central Electricity Regulatory Commission (CERC) for appropriate tariff/auction mechanism and grid connectivity for OW. Year 4 will also see a mid-term sustainability plan being developed for the FOWIND project to make the project outcomes viable.

[3]The model request for proposal (RFP) document shall include terms and conditions for offshore project development in India and also help the federal and state agencies to call for project development proposal from interested project developers under the broader project facilitation guidelines.

Media interaction and outreach activity are planned in Year 4 to build further public awareness and support for OW.

Year 5: Final Documentation and Reporting

The last quarter of the FOWIND project will see final documentation, reporting and further outreach under the grant. The Consortium's lead applicant will provide a project sustainability plan and undertake a final audit of the project in this period in collaboration with all consortium partners.

2.2 WORK PACKAGES

Table **1**: Summary of Work Packages[4]

	Tasks	Expected Result	Expected Impact
WP 1	▪ Baseline analysis and inception report ▪ Pre-feasibility report ▪ Selection of sites for LiDAR installation	▪ Review of existing studies ▪ Identification of suitable zones for offshore wind development ▪ Most suitable location for LiDAR deployment	▪ Preliminary assessment of offshore wind potential in the states of Gujarat and Tamil Nadu through meso-scale models ▪ Promote efforts of the national and state government ministries, agencies and industry to realize this potential
WP 2	▪ Preparing a decision support system using GIS ▪ Maps representing spatial data on wind resource and cost of energy maps for selected zones	▪ A decision support system with wind maps based measurement and meso-scale mapping is created	▪ These maps will facilitate improved decision making by relevant stakeholders for offshore wind development ▪ The map data will be publicly available for further related research and studies by interested agencies
WP 3	▪ Study on grid infrastructure ▪ Assessment of ports and logistics availability for offshore wind ▪ Study on supply chain for the offshore wind sector	▪ The studies and consultations with state actors and industry will help to identify existing grid capacity, supporting infrastructure, the gaps and recommendations for augmentation of the same.	▪ Report findings would influence decision makers to install an incentive structure for encouraging broader industry participation in the OW sector ▪ Knowledge gap regarding necessary infrastructure will be reduced ▪ Findings will encourage research groups to propose studies to offer solutions for existing challenges
WP 4	▪ Leasing and installation of LiDAR equipment ▪ LiDAR data & resource analysis	▪ Identification of suitable sites based on LiDAR data ▪ Permitting procedure will be identified through permitting	▪ Validation of existing studies through site-specific measured data ▪ The reliability issues surrounding

[4]Yearly Timeline for Work Packages is provided in Annexure 2

	Tasks	Expected Result	Expected Impact
	▪ Selection of suitable sites for full techno-economic feasibility ▪ Consolidation of wind data and LiDAR validation report	process of LiDAR deployment ▪ Establishment of offshore potential with higher certainty, based on the measured data from the states	the indications of offshore potential will be reduced
WP 5	▪ Conduct techno-commercial analysis for identified locations in Gujarat and Tamil Nadu	▪ Identification of India specific (Gujarat and Tamil Nadu) technical and commercial parameters for an offshore wind farm	▪ The analysis will provide useful information regarding project financing and incentive structure mechanism ▪ Study will provide indicators for customized procedures of offshore development ▪ Techno-commercial study will provide an indicative framework for offshore project development in India ▪ Outcome of work package 5 and work package 6 will help develop indicative regulatory, legal and permitting processes for both states
WP 6	▪ Conduct offshore site visits in Europe for key stakeholders ▪ Review of existing policy framework for offshore wind in key global markets ▪ Facilitate collaboration amongst Indian and European research institutes ▪ Develop tariff framework for offshore wind in India ▪ Petition electricity sector regulators for incentive/support mechanisms	▪ Policy, regulation and Incentive structuring support to key decision makers and the state government agencies ▪ Recommendations for procedures and documentation required to obtain clearances for offshore deployment activity in Gujarat and Tamil Nadu ▪ Technology adoption recommendations and reference documents customized to Indian conditions ▪ Structural cooperation between EU and Indian stakeholders	▪ Knowledge exchange, capacity building and structural cooperation will help policy makers, power sector entities and institutions to make informed decisions regarding offshore wind technology. ▪ Help ensure informed support towards developing a domestic offshore wind sector
WP 7	▪ Development of a public portal ▪ Stakeholder consultation / survey for knowledge and skill gap analysis	▪ Launch of the project website ▪ Regular media outreach activities about the project and its outcomes ▪ Spreading awareness on offshore wind amongst identified	▪ This multi-stakeholder cooperation and knowledge-exchange opportunity will allow for improved benchmarking of regulatory incentives

Tasks	Expected Result	Expected Impact
▪ Conduct sensitizing workshops to build awareness ▪ Conduct roundtable on market mechanisms for policy development ▪ Organise consortium partners meet ▪ Develop a pathway for Offshore wind in India till 2032	stakeholders ▪ Engineers in state utilities made aware of the details of managing large-scale variable generation from wind ▪ Investors, project developers and decision makers have a meaningful dialogue on developing offshore wind projects based on the data and reports generated under the project	▪ Public awareness would be built through increased media interaction and outreach activities

2.2.1 WORK PACKAGE 1: REVIEW OF EXISTING STUDIES, GAP ANALYSIS & PRE-FEASIBILITY ANALYSIS

2.2.1.1 Definition

The main objective of this work package is to validate the existing studies on offshore wind energy in Tamil Nadu and Gujarat and to select suitable zones for deployment of LiDAR (s). To identify these zones a detailed baseline assessment and knowledge gap analysis will be conducted. In addition, the existing research and datasets on wind resource along the coast of Gujarat and Tamil Nadu will be studied. A pre-feasibility study for offshore wind will be conducted. A list of high priority zones will be developed from the constraint and pre-feasibility analysis. This will be done in close cooperation with the MNRE, C-WET and state agencies.

2.2.1.2 Methodology

In order to define the baseline scenario, the consortium partners would engage in a detailed review of wind resources, infrastructure and support mechanism in both the national and international context. The consortium will also review the existing and proposed transmission systems, port, logistics, vessels and other supporting infrastructure in Gujarat and Tamil Nadu to develop a knowledge base on offshore wind capabilities in the two states. To reduce the gap in technical understanding about OW, the project will promote knowledge exchange through study trips and direct interaction with OW sector experts in Europe under Work Package 6.

CSTEP and WISE will collect the required data and information from multiple state agencies of Tamil Nadu and Gujarat respectively. DNV GL would develop a meso-scale wind map covering the waters of Gujarat and Tamil Nadu. DNV GL will work towards mapping this wind resource model against the acquired constraint data sets to identify areas of interest. A pre-feasibility study for the area of interest will be conducted. DNV GL will provide a checklist and outline of pre-feasibility attributes along with a preliminary GIS and with that CSTEP and WISE will carry out pre-feasibility analysis for Tamil Nadu and Gujarat. In the process, a list of suitable wind farm zones will be developed in consultation with relevant state agencies. Small and medium business, utilities, public as well as private ports, nodal agencies and other relevant organization shall be consulted for this study.

2.2.1.3 Outcomes

Execution of WP1 will bring clarity on current infrastructure availability and gaps that would need to be addressed for a robust OW sector to develop. It will also help identify the gaps in supporting infrastructure that would need to be addressed for a comprehensive plan for the long-term growth of the OW sector. This exercise is expected to support concerted efforts from the national and state government decision makers towards realization of offshore wind development in India. In summary the key actions under this work package are:

- Validation of existing studies
- Identification of suitable zones for offshore wind development
- Identification of most suitable location(s) for LiDAR deployment
- Pre-feasibility analysis of suitable zones
- Preliminary Cost of Energy (COE) map

2.2.2 WORK PACKAGE 2: DEVELOPMENT OF DECISION SUPPORT SYSTEM (DSS) TOOL USING GIS

2.2.2.1 Definition

In this work package, a GIS based decision support system containing wind resource, maritime spatial constraints, and infrastructure capabilities will be developed. The input-output and functionality parameters of the Decision Support System (DSS) will be defined and incorporated within the GIS software system.

2.2.2.2 Methodology

The DSS in general will generate series of interpolated maps showing offshore wind energy potential in relation to resource, spatial and infrastructure constraints.

From the prefeasibility and constraint analysis of WP1 technical parameters will be characterized and a preliminary beta version of GIS platform would be developed. This version will comprise of modelled data inputs of wind resource and constraint variables enabling the creation of an initial spatial map for Gujarat and Tamil Nadu coastline.

DNV GL will design and develop the GIS software from the information and constraint data inputs. CSTEP will collect constraint data for Tamil Nadu and WISE will collect constraint data for Gujarat to be used by DNV GL for the GIS platform. This first version of GIS will feature a generic Cost of Energy map.

The DSS development work package will be executed in two phases. In the first phase preliminary GIS model will be created where the input parameters are well defined and algorithms are modelled based on the available wind data to perform the initial potential assessment. In the second phase, GIS software will be updated by in-situ met-ocean data from the LiDAR and additional constraint parameters from techno-commercial analysis.

At the second phase it is possible to generate more accurate COE map based on high-resolution wind resource modelling, further data including maritime spatial parameters, oceanic conditions, financial and other relevant parameters. This will help conduct various parametric analyses to ascertain the OW potential. The findings of this package will be used to formulate a pathway for offshore wind development in India up to 2032.

2.2.2.3 Outcomes

A decision support system with wind maps (created using meso-scale models and in-situ measurement) and constraint data layers and mapping will be created. The output of the support system will facilitate improved decision making for relevant stakeholders involved in promoting offshore wind development. Moreover, the support system will be a publicly available tool with comprehensive information for offshore wind, covering the states of Gujarat and Tamil Nadu. This information will assist other stakeholders and research organisations in further related research.

2.2.3 WORK PACKAGE 3: INFRASTRUCTURE ASSESSMENT

2.2.3.1 Definition

Under this work package, detailed study of infrastructure (support systems) such as grid and supply chain facilities, for offshore wind energy development will be conducted.

2.2.3.2 Methodology

Assessing the existing infrastructure facilities and its weakness will enable the stakeholders to plan the development appropriately. Amongst the infrastructure concerns and challenges, the grid infrastructure and the supply chain facilities are the key areas to be assessed.

The grid infrastructure for renewable energy generation has been already a concern and will be a key barrier for sustained offshore wind developments in the future. The first part of the scope will focus on grid resource characterization followed by assessment of large-scale grid integration of offshore wind power.

Similarly, there has been concern regarding the logistics and supporting infrastructure for offshore development. Infrastructure assessment in terms of logistics (port study, cranes, and vessels), supply chain and recommendations for the adequacy of the same will help government plan and take suitable measures to facilitate the offshore development.

Infrastructure studies for Tamil Nadu and Gujarat will be carried out by CSTEP and WISE respectively.

2.2.3.3 Outcomes

Expected result

- The studies and consultations with state actors and industry will help identify existing grid capacity, supporting infrastructure, gaps and recommendations for augmentation of the same

Expected Impact

- Decision makers consider the findings while proposing a suitable incentive structure for offshore wind either at the Centre or the state level
- Knowledge gap regarding necessary infrastructure will be bridged based on detailed studies
- Findings will generate interests among research groups to propose and conduct suitable studies towards solutions

2.2.4 WORK PACKAGE 4: LIDARDEPLOYMENT AND DATA ASSESSMENT

2.2.4.1 Definition

In this work package, a LiDAR instrument will be used for capturing wind speed and directional data measurements. This instrument will be installed at identified site(s) for measurement of offshore wind speeds and directional measurements under this project. This will help in detailed data acquisition, resource analysis and validation of available data.

2.2.4.2 Methodology

In offshore wind industry, LiDAR has become a widely used technology to collect data for wind resource characterization. There are several studies (refer section 3.1) available on the offshore wind resource in India. However, none of these studies have considered uninterrupted in-situ data from a wind measurement instrument such as the LiDAR or a met mast. Deployment of LiDAR and data acquisition for at least one year would provide a reliable basis for the resource assessment.

The consortium would procure LiDAR(s) under the project. The LiDAR(s) will be installed on existing platform(s) near locations identified through the work done under work package 1. One-year LiDAR data would be analyzed and DNV GL would prepare a comprehensive report. The findings would be incorporated in the DSS tool.

Based on the LiDAR data analysis, suitable zones would be identified to carry out the techno-economic feasibility study covered in work package 5.

2.2.4.3 Outcomes

Expected result

- Identification of suitable zones having high potential based on LiDAR data
- Permitting procedures identified and established through the permitting process for LiDAR deployment
- Establishment of offshore potential with higher certainty, based on the reliable and measured data, for the states of Gujarat and Tamil Nadu

Expected Impact

- The validation of the existing studies will be verified through site-specific measured data
- The reliability issues surrounding the indications of offshore potential will be settled

2.2.5 WORK PACKAGE 5: TECHNO COMMERCIAL ANALYSIS OF IDENTIFIED SITES

2.2.5.1 Definition

In this work package, a techno-commercial analysis on one site in both states (Gujarat and Tamil Nadu) will be conducted. This will help in proposing appropriate options for an incentive mechanism for OW. This is expected to provide valuable inputs for offshore wind development policy, regulations and permitting processes.

2.2.5.2 Methodology

Techno-commercial analysis of sites (one site in Gujarat and one site in Tamil Nadu) identified through pre-feasibility study and further refined through LiDAR data analysis will be undertaken. This analysis is conducted for a hypothetical 100 MW offshore project that will cover the following aspects:

- Identification of permitting process (recommendation)
- Wind farm layout derivation (recommendation)
- Wind turbine characterization
- Layout design (recommendations)
- Bathymetric analysis (Seabed conditions)
- Energy Production Assessment
- Wind turbine substructure type and sizing (recommendation)
- Electrical design layout (recommendation)

- Installation and Logistics cost analysis (approximation)
- Operations and Maintenance analysis (approximation)
- Estimates for capital expenditure and operational expenditure (approximation)

CSTEP and WISE will undertake techno-commercial analysis of pre-identified sites for Tamil Nadu and Gujarat respectively with assistance from DNV GL in designing the studies. DNV GL and GWEC experts will support and review the studies.

2.2.5.3 Outcomes

Expected result

- The technical and economic parameters for an offshore wind farm project

Expected Impact

- The technical and economic parameters will provide useful information regarding project financing and incentive structure mechanism. This will help governments in formulating suitable permitting procedures and guidelines.
- The studies will provide indicators for customized procedures of offshore development in India.
- The techno-economic study, will provide an indicative framework for offshore project development in India
- EIA guidelines for selected zones developed

Through this process along with work package 6 regulatory, legal and permitting process will be established in each state.

Gujarat has already expressed initial interest in exploring the possibility of developing a 50 MW offshore pilot project off the state's coastline. Actions under the FOWIND work packages will continue to provide support to relevant State agencies in their efforts towards exploring this proposal.

2.2.6 WORK PACKAGE 6: KNOWLEDGE EXCHANGE AND STRUCTURAL COOPERATION

2.2.6.1 Definition

The actions under this work-package will include exchange visits between Indian and European stakeholders including offshore site visits, exchange visits for research groups working on OW related issues.

2.2.6.2 Methodology

GWEC will work with the Indian consortium partners to facilitate sharing of offshore sector experiences from relevant European OW industry and sectoral experts. This will help to facilitate Indian policy makers' efforts towards appropriate policy design, minimize the technology learning curve and support optimization of benefits from offshore wind in India.

Linkages between European R&D institutes and Indian R&D institutes from related fields would also facilitate long-term R&D collaboration possibilities, including technology adoption guidelines for offshore wind. This research could support further development of India-specific research addressing conditions in Indian territorial waters. The partners will also engage in a detail review of global as well as national polices regulation and incentive structures for offshore wind.

A review of India's relevant policy framework for offshore wind will be conducted. In the context of the Electricity Act, 2003[5] which considers wind power and electricity to be a concurrent subject, i.e. both central and state governments share concurrent jurisdiction and legislative influence, a detailed scoping and review of the existing state policies in Gujarat and Tamil Nadu for wind power generation, transmission and distribution will be carried out.

A detailed estimated tariff framework for the cost of offshore wind power generation based on best available resource assessments and other relevant parameters would be developed. This estimation of cost of offshore wind generation (per MW) will be shared with Central and State regulators to help their efforts towards establishing a tariff and regulatory framework for OW power in India.

2.2.6.3 Outcomes

Expected result

- Policy, regulation and incentive structuring support to the government
- Recommendations for procedures and documentation required to obtain clearances/approvals for offshore development activity in Gujarat and Tamil Nadu
- Technology adoption recommendation and reference documents customised to Indian Conditions
- Structural cooperation between EU and Indian stakeholders through the R&D Platform

Expected Impact

Knowledge exchange, capacity building and structural cooperation activities will help policy makers, power sector entities and Indian scientific and research institutions to make informed decisions regarding offshore wind technology, and ensure sustained domestic support for the sector.

2.2.7 WORK PACKAGE 7: TRAINING WORKSHOPS, 2032 OFFSHORE OUTLOOK & MEDIA/COMMUNITY OUTREACH

2.2.7.1 Definition

The consortium will hold awareness raising workshops for various stakeholders during the project tenure. These workshops will raise the awareness of state based nodal agencies, policy makers, utilities, CSOs and R&D institutes. The events will serve as a knowledge exchange platform of European offshore wind energy developments for Indian stakeholders.

2.2.7.2 Methodology

India's long coastline has numerous coastal communities dependent on shallow continental shelf fisheries. Research published by the Technical University of Denmark (DTU) - Aqua, National Institute of Aquatic Resources, Denmark in August 2012[6] after a detailed ten year review of the impact of the Horns Rev 1 offshore wind farm has shown that the turbine foundations function as artificial reefs. In India, CSOs and research institutes such as the M S Swaminathan Research Foundation have been working closely with fishing communities for enhancing their income through sustainable and ecologically sensitive methods. The project consortium partners will work with local communities and reputed civil society organizations (CSO) and domain experts to promote ecologically sensitive offshore project development guidelines that would safeguard the livelihood of coastal communities.

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[5] http://powermin.nic.in/acts_notification/electricity_act2003/preliminary.htm

[6] Sustainable Guernsey (2013), "Habitat provided by sea wind farms can enhance some fish populations"; Available (online) : http://www.sustainableguernsey.info/blog/2012/04/habitat-provided-by-sea-wind-farms-can-enhance-some-fish-populations/, last accessed on : 03/07/2014

Such outreach activities would be held in consultation with specific fisheries departments and the Coastal Zone Management Authorities of both states. An Environmental Impact Assessment guideline for a typical 100 MW Offshore Project will be developed. This guideline may serve as a reference tool for future project developers.

The project consortium developed a portal in the first year of the project. This portal will provide complete information on the project activities. The consortium will provide media briefings, notes and FAQs about the project through the portal. The project portal was launched on 25th April 2014 (www.fowind.in).

The consortium will hold a high-level round table discussion/conference on market mechanisms and policy for promoting offshore wind in India. This roundtable discussion will seek to invite all high-level political decision makers, policy makers, industry leaders, representatives of relevant inter-governmental organizations and multi-lateral financial institutions.

2.2.7.3 Outcomes

Expected result

- Launch of the project portal and regular media outreach activities about the project and its outcomes
- Increased awareness on offshore wind amongst identified local communities in project sites
- Increased understanding among the state utilities about conditionality of offshore wind power generation
- Investors, project developers and decision makers have a meaningful dialogue on development of offshore wind projects

Expected Impact

The multi-stakeholder cooperation and knowledge-exchange opportunities will allow for benchmarking of regulatory incentives. Communities in project sites will be empowered to make informed decisions about the benefits of any potential offshore wind projects. Public awareness will be built through increased media interaction, publications and collaborations with other agencies across India and Europe. Table 2 below highlights the lead responsible partner(s) for each of the work packages. All other partners will provide relevant support and content for each of the actions.

Table **2**: Lead Responsibility of Work Packages

Work package	Description	Lead Responsibility
1	Review of existing studies and pre-feasibility analysis	CSTEP (TN) and WISE (GUJ), GWEC and DNV GL
2	Development of decision support system tool	DNV GL
3	Infrastructure assessment	CSTEP (TN) and WISE (GUJ)
4	Deployment of LiDAR and assessment of LiDAR data	DNV GL, CSTEP (TN) and WISE (GUJ)
5	Techno-commercial analysis of the identified sites	CSTEP (TN) and WISE (GUJ)
6	Knowledge exchange and structural cooperation	GWEC
7	Training workshops, 2032 Offshore Outlook development and media and community outreach including CSOs and local communities	GWEC, CSTEP (TN) and WISE (GUJ)

2.3 ORGANISATIONAL STRUCTURE

For the purpose of this project, the consortium has developed a Project Management Framework [see Figure 1] with detailed roles[7] and responsibilities for each group/committee for the duration of the project.

For smooth functioning, the lead responsibility of coordination with state government agencies for Gujarat is delegated to WISE and for Tamil Nadu to CSTEP.

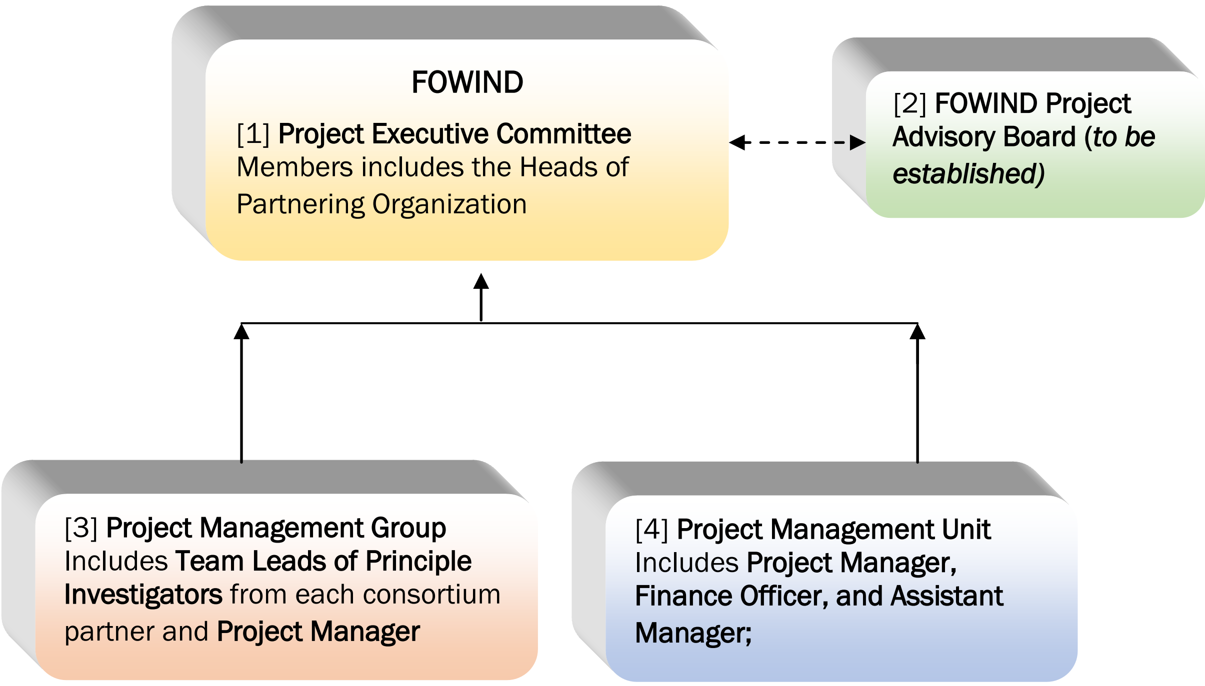

Figure **1:** Project Management Framework

1) PROJECT EXECUTIVE COMMITTEE (PEC)

The PEC is responsible for ensuring good project governance and providing a vision for the Project Management Group to enable delivery of robust, timely and cost-effective project outcomes. It also provides financial oversight including approval of quarterly accounts and project reports. It is responsible for final sign-off on annual reports to the EU Delegation in India including approving requests for changes in project design or financial matters.

GWEC Chairs the PEC, as the Lead Applicant for FOWIND. It has the final appointment and termination authority over the Project Manager and Project Finance Officer. PEC is expected to meet in-person, at least twice in a project year, and promotes transparency about this Project. The PEC will engage at least annually with the Project Advisory Board.

Members of the PEC are senior personnel (Vice President level or above) from each partner and strategic partner organization. As of June 2014, its members include Steve Sawyer (GWEC, Chair of PEC); V S Chandrasekaran (C-STEP); Mathias Steck (DNV GL); DJ Pandian, (GPCL); G M Pillai (WISE); Rajsekhar Budhavarapu (IEDCL).

[7] For detailed roles of consortium partners see Annexure 1

2) PROJECT ADVISORY BOARD (PAB)

The Project Advisory Board would be constituted in the second half of 2014.

The PAB is expected to provide time bound guidance and feedback to the Project Executive Committee on matters relating to project milestones; activities and outreach efforts. PAB is also expected to strengthen collaboration between representatives of key national and state-level decision makers, relevant national and state agencies, public sector undertakings and the global offshore and national wind sector on project activities. The Advisory Board will meet at least annually, as far as possible, in conjunction with the PEC project monitoring exercise.

Members of the PAB will include senior representatives from the stakeholder groups identified in the project proposal. Project Advisory Board would be chaired by the representative of the MNRE and convened by GWEC on behalf of the project consortium.

3) PROJECT MANAGEMENT GROUP (PMG)

The PMG is responsible for the overall delivery and coordination of the project content. Individual Team Leads in close cooperation with the Project Manager will work together to ensure respective organizations provide timely delivery of all expected project outcomes and financial accounts related to the project. PMG will meet in-person at least quarterly in each project year to assess progress, streamline plans for the next quarter and coordinate activity schedules. The PMG meets bi-monthly through telephonic meetings to monitor progress and to address any issues.

Members of the PMG are principle investigators and/or team leads from each partner and strategic partner organization. As of June 2014, its members include Shruti Shukla (GWEC); Meera Sudhakar (C-STEP); Alok Kumar (DNV GL); Rajendra Mistry (GPCL); Rajendra Kharul (WISE) and Samrat Sengupta (PMU).

4) PROJECT MANAGEMENT UNIT (PMU)

The Project Management Unit is responsible for the day-to-day coordination, delivery of project actions and financial management for the duration of the project.

It is responsible for responding to any requests for information from the project. It is responsible for writing and producing the annual reports. The PMU has the final responsibility of providing quarterly project reports (including financial accounts) to the PEC.

Members of the PMU include Samrat Sengupta (Project Manager); Erika Krkosova (Finance Officer); and Malathy Swaminathan (Assistant Manager, Project Management).

3

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3 Baseline Assessment

3. Baseline Assessment

3.1 OFFSHORE WIND RESOURCE CHARACTERIZATION

In order to aid the promotion of offshore wind in Gujarat and Tamil Nadu a good understanding of several underlying characteristics is fundamental. Seven principle factors, based on long-term international experience in the sector, have been identified which are likely to have a significant impact on the feasibility of deployment of commercial scale offshore wind farms in these two states or any other coastal state that the government may deem suitable for offshore wind development in the future.

Table **3**: Factors Influencing the Feasibility of an Offshore Wind Farm

S. NO	Factors	Description
1	Offshore wind resource	Wind resource plays an important role in determining the economic viability of any wind energy development. A well-designed wind measurement campaign to estimate the average mean wind speed across the region of interest at the proposed hub height is vital. Risk of extreme wind conditions such as tropical cyclones need to be evaluated.
2	Water depth and seabed characteristics	Water depth and the geo-technical strength of the seabed play an important role, both in terms of a project's technical feasibility and economic viability. They will influence the choice of foundation and construction logistics.
3	Proximity to construction ports	Proximity to construction ports refers to the linear (navigable) distance at any point in the study domain to the closest identified suitable port for the staging of wind farm construction. Port facilities for operation and maintenance activities should also be considered.
4	Visual impact	Visual impact concerns are a function of the distance of a potential offshore wind development from the coast with near-shore projects potentially facing more local opposition, which may impact the consent of a project depending on the local planning regulatory regime.
5	Proximity to grid connection	Grid connection proximity is highly sensitive to capital costs associated with electrical infrastructure and the difficulties often associated with achieving grid connection agreement with transmission system operators.
6	Social and Environmentally sensitive areas	Environmentally and socially sensitive areas should be approached with caution.
7	Area for development	This refers to potential areas that are available for OW wind energy development after removing all the 'hard' constraints.

Source: DNV GL, 2014

This section mainly focuses on offshore wind characteristics (factor 1). The key atmospheric characteristics that should be measured before an offshore wind farm is built include:

- Wind speed preferably at hub height;
- Barometric pressure;
- Temperature;

- Wind direction preferably close to hub height;
- Wind shear (how wind speed and direction changes with height);
- Turbulence intensity[8];
- Temporal variation (diurnal, seasonal and year to year variations)

To assess wind energy availability in any location, deriving the wind power density (WPD) is essential. WPD gives the mean annual power availability per square meter of swept area of a turbine. Wind speed, wind direction, air density (resultant of barometric pressure and humidity), turbulence and wind shear are the key parameters to derive wind power density.

Variability of all of the above parameters with seasons and years need to be captured to best possible estimations. Hence it is highly recommended to measure and collect as much consistent data as possible to identify the most appropriate zones in Gujarat and Tamil Nadu for OW developments.

Development of a robust offshore wind resource assessment campaign that minimises uncertainty in the project's energy estimates, while managing the cost and uncertainty is a complicated-balancing act for all wind development projects. For onshore wind projects, the options for measurement are relatively well known, with moderate cost, and are accepted by the financial community. Nearly every onshore wind project uses multiple on-site meteorological masts as the primary method for wind resource characterisation, possibly with off-site masts, modelled data, and/or remote sensing data as supplements. In the case of offshore wind farms, the installation of multiple masts and/or remote sensing devices can be more difficult to deploy, and modelled data are more difficult to validate without availability of other high-quality measured data for calibration.

Based on experiences in the European offshore markets, an offshore wind resource measurement campaign that provides the best balance of the following four goals offers a better chance of success:

1) Low Cost – Keeping expenses as low as possible during the development phase of an offshore wind project is critical for developers, especially when the commercial viability of the project is not known. For example, some developers may avoid significant expenses towards data collection while an offshore project is in an early permitting stage.

2) Short Schedule – Offshore wind projects typically have longer development schedules relative to onshore projects, some approaching ten years. Streamlining of the consent (permits) application and environmental assessment processes help in shortening development schedules. But to truly cut project schedule timelines the supply chain concerns should be addressed at the earliest including grid infrastructure, installation vessels, ports and turbine manufacturers.

3) Lowering Uncertainty – Project financing is frequently driven by the uncertainty in project energy estimates, and a wide spread between the P90 energy level and the P50 can make financing terms unacceptable[9]. Minimising uncertainty to the greatest extent possible is therefore critical for a successful project.

[8]Turbulence intensity is the ratio of the wind speed standard deviation to the mean wind speed. EWEA 2010. Available at http://proceedings.ewea.org/ewec2010/allfiles2/651_EWEC2010presentation.pdf

[9]Investors developed a method to put power production requirements on renewable energy projects to de-risk a loan. These requirements involve the calculation of probabilities for energy production that are expressed as P values. In the European context typically P50 and P90 probabilities are used. A P50 figure is the level of generation that is forecasted to be exceeded 50% of the year A P90 figure is the level of generation that is forecasted to be exceeded 90% of the year.

4) High "Bankability" – Advances in resource assessment technologies need to be accepted by investors as well as project developers – if the investors are not sufficiently comfortable with the available data, a project is unlikely to be financed. Most investors are hesitant to accept new technologies, particularly if they have had limited or no exposure to projects based on that technology in the past.

In most cases, balancing these four goals will involve a combination of strategies to be employed under any project, and there will often be trade-offs among these four goals that make options more or less attractive for a particular site. For example if a project's schedule allows for greater than five years of data collection, there will be more opportunities to try higher-risk but lower cost collection systems than under a schedule where only one year is available for data collection.

In developing a wind measurement plan it is important to establish clearly defined objectives. This is true for both onshore and offshore wind projects. However, due to the higher cost of offshore measurements, it is important to ensure that the wind measurements are both productive and aligned with the stated objectives.

3.1.1 OFFSHORE WIND RESOURCE ASSESSMENT

India has a coastline of 7,516 km and an Exclusive Economic Zone (EEZ) of nearly 2.3 million km^2 that gives it access to a vast offshore area. India has 9 Maritime States, of which Gujarat has the longest coastline, followed by Tamil Nadu. The state of Gujarat has a coastline length of about 1,600 km, which can be broadly divided into 3 regions - the Gulf of Kutch, the open coast of Saurashtra and the Gulf of Khambhat[10] - as illustrated in Figure 2. The State of Tamil Nadu has a coastline length of 1,076 km as illustrated in Figure 3.

The process of estimating the wind power density at the proposed site is one key factor for site selection. Once the wind power density is known, the total energy production expected from the selected wind turbine and total installable capacity (in MW) can be calculated. Incorrect estimation of wind resource could lead to unviable projects with poor financial and operational performance. So far various studies have been carried out by both international and national agencies to assess the broad level wind resource potential for the Indian Coastline, including some specific desk studies for the states of Gujarat and Tamil Nadu. Brief summaries of major publicly available studies are discussed in the following section. Thereafter Table 4 summarizes the key findings of the international and national studies.

[10] Presentation by Gujarat Maritime Board in International Seminar on Offshore Wind Power Potential of Gujarat; held at Gandhinagar, Gujarat, on 1 February 2014

Figure **2**: Three Regions of Gujarat Coastline (Gulf of Kutch, Gulf of Khambhat and Open Coast of Saurashtra)

Source: Google Maps, Notations by WISE, 2014

Figure **3**: Tamil Nadu Coastline

Source: Google Maps, Notations by CSTEP, 2014

3.1.1.1 International Studies on Offshore Wind Resource Assessment including Indian Territorial Waters

A) Global Potential for Wind Generated Electricity (2009)

In 2009 a study entitled 'Global Potential for Wind Generated Electricity[11], numerically modelled wind speed data (GEOSS 5 Analysis) was extrapolated to 100 m hub height. This wind speed data was used to evaluate the global offshore wind potential. Other constrains considered for the study were water depth of less than 200 m within 50 nautical miles (NM) of closest coastlines. The capacity of the turbine employed for the calculation was 3.6 MW.

The study estimated 1100 TWh of theoretical annual OW energy potential along the entire coast of India. The study did not assess state-specific potential for India and did not consider any spatial constraints.

B) UNEP-NREL Offshore Wind Map (2005)

National Renewable Energy Laboratory (NREL[12]) used a 5-year average from 2000-2004 to produce its offshore wind map. NREL applied a simple extrapolation to generate the 50 m estimates from the original 10 m QuikSCAT (Quick Scatterometer) data. Scatterometer measurements of the state of the ocean surface are used to estimate ocean winds at 10 m height in the QuikSCAT satellite data set. The frequency of data is approximately two observations per day as QuikSCAT typically observes a particular spot on the Earth twice a day - once around 6 AM local time and again around 6 PM local time. Figure 4 (A) shows the wind power density and Figure 4 (B) wind speed at 50 m height for the Indian[13] coast.

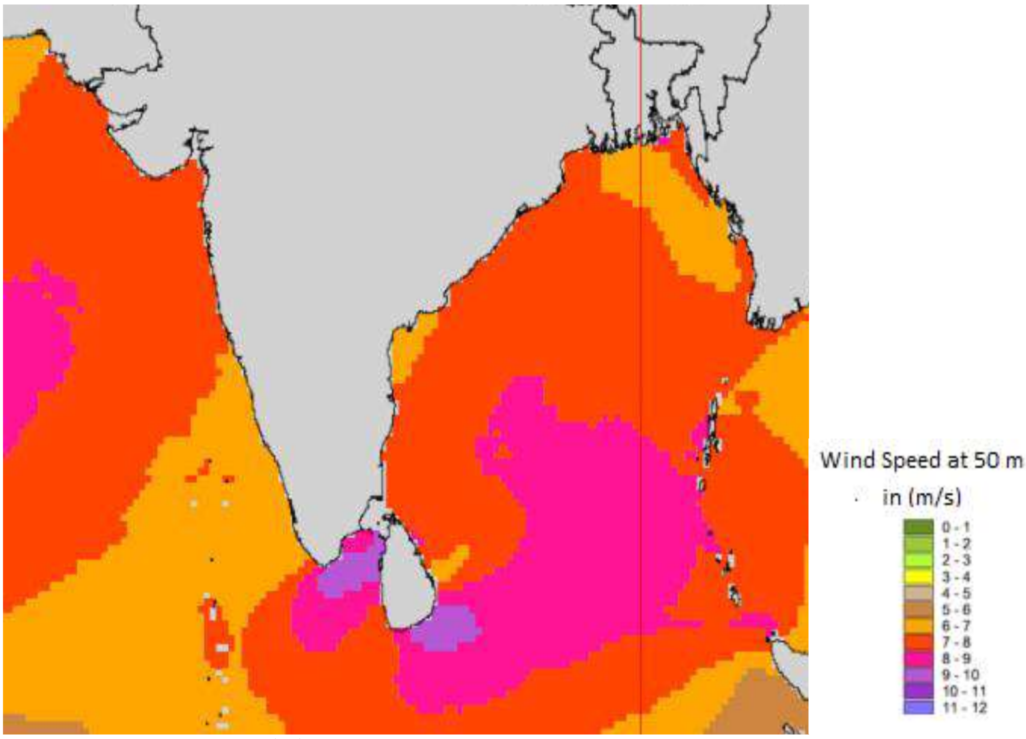

Figure **4(A)**: Wind Speed at 50 m Height for India from QuikSCAT

Source: UNEP -NREL, 2005

[11] Lu, Xi, Michael B. McElroy, and Juha Kiviluoma. 2009. Global potential for wind-generated electricity. Proceedings of the National Academy of Sciences of the United States of America 106(27): 10933-10938

[12] This GIS data was developed by the National Renewable Energy Laboratory, which is operated by the Midwest Research Institute for the U.S. Department of Energy. UNEP published the results (maps) of this study publicly. The maps are available athttp://en.openei.org/datasets/taxonomy/term/471?page=1 .The study was further updated in 2007.

[13] National Renewable Energy Laboratory (NREL), 2011, www.remss.com,http://en.openei.org/wiki/File:QuikSCAT-_Annual_Wind_Power_Density_at_50m.pdf ,Last accessed on 12/06/2014

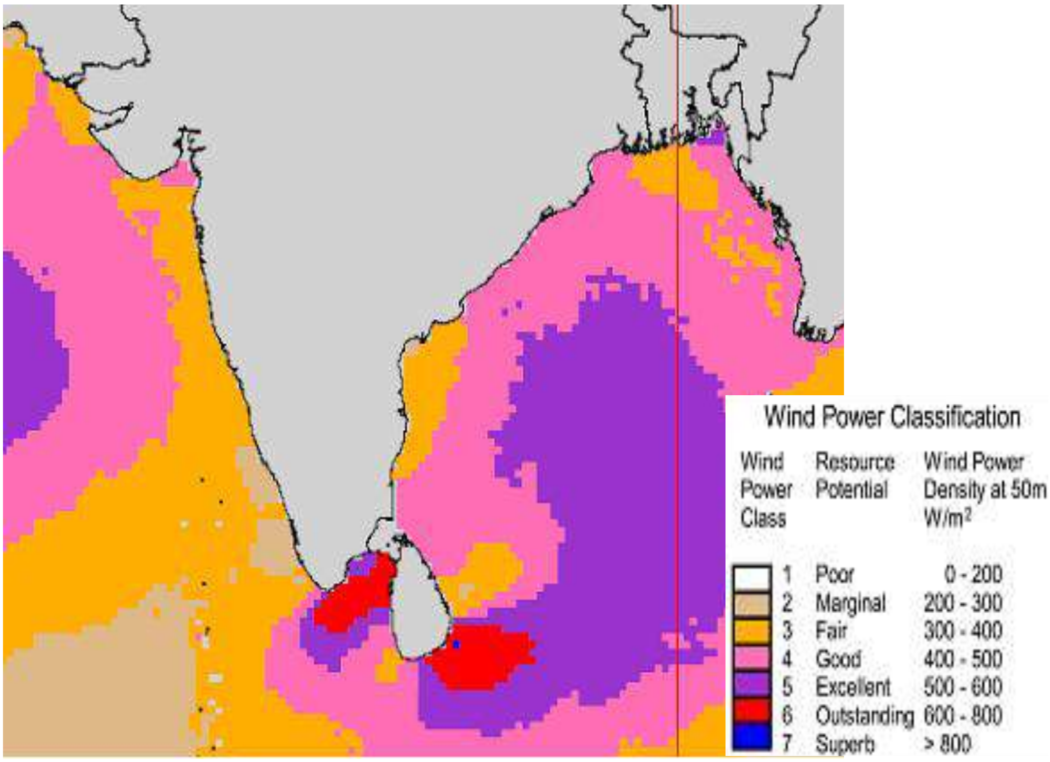

Figure **4(B)**: Wind Power Density at 50 m Height for India from QuikSCAT

Source: UNEP -NREL, 2005

The above map shows 'good' wind power density areas in Saurashtra and Gulf of Khambhat region and 'fair' wind power density in the Gulf of Kutch region. The map also shows excellent wind power density in areas along the southern coast of Tamil Nadu. Due to lack of details of the assumptions made by the source, any theoretical GW potential has not been derived here.

C) National Renewable Energy Laboratory (2012)

NREL prepared a global offshore wind map that extended to include India's exclusive economic zone (EEZ). This analysis combined wind-vector grid data for ocean areas with bathymetry maps, country EEZs, wind turbine power curves, and other datasets and relevant parameters to build supply curves that estimate a country's OW resource defined by resource quality, depth, and distance from shore. This study did not exclude shipping lanes from the analysis, but did exclude protected areas with IUCN codes of I-III; it also excluded all areas within 5 nautical miles of the coast as a broad indicator of public resistance to any possible visual disturbance.

The wind resource data is based on National Oceanic and Atmospheric Administration (NOAA) blended sea winds (wind speeds generated by blending observations from multiple satellites. This study uses wind speed data at 10 m elevation with a 6 hour time resolution from 1995 to 2005. The horizontal resolution of data is 0.25 degrees latitude x 0.25 degrees longitude (30 km). From this data a wind map is generated for 90 m hub height by extrapolating data from 10 m height. The horizontal resolution of the resultant map is 30 km[14].

Figure 5 shows the wind speed map at 90 m hub height for the entire coast of India up to its EEZ. The map shows higher wind speed (7.06 – 8.27 m/s) areas in Gulf of Khambhat region and in few parts of Saurashtra and Gulf of Kutch. It can be also inferred that the southern and south-eastern coast of Tamil Nadu has high to very high (> 9 m/s) wind regions. This study also estimated 1100

[14]International Renewable Energy Agency (IRENA), 2012 Irena-Masdar website, http://irena.masdar.ac.ae/, last accessed on 23/04/2014

TWh offshore wind potential for India[15]. An indication of whether this is a "theoretical" or "practical" resource estimates have not been considered at this stage.

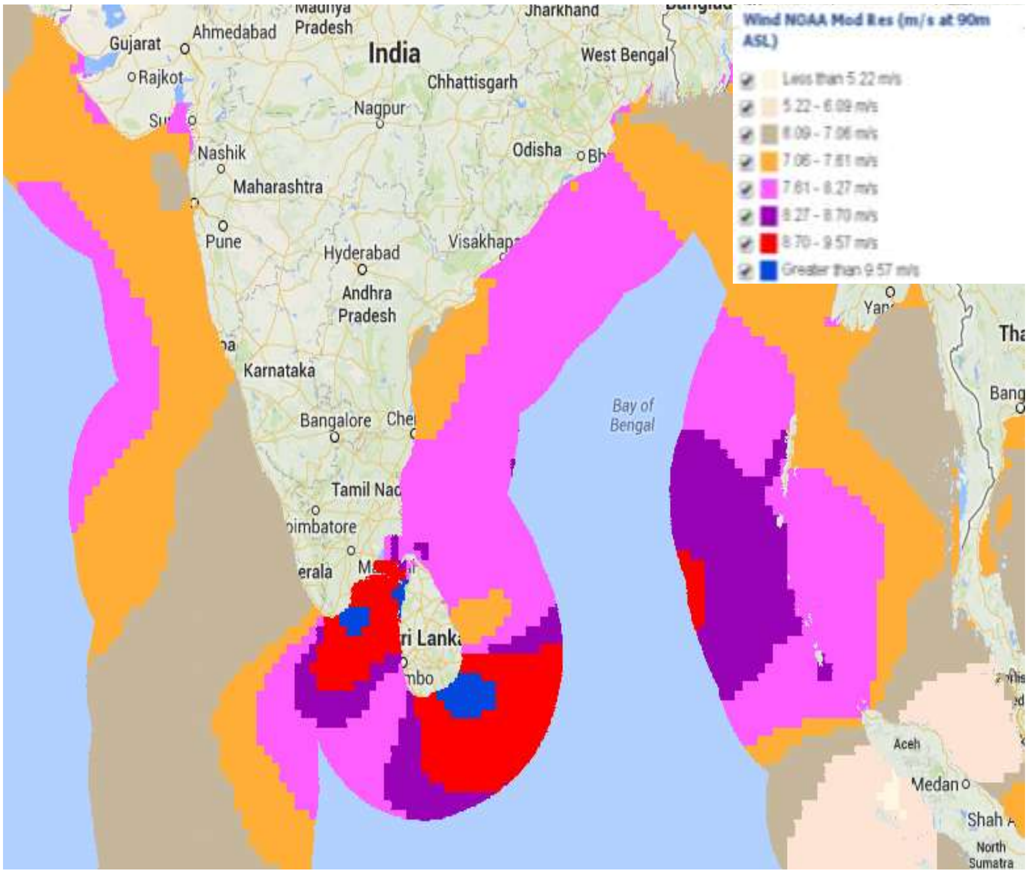

Figure **5** Wind Speed at 90 m Height along the Indian Coast

Source: NREL, 2012[16]

D) Sander-Partner Global Wind Map (2011)

Sander-Partner prepared a global wind map[17] by utilizing the MERRA data. This map uses mean wind speed at 50 m hub height based on values for each hour between the years 1980 to 2011. The resolution of data is 0.5 degrees latitude x 2/3 (0.667) degrees longitude, which is approximately 50 km.

The map shows regions of wind speeds around 9 m/s along Tamil Nadu coast (southern tip of India). The map shows above 6 m/s wind speeds along the open coast of Saurashtra and some parts of Gulf of Kutch.

[15] http://www.nrel.gov/docs/fy13osti/55049.pdf Page 6

[16] http://maps.nrel.gov/swera?visible=swera_wind_nasa_lo_res&opacity=50&extent=91.59,26.86,97.40,29.47

[17] International Renewable Energy Agency (IRENA), Global Wind 50 m Height from MERRA by Sander+Partner, Irena-Masdar website, http://irena.masdar.ac.ae/ last accessed on 15/04/2014

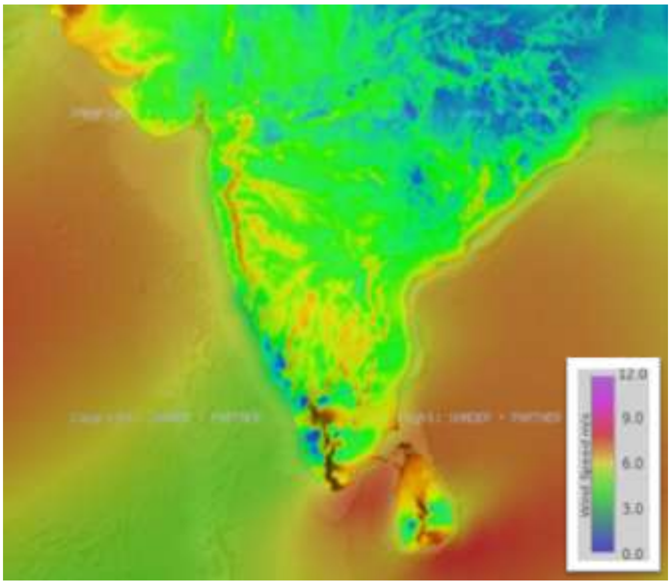

Figure **6**: Wind Resource Map for India

Source: Sander-Partner, 2011

E) DTU Risø in collaboration with C-WET (2011)

DTU Risø (Technical University of Denmark) in collaboration with C-WET, prepared offshore wind maps for South India[18] and identified wind speed and WPD at various heights of 10 m, 25 m, 50 m, 100 m and 200 m. The report mapped potential sites near the coast of Tamil Nadu. The resolution of this data was 0.01 degree by 0.01 degree or roughly 1 km by 1 km. The area of interest was from 77°E to 80°E longitude and from 7°N to 10°N latitude.

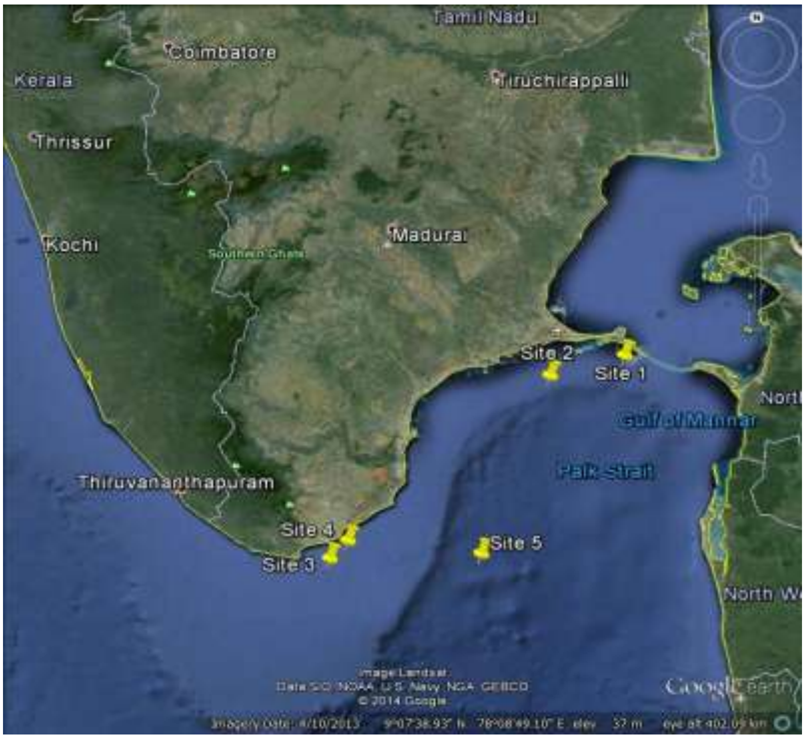

Figure **7**: Potential Sites Suggested By DTU RISØ off the Coast of Tamil Nadu

Source: DTU RISØ, 2011

[18] Hasager, CB, Bingöl, F, Badger, M, Karagali, I & Sreevalsan, E 2011, Offshore Wind Potential in South India from Synthetic Aperture Radar. DanmarksTekniskeUniversitet, RisøNationallaboratoriet for BæredygtigEnergi, Roskilde. Denmark.Forskningscenter Risoe. Risoe-R, no. 1780(EN)

DTU Risø used a total of 164 archived scenes from the Advanced SAR instrument on-board the European ENVISAT satellite, which were retrieved for the period 2002-2011. In addition, 10 years (1999-2009) of QuikSCAT data from the SeaWinds satellite was utilized. Satellite data from the European Space Agency (for period of 2002-2011) and Remote Sensing Systems were also utilised. The study did not assess potential for cyclones in the region.

The mean wind speed near the coast was found to be 4 to 5 m/s whereas mean wind speed up to 7.6 m/s was found further offshore, indicating wind resources from 200 to 500 w/m^2. These results were for 10 m above sea level.

The sites with promising wind speeds appear close to the coastline in two areas – sites 1 and 2 in the north and sites 3 and 4 in the south. Strong winds prevail in site 5, which is further from offshore. The suggested sites are shown in Figure 7. The co-ordinates are (1) 9.1 N, 79.3 E, (2.) 9.0 N, 78.9E, (3.) 8.0N, 77.7E, (4.) 8.1N, 77.8E and (5.) 8.0N, 78.5E. The study further suggested that strongest mean wind speeds around 7.5 m/s were in the area from 78°E to 79°E longitude to 8°0'N to 8°15'N latitude. The study did not consider any spatial constraints.

3.1.1.2 Indian Studies on Offshore Wind Resource

A) Indian National Centre for Ocean Information Services (2011)

In 2011, the Indian National Centre for Ocean Information Services (INCOIS) mapped[19] the daily climatology. The map shows the number of days with wind speeds exceeding 6, 8, 10 and 12 m/s along the Indian coast using QuikSCAT satellite data. Figure 8 shows daily climatological maps of winds exceeding 6 m/s and 8 m/s for Indian territorial waters. It validated the data using in-situ wind measurements obtained from 5 moored buoys of the National Institute of Ocean Technology (NIOT).

The buoy measures the wind speed at 3 m and the QuikSCAT data indicate wind speeds at 10 m height. Hence, to bring both measurements on the same level, the buoy measurements were extrapolated to 10 m hub height. Subsequently, the buoy data was validated with QuikSCAT wind speed data and extrapolated to 80 m hub height.

Daily-climatology, monthly-climatology and annual average climatology of WPD[20] have been derived from bias corrected wind speeds at 80 m hub height. INCOIS constructed the daily climatology of winds at 80 m hub height and the number of windy days exceeding 6 m/s, 8 m/s, 10 m/s and 12 m/s were estimated.

Due to the lack of information an analysis relating the number of wind days to high level annual energy production values (P50 and P90) has not been considered here.

Gujarat

The INCOIS study suggests that along the Gujarat coast winds of magnitude of 6 m/s or more persist for more than 300 days and winds having magnitude of 8 m/s or more persists for about 100 days. However, the availability of winds above 10 m/s is less than 25 days.

The study indicates that Gujarat's Saurashtra region has better wind resource than the Gulf of Khambhat and Gulf of Kutch regions.

[19] R. Harikumar, L. T. (2011). Report on the Assessment of Wind Energy Potential Along the Indian Coast for Offshore Wind Farm Advisories. INCOIS.

[20] Climatology of WPD denotes long term average of Wind Power Density

Tamil Nadu

The study further suggests that wind speeds of > 6 m/s or more persists for more than 300 days and around 8 m/s magnitude or more persists for about 200 days along the Tuticorin region in Tamil Nadu.

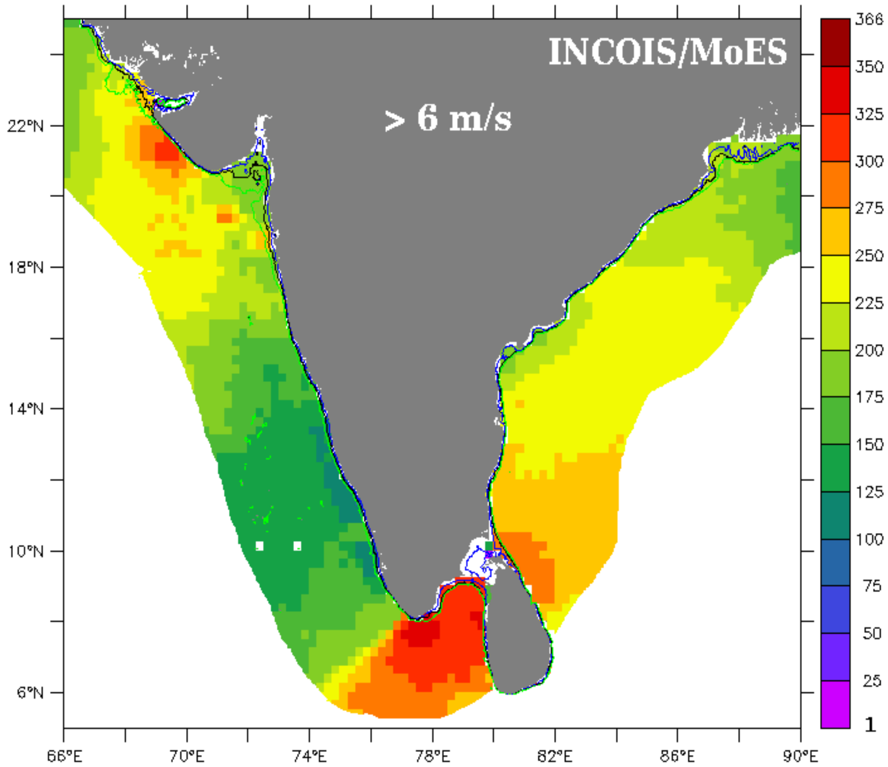

Figure **8(A)**: Daily Climatological Maps of Wind Speeds Exceeding 6 m/s (Color Scale Indicates Number of Days)

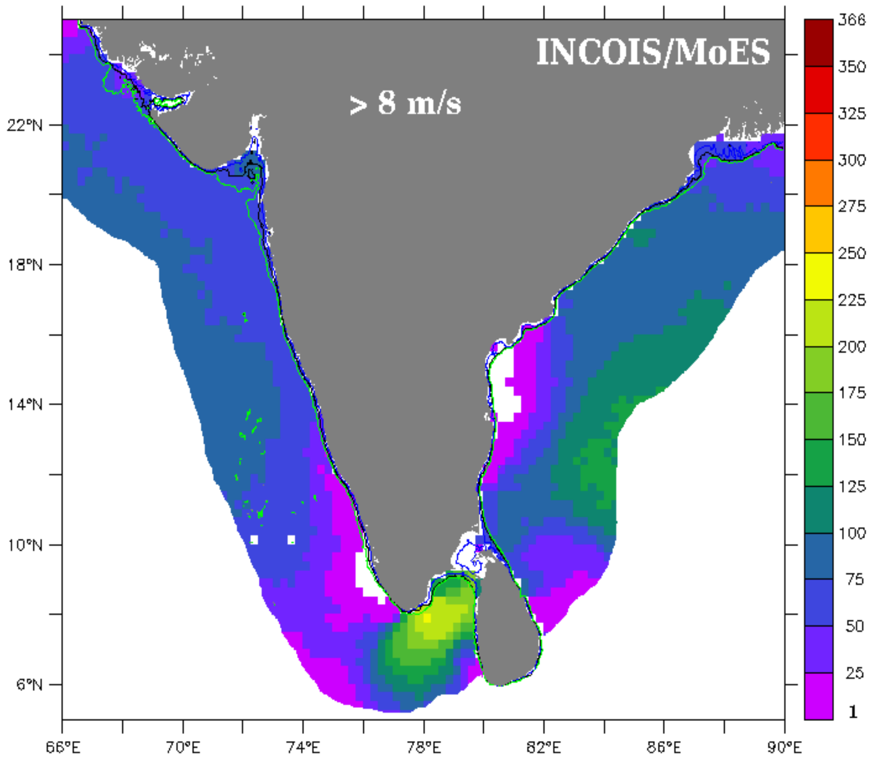

Figure **8(B)**: Daily Climatological Maps of Wind Speeds Exceeding 8 m/s (Color Scale Indicates Number of Days)

Source: INCOIS, 2011

B) Indian Wind Atlas[21] (2010)

C-WET and DTU Risø carried out a study in 2010 to estimate the indicative offshore wind speeds and wind power densities along the coast in India. The study utilized reanalysed data for the period of 1977 to 2006 from the National Center for Environmental Prediction (NCEP)/ National Center for Atmospheric Research (NCAR) to create the maps. The sampling frequency of the data was 6 hours. The data was used to create wind classes, which represented the large-scale wind climate in terms of wind speed and wind power density at 50 m and 80 m height along the Indian coast.

The spatial resolution in the wind atlas is 5 km. The maps developed under this study provide only indicative wind characteristics and lack adequate spatial or temporal resolutions required for planning offshore wind farms.

Gujarat

Indicative offshore wind speeds and WPDs along with the potential areas for the state of Gujarat are shown in Figure 10. The wind power density is in the range of 300–500 W/m^2, indicating fair to good wind resource at 80 m.

The wind speed along the coast of Gujarat is in the range of 6.5 – 9.0 m/s at a hub height of 80 m. The study also indicates that parts of the Gulf of Khambhat have higher (above 8 m/s) wind potential than the open coast of Saurashtra and Gulf of Kutch regions.

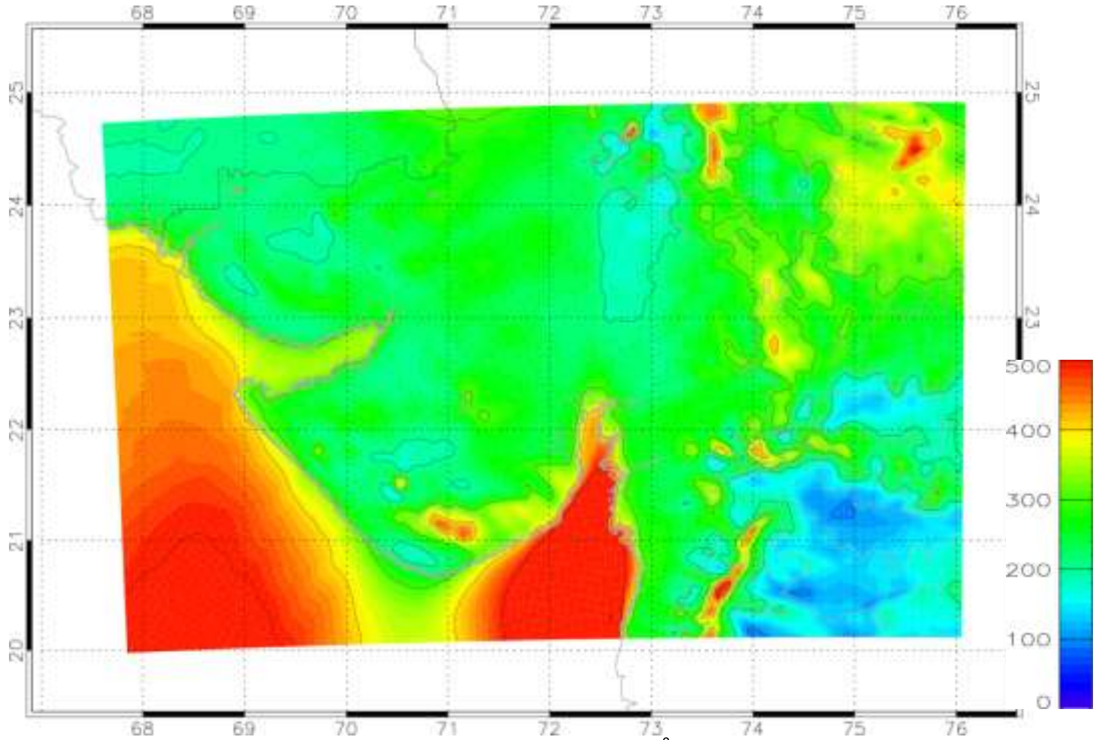

Figure **9** : Mean Simulated Wind Power Density (W/m^2) in Gujarat at 80 m Hub Height

Source: C-WET, 2010

[21] C-WET (2010), Indian Wind Atlas

Tamil Nadu

Figure 10 shows the WPD map at 80 m height for the coastal regions of Tamil Nadu. The region shows promising wind resource with 400 – 500 W/m² of wind power density. Also the estimated wind speed for these pasts in Tamil Nadu is in the range of 7.0 – 9.5 m/s at hub height of 80 m.

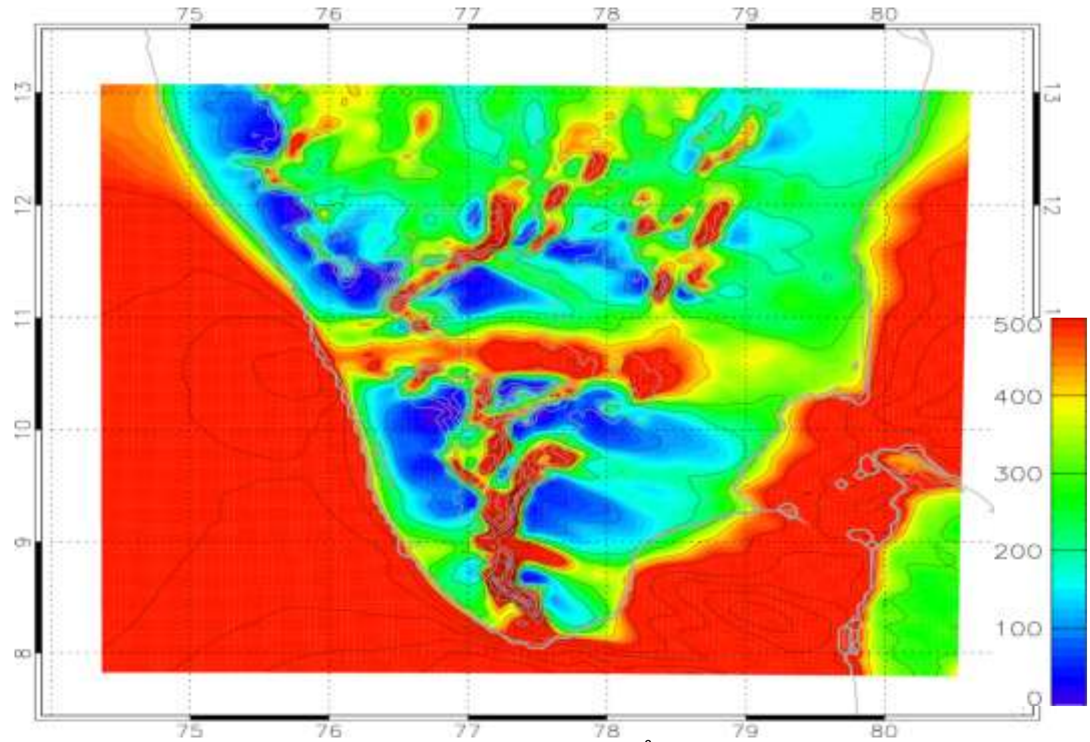

Figure **10**: Mean Simulated Wind Power Density (W/m²) In Tamil Nadu at 80 m Hub Height

Source: CWET, 2010

C) WinD Force Management, India (2014)

In a preliminary assessment conducted by Jami Hossain[22], the theoretical offshore wind potential of India is assessed to be 966 GW over territorial cover of 40 km from India's coastline and up to a depth of 40 m. The offshore potential capacity for Gujarat was estimated to be 262 GW. This paper estimates that Gujarat has 3,590 km² regions with the wind speeds ranging between 6.0 - 8.0 m/s; 16,136 km² with wind speeds ranging from 8 – 10 m/s; and 14,656 km² in 10 - 12.5 m/s respectively. Figure 11 shows the offshore wind speed map for Gujarat at 120 m hub height.

The validity of the results in this report has not been considered here.

[22]Dr. JamiHossain, M. Z. (Jan 2014). Offshore Wind Power Development in India.Windpro 38-40

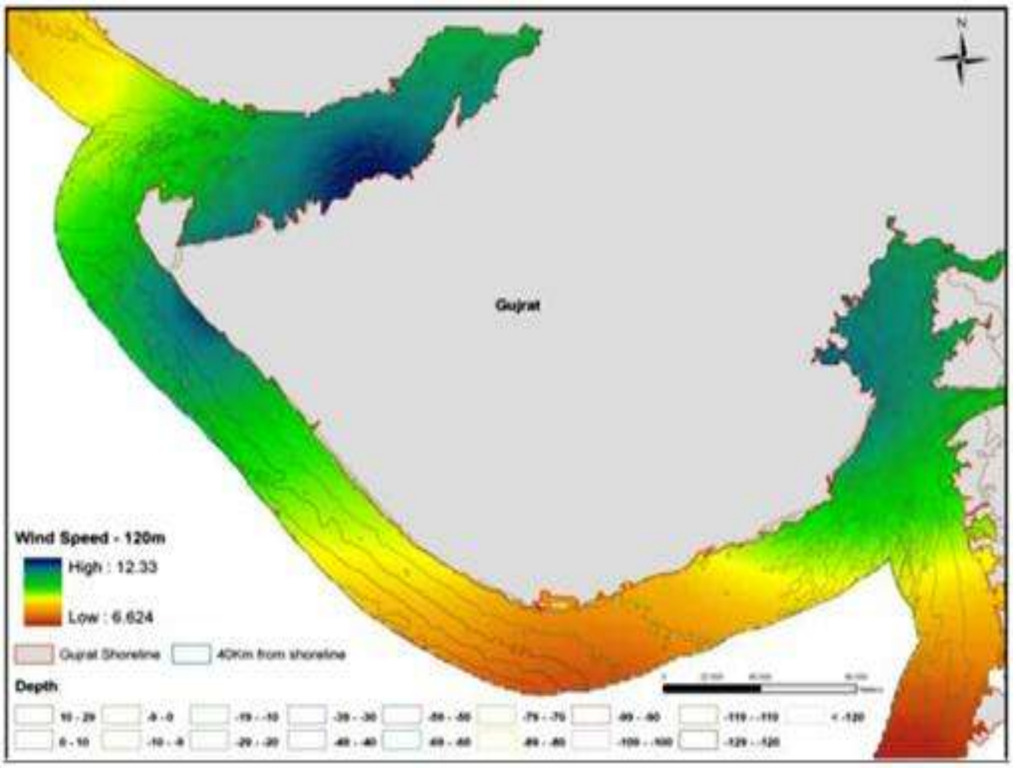

Figure **11**: Offshore Wind Speed Map for Gujarat at 120 m hub height

Source: WINDFORCE, 2014

The paper indicates high potential areas for Gulf of Kutch as compared to Gulf of Khambhat and the Saurashtra region. This conclusion is different from studies listed above, including the India Wind Atlas (CWET, 2010) which indicate higher wind speeds in Gulf of Khambhat.

The study also indicated significant offshore potential capacity at 187 GW for Tamil Nadu. The potential for Tamil Nadu has also been analysed at 120 m height.

Also, Tamil Nadu coastline experiences considerably good wind potential area of 6,912 km^2 in the wind speed range between 9-10 m/s, followed by 18,529 km^2 in 10- 12 m/s.

The validity of these results has not been considered here.

D) Oldbaum Services (2011)

Oldbaum Services completed a study[23] for C-WET in 2011 on two sites, Rameswaram and Kanyakumari, in Tamil Nadu. The report was based on the datasets given by C-WET for Rameswaram and Kanyakumari. C-WET has the data for Rameswaram[24] from August 1988 till July 1993 and for Kanyakumari from January 2004 to December 2004. The average wind speeds for Kanyakumari was approximately 9.7 m/s and for Rameswaram it was 10.4 m/s at 100 m hub height.

For the long-term data, Oldbaum used the following sources:

- Long-term meteorological stations
- Meso-scale model
- Satellite-based remote sensing

[23]Oldroyd, A. M. (2011). Offshore Wind Potential Tamil Nadu India. Scotland: Oldbaum Services Ltd.

[24]The Rameswaram data was already 18 years old at the time of analysis. Hence it is probable that the local climate condition would have changed considerably during this period.

For Kanyakumari, only 1 year of data was available. In this case, the wind speed data was presented at 20 m, measured and scaled to 100 m AMSL (Above Mean Sea Level) using the WAsP linear flow model, but evaluation studies tracked traces of directional modification of the predominant wind direction, which naturally changes as the point of observation migrates further offshore to the same dominant wind direction as Rameswaram.

The results drawn from the data seemed promising, but further validation of datasets is needed. The major areas of concern cited were a lack of detailed time series information, a lack of long-term (10 years or more) wind data and no measurements at heights likely to be used for offshore wind projects.

Given that currently available offshore wind data is out dated and insufficient to fully describe the wind climate and offshore wind potential; the study suggests that LiDAR measurements should be used to validate the present datasets or met mast measurements at appropriate hub heights for at least two consecutive years. With this, it recommends a pilot project of 100 MW to be undertaken before wider uptake of commercial offshore wind project developments.

E) World Institute of Sustainable Energy (2012)

As a part of a study titled “Action Plan for Comprehensive RE Development in Tamil Nadu”, WISE carried out a GIS-based assessment for renewable energy resources in Tamil Nadu in 2012 with the support of Shakti Sustainable Energy Foundation. For the exercise, WISE obtained numerically modelled wind resource data from AWS Truepower.

The wind data in GIS compatible format was obtained for three hub heights, 80 m, 100 m and 120 m and had a resolution of 200 m x 200 m. The CUF (Capacity Utilization Factor) was calculated using wind speed to power curve correlation of REpower MM -100, 3 MW turbine model. Weibull wind speed distribution was used with turbine power curve to estimate the annual energy output /CUF.

Offshore wind potential was determined with limitations of water depth up to 30 m and distances from the coast up to 25 km. The results were mapped on a GIS platform. The unconstrained offshore wind potential at 80 m hub height was determined to be 127 GW[25] having a net CUF of over 33%.

[25] WISE. (2012). Action Plan for Comprehensive RE Development in Tamil Nadu. WISE.

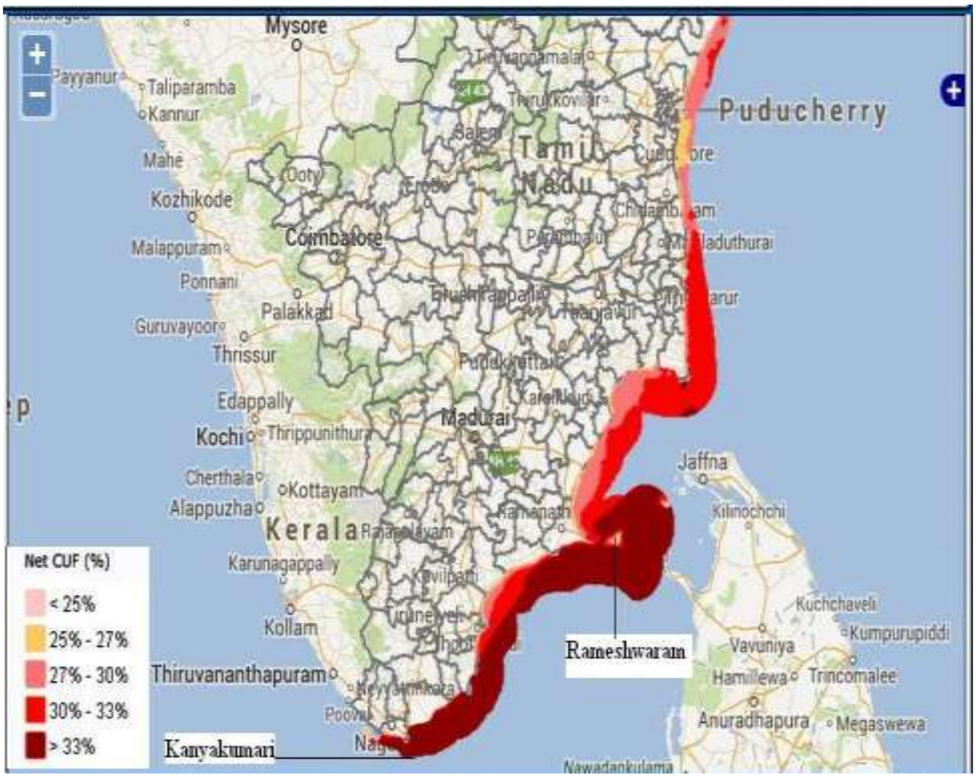

Figure **12**: Estimated net CUF for Offshore Wind along the Tamil Nadu coast

Source: www.tnrepotential.wisein.org

3.1.1.3 C-WET Met Masts in Gujarat and Tamil Nadu

C-WET has installed a number of masts along the coastline in Gujarat. Annexure 3 provides the list of C-WET coastal masts located in Gujarat. Annexure 4 provides the list of coastal met masts located in Tamil Nadu.

Figure **13**: Location of C-WET Coastal Masts in Gujarat (reproduced using Google Earth)

Source: WISE, 2014

Figure **14:** Location C-WET Coastal Masts in Tamil Nadu (reproduced using Google Earth)

Source: CSTEP, 2014

Table **4**: Summary of Available Offshore Wind Resource Assessment Studies

A: International Wind Resource Assessment Studies

STUDY/REPORT (REFERENCE)	UNEP-NREL	NREL	SANDER + PARTNER
Year of publication	2005	2012	2011
Study area	Global	Global (EEZ)	Global
Wind data source	QuikSCAT satellite data	Multiple satellites data	MERRA
Wind measurement year(s)/Data period	2000-2004	1995-2005	1980 - 2011
Primary wind data measurement frequency	2 observations per day	6-Hourly, Daily, Monthly data and climatological monthlies over a period of 11 years (1995-2005)	Hourly
Height of primary wind measurements (m)	10	10	50
Extrapolated wind speed height (m)	50	90	50
Resolution of grid (km)	50	30	(0.5°Latitude X 0.667° Longitude,) ~50

STUDY/REPORT (REFERENCE)	UNEP-NREL	NREL	SANDER + PARTNER
Distance from the coast (km)	Indian EEZ (~ 370)	Indian EEZ (~ 370)	Global Offshore Assessment
Sea bed depth (m)	Not considered	Not considered	Not considered
Wind speed (m/s) at extrapolated height (m)	7 – 8 (at 50 m)	7.06 - 8.27 (at 90 m)	3.5 – 8 (at 50 m)
Wind power density (W/m^2) at extrapolated height (m)	200-800 (at 50 m)	N.A (at 90 m)	N.A (at 50 m)
Estimated offshore wind potential at extrapolated height (GW) and (TWh)	N.A	1100 TWh	N.A
Note: The validity of these results has not been considered here.	Gujarat - Good wind power density areas in Saurashtra and Gulf of Khambhat region and fair wind power density in the Gulf of Kutch region Tamil Nadu – Coastline between Kanyakumari and Rameswaram has higher potential as compared to rest of the coast	Gujarat - High wind speed areas in Gulf of Khambhat region and also in few parts of Saurashtra and Gulf of Kutch Tamil Nadu – This study re-affirms that coastline between Kanyakumari and Rameswaram has higher potential as compared to rest of the coast	Gujarat - High windy regions for Saurashtra and some parts of Gulf of Kutch region and low windy region for Gulf of Khambhat Tamil Nadu – Coastline between Kanyakumari and Rameswaram has higher potential as compared to rest of the coast

B: National Wind Resource Assessment Studies

Study/Report (reference)	INCOIS		INDIA WIND ATLAS (2010)	WIND FORCE MGMT.	WISE
Year of publication	2011		2010	2014	2012
Study area	India		India	India	Tamil Nadu
Wind data source	Moored buoys	QuikSCAT	NCEP/NCAR	AWS Truepower	Multiple sources
Wind measurement year(s)/Data period	N.A	N.A	From 1948	N.A	N.A

Study/Report (reference)	INCOIS		INDIA WIND ATLAS (2010)	WIND FORCE MGMT.	WISE
Primary wind data measurement frequency	N.A	N.A	6 Hourly	Hourly	N.A
Height of primary wind measurements (m)	3	10	N.A	N.A	N.A
Extrapolated wind speed height (m)	80		50 & 80	120	Modelled at 80, 100 and 120
Resolution of grid	N.A		5 km	N.A	200 m
Distance from the coast (km)	300		N.A	40	25
Sea bed depth (m)	Not considered		Not considered	40	30
Wind speed (m/s) at extrapolated height	< 6 for 200 - 325 Days in a year	< 8 for 200 - 300 Days in a year	6 - 8 at 50 m 6.5 - 9 at 80 m	N.A	6 – 12 at 80 m
Wind power density (w/m^2) at extrapolated height	N.A		250 - 500 at 50 m, 350 - 500 at 80 m	N.A	N.A
Estimated offshore wind potential at extrapolated height (GW) or (TWh)	N.A		N.A	Gujarat – 262 GW Tamil Nadu – 187GW (at 120 m)	127 GW (at 80 m)
Note: The validity of these results has not been considered here.	Gujarat - Saurashtra region has better wind resource than the Gulf of Khambhat and Gulf of Kutch regions Tamil Nadu - Coastline between Kanyakumari and Rameswaram has higher potential as compared to rest of the coast		Gujarat - Gulf of Khambhat has higher potential than Saurashtra & Gulf of Kutch regions Tamil Nadu – Entire coastline shows high WPD which ranges from 400-500 W/m^2	Gujarat - High potential areas for Gulf of Kutch as compare to Gulf of Khambhat and the Saurashtra region	Tamil Nadu - Coastline between Kanyakumari and Rameswaram has higher CUF as compared to rest of the coast

3.1.2 CONCLUSION

A number of agencies and institutions have assessed the offshore wind potential of the Indian coast including the coasts of Gujarat and Tamil Nadu. However, all of these studies are subject to various limitations with a possibility to draw various conclusions. Most of these studies are based on modelled data wherein the nature of uncertainty is higher. These wind data sets are available for 10 m or 50 m above sea level and are then extrapolated to 80 m or above. The temporal (e.g. diurnal, seasonal) and spatial variations in available wind data sets used for these studies are inadequate for dependable resource assessment. Further the studies do not take into consideration spatial constraints and oceanographic conditions for potential OW regions.

A couple of the above referred resource assessment studies are based on the data from coastal met masts, which alone do not provide correct representation of wind speeds or direction for offshore conditions. Further the coastal met mast data is available for very low height (20 m). These data sets can be used to complement, rather than replace on-site measurements and numerical wind flow modelling.

Based on the available studies the following conclusion can be drawn:

- Gujarat: There are regions (Gulf of Khambhat, Gulf of Kutch and Saurashtra open coast) with wind speed in the range of 6- 12 m/s at 50-120 m hub heights at varying distance from coast
- Tamil Nadu: There are regions (area around Rameswaram and Kanyakumari) with wind speeds in the range of 9 -12 m/s at 80-120 m hub heights at varying distance from coast

The reliability of quoted wind speed ranges and subsequent analysis would greatly benefit from on-site measurements. For example at 80-100 m hub height in Europe mean wind speeds of >8 m/s may be considered exploitable and 7-8 m/s perhaps exploitable with large rotor diameter turbines. Overall, it seems that Tamil Nadu's south and southeast coasts have better offshore wind resource when compared to Gujarat's coastline.

For developing an offshore wind project, a well-designed multi-year wind measurement campaign is essential. On-site measurement should provide 10 minutes average wind speed and direction at different hub-heights for dependable analysis. The anemometer/LiDAR/Met mast should be calibrated and installation reports and maintenance reports should be kept up to date. The met mast set up must follow IEC (International Electrotechnical Commission) standard or equivalent industry standard. Objectives of multi-year measurement campaigns are to make the wind resource bankable and to reduce the uncertainty for project developers and investors in the OW sector. This analysis would also involve extrapolation, measurement of other on-site parameters like temperature, pressure and their maximum and minimum values to calculate the standard deviation and turbulence intensity.

In summary, based on the limited resource assessments carried out along the Indian coast it seems that there are some good locations for potential offshore development where validation is needed. At this stage both the states need to implement long-term wind measurement campaigns to exploit this clean and indigenous source of energy.

Building on the experience of the onshore wind industry in India - the deployment of larger diameter WTGs and acceptance of lower capacity factors - greater areas may be possible for offshore wind deployment.

3.1.3 ELECTRICITY SECTOR AND GRID INFRASTRUCTURE

3.1.3.1 Summary of Indian Electricity Sector

Under the Indian Constitution, 'electricity' is a concurrent subject, implying that both the Parliament of India and the State legislatures are empowered to make laws on the subject. The legislative authority between the Centre and the State was formally divided through the Electricity Supply Act of 1948[26] that established the Central Electricity Authority (CEA) and the State Electricity Boards (SEBs).

Until 1991, the sector was characterized by one vertically integrated entity that generated, transmitted and distributed power under the respective state's Ministry of Power. The CEA was responsible for the overall planning of the power sector and played an advisory role to the Central Government.

The sector has seen gradual reforms from permitting private investment in power generation in 1991 to initiating regulatory reforms through Electricity Regulatory Commissions Act in 1998[27]. The reforms in 1998 led to the setting up of the Central Electricity Regulatory Commission (CERC) at the central level and the State Electricity Regulatory Commissions (SERCs) at the state level in order to distance governments from the tariff setting process. Currently, the main functions of CERC include regulating tariffs for generating companies owned or controlled by the Central Government and those catering to more than one state, in addition to regulating tariffs for the inter-state transmission of electricity.

The Electricity Act of 2003[28] furthered the reform process and replaced all previous legislation in the Sector. The Act mandated SEBs to be restructured into separate generation, transmission and distribution entities. It also had other key provisions such as license-free thermal generation, non-discriminatory open access for the transmission system, and gradual implementation of the provisions of Electricity Act in the power distribution system and provision for power trading as an activity[29].

In India, the Power Grid Corporation of India Ltd. (PGCIL), the Central Transmission Utility (CTU) and the State Transmission Utility (STU) at the state level have historically undertaken the task of building transmission infrastructure. Figure 15 provides an overview of the principal actors in the power transmission sector in India.

Ministry of Power (MoP)

Perspective planning, policy formulation, processing of projects for investment decision, monitoring of the implementation of power projects, training and manpower development and the administration and enactment of legislation in regard to power generation, transmission and distribution

Central Electricity Authority of India (CEA)

Advises the government on matters relating to the National Electricity Policy and formulates short-term and perspective plans for the development of electricity systems

[26] http://cercind.gov.in/ElectSupplyAct1948.pdf
[27] http://cercind.gov.in/ElectReguCommiAct1998.pdf
[28] http://powermin.nic.in/acts_notification/electricity_act2003/preliminary.htm (Electricity Act 2003 subsumes all previous legislations related to Electricity sector)
[29] Sharma et al (2007). Power Sector Reforms in India.

Central Electricity Regulatory Commission (CERC)	State Electricity Regulatory Commission (SERC)
Regulates tariff; formulates policies regarding subsidies, and promotion of efficient and environmentally benign policies at central level	Regulates tariff; formulates policies regarding subsidies, and promotion of efficient and environmentally benign policies at state level

Central Transmission Utility (CTU)	Private / PPP	State Transmission Utility (STU)
Ensures development of an efficient, coordinated and economical system of inter-State transmission lines and undertakes inter-state transmission	Develops transmission lines on BOO model and charges for wheeling electricity within the tariffs specified by CERC/SERC	Ensures development of an efficient, coordinated and economical system of intra-State transmission lines and undertakes intra-state transmission

Figure **15**: Power Transmission Sector Actors in India
Source: Federation of Indian Chambers of Commerce and Industry, 2013

In order to have an efficient and integrated transmission and supply system, a three-tiered jurisdiction has been constituted. Power System Operation Corporation (POSOCO), currently a subsidiary of state-owned PGCIL, oversees India's electricity load management functions. POSOCO manages these functions through the National Load Dispatch Centre (NLDC), which is responsible for scheduling and dispatch of electricity across various regions and also for overseeing cross border energy exchanges in real time. Regional Load Dispatch Centers (RLDCs) have jurisdiction over the five regional grids and the state grids are managed and operated by a State Load Dispatch Centre (SLDC).

The country has 33 SLDCs, 5 RLDCs - one for each regional grid - and 1 NLDC[30]. These control centers collaborate with each other for executing their statutory responsibilities of ensuring a secure, reliable, efficient and economical power system operation.

3.1.3.2 Challenges for grid integration of wind power

Grid integration of variable power generation sources like large-scale wind power is challenging. However problems caused in integrating large-scale variable generation are often structural. Traditionally grid modernization and building of long-distance high voltage transmission lines involve high capital cost. The State and Centre would have to plan for long-term expansion and ensure financing support is available over the duration of this grid augmentation effort.

Offshore wind is a large-scale variable generation technology. This section describes the current challenges faced in integrating onshore wind in India and potential challenges for grid integration of offshore wind.

Operational Complexities

The onshore wind resource in the Southern and Western states is highly seasonal[31]. The average CUFs see a peak during the monsoon season between June and September and comparatively lower values in other months. Even during peak season, there is wide intra-day variation. This variability presents hurdles in optimizing generation for system operators.

Improper grid access has commercial implications. During periods of high congestion the SLDCs tend to ask wind farms to restrict their generation. In 2013, Tamil Nadu encountered evacuation

[30] Kerala State Electricity Board(KSEB) Officer Association (Jan, 2014), CERC wants to fix responsibility for grid failure, Available online http://www.kseboa.org/news/cerc-wants-to-fix-responsibility-for-grid-failure-04012586.html : Last accessed on 03/07/2014
[31] C-WET (2010), Indian Wind Atlas, Wind Climatology of India, Page 9 - 27

loss of around 3 billion units (Business Standard, 2014). This curtailment leads to financial losses for the wind farm owners.

Technical Standard for Grid Connectivity

Early implementation and further elaboration of the Grid Code (IEGC 2010) [32] is important. According to a recent analysis done by TERI, neither the IEGC-2010 nor the GEGC-2004 satisfactorily elaborate the following[33] points.

- Active power restoration
- Fault ride through requirement
- Voltage control
- Energy balance
- Reactive power compensation
- Active power and frequency control

Hence for India to move towards higher RE generation penetration there is an acute need for a modern system wide grid-integration plan with a long-term view towards a clean, low carbon energy system.

The subsequent section discusses the current state of national and state grid preparedness for large-scale variable renewable energy generation[34].

3.1.3.3 National Grid and Regional Grid Preparedness

India has 31,692.14 MW of grid-connected renewable capacity excluding hydro power stations as on the end of May 2014[35]. Out of this, onshore wind accounts for about 21,000 MW.

In-order to encourage better load management practices by the load dispatch centers (LDCs), an independent LDC for renewable energy was proposed so that the consolidated data for all RE generation could be transferred to the respective State and Regional LDCs for the grid to be operated in a secure manner[36].

Later CERC issued orders for a renewable regulatory fund (RRF) in order to improve the scheduling and forecasting of wind and solar power[37]. This mechanism allows state utilities to socialize the deviation charges[38]. The RRF would be maintained and operated by the NLDC in accordance with provisions of the Grid Code. It would make wind generators immune from paying variation charges up to a certain level of deviation. However, recently CERC has barred all commercial settlements under RRF mechanism[39] and forecasting and scheduling efforts are still in an experimentation mode.

As a step to prevent RE curtailment, flexibility of thermal generators could be increased so that more wind can be incorporated in the power supply. Nonetheless, nationwide utility cooperation will need an interconnected grid with high capacity transmission networks. The synchronization of the southern grid with India`s northern, eastern and western grids in January 2014 has been a

[32]http://powermin.nic.in/transmission/pdf/Indian_Electricity_Grid_Code.pdf

[33] TERI. (2013, January). Renewable Energy. Retrieved from Shakti Sustainable Energy Foundation: www.shaktifoundation.in/cms/UploadedImages/Gujarat%20Grid%20Study_Final%20Report_TERI-PDF.pdf

[34]Annexure 5 *has summary of all Renewable Energy enabling measures implemented by the Central Government*

[35] CEA (2014) Monthly report: May http://www.cea.nic.in/reports/monthly/inst_capacity/may14.pdf

[36] Government Of India, Ministry of Power (2012) Working Group Report 12th Plan, Available at :http://www.indiaenvironmentportal.org.in/files/file/wg_power.pdf

[37] Renewable Regulatory Fund: Implementation mechanism, POSOCO, 2011

[38]Charges are receivable for lower than scheduled withdrawal of power by a buyer and over injection of power by a seller; while Charges are payable for higher than scheduled withdrawal of power by a buyer and under injection by seller.

[39]REConnect: Wind producers in TN favoring power forecasting & scheduling, 2014

progressive move towards achieving inter-regional power transfer capabilities by creating single larger grid[40].

National Grid Transmission Planning

The National Action Plan on Climate Change (NAPCC[41]) set a renewable energy target of 15% of the total generation mix by 2020. The total cumulative capacity from all RE generation would have to be over 100 GW to meet the 15% target (WISE, 2011[42]). Additionally as the individual states across the country reach higher levels of renewable energy penetration, grid availability and integration related challenges will arise.

To prevent such bottlenecks from arising and stunting the growth of RE in India, a long-term national transmission plan for renewable energy generation is crucial. RE projects usually have short gestation periods. Conversely, grid infrastructure development is historically linked with longer gestation periods. This difference in timelines fails to accommodate the rapid rise in RE installations[43].

Building a transmission system that is able to absorb higher levels of variable generation requires a political vision that enables long-term integrated energy planning to address both the energy access and energy security concerns of a country. The capacity additions and grid modernization and augmentation work needs to be complementary.

There are two types of transmission systems, namely high voltage alternating current (HVAC) and high voltage direct current (HVDC). HVDC systems may be economically viable for projects with a distance of over 100 km from shore. HVAC systems are commonly used for offshore projects nearer to the coast. The majority of the world's offshore projects are connected by HVAC transmission. The advantages of HVDC systems are very low line losses and higher power carrying capacity preferably for projects with capacity of more than 500 MW. For India the HVDC option will only be feasible once the offshore wind sector is matured. The basic differences between these two systems are shown in Table 5[44].When comparing HVAC and HVDC links, the total system cost for equivalent energy transmission over a similar distance should be considered.

Table **5:** Comparison of HVAC and HVDC Systems

System	HVAC	HVDC
Voltage form of transport system	Three phase alternating voltage	Direct voltage, two pole
Voltage Range	Up to extra high voltage (<420 kV)	Up to extra high voltage (<800 kV)
Required Cable	Either three single cables or one three conductor cable	Two single cables or one two conductor cable
Required Station at sea	Transformer from medium to extra high voltage (e.g.: 30kV to 400 kV)	Convertor from medium AC voltage to extra high DC voltage (e.g.: 30 kV AC to 400 kV DC)

[40]On 31st December 2013, Southern Region was connected to Central Grid in Synchronous mode with the commissioning of 765kV Raichur-Solapur Transmission line. http://www.powergridindia.com/_layouts/PowerGrid/User/ContentPage.aspx?PId=78&LangID=english

[41]The National Action Plan on Climate Change (NAPCC) announced by the Prime Minister's council on Climate Change was notified in June 2008. As per NAPCC, renewable electricity injection into the national grid has to be set at 5% at the beginning of FY 2009–10 and needs to be increased at 1% per annum in the subsequent years to reach 15% at the end of FY 2019–20.

[42]Achieving 12% Green Electricity by 2017, WISE. The 100GW estimate is based on the demand projection numbers published under the 17th Central Electric Survey (CEA). http://wisein.org/WISE_Projects/Final_12_RE_Report.pdf

[43]WISE (2012). Action Plan for Comprehensive Renewable Energy Development in Tamil Nadu: http://wisein.org/WISE_Projects/TN_ActionPlan_Web.pdf

[44]Sven Tseke. (2005). Offshore Wind Energy -Implementing a New Powerhouse for Europe. Retrieved from http://www.greenpeace.org/international/Global/international/planet-2/report/2006/3/offshore-wind-implementing-a.pdf

System	HVAC	HVDC
Required Station on Land	Transformer from extra high voltage to main land grid voltage (e.g.: 400 kV to 380 kV)	Convertor from extra high DC voltage to main land AC grid voltage (e.g.: 400 kV DC to 380 kV AC)
Space requirement for offshore substations	Small	Depends upon capacity, larger than HVAC system
Levels of Fault	High	Low

Source: Greenpeace, 2005

Table 6 and Table 7 provide an overview of the development plans for the transmission system in India during the 12th Five Year Plan period that runs from April 2012 to March 2017.

Table **6:** Transmission Lines Addition in India (in Circuit km)

Transmission Lines (AC and HVDC) kV	Expected addition during 12th Plan	Cumulative capacity by end of 12th plan
HVDC Bipole Lines (>500)	9,440	18,892
765	27,000	31,164
400	38,000	152,979
220	35,000	175,976
Total	109,440	379,011

Source: Ministry of Power Working Group Report, 2012

Table **7:** Substation Additions in India

Substations (AC and HVDC)	Planned addition during 12th Plan	Cumulative substation count by end of 12th plan
Total- HVDC Terminal Capacity, MW	13,000	26,500
Total- AC Substation capacity, MVA	270,000	642,894

Source: Ministry of Power Working Group Report, 2012

Recent Initiatives by Indian Government

In 2013, India and Germany expressed their intention to support renewable energy by strengthening the power transmission infrastructure in India. Both governments signed a Joint Declaration of Intent on the occasion of the second Indo-German Government Consultations in Berlin, Germany, on 11th April 2013.

The German Government expressed its willingness to provide concessional loans of up to EUR 1 billion through German Reconstruction Credit Institute (KfW) under the Indo-German Financial Cooperation[45]. Two projects have been approved under this agreement. These projects are located in Rajasthan and Tamil Nadu and supported by funds from the Asian Development Bank and KfW, respectively.

[45] (German Embassy's Department for Press) Retrieved from German Missions in India: Available at http://www.india.diplo.de/Vertretung/indien/en/12__Climate__Development__Cooperation/Energy/Cooperation/Green__Corridor.html:, last accessed on 13/06/2014

3.1.3.4 State of Gujarat

The state of Gujarat has one of the highest wind power potentials of all the states in India[46]. Further, a stable regulatory and policy framework and well-developed transmission and evacuation infrastructure have supported Gujarat in achieving the third highest installed wind power capacity in India. The total installed power generation capacity in Gujarat was 28.42 GW as of March 2014. Out of this total power generation capacity, renewable power contributes 4.4 GW (~15.3%)[47]. Figure 16 shows the renewable energy mix of Gujarat.

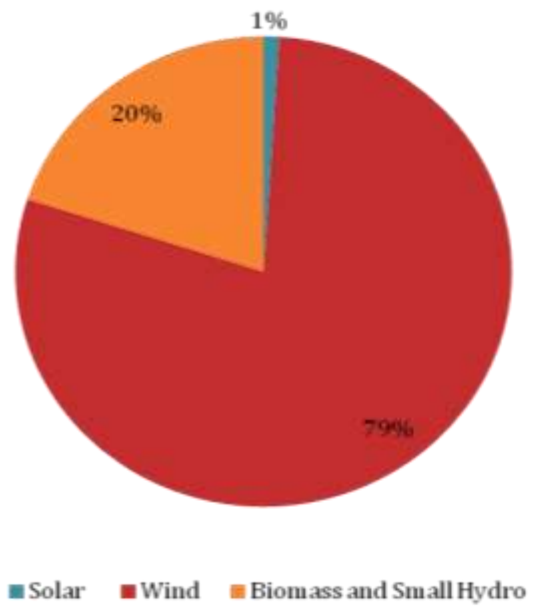

Figure **16:** Renewable Energy Mix of Gujarat May 2014

Source: State Load Dispatch Centre-Gujarat, 2014

Onshore Transmission Infrastructure and Planning

Gujarat Energy Transmission Corporation Limited (GETCO) owns and operates the state transmission network consisting of approximately 47,973 circuit km of transmission lines and 1,350 substations[48].

Table **8:** Transmission Infrastructure in Gujarat

Voltage Class (kV)	No. of substations	Transmission lines in Ckt. km
400	11	3,602
220	83	15,774
132	50	4,938
66/ 33	1,206	23,659
TOTAL	1,350	47,973

Source: GETCO, 2014

The state has committed itself to increasing the share of renewable energy based power generation capacity further. Both Solar and Wind based generation are set to grow rapidly over the next few years. Figure 17 shows the planned RE capacity additions in the State of Gujarat by 2016-17[49].

[46] http://www.cwet.tn.nic.in/html/departments_ewpp.html
[47] CEA. (2014, May). Executive Summary of Power Sector. Retrieved from Central Electricity Authority: http://www.cea.nic.in/reports/monthly/inst_capacity/may14.pdf
[48] GETCO. (2013, March 31). Transmission Network Data. Retrieved from http://getco.co.in/getco_new/pages/tr%20network%20data.php

The Power Grid Corporation (PGCIL) in its 2012 report titled, 'Transmission Plan for Envisaged Renewable Capacity', carried out an analysis of electricity load flow during peak and off-peak periods on the basis of data collected from all the state nodal agencies.

Figure **17**: Planned Capacity Additions For Renewable in the State Of Gujarat

Source: PGCIL, 2012

The analysis showed that there is a constraint in transfer of power from Gujarat to the Northern regional grid. It is noted that the load on the 400 kV Zerda-Kankroli D/C line, a northwest inter-connection is critical for smooth transfer of power from Gujarat to Northern grid of India. To improve grid integration, strengthening of the Western and Northern regions' transmission corridor emanating from Gujarat is important and should be built. The Gujarat Energy Transmission Company (GETCO) published a map in November 2013 that shows the existing and proposed transmission and power infrastructure in the state[50].

[49] PGCIL. (2012). Transmission Plan for envisaged Renewable Capacity, Vol. I.

[50] GETCO. (2014, March 31). Power Map. Retrieved April 17, 2014, from Gujarat Energy Transmission Corporation Ltd.: http://getco.co.in/getco_new/pages/files/maps/POWER%20MAP%20OF%20GUJARAT-%20%2031.03.2014.pdf

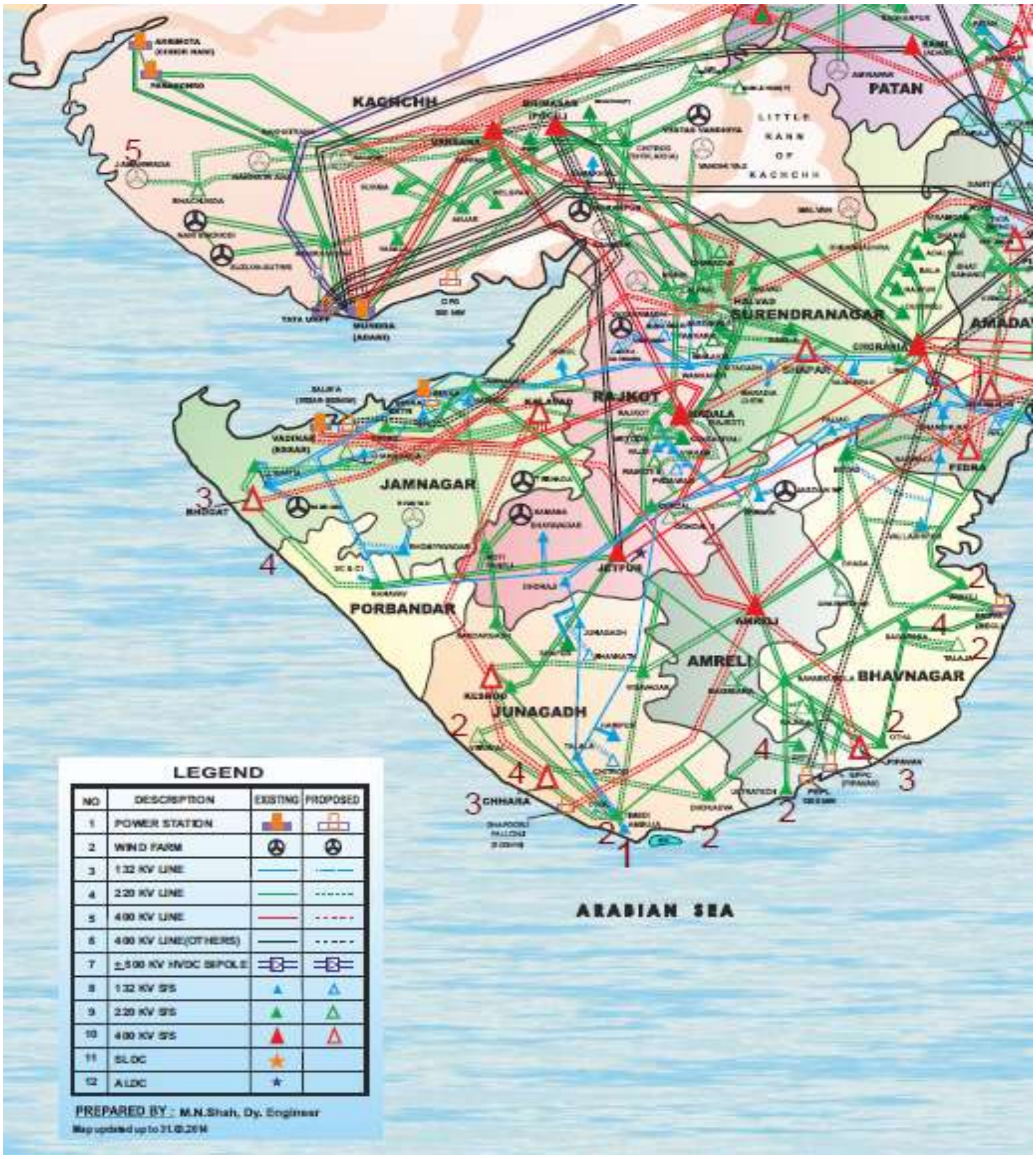

Figure **18**: Power Map of Gujarat

Source: GETCO, 2014

On analyzing the map (Figure 18) the following observations can be made:

- There is an existing 132 kV substation in the Junagadh district. The substation is located in Ambuja, close to the coast (<15 km).
- There are five existing 220 kV substations near the coast in the districts of Junagadh, Amreli and Bhavnagar. The existing substations are in Timbdi, Dhokadva, Ultratech, Otha and Vartej spread along the coastline of the 3 districts mentioned above. New substations of 220 kV are proposed in Veraval and Talaja that are in the districts of Junagadh and Bhavnagar respectively.
- 400 kV substations are proposed in the districts of Jamnagar, Junagadha and Amreli. The locations of the proposed substations are Bhogat, Chhara and Pipavav respectively.
- A 220 kV line is proposed along the coastline in the districts of Jamnagar, Junagadh, Amreli and Bhavnagar.
- There is a proposed onshore wind farm in Jamanwada in the district of Kachchh that would feed power to a proposed 220 kV substation in Bachunda in the district of Kachchh.

Most of the existing and proposed substations and transmission lines along the coastline have the rated transmission capacity of 220 kV or 400 kV with an exception of Ambuja substation, which has a rated capacity of 132 kV. The proposed transmission infrastructure could be utilized for transmission of power from offshore wind farms in the future. In comparison to other states accessing grid interconnection points would be possible across several locations along the Gujarat coast.

3.1.3.5 State of Tamil Nadu

State Grid Generation Capacity

The overall installed power generation capacity of Tamil Nadu as of February 2014 was 21,063.39 MW[51]. Table 9 shows the technology and ownership-wise breakdown of existing installed capacity.

The major constituent of the overall energy mix is coal; followed by renewables, with an installed base of about 7,946 MW the majority (7,276 MW[52]) of which is from wind.

Table **9:** Installed Generation Capacity (MW) In Tamil Nadu by Fuel (February 2014)

Ownership / Sector	Thermal			Total Thermal	Nuclear	Hydro	Renewable	Grid Total
	Coal	Gas	Diesel					
Total	8,973	1,026	412	10,411	524	2,182	7,946	21,063

Source: CEA, 2014

Power Demand Projections for Tamil Nadu

Tamil Nadu is struggling to fulfil electricity demands. The electricity demand in the state has steadily increased but the capacity of the generating facilities has not kept pace with growing demand. According to the policy note of the Tamil Nadu Electricity Board (TNEB), for financial year FY2013-14, the shortfall during peak hours was around 5,100 MW[53] and gross power availability was 9,871 MW. The state has been facing a massive power deficit of around 34% as of March 2014[54]. State-owned generation stations could only contribute 73,323 MU of power against a requirement of 99,765 MU as shown in Table 10. The state relies heavily on independent producers (IPPs) and purchases power through power exchanges on a daily basis. To avoid a decline in overall growth it is imperative for the power sector to grow in proportion to the industrial sector needs.

Table **10:** Power Shortfall in Tamil Nadu

Month	Peak Energy			
	Demand (MW)	Availability (MW)	Deficit (-) (MW)	(%)
Jan-14	13,074	9,052	-4,022	-31
Feb-14	14,069	9,616	-4,453	-32
Mar-14	14,970	9,871	-5,099	-34
Annual	14,970	9,871	-5,099	-34

[51] CEA. (2014, March). Executive Summary of Power Sector. Retrieved from Central Electricity Authority: http://www.cea.nic.in/reports/monthly/inst_capacity/mar14.pdf
[52] Indian Wind Turbine Manfacturers Association (May 2014) State Wise Installed Wind Capacity, Available online: Last Accessed on http://indianwindpower.com/news_views.html#tab1
[53] TN Energy Department. (2013). Policy Note of TN Energy Department 2013 - 14.
[54] CEA: Load Generation Balance Report 2013-2014

Month	Energy			
	Requirement (MU)	Availability (MU)	Deficit (-) (MU)	(%)
Jan-14	7,879	6,117	-1,762	-22
Feb-14	8,374	5,639	-2,735	-33
Mar-14	9,133	6,170	-2,963	-32
Annual	99,765	73,323	-26,442	-26

Source: CEA, Load Generation Balance Report 2013-2014

Several measures such as load curtailment and demand side management are taken by the state utility to address the present shortfall.

In terms of future energy requirements, the 18th Electric Power Survey suggests an increase in annual energy requirement from 80.69 billion units[55] (BU) presently to 110.25 BU by 2016-17 and 154.59 BU by 2021-22. The subsequent increase in peak load is expected to be 18,994 MW by 2016-17 and 26,330 MW by 2021-22 projected from the 2011-12-demand level of 11,971 MW[56].

Figure 19 shows the growth witnessed in the electricity sector in Tamil Nadu. In the future, if proper scheduling mandates are in place wind power can help mitigate the power deficit.

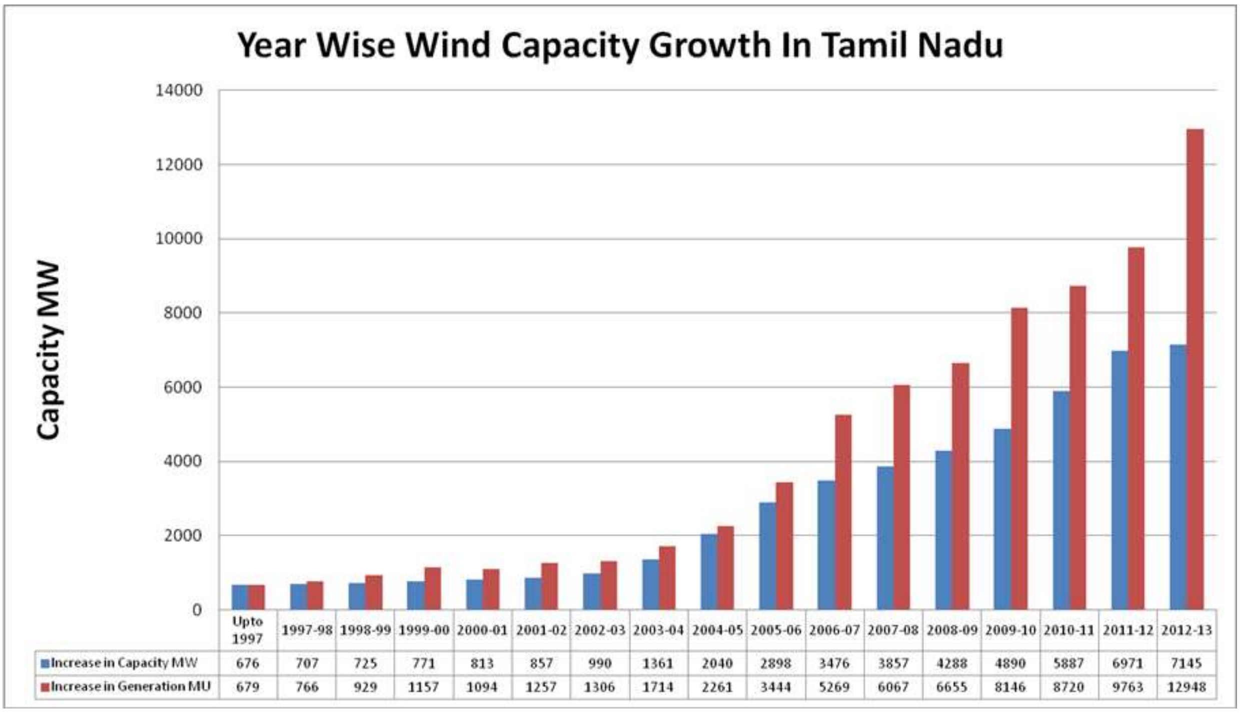

Figure **19**: Growth in Renewable Energy Capacity and Generation in Tamil Nadu

Source: Tamil Nadu Energy Secretary Presentation, 2014

Existing Renewable Energy Capacity in Tamil Nadu

Table 11[57] illustrates the forecasted RE development in Tamil Nadu by the end of 12th Plan period. Tamil Nadu has planned to install more onshore wind power in the near future because, unlike other non-conventional energy options, the wind sector has matured faster and delivered projects with higher capacity.

[55] *1unit = 1 Kwh*

[56] Shakti Foundation- Action Plan for Comprehensive Renewable Energy Development in Tamil Nadu: 2012 report

[57] Government of Tamil Nadu (2012), 12th Five Year Plan, State Planning Commission, Chennai

Table **11**: RE Capacity Addition in 12th Plan (2012 – 2017) in Tamil Nadu

Existing Capacity (MW) as on February 2014		Addition in 12th plan (MW)		Total Capacity (MW)	
Wind	Solar	Wind	Solar	Wind	Solar
7,276	29	6,000	3,000	13,276	3,029

Source: Tamil Nadu Energy Secretary Presentation, 2014

Review of Existing Transmission Capacity Infrastructure

Under the 11th Five Year Plan(2007 – 2012), installations of 1,320 substations of various voltage categories, Extra High Tension (EHT) lines of 24,000 circuit km, High Tension (HT) lines of 156,000 circuit km (ckt. km), LT lines of 567,000 km and 213,000 units of distribution transformers was achieved as on 31.3.2012.

PGCIL has recommended creation of transmission infrastructure in 3 phases in TN for a smooth rollout of the plans.

a) Phase-1: INR 22.5 Billon or EUR 274.3 Million-740 km of 400 kV Transmission line from Southern end of the state to north with 2 new 400 kV substations.

b) Phase-2: INR 15 Billon or EUR 183.7 Million- 445 km of 400 kV Transmission line in south &south-western part of the state with 4 new 400 kV substations.

c) Phase-3: INR 22.5 Billon or EUR 275.5 Million- Network for connecting the generating stations of wind energy with the capacity transmission corridor proposed in Phase- 1 & 2[58]. Table 12 shows future transmission line installation plans.

Table **12**: Transmission and Distribution Works Planned Under the 12th Plan Period

Description	As on March 2012	Expected Addition for Twelfth Plan				
		2012-13	2013-14	2014-15	2015-16	2016-17
LT Lines (in Km)	567,160	14,250	14,600	15,000	15,350	15,750
HT Lines (in ckt km)	155,602	4,725	4,850	5,000	5,150	5,300
Transformers (Nos.)	212,921	9,600	10,025	10,475	10,950	11,450

Source: Government of Tamil Nadu 12th Plan, 2012

Grid integration challenges in Tamil Nadu

Tamil Nadu accounts for over a third of the country's installed wind power capacity. However over the past couple of years wind farms faced severe problems due to curtailment by the grid operator. As an example we highlight two key regions of Tirunelveli and Coimbatore and their power demand-supply constraints below:

- Many of the 220-kV/110 kV lines get severely overloaded during the peak wind time in Tirunelveli area. TANGEDCO is planning to build a dedicated 400 kV substation to ease this load on the existing grid lines in the Tirunelveli area. This includes provisions of Long Term Access (LTA) on existing as well as planned corridors.
- Coimbatore area power demand is fed from power generation from the Kundah and Mettur hydropower stations. During times of low hydropower availability, the grid lines from Mettur to Arasur (Coimbatore) are overloaded; hence minimum generation has to be maintained at

[58] S Akshayakumar (2014), Large Scale Power Evacuation Tamil Nadu Experience; Ministry of New and Renewable Energy, National Wind Energy Mission Meet 01/09/2014, Url :http://mnre.gov.in/file-manager/UserFiles/Presentations-NWM-09012014/S-Akshayakumar.pdf last accessed 13/06/2014

Kundah. Commissioning of 400/230KV substation at Arasur during Januray 2013 has alleviated the problem to some extent. The power demand on Kundah-Thudiyalur-Mandapam section is also high. The supply depends on availability of wind power and hydropower generation.

In a welcome development, the interlinking of the southern grid to the rest of the country via the commissioning of the Raichur-Solapur 765 kilovolt (kV) single-circuit transmission line by PGCIL could help to manage more variable generation[59]. Synchronous integration of the Southern Grid with rest of the national power grid augments the inter-regional power transfer capacity of the Southern region and also relieves the congestion being experienced in some of the regional transmission corridors. The Tamil Nadu state transmission utility needs to augment the state's grid capacity and enforce better grid management standards with a view towards integration of higher percentages of variable generation[60] regionally and nationally.

Conclusion

In summary it is clear that on the supply side India's power grid has systemic, structural and management related challenges, such as:

- Current experiences and risks of curtailment, required grid strengthening and development
- Requirement of improved of the grid/code to balance at national scale
- Variability of the wind resource (seasonal) is an identified risk
- Grid infrastructure development has historically lagged behind RE development due to much longer gestation periods when compared with RE development
- Government has plans to develop electrical infrastructure (driven by RE targets – 15% RE in India by 2020 – NAPCC), but this may not be sufficient to meet the offshore wind sector requirements

On the demand side a modern day energy consumer wants to make smarter energy choices while demanding complete energy access. This demand and supply equation can be effectively solved with introducing flexibility into the grid management code. This would require a number of options to be introduced at an appropriate scale including demand side management, flexible power generation options, energy storage facilities (e.g. pumped hydro), and HV grid interconnections across regions.

3.2 PREPAREDNESS OF OTHER SUPPORTING INFRASTRUCTURE

For offshore wind turbines, the ongoing trends indicate higher capacity and larger rotor diameters due to advantage in yield and project economics. The current average is 4 MW with a trend for future projects moving towards 5-6 MW Class WTGs. 7-8 MW demonstration WTGs are already in existence.

Turbine and towers are major infrastructure cost components for an offshore wind farm accounting for approximately 45-50% of the CAPEX (Capital Expenditure). The staging areas, ports and vessels also form a large part of capital expenditure during project construction stage.

Power evacuation for offshore projects is also expensive compared to onshore wind projects. Electrical systems account for approximately 20% of the CAPEX. In European projects transmission cables have been the single most challenging part of developing offshore wind with 80% of insurance claims related to these.

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[59]http://www.livemint.com/Politics/jIOljqqvinQqqngk7BYLZP/Southern-transmission-line-connected-to-National-Grid.htmlWebsite accessed on 28-06-2014
[60]Power System Operation Corporation Limited (2012). Operational Feedback Report

VESSELS

During the initial development years, the European offshore wind industry adapted vessels from the offshore oil and gas sector and civil marine sectors. However, the need for quick and efficient installation and maintenance of offshore wind turbines has fostered the creation of specialized transport and installation vessels. The following factors currently drive the development of turbine installation and maintenance vessels:[61]

- Wind turbine size: Based on European experience with OW, with increasing size of offshore wind turbines, bigger vessels (e.g. with cranes with much higher under-hook heights) are usually required for installation.
- Water depth: As more and more offshore wind farms are being developed in deeper waters, larger and specialized turbine installation vessels would be needed with longer jack-up legs or advanced floating installation using Dynamic Positioning.
- Distance from shore: Offshore wind farms located far out in sea necessitate longer travel time during the installation and O&M work. This necessitates access to high-quality, trained manpower and larger capacity (cargo) installation vessels for any O&M or installation work.
- Optimization of installation in varying weather condition: Much of the offshore capacity exists in Northern Europe, where offshore wind farm sites witness harsh conditions which limit crane operations in terms of available time for lifting the components safely.

Some of the different types of vessels that are used for installation, commissioning and O&M activities are listed in Table 13.

Table **13**: Example of Types of Vessels Used in Offshore Wind Turbine Installations

Vessel type	Use
Survey Vessel	Survey of sea floor in preparation for setting up an offshore wind farm Smaller survey vessels are used to perform environment impact assessment studies and post-evaluation.
Turbine Installation Vessel	Custom-built self-propelled installation vessels that can carry multiple turbines at a time. Self-propelled jack-up vessel is used for 52 monopole foundation up to a depth of 40 m.
Construction Support Vessel	To assist in the construction of offshore wind parks. Includes motorized and non-motorized jack-up barges, barges, shearleg crane-barges, cargo vessels, leg-stabilizer crane vessels, pontoons and platforms.
Work Boats	Support the work of other vessels by providing supplies of tools and consumables to other boats.
Service Vessel	Used for scheduled maintenance work
Crew Transfer Vessel / Helicopter	Carrying crew for small tasks, quick to build or procure
Cable Laying Vessel	Used for laying of sub-sea cables to connection points onshore and also for cabling within the wind-farm

Source: EWEA, 2011

[61]EWEA. (.2009). Oceans of Opportunity. (European Wind Energy Association) Retrieved fromhttp://www.ewea.org/fileadmin/ewea_documents/documents/publications/reports/Offshore_Report_2009.pdf

PORTS

Offshore projects require access to well-developed ports with appropriate facilities which may not exist and require extensive upgrades. The decision on port infrastructure requirements depends upon what a port is to be used for. It can be utilised as a manufacturing port, a mobilization port for installation or O&M purpose. Manufacturing ports will have more requirements as they involve manufacturing and/or assembly of wind turbines and foundation components. Assembly is usually more expensive offshore, so most of the parts are pre-assembled on ports and shipped to the site. According to the European Wind Energy Association's "Wind in Our Sails" report[62], the quayside should have adequate space to accommodate these vessels. The port should be able to bear thrust of approximately 15–25 tonnes/m^2. The strength of the seabed next to the quay side is also important for loading jack-up vessels. Mobilization ports may be used if the manufacturing port is far away from the offshore wind site.

Various reports have identified criteria for ports that can serve offshore wind projects. However, as the OW technology matures some of these criteria may change. Some of the 1st tier hard criterion is identified and listed below in Table 14[63] [64].

Table **14**: Criteria for port-facilities required for offshore wind projects

▶ A sheltered harbour
▶ Quayside long enough to accommodate necessary vessels simultaneously
▶ Unobstructed overhead clearance in line with your vessel requirements
▶ Parallel berths for unloading and loading and usage of harbour and vessel cranes
▶ Draft of 24 feet (7.5 m) at low tide (minimum)
▶ 1,000- 4,000 tonne crane on the port for components and sub-stations
▶ Area of 25 – 50 hectare or more for storage, assembly, and handling of components. This will be based on your inventory management practices.
▶ 24 × 7 operations
▶ Proximity to the offshore site
▶ Rail and roadways access that can handle large components

The EWEA report[65] further discusses the requirements for Operations and Maintenance (O&M). These requirements are listed below:

- Full-time access for service vessels and helicopters
- Full-time and safe access for technicians and service personnel
- Fresh water, electricity, and fuelling facilities at the port
- Waste disposal facilities
- Loading and unloading facilities and transport equipment

[62] EWEA. (2011). Wind in our sails. Retrieved from European Wind Energy Association: http://www.ewea.org/fileadmin/ewea_documents/documents/publications/reports/23420_Offshore_report_web.pdf

[63] Kinetic Partners. (2011). Analysis of Maryland Port Facilities for Offshore Wind Energy Services. Retrieved from http://energy.maryland.gov/documents/AnalysisofMarylandPortFacilitiesforOffshoreWindEnergyServices.pdf

[64] Tetra tech EC, Inc. (2010).Port and Infrastructure Analysis for Offshore Wind Energy Development. Retrieved from:http://images.masscec.com.s3.amazonaws.com/uploads/attachments/Port%20and%20Infrastructure%20Analysis%20for%20Offshore%20Wind%20Energy%20Development/MA%20Port%20Study%20Final%20Report_4-20-10.pdf

[65] EWEA. (2011). Wind in our sails. Retrieved from European Wind Energy Association: http://www.ewea.org/fileadmin/ewea_documents/documents/publications/reports/23420_Offshore_report_web.pd

INFRASTRUCTURE SCENARIO IN GUJARAT

Gujarat has the longest coastline in India, over 1,600 km and sheltered harbours. The Gujarat Maritime Board (GMB) manages a total of 41[66] minor ports. The state has plans for development of port infrastructure and facilities and has also requested the central government to prepare a coastal policy[67]. Figure 20 shows the ports under management of GMB and also private ports in Gujarat. Two new ports of Mandvi and Dholera are proposed to be built. Mandvi will be operated by GMB whereas Dholera will be privately operated.

The ports in Gujarat have various opportunities and scope of development for different industries like energy, oil and gas, ship building, fisheries, etc. GMB in this regard has planned a development strategy for different ports in Gujarat. These development opportunities are shown in Figure 21.

Figure **20**: Ports in Gujarat

Source: GMB

[66] The major ports are under the direct administration of Ministry of Shipping whereas the minor ports are the under the supervision of State Agencies.

[67] PwC. (2011).Gujarat Ports- A catalyst for India's development. Retrieved from http://www.vibrantgujarat.com/images/pdf/ports-shipbuilding-and-related-activities-seminar-outcomes.pdf

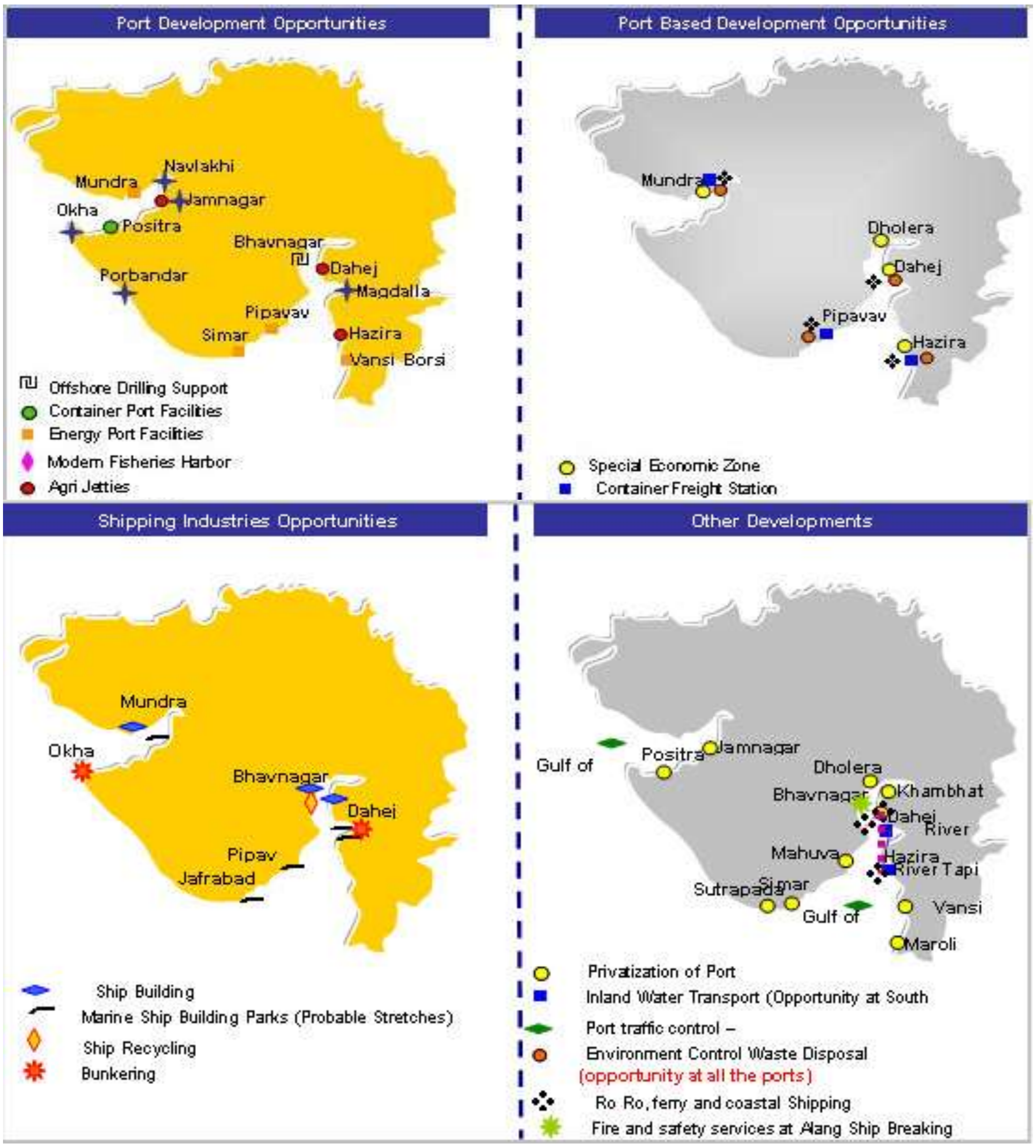


Figure **21**: Emerging Areas and Opportunities in Gujarat Ports

Source: GMB, 2013

GMB promotes and develops Greenfield ports. These projects are taken up under its Port Privatization model. These ports will be developed in close participation of private sector and industry. Till date, GMB has identified 11 sites (including pipeline) for developing Greenfield ports; out of which 4 are operational. (GMB, 2014).

GMB will facilitate direct berthing in all weather conditions. These capital-intensive port projects are being developed under BOOT[68] (Build Own Operate Transfer) policy and will be transferred back to GMB after completion of the 30 years BOOT period (GMB, 2013).

[68]http://www.ripublication.com/ijcer_spl/ijcerv5n2spl_06.pdf

Figure 22 shows the location of the Greenfield sites identified by GMB. Table 15 gives the details of the Greenfield ports of Gujarat that are in pipeline.

Figure **22**: Location of Greenfield Ports
Source: GMB, 2013

Table **15**: Greenfield Ports in Pipeline

Port	Status
Dholera	To be developed with the facility of eight dry cargo jetties, three for liquid products and one container depot. It will be an all weather direct-berthing port. It is expected to have a production capacity of 2 million tones
Positra	Awaiting environment clearance
Maroli	To be developed as container and Bulk cargo terminal port, with the total port capacity of around 10 MMTPA
Chhara	To be developed with 2 berths for solid bulk cargo facility. The total port capacity envisaged is 5.5 MMTPA
Vansi-Borsi	To be developed with the facility of 4 berths for solid and liquid cargo. The port is expected to have a capacity of 14 MMTPA
Mithivirdi	Planned to have a facility of 2 berths for bulk cargo and steel products with envisaged capacity of 5 MMTPA Its location will be decided after finalization of location for a proposed Nuclear Plant
Bedi	A facility of 2 berths for solid cargo with the total capacity of 10 MMTPA has been planned

Source: GMB, 2013

Table **16**: Salient Features of Some Ports Operated by Gujarat Maritime Board

No	Port	Quay length	Draft	Area	Connectivity	Traffic	Capacity (Million Tonnage/ Annum)	Suitability
1	Kandla	Twelve Dry Cargo berths are available with Quay Length of 2532 m. 545 m of quay length for container handling	A draft of up to 33 m at the offshore terminal	Existing dry cargo storage area is approx 120 hectares	The port is well connected to NH8. Excellent connectivity by rail as well	Kandla port handled a total cargo of 87.01 million tonnes in 2013-14	As of march 2014, the total capacity was 102.32 MTPA	Suitable
2	Mundra SEZ	Eight multipurpose berths capable of handling Panamax and Capesize ships, i.e. more than 300 m in length and 33 m in width	Deep water draft of 17.5 m	Port has 8, 00,000 sq m of well demarcated open storage space.	Good connectivity by rail, road, and air	Mundra port handled a total cargo of 96.2 million tonnes during 2013-14.	75.44 as of 2012	Suitable
3	Jafrabad	Minimum length of 45m to maximum of 450 m available	permissible draft - 4 m	25.88 hectares	Port is well connected with (SH-34) Broad gauge rail link is 22 km away at Rajula (NH-8E) is 20 km away Nearest urban centre Rajula is about 21 km away Nearest airport is Diu i.e. about 75 km away	3.5 MMTA (million metric ton per annum)	4.53 as of 2012	Needs expansion of quay length and storage area
4	Okha	Two quays 180 m and 145 m long and 20 m and 14 m wide	8 m and 4 m	50,000 m^2 stacking area (storage area)	State Highway: directly connected National Highway: 28 km Rail: Broad gauge rail link	-	4.96 as of 2012	Needs expansion of quay length
5	Pipavav	Total of 735 m for container cargo and 1,075 m for bulk cargo	14.5 m	Total Storage area of 15.5 hectare	Rail: Broad gauge rail link	handled total cargo of 9.07 million tonnes during the year 2013-14	23.41 as of 2012	Needs expansion of storage area
6	Porbandar	For steamers = 385 m For lightering =	Up to 9.8 m	2,41,173 m^2 for storage in	State Highway: 3 km National	-	5.26 as of 2012	Needs expansion of storage area

No	Port	Quay length	Draft	Area	Connectivity	Traffic	Capacity (Million Tonnage/ Annum)	Suitability
		2,128 m		warehouses	Highway: 2 km Rail: Broad gauge rail link			
7	Sikka	For crude vessels = 345 m and for other products vessels = 300 m	Max permissible of 22.5 m	-	Good connectivity by rail and road	Sikka Port handled cargo tonnage of 124.52 million tonnes in 2012-13	109.57 as of 2012	Storage area not available
8	Veraval	Five berthing quays of 500 m	Up to 9.44 m	-	State Highway: 2 km National Highway: 1 km Airport: 51 km	2 MMTA (million metric ton per annum)	2.17 as of 2012	Storage area not available
9	Hazira	Southern spur can provide a quay length of about 1000 – 1700 m for containers and about 600 m for bulk / break-bulk cargoes.	Draft = 12 m	1.2 million TEU[69] cargo space	National Highway: NH6 and NH8 Rail: Dedicated rail corridor proosed Near major cities: Surat (25 km), Mumbai (250 km)	During the year 2013-14, the port handled about 2.84 million tonnes of LNG. Phase 1B of the port handled about 3.58million tonnes of cargo during the year 2013-14.	-	Suitable

Source: GMB, 2013

Based on the preliminary data available in public domain, the ports in Gujarat can be evaluated against the 1st tier hard criterion[70] (see Table 14) to see if any of them would be adequate for OW project development activities. Currently the ports of Kandla, Mundra and Hazira in Gujarat fulfil the basic key criteria mentioned in Table 14. However, detailed analysis has to be carried out based on specific offshore wind development plans in the future.

The state government in conjunction with the Centre could provide incentives to strengthen port and manufacturing facilities for offshore wind turbines and components in India. This could provide an opportunity for the development of a national manufacturing facility at one of the proposed ports in the State.

INFRASTRUCTURE SCENARIO IN TAMIL NADU

Tamil Nadu has 7 government ports out of which only 3 are currently operational. The salient features of these ports are summarized in the Table 17. Government ports are ports notified and developed by the state government as a multi-user and multi-purpose port. In addition, Tamil Nadu has 17 captive ports developed by private companies[71]. However, these captive ports are designed for specific activities and for handling particular cargo as per the requirements of the

[69] TEU: Twenty-foot equivalent unit is an inexact unit used to describe cargo capacity. 1 TEU ≈ 6.1 m X 2.44 m (length x breadth)

[70] *Tetra tech EC, Inc (2010): Port and Infrastructure Analysis for Offshore Wind Energy Development, Available at* :http://images.masscec.com.s3.amazonaws.com/uploads/attachments/Port%20and%20Infrastructure%20Analysis%20for%20Offshore%20Wind%20Energy%20Development/MA%20Port%20Study%20Final%20Report_4-20-10.pdf

[71] TNMB (2013), Government Ports. (Tamil Nadu Maritime Board) Retrieved from Tamil Nadu Maritime Board.

company/industry developing it. These ports operate on Build, Own and Operate (BOO) system. Table 18 gives details of the seventeen captive ports in Tamil Nadu.

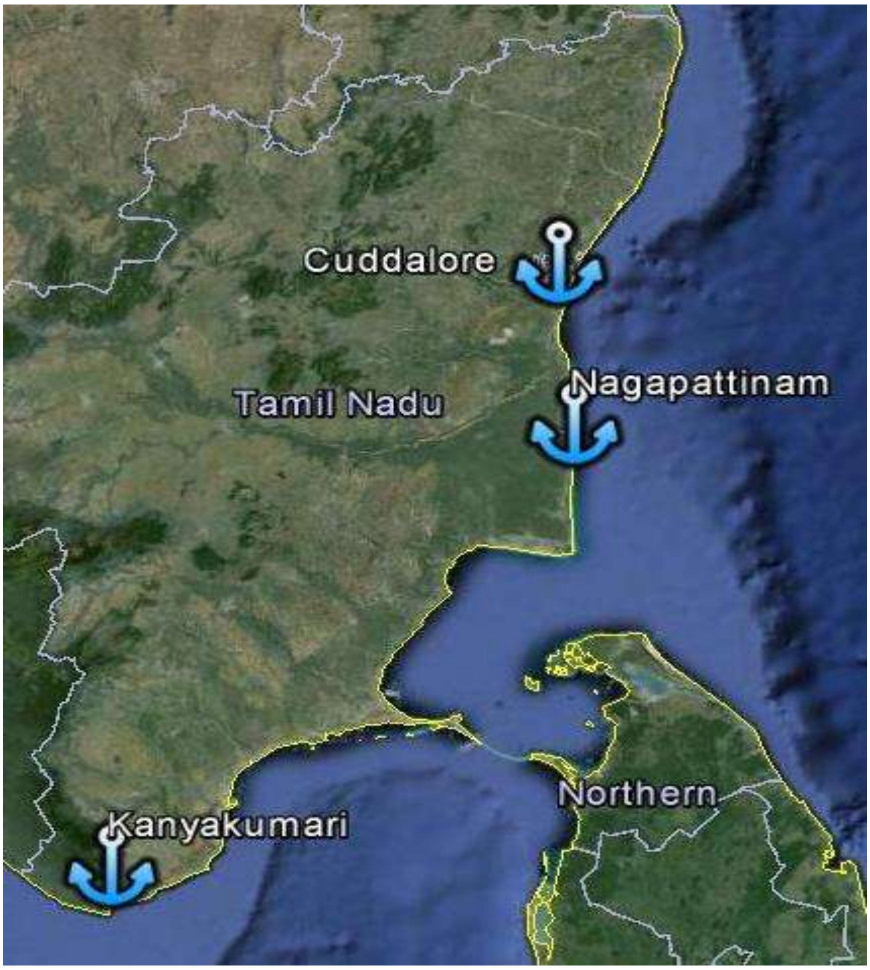


Figure **23**: Government Ports in Tamil Nadu
Source: TNMB, 2014

Based on evaluation criteria and preliminary data available in the public domain, it can be concluded that the Cuddalore port meets the basic criteria mentioned in Table 14. Overall, it can be said that infrastructure in Tamil Nadu is not adequate for facilitating offshore wind project development activities[72].

[72]Tetra tech EC, Inc. (2010).Port and Infrastructure Analysis for Offshore Wind Energy Development. Retrieved From:http://images.masscec.com.s3.amazonaws.com/uploads/attachments/Port%20and%20Infrastructure%20Analysis%20for%20Offshore%20Wind%20Energy%20Development/MA%20Port%20Study%20Final%20Report_4-20-10.pdf

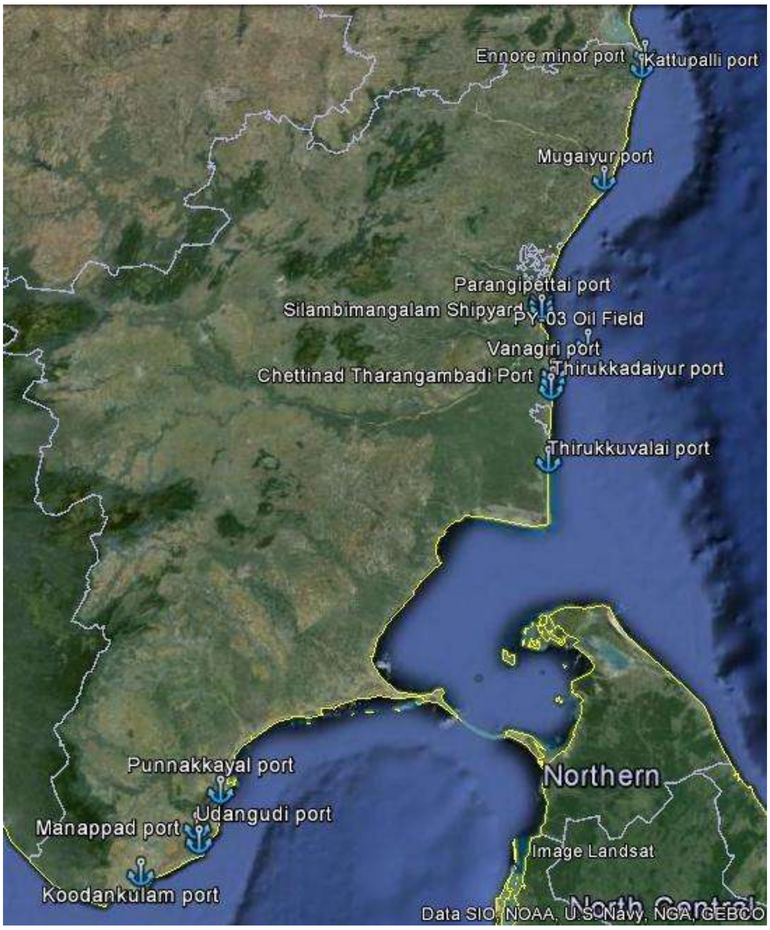


Figure **24**: Captive Ports in Tamil Nadu

Source: TNMB, 2014

Tamil Nadu in cooperation with the Central government agencies could look towards providing comprehensive incentive schemes for developing a national manufacturing facility at a suitable location alongside the proposed ports in the State. This could be done in collaboration with the private sector or as part of Tamil Nadu's industrial development plans for the future. In comparison, there is more information available in relation to the ports for the State of Gujarat.

Table **17**: Salient Features of Operational Government Ports in Tamil Nadu

S. No.	Port	Quay length	Draft	Area	Connectivity	Miscellaneous
1	Cuddalore	1132.4 m	8 – 10 m	Open stacking area of 63 acres suitable for handling general and bulk cargo	National Highway: 1 km Rail: Broad gauge rail link is 1.5 km away	Ready to handle all types of cargo. Proposed to develop on Public Private Partnership (PPP) mode
2	Nagapattinam	NA	8 – 10 m at a distance of 1.5 mile from lighthouse	NA	NA	It is an open roadstead port (It is protected from rip currents, spring tides or ocean swells)
3	Kanyakumari	NA	NA	NA	NA	Infrastructure available for passenger

S. No.	Port	Quay length	Draft	Area	Connectivity	Miscellaneous
						embarking/ disembarking to and from the tourist ferry

Source: Tamil Nadu Maritime Board, 2013

Table **18**: Salient Features of Captive Ports in Tamil Nadu

S. No.	Port	Quay length	Draft	Area	Connectivity	Miscellaneous
1	Kattupalli	2,200 m (approx)	15 m	Extent of local coastal land - 76.86 acres	NA	Proposed quantity of cargo handle – 1.5 MMTPA
2	Ennore minor port	510 m (approx)	NA	Extent of coastal land leased – 3.04 acres	NA	Cargo handled – Liquid Ammonia Approximately 50,000 MTs per annum
3	Mugaiyur	2100 m	NA	Extent of Coastal Land Leased – 150.26 m^2	NA	Expected by 2014-15 Ship repair facility 1 dry dock for maximum ship size up to Cape size vessel 1 Dry dock for Offshore rigs
4	Cheyyur	NA	NA	NA	NA	Not readily available for operation
5	Marakkanam	NA	NA	NA	NA	Technical Feasibility Report under process
6	Thiruchopuram	NA	NA	Extent of coastal land leased – 42.28 acres	NA	Expected quantity – 10 MMTPA
7	Silambimangalam Shipyard	NA	NA	NA	NA	All relevant agreements have been cancelled/ withdrawn by TNMB.
8	Parangipettai	1.4 km	NA	Extent of coastal land leased – 117 acres	NA	Expected operation – 2014-15 Quantity of cargo handled – 16 MMTPA coal
9	PY-03 Oil field	NA	NA	NA	NA	Offshore port Cargo handled – 250,000 metric tonnes per annum
10	Kaveri	NA	NA	NA	NA	Expected by 2014-15 Expected cargo- 3.5 to 4 million metric tonnes per

S. No.	Port	Quay length	Draft	Area	Connectivity	Miscellaneous
						annum of coal
11	Vanagiri	NA	NA	NA	NA	Expected by 2014-15 Expected cargo- 4.5 million metric tons per annum
12	Thirukkadaiyur	NA	NA	Extent of coastal land leased – 13,980 m^2	NA	Cargo- 4.5 million metric tons per annum of Naptha
13	Thirukkuvalai	NA	NA	Extent of coastal land leased – 1, 11,689 m^2	NA	Offshore coal handling facility Expected by 2014-15 Expected cargo- 8 million metric tonnes per annum
14	Punnakayal	NA	NA	NA	NA	Not readily available
15	Udangudi	NA	NA	NA	NA	Not readily available
16	Manappad	NA	NA	NA	NA	Not available for operation
17	Koodunkulam	NA	NA	Extent of coastal land-only waterfront of 1000 m allotted	NA	Ro-Ro jetty

Source: Tamil Nadu Maritime Board, 2013

3.3 BARRIERS FOR OFFSHORE WIND

One of the tasks under FOWIND is to identify and assess the barriers that may pose an obstacle for offshore wind development in India and learn from European experience to overcome them.

Development of offshore wind is complex in comparison to development of onshore wind farms and hence it is expected that challenges and hurdles are more complex for offshore wind power. Barriers and challenges are distributed across almost all aspects, from initial planning to operation & maintenance to supporting infrastructure to supply chain issues. In order to optimally harness the offshore wind potential, challenges should be fully understood and addressed in a timely manner.

It is expected that the barriers faced by the offshore wind stakeholders in India over the next few years will likely be similar to established European offshore markets in their early days of project development. However, in addition India will also present some of its own local challenges such as tropical cyclones, high seasonal wind speed variation, and seismic activities in some of the regions and requirements for new supporting infrastructure.

The barriers can be categorized as: a) Wind characterization barriers; b) Policy and regulatory barriers; c) Supply chain barriers; d) Financial barriers and e) Infrastructure and human resource barriers. These barriers are explained in detail below:

Table **19**: Barriers to Offshore Wind Development in India

Category	Barriers
Wind Characterization and other preliminary	▪ As a first step, verification of the meso-scale data is required. ▪ Pre-development assessments including installation of an offshore met mast are costly.

Category	Barriers
assessments	Costs of seabed assessment, bathymetric studies and environmental impact assessment (EIA) add to the overall project costs. ▪ Availability of reference data is another bottleneck in India, especially long-term data. In addition, sea depth, sea surface roughness and atmospheric stability data are also required which is not freely available for India. ▪ Constraints such as cables/pipelines, ship wrecks, unexploded ordinance, fishing channels, shipping channels and marine mammal movements are needed to be mapped thoroughly to understand the restrictions which may arise during the development of offshore wind farms.
Policy & Regulations	▪ Even though an offshore policy and regulatory framework is in the pipeline (Central Government has come out with a draft National Offshore Wind Policy), a concrete framework is yet to be established. ▪ For Marine National Park and Sanctuary Zones, although permission to build around these zones is possible within the frameworks provided by the Ministry of Environment and Forests, local public opinion and CSOs may play a significant role for successful implementation of offshore wind power in India in the long run. Local fishing communities will have to be made aware of offshore wind as a technology and its benefits towards growth in India.
Supply Chain	▪ Offshore wind turbines are different in design and size in comparison with onshore wind turbines. It will pose a great challenge to fabricate offshore wind turbines in existing manufacturing facilities that are designed for onshore wind turbines. Therefore, dependence on imports would be high initially. Over time as the market develops there might be local manufacturing. ▪ Ensuring timely supply of subsea cables and installation vessel including trained technicians may pose a challenge for timely offshore project implementation. There are limited suppliers for high voltage (HV) subsea cables due to high investment costs. ▪ Like onshore wind in India, offshore wind could also face challenges related to supply of raw material. The supply of materials and sub components will be an important barrier for offshore wind sector manufacturing plans. These could include timely and cost effective availability of: • Large casting and forging ability for bearings, shafts, gearing systems and foundations in addition to jacket notes, transition pieces, and large tripod connections • High powered semiconductors for control and power conditioning • High modulus carbon fibre for wind turbine blades • Copper for cables, transformers, generators • Availability of high grade steels with sufficient fracture toughness to withstand the large fatigue loads ▪ Accounting for the large size of offshore turbines, lack of large forging and casting facilities in India will prove a major challenge from the supply chain perspective. This would in reliance on imports till such time as a long-term steady offshore projects pipeline is envisaged in the country, encouraging the Industry to invest in local production facilities. . ▪ There are no turbine installation vessels and installation equipment e.g. large enough diameter hammers for driving monopiles, pile lifting tools, reverse circulation drills in

Category	Barriers
	India. Also, the vessels suitable for offshore oil platform installation may not necessarily be suitable for offshore wind farm development, but can be retrofitted to a degree depending on the activity. ▪ Lack of experience with building offshore wind turbine substructures/ foundations/ substation will need to be addressed
Finance, Infrastructure and Human Resources	▪ Higher capital and operational expenditure is a barrier to offshore wind development. Further, cost uncertainty and upward cost pressure may be introduced because of INR/Euro exchange rates. Also because of the high cost and the long lead-time associated with offshore projects, investors may need to be motivated to invest in offshore wind development. Additionally, prevailing high interest rates scenario in India may prove a hurdle for project developers. ▪ Major ports existing in India today are inadequate for development of offshore wind projects. ▪ Special training has to be provided to the personnel working at such ports. ▪ Grid evacuation problems are being faced in India for onshore wind and they will be experienced on a larger scale for offshore wind as well. ▪ If the State Utilities are made responsible for providing the grid infrastructure for offshore wind farms, it may add to the risk for developers since investments in grid infrastructure take time and the SEBs could be in financial difficulties. ▪ Space requirements for turbine components, foundations, electrical infrastructure and vessels are some of the most important parameters to be considered while developing dedicated ports for offshore wind industry. Existing rail and road accesses to the ports need to be assessed prior to offshore developments. ▪ Operation and maintenance of offshore wind turbines is more challenging than onshore turbines given the limitation in access due to rougher weather conditions. ▪ International expertise will be required for training and development of personnel working for design, installation and operation & maintenance of offshore wind projects in India.

Source: WISE, 2014

3.4 STAKEHOLDERS FOR OFFSHORE WIND SECTOR IN INDIA

India has a long coastline of 7,500 km and an Exclusive Economic Zone (EEZ) of total area of 2.02 million km^2 spread across the Arabian Sea, Bay of Bengal and the Indian Ocean. It is essential to interpret the use of specific sea zones for different purposes and study the impact of offshore wind farm on those activities.

The coastal and marine zone is utilized for multiple economic activities such as fisheries, oil and gas exploration, shipping, seabed mining, gas pipeline, telecommunication cable, tourism and archaeological exploration. In addition, coastal and marine zones are natural habitat areas for sea life and ecosystems.

Movement of large vessels and ships need secure routes. A significant part of Indian EEZ is utilized for oil and gas exploration activities. Seabed is also utilized for laying telecommunication cables and gas and oil pipelines. In order to provide protection and maintenance, a suitable area on both sides of cables and pipes is defined as exclusion zones.

In addition, installation activities such as turbine installation or cable lying could temporarily impact the habitat of fishes in those zones and could be a reason for conflict between fishing communities and project developers. Although, studies have indicated a long-term benefit with WTG foundations acting as artificial reefs with resultant increase in fish populations from the new food supply[73]. Protected areas or ecologically sensitive areas like the Gulf of Mannar Biosphere Reserve in Tamil Nadu alongside potential offshore zones are no-go areas for any economic activity.

For safe and reliable construction and operation of offshore wind projects, a safe distance needs to be maintained.

Finally, it is also essential to identify those areas that are reserved for military and scientific use, satellite launch pads, firing range, submarine exercises since these will be no-go area for any offshore wind project activity.

Considering the interest of various stakeholders for different resources, it is essential to consult and operate in close cooperation with all of them as far as possible. Stakeholder analysis can be done through agencies/ authorities - central, state and district level bodies, as discussed in this section.

Research and information agencies can also play a vital role in this process. List of expected stakeholders and their expected role in offshore wind power is mentioned in the Table 20, Table 21, Table 22, and Table 23 in the following pages.

Table **20**: Stakeholders for Offshore Wind Sector at the Central Level

Stakeholders	Expected Role
Ministry of New &Renewable Energy	MNRE will be the nodal ministry for the development of offshore wind power in India. It will be monitoring the development, coordinating with other ministries, issue guidelines/directives and provide necessary support to NOWA.
National Offshore Wind Energy Agency (NOWA)	NOWA would be the nodal agency for all clearances for development of offshore wind power in India. The preliminary resource assessment and impact assessment will be conducted by NOWA. It will be the contracting authority for sea-bed lease and issue commencement certificate for offshore wind project
Offshore Wind Energy Steering Committee (OWESC)	The OWESC has been constituted in the year 2013 under the chairmanship of secretary of Ministry of New & Renewable Energy with the members comprising of the stakeholder departments / organizations / ministries. It will provide policy guidelines and will see execution and effective implementation of specific offshore wind activities.
Ministry of Environment & Forest (MoEF)	MoEF is the nodal agency for the India's environmental and forestry policies and program. It is also nodal agency for UNEP, SACEP and ICIMOD in India. The role of MoEF will be to provide clearances for environmental impact assessment and coastal zone regulations.
Ministry of Finance (MoF)	MoF would allocate the finance for offshore wind power development in budgets and brings amendment in case of tax exemption\ and other financial incentives.
Ministry of Civil Aviation (Director General of Civil Aviation)	Ministry of Civil Aviation is nodal ministry for civil aviation. It will issue clearances related to air traffic route and air safety.
Ministry of Petroleum and Natural	MoPNG provide clearances for utilization of seabed outside the oil and gas

[73]Ref http://www.oceanenergycouncil.com/ocean-energy/offshore-wind-energy/

Stakeholders	Expected Role
Gas (MoPNG)(Directorate General of Hydrocarbons)	exploration zone and pipeline route. The experience of Ministry of implementation of projects in offshore exploration can be utilized for offshore wind power development.
Ministry of Shipping (MoS)	MoS provide clearances to operate outside the international and national sea route, utilisation of national port, and permission for utilisation of vessels and ships for the offshore wind power projects.
Ministry of Defense (MoD) (Indian Coast Guard and Naval Department)	MoD provides security clearances for projects. Naval Department under MoD holds the right to offshore area data utilization for bathymetry, geophysical and geotechnical. The function of Indian Coast Guard is to ensure safety and protection of the artificial islands, offshore installations and other structure in Indian maritime zones.
Ministry of Home Affairs (MoHA)	MoHA would provide security clearances, permission to utilization of seabed, permission to installation of offshore wind farm
Ministry of Communication & Information Technologies (Department of Telecommunication)	DoT provide clearances for utilization of seabed outside the seabed telecommunication cable route
Ministry of Mines (MoM)	MoM provide clearances for utilization of sea bed outside area of possible seabed mining
Ministry of Earth Science	Ministry of earth science will deal with science and technology for exploration and exploitation of ocean resources and play a nodal role in Western and Southern ocean research.
Ministry of Agriculture (Department of Animal Husbandry, Dairying & Fisheries	MoA would assess the impact of offshore wind on fisheries zone and issue no impact clearance to specific projects through NOWA
Ministry of Tourism (MoT)	MoT is a nodal agency for formulation of national policies and programs and inter-ministerial co-ordination among central agencies, state agencies and private sector for the development of tourism
Central Electricity Regulatory Commission (CERC)	CERC would issue guidelines and policies related to offshore wind such as, but not limited to, tendering mechanism, power procurement, tariff determination, transmission, open access, power market etc.
Central Electricity Authority (CEA)	CEA would specify the technical standard for electrical lines and grid connectivity, safety standard for construction, operation and maintenance of electrical lines.
Center for Wind Energy Technology (CWET)	C-WET as specified in Draft offshore wind power policy -2013 will be responsible for testing and certification of wind turbine based on international standard, research and development and wind resource assessment.
Power Grid Corporation (PGCIL)	PGCIL would determine the availability of transmission facilities and would plan and coordinate all functions related to interstate transmission systems and will manage the offshore substations

Table **21**: Stakeholders for Offshore Wind at the State Level

Stakeholders	**Expected Role**
State Government	State Govt. would provide clearance for working in coastal economic zone
State Electricity Regulatory Commission (SERC)	SERC would determine tariff, approve tendering documents, validate power purchase agreement, regulate electricity purchase, decide renewable purchases obligation, facilitate intrastate transmission and wheeling, specify grid code at the state level
State Maritime Board (SMB)	SMB would provide permission for utilization and development of minor port, and related infrastructure for offshore wind development
Department of Tourism (DoT)	DoT is involved in policy formulation, infrastructure development and protection of tourist places in state
State Transmission Utility (STU)	STU would provide permission to utilize the onshore state transmission line, provide infrastructure support for onshore grid connectivity, operation and maintenance of grid
Department of Environment & Forest	DoEF would provide clearances related environmental impact for activities on the coastal areas
State Fisheries Department (SFD)	Fisheries department issue clearances on no impact on fisheries zone due to offshore wind project after impact assessment process
Power Distribution Company (DISCOM)	Distribution utilities would sign the power purchase agreement, provide infrastructure for local distribution

Table **22**: Stakeholders at District, Taluk and Village Level for Planning Stages Including Civil Society Organisation

Stakeholders	**Expected Role**
District Collector office (DC)	DC office will issue land use permits and conduct public hearing for environmental impact assessment
Gram Panchayat (Local Self-governing Body)	Gram Panchayat will provide clearances for the use of land in the coastal areas. Also it can be involved to create awareness and engage in discussions with villagers through gram sabhas.
Civil Society	Civil society representatives would participate in public hearings and express their concerns on impact of offshore wind on employment, environment and health on local population. Civil societies may includes NGOs, environment and nature protection groups, local industrial bodies, local tourism committees, trade unions, etc.

Table **23**: Stakeholders for Offshore Wind within the R&D Community

Stakeholders	**Expected Role**
Center for Wind Energy Technology	C-WET as specified in Draft offshore wind power policy -2013 will be responsible for standard and certification of wind turbine, research and development, Wind resource development.
INCOIS	INCOIS is an autonomous body under Ministry of Earth Science. It will provide information for potential fishing zone, marine meteorological advisory and weather forecasts etc
National Institute of	NIOT is autonomous body under Ministry of Earth Science (MoES). The major aim of NIOT is to

Stakeholders	Expected Role
Ocean Technology (NIOT)	develop reliable indigenous technology to solve the various engineering problems associated with resources in the Indian Exclusive Economic Zone (EEZ).
National Institute of Oceanography (NIO)	NIO is one of the constituent laboratories of the Council of Scientific & Industrial Research (CSIR). It conducts research and studies on observing and understanding the special oceanographic features of the North Indian Ocean. These studies include oceanographic data collection, environmental impact assessment and modelling to predict environmental impact. The institute also provides consultancy on a number of issues including marine environmental protection and coastal zone regulations.

In summary, there are a very large number of stakeholders other than the wind industry stakeholders that would have to be consulted before OW projects could be executed in the Indian EEZ. The task of individually addressing each one of them in the process of developing a project plan would be herculean for any developer.

One possible way to address this issue would be for the Government to allow for time-bound single window clearance for an offshore wind project. Another useful tool could be to conduct relevant stakeholder outreach either prior to or concurrently with OW zones identification and notification by the government.

FOWIND can help raise awareness about offshore wind technology, its benefits amongst local communities, and CSOs during its implementation phase. FOWIND will also reach out to relevant stakeholders at the centre and the state level to help bridge any knowledge gap about this large-scale variable generation offshore wind technology and its benefits for India’s energy needs and low carbon development plans.

4

© FOWIND

4 Role of Offshore Wind in facilitating Low Carbon Development

4. Role of Offshore Wind in Facilitating Low Carbon Development

The IPCC's Fifth Assessment Report[74] concluded with a high degree of confidence that human-induced changes to the climate system are happening. Concerns regarding climate change will play a big role in how developing countries – including India - will procure their energy services in the future. According to IEA estimates, India will overtake China sometime in the next decade to become the biggest contributor for net increase in global energy demand[75]. Greenhouse gas (GHG) emissions resulting from provision of energy services is a significant contributor to atmospheric GHG concentrations, with the electricity sector being the highest contributor in India, according to the 2007 Ministry of Environment & Forest (MoEF) estimate[76].

India's current power generation is heavily dependent on fossil fuels - about 65% of its generation capacity is from coal. India is also expected to have about one fifth of the world's population by 2020[77]. India currently accounts for only about 6% of global emissions[78].This is partly explained by the fact that more than 300 million people still lack access to reliable and modern energy options; and about one third of the world's poor live in India.

Energy-related emissions will go up due to increased energy consumption necessitated by the rise in living standards of Indian citizens. India still faces severe power deficits and frequent power outages are cited as a major barrier for industrial and economic growth. Since reliable energy access is a key input factor for sustaining growth and development of a society today, it is imperative that India increases its electricity generation capacity to keep pace with growing demand. The IEA estimates that India will need to add between 600-700 GW of electricity capacity by 2035 to meet its growing energy demand. However the actual path and investments for building India's electricity infrastructure will have a huge impact on global climate change mitigation efforts.

Although the rate of decarbonisation and how it will be done is still a matter of international negotiation, there is growing recognition among Indian policymakers that India needs to transition into a lower carbon pathway for its sustainable development. This is reflected in the Prime Minister's National Action Plan on Climate Change (NAPCC) released in 2008. NAPCC has eight missions that outline a strategy for India to adapt to climate change and to enhance the ecological sustainability of India's development path. NAPCC has also set a target that renewable energy sources will contribute 15% of the total energy purchased from the national grid by 2020.Renewables contribute over 5% of India's power generation and about 13% of the total installed capacity in the country.

India is already committed to decreasing carbon intensity per unit of GDP. This effort is expected to continue supported by policies that encourage energy efficiency in several energy intensive sectors as well as ambitious plans to support renewable energy. Renewable capacity in the country has grown rapidly in the past decade - from 3,400 MW in 2002 to 30,000 MW by early 2014 as shown in Figure 25 below. In the 12th five-year plan, India is set to add 30 GW of renewables, out of which 15 GW is expected to be from wind.

[74] http://www.ipcc.ch/report/ar5/
[75] International Energy Agency (2013), World Energy Outlook, IEA
[76] About 38% of India's 2007 GHG emission came from the electricity sector.
[77] World Bank (2013), population projections
[78] World Bank (2013), population projections

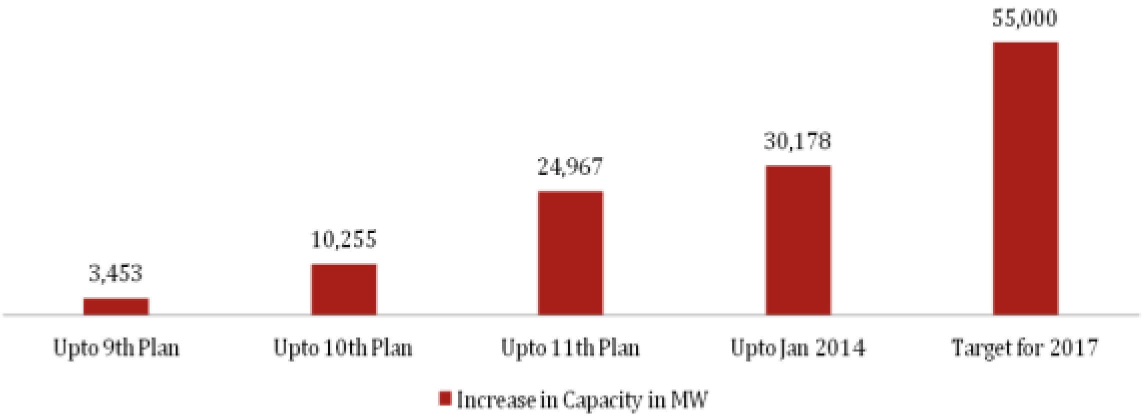


Figure **25**: Plan-Wise Capacity Addition of Renewable Capacity in India

Source: MNRE, 2014

Onshore wind has been the major contributor of renewable power in India contributes 66% of renewable capacity. Until March 2014 – out of the 31.7 GW of renewable capacity installed, onshore wind contributed a share of over21 GW[79].

However, onshore wind resources in India are concentrated mainly in the five Western and Southern States of Tamil Nadu, Karnataka, Maharashtra, Andhra Pradesh, and Gujarat. The rate of capacity addition has fallen since 2012 due to policy instability as well as state-specific issues linked to land acquisition for projects.

Offshore wind, in comparison, holds the potential for alleviating the land acquisition challenge and has the potential to be another option in India's portfolio of clean, low carbon power generation energy mix. It can also play a role in meeting the demand from load centres closer to the coastline. For example, coastal Indian cities that are projected to be major load centres according to 18th Electric power survey - Greater Mumbai, Chennai and Surat as well as other big cities like Vishakhapatnam, Vadodara, etc., might hold potential to be served through offshore wind power subject to technical and economic feasibility.

India should take a longer-term view towards inclusion of offshore wind technology in its renewable energy portfolio. Economic feasibility will depend on whether good wind resource is available in shallow waters and close to the shore. A thorough feasibility study to identify blocks of favourable wind development zones will be the first big step towards assessing the technical and economic potential for offshore wind in India.

[79]MNRE (2014).Ministry of New and Renewable Energy. Retrieved May 10, 2014, from http://www.mnre.gov.in

5

Denmark © Saylor / GWEC

5 Current Status of Wind Power

5. Current Status of Wind Power

5.1 WIND POWER IN INDIA

Over 35 GW of new wind power capacity was installed globally in 2013. The total cumulative installed capacity by the end of 2013 was over 318 GW. Globally the wind sector saw investments of over US$ 80 billion in 2013.

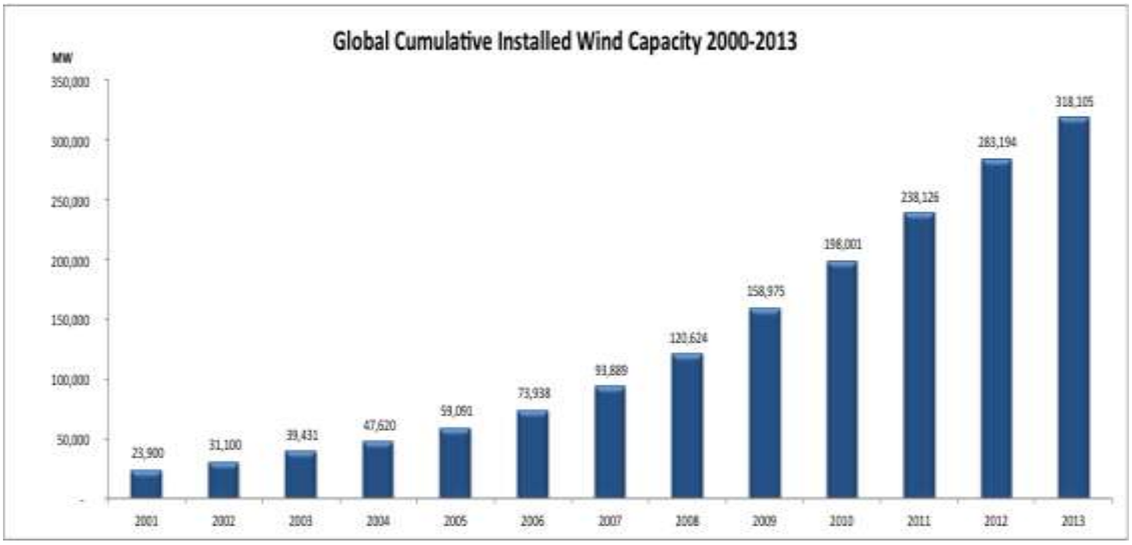


Figure **26**: Global Cumulative Installed Wind Capacity 2000– 2013 (MW)

Source: GWEC, 2014

By the end of 2013, over twenty-four countries had installed over 1 GW of wind power capacity including sixteen countries in Europe, four countries in the Asia-Pacific, three countries in North America, and one country in Latin America[80]

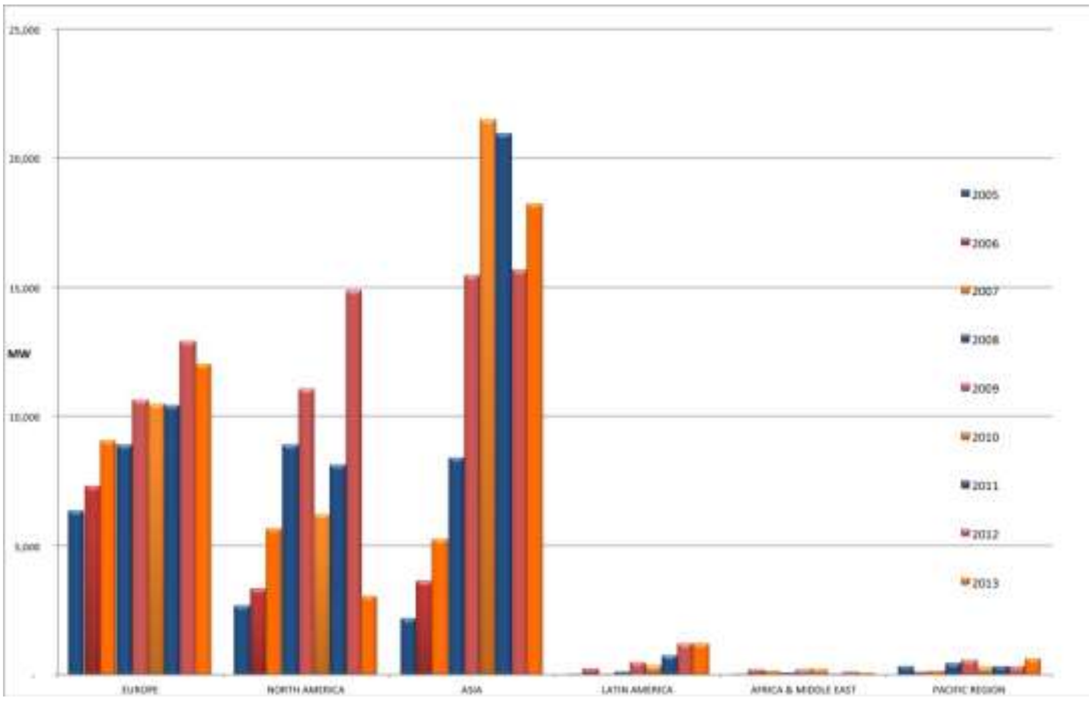


Figure **27**: Annual Installed Capacity by Region 2005 – 2013 (MW)

Source: GWEC, 2014

[80]GWEC 2014: Annual Market Update 2014, Global Wind Energy Council, April 2014 www.gwec.net

India today is the second largest wind market in Asia, presenting substantial opportunities for both international and domestic players. The Indian wind sector has struggled in the last couple of years to repeat the strong market in 2011 when over 3 GW was installed, and 2013 was a slower year in large part due to a lapse in the Accelerated Depreciation policy in 2012.

Nonetheless, India saw new wind energy installations reach 1,729 MW by the end of 2013 calendar year, for a total of over 20 GW. This pace of growth kept the Indian wind power market firmly in the top five rankings globally.

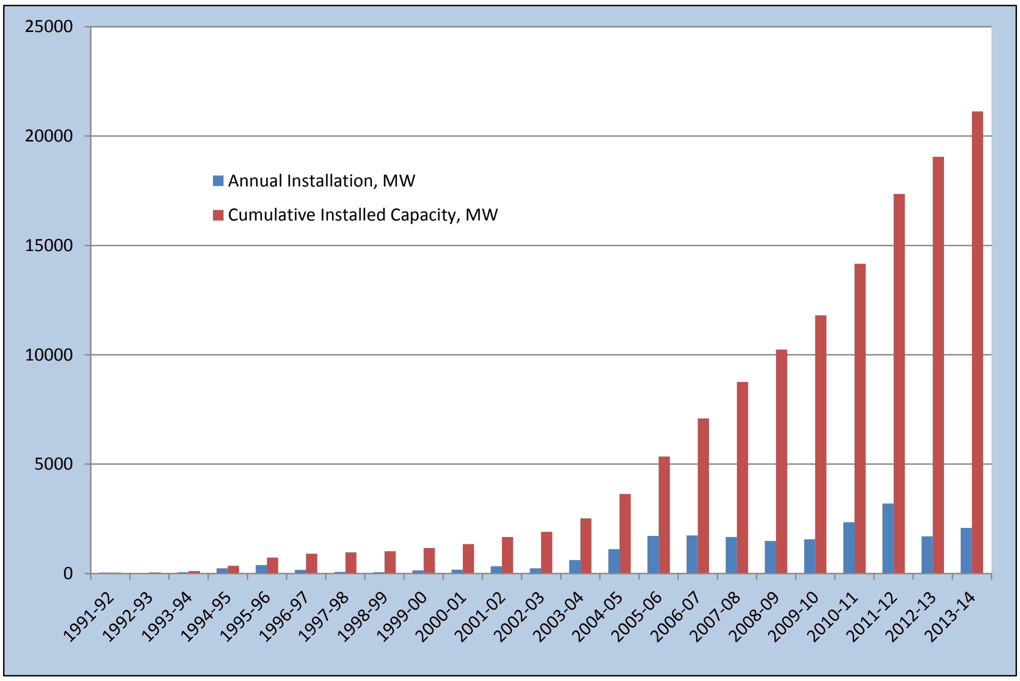


Figure **28**: Wind Power Capacity Addition between FY 1991-92 and FY 2013-14

Source: MNRE, 2014

By the end of the 2013-14 fiscal year in March 2014, the total wind installations had raised to 21,136 MW bringing the total grid connected renewable energy installations in the country to 31,707 MW[81].

By the end of 2013, renewable energy accounted for almost 13 % of India's total installed capacity, and about 5% of electricity generation[82].Wind power accounted for about 66% of total renewable energy capacity and over 8% of the total installed capacity of 245 GW at the end of the fiscal year[83].

With the acute need for electrification and rising power consumption in the country, wind energy is going to provide an increasingly significant share of the renewables based capacity. The Government has provided various regulatory, policy and fiscal incentives for onshore wind power development.

In a more recent development the Government is considering the possibility of launching National Wind Energy Mission (NWEM) along the lines of the National Solar Mission sometime in 2014. This could give a boost to the wind power sector and bring it in the same league as the high-profile solar mission. The Wind Mission is expected to focus on strengthening grid infrastructure for wind power, identifying high wind power potential zones, easing land clearances for wind projects, regulating wind power tariff and incentivizing investment in the wind sector. However, unlike the earlier

[81]Ministry of New and Renewable Energy www.mnre.gov.in Website accessed on May-10-2014
[82]Central Electricity Authority, India http://www.cea.nic.in/reports/powersystems/large_scale_grid_integ.pdf
[83]http://www.cea.nic.in/reports/monthly/inst_capacity/mar14.pdf

National Solar Mission, the Wind Mission is unlikely to involve bidding for the wind projects but will act as a facilitator for wind power development[84].

Table **24**: Comparison of Policies in Key States for Wind Power

States	Tariff rates / kWh	Annual tariff escalation	Percentage of Renewable Portfolio Standard (non solar)
Andhra Pradesh	INR 4.70	Constant for 25 years for the PPAs to be signed by 31-03-2015	6.8 % for non solar RE (2014/15)
Gujarat	INR 4.15	No escalation for 25 years of project life (for projects to be commissioned by 31/02/2016)	6.75% for non solar (2014/15)
Haryana	Wind Zone I– INR 6.81 Wind Zone II–INR 5.44 Wind Zone III– INR 4.54 Wind Zone IV– INR 4.25	Tariff is for FY 2014-15	3% for all non solar RE(2014/15)
Karnataka*	INR 4.20	No escalation for 10 years	7-10% (2014/15) for all non solar RE
Kerala	INR 4.77	No escalation for 20 years of project life	3.95% (2014/15) for non-solar RE
Madhya Pradesh (a)	INR 5.92	No escalation for 25 years of project life	4.7% for non-solar RE (2014/15)
Maharashtra	Wind Zone I– INR 5.70 Wind Zone II–INR 5.01 Wind Zone III– INR 4.18 Wind Zone IV– INR 3.92	No escalation for 13 years	8.5% for non-solar RE(2014/15)
Orissa	INR 5.31	No escalation for 13 years	6.25%for all non-solar RE (2014/15)
Punjab	INR 6.29 (for zone I) –and INR 5.80 if AD benefit is availed	No escalation for 10 years	3.81% for all non-solar RE (2014/15)
Rajasthan	INR 5.64 – 5.93 for plants commissioned in 2013-14	No escalation for 25 years of project life INR 5.64/kWh for project located in Jaisalmer, Jodhpur & Barmer districts INR 5.93/kWh for other districts	7.5% for all non-solar RE (2014/15)
Tamil Nadu	INR 3.51	No escalation for 20 years of project life	8.95% for all non-solar RE (2013/14)
Uttarakhand	Wind Zone I– INR 5.45	INR 5.65 for 1st 10 year & INR 3.45 for 11th year onward	7.00% for all non solar RE (2014/15)
	Wind Zone II– INR 4.85	INR 4.75 for 1st 10 year & INR 3.00 for 11th year onward	
	Wind Zone III– INR 4.15	INR 3.95 for 1st 10 year & INR 2.55 for 11th year onward	
	Wind Zone IV– INR 3.35	INR 3.45 for 1st 10 year &INR 2.30 for 11th year onward	
West Bengal	INR 5.71	No escalation for 10 years	4.35% for non-solar RE (2014/15)
* RPS for Bangalore Electricity Supply Company Limited (BESCOM) Mangalore Electricity Supply Company Limited (MESCOM) and Calcutta Electricity Supply Company Limited (CESC) is 10%. RPS for Gulbarga Electricity Supply Company Limited (GESCOM) Hubli Electricity Supply Company Limited (HESCOM) and Hukeri, it is 7%.(a) Only wind power specific RPS percentage			

Source: WISE, 2014

[84]The Economic Times : (2014, January, First National Wind Energy Mission to begin by mid-2014. Retrieved April 2014, from The Economic Times :http://articles.economictimes.indiatimes.com/2014-01-08/news/45991703_1_wind-sector-generation-based-incentive-wind-power

India is one of the major wind turbine manufacturing markets globally. Leading OEMs including Suzlon, Wind World, RRB Energy, RegenPowertech, Gamesa, Inox, Kenersys, GE, Siemens and lately Nupower, Sinovel and Garuda have established wind turbine production or assembly facilities in India.

By the end of March 2014, nineteen existing manufacturers offered over 50 variants of wind turbines and had a consolidated annual production capacity of over 12,000 MW. New companies are slated to enter the Indian wind sector over the next couple of years. Annexure 6 provides a detailed list of WTG manufacturers and models available in India.

Table **25**: Major Wind Power Investors in India

S. No	Independent Power Producers and Captive Consumers with Wind Projects	Installed Capacity (MW) by end of March 2013
1	CLP Wind Farms (India) Pvt. Ltd.	416.25
2	Tata Power Company	349.45
3	IL&FS	325.60
4	Hindustan Zinc Limited	273.50
5	Vish Wind Infrastructure LLP	270.40
6	Vaayu (India) Power Corp. Private Limited	202.40
7	Tadas Wind Energy Limited	200.80
8	Madras Cement Limited	185.58
9	Simran Wind Project Private Limited	184.50
10	BinduVayuUrja Private Limited	179.70
11	DLF Limited	161.20
12	Beta Wind Farm Private Limited	139.35
13	EnerconWindfarms Hindustan Private Limited	128.80
14	Gujarat Paguthan Energy Corporation Limited	127.95
15	MSPL Limited	121.95
16	Gujarat FlouroChemicals Limited	119.10
17	Gujarat State Fertilizers & Chemicals Limited	113.40
18	Nu Power Renewables	111.00
19	Gail (India) Limited	102.95
20	Powerica Limited	102.75
21	BP Energy India Private Limited	99.40

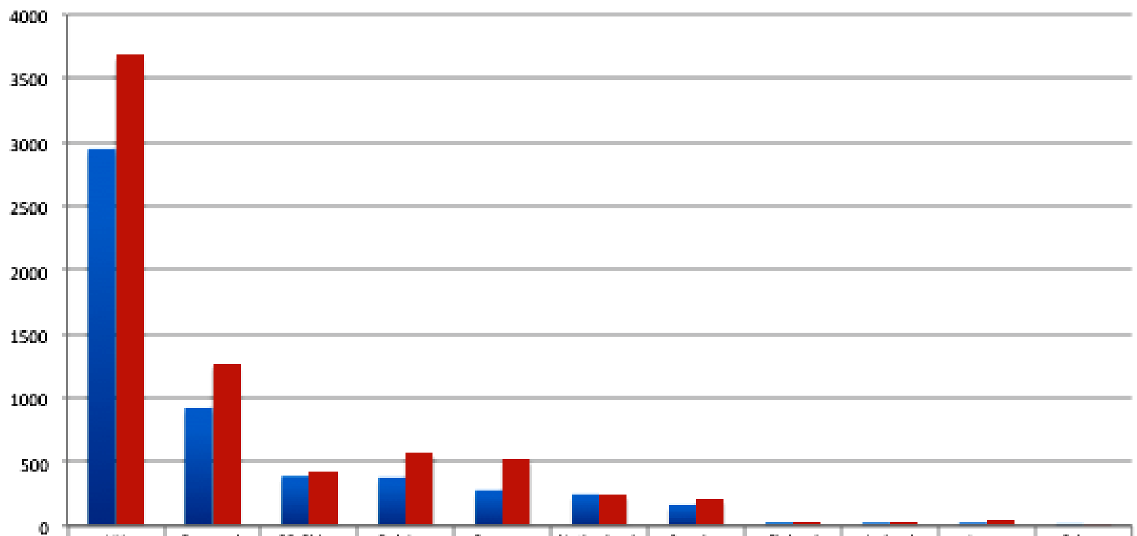
Source: WISE, 2013

Several challenges still remain for the more established onshore wind power sector in India. However, the mid-term outlook for the wind sector is looking more promising than in 2012 and 2013.

5.2 STATUS OF OFFSHORE WIND

Since the first offshore wind farm was built in shallow waters off the coast of Denmark over twenty years ago, the offshore wind turbine size has increased from 450 kW to 7-8 MW, costs have reduced by about 30% per decade, and projects have moved to water depths of over 40 meters and up to 100 km from shore.

By the end of 2013, the total offshore wind installed capacity had reached 7,046 MW. More than 90% of this installed capacity is in European waters: in the North Sea, Baltic Sea and in the Atlantic Ocean. However, offshore development in China is starting to take off, followed by Japan, South Korea, Taiwan and the US[85].



	UK	Denmark	PR China	Belgium	Germany	Netherlands	Sweden	Finland	Ireland	Japan	Others
2012	2,948	921	390	380	280	247	164	26	25	25	9
2013	3,681	1,271	429	572	520	247	212	26	25	50	14

Figure **29**: Cumulative Offshore Wind Capacity in Key Markets 2012-2013 (MW)

Source: GWEC, 2014[86]

During 2013, the Ministry of New and Renewable Energy (MNRE) in India launched consultations on its draft policy for Offshore Wind. The draft offshore policy and various guidelines on resource assessment, clearances, for setting up of offshore wind projects are likely to be approved by the Union Cabinet in 2014. The objective of the draft policy is to promote development of offshore wind farms.

The nodal ministry for overall monitoring of offshore wind development in the country will be the MNRE. The Ministry will establish an Offshore Wind Energy Steering Committee (OWESC) that will be responsible for providing policy guidance for offshore wind. A nodal agency called the National Offshore Wind Energy Agency (NOWA) would be established as the implementing agency.

NOWA is likely to be a single-window agency, tasked with coordinating with all the concerned ministries and departments for various clearances and approvals. NOWA is also expected to be responsible for carrying out preliminary resource assessments and surveys. It will also contract developers for developing offshore wind projects.

Under the draft policy guidelines, State governments may form committees for monitoring offshore wind energy projects in their own states. Other state authorities such as maritime boards would be responsible for providing access to port infrastructure, and state electricity boards would be responsible for providing onshore grid connectivity and integration.

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85 GWEC 2014: Annual Market Update 2014, Global Wind Energy Council, April 2014 www.gwec.net

86 Others' : this category includes numbers for Korea, Spain, Norway, Portugal and the United States

Under the latest draft policy incentives given for offshore projects would be in the form of tax holidays up to the first 10 years, concessions in customs duty and excise duty, exemptions for procurement of technology and equipment for offshore wind turbines. It is proposed that no service tax (~ 12.36%) would be levied for studies and resource assessments undertaken for the offshore wind sector.

According to the draft offshore policy, the turbine certification and standards issue, the Centre for Wind Energy Technology (C-WET) will continue to be the nodal agency in India. Conformance to turbine standards for offshore wind will be the responsibility of C-WET in line with international standards. The onus would be on the wind farm developer to demonstrate the technical suitability of the foundation design for prevailing seabed conditions.

The Government may invite proposals for demonstration projects on offshore wind. These projects would be exempted from paying a lease-fee over a pre-specified period, after which the ownership of the demonstration project would be transferred to the Government of India. However, the draft offshore policy is in the process of further amendments and the final policy document could have similar or new elements in it.

The on-going dialogue with various stakeholders on developing offshore wind in India is encouraging. The project will provide support for broadening stakeholder awareness and involvement in this dialogue.

In the coming months, the FOWIND project consortium will work closely with the Ministry of New and Renewable Energy, the Centre for Wind Energy Technology and relevant central and state based agencies to develop a roadmap for offshore wind development in India with a focus on the states of Gujarat and Tamil Nadu.

6

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6 Concluding Analysis

6. Concluding Analysis

A key focus of this report was to assess the prevalent baseline conditions with respect to offshore wind. FOWIND actions will attempt to provide answers to some of the challenges and concerns surrounding offshore wind in its implementation phase.

Access to some form of energy is a prerequisite for almost all modern-day economic activity and has a direct impact on people's quality of life. Rising concerns about climate change and greenhouse gas emissions from combustion of fossil fuels combined with the need to achieve 'energy independence' has led policy makers to consider new energy generation options including from wind energy - a clean, affordable and indigenous renewable energy source. India is a rapidly developing country with a burgeoning demand for energy.

Offshore wind will help the country harness large-scale, indigenous, renewable energy generation. It has some inherent advantages such as a large wind resource, utility-scale renewables, larger WTGs, reduced visual impact, more clarity over land tenure and fewer environmental constraints.

Over the coming three and a half years, FOWIND will work towards delivering on its principle goal and all of its aforementioned objectives. This will be done in close cooperation with the Indian Government, States of Gujarat and Tamil Nadu, the wind industry, civil society and local communities.

To make a convincing case for the offshore wind sector in India, the political signal will have to be strong and provide a long-term vision for the industry.

An offshore wind project is capital intensive and requires proper planning to ensure a good yield over the long-term and to minimize operational and maintenance expenses. In the short-term however the lack of any long-term offshore wind resource assessment is a fundamental barrier. Further critical planning activities would include a thorough on-site wind resource assessment, met-ocean studies and geophysical/geotechnical surveys of the seabed (bathymetry) before proceeding with detailed design and construction of an offshore wind farm.

Globally the offshore wind industry's progress over the past decade has been slower than predicted, but is now on the verge of reaching critical mass. Generally one could conclude that traditionally it was the technology that created 'risk'; today in Europe the 'risk' to the OW sector stems more from a lack of political will and rising regulatory uncertainty.

The Indian experience with offshore wind could be distinctly different with the Indian Government providing regulatory certainty and firm capacity targets which utilities, financiers and developers need to make investment decisions. Through the FOWIND project outcomes the consortium will actively try to bring forth aspects that would specifically benefit and those that could adversely impact the future of an OW sector in India.

7

7 Annexures

Annexure 1: Summary - Principle Role of Consortium Partners

Global Wind Energy Council (GWEC) -The Global Wind Energy Council is the international trade association for the wind power industry based out of Brussels, Belgium and represents manufacturers, component suppliers, developers, operators, service providers and consultancies globally. GWEC works at the highest international political level to create a better policy environment for wind power.

GWEC is the lead partner for the project and the grant applicant. GWEC is responsible for the overall delivery of the project. GWEC chairs the Project Executive Committee.

GWEC will work with the Indian consortium partners for facilitating sharing of regulatory and experience from EU member states, industry and experts to facilitate effective policy design towards optimization of techno-economic benefits from offshore wind in India. This knowledge exchange and structural cooperation will be promoted in close cooperation with the MNRE and all relevant government agencies at the Centre as well as relevant stakeholders and decision makers in the States of Gujarat and Tamil Nadu.

Centre for Study of Science Technology and Policy (CSTEP) –CSTEP with its expertise in wind power will focus its study on state of Tamil Nadu. CSTEP would engage with multiple state agencies in Tamil Nadu to collect relevant data and information, which will be further used in conjunction with GIS with help of other consortium partner (DNVGL) resulting list of suitable wind farm zones towards LiDAR deployment and data assessment. Based on the outcome one LiDAR will be deployed and data will be analyzed with support from partner (DNVGL)

CSTEP will also carry out, in the state of Tamil Nadu, studies on logistics, supply chain and other infrastructure requirements, specially the grid infrastructures for evacuation of power, and enable the energy agencies, distribution companies and power utilities to develop long term plan with adequate safeguards in place.

CSTEP will undertake with the help of design support from DNV GL, techno-commercial analysis of one pre-identified site in Tamil Nadu, with a hypothetical 100 MW offshore project.

With other consortium partners CSTEP will work with local communities and reputable CSOs and issue experts to promote ecologically sensitive offshore project development guidelines. With support from project partners CSTEP will also develop the portal for effective dissemination of all the activities being undertaken to public at large. The portal will also serve as the tool for dissemination of consolidated wind data, media briefings, notes and FAQs on the issue of offshore wind in India as well as in EU.

GL Garrad Hassan Pvt Ltd. India (DNV GL) – DNVGL are recognised world leaders in offshore wind strategy and engineering services and have contributed to the majority of the world's major projects since first being involved with offshore technology in 1993. As one of the world's largest dedicated renewable energy consultancies, DNV GL has a unique integrated service offering through all phases of the investment life-cycle; from understanding market structure and trends to project design support, technology assessment and technical due diligence. As partner to the consortium, the organisation will provide its long expertise in the offshore industry, as well as its experience in technology assessment, project design, due diligence and other areas. DNVGL is primarily responsible for development of a decision support system (DSS) tool by conducting pre-feasibility study, analysing LiDAR data and GIS mapping, in both Gujarat and Tamil Nadu.

Gujarat Power Corporation Limited (GPCL) - GPCL is a state energy agency of Gujarat, based in Gandhinagar, India. The organization identifies power projects of various fuels, prepares techno-economic feasibility reports, identifies suitable private joint sector parties and implements these jointly with the selected parties. In the action, GPCL will provide co-funding to the project and will facilitate smooth implementation of the project activities in Gujarat.

World Institute of Sustainable Energy (WISE) - Center for Wind Power (CWP) at WISE will be responsible for ensuring timely delivery of actions in the state of Gujarat. Initially, WISE will undertake the review of the existing studies specific to the state of Gujarat. WISE with the assistance of Gujarat based state agencies will collect constraint data and information regarding the selection of suitable zones for deployment of LiDAR.

WISE in cooperation with GPCL will ensure timely deployment of the LiDAR at selected site(s). WISE will ensure delivery of LiDAR data to DNV GL for updating GIS platform for offshore site identification in Gujarat. Based on the analysis of LiDAR data for at least a period of one year, a potential site will be identified in the state of Gujarat and the consortium would conduct a techno-commercial feasibility analysis for the site.

In addition, WISE will conduct top line infrastructure studies for the State of Gujarat including ports, logistics, vessels, value chain, grid and other infrastructure to assess preparedness for the OW sector.

WISE will work with consortium partners for facilitating sharing of regulatory knowledge and experience from EU member states, industry and experts from relevant energy agencies/regulators. WISE hosts the Project Management Unit within its premises in Pune, India.

STRATEGIC PARTNER

IL&FS Energy Development Company Limited (IEDCL)- is a subsidiary of Infrastructure Leasing & Financial Services Limited (IL&FS). The company own and operate power generation and power transmission assets in India. In a span of five years IEDCL has secured a number of power generation projects having diverse fuel linkages, such as gas, coal, hydro and bagasse. IEDCL has considerable in-house expertise in various facets of project development and management such as technical, legal, regulatory, environment and financial. IEDCL provides advisory in project development and implementation to State Governments, large Public Sector companies as well as Private Sector clients. As a strategic partner, IEDCL apart from providing co funding, will participate in project steering activities to set strategies, advice on approach and methodologies for successful execution of the project.

Annexure 2: Expected Timeline for Actions under Work-Package 1 To 7

The broad time frame for the action is presented below:

Year 1	▪ Publish detailed baseline assessment and knowledge gap analysis ▪ Publish global review of policies, regulations and incentives for offshore wind ▪ Review of existing studies and data set on offshore wind resources in Gujarat & Tamil Nadu ▪ Collection of information and data for constraints analysis for the pre-feasibility study ▪ Identification of target groups from India and abroad for knowledge exchange ▪ Field visit of Indian OW Stakeholders and target R&D group to Europe ▪ Review of existing and proposed transmission plans in both states (pre-feasibility) ▪ Designing and development of GIS platform for site identification using modelled data ▪ Publish pre-feasibility analysis for potential OW zone/s ▪ Initiate study on supply chain for offshore wind industry ▪ Sensitization workshops for offshore wind stakeholders- in Gujarat, Tamil Nadu and Delhi
Year 2	▪ Completion of the supply chain study ▪ Study on impact of large scale integration of offshore wind in the national grid ▪ Study on logistics (ports, vessels) and other infrastructure requirements in both states ▪ Capacity building initiatives and field visit of the Indian delegation to Europe ▪ Selection of site and deployment of LIDAR ▪ Begin LIDAR data acquisition and resource analysis ▪ Inception workshop in India for EU India offshore research platform ▪ Creation of research platform and promotion of best-practice exchange ▪ Follow-up workshop for cross-study training in Europe for EU India offshore research platform ▪ Outreach activity to engage local community ▪ Completion and release of all infrastructure assessment studies (compendium)
Year 3	▪ Wind data acquisition from LIDAR and resource analysis ▪ Best practice and knowledge exchange- EU experts' visit to India ▪ Final roundtable workshop for R&D and standardization institutes in India for EU India offshore research platform ▪ Initiating a development of national offshore project facilitation guidelines (including draft guideline for a Request for Proposal) ▪ Developing procedures and documentation required to obtain clearances/approvals ▪ Initiation of techno-commercial analysis of the sites with highest potential identified through LIDAR data (for a hypothetical 100 MW project) ▪ Consultation and outreach activity to engage local community ▪ Media interaction and outreach activity-I

Year 4	▪ Consolidation of LIDAR data and validation report for Gujarat and Tamil Nadu ▪ Updated wind maps and COE maps for accurate spatial mapping ▪ Dissemination of consolidated wind data into public domain ▪ Completion of techno-commercial analysis of the sites with highest potential ▪ Petitioning electricity sector regulators for incentive/support mechanism for offshore wind ▪ Roundtable on market mechanisms and policy and regulatory framework for offshore wind ▪ Engineer's training workshop in two states ▪ Adapt and customized technology adoption guidelines for Indian conditions ▪ Preparation of Offshore Wind Outlook and pathway for offshore wind development up to 2032 ▪ Media interaction and outreach activity-II ▪ Preparation of project sustainability plan
Year 5	▪ Project completion, documentation and reporting [first quarter]

Annexure 3: Detailed List of Existing Coastal Met Masts Installed by C-WET for Gujarat

S. N.	Region	Mast name	Location		District	Data Period		Mast Height (m)	Distance from near east shoreline (km)	MAWs AT MAST HEIGHT (m/s)	WPD at 50m height (w/m^2)
			Latitude	Longitude		Commen-ced on	Closed on				
1	Gulf of Kutch	Jamanvada	23.58	68.60	Kutch	22-Feb-93	11-Dec-96	20	11	5.17	299
2		MotiSindholi	23.16	68.78	Kutch	28-May-88	21-Oct-93	20	8	4.87	204
3		Bayath	22.94	69.17	Kutch	14-Jun-97	13-Jul-99	20	8	5	204
4		Mundra	22.79	69.72	Kutch	29-May-88	21-Oct-93	20	3	5.42	303
5		Sinai	23.05	70.06	Kutch	13-Aug-96	18-Dec-98	20	15	5.77	244
6		Vandhya	23.22	70.60	Kutch	13-Jun-03	19-Oct-05	45	35	5.76	203
7		Surajbari	23.22	70.71	Kutch	13-Jun-88	22-Oct-93	20	40	5.42	270
8		Warshamedi	22.97	70.57	Rajkot	11-Nov-00	27-Aug-03	20	17	5.67	282
9		Haripar	22.27	69.64	Jamnagar	8-Sep-96	20-Dec-98	20	11	5.46	210
10		Nana Asota	22.25	69.54	Jamnagar	6-Jul-08	6-Jan-10	50	11	5.76	151
11		Okha	22.46	69.04	Jamnagar	12-Aug-86	24-Oct-93	20	0.2	5.39	260
12	Open Coast of Saurashtra	Okhamadhi	22.08	69.11	Jamnagar	14-Jun-88	24-Oct-93	20	0.5	5.28	209
13		Navadra	21.95	69.24	Jamnagar	23-Dec-92	2-Oct-97	20	1	5.78	297
14		Lamba-I	21.89	69.29	Jamnagar	22-Dec-92	2-Oct-97	20	0.1	5.56	232
15		Lamba-II	21.90	69.28	Jamnagar	12-Jul-08	-	120	0.5	6.85	183
16		Harshad	21.84	69.36	Jamnagar	12-Jul-86	27-Feb-92	20	0.3	5.56	239
17		NaviBander	21.45	69.79	Porbandar	14-Jun-88	24-Oct-93	20	0.2	5.42	213
18		Veraval	20.91	70.35	Junagad	31-May-88	29-Feb-92	20	0.15	4.89	168
19		Velan	20.71	70.83	Amreli	15-Jun-88	25-Oct-93	20	1.5	4.42	197
20	Gulf of Khambhat	Jafrabad	20.90	71.39	Amreli	15-Jun-88	25-Oct-93	20	3.5	4.86	242
21		Sanodar	21.56	72.11	Bhavnagar	8-Nov-96	24-Dec-98	20	16	6.24	373
22		Vadgam	22.34	72.58	Anand	26-Jul-06	31-Jan-09	50	35	5.09	188
23		Dandi	20.89	72.81	Navsari	6-Feb-88	24-Aug-92	20	1.3	4.03	106

Source: C-WET, 2014

Annexure 4: Detailed List of Existing Coastal Masts Installed by C-WET for Tamil Nadu

S. N	Station	District	Data Period Commenced on	Closed On	Mast Height (m)	Latitude N (DD)	Longitude E (DD)	Distance From Shore (km)	MAWS At 20/25/30/ 50/80/120 m	WPD Measured AT 50 m (w/m^2)
1	Ennore	Tiruvallur	23-03-1992	20-04-1995	20	13.24	80.33	0.5	5.36	243
2	Dubarayapet	Puducherry	15-10-1996	19-01-1998	25	11.9	79.83	0.5	4.44	119
3	Pannithittu	Puducherry	16-10-1996	19-01-1998	25	11.83	79.8	0.5	3.72	71
4	Poompuhar	Nagapattinam	22-06-1991	16-07-1994	20	11.14	79.86	1	4.77	149
5	Keezhayur	Karaikal	18-10-1996	20-01-1998	25	10.87	79.83	1.5	4.86	166
6	Vedaranyam	Nagapattinam	12-09-1996	18-11-1997	20	10.36	79.85	1.5	3.78	101
7	Agasthianpalli	Nagapattinam	11-06-2004	11-07-2006	50	10.35	79.85	2.2	5.76	157
8	Kalianagari	Ramanathapuram	31-01-2008	31-01-2010	50	9.8	79.08	0.5	5.56	157
9	Rameswaram	Ramanathapuram	24-07-1988	11-11-1993	20	9.23	79.34	0.5	6.64	426
10	Tuticorin	Tuticorin	31-08-1986	24-05-1993	20	8.73	78.13	4	4.89	245
11	Vakaikulam	Tuticorin	04-03-1996	16-11-1998	20	8.75	77.99	20	4.61	256
12	Ovari	Tirunelveli	03-03-1996	10-03-1998	20	8.29	77.87	4.5	5.08	221
13	Kanyakumari	Kanyakumari	28-06-2003	26-12-2004	30	8.08	77.56	1	7.32	436
14	Muttom	Kanyakumari	11-07-1994	04-07-1997	25	8.12	77.32	1	4.75	203

Annexure 5: Renewable Energy Enabling Measures by the Central Government

Renewable Energy enabling measures implemented by the Central Government	
Electricity Act 2003	▪ Provides suitable measures for connectivity to the grid for RE projects. ▪ Provisions for defining renewable purchase obligation/specifications ▪ Promotes renewable energy while specifying tariff ▪ Recommends preparation of National Electricity and Tariff Policy ▪ No license required for setting up power/RE power generation project ▪ Empowers state regulators to promote RE power, decide feed-in tariff, define RE purchase obligations, and ensure connectivity to grid for RE project
National Electricity Policy 2005	▪ Need to reduce the cost of non-conventional sources of energy by promoting competition within such projects ▪ RE generation needs to be promoted by creating suitable measures for grid connectivity and by specifying progressively increasing RPO ▪ Advocates procurement of power by distribution licensees through competitive bidding.
Integrated Energy Policy 2006	▪ Acknowledges the role of RE in the country's energy mix and promotes renewable energy generation ▪ Advocates energy production linked incentives for RE sector in lieu of investment linked incentives
National Tariff Policy 2006	▪ Appropriate Commission shall fix a minimum percentage for purchase of energy from such sources taking into account availability of such resources in the region and its impact on retail tariff. ▪ Procurement by distribution companies shall be done at preferential tariffs determined by the Appropriate Commission ▪ RE procurement by Distribution Licensees for future requirements shall be done, as far as possible, through competitive bidding process. ▪ The Central Commission should lay down guidelines for pricing non-firm power, especially from non-conventional sources, to be followed in cases where such procurement is not through competitive bidding
National Action Plan on Climate Change 2009	▪ Mandates 15% renewable energy in the electricity generation mix by 2020 – implying above 100 GW installed RE generation capacity by then ▪ Proposed to set up National Wind Power Mission during 12th FYP
Central Electricity Regulatory Commission initiatives	▪ In line with the provisions under NTP, the Commission had issued a multi-year RE Tariff Regulations first time in 2009 and revised the same in 2012. ▪ The Commission's regulation had helped bringing clarity among state regulators on various tariff determining parameters. ▪ Facilitates adoption of long term RPO trajectory and established renewable energy certificate (REC) mechanism in India ▪ Actively promoting development of voluntary REC market and RPO compliance
State Electricity Regulatory	▪ Preparation Renewable Energy policy for the state

Renewable Energy enabling measures implemented by the Central Government	
Commissions	▪ Fixing the RPO of the state ▪ Issue order for multiyear feed in tariff for RE based resources
13th Finance Commission's Incentives to States promoting RE	▪ Grant of INR 50,000 million to be paid as an incentive to states who increase the share of electricity generated from renewable sources between FY 2010/11 to FY 2013/14 ▪ Grants to be awarded based on two part formula relating to absolute achievements in MW and relative achievements with respect to RE Potential in the state
Feed–in tariff	▪ 13 SERCs have declared feed in tariff for purchase of electricity generated from wind power projects in their respective states ▪ All the SERC's have adopted a 'cost plus' methodology to determine the tariff
Renewable Purchase obligation	▪ 27 SERCs have specified the mandatory purchase obligation under Section 86, 1(e) of the Electricity Act, 2003, for purchase of fixed percentage of energy generated from RE sources. ▪ The RPS percentage varies from 0.075 - 1.00% for solar and 3.81 - 10.25%, for Non solar depending on the local renewable resources and the electricity distributed in that area. ▪ RPS obligation can be fulfilled trough direct purchase via bilateral contracts and tradable REC mechanism that can further generate revenue for RE projects.
REC	▪ Launched in 2010, REC is a tradable certificate where one certificate is equal to 1MWh of renewable energy generated ▪ Purchased by DISCOM, Open Access and Captive Consumer to fulfill the RPO obligation
Generation Based Incentive(2013)	▪ Generation-based incentive of INR 0.5/kWh has been reintroduced for wind energy projects and INR 800 Crore allocated in FY 2013/14 budget.
Grid connectivity	▪ As per the Electricity Act, 2003, the respective State Transmission Utility (STU) is responsible for creation of grid inter connection infrastructure for RE connectivity at its own cost. However, due to the poor financial health of the STUs and the time required to create such infrastructure, states adopt different practices for creation of the required infrastructure.
Wheeling, Banking & third party sale	▪ Favourable provision for wheeling, banking and third party sale by wind power producers
SNA project facilitation	▪ State nodal agencies (SNAs) facilitate project development right from resource assessment to the final commissioning. ▪ SNA through its initiative undertakes resource assessment studies ▪ SNA supports the developer by facilitating development of infrastructure at identified sites and also verifies the legal statutory clearances sought by the developer from different departments. ▪ MEDA in Maharashtra has created the Green Cess (tax) fund. This is a dedicated fund in Maharashtra for the development of RE and a part of this fund is utilized to create infrastructure for grid connectivity with proposed wind farms. Similar tax (Cess) is being collected in Karnataka.
National Clean Energy Fund	▪ NCEF collected as clean energy cess of INR 50/tonne of coal produced domestically

Renewable Energy enabling measures implemented by the Central Government	
(NCEF)	and imported in India ▪ NCEF is proposed to be utilized for the development and deployment of clean energy technologies in India ▪ Part of this fund may be utilized for development of grid infrastructure that is proposed under the Green Energy Corridor report prepared by PGCIL. ▪ GOI has announced supporting soft loans /interest subsidy for the RE projects through NCEF during FY 2013-14 budget presentation.
Supporting infrastructure development - Green Energy Corridor plan & Desert Power 2014	▪ PGCIL had published research report on 'Green Energy Corridor'. Plans for building transmission infrastructure of electricity envisaged RE capacity additions during 12th/ 13th FYP. ▪ PGCIL has also proposed various grid strengthening plans to accommodate RE capacity addition of around 40,000 MW in the RE resource rich states by FY 2016/17. ▪ INR 425,570 million CAPEX plan proposed for RE rich states by FY 2016/17 for grid strengthening.
Draft National Offshore wind Power Policy 2013	▪ With the objective to promote the development of offshore wind energy and promotes investment in energy infrastructure for the purpose of achieving energy security and reduces carbon emission Government of India is preparing the offshore wind power policy for India. ▪ Create framework for the offshore wind power development in India
Technical standards for connectivity to the grid	▪ CEA amended the technical standards for connectivity to the grid to include Wind generating stations ▪ Technical requirements such as Flicker emission, Low Voltage ride through were included for wind generating stations.
Proposed National Wind Mission 2014	▪ A National Wind Energy Mission on the lines of Jawaharlal Nehru National Solar Mission (NSM) may soon be set up by the Centre in order to fuel growth in wind energy sector as enumerated in the 12th FYP document.

Annexure 6: List of Wind Turbines Manufacturers and WTG Models Available in India

S. NO	WTG Manufacturer	Model	Capacity (kW)
1	M/s. Chiranjjeevi Wind Energy Limited, Coimbatore, Tamil Nadu	CWEL C30/250 kW	250
2	M/s. Gamesa Wind Turbines Private Limited, Chennai, Tamil Nadu	G52-850 kW 50 Hz	850
		G58-850 kW	850
		G58-850 kW 50 Hz	850
		G80-2.0 MW	2000
		G87-2.0 MW	2000
		G90-2.0 MW	2000
		G97-2.0 MW	2000
3	M/s. Garuda Vidyut Shakti Limited, Chennai, Tamil Nadu	Garuda 700.54 EU	700
4	M/s. GE-India Industrial Private Limited, Bangalore, Karnataka	GE 1.6-82.5, 50 Hz	1600
		GE 1.6-87, 50 Hz	1600
		GE 1.7-103, GE 50.2,	1700
5	M/s. Global Wind Power Limited, Chennai, Tamil Nadu	Norwin 750 kW	750
		FL 2500-100/W2E-W100 2.5 MW	2500
		Mingyang 1.5 MW	1500
6	M/s. Inox Wind Limited, Noida, Uttar Pradesh	WT2000DF	2000
7	M/s. Kenersys India Private Limited, Pune, Maharashtra	K82	2000
		K100	2500
		K110	2400
8	M/s. LeitwindShriram Manufacturing Limited, Gummidipoondi, Tamil Nadu	Leitwind LTW77- 1.5 MW	1500
		Leitwind LTW80- 1.5 MW	1500
		Leitwind LTW80- 1.8 MW	1800
		Leitwind LTW 86 - 1.5 MW	1500
9	M/s. NuPower Technologies Limited, Mumbai, Maharashtra	W8x, W93-2.05 MW, 50 Hz LM 45.3P	2050
10	M/s. Pioneer Wincon Private Limited, Chennai, Tamil Nadu	Pioneer 750/49	750
		Pioneer 250/29	250
11	M/s. RegenPowertech Private Limited, Chennai, Tamil Nadu	VENSYS 82	1500
		VENSYS 87	1500
		VENSYS 77	1500
12	M/s. RRB Energy Limited, Chennai, Tamil Nadu	Pawan Shakti PS 1800	1800
		V39- 500 kW	500
		Pawan Shakti PS 600	600

S. N0	WTG Manufacturer	Model	Capacity (kW)
13	M/s. Shriram EPC Limited, Chennai, Tamil Nadu	SEPC 250T, HH: 41.5m	250
		SEPC 250T, HH: 51.5m	250
14	M/s. Siva Wind Turbine India Private Limited, Erode, Tamil Nadu	Siva 250/50	250
15	M/s. Southern Wind Farms Limited, Chennai, Tamil Nadu	GWL 225	225
16	M/s. Suzlon Energy Limited, Pune, Maharashtra	Suzlon S97 DFIG 2.1 MW, 50 Hz	2100
		Suzlon S52/600 kW	600
		Suzlon S66-1.25MW/ Mark II	1250
		Suzlon S82 V3-1.5 MW	1500
		Suzlon S88 V3A-2.1 MW	2100
		Suzlon S95 DFIG 2.1 MW	2100
17	M/s. Vestas Wind Technology India Private Limited, Chennai, Tamil Nadu	Vestas V100-1.8MW 50 Hz VCS Mk7	1800
		Vestas V100-2.0 MW 50 Hz VCS Mk7	2000
		Vestas V100-1.8 MW 50 Hz VCS Mk7.1	1800
18	M/s. Wind World (India) Limited, Mumbai, Maharashtra	E-53	800
19	M/s. WinWind Energy Private Limited, Chennai, Tamil Nadu	WinWInd 1 MW	1000

Source: WISE, 2013

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Consortium Partners

Global Wind Energy Council
www.gwec.net

Center For Study Of Science Technology And Policy
www.cstep.in

DNV GL
www.dnvgl.com/energy

Gujarat Power Corporation Limited
www.gpclindia.com

World Institute of Sustainable Energy
www.wisein.org

Strategic Partner (since April 2014)

IL&FS Energy Development Company Limited
www.ilfsindia.com

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