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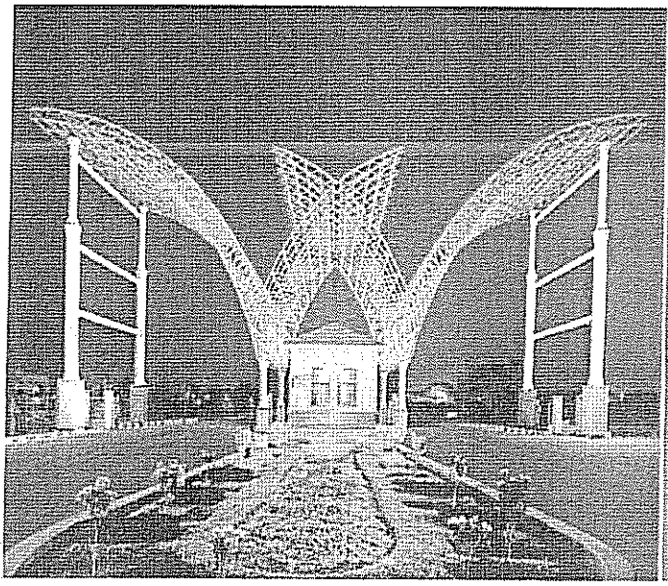
WELSPUN ENERGY RAJASTHAN PRIVATE LIMITED



DETAILED PROJECT REPORT
FOR
126 MW WIND ENERGY PROJECT
AT DHAMOTAR, District PRATAPGARH, RAJASTHAN

BY: Dr N. Karuna Moorthy

AWT ENERGY PRIVATE LIMITED: 9TH FLOOR, C WING, GODREJ COLISEUM, EVERARD NAGAR, SION TROMBAY Rd. SION.MUMBAI 400 022.

To collect site specific information, Engineers of Welspun Energy visited the site. Based on the information collected from site, information collected from various other sources and WRA report submitted by wind department, the Detailed Project Report has been prepared and presented in the following chapters:

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CHAPTER -1

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Executive Summary

During the last few years wind energy has emerged as one of the most promising among various renewable energy sources for large scale power generation on commercial basis.

According to preliminary assessment total estimated wind power potential in India is around 1,02,788 MW. Against this, so far 20,150 MW has been realized as on 31-01-2014. The average annual growth rate for the period of 2008-2013 is found to be 16.89 %. Also, the annual growth rate for 2012-2013 is 9.79%.

India ranks 5th in the world amongst the wind power producing countries. First four countries are China, USA, Germany & Spain. Worldwide installed capacity of wind power has reached to 3,18,105 MW by the end of December 2013.

Rajasthan state is endowed with very good wind resource. Owing to good wind resource and supportive Government policy regime a large number of private sector companies have ventured in wind power generation in Rajasthan.

To avail advantage of growing wind power industry in India and in particular Rajasthan, M/s Welspun Energy Rajasthan Private Limited (WERPL) plans to establish a wind power project in Rajasthan with intention of selling the generated energy to the utility.

WERPL has proposed to go ahead with 71 No. of WTGs with a capacity of 126MW.

The Detailed Project Report has been prepared and presented covering various aspects of development of wind power project at the proposed site. The salient points of the report are given below:

- Wind studies indicate excellent wind resource to make the site suitable for establishment of wind farm. Annual mean wind speed at WTG's hub height is 6.23 m/sec.
- For evacuation of power generated by the proposed wind farm, WERPL has planned to construct 132 kV pooling station in the wind farm site and the generated power will be transmitted through 132kV double circuit OH transmission line on 132 kV tower to the RRVPNL's existing 132/33 kV

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sub-station at Pratapgarh located at an aerial distance of around 14 km from the proposed site. (Evacuation plan is expected to get Net P-50 figures for 40X1.6 MW +31X2 MW to be 26.5 %)

- 60.96 hectares of Revenue land is available.
- We have installed a Wind monitoring station on 21st May 2012 and have duly registered the same with CWET Chennai and are regularly obtaining wind data from the same.
- We have received Power Evacuation approval from RRVPNL vide their letter dated 18-09-12 and RRECL vide their letter dated 26-09-12.Revised power evacuation approval was issued from RVPNL dated 23-04-2014.
- We have applied for the approval under Section 68 of the Electricity Act to lay Overhead Transmission line through the various villages.
- We have also acquired parcels of private land for wind turbines adjoining the allocated Revenue land to execute the complete wind farm.

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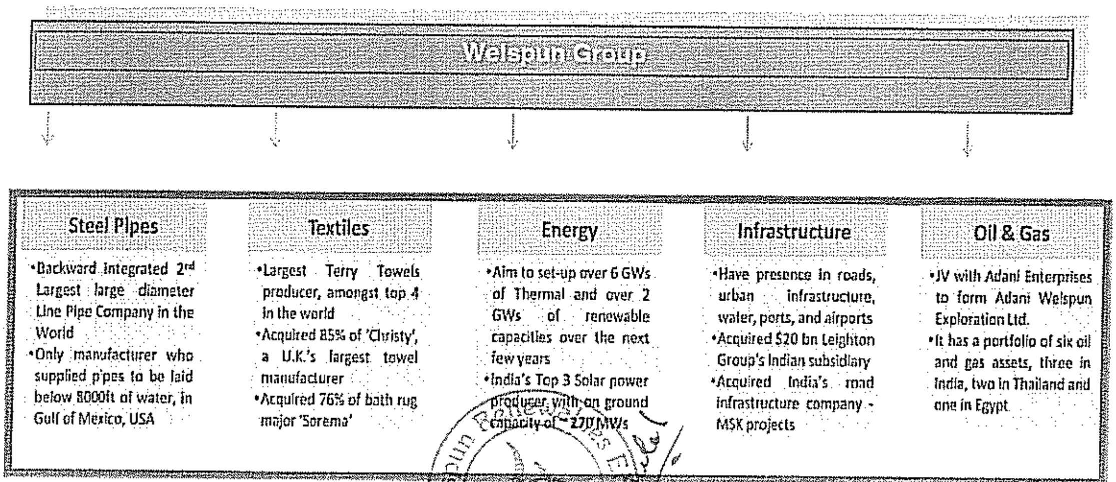
INTRODUCTION

The importance of electricity in modern world cannot be overemphasized. The quantum of electricity generated in a country has an important bearing on the Industrial growth and also on the quality of life.

Major electricity producing sources are coal and oil, which have limited reserve for long-term consumption. Apart from that, these fuels produce atmospheric pollution due to emission of Green House Gases (GHG) and other pollutants. Efforts are being made globally to mitigate this problem and to concentrate more on producing energy through renewable sources. Wind energy is now generally considered as a commercially viable option to increase energy generation as well as reduce the atmospheric pollution and consequently the global warming. In last two decades, the technology has developed well and the energy converting systems now operate with reliability in a cost effective manner.

THE WELSPUN GROUP

The Welspun Group is one of the fastest emerging Indian conglomerates with revenues of over U.S. $ 3.5 billion. The Group has diversified business interests with a major presence in the following business lines:



Welspun Corp Limited (WCL), the flagship Company of the Group is the world's largest steel pipe producer and the second largest producer of large diameter pipes. The Company has supplied pipes for the world's deepest pipeline project (Independence Trail', Gulf of Mexico), highest pipeline project (Peru LNG), longest pipeline (Canada to US) and the heaviest pipeline (Persian Gulf). WCL has an esteemed client list which includes Transcanada Enterprise, Kinder Morgan, Texas Gas, Hunt Oil, Saudi Aramco, Elpaso, Exxon Mobil and Qatar Petro DOW to name a few. Welspun is considered one of the premier Global Line Pipe and Home Textile Companies.

Brief Synopsis

- One of the fastest emerging global groups, with multiple countries strategy and manufacturing facilities
- **2nd Largest Large Diameter Pipe Company in the World** (Financial Times, UK, 2008)
- **3rd Largest Home Textile Company in the World** (Home Textiles Today 2010)
- Equity investment by renowned investors like Apollo, ICICI Life, Temasek (Govt. of Singapore), 3i (UK), Genesis (UK)
- Excellent relationship with domestic and international lenders. Marquee client includes Exxon Mobil, Chevron, Shell, Transcanada, Wal-Mart, Target and many more.
- The company has the distinction of having supplied pipes for the **world's deepest gas pipeline in the Gulf of Mexico** and was **ranked 39th by Standard and Poor amongst India's top 100 companies.**
- Business India, a leading Indian business magazine, has ranked Welspun as India's fastest growing company.

Key Markets

- 80% export mainly to US, Europe, Latin America, Africa, South East , Middle East etc

International Setup

- Christy, UK
- Office in Manhattan-NY, Huston-US
- Pipe & Coating Facility in Saudi Arabia
- Pipe & Coating facility in Arkansas, US

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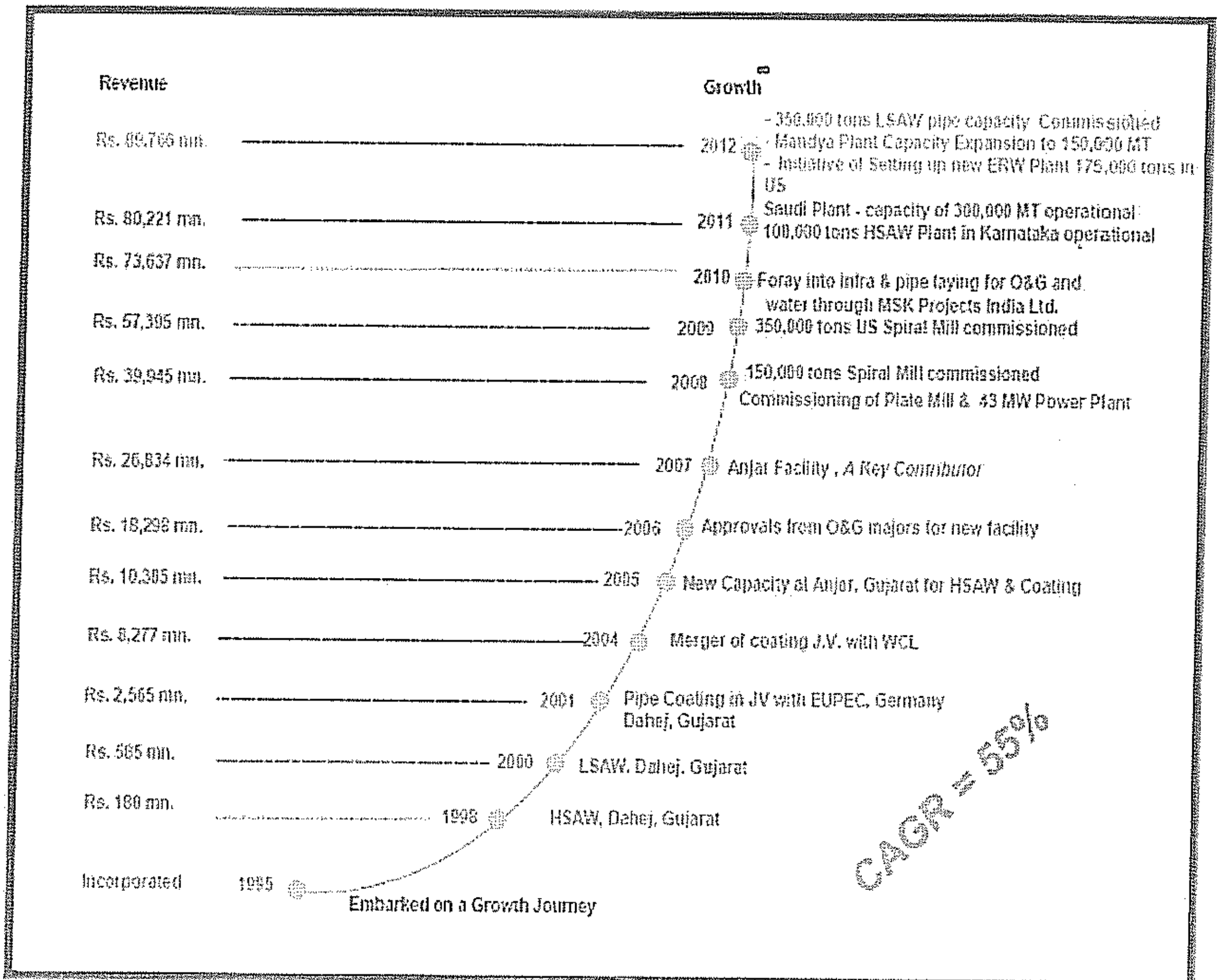
Welspun Key Financial Highlights

In the last FY, in one of the largest private equity (PE) deal of its time, Apollo Global Management has invested $500 million in the diversified Welspun Group.

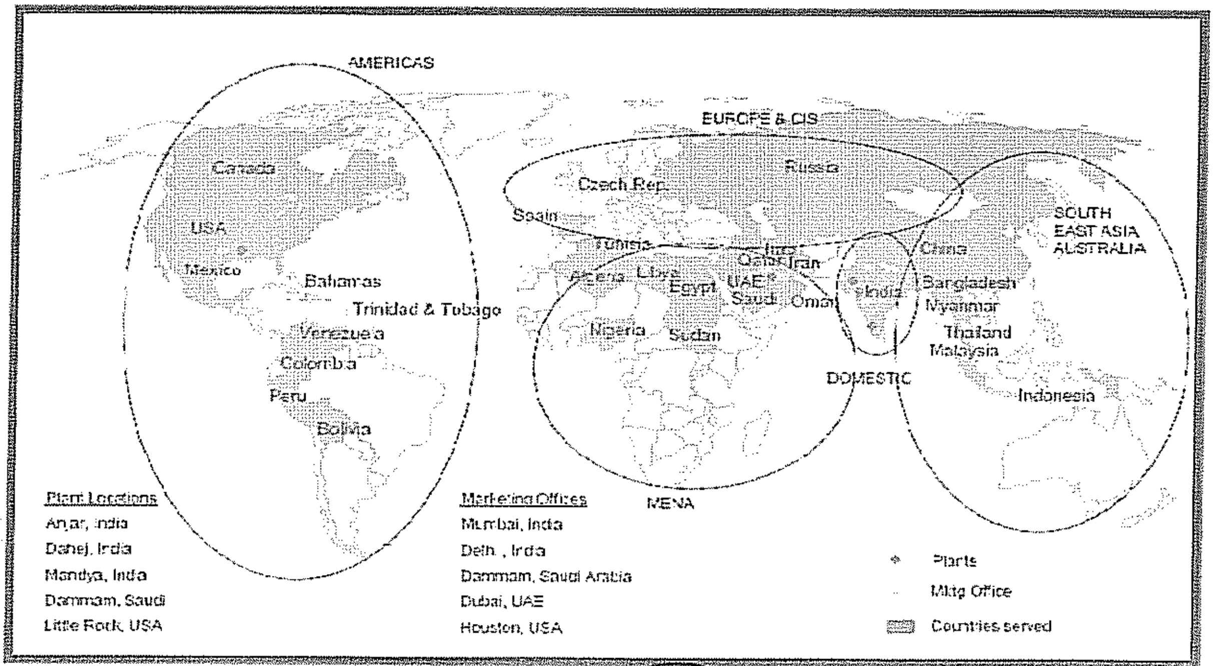
This was Apollo's second and largest investment in India. It is also the second-largest investment by a single PE player in India, after Carlyle put in $660 million (Rs 2,970 crore) in HDFC Bank in 2007. As stated by Mintoo Bhandari, Managing Director, Apollo Global Management (India) Advisors Ltd, "This is the largest investment we have made in India. Welspun has a strong history of growth and profitability in global oil & gas pipeline industry and is at the cusp of becoming a leading globally integrated pipe manufacturer" shows the strong faith of investors in Welspun`s capabilities.



Our Relationships

WCL is the Partner of Choice for more than 50 Oil & Gas giants across the globe with a geographically diverse client base including Chevron, Exxon Mobil (Golden Pass Pipeline), Saudi Aramco, British Gas, Kinder Morgan etc.

Welspun Global Presence



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Welspun Energy Private Ltd. (WEPL)

Welspun Energy, a group company of Welspun, is committed towards a Greener Environment by setting up 1000 MW of Solar Power and 750 MW Wind Power.

To achieve this goal, we are spreading our footprint globally by continuously exploring opportunities for renewable and thermal energy based generation projects. Welspun Energy considers the environment its responsibility and is committed towards low carbon emissions and proactive mitigation efforts.

Vision

- To make people's lives easier by providing clean electricity in a sustainable way. This requires us to constantly look for ways to improve, to grow and to reduce our impact on the environment

Objectives

- To operate and maintain profitable thermal, solar and wind power plants in an efficient and environmental friendly way in order to meet India's growing demand for electricity.

WELSPUN ENERGY RAJASTHAN PRIVATE LTD. (WERPL)

Welspun Energy Rajasthan Private Ltd (WERPL or Company) has been incorporated for developing Wind Energy Project of 126 MW in Pratapgarh District of Rajasthan. WERPL is a step-down subsidiary of Welspun Energy Private Limited ("WEPL") and wholly owned subsidiary of Welspun Renewable Energy Private Limited ("WREPL").

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ADVANTAGE OF WIND POWER GNERATION

There are various factors which indicate the suitability of harnessing wind power for producing electrical energy.

i. The technology of electricity generation from wind has been developed fully for its smooth and trouble-free operation as well as for its economic viability.

ii. It is pollution free and eco-friendly.

iii. Low gestation period – less than twelve months from concept to commissioning, enabling fast bridging of power gap even in remote areas.

iv. With no fuel consumption, power generation becomes almost free after recovery of capital cost. O & M. cost is nominal.

v. It can be developed in modular form with facilities for extension at a later date.

WIND POWER DEVELOPMENT IN INDIA

The importance of power generation in India was realized during seventh five year plan (1985 to 1990). According to preliminary assessment, the gross potential of wind power in India is estimated as 1,02,788 MW at 80m Hub height which is likely to increase. Major states having wind power potential are Tamil Nadu, Karnataka, Kerala, Andhra Pradesh, Gujarat, Rajasthan, Maharashtra and Madhya Pradesh. State wise estimated potential is as shown:

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STATE-WISE ESTIMATED WIND POWER POTENTIAL IN INDIA

Sl. No.	State / UTs	Installable Potential (MW) @80 m	Sl. No.	State / UTs	Installable Potential (MW) @80 m
1	Andaman & Nicobar	365	16	Madhya Pradesh	2931
2	Andhra Pradesh	14497	17	Maharashtra	5961
3	Arunachal Pradesh	236	18	Manipur	56
4	Assam	112	19	Meghalaya	82
5	Bihar	144	20	Nagaland	16
6	Chhattisgarh	314	21	Odisha	1384
7	Dieu Daman	4	22	Pondicherry	120
8	Gujarat	35071	23	Rajasthan	5050
9	Haryana	93	24	Sikkim	98
10	Himachal Pradesh	64	25	Tamil Nadu	14152
11	Jammu & Kashmir	5685	26	Uttarakhand	534
12	Jharkhand	91	27	Uttar Pradesh	1260
13	Karnataka	13593	28	West Bengal	22
14	Kerala	837	29	Others	-
15	Lakshadweep	16	Total		102788
			(Source : MNRE)		

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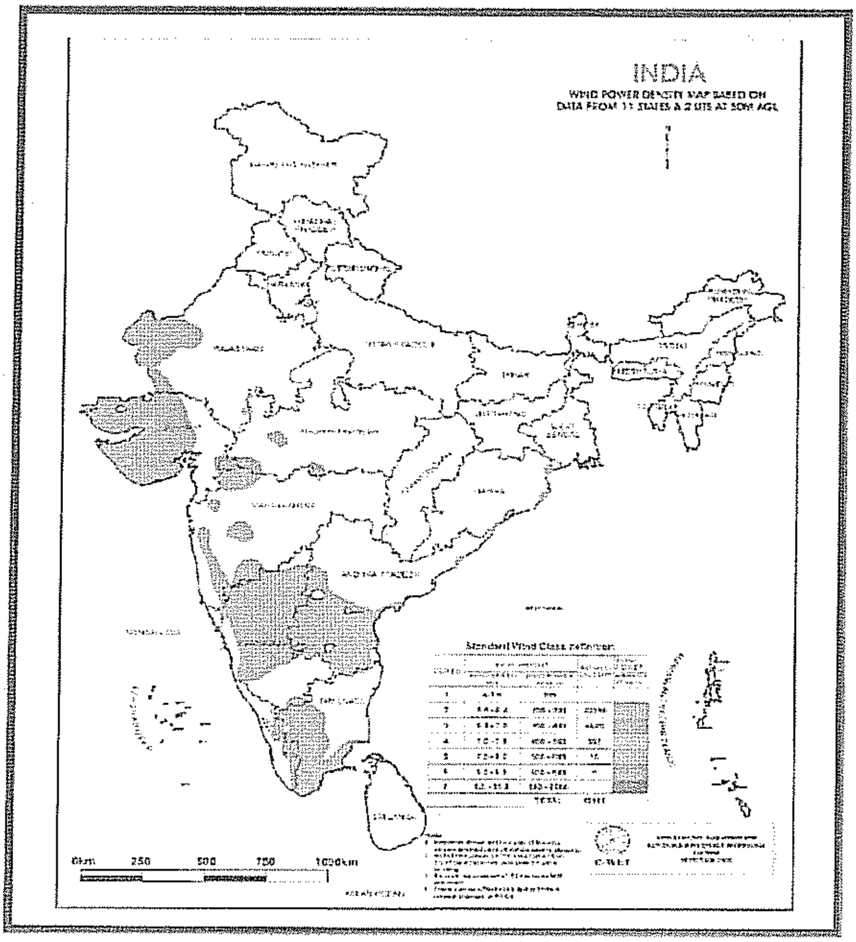
WIND RESOURCE ASSESSMENT

Wind resource is expressed in terms of annual average power per unit area, which is known as Wind Power Density or WPD. The primary requirement for successful implementation of wind power development program rests on proper assessment of these natural resources. Ministry of New and Renewable Energy (MNRE), Govt. of India is carrying out nationwide wind resource assessment program under which wind mast with measuring instruments are installed at selected places and data are collected for 1 to 3 year period to assess the wind resource for commercial exploitation. So far 598 wind monitoring stations have been installed in India, out of which 225 stations have recorded wind data which meets the qualifying benchmark of 200 W/m2 Wind Power Density (WPD) at 50 m height



Wind power map of India

BASIC CONCEPT OF WIND ENERGY CONVERSION

Air in motion is called wind. Power is available in the wind in the form of Kinetic energy. Power available in the wind is defined by the relation:

$$P = 1/2\, d\, AV^3$$

where, P = Wind Power

d = Air density

A = Area intercepted

V = Wind speed

& $P/A = 1/2\, dV^3 = WPD$

Where, WPD means Wind Power Density, which is a measure of wind. Power available in the wind can be defined as wind power per unit area. Wind Electric Generator converts Kinetic energy available in wind to Electrical energy by using rotor, gear box and generator. Wind Electric Generators are highly sophisticated machines based on aerodynamic principles and electronic control system.

WIND POWER INSTALLED CAPACITY IN INDIA

According to MNRE, the installed capacity of wind power in India ,till January 2014, is 20,150 MW. State wise installed capacity of wind power in order of capacities is as below:

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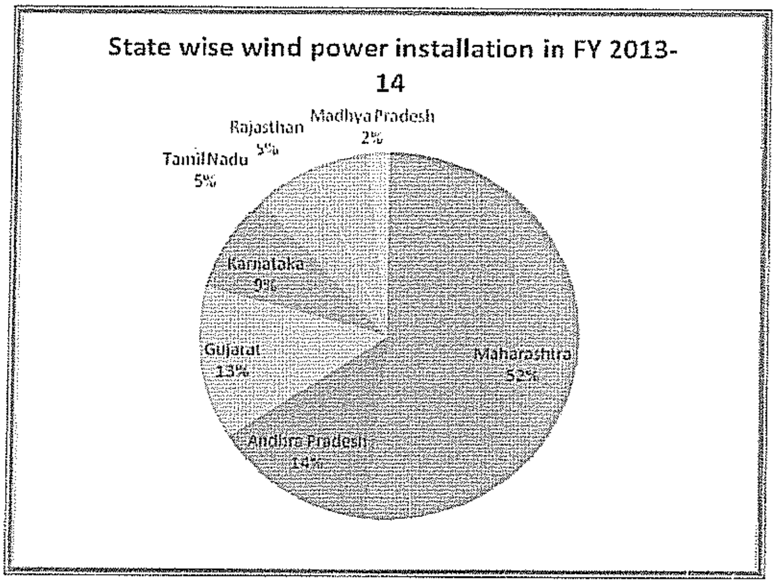

GOVT. INITIATIVES FOR WIND POWER DEVELOPMENT

Keeping in view the global trend, the Government of India has taken various steps to increase energy generation through wind and other nonconventional sources. India is perhaps the only country in the world to have an exclusive Ministry for New and Renewable Energy (MNRE). Program for Renewable Energy Technologies are implemented through State Nodal Agencies (SNAs). In order to promote Renewable Energy Technologies on commercial basis, MNRE has established Indian Renewable Energy Development Agency (IREDA) for providing financial assistance. MNRE has established Centre for Wind Energy Technology (C-WET) to act as a technical focal point for wind power development in the country.

Supportive government policies and incentives have been formulated and the investment in this sector has been substantial and is on the increase.

Electricity Act 2003 makes it mandatory for state utilities to purchase a certain portion of their energy requirement from renewable energy sources. Through State Electricity Regulatory Commission (SERC), the terms and conditions of electricity generation and sale through wind farm projects are being rationalized.

ESSENTIAL REQUIREMENTS FOR WIND POWER PROJECT

The essential requirements for establishment of a wind power project for optimal exploitation of the wind are:

i. High Wind Resource at particular site.

ii. Adequate Land availability.

iii. Suitable Terrain and good soil condition.

iv. Proper approach to site.

v. Suitable power grid nearby.

vi. Techno-Economic selection of WTGs.

vii. Scientifically prepared layout.

However, financial viability of the project is the most important factor which mainly depends upon cost of the project ,plant generation, O & M, tariff declared by the state and other incentives provided by state and central government.

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WIND RESOURCE ASSESSMENT

General

The most important aspect for a wind farm project is the estimation of wind resource of the site. Generally wind resource and power generation potential is estimated on the basis of wind data obtained over a period of few years. Since power in the wind is proportional to the cube of wind speed, it is not sufficient to know only the mean wind speed over a period of month or year but it is also necessary to know the frequency distribution and direction of wind speed. It is therefore, essential that data should be available for wind speed distribution over a period of time.

In Pratapgarh District 2 stations have been established by CWET, and both the met mast has shown wind speed of more than 5 m/s at 20 m height.

Wind characteristics of the site:

The Indian Institute of Tropical Meteorology has so far mapped wind resources of Rajasthan at 26 locations. The Wind Mast Site, the Name of the District, Average Wind Speed, Wind Density profile and Power Potential per square meter for eight feasible sites are as under:

Wind Mast Site	District	Annual Mean Wind Speed KMPH		Annual Mean Wind Power Density (W/M^2)	
		[illegible]	[illegible]	[illegible]	[illegible]
Dhamotar	Pratapgarh	18.8	19.50	149	163
Devgarh	Pratapgarh	19.88	21.38	151	186
Harshnath	Sikar	20.62	22.60	206	277
Jaisalmer	Jaisalmer	17.80	19.50	159	202
Jaswantgarh	Udaipur	18.90	19.40	142	152
Khodal	Barmer	17.00	18.50	135	170
Mohangarh	Jaisalmer	15.50	17.50	117	161
Phalodi	Jodhpur	17.40	19.20	142	185

The wind data has been analyzed to understand the nature of site in terms of the Wind Climatology

Roughness:

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It is observed that site is on a track of barren lands surrounded by small hills. Bunches of trees were also found sparsely distributed along the roadside at few places near to the site ranging in height from 2 to 3m. Overall, the site has roughness which falls in 0.03m to 0.09m roughness length. Direction wise surface length descriptions at the site are shown in table shown on the next page:

S. No.	Direction Sector	Surface Roughness Length (m)
1	North	0.03
2	North West	0.09
3	West	0.03
4	South West	0.03
5	South	0.03
6	South East	0.09
7	East	0.09
8	North East	0.03

Wind Rose:

The predominant wind direction of the proposed site with the frequency distribution of the wind speed of the meteorological mast at the site is South West as depicted in the wind rose provided below:

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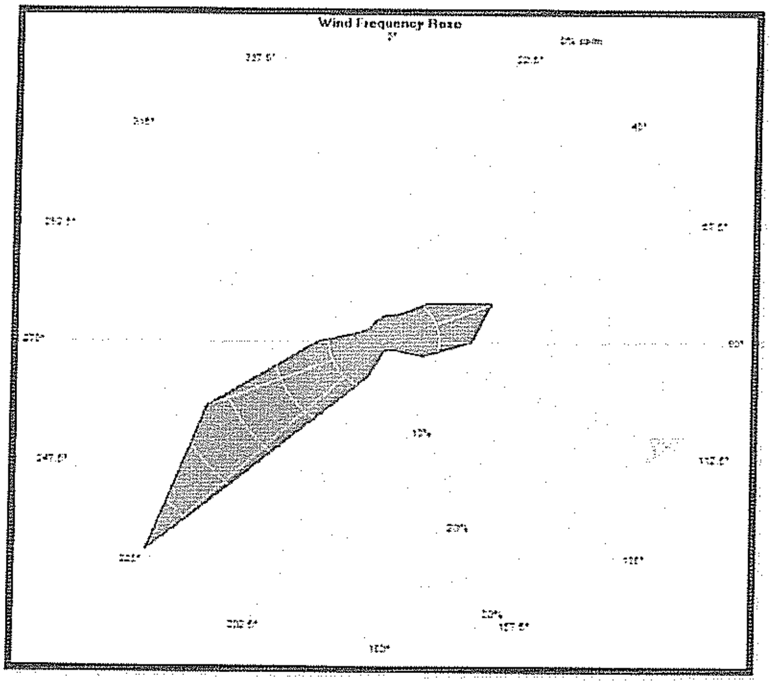

Wind Rose

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Wind Masts

Welspun Energy aims to develop 750 MW of wind power projects in the next three years. We envision developing our wind power projects pan India, focusing on states like Rajasthan, Karnataka, Gujarat, Madhya Pradesh, Maharashtra, Andhra Pradesh and Tamil Nadu.

We prefer to develop our sites through the self development model and carrying out wind assessment for a period of 1-3 years is a first step in that direction. We have started assessing wind potential by installing wind monitoring stations at various strategic locations in India to capture more reliable site specific wind data. Coupled with this, in-house assessment/analysis of collected wind data and estimates of generation is done. These are also being validated by external consultants like 3Tier, AWS etc.

We have carried out pan India mesoscale mapping in order to identify suitable sites for wind farms. We have installed wind masts across 5 states in India for continuous wind data monitoring. Based on detailed wind resource assessment, a significant land bank is envisaged to be identified and acquired. The process of acquiring land has been started in some sites.

SITE DETAILS

LOCATION

The proposed site is spread across 6 villages in Pratapgarh District namely Dhamotar, Kulmipura, Nakor, Tanda, Mahuri Khera & Tila located at an aerial distance of around 10 km on North of Pratapgarh City of Pratapgarh district of Rajasthan State. The site is accessible by roadways:

AMBIENT CONDITIONS

The ambient conditions at the proposed site are given below:

Maximum temperature	:	30°C – 45°C.
Minimum temperature	:	08°C to 15°C.
Average Annual Rainfall	:	Approx 200 mm

The atmosphere : non-saline.

LAND AVAILABILITY

The wind farm site is a mix of private and revenue land. The total area of the land required is around 150 acres. The micro-sitting for the 71 locations has been prepared.

WERPL has proposed to go ahead with 71 No. of WTGs with a total capacity of 126 MW.

The altitude of the site is between 450m to 550 m from the mean sea level. The site is having gentle ups and down and more of plane region.

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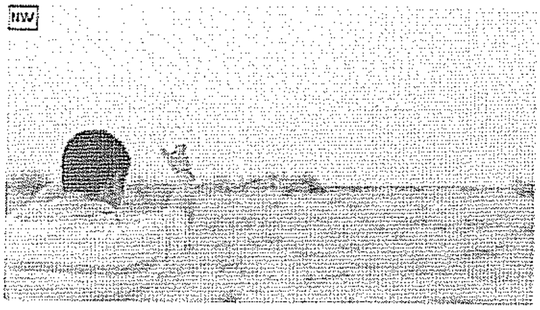

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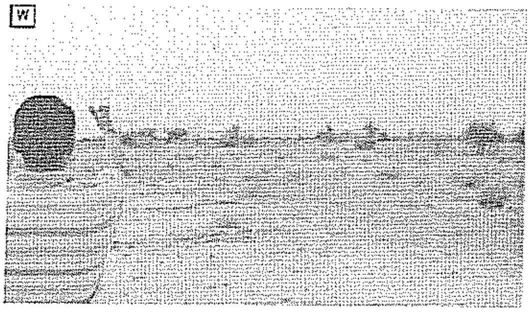

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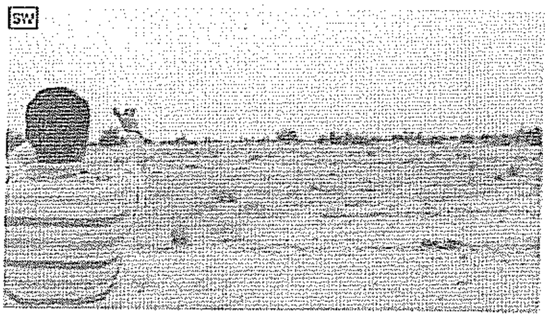

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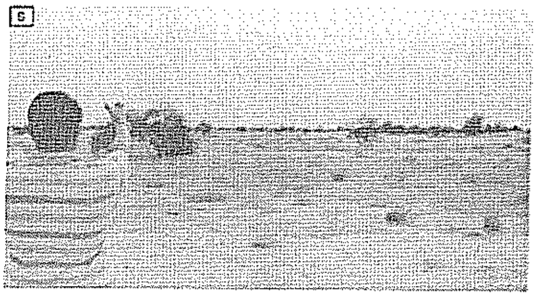

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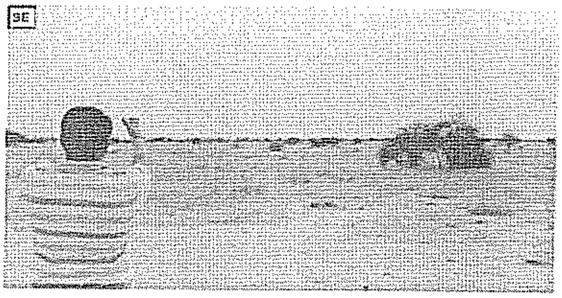

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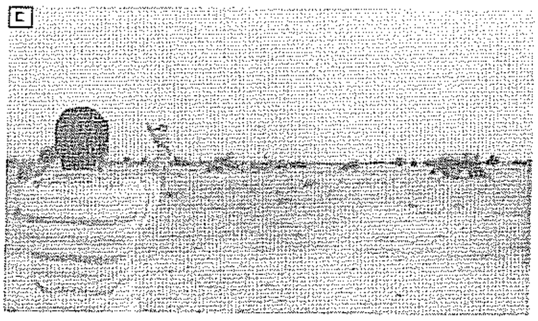

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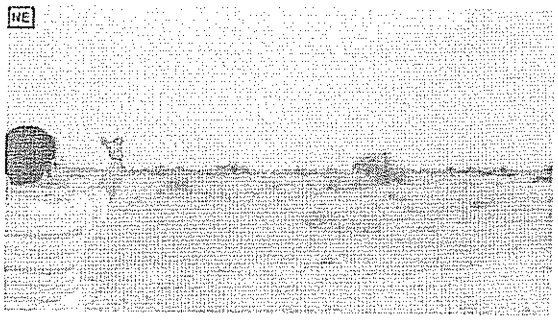

Panoramic View from the Base of Welspun mast.

GRID SUB STATION

Proposed EHV substation of Rajasthan Rajya Vidyut Prasaran Nigam Limited (RVPNL) is located at Pratapgarh (132/33 kV) extension proposed for up to 220 kV which is approx. 14 kms from the proposed site.

It is proposed to connect WERPL's wind farm to WERPL's 132 KV pooling substation through 33 KV internal overhead transmission line. This overhead line will be laid by using conductor and length will be according to the locations of WTGs and number of feeders.

Further M/s WERPL will construct 132KV double circuit external overhead lines which will be terminated at 132kV bay of Pratapgarh RVPNL substation with necessary required bay modifications.

Each Wind Turbine will be connected to internal OH line through individual unit transformer with necessary metering and protection arrangement.

M/s WERPL has received the permission from RRVPNL for evacuation of power generated from the proposed Wind farm vide letter dated 26.09.2012 and 23.04.2014.

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ACCOMMODATION

Good hotels are available at Udaipur and Chittorgarh. Accommodation for O&M staff can be arranged in nearby town.

BRIEF INFORMATION OF SITE

Sl.No	Item	Description
1.	Name of the villages	Dhamotar/ Kulmipura/ Nakor/ Tanda/ Mahuri Khera & Tila
3	District	Pratapgarh
4	State	Rajasthan
5	Nearest Town	Pratapgarh
6	Approach	NH 113 passes through above said villages
7	Nearest Railway Station	Pratapgarh
8	Nearest Airport	Udaipur
9	Type of Terrain	Plain/ Complex
10	Ownership of land	Revenue and Private
11	Area of the project site	150 acres
16	Nearest Grid Substation of Electricity Board	R.R.V.P.N.L 's 132/33 kV GSS Pratapgarh
17	Nearest existing Wind farm to the site	2.25 MW Demo Wind Power Project of RRECL
18	Soil Condition	Rocky / Murram

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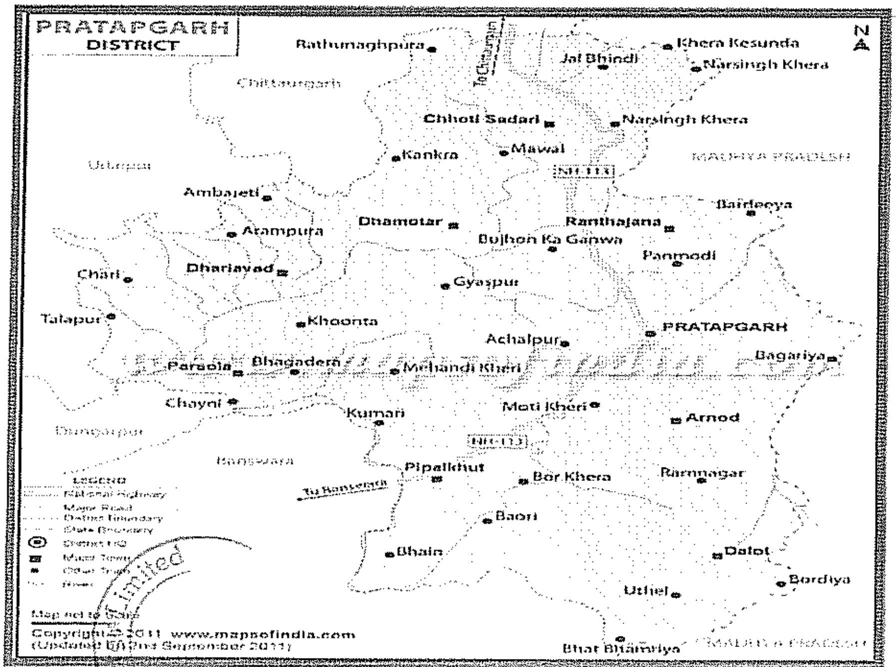
DISTRICT MAP OF RAJASTHAN

PRATAPGARH DISTRICT MAP



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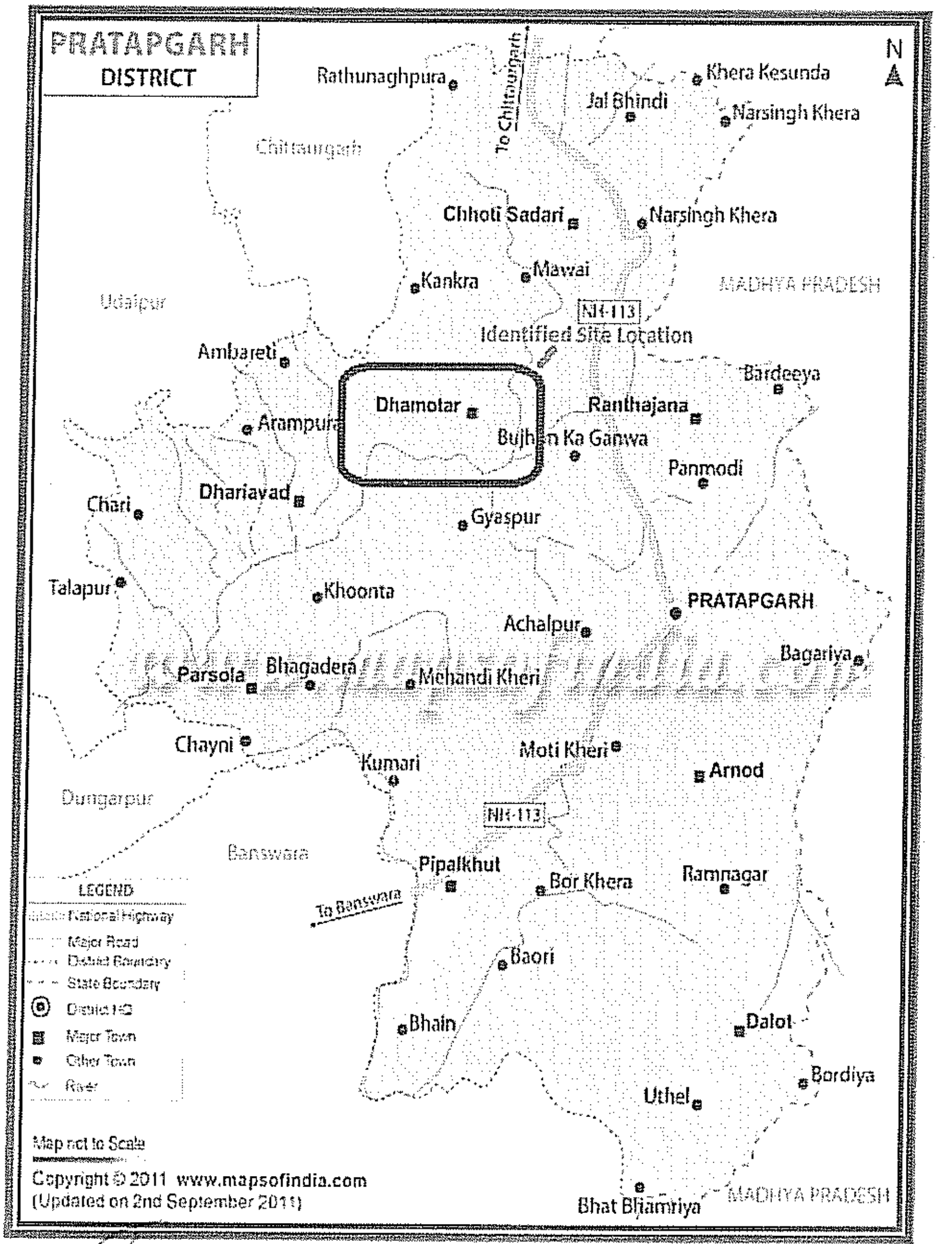
SITE LOCATION



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CHAPTER -5

2) METHODOLOGY

Wind resource assessments are conducted using 3TIER's modeling platform that combines on-site observations with mesoscale and microscale weather simulation models. The output from the modeling system is a four-dimensional data set of modeled historical weather for each meteorological (met) tower and wind turbine location. Model output is statistically calibrated using observed data from met towers. The resulting data sets are the basis for analysis of the wind resource.

The core of this modeling system is the Weather Research and Forecasting (WRF) Numerical Weather Prediction (NWP) model, developed in a partnership between U.S. federal agencies and universities. WRF is suitable for a broad spectrum of applications including air quality plume modeling, wind resource assessment, and climate modeling. WRF provides a flexible and computationally efficient framework that allows the worldwide academic, government, and private research communities to contribute advancements in physics, numerical methods, and data assimilation.

The WRF model uses the NCEP/NCAR reanalysis data for initial and boundary conditions . The reanalysis data set is a coarse resolution, observational-based data set that exists for the past several decades. WRF relies on the reanalysis data set to provide an accurate representation of the large-scale (hundreds of kilometers) historic flow patterns throughout the atmosphere (e.g. the location of high and low pressure centers, the position of the jet stream, etc). In addition, WRF requires as input high-resolution topographic and land-use data in order to accurately represent surface conditions. Land surface characteristics are derived from the 10 arc second (approximately 300m) resolution European Space Agency (ESA) GlobCover data set. Topographic data are sourced from the Shuttle Radar Topography Mission (SRTM) data set at 3 arc-second (approximately 90m) resolution. With these primary inputs, WRF then solves the dynamical and physical equations that describe the processes of the atmosphere. A nested grid configuration is used to simulate the fine-resolution, local-scale flow conditions given the large-scale state of the atmosphere (as described by the reanalysis data).

The Time-Varying Microscale (TVM) Model enables high-resolution mapping (tens of meters to a few hundred meters) of meteorological fields without the computational cost of running a high-resolution NWP model, such as the WRF model. TVM uses several techniques to analyze microscale winds. Kinematic terrain effects are applied to the wind field allowing TVM to resolve the effects of microscale terrain features, effects that are unresolved by a mesoscale NWP model. A Froude number adjustment is applied, which incorporates terrain blocking effects on the wind flow (i.e., determine whether the wind flows over or around specific terrain features). A log-profile surface roughness adjustment is also calculated to adjust the near-surface wind fields for the effects of roughness features that could not be resolved on the coarser WRF model grid. These effects are computed at each time step in the study period and are based not only on wind speed and elevation, but also on other quantities, including wind direction and the thermodynamic properties of the lower atmosphere. This enables a sophisticated time-varying spatial analysis at high-resolution.

On-site observational data are incorporated into the analysis to validate and correct the raw model data from WRF and TVM using a process of Model Output Statistics (MOS) correction. MOS uses multi-linear regression equations to remove bias and adjust the variance of the raw model output to improve the match with observational data at met tower locations. The MOS equation for each met tower is fit to the observational period of record. The MOS equation is then applied over the entire data set, correcting the historical period during which direct observational data are unavailable. MOS corrections are distributed across the model domain using a weighting scheme that depends on horizontal and vertical distance from the met tower.

A detailed analysis of the data set from each met tower ensures the integrity of the observational data before MOS- correction. Data are reviewed to ensure that:

- The functions to convert anemometer output to wind speed are appropriate, assuming raw data logger files and conversion functions are provided.
- Periods of icing affecting the accuracy of wind speed and direction measurement are excluded.
- Sensor data affected by the tower structures may be properly accounted for.
- Periods of anemometer dragging and/or malfunction are excluded.

During wind project development, met tower sensors are usually placed lower than the hub height of the proposed wind turbines. The analysis process must extrapolate the sensor data to hub height using a wind shear coefficient. Wind shear is a meteorological phenomenon in which wind speed values generally increase with height above ground level (AGL); the surrounding ground cover, trees, and topographic features such as hills and valleys can significantly affect the measured wind shear. The analysis calculates the shear coefficient from the observed data and then applies the coefficient to highest observed wind speed data to estimate wind speed values at hub height.

Long-term time series at the location of each proposed turbine location are extracted from the MOS-corrected data set. These hourly time series are then combined with the manufacturer's specified power curve to compute gross capacity factor values. Applying site-specific loss factor estimates to the mean P50 gross capacity factor yields the P50 net capacity factor. Uncertainty of the measured data and modeling data is then estimated to calculate the final net capacity factors at various probabilities of exceedance.

2.1 Wind Resource Assessment Steps

To determine the energy production potential of the proposed Pratapgarh wind project, the following procedure was implemented:

1. Simulate 43 years at 4.5km resolution using WRF to understand the long-term temporal variability of weather over the project site.

2. Simulate 1 year at 500m resolution using WRF to understand the spatial variability of the wind resource at the site.

3. Run TVM to downscale 500m WRF simulation to 90m spatial resolution.

4. Validate time series data collected from each met tower.

5. Run MOS to eliminate temporal bias and mitigate spatial bias of WRF/TVM model output. Compute MOS corrections at each met tower. Combine the high-resolution spatial model data with the coarser resolution long-term data, creating the final MOS-corrected 90m resolution 43-year data set.

6. Calculate the expected (P50) gross capacity factor using modeled long-term time series at the location of each turbine location in combination with the appropriate power curve.

7. Perform numerical wake and turbulence modeling.

8. Apply wake deficit as well as other site-specific loss factor estimates to the gross capacity factor, yielding the expected(P50) net capacity factor.

9. Calculate probability of exceedance levels for the net capacity factor data based on year-to-year wind resource variation, measurement uncertainty, and modeling uncertainty.

The following sections provide detail regarding the process outlined above as applied to the Pratapgarh wind project.

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3) OBSERVATIONAL DATA

Welspun Renewables Energy Limited provided observational data from the following towers at the proposed Pratapgarh site:

- Tower Pratapgarh

The location of each tower and the proposed turbine locations are shown in Figure on page 30 , and a summary of each tower is presented in Table below. 3TIER performed a site visit of the Pratapgarh wind project, and the data were inspected for quality control purposes following the visit. Site visit information and quality control of the observed data for each tower are described in detail within the following sections.

	Pratapgarh
Latitude	24.12255
Longitude	74.728288
Time Series Start	May-12
Time Series End	Jan-14
Max Sensor Height	100m
Observed 80m Sensor Height Wind Speed	6.24
Observed 100m Sensor Height Wind Speed	6.46
Extrapolated 80m Hub Height Wind Speed	6.24
Extrapolated 90m Hub Height Wind Speed	6.36
Long-term 80m Extrapolated Hub Height Wind Speed	6.26
Long-term 90m Extrapolated Hub Height Wind Speed	6.38
Average Shear	–
Turbulence Intensity at 15 m/s	0.11

On-site Met Tower Summary

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3.1 Tower Pratapgarh

The Pratapgarh Tower is located at 24.12255° N, 74.728288° E. The location of the tower and the turbine locations are shown in Figure on page 30. The tower is located on a flat plain used for agricultural purposes. At the time of the site visit, there were small crops, less than 0.5 m tall, in the fields surrounding the tower. An image of the terrain surrounding the Pratapgarh Tower is shown in Figure below. This lattice tower has instrumentation at three heights, including redundant anemometers at 100m and a single anemometer at the 80m hub height. A summary of instruments installed on the tower is shown in Table below:

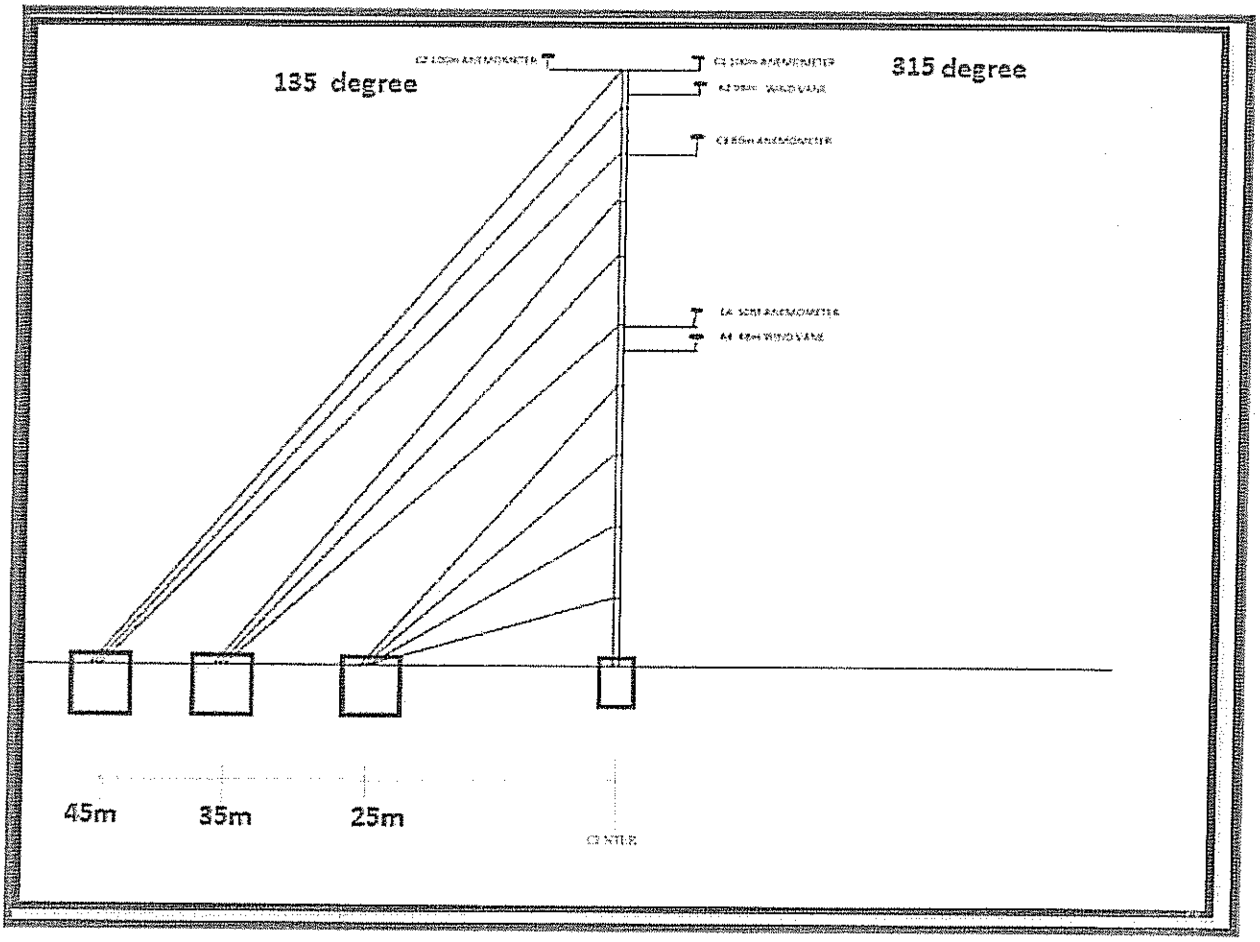
Instrumen	Height (m)	Boom
Anemometer	100	319°
Anemometer	100	124°
Anemometer	80	318°
Anemometer	50	319°
Wind Vane	95	319°
Wind Vane	50	318°

Pratapgarh Tower Instrumentation

Panoramic View from the Base of the Pratapgarh Tower.

DESCRIPTION OF METROLOGICAL MAST

The wind measurement on Pratapgarh sites is done using the installed with 100m Lattice mast. The instrument mounting arrangement is shown in given figure below:



Sketch of 100m Lattice Tower with Instrument Mounting Arrangements

Note: According to our requirement, the instrument mounting arrangement is NW (315) and only one anemometer at SE (135) is kept as redundant sensor. The wind data have been recorded using Second wind NOMAD 2 data logger, Second wind Class 3 cup type Anemometer (SWI C3C), Second wind Wind-vanes (SWI PV1). The data loggers were programmed to record mean and standard deviation of wind speed and direction, max wind speed, temperature and pressure at 10- minute intervals.

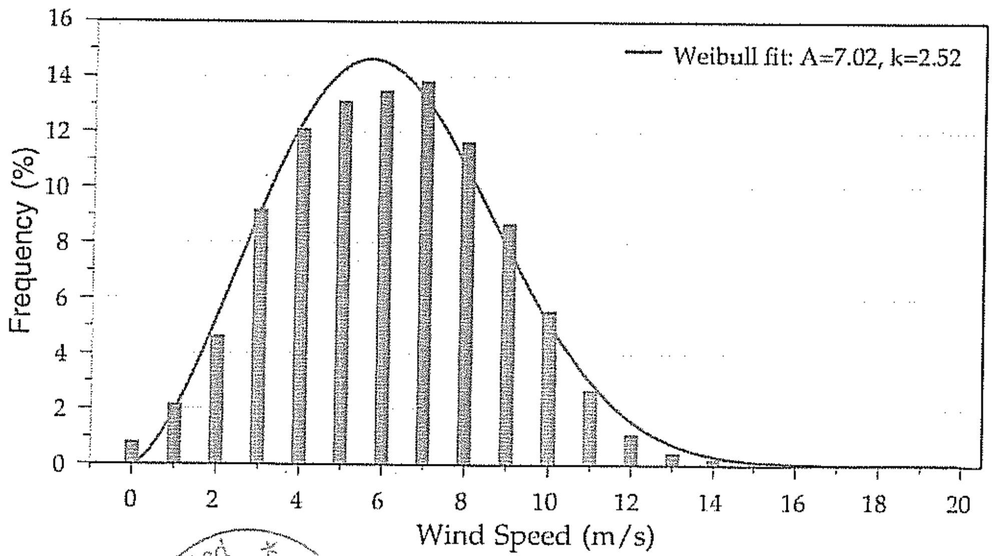
4) GROSS GENERATION

4.1 Wind Resource Variability

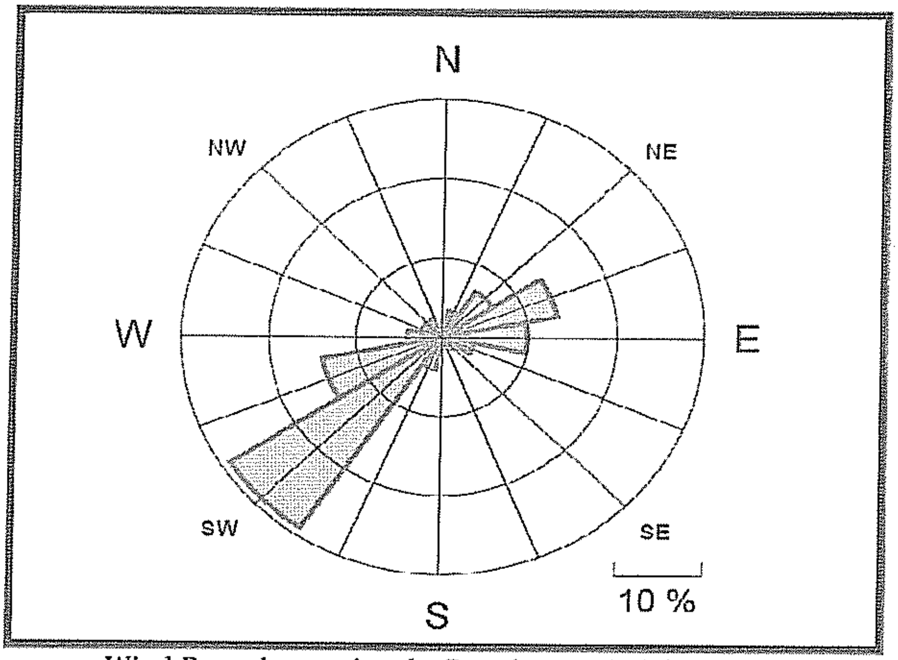
This section provides an analysis of the MOS-corrected model-simulated project-average wind resource at a height of80m over the past 43 years (January, 1971 – January, 2014). To generate the project-average wind resource time series, MOS-corrected wind resource time series data are extracted at each turbine location and then averaged across all 71 turbine locations. The long-term mean project-average wind speed at hub height is 6.23 m/s. A map of the 43-year average wind speed values at HH.

The distribution of hourly MOS-corrected project-average wind speed values is shown below. The distribution is based on the full 43 years of modeled data. . The figure displays the time series of gross project-average annual-mean wind speed values. The tables below show the average diurnal profile of wind speed values for each month of the calendar year. The second figure shows the monthly-mean wind speed value for each month of the 43-year analysis period.

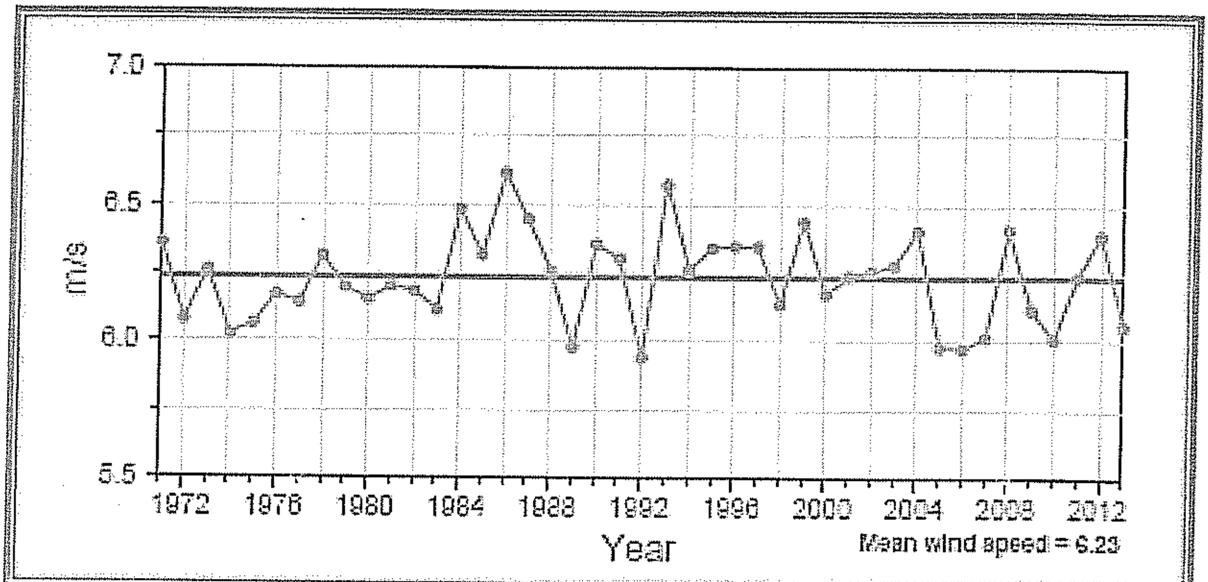
Based on the results of 3TIER's Energy Risk Framework, the last 43 years of data have been utilized for estimating the expected future generation at Pratapgarh. The mean project-average wind speed at HH over the past 43 years is 6.23 m/s.



Hourly distribution of simulated project-average wind speed using 1 m/s bins. (0 m/s bin contains only values ≤ 0.5.) Weibull distribution is also shown with the scale (A) and shape (k) parameters.



Wind Rose showcasing the Prominent wind direction



Year-wise wind speed variation

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Hour of Day (IST)	Jan	Feb	Mar	Apr	May	Jun	Jly	Aug	Sep	Oct	Nov	Dec	Avg
0:30	7.43	7.43	6.59	7.07	7.96	8.45	7.90	6.79	5.33	5.66	6.70	6.78	7.01
1:30	7.19	7.22	6.35	6.43	8.01	8.51	8.23	7.03	5.39	5.83	6.74	6.50	6.95
2:30	7.01	7.09	6.30	6.00	7.72	8.57	8.43	7.17	5.45	5.93	6.77	6.34	6.90
3:30	6.90	7.14	6.53	5.73	7.51	8.46	8.35	7.12	5.40	5.84	6.70	6.40	6.84
4:30	6.85	6.82	6.35	5.46	7.23	8.41	8.06	7.01	5.32	5.71	6.81	6.58	6.72
5:30	6.86	6.83	6.39	5.45	7.18	8.54	7.99	6.90	5.37	5.69	7.12	6.74	6.76
6:30	6.97	6.87	6.41	5.28	7.14	8.45	7.98	6.92	5.41	5.62	7.16	6.88	6.76
7:30	7.11	6.77	6.05	4.97	6.59	8.14	7.64	6.53	5.17	5.54	7.33	7.01	6.56
8:30	6.84	6.03	5.19	4.40	6.60	8.05	7.41	6.32	4.62	4.61	6.89	6.91	6.15
9:30	5.51	5.07	5.27	4.91	6.57	7.92	7.15	6.10	4.61	3.64	5.59	6.62	5.71
10:30	5.00	4.26	4.86	4.87	6.97	7.62	6.85	5.89	4.60	3.40	4.72	4.99	5.36
11:30	4.49	3.75	4.61	5.12	7.16	7.41	6.77	5.59	4.77	3.39	4.41	4.66	5.18
12:30	4.03	3.69	4.65	5.49	7.37	7.30	6.75	5.43	4.74	3.68	4.22	4.23	5.14
13:30	3.91	3.69	5.24	5.71	7.31	7.26	6.83	5.74	4.79	3.90	4.05	3.62	5.21
14:30	4.04	4.18	5.91	6.11	7.32	7.54	6.95	5.81	4.87	4.18	3.62	3.54	5.36
15:30	4.03	4.43	6.19	6.68	7.83	7.39	6.60	5.87	5.17	4.22	3.96	3.52	5.50
16:30	4.14	4.66	6.02	7.22	8.08	7.81	6.85	5.89	5.60	4.60	4.14	3.64	5.70
17:30	4.71	5.10	5.97	7.20	8.23	7.54	6.80	5.71	5.18	4.61	4.50	4.10	5.83
18:30	5.29	5.75	5.97	7.18	8.26	7.49	6.16	5.51	5.37	5.30	5.07	4.67	6.00
19:30	5.70	6.04	6.38	7.84	8.41	7.34	6.28	5.85	5.46	5.57	5.28	5.18	6.28
20:30	5.98	6.35	6.60	7.84	8.46	7.50	6.87	6.21	5.60	5.65	5.67	5.73	6.52
21:30	6.59	6.83	6.99	8.12	8.82	8.05	7.33	6.49	5.42	5.67	6.07	6.28	6.89
22:30	7.19	7.23	7.43	8.33	8.56	8.25	7.49	6.73	5.46	5.85	6.29	6.66	7.13
23:30	7.42	7.29	7.08	7.63	8.19	8.50	7.75	6.73	5.36	5.82	6.46	6.78	7.06
Avg	5.86	5.88	6.04	6.29	7.67	7.94	7.31	6.31	5.20	4.88	5.69	5.56	6.23

Wind Speed (m/s): 3 4 5 6 7 8 9

Hourly Mean values of simulated project average wind speed

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Year	Jan	Feb	Mar	Apr	May	Jun	Jly	Aug	Sep	Oct	Nov	Dec	Avg
1971	5.97	5.76	6.14	6.24	7.75	8.71	7.72	6.65	5.44	4.68	5.42	5.57	6.30
1972	5.30	5.65	5.95	6.68	7.45	7.42	6.01	6.29	5.40	4.59	4.94	5.34	6.08
1973	5.36	6.42	6.41	6.14	7.25	8.55	6.90	5.67	5.09	5.37	4.92	6.16	6.26
1974	4.76	5.93	5.90	6.60	7.42	8.25	7.20	6.92	5.03	4.78	4.80	4.52	6.03
1975	5.52	6.03	6.43	5.73	6.07	7.39	7.12	5.34	5.43	5.32	5.54	4.95	6.06
1976	5.44	5.62	5.63	6.33	5.63	8.15	6.36	6.49	4.96	4.56	6.07	5.59	6.17
1977	5.66	5.99	6.16	6.76	7.35	7.25	7.12	6.19	5.67	4.61	6.40	4.93	6.14
1978	6.06	5.79	6.06	6.10	7.74	7.35	6.73	6.67	5.50	5.26	5.64	5.95	6.31
1979	6.67	6.07	5.92	5.66	6.78	7.37	7.65	5.96	5.10	5.10	6.66	5.33	6.20
1980	6.20	5.40	6.24	6.31	5.03	6.30	7.58	6.10	5.05	4.77	6.17	5.50	6.15
1981	5.79	5.74	6.24	5.85	7.56	8.37	7.11	5.23	5.03	5.00	5.32	6.52	6.20
1982	6.81	5.65	6.09	6.66	6.52	7.50	7.29	6.05	4.84	5.32	5.73	5.29	6.18
1983	5.71	5.85	6.64	7.02	7.25	6.97	6.91	5.49	4.45	4.65	6.00	5.59	6.11
1984	5.77	6.45	5.92	6.30	5.33	8.17	7.28	6.71	6.04	4.65	5.75	6.45	6.48
1985	6.68	4.29	5.32	6.72	7.27	9.46	7.33	6.64	5.51	5.20	5.41	6.07	6.32
1986	6.26	6.23	6.51	6.20	7.20	7.86	8.34	7.00	6.00	5.40	5.71	6.41	6.62
1987	6.64	5.24	6.04	6.33	7.21	7.19	8.09	6.69	5.77	5.36	6.05	6.17	6.45
1988	6.09	5.72	5.67	6.20	7.76	7.96	6.60	6.33	5.65	4.90	6.20	5.92	6.26
1989	4.92	4.25	6.55	5.74	6.63	7.33	7.78	5.60	4.71	4.92	6.24	6.59	5.98
1990	5.12	5.82	5.83	6.45	7.20	8.06	6.80	5.21	6.51	5.37	5.77	6.44	6.36
1991	5.78	5.65	6.40	6.26	7.23	7.72	6.78	7.61	5.59	4.96	6.05	5.23	6.30
1992	6.02	5.23	5.46	6.03	6.65	7.56	6.79	5.46	4.73	5.11	6.45	5.52	5.94
1993	5.11	5.09	6.97	6.57	5.16	7.57	6.99	7.16	5.75	5.78	5.94	6.41	6.57
1994	6.21	6.30	5.55	6.38	7.54	7.51	7.08	5.97	4.76	5.88	6.94	5.06	6.26
1995	6.29	5.60	6.52	6.53	6.90	7.59	6.93	7.05	4.99	5.98	5.69	5.96	6.34
1996	6.55	5.43	6.06	6.12	7.28	7.95	6.58	6.95	4.63	5.65	5.11	6.27	6.35
1997	6.15	4.85	6.21	6.36	7.25	7.59	6.96	6.51	5.42	5.77	6.10	5.96	6.35
1998	6.13	5.72	6.05	6.26	7.03	7.42	7.56	6.30	4.59	4.99	5.95	6.31	6.14
1999	5.26	7.40	5.62	6.84	7.97	8.46	8.14	7.25	6.54	4.81	4.89	5.84	6.44
2000	5.53	5.91	5.90	6.60	7.99	8.35	7.68	7.04	5.72	3.75	4.66	4.95	6.17
2001	5.61	5.46	6.75	6.28	6.13	8.36	7.57	6.16	5.17	4.14	5.69	5.49	6.24
2002	5.95	5.76	6.27	6.20	5.42	7.55	8.60	6.45	4.95	4.60	5.31	4.74	6.26
2003	6.60	6.45	6.07	6.01	7.52	8.47	6.04	6.12	5.76	5.60	5.64	5.12	6.28
2004	6.40	5.28	5.25	6.90	7.97	8.66	7.14	6.89	4.90	5.56	6.01	5.47	6.40
2005	5.92	5.60	5.90	6.33	7.03	7.06	6.72	6.44	5.05	4.96	4.99	5.71	5.98
2006	5.62	5.22	5.80	5.64	7.36	7.62	7.77	5.68	4.56	4.95	5.27	5.33	5.97
2007	5.63	5.66	6.03	6.04	7.65	7.57	7.69	5.95	4.90	4.27	4.90	5.55	6.02
2008	6.16	4.97	5.51	6.38	9.36	9.21	8.18	6.18	6.07	4.52	5.64	5.71	6.41
2009	5.89	5.18	5.85	6.31	7.63	7.91	7.22	6.42	4.56	4.81	5.75	5.52	6.12
2010	5.72	5.84	6.29	7.16	6.15	7.55	5.78	4.77	4.74	5.14	5.98	6.04	6.01
2011	5.17	6.40	5.99	6.05	6.24	9.62	6.74	5.93	5.26	5.12	5.36	6.02	6.24
2012	6.24	5.97	5.85	6.79	7.71	9.45	8.05	6.69	4.91	4.65	4.95	5.39	6.39
2013	6.15	6.81	5.72	5.61	7.98	7.41	6.67	6.34	5.12	4.41	5.62	4.76	6.06
2014	5.89												5.89
Avg	5.89	5.85	6.04	6.30	7.67	7.95	7.30	6.29	5.19	5.01	5.69	5.57	6.23

Wind Speed (m/s): 3 4 5 6 7 8 9 10

Monthly Mean values of simulated project average wind speed

Wind Technical Department, Welspun

4.2 Gross Generation Variability

Following WRF/TVM modeling and MOS correction, 43-year simulated hourly time series of wind speed, wind direction, temperature, and pressure were extracted for each proposed turbine location at hub height. The simulated temperature and pressure data are used to normalize simulated wind speed data to the power curve's reference density with the equation

$$V_{norm} = V \left(\frac{\rho}{\rho_0}\right)^{1/3}$$

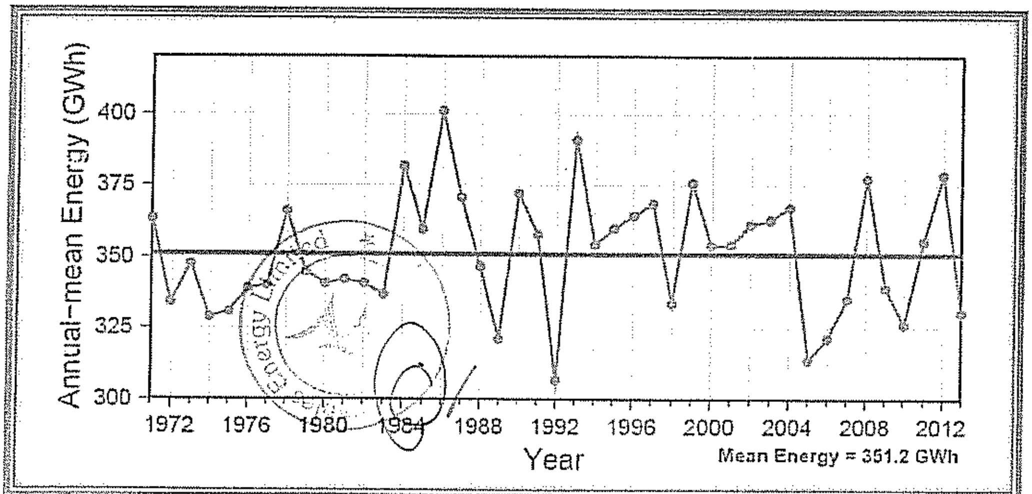
where V_{norm} is normalized hourly wind speed at hub height, V is simulated hourly wind speed at hub height, ρ is density calculated from simulated hourly temperature and pressure at hub height using the Ideal Gas Law, and ρ_0 is the reference density of the power curve.

The turbine power curve is then applied to the normalized wind speed data using piecewise linear interpolation between the power curve points supplied by the manufacturer. Turbine specific cut-in and cut-out limits on wind speed are also applied. This allows the manufacturer's power curve to be applied to the wind speed time series to calculate gross expected energy for all proposed turbine locations for each hour over the past 43 years.

Computing the nameplate capacity factor at each turbine and then averaging across all turbines yields the project-wide gross capacity factor value. Multiplying the project-wide gross capacity factor by the number of turbines, the nameplate capacity, and by 8766 hours yields the project-average gross energy estimate. The 43-year long-term mean gross energy estimate at the proposed Pratapgarh project is 351.2 GWh. Figure below shows the time series of gross project-average annual-mean energy values.

Based on the results of 3TIER's Energy Risk Framework, the past 43 years of data have been utilized for estimating the expected future generation at Pratapgarh. The 43-year mean gross energy estimate (i.e. the gross P50) at the proposed Pratapgarh project is **351.2 GWh**.

It is expected that GE1.6-87 and Gamesa G97-90 turbines will be erected at the site, each with a hub heights of 80m & 90m above ground level.



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Year-wise energy generation variation

Wind Speed (m/s)	Power (kW)
3.0	4.0
3.5	39.0
4.0	84.0
4.5	138.0
5.0	202.0
5.5	278.0
6.0	368.0
6.5	475.0
7.0	598.0
7.5	736.0
8.0	888.0
8.5	1047.0
9.0	1203.0
9.5	1349.0
10.0	1463.0
10.5	1542.0
11.0	1585.0
11.5	1610.0
12.0 – 25.0	1620.0

Power curve values for the GE1.6-87 - 1600kW turbine with a reference density of 1.225 kg/m^3.

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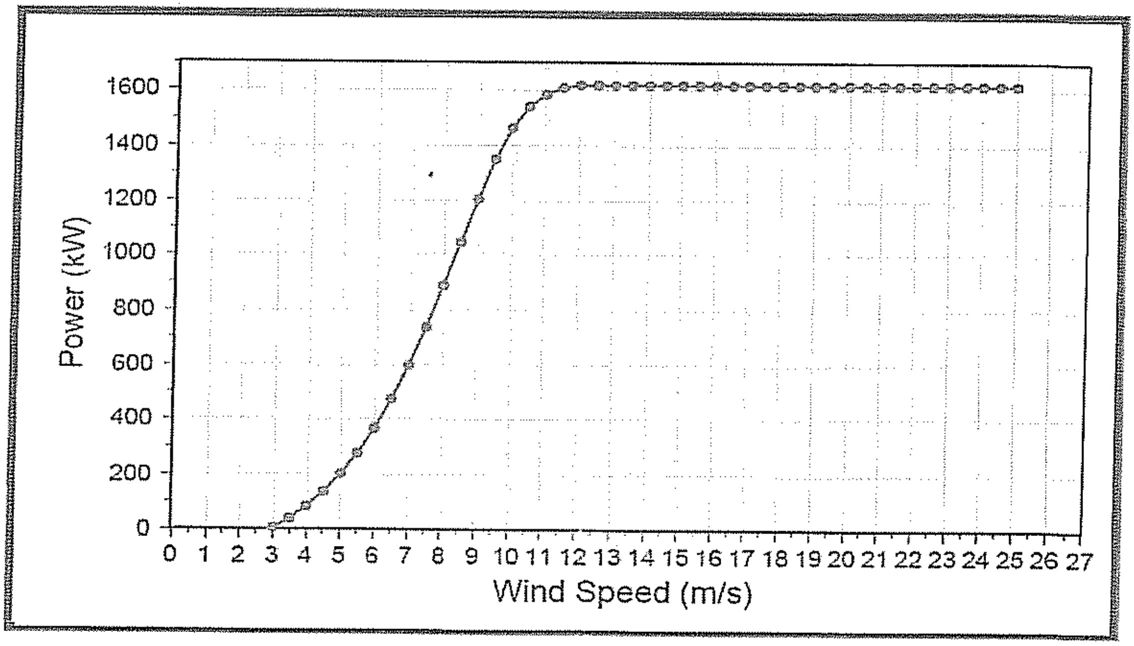
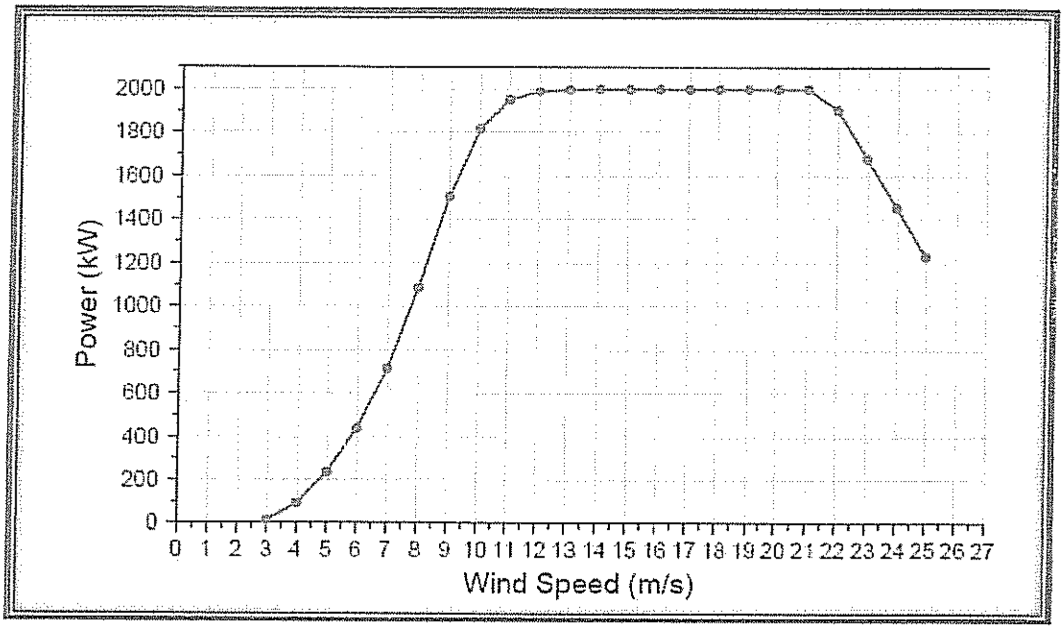


Power curve values for the GE1.6-87 turbine with a reference density of 1.225 kg/m³.

Wind Speed (m/s)	Power (kW)
3.0	14.0
4.0	94.0
5.0	236.0
6.0	438.0
7.0	714.0
8.0	1084.0
9.0	1507.0
10.0	1817.0
11.0	1951.0
12.0	1990.0
13.0	1998.0
14.0 – 21.0	2000.0
22.0	1906.0
23.0	1681.0
24.0	1455.0
25.0	1230.0

Power curve values for the Gamesa G97 - 2000kW turbine with a reference density of 1.225 kg/m³.



Power curve values for the Gamesa G97 turbine with a reference density of 1.225 kg/m³.

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5) LOSS FACTORS

To convert from expected gross generation to expected net generation, the following loss factor categories are considered: availability, curtailment, wake deficit, electrical efficiency, turbine performance, and environmental. Details for each loss factor are discussed below:

5.1 Availability

Availability losses include losses driven by turbine and transmission shutdowns caused by planned and unexpected faults.

5.1.1 Turbine Availability

3TIER has observed that turbine availability at newly constructed wind farms achieve 97.0% or higher availability when averaged over an entire calendar year. Therefore, the turbine availability loss factor is estimated to be 97.0%.

5.1.2 Balance of Plant Availability

The balance of the plant is estimated to have an expected availability of 99.7% based on a total of 24 hours of outage time per year per turbine for transformer inspections and maintenance. Therefore, the balance of plant availability loss factor is estimated to be 99.7%.

5.1.3 Grid Availability

The ability of the electric grid to receive and transmit wind power to load centers varies by year, season and location. Issues with grid availability are very dynamic and may actually be worsened as wind penetration levels increase. Data that 3TIER have received regarding grid availability for operational wind farms shows values ranging from 99% to 100% on an annual-average basis. The grid availability loss factor is estimated to be 99.0% for the Pratapgarh wind energy project.

5.2 Curtailment

Curtailment losses are based on forced wind plant shutdowns resulting from environmental conditions that can adversely affect the turbines. These curtailments include wind driven sector management, high wind hysteresis, extreme icing events, and extreme temperatures.

5.2.1 Sector Management

Standard minimum turbine spacing of three rotor diameters perpendicular to the dominant wind direction and five rotor diameters parallel to the dominant wind direction was tested against the layout. All turbine locations in the turbine layout comply with this requirement, therefore curtailment loss factor associated with sector management is estimated to be 100.0%.

5.2.2 High Wind Hysteresis

High wind speed hysteresis may occur when wind speed values exceed the turbine cut-out wind speed and are shut down. Before the turbine can re-start, the wind speed must slow down to the hysteresis cut-in wind speed. The hysteresis loss occurs when the turbine has shut down due to high wind speed cut-out and the wind speed remains between the hysteresis cut-in and the cut-out wind speed. Based on 43 years of modeled hourly wind speed data, cut-out wind speed events are very rare. Thus, the hysteresis loss factor is expected to be negligible, and a high wind speed hysteresis loss factor of 100.0% is applied.

5.2.3 Extreme Temperature

The Gamesa G97 turbines planned for the site are the Standard+ model, which allows for normal operation up to 35 degree Celsius. A de-rating scheme is applied on the G97 turbine for temperatures between 35 and 40 degrees. Based on 34 years of MOS-corrected data, temperature values at the site are not expected to exceed 40 degree Celsius at hub height; thus, the turbines are not expected to experience extreme temperature shut-downs. Temperature values are expected to periodically exceed 35 degree Celsius; however, when temperature values are high, wind speed values tend to be low. The Gamesa G97 de-rating scheme limits the rated power, which means the de-rating scheme only reduces power output when wind speed values are high. Because of this, the impact of the Gamesa G97 de-rating scheme is expected to be minimal. The GE 1.6-87 turbines are expected to operate normally up to 40 degree Celsius. The total loss factor for extreme temperature is estimated to be 99.9%.

5.3 Wake Deficit

3TIER's wake model is used to determine the expected expected wake deficit for the turbine layout. The magnitude of the losses at any given time is a combination of the gross wind field and ambient turbulence intensity across the park, the turbine layout, and physical characteristics of the installed turbines. 3TIER analyzes wakes using a proprietary time- varying wake model that analyzes the wake at every individual time within the simulated record, rather than relying on bulk statistical descriptions of the wind field. Wakes for each turbine are computed individually and interact in a physically consistent way, eliminating the need for posterior models to combine wakes from multiple turbines or add in deep-array effects. The single turbine wake model is based on concepts originally presented by Larsen et al. (1996). 3TIER's internal research has shown that the low bias associated with other Larsen-derived wake models is a result of poorly handled wake addition rather than the underlying model. The full system has been calibrated using production numbers from permanently installed turbines under a wide range of environmental conditions, including a broad span of turbulence intensities and stability regimes. The outputs from the model are wake-induced velocity deficit and turbulence intensity at all turbine locations, and can include additional reference locations.

5.3.1 Internal Wakes

Internal wakes represent wakes caused by turbines within the project. The effect of wake deficit on energy output for the layout leads to an internal wake loss factor of 94.4%.

5.3.2 External Wakes

External wakes represent additional wakes caused by turbines from surrounding wind farms. At this time 3TIER is unaware of any additional wind farms in the region that may wake the project.

5.3.3 Future Wakes

Future wakes represent wakes caused by turbines that will be built in the future, not related to this project. At this time 3TIER is unaware of any planned wind farms in the region.

5.3.4 Total Wakes

The total wake loss factor, including the project (i.e. internal) turbines, external turbines, and potential future turbines is 94.7%.

5.4 Electrical Efficiency

Electrical efficiency considers losses associated with the electrical systems connecting the turbines to the metering point. These systems include the on-site collection system, the substation power transformer, and the transmission line depending on the meter location. 3TIER assumes that the project will be metered at the low side of the substation power transformer. Based on the this metering point, the total electrical system efficiency is expected to be 98.0%.

5.4.1 Collection System Efficiency

The collection system efficiency covers the efficiency of all components from the turbines to the pooling substation, including the medium voltage transformer efficiency that steps up the turbine voltage to the collection system voltage.

5.4.2 Substation Power Transformer Efficiency

The substation power transformer converts the voltage of the collection system to the voltage of the high voltage transmission line. 3TIER assumes that the plant will be metered at the low side of the substation transformer; therefore, substation power transformer losses are not applicable.

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5.4.3 High Voltage Transmission Line Efficiency

Transmission line efficiency is dependent on the cable type, voltage, load, and the distance from the pooling substation to the plant metering point. 3TIER assumes that the plant will be metered at the low side of the substation transformer; therefore, high voltage transmission line losses are not applicable.

5.5 Turbine Efficiency

Turbine efficiency is based on the ability of the turbines to perform at a level relative to the manufacturer's suggested performance rating. This can be affected by many factors, including the manufacturer's warranted performance level, the turbulence, and inflow angle.

5.5.1 Turbine Performance

Based on 3TIER's experience with wind farms in the region, a loss factor should be applied for turbine performance. This loss factor is related to turbines not performing at the manufacturer's rated power curve. It is suggested that a turbine performance loss factor of 98.0% be applied to account for the risk that the turbines do not perform exactly at the manufacturer's rated power curve.

5.5.2 Turbulence Intensity

Research has linked turbine underperformance to stable atmospheric conditions. These conditions are often identified by low turbulence intensity. In addition, periods of low or high turbulence intensity can affect the specified power curve by creating a statistical averaging effect. The statistical averaging effect is assessed by comparing the average of the instantaneous wind speeds using a theoretical zero turbulence power curve against the manufacturer's power curve at given turbulence level. 3TIER analyzes the potential for both of these effects using the measured turbulence intensity and has calculated a loss factor of 98.0%.

5.5.3 Inflow Angle

Reduced efficiency associated with extreme inflow angles is expected to be negligible; therefore, an inflow angle loss factor of 100.0% is applied.

5.6 Environmental

Potential environmental losses include turbine under-performance caused by turbine blade soiling and degradation, extreme weather conditions such as icing and thunderstorms, and changes to the surrounding environment such as tree growth.

5.6.1 Blade Degradation

Blade degradation, unlike blade soiling, is permanent damage caused to the turbine blades by material in hitting the blades. This can include corrosive material, such as sodium chloride (sea salt), and larger diameter soil and dirt particles. 3TIER has analyzed projects in similar terrain and has calculated a standard loss factor for cultivated farmland conditions. A loss factor of 99.5% is applied for blade degradation.

5.6.2 Blade Soiling

In locations where the ground is dry and the soil is loose, turbine blades can build up substantial amounts of soil, leading to a power curve derating. 3TIER has analyzed projects in similar terrain and has calculated a standard loss factor for cultivated farmland conditions. A loss factor of 98.5% is applied for blade soiling.

5.6.3 Other Environmental Losses

Additional environmental losses, such as icing, thunderstorms and tree growth, are expected to be negligible.

5.7 Aggregate Loss Factor

Table below shows the individual loss factors for all considered categories and the aggregate loss factor. The product of all considered losses is 83.3%. The expected gross P50 generation is 351.2 GW h; therefore, the net P50 generation is the product of 83.3% and 351.2 GW h, which equals 292.4 GW h.

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Loss Factor	Percent Loss
Availability	
Turbine Availability	97.0 %
Balance of Plant Availability	99.7 %
Grid Availability	99.0 %
Curtailment	
Sector Management	100.0 %
High Wind Hysteresis	100.0 %
Extreme Temperature	99.9 %
Wake Deficit	
Total Wakes	94.4 %
Electrical Efficiency	
Total Electrical Efficiency	98.0 %
Turbine Efficiency	
Turbine Performance	98.0 %
Turbulence Intensity	98.0 %
Inflow Angle	100.0 %
Environmental	
Blade Soiling	98.5 %
Blade Degradation	99.5 %
Aggregate Loss Factor	**83.3 %**

Summary of Loss Factors

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6) UNCERTAINTY ANALYSIS

To calculate uncertainty and estimates of probabilities of exceedance, 3TIER has utilized its Energy Risk Framework. This framework is based on theoretical propagation of error theory and models hundreds of sources of uncertainty and their relationships throughout the modeling process. Each source of uncertainty is treated in a separate model that interacts with the framework through overlying covariance models. The analysis considers the following sources of uncertainty: measurement, vertical extrapolation, MOS correction, climate variability, spatial modeling, and power modeling.

6.1 Uncertainty Methodology

6.1.1 Measurement Uncertainty

Measurement uncertainty captures the uncertainties related to the on-site measured data utilized in the energy assessment. It is a measure of the confidence that the recorded data, which are presumed to represent the truth, actually do represent the truth. Individual components of measurement uncertainty include the following: anemometer uncertainty, benefits of utilizing redundant sensors, measurement height uncertainty, and the statistical propagation of these uncertainties through the wind shear and extrapolation calculations to estimate hub height wind speed values. Uncertainty is separately estimated for each measurement sensor, and the sensor uncertainties are aggregated together to represent the total measurement uncertainty at hub height level for each met tower. Measurement uncertainty estimates at each met tower are considered to be independent when predicting measurement uncertainty at each turbine location.

6.1.2 Vertical Extrapolation Uncertainty

If on-site measurements are not directly recorded at hub height, an uncertainty exists that the true vertical wind speed profile may differ from the assumed power law profile. A vertical extrapolation uncertainty is required to account for this uncertainty. Remote sensing and/or hub height measurements can reduce and potentially eliminate this uncertainty. Vertical extrapolation uncertainty is estimated at each met tower individually and, met tower estimates are combined assuming partial dependency on the mast and turbine heights when estimating vertical extrapolation uncertainty at the turbine locations. For example, if met towers are located in meteorologically similar environments, risk is increased that common errors are present in the vertical extrapolation process.

6.1.3 MOS Correction Uncertainty

A MOS Correction uncertainty is applied at each met tower that accounts for the probability that the statistical correction applied to the long term climate signal will accurately capture the true historic climate variability. The uncertainty associated with 3TIER's MOS correction algorithm decreases as the training period increases. The uncertainty depends on the length of data available at the met tower and the quality of the relationship between the met tower and the long

term data set.
MOS correction uncertainty is estimated at each met tower, and then individual uncertainties are combined to predict the uncertainty at each turbine location assuming partial dependence between

each met tower. This dependence is a function of the concurrency of measurements between the met towers, since the uncertainty of this relationship will depend on common errors in the climate signal used as the reference.

6.1.4 Climate Variability Uncertainty

Climate variability uncertainty is comprised of the following individual component uncertainties: historic climate, future climate, climate change, and climate signal consistency. Historic and future climate uncertainties represent the uncertainty associated with the natural variability of the climate and whether the climate reference period or future prediction period will capture the true climate. These uncertainties are a function of the inter-annual variability and auto-correlation of the climate signal. Climate change and climate signal consistency uncertainties represent the probability of error of the future prediction because the climate of the future may not be accurately represented by the climate of the past. These uncertainties are higher if the past few years show potential trends that may point towards a changing pattern. Climate variability uncertainty is considered common across all met towers and is modeled with complete dependence in the uncertainty framework.

6.1.5 Spatial Modeling Uncertainty

Spatial modeling uncertainty is estimated by calibrating a spatial model for each met tower that applies the MOS correction derived at that met tower to all the turbine locations. The individual spatial models are combined at each turbine location using weights that are a function of the total uncertainty at each met tower considering dependence and independence of each component uncertainty. Spatial uncertainties are a function of the geographic covariance between each met tower and turbine location. 3TIER applies two spatial modeling uncertainties: micro spatial uncertainty and macro spatial uncertainty. Micro spatial uncertainty represents the uncertainty associated with the grid resolution of the spatial model and whether the model is capturing micro scale effects. Macro spatial uncertainty represents the risk that a spatial model calibration at the location of a met tower is applicable at distances away from that met tower. This complex uncertainty is a function of all the prior uncertainties and relative proximity and complexity of each geospatial relationship. The dependence on prior uncertainties is driven by the weighting scheme of each met tower, which has uncertainty dependence. Spatial covariance is also considered when aggregating each individual turbine uncertainty into a project average uncertainty.

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6.1.6 Power Modeling Uncertainty

Power modeling uncertainty considers each step in converting wind speed estimates into energy estimates. In this step, wind speed uncertainties are expanded by the wind speed to energy relationship and then the following is considered: representativeness of the modeled frequency distribution when applying the specified power curve, wakes, availabilities, electrical losses, and all other losses considered in the loss evaluation process. Power modeling uncertainties are considered to be dependent between each turbine location.

6.2 Uncertainty Framework Results

The primary source of uncertainty for the Pratapgarh Wind Farm Project originates in the spatial modeling uncertainty. The turbines are spread over a relatively large area. The average weighted distance from the met tower to turbine locations is 4.2km. Installing an additional met tower within the proposed turbine array would help to reduce the spatial modeling uncertainty. 3TIER can provide specific recommendations concerning placement and configuration of an additional met tower, if needed. The measurement uncertainty also contributes significantly to the overall uncertainty of the analysis. Wind speed uncertainties can become significant components of the uncertainty analysis when converted to energy if the wind speed to energy sensitivity ratio is high. The sensitivity ratio is relatively high at this site. The sensitivity ratio is a function of the wind speed distribution and turbine type, which means additional data collection will not lower the value. Other than the spatial modeling uncertainty, the remaining uncertainty values fall within the typical ranges for a pre-construction analysis, given the relatively high sensitivity ratio.

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6.2.1 Met Tower Uncertainty

Uncertainty values for each met tower are presented as a function of wind speed below:

	Pratapgarh
Measurement	2.6
Vertical Extrapolation	0.0
MOS Correction	1.4
Climate Variability	1.2
Combined Uncertainty	3.1

Standard Error of Wind Speed Estimation at each Met Tower (%)

6.2.2 Combined Project Uncertainties

The total project uncertainties, represented as a percent of the P50 estimate are presented in Table 8 as a function of energy. Since the uncertainties are combined in a very complex manner that propagates through the full modeling process with varying degrees of dependence, individual categories of uncertainty are inferred.

	1-Year	5-Year	10-Year	20-year
Measurement	5.9	5.9	5.9	5.9
Vertical Extrapolation	0.0	0.0	0.0	0.0
MOS Correction	3.2	3.2	3.2	3.2
Climate Variability	6.6	3.7	3.1	2.2
Spatial Modeling	9.6	9.6	9.6	9.6
Power Modeling	4.4	4.4	4.4	4.4
Combined	14.2	13.0	12.9	12.8

Standard Error of Wind Energy Estimation (%)

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7) PROBABILITY OF EXCEEDANCES

Based on the estimated total project uncertainties, Tables below present the probability of exceedance levels associated with the P50 project estimate.

	1-Year	10-Year	20-year
Gross-P50	351.2	351.2	351.2
Net-P50	292.4	292.4	292.4
Net-P75	264.5	267.0	267.1
Net-P90	239.3	244.1	244.4
Net-P95	224.3	230.4	230.7
Net-P99	196.0	204.7	205.2

Probability of Exceedance Values (GWh)

	1-Year	10-Year	20-year
Gross-P50	31.8	31.8	31.8
Net-P50	26.5	26.5	26.5
Net-P75	23.9	24.2	24.2
Net-P90	21.7	22.1	22.1
Net-P95	20.3	20.9	20.9
Net-P99	17.7	18.5	18.6

Probability of Exceedance Values (%)

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CHAPTER -6

ESTIMATION OF INSTALLED CAPACITY

The proposed site is located in the radius of 10 kms of existing wind mast of CWET at Dhamotar. The total area is spread over 6 different villages. The proposed site is on a mix of revenue and private land and is a mix terrain with very gentle ups and down.

Estimation of installed capacity of a wind power project mainly depends on following factors:

a) Total area available

b) Geometry of the area

c) Obstacles like trees, buildings etc in the area

d) Orography of the site

e) Diameter of the rotor of the WTG

f) Rating of WTG

g) Predominant wind direction/ Wind rose

h) Micro sitting layout plan of WTGs

Estimation of installed capacity has been done for the proposed site of wind farm and considering with above suitable factors, WEL prepared a WTG layout considering Gamesa G97/90 HH 2MW & GE-87/ 80 HH 1.6 MW capacity models commercially available in Indian market

Make	Rating	Model	Rotor Diameter	Hub Height
Gamesa	2000KW	G97	97m	90m
GE	1600 kW	GE-1.6-87/80	87 m	80 m

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ESTIMATED ANNUAL GENERATION

GENERAL

Estimation of annual generation is the most important activity for examining the feasibility of installing a wind power project at any site. There are many software for energy estimation among them WASP is the most popular program and widely used in the world for energy estimation.

WASP – the Wind Atlas Analysis and Application Program is powerful software developed by RISO National Laboratory, Denmark for wind climate estimation, data analysis and sitting of wind turbines. It takes into account the effects of different roughness conditions, sheltering effects due to nearby buildings and other obstacles and modification of the wind imposed by hills and complex terrain. The following inputs are required to run the WASP:

- Time-series wind data (Directional)
- Height of anemometer above ground level
- Details of obstacles around wind mast
- Surface roughness around the mast
- Topography (i.e. contour map of the site)
- Exact locations of wind electric generators on the contour map.
- Technical details of WTG like Power Curve, Rotor diameter & Hub height

ESTIMATION OF ANNUAL GENERATION

Based on wind data, Contour map of the site, Co-ordinates of proposed WTG Locations, Details collected from site regarding roughness, topography, obstacles, Power curve of Gamesa (G97 /90) & GE (GE-1.6-87/80) WTG; generation of respective Nos. of WTGs proposed for WERPL's wind farm has been estimated using WASP. For estimating the net annual average generation per WTG, following correction factors have been considered:

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a) Air Density

Power curve of both GE machines is for Air Density 1.225 kg/m3.

b) Machine Availability

The machine availability has been taken as 97% for this report.

c) Grid Availability

The grid availability depends upon the interruption of data in the nearest sub-station from which the proposed wind farm is to be connected. Grid availability of 99% has been considered for the purpose of energy estimation.

d) Wake Loss

Loss factor due to wakes has been considered as 94.4%

e) Uncertainties

There are a number of uncertainties associated with the energy estimation such as accuracy of data collection system, temporal variation, temporal modeling error, spatial modeling error etc. After consideration of above parameters, total uncertainty has been considered as 12.8%.

SUMMARY OF ESTIMATED GENERATION

The summary indicating net average generation per WTG per year is given below:

Supplier	Capacity(MW)	No of Turbines	Gross AEP GWh	Net AEP GWh	Net-PLF (%)
Gamesa G97/90 & GE-87/80 HH	126	71	351.2	292.4	26.5%

Correction Factors considered in above estimated generation are as given below:

Machine Availability : 97.0%

Grid Availability : 99.0%

SUMMARY OF ESTIMATED ANNUAL AVERAGE GENERATION OF PROPOSED WTG's

Sl No.	Particulars	Data
1	Make of WTG	Gamesa G97/90 & GE 1.6-87/80, MW
2	Rating of WTG (Kw)	2000 & 1600
3	Rotor Diameter of WTG (m)	97 & 87
4	Hub height of WTG (m)	90 & 80
5	No. of WTGs	40 GE + 31 Gamesa
6	Net annual average estimated generation per WTG with correction factors considered above (GWh)	4.94
7	Total Net generation (GWh)	292.4
8	Net Generation per MW (GWh)	2.32
9	Plant Load Factor (PLF) (%)	26.5%

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CHAPTER -7

Technical Details GE-1.6-87/80

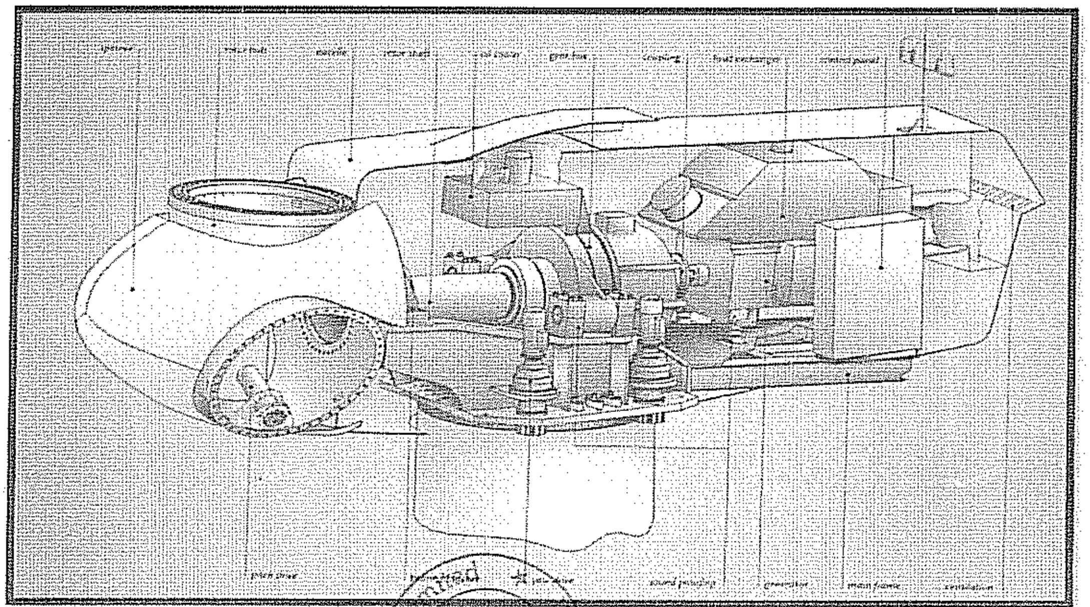
1) Introduction

This document summarizes the technical description and specifications of the GE Energy (GE) 1.6-87 wind turbine generator system.

2) Technical Description of the Wind Turbine and Major Components

The wind turbine is a three bladed, upwind, horizontal-axis wind turbine with a rotor diameter of 86.7 m. The turbine rotor and nacelle are mounted on top of a tubular tower giving a rotor hub height of 80 m or 100 m. The machine employs active yaw control (designed to steer the machine with respect to the wind direction), active blade pitch control (designed to regulate turbine rotor speed), and a generator/power electronic converter system.

The wind turbine features a distributed drive train design wherein the major drive train components including main shaft bearings, gearbox, generator, yaw drives, and control panel are attached to a bedplate.



GE Energy 1.6-87 Wind Turbine Nacelle Layout

2.1 Rotor

The rotor diameter is 86.7 m, resulting in a swept area of 5,904 m2, and is designed to operate between 9.8 and16.8 revolutions per minute (rpm). Rotor speed is regulated by a combination of blade pitch angle adjustment and generator/converter torque control. The rotor spins in a clock-wise direction under normal operating conditions when viewed from an upwind location.Full blade pitch angle range is approximately 90°, with the 0°-position being with the airfoil chord line flat to the prevailing wind. The blades being pitched to a full feather pitch angle of approximately 90° accomplishes aerodynamic braking of the rotor; whereby the blades "spill" the wind thus limiting rotor speed.

2.2 Blades

There are three rotor blades used on each wind turbine. The airfoils transition along the blade span with the thicker airfoils being located in-board towards the blade root (hub) and gradually tapering to thinner cross sections out towards the blade tip.

2.3 Blade Pitch Control System

The rotor utilizes three (one for each blade) independent electric pitch motors and controllers to provide adjustment of the blade pitch angle during operation. Blade pitch angle is adjusted by an electric drive that is mounted inside the rotor hub and is coupled to a ring gear mounted to the inner race of the blade pitch bearing (see Figure 1).GE's active-pitch controller enables the wind turbine rotor to regulate speed, when above rated wind speed, by allowing the blade to "spill" excess aerodynamic lift. Energy from wind gusts below rated wind speed is captured by allowing the rotor to speed up, transforming this gust energy into kinetic which may then be extracted from the rotor.Three independent back-up units are provided to power each individual blade pitch system to feather the blades and shut down the machine in the event of a grid line outage or other fault. By having all three blades outfitted with independent pitch systems, redundancy of individual blade aerodynamic braking capability is provided.

2.4 Hub

The hub is used to connect the three rotor blades to the turbine main shaft. The hub also houses the three electric blade pitch systems and is mounted directly to the main shaft. Access to the inside of the hub is provided through a hatch.

2.5 Gearbox

The gearbox in the wind turbine is designed to transmit power between the low-rpm turbine rotor and high- rpm electric generator. The gearbox is a multi-stage planetary/helical gear design. The gearbox is mounted to the machine bedplate.The gearing is designed to transfer torsional power from the wind turbine rotor to the electric generator. A parking brake is mounted on the high-speed shaft of the gearbox.

2.6 Bearings

The blade pitch bearing is designed to allow the blade to pitch about a span-wise pitch axis. The inner race of the blade pitch bearing is outfitted with a blade drive gear that enables the blade to be driven in pitch by an electric gear-driven motor/controller.The main shaft bearing is a roller bearing mounted in a pillow-block housing arrangement.The bearings used inside the gearbox are of the cylindrical, spherical and tapered roller type. These bearings are designed to provide bearing and alignment of the internal gearing shafts and accommodate radial and axial loads.

2.7 Brake System

The electrically actuated individual blade pitch systems act as the main braking system for the wind turbine. Braking under normal operating conditions is accomplished by feathering the blades out of the wind. Any single feathered rotor blade is designed to slow the rotor, and each rotor blade has its own back-up to provide power to the electric drive in the event of a grid line loss.The turbine is also equipped with a mechanical brake located at the output (high-speed) shaft of the gearbox. This brake is only applied as an auxiliary brake to the main aerodynamic brake and to prevent rotation of the machinery as required by certain service activities.

2.8 Generator

The generator is a doubly-fed induction type. The generator meets protection class requirements of the International Standard IP 54 (totally enclosed). The generator is mounted to the bedplate and the mounting is designed so as to reduce vibration and noise transfer to the bedplate.

2.9 Flexible Coupling

Designed to protect the drive train from excessive torque loads, a flexible coupling is provided between the generator and gearbox output shaft this is equipped with a torque-limiting device sized to keep the maximum allowable torque below the maximum design limit of the drive train.

2.10 Yaw System

A roller bearing attached between the nacelle and tower facilitates yaw motion. Planetary yaw drives (with brakes that engage when the drive is disabled) mesh with the outside gear of the yaw bearing and steer the machine to track the wind in yaw. The automatic yaw brakes engage in order to prevent the yaw drives from seeing peak loads from any turbulent wind.The controller activates the yaw drives to align the nacelle to the average wind direction based on the wind·vane sensor mounted on top of the nacelle.A cable twist sensor provides a record of nacelle yaw position and cable twisting. After the sensor detects excessive rotation in one direction, the controller automatically brings the rotor to a complete stop, untwists the cable by counter yawing of the nacelle, and restarts the wind turbine.

2.11 Tower

The wind turbine is mounted on top of a tubular tower. The tubular tower is manufactured in sections from steel plate. Access to the turbine is through a lockable steel door at the base of the tower. Service platforms are provided. Access to the nacelle is provided by a ladder and a fall arresting safety system is included. Interior lights are installed at critical points from the base of the tower to the tower top.

2.12 Nacelle

The nacelle houses the main components of the wind turbine generator. Access from the tower into the nacelle is through the bottom of the nacelle. The nacelle is ventilated.

It is illuminated with electric light. A hatch at the front end of the nacelle provides access to the blades and hub. The rotor can be secured in place with a rotor lock.

2.13 Anemometer, Wind Vane and Lightning Rod

An anemometer, wind vane and lightning rod are mounted on top of the nacelle housing. Access to these sensors is accomplished through a hatch in the nacelle roof.

2.14 Lightning Protection

The rotor blades are equipped with a lightning receptors mounted in the blade. The turbine is grounded and shielded to protect against lightning, however, lightning is an unpredictable force of nature, and it is possible that a lightning strike could damage various components notwithstanding the lightning protection deployed in the machine.

2.15 Wind Turbine Control System

The wind turbine machine can be controlled automatically or manually from either an interface located inside the nacelle or from a control box at the bottom of the tower. Control signals can also be sent from a remote computer via a Supervisory Control and Data Acquisition System (SCADA), with local lockout capability provided at the turbine controller.

Service switches at the tower top prevent service personnel at the bottom of the tower from operating certain systems of the turbine while service personnel are in the nacelle. To override any machine operation, Emergency-stop buttons located in the tower base and in the nacelle can be activated to stop the turbine in the event of an emergency.

2.16 Power Converter

The wind turbine uses a power converter system that consists of a converter on the rotor side, a DC Inter mediate circuit, and a power inverter on the grid side.

The converter system consists of a power module and the associated electrical equipment. Variable output frequency of the converter allows operation of the generator.

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3 Technical Data for GE 1.6 87/80

3.1 Rotor

Diameter	86.7 m
Number of blades	3
Swept area	5,904 m2
Rotor speed range	9.8 to 16.8 rpm
Rotational direction	Clockwise looking downwind
Maximum tip speed	76.4 m/s
Orientation	Upwind
Speed regulation	Pitch control
Aerodynamic brakes	Full feathering

3.2 Pitch System

Principle	Independent blade pitch control
Actuation	Individual electric drive

3.3 Yaw System

Yaw rate	0.5 degree/s

3.4 Corrosion Protection

Atmospheric corrosion protection (corrosion categories as defined by ISO 12944-2:1998)				
50 Hz	Standar		Enhanced (Option)	
Compone	Internal	External	Internal	External
Tower shell	C-2	C-3	C-4	C-5M
Tower internal fasteners, tower stair	C-3	C-3	C-5	C-5
Hub, Bedplate, generator frame, main shaft, pillow block, and	C-4	C-5	C-4	C-5
Higher Corrosion-Risk Hardware	C-2	C-3	C-4	C-5
Blades	C-4	C-5	C-4	C-5
All Other	C-2	C-3	C-2	C-3

4 Operational Limits

Height above sea level	Maximum 2500 m. See notes in section maximum standard ambient temperature below.
Minimum temperature (standard) operational / survival	Standard weather: -15°C / -20°C Cold weather package: -30 °C/ -40 °C Switching on takes place at a hysteresis of 5K (-10°C resp. -25°C)
Maximum standard ambient temperature (operation / survival)	+40°C / +50°C The turbine has a feature reducing the maximum output, resulting in minimized turbine revolutions once the component temperatures approach predefined thresholds. This feature operates best at higher altitudes, as the heat transfer properties of air diminish with decreasing density. Please note that the units
Wind conditions according to IEC	Vaverage = 7.5 m/s, TI = 16% @ 15 m/s
Maximum extreme gust (10 min)	40 m/s
Maximum extreme gust (3 s) according to IEC 61400	56 m/s

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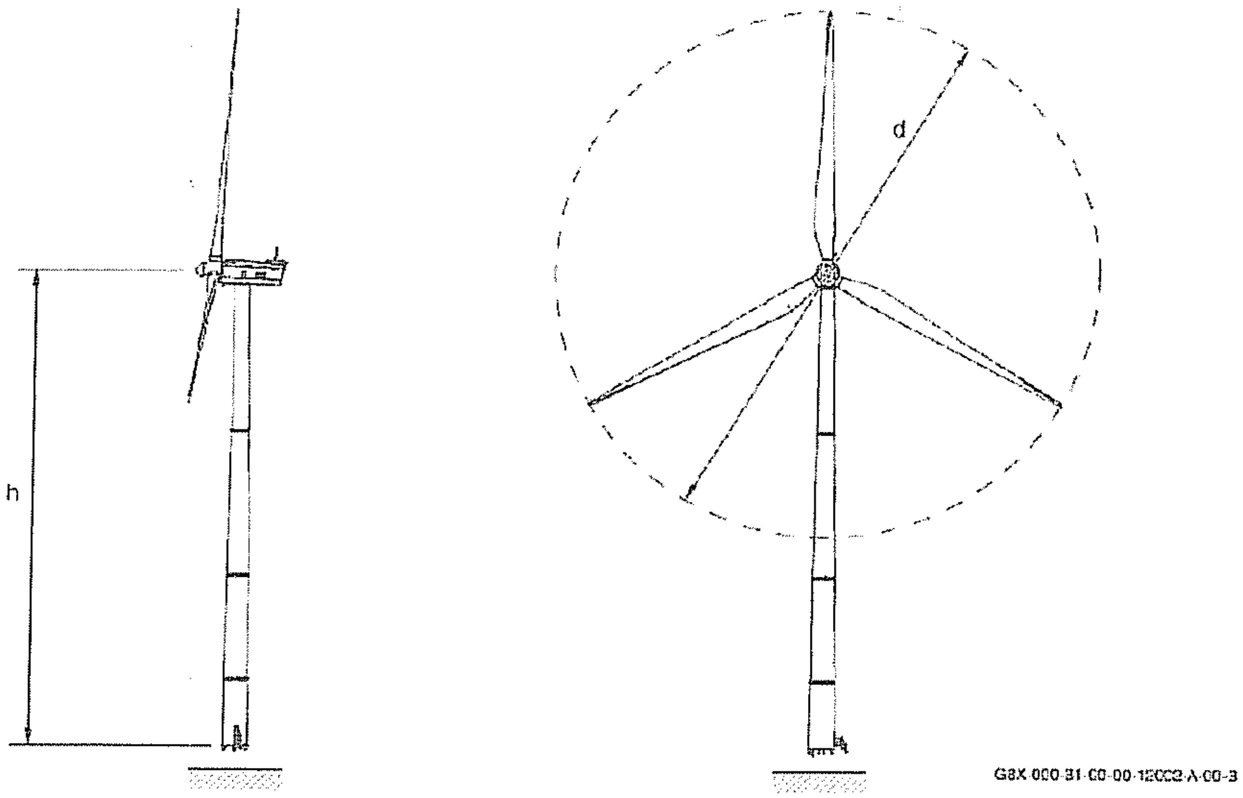
Technical Details Gamesa 2MW G97/90

The **Gamesa G9X-2.0 MW** wind turbines are of the three-bladed wind-facing rotor type and produce a nominal power of 2 MW.

The platform consists of 3 wind turbine models with rotor diameters of 87 m, 94 m and 97 m (Position d in Figure 1) and hub heights of 78 m and 90 m (Position h in Figure 1), with the remaining mechanical, electrical and control components being common to all models. The various models are designed to operate in different wind conditions.



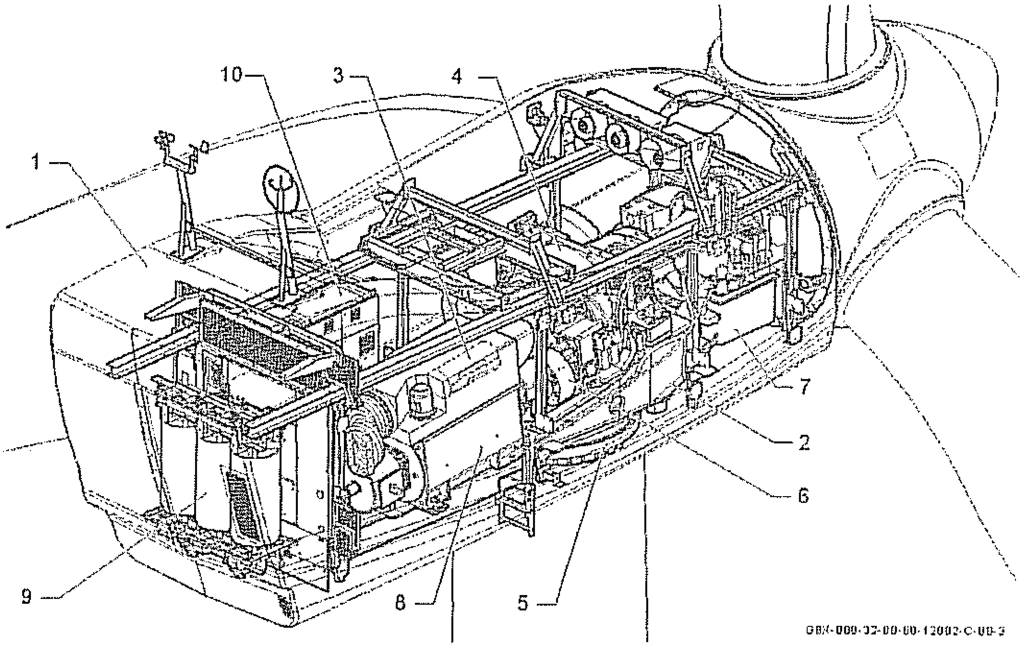
Position	Name
h	Hub height
d	Rotor diameter

Figure : Complete wind turbine

The **Gamesa G9X-2.0 MW** wind turbines are regulated by an independent pitch control system in each blade and have an active nacelle yaw system. The control system allows the wind turbine to be operated at variable speed, maximizing the power produced at all times and minimizing the loads and noise.

A description is given below of the main components of the **Gamesa G9X-2.0 MW wind turbines.**

NACELLE DESCRIPTION



Position	Name
1	Cover
2	Frame
3	Main shaft
4	Gearbox
5	Yaw system
6	Mechanical brake
7	Hydraulic unit
8	Generator
9	Power
10	Electrical cabinets

Figure 2 : Main components of the nacelle

Cover

The cover protects the wind turbine components within the nacelle from exposure to meteorological events and external environmental conditions. It is made of composite resin and reinforced with fiberglass.

Within the cover there is sufficient space in order to carry out wind turbine maintenance operations. The cover has three hatchways:

- Hatchway giving access to the nacelle from the tower, located on the nacelle floor
- Hatchway giving access to the interior of the cone/hub, located in the front
- Crane operating hatchway, located on the floor of the rear section

There are two skylights on the roof allowing sunlight to enter during the day and providing additional ventilation and access to the exterior, where the wind measuring instruments and the lightning rod are located.

The revolving parts are duly protected to guarantee the safety of maintenance

personnel. The nacelle contains an 800 kg service crane inside.

Frame

The frame of the **Gamesa G9X-2.0 MW** wind turbines has been designed using the criteria of mechanical simplicity along with the appropriate robustness to be able to support the elements of the nacelle and transmit the loads to the tower. These loads are transmitted via the yaw system bearing.

The main frame is divided into two parts:

Front frame: Cast iron bedplate to which the main shaft supports are fastened, where the gearbox torque arms and the yaw ring react.

Rear frame: Mechanically-welded structure formed by two beams joined at the front and the back.

The frame is subjected to exhaustive ageing tests at the frame test bench, Gamesa UPB, belonging to Gamesa. These tests mainly involve extreme load cycles which reproduce, in an accelerated manner, the stresses and forces to which the frame will be subjected throughout its lifetime. This guarantees and improves the reliability of the component, validating its correct design. In addition, the test results are used for feedback and to correlate the simulation models of the frames developed by Gamesa, guaranteeing continuous improvement and greater precision of the designs.

Main shaft

The motor torque produced by the wind on the rotor is transmitted to the gearbox through the main shaft. The shaft is attached to the hub with a screwed-on flange and is supported on 2 bearings housed in cast- iron supports. The connection to the low speed input on the gearbox is made with a conical tightening collar that transmits the torque by friction.

The shaft is made from forged steel and has a longitudinal central opening to house the hydraulic hoses and control cables for the pitch control system.

The support of the main shaft on 2 bearings offers significant structural advantages. All the stress from the rotor is transmitted to the front frame, except for the torque, which is used downstream in the generator to produce electric power. This guarantees that the gearbox only transmits this torque and that the bending, axial and shear stress goes directly to the bed plate. In addition, the system makes maintenance easier, as the gearbox can be removed without having to dismount the main shaft or the rotor.

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Gearbox

This transmits the main shaft's power to the generator. The gearbox consists of 3 combined stages, a planetary gear and two parallel shaft gears. The gearbox's cogs are designed for maximum efficiency and low noise and vibration levels. As a result of the gear ratio, part of the input torque is absorbed by the reaction arms. These symmetrical reaction arms fix the gearbox to the frame by means of shock absorbers which minimize vibration transmission. The high speed shaft is linked to the generator via a flexible coupling with torque limiter that prevents excess loads to the transmission chain.

Due to the modular design of the drive train, the gearbox weight is supported by the main shaft, while the gear tie rods react only to the torque, preventing the gearbox from rotating and ensuring the absence of unwanted loads.

The gearbox has a main lubrication system with a filtering system associated with the high speed shaft. There is a secondary electrical filter which permits the cleaning of the oil to 3 μm, thus reducing the potential number of breakdowns, together with a third extra cooling circuit.

The gearbox's various components and operating parameters are monitored by different sensors, of both the control system and the **Gamesa PMS** predictive maintenance system.

All the gearboxes are subjected to load tests at nominal power during their manufacture. These tests reduce the probabilities of failure during operation and guarantee product quality.

Gamesa Active Yaw system

The **Gamesa Active Yaw** system enables the nacelle to rotate around the axis of the tower. This is an active system and has four yaw gears electrically operated by the wind turbine control system according to the information received from the anemometers and wind vanes mounted on the upper section of the nacelle. The yaw system motors turn the gears of the yaw system, which engage with the cogs of the yaw ring mounted in the upper part of the tower, producing the relative rotation between the nacelle and the tower.

A friction bearing is used to obtain an adequate retention torque in order to control yaw rotation. In addition, the hydraulic brake, consisting of 5 active clamps, provides a greater retention torque to fix the wind turbine. The combined action of these 2 systems prevents fatigue and possible damage to the gears, thus ensuring stable and controlled yaw.

The ring is divided into several sectors to make it easier to repair possible damage to the teeth.

As with the main frame, the **Gamesa Active Yaw** system is subjected to accelerated life cycle and ageing tests at the **Gamesa UPB** test bench. These tests consist mainly in orientation cycles with operating loads compressing the length of the durability or ageing tests in order to simulate the yaw system's service life. These tests guarantee and improve the reliability of the component, validating its correct design and providing feedback to the virtual models for subsequent redesign and improvements.

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Brake system

The wind turbine primary brake is aerodynamic through the full-feathering blades. As the pitch control system is independent for each of the blades, it provides safety in the event of failure in any of them.

The mechanical brake consists of a hydraulically activated disk brake, which is mounted on the high-speed shaft of the gearbox This mechanical brake is only used as a parking brake or if the emergency button is applied.

Hydraulic system

The hydraulic system supplies pressurized oil to the 3 independent pitch control actuators, the high speed shaft mechanical brake and the yaw system brake system. It includes a fail-safe system which guarantees the required oil pressure and flow levels in the event of absence of current to activate the blade pitch control cylinders, the disc brake and the yaw system brake, switching the wind turbine to safe mode.

Generator

The generator is an asynchronous double-feed unit with 4 poles, coil rotor and slip rings. It is highly efficient and is cooled by an air-air exchanger. The control system permits operation at variable speeds using the rotor intensity frequency control.

The characteristics and functions introduced by this generator are: Synchronous behavior toward the grid. Optimal operation at any wind speed, maximizing production and minimizing loads and noise, thanks to variable speed operation. Control of active and reactive power via control of amplitude and rotor current phase. Smooth connection and disconnection from the electrical grid. The generator is protected against short-circuits and overloads. The temperature is monitored continuously via probes at points on the stator, bearings and the slip ring box.

Transformer

The transformer is three-phase, dry encapsulated, with different output voltage options between 6.6 kV and
35 kV, different apparent power ranges and is particularly designed for wind energy applications. It is located in the rear section of the nacelle in a compartment separated by a metal wall which provides thermal and electrical insulation from the rest of the nacelle components.

As it is a dry type unit, the risk of fire is minimized. In addition, the transformer includes all the necessary protections against damage, including arc detectors and protection fuses.

The transformer's location in the nacelle prevents electrical losses thanks to the reduced length of the low voltage cables, and also reduces visual impact.

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Electrical cabinets for control and power

The electrical system's hardware is distributed into three cabinets:

1. **TOP** cabinet located in the nacelle. In turn, this cabinet is divided into three parts:

    Control section: responsible for governing the nacelle, e.g., monitoring wind, changing pitch angle, yaw, interior temperature control, etc.

    Frequency converter: this is responsible for controlling the power and managing the connection and disconnection of the generator to/from the grid.

    Protections and busbar section: the output of the power produced, with the necessary electrical protections, is located here.

2. **GROUND** cabinet located at the tower's base. From the GROUND cabinet's touch screen it is possible to check the wind turbine's operating parameters, stop and start the wind turbine, test the various subsystems, etc. A touch screen can also be connected to the TOP cabinet in order to perform these tasks.

3. **HUB** cabinet located in the revolving part of the wind turbine. Responsible mainly for activating the pitch control system cylinders.

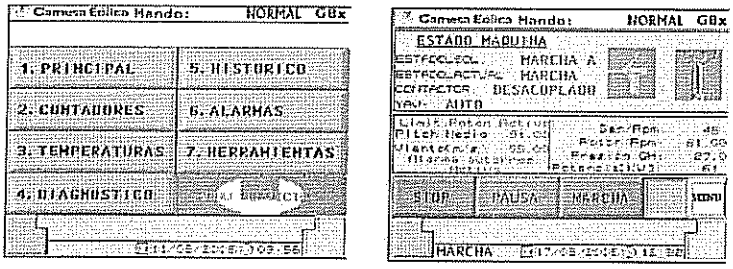
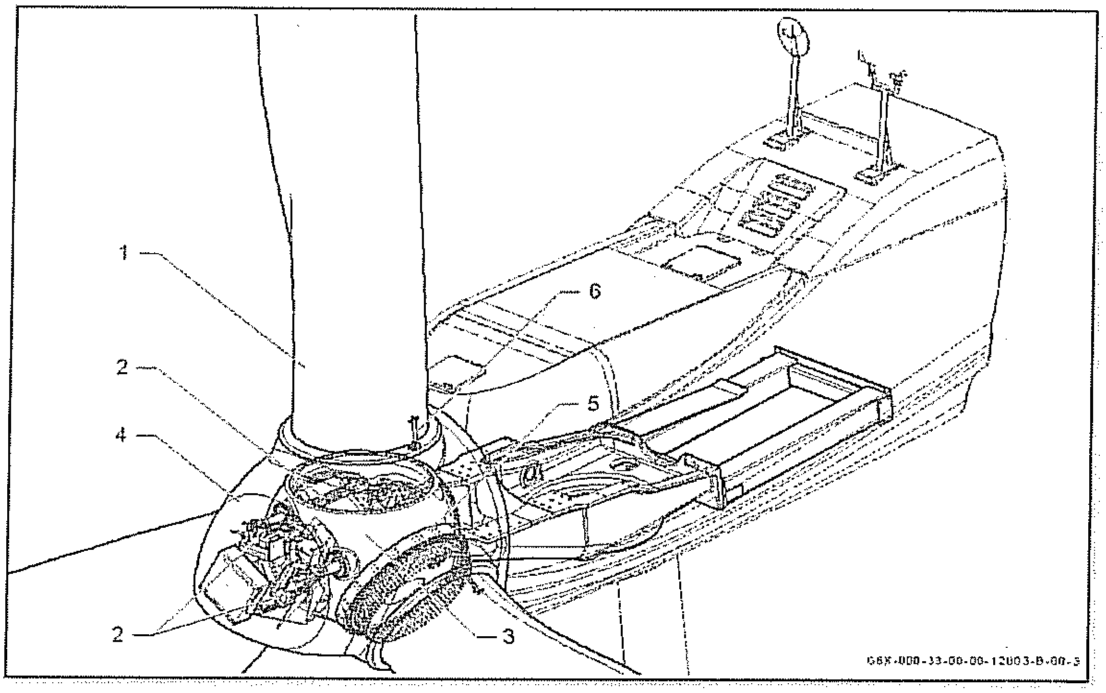


Figure 3: Examples of touch screen

ROTOR

The rotor of the **Gamesa G9X-2.0 MW** wind turbines consists of three blades joined to a hub by blade bearings. The hub has a conical angle of 2° in the flanges joining the blades to it, which keeps the tips of the blades away from the tower.

The rotor diameters of the different models in the platform are 97 m, 94 m and 87 m.



Position	Name
1	Blade
2	Pitch control system
3	Hub
4	Cone
5	Blade bearing
6	Lightning transmission system

Figure 4 : Main components of the rotor

Blades

The blades of the Gamesa G9X-2.0 MW wind turbines are manufactured in a composite material with fiberglass and carbon fiber and are preimpregnated, which provides the necessary rigidity without increasing the weight of the blade. The blades have pitch control along the whole length of the bade, thus maximizing energy production and reducing loads and noise.

The lengths of the blades are 47.5 m (G97), 46 m (G94) and 42.5 m (G87cS). The distance from the root of the blades to the center of the hub is 1 m in all cases.

The structure of each blade consists of two shells attached to a structural beam or internal rails. The blade is designed to fulfill two basic functions: structural and aerodynamic.

In addition, the blade is designed taking into account both the manufacturing method used and the materials chosen, in order to ensure the necessary safety margins.

The blades have a protection system against lightning which serves to conduct the ray from the receptor to the blade root where it is transmitted to the turbine to be discharged into the ground.

Additionally, the blades come with the necessary drains to prevent water being retained inside, which can cause an imbalance or structural damage due to water vaporization upon lightning striking them.

Blade bearing

The blade bearings are the interface between the blade and the hub and permit the pitch control movement. The blade is attached to the inner race of the blade bearing by means of tensioned bolts to facilitateinspection and removal.

Hub

The hub is manufactured in nodular cast iron. It is attached to the outer race of the three blade bearings and to the main shaft with bolted joints. It has an opening at the front to permit access to the interior for inspection and maintenance of the pitch control system's hydraulics and the tightening torque of the blades' bolts.

Cone

The cone protects the hub and the blade bearings from the atmosphere. The cone is bolted to the front of the hub and is designed to allow access to the hub for maintenance tasks.

Pitch control hydraulic system

This consists of independent hydraulic actuators for each blade that provide a rotation capacity of between –5° and 87° and a system of accumulators which ensure feathering in the event of an emergency. The pitch control system acts according to the following setting:

When the wind speed in less than nominal, a pitch angle is selected that maximizes the electrical power obtained for each wind speed.

When the wind speed is higher than nominal, the pitch angle is the one that provides the turbine's rated power.

In addition, it controls the activation of the aerodynamic brake in the event of an emergency, taking the wind turbine to a safe mode.

The hydraulic system acts more quickly than other systems. Due to the hydraulic accumulator system, it does not require batteries to operate, thus increasing its reliability in an emergency.

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TOWER AND FOUNDATION

Tower

The wind turbine tower is made of tubular steel, in a truncated conical shape, divided into three or four sections, depending on the height of the tower. It is supplied with the corresponding platforms, ladders and emergency lighting.

Gamesa offers a cable guided elevator as standard to make maintenance of the wind turbine easier.

Foundation

The standard foundations are of the slab type, made of concrete reinforced with steel. They have been designed using calculations based on the certified loads of the wind turbine and considering standard ground.

Where the hypothetical values used vary, the established standard values are useless and the foundations must be recalculated. Therefore, for each site, the ground characteristics and wind data should be reviewed in order to ensure that the most suitable foundation is selected.

CONTROL SYSTEM

The wind turbine functions are controlled in real time by a PLC-based system (Programable Logic Controller). The control system is made up of control and monitoring algorithms.

A) Control System

The control system selects the correct shaft torque values, the blade pitch angle and the power settings. These are modified at all times depending on the wind speed reaching the turbine, thus guaranteeing safe and reliable operating in all wind conditions.

The main advantages of the control system for the **Gamesa G9X-2.0 MW** wind turbines are:

1. Maximization of energy production.
2. Limitation of mechanical loads.
3. Aerodynamic noise reduction.
4. High energy quality.

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A-1) Pitchcontroladjustment

At wind speeds above the rated speed, the control system and pitch control system keep the power at its rated value. At wind speeds below the rated speed, the variable pitch control system and the control system optimize energy production by selecting the optimum combination of rotor rotation speed and pitch angle.

A-2) Powercontrol

The power control system ensures that the wind turbine's rotation speed and motor torque always supply stable electric power to the grid.

The power control system acts on a set of electrical systems consisting of a doubly-fed generator with wound rotor and slip rings, a 4-quadrant IGBT-based converter, contactors and electrical protection and software. Electrically, the generator-converter unit is equivalent to that of a synchronous generator and therefore it ensures optimum coupling to the electrical grid with smooth connection and disconnection processes.

The generator-converter unit is able to work with variable speeds to optimize operation and to maximize the power generated for each wind speed. In addition, it makes it possible to manage the reactive power evacuated in collaboration with the **Gamesa Windnet®** remote control system.

B) Monitoringsystem

The monitoring system continuously checks the state of the different sensors and internal parameters: Environmental conditions: wind speed and direction or ambient temperature. Internal parameters of the various components, such as temperatures, oil levels and pressures, vibrations, mid-voltage cable winding, etc.

Rotor state: rotation speed and pitch control position.

Grid situation: active and reactive energy generation, voltage, currents and frequency.

GAMESA PMS PREDICTIVE MAINTENANCE SYSTEM

The **Gamesa G97-2.0 MW**wind turbine includes the **Gamesa PMS** Predictive Maintenance System, developed by Gamesa, based on the analysis of vibrations, and optimized for use in wind turbines. The system can simultaneously manage and process the information from up to 12 accelerometers, which are located at strategic points on the turbine, such as the gearbox, the generator and the main shaft's front bearings.

The main characteristics of the **Gamesa SMP** are as follows:

- Continuous monitoring of the wind turbine's critical components
- Signal processing and alarm detection capability
- Integrated with the PLC and **Gamesa WindNet®** wind farm networks
- Easy maintenance
- Low cost

In general, the main purpose of a predictive maintenance system is the early detection of faults or wear in the main components of the wind turbine. The following are some of the important benefits of installing a system of this type:

- Reduction in major corrective actions required
- Protection of other wind turbine components
- Improvements in the wind turbine's useful life and operation
- Reduction in dedicated maintenance resources
- Access to markets with strict regulations, such as the Germanischer Lloyds certification
- Reduction in insurance company rates

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GAMESA WINDNET® INTEGRATED MANAGEMENT SYSTEM FOR WIND FARMS

The **Gamesa G9X-2.0MW** wind turbines are integrated into the **Gamesa WindNet®**, supervisory, control and data acquisition system (SCADA), which allows the wind farm information to be accessed easily and intuitively through a browser.

The **Gamesa WindNet®** system is easy to configure and adapt to any wind farm layout, including those with a wide variety of wind turbine models. It can quickly and reliably link up any wind farm topology based on Ethernet network technology. It can also integrate wind farm installations such as electrical substations, reactive power equipment, capacitor banks, etc.

The **Gamesa WindNet®** system supports a wide variety of communications protocols used in wind farm systems, such as OPC DA, MODBUS and DNP3. Communication with Gamesa wind turbines is based on a robust and efficient proprietary protocol.

With this tool, the user can perform the following tasks at any time:

- Track and monitor the wind farm's equipment.
- Be informed about the energy production of each wind turbine in the wind farm.
- Monitor the alarms for the different elements of the wind farm in real time and display the alarm log.
- Send direct orders to the wind turbines (start, pause or switch to emergency mode) and substation.

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Analyze the evolution of variables over time in a simple manner, thanks to the trend history graphs:

Gamesa Trend Viewer.

- Create production and availability reports: **Gamesa Report**
- **Generator.** Send status messages and alarms to a cell phone using SMS text messaging. Integrate the reactive power compensation equipment (STATCOM and SVC). Manage predictive maintenance with the integration of **Gamesa PMS.**
- Manage different user profiles, thus maintaining security and simplifying at the same time the application's daily use.

The user interface has been designed using accessibility, user-friendly and simplicity criteria. The information is displayed in graph form. There is also web access to up-to-date information through any device with a browser and Internet connection.

The **Gamesa WindNet®** system offers different user, administrator, configuration, developer and maintenance profiles for access to the specific functions and information required for each user type, thus increasing security and simplifying the daily use of the application.

Optionally, a series of modules are available to add advanced functions to the **Gamesa WindNet®** system:

Active power limitation module.
Generated reactive power control module. Frequency regulation module.
Generation of customized reports with **Gamesa Information Manager**, through the categorization of energy losses.
Wake control module.
Noise control module: **Gamesa NRS®**. Shade control module.
Ice control module.

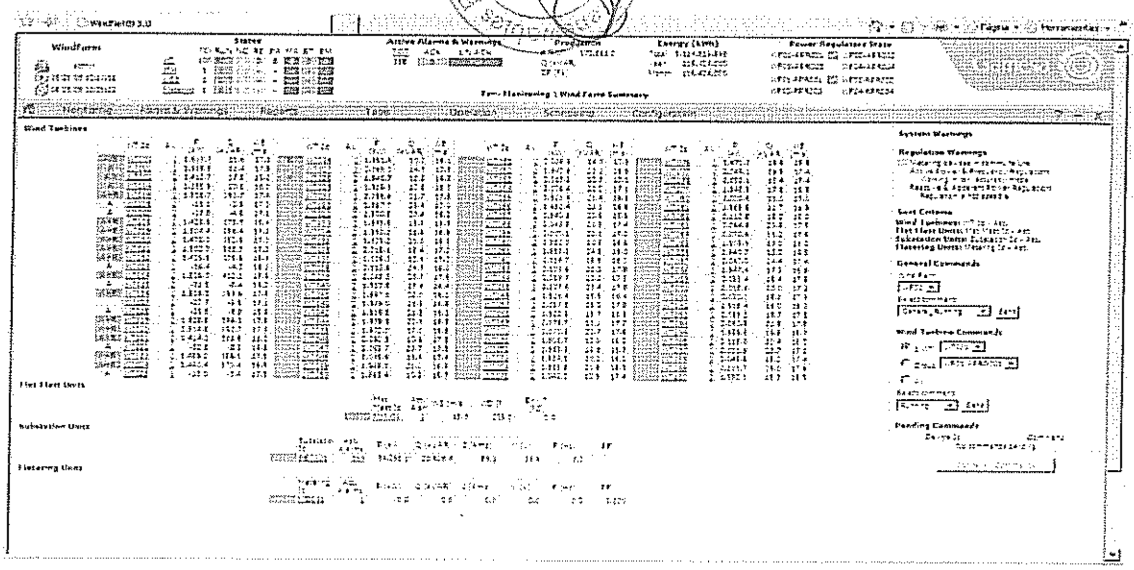

Figure 5: Example of a WindNet® screen accessed via the Web

SENSORS

The **Gamesa G9X-2.0 MW** wind turbines are equipped with various different sensors that are continuously checking on different parameters. It has sensors that capture signals external to the wind turbine, for example, the outside temperature or the wind speed and direction. Other sensors record turbine operating parameters such as component temperatures, pressure levels, vibrations or blade position.

All this information is recorded and analyzed in real time and fed into the monitoring and control functions of the control system.

LIGHTNING PROTECTION SYSTEM

The **Gamesa G9X-2.0MW** wind turbines are protected against lightning by a transmission system that goes from the blade and nacelle receptors, passing through the cover, the main frame and the tower, to the foundations. This system prevents the passage of lightning through components which are sensitive to these discharges. The electrical system also has additional overvoltage protection.

All these protection systems are designed to obtain a maximum protection level Class I in accordance with standard IEC 62305. IEC 61400-24 and IEC61024 are considered reference standards.

GRID CONNECTION AND SITE

GRID CONNECTION

The **Gamesa G97-2.0 MW** wind turbines are available in versions which are capable of operating in 50 Hz and 60 Hz networks.

The wind turbine's transformer must be suitable for the grid's voltage. The voltage of the low-voltage grid must lie within the ± 10% range and the grid frequency must lie within the 3 Hz range in both 50 Hz and 60 Hz networks.

The grounding system included in the civil engineering project has two concentric rings with a global impedance according to the requirements established in IEC 62305. The pass-through and contact currents must comply with standards IEC 60478-1 and IEC 61936-1. Local regulations shall take precedence where these are more restrictive than the above international standards.

The grid voltage specified for the **Gamesa G9X-2.0MW** wind turbines is defined in section 4.6 of this document.

The power factor for the **Gamesa G9X-2.0MW** wind turbines is between 0.95 capacitive and 0.95 inductive in the entire power range under the following conditions: ± 5% rated voltage for the corresponding temperature interval, as long as the transformer's apparent power is equal to or greater than 2,350 kVA. See special conditions for other transformer models.

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ENVIRONMENTAL CONDITIONS

The standard versions of the wind turbines in the **Gamesa G9X-2.0 MW** platform are designed to operate at external ambient temperatures between –20 °C and +30 °C. There are turbine versions which are capable of withstanding more extreme ambient temperatures.

The **Gamesa G97-2.0MW** wind turbines are capable of operating continuously at ambient relative humidity of 95%, and are also capable of operating in conditions of 100% relative humidity for periods of time under 10% of operating time.

The degree of anti-corrosion protection of the various components of **Gamesa G9X-2.0 MW** wind turbines, in accordance with standard ISO 12944-2, is shown in the following table:

COMPONENT	EXTERNAL	INTERIOR
Tower	C5-I/H	C4/H
Nacelle-Rotor	C4/H or C5/H	C2/H or

Table 1. Degrees of protection against corrosion

[1] According to components.

Gamesa has product versions designed specially for corrosive environments.

WIND CONDITIONS

The annual wind distribution for a site is normally specified by a Weibull distribution. This distribution is described by scale factor A and form factor k. Factor A is proportional to the average wind speed and factor k defines the form of the distribution for different wind speeds. Turbulence intensity is the parameter that quantifies the instant variations in wind speed.

The design conditions of the **Gamesa G9X-2.0 MW** platform are indicated below:

Standard	**IEC - IIIA**
Average annual wind speed (m/s) [1]	7,5
Turbulence intensity I_{15} (%)	18
Reference 10-minute wind speed in 50 years (m/s).	37,5
Extreme wind speed in 50 years over a 3-second average (m/s)	52,5

Table 2. Design parameters for the G9X-2.0 MW platform. Class IIIA

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Standard	IEC - IIIA
Average annual wind speed (m/s) [1]	8,5
Turbulence intensity I15 (%)	18
Reference 10-minute wind speed in 50 years (m/s).	42,5
Extreme wind speed in 50 years over a 3-second average (m/s)	59,5

Table 3. Design parameters for the G9X-2.0 MW platform. Class IIA

Standard	IEC - S
Average annual wind speed (m/s) [1]	10
Turbulence intensity I15 (%)	18
Reference 10-minute wind speed in 50 years (m/s)	47
Extreme wind speed in 50 years over a 3-second average (m/s)	65.8

Table 4. Design parameters for the G9X-2.0 MW platform. Class S

VERIFICATION OF SITE CONDITIONS

Broadly speaking, the wind turbine may be installed in wind farms with a minimum distance of 5 rotor diameters between wind turbines facing the prevailing wind direction. If the wind turbines are located in rows, perpendicular to the direction of the prevailing wind, the distance between turbines should be a minimum of 2 rotor diameters. These criteria are subject to modification in certain conditions following a specific technical study for each case.

The wind turbines may be placed under different and varied weather conditions where the air density, turbulence intensity, average wind speed and the k form parameter are the main parameters to be considered. If the turbulence intensity is high, the loads on the wind turbine increase and the turbine life decreases. On the other hand, the loads decrease and the turbine life increases if the average wind speed or turbulence intensity or both are low. Therefore, wind turbines may be placed on sites with high turbulence intensity if the average wind speed is fairly low.

Turbulence intensity (I) is the quotient of the standard deviation of the wind speed from the average measured or estimated speed (See IEC 61400-13). Turbulence intensity I15 is used as a characteristic value for the 10-minute average wind speed of 15 m/s.

On complex ground, the wind conditions are checked on the basis of measurements taken on site. In addition, the effect of the topography on the wind speed and shear, the turbulence intensity and the wind flow inclination on each wind turbine should be considered.

The supply of the required data is necessary in order to assess the main characteristics of the site:

Ambient conditions of temperature, density, salinity, dust and/or sand concentration, etc.
Wind measured on the site, as well as the topographic plans and the layout of the wind turbines at a scale that will enable the site characteristics to be assessed.
Grid voltage and frequency and service voltage.
Any other information required by Gamesa for the correct definition of the wind turbine to be installed.

CERTIFICATES

The **Gamesa G9X-2.0MW** wind turbines are certified according to the data shown in table 5:

Standard	IEC [1]					
Class	III A		II A		S	
Hub height (m)	78	90	78	90	78	90
G97						
G94						
G87cS						

Table 5. G97-2.0MW product certifications table

[1] Certificacion according to design regulation IEC61400-1 Ed2 in accordance with certification scheme IEC61400-22.

OPTIONS

EXTREME ENVIRONMENTAL CONDITIONS

Gamesa has product versions that are specially designed for extreme temperature, dust and/or corrosion environmental conditions.

VOLTAGE DROPS

Gamesa G8X-2.0 MW platform wind turbines are capable of staying connected to the grid during voltage drops, thus contributing to guaranteeing power quality and supply continuity.

The wind turbines can optionally be equipped with **Gamesa Brake Chopper**, a device that is capable of withstanding more extreme drops and contributing to injecting reactive power as required by certain grid codes.

The Gamesa G9X-2.0 MW platform wind turbines have certificates issued by official institutes on compliance with voltage drops according to P.O.12.3 of REE and EON2003.

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LOW-NOISE VERSIONS

The wind turbines in the **Gamesa G8X-2.0 MW** platform have different control versions to minimize noise emissions. The application of these versions may involve a modification to the power curve.

These noise-control versions are managed by the **Gamesa NRS®** system, which ensures optimization of production by maintaining previously programmed noise levels in accordance with local legislation.

BEACONS

As an option, Gamesa offers the inclusion of luminous beacon systems in accordance with the corresponding air traffic legislation and regulations. This is exclusively supplied by Gamesa

These beacons may be powered by a UPS module, defined in accordance with client requirements. In addition, there is an option to include a flashing synchronization model.

MID-VOLTAGE SWITCHGEAR

Gamesa offers to supply the wind turbine connection unit to the mid-voltage electrical grid as an option. The mid-voltage wiring connection to the mid-voltage switchgear is at the bottom of the tower. Gamesa recommends an automatic switch type switchgear unit (not a breaker box).

Gamesa requires the necessary information to correctly define the switchgear unit. Where the client supplies the medium voltage switchgear unit, this must comply with Gamesa's technical specifications for the rating and other aspects which may affect the wind turbine.

GRID VOLTAGE

Gamesa has various transformer options designed to be connected to 50 Hz and 60 Hz grids at different grid voltage levels in the range of 6.6 ~ 35 kV.

At the request of the client, Gamesa may design transformers with voltage levels not available within the previously specified range.

SERVICE VOLTAGE

The models in the **Gamesa G9X-2.0 MW** platform are available in versions which are capable of operating with service voltage of 230V or 120V as an option.

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TECHNICAL DATA

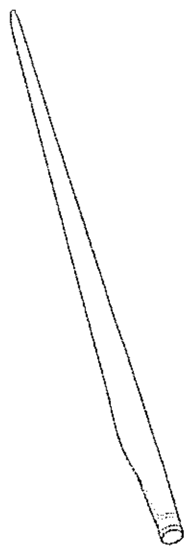
The main technical data of the different components of the wind turbines in the **Gamesa G9X-2.0 MW** platform are listed below.

ROTOR

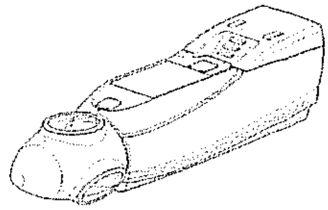
Wind turbine	G97	G94	G87cS
Rotor diameter (m)	97	94	87
Swept area (m^2)	7389.8	6939.2	5.944.7
Wind speed in operation (rpm)	9 : 19	9 : 19	9 : 19

BLADES

Material		Composite material with fiberglass, carbon fiber and preimpregnated.
Length (m)	G97	47.5
	G94	46
	G87cS	42.5
Blade cord (maximum/minimum) (m)	G97	3.41 / 0.057
	G94	3.005 / 0.040
	G87cS	3.36 / 0.013
Torsion (°)	G97	8.50
	G94	12.527
	G87cS	15.74



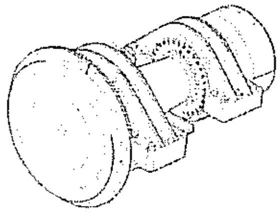
COVER

Dimensions (approx.) (m)	10.583 x 3.505 x 4.487	
Material	Organic matrix composite reinforced with fiberglass	

HUB

Material	Nodular cast iron	

MAIN SHAFT

Type	Cast shaft	
Shaft support	Nodular cast iron	

FRONT FRAME

Material	Nodular cast iron	

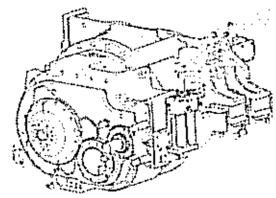
YAW SYSTEM

Type	Yaw ring with friction bearing	

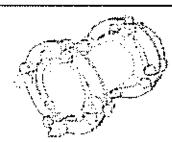
TOWER

Type	Conical barrel tube	
Material	Structural carbon steel	
Surface treatment	Painted	
Hub height (standard options) (m)	78 (three sections)	
	90 (four sections)	

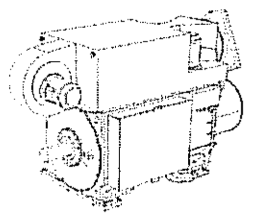
GEARBOX

Type	1 planetary stage / 2 parallel stages	
Ratio	106.793+/-0.7% (50 Hz) 127.188+/-0.7% (60 Hz)	

COUPLINGS

Main shaft	Shrink disc	
High-speed shaft	Flexible coupling	

GENERATOR

Type	Doubly-fed with coil rotor and slip rings	
Nominal power (kW)	2070 (stator + rotor)	
Voltage (Vac)	690	
Frequency (Hz)	50 / 60	

MECHANICAL BRAKE

Type	Disc brake	

HYDRAULIC UNIT

Operating pressure (bar)	220	

WIND SENSORS

Standard configuration	1 2D ultrasonic anemometer with simultaneous speed and direction measurement + 1 cup anemometer and wind vane	
Number	1 + 1	

CONTROL UNIT

Frequency (Hz)	50 / 60	
Voltage (Vdc)	24	
PLC (according to configuration)	Sisteam A (Option A) Phoenix Contact (Option B)	
Field buses	CAN (Option A) Interbus (Option B)	

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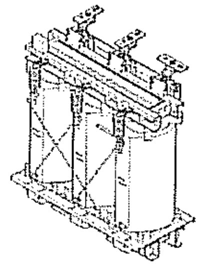
TRANSFORMER

Type	Three-phase, dry-type encapsulated
Rated power	Different options available
Voltage in mid-voltage	Different options available
Frequency (Hz)	50 / 60
Insulation class	F or H



APPROXIMATE WEIGHTS

Nacelle weight (t)	70

Rotor	G97	G94	G87cS
weight (t)	42	41	40

Tower weight (t)		Flange type	G97	G94	G87cS
IIIA Towers	78 m	T	165	165	165
	90 m	T	216	216	216

GENERAL RESTRICTIONS

All data shown is valid for conditions at sea level and standard air density.

In periods of low wind speeds, an increase in power consumption for nacelle heating and dehumidification is to be expected.

In the event of a build-up of large quantities of ice on blades or other wind turbine components, interruptions to the turbine operation should be expected. In addition, high winds in combination with the following conditions - high temperatures, low temperatures, low density and/or low grid voltage - may lead to a reduction in the nominal power to ensure that the thermal conditions of certain principal components, such as the gearbox, generator, transformer, power cables, etc. are maintained within limits.

It is usually recommended that the electrical grid voltage be kept as close as possible to the nominal value.

In the event of a loss of electric power and very low temperatures, a certain period of time should be allowed for heating before the wind turbine starts to operate.

If there is a slope of more than 10° within a radius of 100 meters of a wind turbine, special considerations may be necessary.

G9X wind turbines are ready to operate up to 2500 m above sea level. Up to 1000m the wind turbine operates in full-power conditions. From 1000m the wind turbine operates in production conditions with power derating based on ambient temperature. In addition, on sites above sea level, the risk of freezing is greater.

All the parameters given for start up and stopping (temperatures, wind speeds, etc.) have an associated hysteresis in the control system. In certain conditions, this may involve a wind turbine being stopped, even when the instantaneous ambient parameters of the environment are within the specified limits.

Intermittent or rapid fluctuations in the electrical grid frequency may cause serious problems to the wind turbine.

Drops in the electrical voltage should not occur more than 52 times per year.

Due to modifications and updates to our products, Gamesa reserves the right to change the specifications.

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CHAPTER -8

WELSPUN
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The Wind Energy People

126MW Wind Energy Project @ Pratapgarh, Rajasthan

PROJECT IMPLEMENTATION PLAN

Description	Date
Award of WTG for 64 MW	19-Mar-14
BOS material delivery start	21-Mar-14
Award of EPC contract	20-Mar-14
Start of 132 KV transmission line construction	21-May-14
Start of WTG civil foundation for 64 MW	21-May-14
Internal transmission line start	30-May-14
Start of 132 KV SWITCHYARD civil work	20-Jun-14
Award of WTG for remaining 62.0 WTG's	15-Jul-14
Land acquisition complete for 64 MW	15-Jul-14
WTG delivery start for 64 MW	01-Oct-14
Start of WTG civil foundation for 62.0 MW	03-Oct-14
Land acquisition complete for remaining 62.0 MW	20-Oct-14
WTG erection start for 64 MW	01-Dec-14
WTG delivery start for 62.0 MW	12-Jan-15
132 KV Transmission line readiness	15-Jan-15
Internal transmission line start for remaining 62.0 MW	16-Jan-15
WTG erection start for remaining 62.0 MW	28-Feb-15
132KV SWITCH YARD readiness for charging	28-Feb-15
BOS material delivery finish	30-Jun-15
Internal transmission line complete	15-Jan-15
Complete WTG erection for 64 MW	30-Jun-15
COD for 64 MW	1-Jul-15
Internal transmission line complete for 62.0 MW	15-Aug-15
Complete WTG erection finish for 62.0 MW	30-Sep-15
COD for the Entire Project	1-Oct-15

Note: Implementation plan may change as per actual site condition.

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PREPARATORY

On the basis of D.P.R. following activities shall have to be completed on priority:

i. Arrangement of Finance.

ii. Construction/Modification of approach road.

iii. Arrangement of power and water for construction.

iv. Approval from Electricity Board regarding grid – interfacing of wind farm and Wheeling/Banking facility.

Scope Matrix

The job responsibilities for implementation of the project shall be as below:

	ACTIVITIES	RESPONSIBILITY
A.	**Documents**	
1	Preparation, Invitation & finalization of tenders for WTGs, Civil & Electrical	WERPL
2	Approval of procurement procedure of WTGs by financing Organization	WERPL
3	Final work plan for implementation of project.	WERPL/ WTG Supplier
4	Tower foundation drawing	WTG supplier
5	Electrical equipment & layout drawings	WERPL/ WTG Supplier
6	Construction drawings (Electrical)	WERPL

	ACTIVITIES	RESPONSIBILITY
B.	**Preparatory**	WERPL

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1	Agreement with State Electricity Board	WERPL
2	Financing arrangement	WERPL
3	Temporary power supply	WERPL
4	Water for construction	WERPL
5	Micro sitting	WERPL
C	**Material Procurement**	
1	WTG Towers with Stubs & Templates	WERPL
2	Civil construction material	WERPL
3	Electrical equipment & Accessories	WERPL
4	Transport of WTG component	WERPL
5	Inspection of WTGs and Electrical equipments	WERPL
6	Material for Grid extension	WERPL
7	WTG erection equipment & tools	WERPL
D.	**Construction Activities**	
1	Site clearance and approach road to site	WERPL
2	Internal Roads & turning areas	WERPL
3	Tower Foundations	WERPL
4	Office-cum-Control Room Building	WERPL
5	WTG erection	WERPL
6	LT Cable laying	WERPL
7	Unit Sub-stations	WERPL
8	Transformer Erection	WERPL
9	Metering station,	WERPL
10	Inter O / H lines	WERPL

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11	Grid Extension	WERPL
12	Earthing stations	WERPL

	ACTIVITIES	RESPONSIBILITY
E.	**Commissioning & Handing over**	
1	Approval of Electrical Installation by Electrical Inspectorate	WERPL
2	Grid extension commissioning	WERPL
3	Electrical Installation Commissioning	WERPL
4	WTG commissioning	WTG Supplier
5	Training of O & M Staff	WTG Supplier
6	Handing over	WERPL/ WTG Supplier
F.	**Project Management**	
1	Financial & Administrative control	WERPL
2	Over all project co-ordination	WERPL
3	Supervision of Construction, Erection & Commissioning	WERPL/ WTG Supplier
4	Manpower selection for O & M	WERPL
5	Operation and Routine Maintenance (Balance of system under WERPL	WERPL/ WTG Supplier

* **The activities being of specialized nature, WERPL will get these done through experienced Technical Consultants / Contractor.**

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CHAPTER -9

OPERATION, MAINTENANCE & MONITORING PERFORMANCE

GENERAL

This section is mainly devoted to manpower requirement in operation and maintenance of wind farm which varies depending mainly on the number of WTGs, layout of wind farm and location with respect to nearest town/village. Operation and maintenance forms integral part of overall management process in any system. A properly organized system will need less manpower to keep the wind farm running efficiently over its life term.

The above aspects have been kept in mind while planning the manpower for operation and maintenance of the wind farm.

The proposed manpower, excepting security personnel, shall be recruited in advance so that they are available for the job from the starting days of erection.

JOB CONTENT

Operation and maintenance are two distinct aspects which shall be conducted in harmony for optimum benefit from the wind farm.

Operation of Wind farm

The major task for the operators will be regular logging of hourly electrical data such as voltage, current and energy output of the total wind farm and also the individual wind turbine once a day. Checking of pilot battery voltage, specific gravity and temperature once in the shift and various switching operations involved during the shift.

In addition to this the operators shall also note down line failure, main supply failure, interruption and its duration, mentioning clearly the reasons for such interruption, number of times wind turbines have stopped and the reason shall be noted down in the daily log sheet. For this purpose, a suitable format in the form of daily log sheet shall be prepared by the Engineer-in-charge. The operators under the guidance of Engineer-in-charge shall prepare monthly reports on performance of wind farm indicating turbine-wise production, machine downtime, grid availability, capacity factor, etc. and compute these figures for the entire wind farm.

Maintenance of Wind farm

It shall be the endeavor of the Engineer-in-charge to inculcate the spirit of preventive maintenance to his staff in order to avoid catastrophic break downs.

The suppliers of all major equipment usually provide various daily, monthly, quarterly and yearly maintenance check list for running their equipment smoothly.

The Engineer-in-charge shall make a practice to observe that the above periodic checks are performed as a matter of routine and recorded in the register of preventive maintenance.

The maintenance of the wind farm shall be co-ordinated with requirement of spare parts and various consumables. In this regard initially an attempt shall be made to procure stocks of various spare parts and consumables to run the wind farm for two years. The initial stock of spare parts and consumables for two years shall be clubbed together during the purchase of major equipments.

The maintenance of electrical equipment involved for wind farm are high voltage circuit breakers, transformers, low voltage distribution boards and wind turbines along with their controls etc.

Once in every month the operators shall maintain a record indicating the earth resistance of various earth pits along with the combined value of earth resistance of the earth grid.

The Engineer-In-Charge shall also have in his custody the required tools and tackles specially needed for the maintenance of wind turbine, its control system and other high voltage and low voltage circuit breakers. The requirement of the tools and tackles are generally provided by the manufacturer of the equipment.

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It is necessary for the operators, technicians as well as Engineer-in-charge to completely familiarize with equipments within the wind farm, which can only be achieved by going through the process of on job training.

TRAINING PROGRAMME

On-job training for the engineers and operators shall be a part of overall purchase program for important equipment. The training shall be in two phases. During the first phase the concerned Engineer-in-charge along with any additional persons nominated by the Company shall be trained at the factory of WTG manufacturer for various activities involved in assembling the final product, the operation aspects of the

equipment, periodic maintenance checks for the equipment and testing of the final product, the duration of the first phase of the training maybe between two to three weeks.

During the second phase, the supplier of the equipment shall train the operators and technicians on installation and operation of the equipment. Training should be imparted on various diagnostic methods to find out the fault in the equipment during its operation. The training shall be conducted during the erection and commissioning period of the wind farm and shall constitute both theoretical as well as practical aspects of the equipment. At the end of training programme ,the manufacturer shall certify the ability of the operators and technicians for operation and maintenance of equipment satisfactorily.

The Junior Engineers should be provided special training for fault finding and maintenance of electronic and micro-processor based control system.

During the warranty period, the operation and maintenance personnel shall work under the close guidance of WTG supplier's engineer. Subsequently these people should be able to carry out operation and complete maintenance of wind farm on their own without any guidance from outside.

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MONITORING OF PERFORMANCE

To evaluate performance of WTGs of the wind farm, following monthly data should be logged:

1. Energy and Power

1.1 Active energy production kWh (data)
1.2 Reactive energy production kVArh (data)
1.3 Active energy consumption kWh (data)
1.4 Reactive energy consumption kVArh (data)
1.5 Average power factor Cost (computed)
1.6 Average power MW (computed)
1.7 Capacity factor (computed)
1.8 Specific energy production MWh/MW/month (computed)
1.9 Specific energy production relative to swept area of the rotor kWh/m2/month (computed)
1.10 Power Curve data

2. Hours of operation, down time and number of faults

2.1 Operational hours (data)
2.2 Real availability (computed)
2.3 Wind electric generator ready hour that is no turbine or grid fault (data)
2.4 Technical availability (computed)
2.5 Grid fault numbers and duration of (data):
   i) Power down
   ii) Phase loss
   iii) Asymmetric current
   iv) Over and under voltage
   v) Over and under frequency

2.6 Turbine faults number and duration (data)

   i) Mechanical and electrical components in Nacelle

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ii) Electrical and electronic components in control panel

3. Failures of Wind electric generator components (data)

3.1 Rotor and blades

3.2 Brake and hydraulic system

3.3 Gear box and transmission

3.4 Yaw drive

3.5 Generator

3.6 Pitch control

3.7 Anemometer, wind vane, speed sensor, temp. Sensors, twist sensors etc.

3.8 Power circuit components such as circuit breaker, main fuses, contactor, thrusters, capacitors etc.

3.9 Control circuit components such as transformers, PCBs, IC, EPROM etc.

3.10 Failure analysis - Total time lost, loss of production, percentage of failures

The above mentioned data and information shall be presented in Tabular form.

ORGANIZATION STRUCTURE

It is envisaged that the wind farm shall be under the overall supervision of the Engineer-in-charge having adequate exposures in operation and maintenance of electrical and mechanical equipments. A graduate engineer or its equivalent with an experience of about 7 to 10 years and adequately supported by the specific training programme can serve the purpose.

The above engineer shall be supported by a group of O & M staff members who shall be responsible for running the wind farm continuously. Looking at the type of operation and maintenance duty, a chart indicating likely requirement of staff for operation and maintenance of wind farms is attached for guidance. They shall carry out the operational duty and logging of relevant data as mentioned previously along with specific maintenance required by the plant during any shift. In addition they shall maintain the record for issuing of various spare parts and consumables during each shift. Inventory balance of spare parts and consumables shall be reported to the Engineer-in-charge daily who in turn shall verify the stock position every fortnight.

Keeping in mind the security aspects of the plant it is further envisaged to have one security personnel in each shift.

CHAPTER -10

FINANCIAL ANALYSIS

The financial viability of the project is the most important aspect for any investor. Wind projects have recently attracted attention of many investors due to the encouraging environment. The Govt. policies are in favour of the investor.

PLANT LOAD FACTOR & POWER GENERATION

As described earlier it is proposed to install 40 units of GE-1.6 87/80 1.6 MW rated WTGs and 31 units of Gamesa G-97 2.0MW rated WTGs. As per WRA studies, 31.8% is the annual gross plant load factor at generating terminals, however considering machine availability, grid availability etc. the net PLF at output terminals will be 26.5 % at probability exceedance factor of P (50), 24.2% at a probability exceedance factor of P (75).

Generation in the proposed wind farm is estimated to be:

a) 292.4 million units at probability factor of P (50),
b) 267.1 million units at probability factor of P (75),

The financial analysis for the project has been done based on energy generation at probability factor of P 75.

UNIT PRICE OF SALEABLE POWER

The generation of power at output terminals is estimated to 267.1 million units (kWh) based on 40 units of GE-1.6 87/80 WTGs and 31 units of Gamesa G-97 WTGs , which will be interfaced with the grid at interfacing point. Keeping in view the preferential tariff as fixed by RERC, the Company proposes to sell the power under PPA to RRVPN at tariff determined by Rajasthan Electricity Regulatory Commission. Proposed tariff of 5.73 Rs/kWh + 1% incentive for evacuating power at 33 KV and 2.5% incentive for evacuating power at 132 KV has been assumed for the financial analysis.

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OPERATION & MAINTENANCE, ADMINISTRATIVE & INSURANCE COST

The basic components of operation and maintenance include continuous surveillance of machine operations, regular preventive maintenance activities, periodical technical quality checks, repairs, spare parts, maintenance of control systems etc. As per the discussion with O&M service providers and existing O&M contracts, O&M cost with annual escalation of 5% has been considered for financial projections.

REVENUE FROM CDM and REC (Renewable Energy Certificates)

Wind farm being an environmentally benign has a distinct possibility of reducing green gas house gas emissions and maintains the carbon balance in the atmosphere. Hence the project is eligible for the benefits under the Clean Development Mechanism (CDM).

The CER's after validation and CDM EB registration will attract a competitive price in the international markets and would generate additional revenue to the project.

PROJECT ASSUMPTIONS AND FINANCIALS

The total project cost comprising expenditure towards preliminary expenses, land, EPC, overhead and pre operative expenses including contingency at the bus bar is estimated to be Rs 837.06 Crores. The tentative breakup of the capital cost is given below:

The break-up of Project Cost is as follows:

Project Cost Breakup	*Value (Rs/Crs.)*
Land Cost	14.03
EPC Cost	757.71
Contingency and Misc	18.00
Interest During Construction	38.10
Financing Charges	6.30
Working Capital Margin	5.86
Total Project Cost	840.00

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Land and Site Development

The Project will be located across 6 villages in Pratapgarh District namely Dhamotar, Kulmipura, Nakor, Tanda, Mahuri Khera & Tila located at an aerial distance of around 10 km on North of Pratapgarh City of Pratapgarh district of Rajasthan State. In this regard around 200 acres of land would be required by the company. Land and Site Development of Rs. 14.03 Crores include Site leveling and grading and site development.

Engineering, Procurement & Construction (EPC)

The Company shall procure the wind turbines generators (WTG) from the supplier directly and has appointed EPC contractor for balance scope of works. The Company had invited bids for providing EPC services for the project. Based on technical and commercial eligibilities, the Company has shortlisted Welspun Energy Private Limited (WEPL) as successful EPC contractor for balance of system. EPC cost shall include cost towards procurement of Wind Turbines Generator set, electrical systems, civil works for erection & commissioning and construction of evacuation infrastructure for the project. The total cost estimated to be incurred under EPC works is Rs 757.71 Crores including the cost of Rs 13.40 Crores towards Evacuation System and Switchyard.

Contingency

This is a provision in the project cost to cover any eventualities due to any unforeseen occurrences during construction stage of the project. Contingency could be both price as well as physical contingency. Generally it covers Foreign exchange fluctuations, equipment price etc. As a benchmarking practice in these types of projects, contingency provision is kept as 2.34 % of works cost which works out as Rs. 18.00 Crores approx.

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Interest during Construction

The interest during construction of Rs.38.10 Crore has been calculated for the estimated drawdown schedule based on the schedule for implementation of the entire project. The commercial operation of the project is expected to commence operations for entire project from Oct 2015. The interest rate has been assumed at 11.75% p.a

Financing Charges

Financing charges of Rs. 6.30 Crores includes upfront fee for term loans, expenses for legal counsels and any other incidental expenditure.

Means of Finance

The project is proposed to be financed with a Debt: Equity ratio of 75:25 as under:

Promoter contribution: The Company shall contribute 25% towards promoter's contribution for the project which translates in to Rs 209.99 Crores. The promoter contribution shall be contributed by Welspun Renewables Energy Private Limited.

Debt: The total debt requirement of Rs. 629.96 Crores shall be arranged from banks and financial institutions for the project. The financial projections have been prepared based on the interest cost of 11.75% p.a.

Means of Finance	Rs. Crore	%
Promoter Contribution	210.00	25%
Debt	630.00	75%
Total Means	840.00	100%

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Detailed financial analysis has been done considering the below assumptions for the project

Assumptions	
Project Cost Summary	**Figures in Rs Crs.**
Project Cost	840.00
Project Cost/MW	6.67
Project Cost Breakup	**Value**
Land Cost	14.03
EPC Cost	757.71
Contingency	18.00
Interest During Construction	38.10
Financing Charges	6.30
Working Capital Margin	5.86
Total Project Cost	**840.00**
Plant Parameters	
Plant Capacity(MW)	126.0
Life of Plant	25
CUF	24.20%
O & M Cost (Rs lakhs per WTG) incl of Taxes	12.00
Escalation in O&M Cost	5.00%
Hard Cost Rs cr/MW	6.31
Tariff(Rs./Kwh)	5.73
Financing Assumptions	
Debt	75%

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Assumptions	
Debt (Rs. Crs.)	630.00
Equity	25%
Equity (Rs. Crs.)	210.00
Upfront Equity	50%
Plant COD	Oct 2015

Energy Generation

The energy generation has been estimated based on wind resource assessment study done by 3 TIER. The long term gross energy generation estimates is 351.2 GWh per year with a corresponding gross capacity factor of 31.8%. Loss factors have been considered leading to a net energy estimate of 292.4 GWh with a corresponding net capacity factor of 26.5% at probability factor of P 50 and a net energy estimate of 267.1 GWh with a corresponding net capacity factor of 24.2% at probability factor of P 75.

Revenue

The revenues have been estimated considering sale of energy generated to DISCOM in Rajasthan (100% capacity) at Rs. 5.73 per unit for 25 years. The revenue projections are based on energy generation of 267.1 GWh (corresponding to net CUF at P 75) as per 3 TIER assessment study.

O&M Expenses

Annual fixed operation and maintenance (O&M) cost has been considered at Rs 12.00 lakhs per WTG. An escalation of 5.00% per annum in O&M cost has been considered.

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Ratio Analysis

The table below highlights key financial performance ratios based on the financial analysis carried out for the project. Till commercial operation date, the interest during construction will be capitalized till COD, after the COD the interest on term loan will get charged to Profit & Loss account.

Ratio	*Value*
Average EBITDA Margin	*87%*
Average PAT Margin	*27%*
Average DSCR	*1.44*
Minimum DSCR	*1.36*

Scenario Analysis

In order to ascertain the robustness of the project, sensitivity of the key project parameter was tested. The following is the impact of these sensitivities on the key ratios:

#	Scenario	Avg DSCR	Min DSCR
	Base Case	1.44	1.36
1	Decrease in CUF by 5%	1.36	1.29
2	Increase in interest rates by 100 bps	1.38	1.29
3	Increase in O&M cost by 20%	1.40	1.33
4	Decrease in CUF (5%) + Increase in interest rates (1%) + Increase in O&M cost (20%)	1.29	1.21

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It may be observed that the average DSCR and minimum DSCR for the Project continue to remain comfortable for all the above scenarios. It may be noted that the CUF considered for the project has been derived from a conservative scenario.

Conclusion

The project shall be operational for the life of 25 years generating revenues at fixed tariff of Rs. 5.73 per Kwh. Based on debt equity ratio of 3:1 the project has comfortable Average DSCR of 1.44 and minimum DSCR of 1.36. Hence it can be concluded that the project is technically and economically viable.

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126MW Wind Energy Project @ Pratapgarh, Rajasthan

FINANCIAL STATEMENTS

Welspun Energy Limited

AWT ENERGY PVT. LTD. MUMBAI 400 022.

Wind Technical Department, Welspun

PROJECTED INCOME STATEMENT

(in Rs Crores)

FY Ending March	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Income														
Sale of Power	83.80	154.45	154.45	154.45	154.45	154.45	154.45	154.45	154.45	154.45	154.45	154.45	154.45	154.45
GBI Revenues	7.17	13.22	13.22	13.22	13.22	8.38	6.72	6.72	6.72	5.84	-	-	-	-
Other Income	0.55	2.24	2.20	2.20	2.26	2.21	2.22	2.18	2.15	2.07	2.06	2.04	1.99	1.13
Total Income	*91.51*	*169.92*	*169.88*	*169.87*	*169.94*	*165.04*	*163.38*	*163.35*	*163.31*	*162.36*	*156.51*	*156.50*	*156.44*	*155.58*
Expenses														
O & M Fee	5.55	8.91	9.35	9.82	10.31	10.83	11.37	11.94	12.53	13.16	13.82	14.51	15.23	16.00
Insurance Premium	0.74	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18
Miscellaneous	2.08	3.47	3.65	3.83	4.02	4.22	4.43	4.65	4.89	5.13	5.39	5.66	5.94	6.24
Total Expenses	*8.37*	*13.56*	*14.18*	*14.83*	*15.52*	*16.23*	*16.98*	*17.77*	*18.60*	*19.47*	*20.39*	*21.35*	*22.36*	*23.42*
PBIDT	*83.15*	*156.35*	*155.70*	*155.04*	*154.42*	*148.81*	*146.40*	*145.58*	*144.71*	*142.89*	*136.12*	*135.15*	*134.08*	*132.16*
Depreciation	22.37	35.41	35.41	35.41	35.41	35.41	35.41	35.41	35.41	35.41	35.41	35.41	35.41	35.41
Term Loan Interest	46.64	72.34	68.41	64.17	59.72	54.83	49.55	44.00	38.09	31.90	25.49	18.81	11.69	4.21
WC Interest	2.06	2.74	2.76	2.77	2.78	2.74	2.73	2.75	2.76	2.78	2.72	2.74	2.76	2.79
PBT	12.07	45.85	49.11	52.69	56.51	55.83	58.71	63.41	68.44	72.79	72.50	78.19	84.22	89.75
Tax	8.08	18.15	18.80	19.52	20.28	20.14	20.72	21.66	22.67	23.54	23.48	24.62	20.14	6.47
PAT	*3.99*	*27.70*	*30.31*	*33.17*	*36.23*	*35.68*	*37.99*	*41.75*	*45.77*	*49.25*	*49.02*	*53.57*	*64.08*	*83.29*

AWT ENERGY PVT. LTD. MUMBAI 400 022.

PROJECTED BALANCE SHEET

(in Rs Crores)

FY Ending March	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Sources of Funds														
Equity Capital	210.00	210.00	210.00	210.00	210.00	210.00	210.00	210.00	210.00	210.00	210.00	210.00	210.00	210.00
Reserves & Surplus	3.99	31.69	62.01	95.18	131.40	167.09	205.08	246.83	292.60	341.86	390.88	444.44	508.53	591.81
DTL/(DTA)	5.67	14.64	23.62	32.59	41.56	50.54	59.51	68.48	77.46	86.43	95.40	104.38	107.66	96.17
Networth	219.66	256.33	295.62	337.76	382.97	427.62	474.58	525.31	580.06	638.28	696.28	758.82	826.19	897.98
Term Loans	630.00	598.20	562.65	525.90	486.60	442.20	396.60	347.40	295.80	241.80	186.60	127.65	65.10	0.00
Working Capital	17.57	23.35	23.47	23.61	23.69	23.29	23.24	23.40	23.52	23.64	23.11	23.31	23.46	23.73
Total	**867.23**	**877.88**	**881.74**	**887.27**	**893.25**	**893.12**	**894.43**	**896.11**	**899.38**	**903.73**	**905.99**	**909.78**	**914.75**	**921.71**
Applications of Funds														
Gross Block	834.14	834.14	834.14	834.14	834.14	834.14	834.14	834.14	834.14	834.14	834.14	834.14	834.14	834.14
Acc. Depreciation	22.37	57.79	93.20	128.61	164.03	199.44	234.86	270.27	305.68	341.10	376.51	411.93	447.34	482.75
Net Block	*811.77*	*776.36*	*740.94*	*705.53*	*670.11*	*634.70*	*599.29*	*563.87*	*528.46*	*493.05*	*457.63*	*422.22*	*386.80*	*351.39*
Current Assets	23.43	31.13	31.30	31.47	31.58	31.06	30.99	31.21	31.36	31.52	30.81	31.08	31.28	31.64
DSRA	31.23	32.02	31.48	31.43	32.33	31.54	31.65	31.19	30.65	29.56	29.45	29.19	28.39	16.08
Cash	0.80	38.38	78.03	118.84	159.22	195.82	232.50	269.84	308.90	349.59	388.09	427.30	468.27	522.60
Net Current Assets	55.46	101.52	140.80	181.74	223.14	258.42	295.14	332.24	370.92	410.68	448.36	487.56	527.94	570.32
Total	**867.23**	**877.88**	**881.74**	**887.27**	**893.25**	**893.12**	**894.43**	**896.11**	**899.38**	**903.73**	**905.99**	**909.78**	**914.75**	**921.71**

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PROJECTED CASH FLOW STATEMENT

(in Rs Crores)

FY Ending March	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
PAT		3.99	27.70	30.31	33.17	36.23	35.68	37.99	41.75	45.77	49.25	49.02	53.57	64.08	83.29
Add: Depreciation & NC		22.37	35.41	35.41	35.41	35.41	35.41	35.41	35.41	35.41	35.41	35.41	35.41	35.41	35.41
Add: DTL/(DTA)		5.67	8.97	8.97	8.97	8.97	8.97	8.97	8.97	8.97	8.97	8.97	8.97	3.28	-11.49
Change in WC		23.43	7.70	0.17	0.18	0.11	-0.53	-0.07	0.22	0.15	0.17	-0.71	0.26	0.21	0.36
CF from Operations		*8.60*	*64.39*	*74.53*	*77.38*	*80.51*	*80.60*	*82.44*	*85.92*	*90.01*	*93.48*	*94.12*	*97.69*	*102.58*	*106.85*
Promoter Equity	134.36	75.64	-	-	-	-	-	-	-	-	-	-	-	-	-
Senior Debt Infusion	403.08	226.92	-	-	-	-	-	-	-	-	-	-	-	-	-
Senior Debt Repayment	-	-	31.80	35.55	36.75	39.30	44.40	45.60	49.20	51.60	54.00	55.20	58.95	62.55	65.10
WC Debt	-	17.57	5.77	0.13	0.13	0.08	-0.39	-0.05	0.16	0.12	0.12	-0.53	0.20	0.15	0.27
CF from Financing	*537.44*	*320.13*	*-26.03*	*-35.42*	*-36.62*	*-39.22*	*-44.79*	*-45.65*	*-49.04*	*-51.48*	*-53.88*	*-55.73*	*-58.75*	*-62.40*	*-64.83*
CWIP	537.44	-													
CAPEX	-	296.70													
CF from Investing	*537.44*	*296.70*													
Net Cash Flow	-	*32.03*	*38.37*	*39.11*	*40.76*	*41.29*	*35.80*	*36.79*	*36.89*	*38.52*	*39.60*	*38.39*	*38.94*	*40.18*	*42.02*
Cash Required for DSRA	-	31.23	0.79	-0.54	-0.05	0.90	-0.79	0.11	-0.46	-0.54	-1.09	-0.11	-0.27	-0.79	-12.31
Opening Cash Balance	-	-	0.80	38.38	78.03	118.84	159.22	195.82	232.50	269.84	308.90	349.59	388.09	427.30	468.27
Add/(Deduction)	-	0.80	37.58	39.65	40.81	40.38	36.59	36.68	37.35	39.06	40.69	38.50	39.20	40.97	54.33
Closing Cash Balance	-	0.80	38.38	78.03	118.84	159.22	195.82	232.50	269.84	308.90	349.59	388.09	427.30	468.27	522.60

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