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## EXECUTIVE SUMMARY OF THE KALPASAR PROJECT

### 1.0 Introduction - Renewable energy

Renewable energy sources such as wind, solar, and other forms of solar energy have become the preferred option due to environmental concerns and rapidly depleting fossil fuel reserves. It is projected that India has a renewable energy potential of around 1500 GW, with solar power accounting for 750 GW (assuming that 3% of the country's land is used for solar installations) and wind accounting for 302 GW (at 100-m mast height) and 695 GW (at 120-m mast height), respectively. Small hydro and bioenergy have 20 GW and 25 GW potential, respectively. The Indian government has set a target of 175 GW by 2022. The objective is to generate 60 GW of wind, 100 GW of solar, 10 GW of biomass, and 5 GW of small hydro energy. Rooftop solar is expected to account for 40 GW of the 100 GW total, with the remaining 60 GW coming from ground-mounted, grid-connected medium and large solar installations. The Indian government recently set a target of 500 GW of renewable energy by 2030.

In order to explore the possibilities of Renewable energy, the National Centre for Coastal Research (NCCR), Chennai, has approached the National Institute of Wind Energy (NIWE) to prepare a Detailed Project Report to develop a wind-solar hybrid system around the Kalpasar Dam Project in order to maximize the use of natural resources. An important goal of this project is to explore the possibility of generating electricity from renewable sources such as wind and solar to meet the demand for electricity required to pump water from the dam and deliver it into canals.

The proposed land area near and below the wind turbine will be ideal for installing solar panel arrays. In order to pump irrigation water from the GKDP reservoir, a 1500MW wind farm and 1000 MW solar park has been proposed. Approximately 4000 to 4500 hectares of land will be required for this hybrid project.

### 1.1 Wind energy

The proposed feasibility study site for the wind-solar hybrid plant is the Kalpasar site, as shown in Figure 1, which stretches along the Gulf of Khambhat from Bhavnagar to Bharuch district in Gujarat, in the western part of India. The designated RE area (also referred to as the "Boundary") is a homogeneous coastal land area of 430.6 sq. km that has been designated explicitly for Renewable Energy-related projects. Based on three existing NIWE met mast sites in Gujarat, namely Motibaru, Vadgam, and Khavi the analysis has been carried out. In order to cover up the entire wind farm area, as a part of

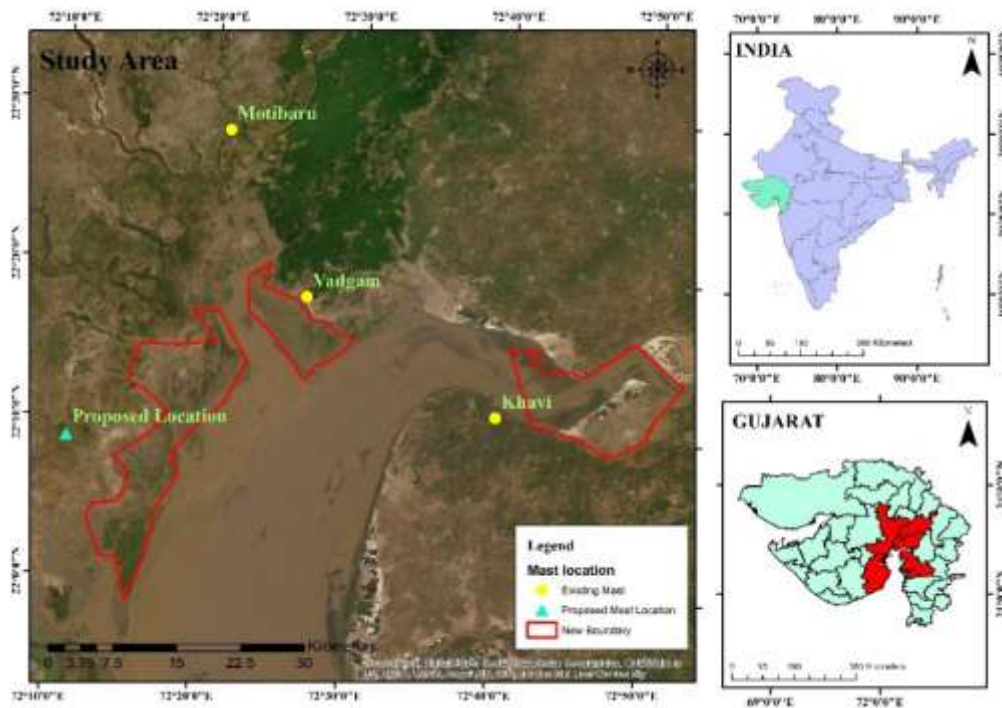
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the proposal, one number of 100m masts was proposed to be installed at the site. The mast was successfully installed on 05.07.2022, and data measurement is underway. In this preliminary study, the Motibaru wind climate has been assumed to represent the new mast location. The geographical information of the met masts at the Khavi and Vadgam sites, and the newly installed mast, are presented in Table 1, and the wind characteristics of the Motibaru, Vadgam, and Khavi sites are shown in Tables 2, 3, and 4.

**Table 1. Location Details**

Met Mast Name	Geographical coordinates							
	N(m)	E(m)	Elev. (m) ASL	Height of Mast (m)	WPD (W/m <sup>2</sup> )	Turbulence Intensity (TI)	Year of data	Organization
Khavi	22°11'14.60"	72°39'59.50"	13	100	206	0.10	Jan 2015- Dec 2015	NIWE
Vadgam	22°20'52.33"	72°23'46.64"	7	50	188	0.14	Aug 2006- July 2007	NIWE
New mat location in the Proposed Region	22°8'47.26"	72°10'57.61"	8	100	-	-	July 2022 -	NIWE



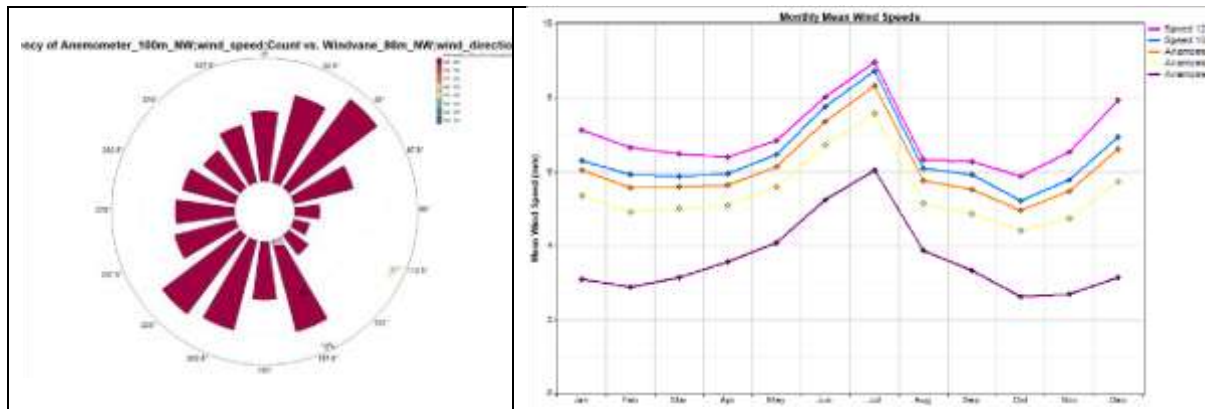
**Figure 1. The Region of Interest**

## 1.1.1 Wind Characteristic Details

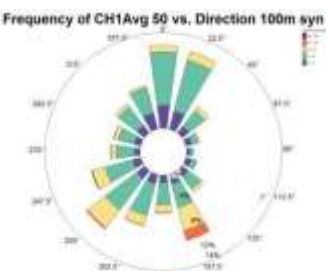
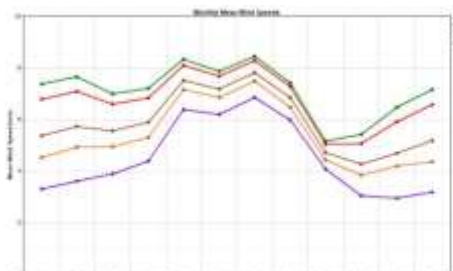
**Table 2. Wind Characteristics of Motibaru Mast  
(Assumed to represent the new proposed mast location)**

Site Name/mast height	<b>Motibaru / 100 m Height</b>
Period of Data taken for Analysis	1 <sup>st</sup> Jan 2015 – 24 <sup>th</sup> Nov 2015
Site Air density	1.185 kg/m <sup>3</sup>
Annual mean wind speed 1 <sup>st</sup> Jan 2015 – 31 <sup>st</sup> Dec 2015 (100 Combined, 80 m, 50 m, 10 m)	6.427 m/s@ 100m AGL, 6.094 m/s@ 80m AGL, 5.441, m/s@ 50m AGL, 3.657 m/s@ 10m AGL.
The predominant wind direction at the site	North - East, South - West

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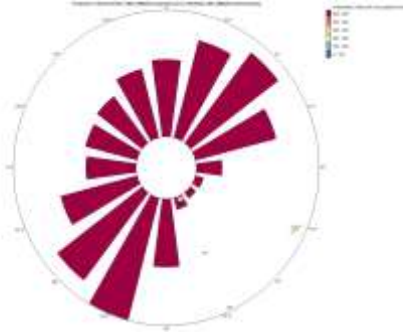
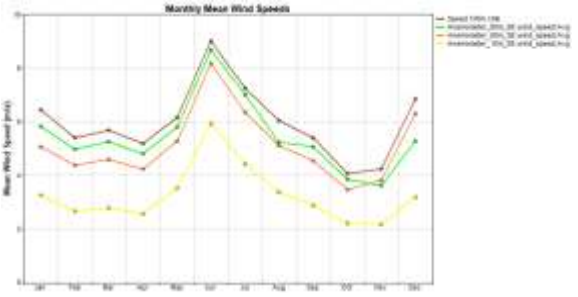


**Table 3. Wind Characteristics of Vadgam Mast**

<b>Site Name/mast height</b>	<b>Vadgam / 50 m Height</b>
Period of data taken for analysis	1 <sup>st</sup> Aug 2006 – 31 <sup>st</sup> Jul 2007
Site Air density	1.217 kg/m <sup>3</sup>
Annual mean wind speed July 2008 - July 2009 (50 m, 30m, 10 m)	5.925 m/s @ 50 m AGL, 5.405 m/s @ 30 m AGL, 4.518 m/s @ 10 m AGL.
The predominant wind direction at the site	North - East, South - West
	

**Table 4. Wind Characteristics of Khavi Mast**

<b>Site Name/mast height</b>	<b>Khavi / 100m Height</b>
Period of data taken for analysis	January 2015 – December 2015
Site Air density	1.163 kg/m <sup>3</sup>
Power law	0.259
Annual mean wind speed January 2015 – December 2015 (100m)	5.911 m/s @ 100m AGL, 5.389 m/s @80m AGL, 5.056 m/s @ 50m AGL,

	3.219 m/s @ 10m AGL.
The predominant wind direction at the site.	North - East, South - West
	

The wind measurement at the site was conducted for one year, whereas the wind farm’s operational period is 20 years. As a result, understanding the long-term variation of wind characteristics with the help of available data sources is critical in order to reduce uncertainty in estimation and mitigate the risk of underperformance of the wind farm. In this regard, ERA5 reanalysis data were used in the current study to perform long-term corrections for each region.

WASP software (Version 12.7) was used for this study’s wind flow modelling analysis, considering the homogeneous/flat terrain available at the proposed site. In this regard, NIWE created the contour map using SRTM (Shuttle Radar Topography Mission) 1 arc data, and the roughness map was created using satellite images. The results of the wind flow model created with WASP were then used to create a wind resource map and perform Micrositing.

### 1.1.2 Wind Turbines used for the study

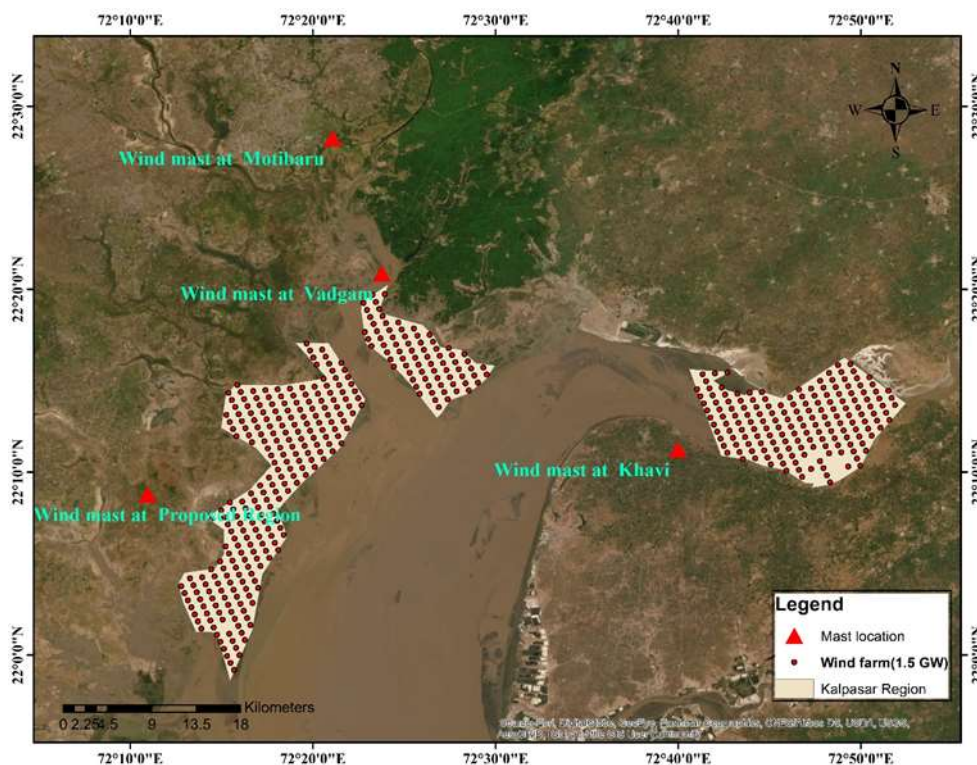
Based on the wind regime and turbulence intensity results of the measurement region, the region of interest falls under the **IEC Class III C** category. Considering the same, NIWE has carried out energy estimation analysis using the following Wind Turbine models extracted from the latest RLMM (Revised List of Models and Manufacturers) list.

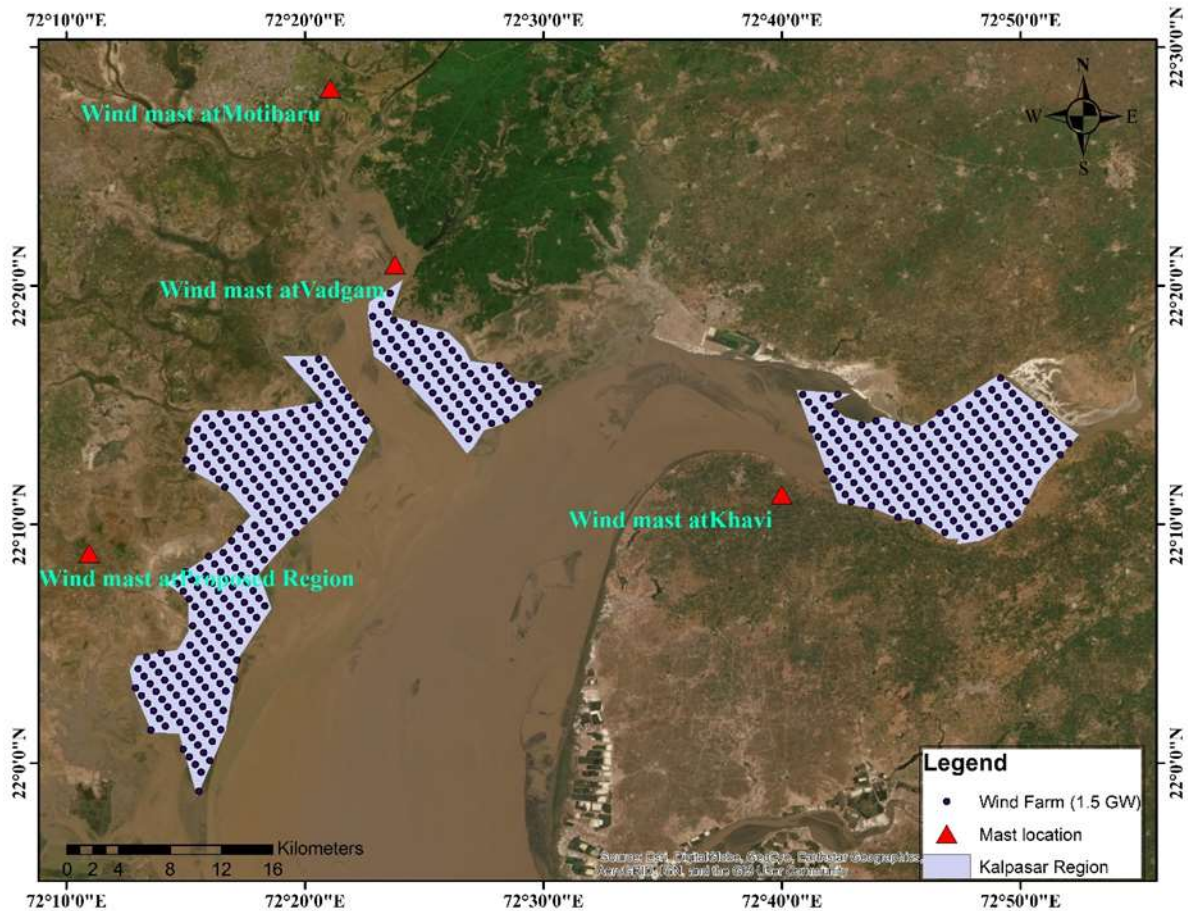
## Wind Turbine Generator Models

S. No	Wind Turbine Generator	Capacity (MW)	Rotor diameter (m)	Hub height (m)	IEC Class
1	Model A	3.3	156	140	Class S
2	Model B	3.465	145	127.5	Class S

### 1.1.3 Micro siting and Estimation of Annual Energy Production (AEP)

Based on the discussion with NCCR, the elevation range between 3m to 5m contour line has been considered for the Micrositing layout preparation. Micrositing with a 5Dx7D configuration is used to design the 1500 MW capacity wind farm. The uncertainty analysis is a critical component of any assessment of a wind farm's long-term energy production. As a result, NIWE considered the standard uncertainties/assumptions when determining generation levels. The micro siting layout for Model A and Model B is shown in Figures 2 & 3.





**Figure 3. Micrositing Layout for Model B**

### 1.1.4 Energy Yield Estimation Summary

Based on the study, it was deduced that the average wind generation profile, when combined with solar generation, can meet the dam’s energy needs in most months, with the annual average generation from wind expected to be 3971.56 GWh with a % CUF of up to 31 % at the P90 probability exceedance level. Therefore, the estimated Annual Energy production (AEP) is displayed in Table 5.

**Figure 2. Micrositing Layout for Model A**

**Table 5. Estimated AEP & %CUF for the wind farm using different wind turbine models**

Wind Turbine Models		
	Model A	Model B
Rated Capacity of the Turbine (MW)	3.3	3.465
Rotor Diameter (m) & Hub height (m)	156 & 140	145 & 127.5
Total number of Turbines	455	435
Wind Farm Capacity (MW)	1501.5	1507.2
Average Energy Generation (GWh) for 20 Years	P50	1632.40
	P75	1470.01
	P90	1323.86
	P95	1236.39
Capacity Utilization Factor (%) for 20 Years	P50	37.82
	P75	34.21
	P90	30.95
	P95	29.00

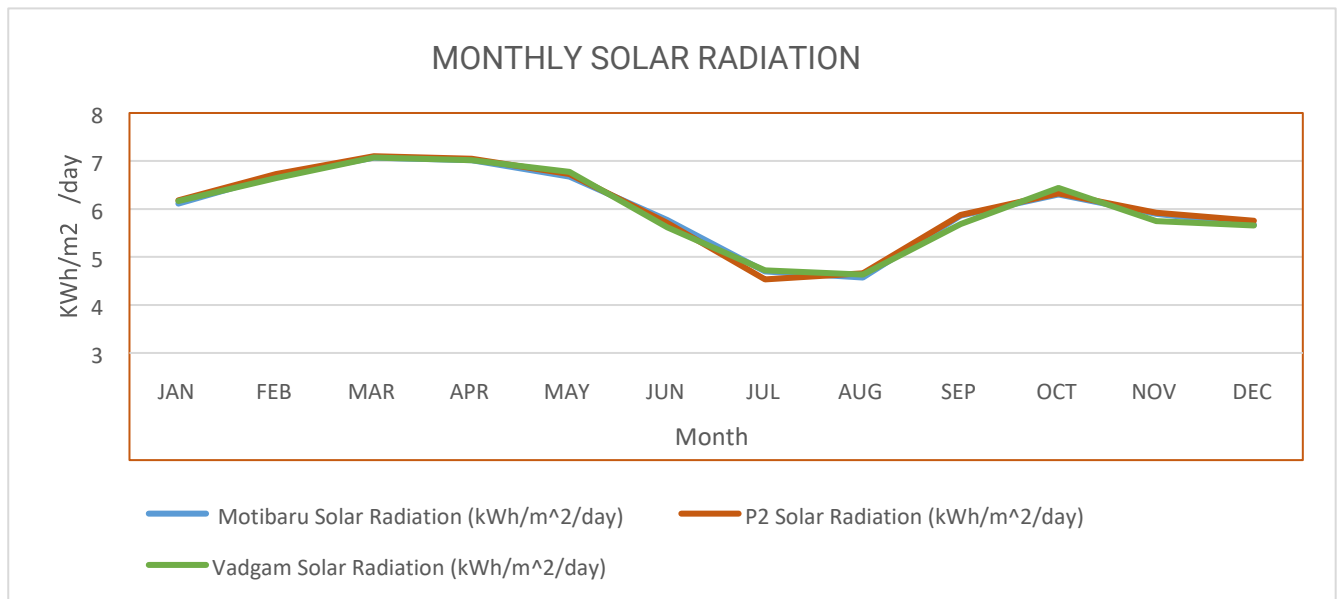
## 1.2 Solar energy

In addition to the wind farm, a 1000 MW capacity solar power plant is being proposed for implementation. The basic parameters of the site for determining the viability of solar power development are as follows;

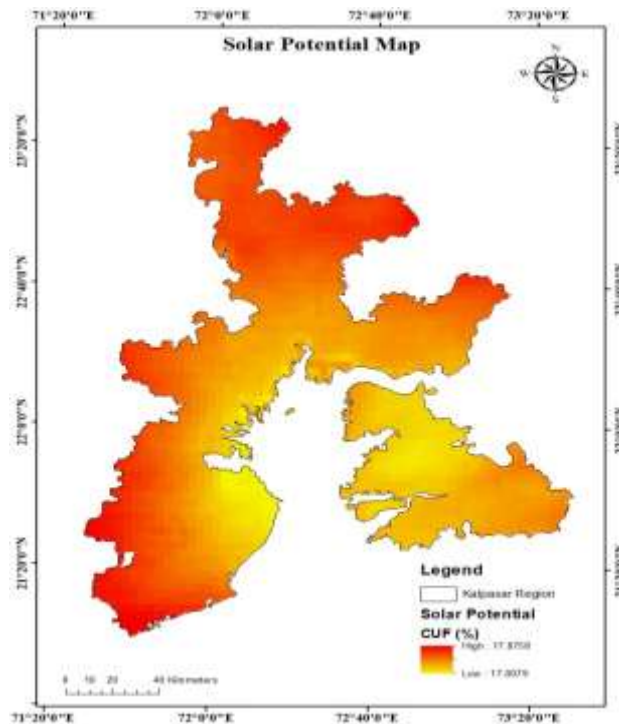
- Solar insolation in this area is 5.8 kWh/m<sup>2</sup> /day.
- A wind park with a land area of 4500 hectares is proposed, of which 3000 hectares (without any shadow effect) will be available for solar power development. We can also plan for the solar plant in the reclaimed area between 5m to 7m contour lines.

- Because the area required for solar PV power is 3.0 hectare/MW, 1000 MW of solar power installation is viable on 3000 ha of land.

Aside from the fact that wind and solar energy development are compatible, there is a significant amount of complementarity between the two. The monthly solar radiation is shown in Figure 4, and the comparison of monthly solar radiation is displayed in Figure 5, which has been referred from Global Solar Atlas.



**Figure 4. Monthly solar radiation (Global Solar Atlas)**



**Figure 5. Solar Potential of Kalpasar Region (NIWE Solar Atlas)**

The PVsyst software was used to calculate the region’s solar power generation and %CUF. In addition, NIWE’s solar Atlas data was considered for Meteo data. Based on the calculation, the Performance Ratio of the region is 83.08%, as shown in Figure 6, and the CUF is estimated as 18.10%. The CUF estimation was based on the 1:1 – DC: AC ratio assumption. The assumed module used for the calculation is mentioned the Table 6, and the performance ratio of the region is shown in Figure 6.

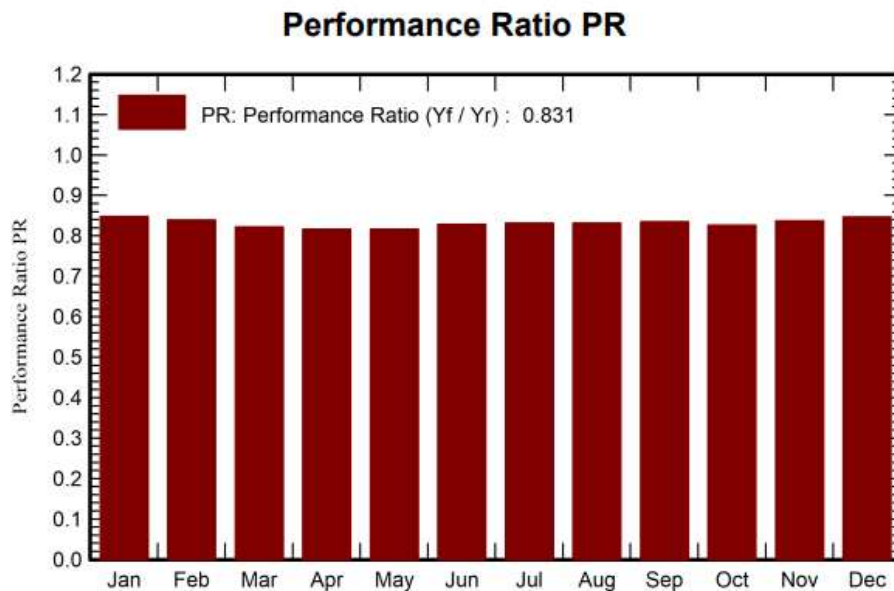
Table 6. The SPV module specification

Tilt/Azimuth		23°
PV module	Unit Nom. Power	505 Wp
	Number of PV modules	1980200 units
	Modules	79208 Strings x 25 in series
	Total PV power	1000001 kWp
	Nominal (STC)	1000001 kWp
	Total	1980200 modules

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		Module area	4731189 m <sup>2</sup>
Inverter	Unit Nom. Power		4000 kWac
	Number of inverters		250 units
	Total power		1000000 kWac
	Operating voltage		802-1500 V
	Pnom ratio (DC:AC)		1.00
	Total inverter power	Total power	1000000 kWac
		No. of inverters	250 units
Pnom ratio		1.00	
Array losses	Array Soiling Losses (Loss Fraction)		3.0 %
	Module mismatch losses		1.0 % at MPP
	Strings Mismatch loss		0.1 %
	DC wiring losses		1.5 % at STC
	Serie Diode Loss		0.1 % at STC
Produced Energy			1586 GWh/year
Perf. PR Ratio (Performance Ratio)			83.08 %
%CUF			18.10 %



**Figure 6- Performance Ratio of the region**

## 1.3 Power Evacuation Analysis and Summary

The wind and solar farms will supply power to a dedicated pooling substation with a voltage of 220/33 kV or 400/33 kV, depending on the voltage level at which the Gujarat state transmission utility grants connectivity. According to the power evacuation study, the pooling sub-station will be connected to the grid sub-station at 400 kV or 220 kV. Based on the Literature review, PGCIL has carried out power system studies for grid strengthening and evacuation of approx. 15 GW power from Khavda potential RE zone in the northern part of Gujarat and 5 GW capacity from the Dholera Ultra Megawatt Solar project by 2025. The proposed 765 kV transmission corridor from Khavda – Halvad-Vataman- Kosamba is one of the possible options for evacuating power from the Kalpasar wind-solar farm.

Since the site is on the coast, the soil conditions must be tested so that a suitable foundation can be made, and specific clearances such as CRZ clearance must be investigated for the project's effective execution. Because the proposed region is closer to salt farming, a proper foundation must be established, and the project's cost will rise as a result. In addition, we considered the boundary region in terms of future realities.

Based on the analysis, the CUF of this region is expected to be 30%. It is to be noted that in the absence of metrological data for the P2 region, we have used wind data

measurement of Motibaru in AEP Analysis. Thus, a Real-time measurement is envisaged to improve the energy yield estimation and to understand the wind potential. NIWE has already installed a Met Mast in the proposed region, and after one year of measurement, the data will be helpful in enhancing the results.

## 1.4 Indicative Financial Evaluation

### 1.4.1 Indicative Financial Evaluation for Wind

Based on the energy estimation analysis, NIWE has carried out an indicative financial evaluation by assuming %CUF as 30% for wind farms. The components of the financial estimation are shown in Table 7. As a result, the Levelised Tariff for 25 Years (Rs./KWh) is estimated to be **3.63 Rs/kWh**. Considering the size of the project and soil conditions, the project cost is assumed to be Rs.700 Lakhs / MW.

**Table 7 – Indicative Financial Evaluation**

Project Inputs		units
Project Cost	700.00	Lakhs
Debt Portion	70	%
Equity Portion	30	%
Debt Portion In Rs. Lakhs	490.00	Lakhs
Equity Portion In Rs.Lakhs	210.00	Lakhs
Repayment of Loan In Years	15	years
Interest Rate	8.00	%
Interest On Working Capital	8.00	%
Return On Equity (In %)	1yr To 10th yr	12
	11th yr To 25yr	12
	Avg ROE	12
Depreciation Of Project Cost	4.67	%

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O & M Expenses @ 1.5% Of Capex	10.50	Lakhs/MW
O & M Escalation Per Annum In %	3.84	%
Life Period	25	years

In addition to this, the foundation cost has to be analyzed by considering the type of foundation used in the region since the region is near the coastal line.

Considering the possibility of variation in project cost and estimated energy yield, the sensitivity analysis (LCOE) has been carried out by increasing and decreasing in the project cost with respect to CUF values, as shown in Table 8.

**Table 8 – Sensitivity Analysis for Project Cost and CUF**

Project cost/CUF	28%	30%	32%	35%
5% increase in Project cost	4.09	3.81	3.58	3.27
10% increase in Project cost	4.28	4.00	3.75	3.42
5% decrease in Project cost	3.70	3.45	3.23	2.96
10% decrease in Project cost	3.50	3.27	3.06	2.80

## 1.4.2 Indicative Financial Evaluation for Solar

The indicative financial evaluation for the Solar plant is carried out by assuming 18% CUF. The financial components are shown in Table 9. As a result, the Levelised Tariff for 25 Years (Rs./KWh) is estimated as **3.64 Rs/kWh**. Considering the huge size of the project, the project cost is considered Rs.400 Lakhs / MW.

**Table 9 – Indicative Financial Evaluation**

Project Inputs		units
Project Cost	400.00	Lakhs
Debt Portion	70	%
Equity Portion	30	%

*Techno-Economic Feasibility Interim Report for the development of Wind and Solar Hybrid Farm for Kalpasar project*

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Debt Portion In Rs.Lakhs	280.00	Lakhs
Equity Portion In Rs.Lakhs	120.00	Lakhs
Repayment of Loan In Years	15	years
Interest Rate	8.00	%
Interest On Working Capital	8.00	%
Return On Equity (In %)	1yr To 10th yr	12
	11th yr To 25yr	12
	Avg ROE	12
Depreciation On Project Cost	4.67	%
O & M Expenses @ 2% Of Capex	8.00	Lakhs/MW
O & M Escalation Per Annum In %	3.84	%
Life Period	25	years

The results of the sensitivity analysis are shown in Table 10.

**Table 10 – Sensitivity Analysis for Project Cost and CUF**

Project cost/CUF	17%	18%	20%	22%
5% increase in Project cost	4.06	3.84	3.45	3.14
10% increase in Project cost	4.26	4.02	3.62	3.29
5% decrease in Project cost	3.68	3.47	3.13	2.84
10% decrease in Project cost	3.48	3.29	2.96	2.69

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## 1.5 Benefits of the projects

With the development of this project, numerous benefits can be accrued at the Kalpasar dam project, which include.

- ✓ Wind and solar energy generation can meet the dam's power demand. As a result, the irrigation process and overall rural development are facilitated.
- ✓ A wind energy project with a capacity of 1500 MW has been proposed for the land. Furthermore, a 1000 MW Solar PV power project is proposed for the land beneath and near wind turbines, resulting in a non-polluting green dam.
- ✓ Environmental imbalance is avoided as a result of the reduction of climate change and other environmental pollution, which helps India meet its target of 500 GW of renewable energy by 2030.
- ✓ The cost per kWh is competitive with rising costs for conventional power projects. It serves as a hedge against the price volatility of fossil fuels, ensuring energy security and preventing conflict over natural resources.

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