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Feasibility study report for the 100 MW wind power project

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Contents

Page No.

List of tables

List of figures

CHAPTER 1 Feasibility report for the wind power projects in the states of Gujarat, Maharashtra, Rajasthan and Andhra Pradesh

Methodology adopted for Feasibility Study

The methodology adopted for analysing the feasibility of developing 100 MW wind power project in the states of Gujarat, Maharashtra, Rajasthan and Andhra Pradesh (50 MW each in any two of these states) had following steps:

1. Assessment of
   a. Overall renewable energy scenario in India
   b. Wind power technology
   c. Development of wind power in India
      - Wind resource
   d. Wind potential and installed wind power capacity in Gujarat, Maharashtra, Rajasthan and Andhra Pradesh
2. Analysis of government policies
   - Central Government
   - State Governments policies
3. Analysis of the wind turbines available in India
4. Evaluation of potential sites and selection of sites based on the wind resource and other infrastructure like power evacuation and road.
5. Estimation of possible energy generation at the selected sites of all four states for different selected turbines
6. Analysis of policies regarding captive use as well as sale of wind power, in all the four states.
7. Financial analysis to assess the feasibility based on various factors like, the tariffs of electricity in these facilities, amount of power which would be used as captive purpose/ sold to the utility, capital cost of the project and projected energy generation at the short listed sites. Further, to assess the impact of possible variation in generation and cost estimation, sensitivity analysis was carried out.

The results of the financial analysis along with the wind resource data and government policies have been used to arrive at the recommendations regarding the selection of states and methodology for project development.

Further a study have been carried out to identify the technical feasibility of the solar power plant in the land available between the wind turbines in a wind farm which are arranged in arrays to minimise the wake losses. The possibility of placing the solar systems in the available land is studied by carrying out the shade analysis using ECOTEC, AUTOCAD and Google sketchup tools to access the actual land area which will be free from any shadow and could be utilized for the solar panels installation. Based on the land area so calculated and the radiation intensity in the area the possible capacity of the solar system that can be installed is estimated.

Renewable energy

There are different renewable energy sources like solar, wind, biomass, small hydro, waste to energy, geothermal, ocean energy etc. Out of these, wind, small hydro, solar and biomass technologies have been successfully demonstrated in India. All these technologies, with the exception of solar energy, have been extensively used for power generation in grid-connected mode. Out of these three options, wind power has maximum potential of 48,561MW in India. The potential along with the support from government in the form of accelerated depreciation, renewable purchase specifications, power purchase tariff and generation based incentives makes this technology viable in India. However, unlike other two sources i.e. small hydro and biomass, the wind power at given site does not face any resource availability constraint with proper resource assessment and site selection. In case of small hydro, most of the identified sites are limited in the range of 5–10MW, while biomass project face the challenge of biomass supply and cost issues. Thus, wind power is comparatively viable option for power generation with availability of detailed wind resource data, policy and regulatory support from Government.

Wind energy

Wind resource

Wind speed

The wind speed or the average wind speed is the most critical indicator of the wind potential at a given site. The wind speed at any site is influenced by large number of parameters e.g. the weather system, local land use, geography of the site. The wind speeds at any location have daily as well as seasonal variations. In case of India, generally the monsoon months have highest wind speeds. The variations in the wind speed are described by the weibull distribution.

$$P(V) = ((k/c)(V/c))^{k-1} e - (V/c)^{k}$$

Where P (V) is the probability of having wind speed V, k is the shape factor, and c is the scale factor. A typical wind distribution is shown in Figure 1.1 given below. The average wind speed and the shape factor 'k' decide the shape of frequency distribution curve at a given location.

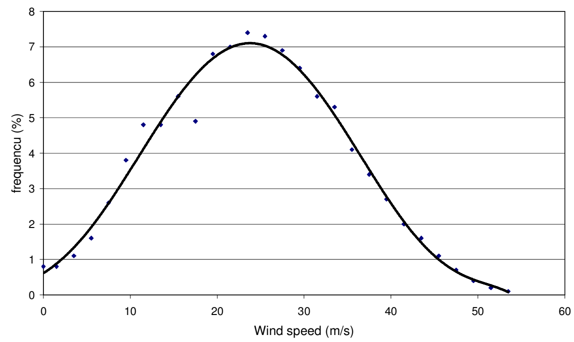


Figure 1.1 Typical frequency distribution of wind speed

Power law index

The wind speeds vary with height. The variation in the wind speeds with height is given by the 'power law index'.

$$(V2/V1) = (H2/H1)^{p}$$

Where V1 and V2 are wind speeds at heights H1 and H2 respectively and p is the power law index.

Wind direction

Like the wind speed the wind direction also varies. This variation in the wind direction is shown as the 'wind rose'. Wind rose is a diagram as shown in figure 1.2 below, showing the percentage of wind blowing from each of the eight directions. It also indicates the strength of the wind in each direction. The wind rose given below shows the percentage frequency of wind blowing from that direction. The wind rose and the frequency distribution of wind direction data are used in siting of wind turbines.

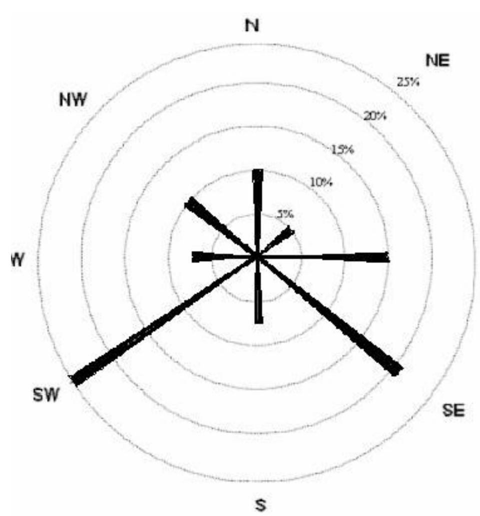


Figure 1.2 Typical wind rose

Energy conversion by the wind turbine

The energy content in wind is given by following equation

$$P = \frac{1}{2} A \rho V^3$$

Where P is power in wind, A is area of cross section, ρ is air density and V is wind velocity. A useful way to evaluate the wind resource available at any site is wind power density. The wind power density P_d is power in wind per unit area (W/m²) of cross section perpendicular to wind direction

$$P_d = \frac{1}{2} \rho V^3$$

The wind turbines convert this wind power in to electricity through use of blades coupled with shaft and generator. Classes of wind power density for two standard wind measurement heights are listed in the table below.

Table 1.1 Classes of wind power and wind power density

Classes of Wind Power Density at 10 m and 50 m(a)				
Wind Power Class	Wind Power Density (W/m²)	Wind Speed m/s (mph)	Wind Power Density (W/m²)	Wind Speed (m/s)
1	<100	<4.4 (9.8)	<200	<5.6 (12.5)
2	100–150	4.4 (9.8) / 5.1 (11.5)	200–300	5.6 (12.5) / 6.4 (14.3)
3	150–200	5.1 (11.5) / 5.6 (12.5)	300–400	6.4 (14.3) / 7.0 (15.7)
4	200–250	5.6 (12.5) / 6.0 (13.4)	400–500	7.0 (15.7) / 7.5 (16.8)
5	250–300	6.0 (13.4) / 6.4 (14.3)	500–600	7.5 (16.8) / 8.0 (17.9)
6	300–400	6.4 (14.3) / 7.0 (15.7)	600–800	8.0 (17.9) / 8.8 (19.7)
7	>400	>7.0 (15.7)	>800	>8.8 (19.7)

(a) Vertical extrapolation of wind speed based on the 1/7 power law

Different wind turbines have different generation at given wind speed; the relation between the wind speed and the output from the turbine is called as power curve. A typical power curve is shown in Figure 1.3 below.

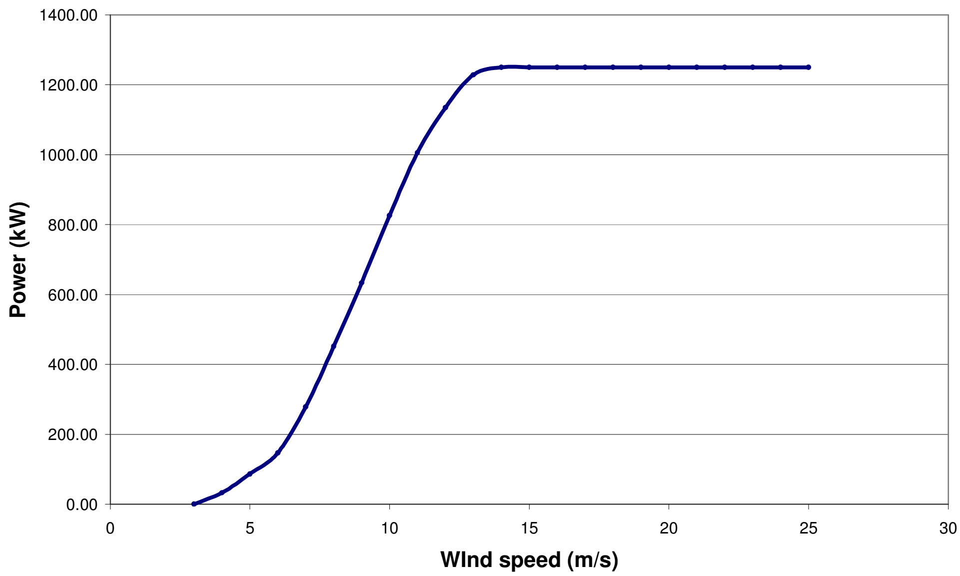


Figure 1.3 Typical power curve of a wind turbine

The wind speed at which the wind turbine starts power generation is called as *cut in wind speed*. The *rated wind speed* for a wind turbine is a wind speed at which the generation from the wind turbine reaches its rated capacity. In case of higher wind speeds the wind turbine shuts down if the wind speeds are higher than the *cut out wind speed* of that wind turbine.

The power generation from the wind turbine depends on the turbine characteristics i.e. the power curve and wind speed. Depending upon the wind speeds the generation from the wind turbine varies. In order to evaluate performance of the wind turbine the Capacity Utilisation Factor (CUF) is estimated. The CUF is ratio of energy generation from the wind turbine to maximum possible generation.

Annual CUF = annual generation (kWh)/ 8760 * Turbine capacity (kW)

The maximum possible generation is the rated generation from wind turbine throughout the year i.e. for all 8760 hours in a year.

Wind turbine

The wind turbines convert the kinetic energy of wind into electricity. The important components of a wind turbine are:

1. Rotor blades
2. Aerodynamic power regulation
3. Generator
4. Reactive power control
5. Yaw mechanism
6. Tower

Rotor blades

The rotor blade is the most critical component of the wind turbine. It captures the wind energy and transfers it to torque required to generate power. The aerodynamic design of the blade is important as it determines the energy capture potential. The type of power control mechanism used also needs to be considered while designing the blades. Another important parameter is the blade material. Commonly used materials are composite materials like glass fibre epoxy, carbon epoxy, fibre-reinforced plastic etc. Out of these materials, the carbon fibres are stronger and stiffer, followed by glass fibre. Sometimes, in order to reduce cost, carbon fibres along with glass fibres are used.

Power regulation of blades

The blades of the wind turbine, through its orientation or design, can regulate/optimise power output. This is called aerodynamic power regulation. There are three different techniques used for power regulation as described below.

Pitch control

In a pitch controlled wind turbine, the turbine's electronic controller checks the power output of the turbine several times per second. When the power output becomes too high, it sends a signal to the blade pitch mechanism, which immediately pitches (turns) the rotor blades slightly out of the wind. Conversely, the blades are turned back into the wind whenever the wind speed drops again. During normal operation the blades will pitch a fraction of a degree at a time - and the rotor will be turning at the same time.

Stall control

It is also known as ‘Passive control’ since control is affected through blade design itself and it involves no moving part. The profile of the rotor blade however is aerodynamically designed to ensure that the moment the wind speed becomes too high; it creates turbulence on the side of the rotor blade, which is not facing the wind, reducing the power output. The basic advantage of stall control is that one avoids moving parts in the rotor itself, and a complex control system. On the other hand, stall control represents a very complex aerodynamic design problem, and related design challenges in the structural dynamics of the whole wind turbine, e.g. to avoid stall-induced vibrations.

Active stall/active pitch

An increasing number of larger wind turbines (1 MW and above) are being developed with an active stall control mechanism. At low wind speeds, the machines will usually be programmed to pitch their blades much like a pitch-controlled machine. However, when the machine reaches its rated power and the generator is about to be overloaded, the machine will pitch its blades in the opposite direction from what a pitch-controlled machine does. This is similar to normal stall power limitation, except that the whole blade can be rotated backwards (in the opposite direction as is the case with pitch control) by a few (3-5) degrees in order to give better rotor control. In other words, it will increase the angle of attack of the rotor blades in order to make the blades go into a deeper stall, thus wasting the excess energy in the wind. The result is known as the 'deep stall' effect, which leads to the power curve bending sharply to a horizontal output line at nominal power and keeping this constant value for all wind speeds between nominal and cut-out. One of the advantages of active stall is that one can control the power output more accurately than with stall, so as to avoid overshooting the rated power of the machine at the beginning of a gust of wind. Another advantage is that the machine can be run almost exactly at rated power at all high wind speeds.

In active pitch control, the blade pitch angle is continuously adjusted based on the measured parameters to generate the required power output. It has been established that active pitch regulation reduces the wind generator output fluctuations.

Generator

Wind turbines are equipped with generator located in the hub of the turbine. There are two types of turbines, 1. with induction generator and 2. with synchronous generator. The wind machines with induction generators come with gearboxes which convert the cut-in to cut-out speed variations to 1-2-3 speeds for the generator. The induction machines are generally rated at 1,500 rpm. A two-speed generator has 4 poles for 1,500 rpm and 6 poles for 1,000 rpm.

Wind machines, which have synchronous generators, have no gearboxes since they could be designed for high speeds or for low speeds and have continuous variation according to the speed of the wind. These machines have an added advantage over induction machines because it is inherently variable speed and it has been proved that variable speed increases the energy capture and hence more energy could be generated.

Reactive power control

When the voltage and current go up and down simultaneously ‘in an AC supply’ there is no reactive power transmitted or consumed. Wind turbines impact this current and voltage synchronisation and result in ‘consumption of reactive power’. The adverse impact due to wind turbines or ‘consumption of reactive power is charged/ compensated by utilities by charging for reactive power consumption.

Synchronous generators are better than asynchronous generators in reactive power handling. They are flexible in the sense that they could be made to generate or consume reactive power whenever required by altering the field current of the machine. Thus, reactive power could be fed into the grid if required by synchronous machines. Asynchronous machines, whether in motoring or generating mode, are reactive power sinks and need reactive power compensation by means of capacitors. Switching surges of capacitors during their cutting in and cutting off is a major concern if done by mechanical switches. This concern could be minimized by introduction of power electronic devices. Dynamically varying compensation systems could be provided for smooth variation of capacitors.

Yaw control

The yaw control continuously orients the rotor in the wind direction. The yaw bearing includes gear teeth around its circumference. A pinion gear on the yaw drive engages with those teeth, so that it can be driven in any direction. The yaw drive normally consists of electric motors, speed reduction gears, and a pinion gear. This is controlled by an automatic yaw control system with its wind direction sensor usually mounted on the nacelle of the wind turbine. Some times yaw brakes are used to hold the nacelle in the position.

Tower

Two most common tower designs are, lattice and tubular. Lattice tower is cheaper compared to the tubular tower and being usually a bolted structure, makes it easy to transport. The external forces, primarily due to the wind and motions of the various components of a wind turbine result in stresses. By nature, tubular tower is stiffer than the lattice one. Secondly, since lattice tower has many bolted connections, these connections need to be tightened and checked periodically, thereby increasing the O&M. Moreover, tubular tower allows full internal access to the nacelle.

It has also been established that tubular towers give a better mitigation option to the problem of avian (birds) interaction with wind turbines. This is due to the fact that the lattice towers offer a lot of perch sites to birds.

The tubular towers are of either steel towers or concrete towers. In India most of the towers for windmills are installed with steel towers. Among all the wind turbine manufacturers in India the only manufacturer who uses both concrete and steel towers for windmills is Enercon India Limited. Steel towers have an advantage that it can be easily constructed and transported to the wind farm site and can be erected easily. Concrete towers are made of cement concrete with steel reinforcement and are pre casted towers, which can be transported to the wind farm sites and erected. Concrete towers are mostly used for marine sites, especially for offshore windmills.

Development of wind power in India

The wind power development in India started in early 90's with demonstration wind power projects in Gujarat and Maharashtra. Simultaneously, a wind resource assessment exercise was initiated by the Ministry of Non-conventional Energy Sources (MNES), presently renamed as Ministry of New and Renewable Energy (MNRE), along with Indian Institute of Tropical Meteorology (IITM). The first five volumes containing wind resource data for sites in Andhra Pradesh, Gujarat, Karnataka, Kerala, Lakshadweep, Madhya Pradesh, Maharashtra, Orissa, Rajasthan and Tamil Nadu, were published by IITM. With formation of Centre for Wind Energy Technology (C-WET), the wind resource assessment exercise along with testing and certification of wind turbines is now undertaken by C-WET. Till now, C-WET has published two volumes (vol VI and VII) of the "Wind Energy Resource Survey in India". With publication of seven volumes of the wind data, the wind resource for 216 stations covering 15 states and 2 union territories has been published.

The total potential for wind power in India, based on the resource assessments carried out under MNRE wind power program, is about 48561MW distributed in different states as given in Table 1.2 below.

Table 1.2 Estimated wind power potential in states

State	Gross potential (MW)
Andhra Pradesh	8968
Gujarat	10645
Karnataka	11531
Kerala	1171
Madhya Pradesh	1019
Maharashtra	4584
Orissa	255
Rajasthan	4858
Tamil Nadu	5530
Total	**48561**

Source: Centre for wind energy technology

http://www.cwet.tn.nic.in/html/departments_wra.html last accessed on 10-11-2009.

The unexploited resource availability has the potential to sustain the growth of wind energy sector in India in the years to come.

The wind power projects are being supported and promoted by Government through various financial and fiscal incentives. The most important is the accelerated depreciation benefit for wind energy projects. The other important factor is the power purchase tariff for the power generated from wind projects, and also the renewable purchase specifications that is the minimum percentage of total power consumption to be purchased from renewables by any distribution licensee. In 1993-94, MNRE issued the guidelines for purchase of power from renewable energy based projects. Subsequently, with the power sector restructuring and passing of The Electricity Regulatory Commission (ERC) Act–1998, the state electricity regulatory commissions started playing crucial role in tariff determination of power including power generation from renewable energy sources like wind. The Electricity Act 2003 provided a major boost to renewable energy sector through the specific mandate to the state regulators to decide the minimum percentage of power to be procured from renewable energy sources. Most of the states with good wind resource have issued tariff orders for purchase of power from renewables. This has created an assured market for power from renewable energy sources. In addition to the sale of power, the state regulatory commissions have also provided guidance on consumption of power from renewable energy sources as a captive use. As a result of the policy support and incentives, the total installed capacity of wind power projects has reached 10891 MW as on 31 October 2009. The statewise wind power installed capacity as on 31 March 2009 are given in table 1.3.

Table 1.3 Statewise total wind power installed capacity in India

State	Total Installed Capacity (MW)
Andhra Pradesh	122.50
Gujarat	1566.50
Karnataka	1327.40
Kerala	27.00
Madhya Pradesh	212.80
Maharashtra	1938.90
Rajasthan	738.40
Tamil Nadu	4304.50
West Bengal	1.10
Others	3.2
Total	**10242.3**

At present there are four major wind turbine manufacturers cum developer in India viz. M/s Enercon India Pvt. Ltd., M/s Suzlon Energy Ltd., M/s Vestas Wind Technologies India Pvt. Ltd. and M/s RRB Energy India Ltd. Apart from these, various other wind turbine manufacturers have entered into Indian market either through the joint venture or under the manufacturing license with foreign companies. In India, the major wind turbine manufacturer also acts as a wind power project developer. Essentially, the turbines manufacturer purchases the land at potential sites, undertakes its own wind measurement, develops the site, undertakes the micro-siting of turbines, puts the necessary evacuation facility in place and facilitates the signing of power purchase agreement (PPA) by the investors with the utility. The manufacturer/developer also undertakes operation and maintenance of the wind project.

The analysis of feasibility of wind power projects is specific to the state policies and the potential wind resource sites along with the turbine characteristics. The subsequent sections look into these issues in detail.

Government policies

Central Government policies / legislations

Electricity Act 2003

The Electricity Act 2003 imposed an obligation on the regulator towards promoting renewable energy. The section 86(e) clause 1 of the Electricity Act 2003, as one of the functions of the state regulatory commission, read as "to promote co-generation and generation of electricity through renewable sources of energy by providing suitable measures for connectivity with the grid and sale of electricity to any persons, and also specify, for purchase of electricity from such sources, a percentage of total consumption of electricity in the area of a distribution licensee". The state regulator hence plays an active role in development of renewable energy across states by creating a portfolio for renewable energy purchase as well as by pricing of energy generated from them. The tariff orders, which are the outcome of such regulation, state the wheeling charges, banking provisions, third part sales, grid interconnection requirements etc, in addition to purchase price for different renewable energy projects including wind energy.

Renewable energy policy

Ministry of New and Renewable Energy sources (MNRE) has formulated a draft comprehensive renewable energy policy. The objectives of the policy are:

a) Minimum energy needs to be met from renewables
b) Decentralized energy options for agriculture, commercial, residential and industry using renewables

The policy also aims at enhancing public private partnerships, private investments as well as FDI also including fiscal and financial incentives. Simplification of procedures, technology upgradation, new technologies and export promotion are some of the features. Incentives include tax holidays, 80% depreciation benefits for first year of installation of the projects, custom duty concessions, excise duty reduction, exemption from central sales tax/octroi etc and financial assistance and soft loans.

Indian Renewable Energy Development Agency (IREDA) provides the financing for renewable energy projects. Apart from these there are various other financing agencies and private sector banks which are involved in the financing of wind power projects.

Generation based incentive

MNRE on June 2008 released policy for generation-based incentives (GBI) for wind power projects. Under this policy a generation based incentive of Rs. 0.50 per kWh for up to 10 years will be given to the power producers of grid interactive Wind Power Generation plants of a minimum installed capacity of five MW who will not getting the benefit of accelerated depreciation. This incentive will be above the tariff fixed by state electricity regulatory commission for the purchase of power from wind energy projects. The GBI would be available only for projects commissioned i.e. Synchronized to the grid and certified by the concerned utility. It will be also provided only for projects installed at wind potential site validated by Centre for Wind Energy Technology (C-WET). The scheme will applicable only to those independent power producers, whose capacities are commissioned for sale of power to the grid.
On December 17th 2009 the MNRE released the Scheme for implementation of Generation based incentives (GBI) for grid interactive wind power projects. Under this scheme, a GBI will be provided to the wind electricity producers at the rate of Rs 0.50 per unit of electricity fed to the grid for a period not less than 4 years and a maximum of 10 years with a limit of Rs. 62 lakhs per MW. This scheme will be applicable to a maximum capacity limited to 4000MW during the remaining period of 11th plan period. This scheme will be in parallel to the Accelerated Depreciation benefits that means the investor either can avail the accelerated depreciation benefit or the benefit of GBI.

For getting this benefit the power producer has to submit application in the required format to the ministry and a copy to IREDA. The detailed guidelines issued by MNRE for this is given in Annex I.

Central Electricity Regulatory Commission guidelines for determination of tariff for renewable energy systems

The Central Electricity Regulatory Commission issued the terms and conditions for tariff determination from renewable energy sources, Regulations 2009. Under these regulations the CERC specified the conditions for the determination of the tariff for renewable energy projects. The control period is specified as 3 years and the first year will be till 31-03-2010. The revision in the regulations for next control period shall be taken atleast 6 month prior to the end of first control period. The main parameters defined under these regulations for the wind power projects are

1. The tariff period will be of 13 years, and will be single part tariff.
2. The wind power projects shall not be subjected to merit order dispatch principles, these shall be treated as must run power plants.
3. Capital cost of Rs 515 lakh per MW is considered which include the cost of plant machinery, civil work, erection and commissioning, financing and interest during construction and evacuation infrastructure up to the inter-connection point.
4. The debt equity ratio shall be 70:30
5. Loan tenure shall be 10 years
6. Depreciation shall be allowed up to maximum of 90% of the capital cost
7. Useful life of the project shall be 25 year
8. Depreciation rate shall be 7% per annum for the first year and the remaining depreciation shall be spread over the remaining useful life of the project from the 11th year
9. The return on equity shall be pre-tax 19% per annum for the first 10 years and pre-tax 24% per annum for the 11th year onwards
10. Operation and maintenance cost shall be Rs. 6.5 lakh per MW per year for the first year of the control period, i.e. 2009-10. This shall be escalated at the rate of 5.72% per annum over the tariff period to compute the levelised tariff.
11. The capacity utilization factor shall be based on the wind power density of the sites at 50 m height, which is given as follows in table 1.4

Table 1.4 Capacity utilization values for tariff determination from wind power projects based on the wind power density of the site

Annual mean wind power density (W/m^2)	Capacity Utilisation Factor
200-250	20%
250-300	23%
300-400	27%
>400	30%

12. The proceeds of carbon credit from approved CDM project shall be shared between the generating company and the beneficiaries in the following manner
    a. 100% of the gross proceeds on account of CDM to be retained by the project developer in the first year after the date of commercial operation of the generating station.
    b. In the second year, the share of the beneficiaries shall be 10% which shall be progressively increased by 10% every year till it reaches 50%, where after the proceeds

shall be shared in equal proportion, by the generating company and the beneficiaries."

The CERC as per its mandate based on the above regulation came out with the determination of levelised tariff for the renewable energy projects. The tariff determined for the wind power projects are as follows in table 1.5

Table 1.5 The wind power tariff determined by CERC.

Wind Zone	Levelised total tariff (Rs/kWh)	Benefits of accelerated depreciation (if availed) (Rs/kWh)	Net levelised tariff upon adjusting for accelerated depreciation benefit (if availed) (Rs/kWh)
20% CUF	5.63	0.37	5.26
23% CUF	4.90	0.32	4.58
27% CUF	4.17	0.28	3.89
30% CUF	3.75	0.25	3.5

The regulations issued by the CERC are being considered at some level by the State electricity regulatory commissions as reference for their specific tariff determination for the wind power projects. All the four states Gujarat, Maharashtra, Rajasthan and Andhra Pradesh have their own regulations, tariff orders and policies for the wind power projects. These aspects are discussed in following section.

State government policies for development of wind power

Gujarat state government policy on wind power

The government of Gujarat came up with a wind power policy in the year 2007, and the first amendment to this wind power policy on July 2009. The policy highlighted upon the following:

1. In Gujarat wind power policy-2007 the wheeling charges for captive consumption of wind power was specified as 4% of the electricity fed to the grid.
2. In the amendment to wind power policy, Wheeling charge for wind power are specified as
   a. To the consumption site at 66 kV voltage level and above within the state shall be allowed on payment of transmission charges and transmission losses otherwise applicable to normal open access.
   b. To consumption site below 66 kV level within the state shall be allowed on payment of transmission charges, otherwise applicable to normal open access consumers and transmission and wheeling losses at 10% of the energy fed to the grid.
   In addition to above transmission charges and losses, the wind farm owners who desire to wheel the electricity

to more than two locations shall pay 5 paise per unit of energy fed to the grid to the concerned distribution company in whose area the power is consumed.

3. The electricity generated from the wind turbine generators (WTGs) commissioned after 1 April 2009 may be sold to the GUVNL or any distribution licensee at the price of Rs 3.50 per unit, however the wind farm developer/owner have to file a petition before Gujarat Electricity Regulatory Commission (GERC) and get the approval of GERC for the tariff to be paid by the licensee.
   GUVNA or any distribution licensee may purchase surplus power from WTGs wheeling power for their captive use after adjustment of energy against consumption at recipient unit(s) at the rate of 85% of the tariff applicable for WTGs selling power to GUVNL/ any distribution licensee.
4. The Project developers shall have to install remote terminal units (RTU) so that the injection of energy can be monitored by the SLDC in real time.
5. Third party sale is permitted
6. Only type tested wind machines can be set up in Gujarat.

The amendment to wind power policy also specified renewable purchase obligations (RPOs) that each distribution licensee shall purchase electricity generated from all renewable energy sources (wind, solar, small/mini hydro, biomass, bagasse cogeneration, geothermal etc.) equivalent to a minimum of 10% of its total consumption of electricity during a year. Whereas the GERC in its notification dated 20 October 2005 specified the quantum of purchase of renewable power by the distribution licensee as minimum 2% of the total power consumption by the licensee.

The Gujarat Electricity Regulation Commission came out with an order on 11/08/06 in the matter of "Determination of price for procurement of power by the Distribution Licensees in Gujarat from Wind Energy Projects". The main points of this order are:

1. A general single part tariff for wind power generation is considered
2. The total evacuation infrastructure cost is to be borne by the developer
3. A CUF of 23% has been considered by the commission in order to determine the tariff
4. The capital cost considered is Rs. 4.65 Crore (inclusive of evacuation arrangement cost) for 1 MW project.
5. O&M expense of 1.5% of the capital cost with 5% escalation was considered
6. A tariff of Rs.3.37/kWh was arrived at which remains constant for the entire project life of 20 years.
7. It was decided by the Commission that GUVNL/distribution company and the developer enter into agreement

8. The reactive power charges are 10 paise/kVArh for the drawl of reactive energy at 10% or less of the net energy exported and 25 paise/kVArh for the drawl of reactive energy at more than 10% of the net active energy exported.
9. The wheeling charges will be 4% of energy injected into the grid
10. 25% of the gross CDM benefit procured by the developer will be shared with the distribution licensee.
11. As per the order, for wind energy generating units set up after 19th June, 2007 opting for self use, the generation shall be set off against the owner's monthly consumption at his manufacturing or other facility in a distribution licensee area. Any excess generation (over and above the set off against monthly consumption) will be treated as sale to the concerned distribution licensee at the tariff rate determined by the Commission. Monthly consumption bills will be adjusted against the generation and if generated units are extra, tariff will be paid for the same by the distribution licensee.

On 30 January 2010 GERC released order on 'determination of tariff for procurement of power by distribution licensees from wind electric generators and other commercial issues'. Main points of this order are

1. The control period for this order will be 3 years from 11th August 2009
2. The capital cost considered is Rs. 4.62 Crore/MW for 1 MW project
3. Power evacuation cost as Rs 38 lakhs per MW
4. O&M expense of Rs 6.5 lakh per MW with 5% escalation is considered.
5. Debt equity ratio of 70:30 is considered
6. Loan tenure of 10 years and rate of interest of 10.75 % is considered
7. Rate of return on equity at 14% is considered
8. CUF of 23% is considered
9. Project life of 25 years to be considered
10. The depreciation rate of 6% of the capital cost per annum in the initial 10 years and 2% per annum from 11th to 25th year is considered (asset value is depreciated upto 90% of its initial value)
11. Tariff of Rs.3.56/kWh is decided, which remains constant for the entire project life of 25 years and will be applicable for wind energy generators who will commission brand new wind energy plants after 1st July 2009.
12. Transmission and wheeling charges are suggested as under
    a. Whenever power is wheeled at 66 KV voltage level and above to the desired location within the State, the users (of transmission system) shall bear transmission losses and pay transmission charges as applicable to normal

open access user/ consumer determined by the Commission.

b. Whenever power is wheeled below 66 KV level and upto 11 KV voltage level whenever the power is wheeled by the WEGs (who are having more than one WEGs) to the desired locations within the State they shall pay transmission charges as applicable to normal open access consumers and transmission and wheeling losses at 10% of the energy fed into the grid. The above loss is to be shared between the transmission and distribution licensee in the ratio of 4:6.

c. Wind farm owners desiring to wheel electricity to more than two locations shall pay 5 paise per unit on energy fed in the grid to the Distribution Company concerned in whose area, power is consumed in addition to above mentioned transmission charges and losses, as applicable.

13. The reactive power charges are 10 paise/kVArh for the drawl of reactive energy at 10% or less of the net energy exported and 25 paise/kVArh for the drawl of reactive energy at more than 10% of the net active energy exported.

14. Commission proposes the sharing of CDM benefits as provided in the explanatory Memorandum of CERC which is quoted as " The proceeds of carbon credit from approved CDM projects shall be shared in the following manner, namely-

    a. 100% of the gross proceeds on account of CDM to be retained by the project developer in the first year after the date of commercial operation of the generating station or the transmission system, as the case may be;

    b. In the second year, the share of the beneficiaries shall be 10% which shall be progressively increased by 10% every year till it reaches 50%, where after the proceeds shall be shared in equal proportion, by the generating company or the transmission licensee, as the case may be, and the beneficiaries."

15. Banking of wind power is allowed for 1 month. The Commission decides that any excess generation (over and above that set off against monthly consumption) would be treated as a sale to the distribution licensee concerned at a rate of 85% of the tariff applicable to WEGs

Inter state open access issues

The section 29 of Gujarat Electricity Regulatory Commission, Open Access Regulation, Notification No. 13 of 2005, states "Open Access will require implementation of the Intra-State Availability Based Tariff (ABT) System". The tariff order in the matter of Determination of Price for procurement of power from Wind Energy Projects issued by Gujarat Electricity Regulatory Commission (Order No. 2 dated 11th August 2006) states that "As wind energy cannot be scheduled, the commission has kept the WEG's out of the settlement mechanism linked with Unplanned Interchange (UI) rate (which comes into play in case of deviations) under Intra State Availability Based Tariff". Since wind energy does not fall under ABT, and Gujarat has not yet implemented ABT, the open access is not into operation as of today. GERC in its order dated 17 June 2009 too stated that the UI shall not be applied to such wind energy generated into the grid.

Maharashtra state government policy on wind power

The government of Maharashtra came up with a wind power policy in October 2008, the main points of this policy are[1]

1. Continuation of use of green energy fund
2. For Evacuation arrangement of wind energy project, 50% amount will be given as a subsidy through Green Energy Fund.
3. Banking of Energy delivered to the grid for self use and/or sale to third party shall be allowed any time of the day and night and subject to the condition that surplus energy (Energy delivered into the grid but not consumed) at the end of financial year shall not be carried over to the next year
4. Surplus energy at the end of the year limited to 10% of net energy delivered by the developer to the grid during the year shall be purchased by the utility at the lowest TOD slab rate for H.T. energy tariff applicable on the 31st March of the financial year in which the power was generated
5. For captive use the wheeling charges and wheeling losses are dependent on the voltage levels at the injection point and drawl point. Similarly the transmission charges and transmission losses are dependent on the voltage levels at injection point and drawl point. The wheeling charges and losses applicable are as given in table 1.6 to table 1.8.

Table 1.6 Wheeling charge and wheeling loss for MSEDCL network

Voltage level	Wheeling charges (Rs/kwh)	Wheeling losses (%)
132 kV	0	0.0
33 kV	0.05	6.0
22kV/11 kV	0.25	9.0
LT level	0.43	14.0

Table 1.7 Wheeling charge and wheeling loss for TPC-D network

Voltage level	Wheeling charges (Rs/kwh)	Wheeling losses (%)
-33kV/22kV/11kV (HT)	0.18	0.66
LT level	0.37	0.66

[1] Information booklet for wind, maharashtra energy development agency, www.mahaurja.com, last accessed on 15 Dec 2009

Table 1.8 Wheeling charge and wheeling loss for REL-D network

Voltage level	Wheeling charges (Rs/kwh)	Wheeling losses (%)
-33kV/22kV/11kV (HT)	0.46	1.5
LT level	0.88	9.0

6. In its earlier order Maharashtra Electricity Regulatory Commission (MERC) declared the wind power tariff for Group III Projects, which are commissioned after 1/4/2003 and during the balance period of tenth plan. The purchase tariff will be Rs. 3.50/kwh for the 1st year from the date of commissioning of the projects. The purchase rate shall be increased at 15 paise/unit every year for a period of 13 years from the date of commissioning of the projects. With declaration of this rate for Group III projects, MERC has envisaged 16% RoE with 70:30 debt equity ratios. MERC has continued with the earlier rate of purchase of electricity generated from wind power projects till 31st March 2010 i.e. Rs. 3.50 per unit and escalation of Rs. 0.15 per unit per year for 13 years.
7. MERC issued a Renewable Purchase Standard (RPS) on 16 August 2006. Through this order, MERC made mandatory to procure energy from renewable sources in percentage of total consumption of energy to distribution licensees, open access and captive consumers. The minimum percentage of renewable purchase fixed for the year 2009-10 is 6% of the total consumption.

Andhra Pradesh state government policy on wind power

The government of Andhra Pradesh announced the policy on wind power development vide Go. Ms No. 48 dated 11 April 2008, which was subsequently amended by Go. Ms. No.99 dated 09 September 2009. The salient features of these policies are as following

1. This policy shall come into operation from the date of issue of this order and will be applicable to Wind Power Plants coming up henceforth and for a period of 10 years from the date of this policy, unless superseded or modified by any other order.
2. The WEGs installed should be new and match the specifications issued by C-WET from time to time.
3. Minimum turbine capacity of WEGs proposed for installation shall not be less than 225 KW.
4. Eligible Developers shall enter into all applicable agreements as per the guidelines issued by the Andhra Pradesh Electricity Regulatory Commission from time to time.
5. Developers would be eligible for using the power produced for captive consumption or making sale to a third party or to

DISCOMs. A PPA will be required to be entered into with concerned DISCOM as per the power purchase guidelines and Wheeling Agreements will be required to be entered into with AP TRANSCO or/and DISCOM(s) as per Open Access regulations, and any other relevant guidelines issued by the Regulatory Commission from time to time.

6. The PPAs may be for 20 years as per the present norms.
7. In case of transfer of power by the Developer for its own captive use or 3rd party sale, it shall be governed by the Open Access regulations issued by the Commission from time to time.
8. Entire cost of evacuation facilities for interconnecting the wind farms with the grid and delivery of power is to be beared by the wind farm developer.
9. The CDM benefit shall be shared in the ratio of 90:10 between the developer and DISCOM.
10. The Eligible Developers may be given concessional wheeling and transmission charges, as there will be no emission of Greenhouse gases from the Wind farms. This will be subject to approval of APERC. The concessional wheeling and transmission charges for captive use or 3rd party sale may be in kind at 5% of energy delivered into the grid (which includes transmission and distribution losses)
11. The Wind Power Projects are not eligible for Banking of Energy. The Energy generated by captive generating Plants, if not consumed during the billing month, would be deemed to have been sold to respective DISCOM and the DISCOM may pay for such un-utilized Energy at the rate of 85% of the tariff as amended (Rs 3.5 per kWh)
12. The tariff for the upcoming Wind Power Projects set up under the policy shall be firm at Rs.3.50 per unit and it will be applicable for a period of 10 years from Commercial operation Date (COD), subject to approval of the APERC
13. The tariff for the period 11th year to 20th year shall be as fixed by APERC

Andhra Pradesh electricity regulatory commission (APERC) issued an order on 1 May 2009 in the matter of determination of tariff/power purchase price in respect of new wind based power projects. Some of the important points of the order are as follows.

1. APERC considered the capital cost of RS 4.70 crore per MW including the evacuation cost.
2. Capacity Utilisation factor of 24.5% was considered for tariff calculation
3. Operation and maintenance cost of 1.25% of the capital cost with an escalation of 5% per year
4. The straight line depreciation with depreciation rate of 4.5% per annum for 20 years is considered
5. Rate of return on equity is considered as 15.5% pre tax

6. rate of interest on loan is considered as 12%
7. Debt Equity ratio of 70:30 is considered

Based on the above mentioned consideration APERC fixed the tariff for wind energy as Rs 3.50 per kWh for the first 10 years from the commercial operation date (COD) of the project. The tariff for next 10 years will be determined thereafter. APERC also specified following conditions in its order

1. The above tariff is applicable in respect of Wind Power Projects, which have entered into PPAs between 01-05-2009 and 31-03-2014.
2. The eligible developer shall bear the entire cost of power evacuation facilities
3. The CDM benefits shall be shared in the ratio of 90:10 between the developer and the DISCOM
4. Minimum capacity of WEGs proposed for installation should not be less than 225 KW.
5. As regards the terms and conditions governing Open access of Wind Power Projects (third party/captive), the existing provisions contained in relevant orders / regulations / codes issued by the Commission shall be applicable.

APERC in its order dated 31 March 2009 specified that every Distribution Licensee shall be required to purchase Electricity, not less than 5% of his consumption of energy, from RP sources as Renewable Power Purchase Obligation (RPPO) during each of the years 2009-10 to 2013-14.

Rajasthan state government policy on wind power

With a view to promote generation of power from non-conventional energy sources, Government of Rajasthan promulgated a Policy on 11-3-1999. This Policy known as "Policy for Promoting Generation of Power through Non-Conventional Energy Sources" ended on 31st March, 2004. A separate Policy was, however, issued on 4th February, 2000 exclusively for promoting generation of electricity from wind. This Policy known as "Policy for Promotion of Electricity Generation from Wind" too ended on 31st March, 2004. During the currency of Wind Policy 2000 a new Policy was promulgated in April 2003 for period up to 31st March, 2009.

The policy known as 'Policy for Promoting Generation of Electricity through Non-Conventional Energy Sources 2004' is effective from 25-10-2004. This policy and various amendments issued on it govern the development of wind power in Rajasthan. The important points of this policy are

1. The Power Producers may use the power for captive consumption or for sale to consumers/licensees including Discoms.
2. Interfacing arrangements such as transformers, panels, kiosks, protection, metering, HT lines from the points of

generation to the pooling station including the pooling station shall be developed and maintained by the Power Producer as per the specifications and requirements of the Rajasthan Vidyut Prasaran Nigam (RVPN)/ Discom, and the entire cost for this will be borne by the Power Producer.

3. For creation of proper facility for receiving power, at the receiving station the Power Producer shall pay Rs. 2 lakh per MW to RVPN/ Discom as the case may be.
4. The transmission system from pooling station to receiving station shall be developed by the Power Producer at his own cost.
5. The Power Producer shall install metering device at the receiving station at his own cost.
6. Except in case of power sold to Discoms, the Power Producer shall pay wheeling charges @ 10% of the energy billed into the grid irrespective of the distance from the generating station and such charges will be inclusive of the T&D losses.
7. Banking of power for one year is allowed. The Power Producer shall execute an agreement (Wheeling and Banking Agreement) with the Discom for such banking.
8. The sale of electricity by Power Producer to Discoms will be governed by the Power Purchase Agreement executed between the concerning Discom and the Power Producer and witnessed by RREC.
9. The Power Purchase Agreement for wind power will be for 20 years.

Rajasthan Electricity Regulatory Commission (RERC) issued regulations for determination of tariff on 23 January 2009 . RERC in its order dated 16-07-2009 in the matter of determination of tariff for sale of electricity from wind power plant specified the levelised tariff of Rs 4.28/kWh for wind power projects in Jaisalmer, Jodhpur and Barmer districts and Rs 4.50/kWh for the projects in other districts. This tariff will be applicable for plants getting commissioned in the Multi Year Tariff period of 5 years i.e. F.Y.2009-10 to F.Y. 2014-15. Being "Feed-in Tariff" for 20 years.

Issues on use of power by subsidiary/Joint Venture

Ministry of Power in its notification dated 8 June 2005 which is called the electricity rules 2005 stated that the power plant shall qualify as captive generating plant only if 1) the captive user holds minimum 26 % of the ownership of the plant and 2) not less than fifty one percent of the aggregate electricity generated in such plant determined on annual basis is consumed for the captive use.

As per the details provided by the ONGC it is observed that ONGC holds at least 26% ownership in its subsidiaries or joint ventures in the states, so there may not be any problem in declaring the wind power plant as captive power plant.

The two cases provided by ONGC as

1) ONGC is the generating company i.e. owner of the wind farm and wants to use the power in an entity where it holds some equity which is greater than 26%. In this case the power consumption may not be considered as captive use as the Joint venture does not have any equity in the generation plant.
2) A Joint Venture (JV) in which ONGC has 26% equity invest in wind farm project and that JV sells energy to another ONGC JV with 26% stake but with different partner. In this case the use of power will be treated as third party sale.

In case if the use of power by subsidiary or joint ventures would be considered as the third party sale then there are various charges by the state utilities on transporting of such energy that is called charges for third party sale. In case of third party sale the electricity duty are to be recovered from the purchaser of the power.

All the four state's wind power policies are summarised in the table 1.9.

Table 1.9 Summary of States wind power policies and orders

Component/State	Gujarat	Maharashtra	Andhra Pradesh	Rajasthan
Order dated	30-01-2010	24-11-2003	01-05-2009	16-07-2009
Control period	11-08-2009 to 10-08-2012	01-04-2009 to 31-03-2014	16-09-2009 to 31-0302012	01-04-2009 to 31003-2014
Feed in tariff of wind power (Rs/kWh)	3.56 per kWh	Rs 3.50 wth an escalation of 15 paise per year up to 13years	Rs 3.50	Rs 4.28/ Rs 4.50
Validity of tariff (Years)	20	13	10	20
Renewable purchase obligations (RPO)	209-10 -- 6% 2010-11—7% 2011-12 – 7%	6%	5%	209-10 -- 7.45% 2010-11—8.50% 2011-12 – 9.50%
Captive use	Allowed	Allowed	Allowed	Allowed
Wheeling charges	For drawl at >66kV line the transmission charges and losses as applicable to Open access consumers and for power drawl below 66 kV line 10% (including transmission losses) +Transmission charges as applicable to open access	Depending on the feeding point and the drawl point (taken as 9% wheeling losses +0.25 Rs per unit for 11kV HT Line)	Wheeling and transmission@5% of the energy wheeled	Transmission charges foe RE systems shall be 50% of the charges specified for others (open access consumers), Loss charges @4.4% to 8% depending upon the voltage at which power is consumed
Reactive power charges (kVarh consumption)	10 paise per kVArh up to 10% and 25 paise per KVArh above 10%	25 paise per kVArh	10 paise per kVArh upto 10% & 25 paise per kVArh above 10%	5 paise per unit year w.e.f. 01/04/2006 with escalation of 5% per year
Sharing of CDM benefit	1st year: 100% to project developer.	No Specifications	Shared in the ratio of 90:10 by the	Shared in the ratio of 75:25 by the power

Component/State	Gujarat	Maharashtra	Andhra Pradesh	Rajasthan
	2nd year- 10% to beneficiaries, to be increased @10% per annum to 50%and thereafter to be shared on equal basis.		power producer and beneficiary	producer and beneficiary
Banking of Energy	0ne month banking is allowed for self use Any excess generation (over and above the set off against monthly consumption) would be treated as a sale to the distribution licensee concerned at a rate of 85% of the tariff applicable to WEGs	Surplus energy at the end of the year limited to 10% of net energy delivered by the developer to the grid during the year shall be purchased by the utility at the lowest TOD slab rate for H.T. energy tariff	Banking not allowed. Unused energy will be deemed to be sold to DISCOM at 85% of the tariff	Banking and drawal shall be on 6 monthly basis. Payment for unutilized banked energy will be settled at 60% rate of energy charges.
CUF considered for tariff estimation	23%	22%	24.5%	21%

Wind resources in Gujarat, Maharashtra, Andhra Pradesh and Rajasthan

Wind resource in Gujarat

The state of Gujarat has one of the best wind potentials in the country. The total identified wind power potential is 10646MW and the total installed wind power capacity is about 1566.5MW as on March 2009. It is endowed with one of the best wind resources in India, with wind power densities in the range of 200–499 W/m^2 at 50 m height. The wind resource is spread in the costal regions of Gujarat as well as in Rajkot and Surendranagar districts. The wind speeds are in the range of 4–9 m/s with pre monsoon and monsoon months, April to August, having higher speeds. The southwest direction of monsoon winds is the predominant wind direction. The wind resource published by C-WET identifies about 38 potential sites where the wind power density is above 200W/m^2. These 38 sites, which have wind power density above 200 W/m^2 are shown in Table 1.10. It can be seen that the sites are clustered in districts of Jamnagar, Kachchh, Rajkot, Surendranagar, Porbandar, Junagarh, Amreli and Surat.

Table 1.10 Wind sites identified in Gujarat with power density above 200W/m^2

S No.	Station	District	Wind power density extrapolated to 50m	Estimated potential (MW)*
1	Adesar	Kachchh	307	-
2	Amrapar (Gir)	Junagarh	241	-
3	Amrapar (Seth)	Jamnagar	221	-
4	Bamanbore- 2	Surendranagar	243	688.9

S No.	Station	District	Wind power density extrapolated to 50m	Estimated potential (MW)*
5	Bayath	Kachchh	300	
6	Bhandariya	Junagarh	208	226.9
7	Butavadar	Jamnagar	240	
8	Dhank -1-1 (Ref.Stn.)	Rajkot	414	493.2
9	Dhank -2	Rajkot	367	
10	Gala	Jamnagar	254	60.0
11	Godladhar	Rajkot	345	518.3
12	Haripar	Jamnagar	210	7.5
13	Harshad	Jamnagar	239	-
14	Jafrabad	Amreli	242	68.9
15	Jamanvada	Junagarh	299	1100.2
16	Jasapar	Amreli	214	-
17	Kagavad	Rajkot	212	-
18	Kalyanpur	Jamnagar	327	418.5
19	Khambada	Rajkot	204	-
20	Kukma	Kachchh	239	358.5
21	Lamba	Jamnagar	232	-
22	Limbara	Surendranagar	227	-
23	Mahidad	Surendranagar	231	42.8
24	Moti Sindholi	Kachchh	311	718.3
25	Mundra	Kachchh	303	-
26	Nani Kundal	Bhavnagar	278	-
27	Navadra-1 (Ref.Stn.)	Jamnagar	297	-
28	Navi Bander	Jamnagar	213	-
29	Okha*	Jamnagar	260	156.6
30	Okhamadhi	Jamnagar	209	-
31	Poladiya*	Kachchh	278	131.1
32	Ratabhe	Surendranagar	212	-
33	Rojmal - 2	Bhavnagar	317	-
34	Sanodar*	Bhavnagar	373	111.8
35	Sinai*	Kachchh	244	159.6
36	Surajbari*	Kachchh	444	545.2
37	Suvarda	Jamnagar	243	-
38	Warshamedi	Rajkot	499	-

* Estimated potential based on the micro survey of the sites carried out by C-WET.

Source: Directory Indian wind power-2009

These sites are concentrated in three wind belts – coastal areas of Jamnagar and Kutch districts and bordering areas of Rajkot and Surendranagar districts.

Wind resource in Maharashtra

The state of Maharashtra too has great wind potentials in the country. The total identified wind power potential is 4584 MW and the total installed wind power capacity is about 1938.9 MW as on March 2009. Wind power densities in the range of 200–325 W/m^2 at 50 m height. The wind resource is spread mainly in Satara, Ahmadnagar and Dhule districts. The average wind speeds are in the range of 5–6.5 m/s. The wind resource published by C-WET identifies about 31 potential sites where the wind power density is above 200W/m². These sites are shown in Table 1.11.

Table 1.11 Wind sites identified in Maharashtra with power density above 200W/m²

S No.	Station	District	Wind power density extrapolated to 50m	Estimated potential *(MW)
1	Alamprabhu Pathar	Kolhapur	224	5.4
2	Amberi*	Satara	275	24.4
3	Aundhewadi	Nasik	295	-
4	Brahmanvel*	Dhule	324	342.3
5	Chakla	Nandurbar	323	-
6	Chalkewadi	Satara	218	-
7	Dhalgaon	Sangli	260	29.4
8	Dongerwadi	Sangli	284	16.6
9	Gawalwadi	Nasik	278	-
10	Gude Panchagani	Sangli	296	74.5
11	Kankora	Aurangabad	204	-
12	Kas	Satara	277	-
13	Kavdya Donger	Ahmadnagar	277	89.7
14	Khandke	Ahmadnagar	250	71.4
15	Kolgaon	Ahmadnagar	238	48.1
16	Lonavla	Pune	285	8.1
17	Mandhardeo	Satara	206	-
18	Matrewadi	Satara	253	72.6
19	Panchpatta	Ahmadnagar	236	-
20	Panchgani	Satara	205	-
21	Raipur	Dhule	214	-
22	Palsi	Satara	254	-
23	Sautada	Bid	223	15.8
24	Takarmauli	Dhule	224	274.8
25	Thoseghar (Ref.Stn.)	Satara	250	85.3
26	Vijayadurg	Sindhudurg	253	6.3
27	Vankusawade - I	Satara	293	-
28	Varekarwadi	Sangli	216	-
29	Vaspet	Sangli	225	-
30	Bhud	Sangli	224	-
31	Rohina	Latur	226	-

*Estimated potential based on the micro survey of the sites carried out by C-WET.

Source: Directory Indian wind power-2009

Wind resource in Rajasthan

The state of Rajasthan has good wind potentials mainly in the region of Jaisalmer, Jodhpur and Barmer districts. The total identified wind power potential is 4858 MW and the total installed wind power capacity is about 738.4 MW as on March 2009. Wind power densities in the range of 200–325 W/m² at 50 m height. The average wind speeds are in the range of 4.3–

5.7 m/s. The wind resource published by C-WET identifies 7 potential sites where the wind power density is above 200W/m². The details of these sites are shown in Table 1.12.

Table 1.12 Wind sites identified in Rajasthan with power density above 200W/m²

S. No.	Station	District	Wind power density extrapolated to 50m	Estimated potential (MW)
1	Devgarh	Chittorgarh	281	7.0
2	Harshnath	Sikar	>206	-
3	Jaisalmer - 1	Jaisalmer	274	70.0
4	Jaisalmer - 2 (Ref.Stn.)	Jaisalmer	311	-
5	Khodal	Barmer	229	-
6	Mohangarh	Jaisalmer	243	-
7	Phalodi	Jodhpur	261	126.0

* Estimated potential based on the micro survey of the sites carried out by C-WET.

Source: Directory Indian wind power-2009

Wind resource in Andhra Pradesh

The state of Andhra Pradesh is rich in wind power potential with the total identified wind power potential MW 8968 MW. The total installed wind power capacity is about 122.5 MW as on March 2009. Wind power densities widely vary over the state in the range of 200–541 W/m² at 50 m height. The average wind speeds are in the range of 4.8–6.5 m/s. The wind resource published by C-WET identifies 35 potential sites where the wind power density is above 200W/m². The details of these sites are shown in Table 1.13.

Table 1.13 Wind sites identified in Andhra Pradesh with power density above 200W/m²

S No.	Station	District	Wind power density extrapolated to 50m	Estimated potential (MW)
1	Alangarapeta	Anantapur	272	-
2	Badhrampalli Kottala	Kurnool	277	-
3	Banderlapalli	Kurnool	320	-
4	Bhimunipatnam	Visakapatnam	282	18.7
5	Borampalli	Anantapur	219	-
6	Burugula	Kurnool	216	-
7	Chinnababayapalli	Anantapur	206	-
8	Jamalamadugu- 1	Cuddapah	265	38.4
9	Jamalamadugu- 2	Cuddapah	248	-
10	Kadavakallu- 1	Anantapur	325	30.2
11	Kadavakallu - 2 (Ref.Stn.)	Anantapur	333	-
12	Kakula Konda	Chittoor	541	-
13	Kodumuru	Kurnool	270	-
14	Kondamithipalli	Kurnool	349	52.7
15	Korrakodu	Anantapur	220	-
16	M.P.R. Dam	Anantapur	269	20.7
17	Madugupalli	Anantapur	266	-

S No.	Station	District	Wind power density extrapolated to 50m	Estimated potential (MW)
18	Mustikovala	Anantapur	237	-
19	Nallakonda	Anantapur	324	29.9
20	Narasimha Konda	Nellore	403	-
21	Nazeerabad	Rangareddy	232	1.9
22	Pampanoor Thanda	Anantapur	232	4.4
23	Payalakuntla	Cuddapah	257	-
24	Ramagiri-I	Anantapur	308	31.9
25	Ramagiri -II (Ref.Stn.)	Anantapur	226	-
26	Ramagiri- III	Anantapur	246	-
27	Siddanagatta	Kurnool	231	-
28	Singanamala	Anantapur	392	-
29	Talaricheruvu	Anantapur	298	-
30	Tallimadugula	Anantapur	288	-
31	Tirumala	Chittoor	374	-
32	Tirumalayapalli	Cuddapah	285	34.9
33	Ulindakonda	Kurnool	225	-
34	Vajrakarur-I	Anantapur	243	678.7
35	Vajrakarur - II	Anantapur	202	-

* Estimated potential based on the micro survey of the sites carried out by C-WET.

Source: Directory Indian wind power-2009

Wind turbines available for Installation in India

The designs of specific types of wind turbines that have been installed in India, or those being offered for installation, are validated by a standardised certification process under the guidelines of Ministry of New and Renewable Energy, Government of India. The certification process is called Type certification and the certification agency for this is the Centre for Wind Energy Technology (C-WET), Chennai. In the previous years the wind turbines ranging from 225 kW to 2.1 MW, from various manufacturers, having the type certificates from C-WET, have been installed in India. Those manufacturers include the major wind turbine manufacturers of MW scale such as Bharat Heavy Electricals Limited (BHEL) (800 kW), Enercon India Limited (600 kW and 800 kW), GE Wind Energy India (1500 kW), NEG Micon Pvt. Ltd. (1500 kW and 1650 kW), Pioneer Asia Wind Turbines (850 KW), Suzlon Energy Limited (1000 kW, 1250 kW, 1500 kW and 2100 kW) Vestas RRB (500 KW, 600 kW), etc. Currently there are eleven manufacturers in India with the type test certification of C-WET, and some are under the process of obtaining certification. Out of these the four major wind turbine manufacturers who manufacture the wind turbines and also act as the developer of the wind farms are 1) Suzlon Energy Limited, 2) Vestas Wind Technology India Private Limited 3) Enercon India Private Limited and 4) RRB Energy limited. Other than these major manufacturers some new manufacturers like Regen Powertech, Global wind power etc are coming in the Indian wind turbine market either as joint venture/subsidiary with some foreign manufacturers or having the licence from any foreign wind turbine manufacturing company. The specifications of wind turbines being offered in India by the major manufacturers are given in table 1.14 below

Table 1.14 Details of wind turbines in India having type test certificate

Name of Manufacturers	Model Name	Capacity (kW)	Rotor Dia (m)	Hub Height (m)	Aerodynamic control	Generator
Turbines which are having type test certification from C-WET						
M/s Suzlon Energy Limited	S52	600	52	75	Pitch	Asynchronous
	S82	1500	82	78	Active pitch	Asynchronous
	S88	2100	88	80	Active pitch	Asynchronous
M/s Enercon India Limited	E-48	800	48	50/57/75	Active Pitch	Synchronous
	E-53	800	53	73/75	Active Pitch	Synchronous
M/s Global Wind Power Limited	Norwin 750 kW	750	47	65	Active Pitch	Asynchronous
M/s Leitner Shriram Manufacturing Limited	Leitner LT77-1.35 MW	1350	76.6	65	Active Pitch	Synchronous direct drive
M/s Pioneer Wincon Private Limited	Pioneer P250/29	250	29.6	50	Pitch	Asynchronous
M/s Regen Powertech Pvt Ltd	VENSYS 77	1500	77	85	Active Pitch	Synchronous direct drive
M/s RRB Energy Limited	V-39/500	500	47	59	Pitch	Asynchronous
	Pawan Shakti-600 kW	600	47	50	Pitch	Asynchronous
M/s Siva Windturbine India Pvt Ltd	SIVA 250/50	250	30	50	Pitch	Asynchronous
M/s Southern Wind farms Limited	GWL 225	225	29.8	45	-	Asynchronous
M/s Vestas Wind Technology India Private Limited	NM-48/750	750	48.2	45/50/55	Stall	Asynchronous
	V82-1.65 MW	1650	82	70/78/80	Active Stall	Asynchronous
M/s Winwind power energy private limited	WinWind 1 MW	1000	60	70	-	Asynchronous
Turbines which are under process of type test certification from C-WET						
M/s Elecon Engineering Company Limited	T600-48	600	48	50/55/60	-	Asynchronous

Name of Manufacturers	Model Name	Capacity (kW)	Rotor Dia (m)	Hub Height (m)	Aerodynamic control	Generator
M/s India Windpower Limited	I-29/250	250	29.7	50	-	Asynchronous
M/s Kenersys India Pvt Ltd	K82	2000	82	80	Active Pitch	Asynchronous
M/s Suzlon Energy Limited	S66-1250 kW	1250	66	65/75	Active Pitch	Asynchronous

Source: Revised list of models and manufacturers of wind electric generators, issued by C-WET on 22-06-2009. http://www.cwet.tn.nic.in/html/information_ml.html List of manufacturers last accessed on 10 Dec 2009.

The selection of wind turbines depends on its power ratings, performance characteristics, costs, energy capture, land required for installation, and the availability of suitable sites. In India most of the wind farm sites are class II or III sites for which the wind turbines of higher ratings with larger hub height and larger rotor diameters should be preferred. As the wind turbines of higher rated capacity with high hub height and rotor diameter can produce greater amount of electricity compared to the low size wind turbines and hence can give the better cost economics. In this study the wind turbines of MW scales i.e. the wind turbines of rated capacity greater that 1 MW are considered. The wind turbines are analysed based on the technical specifications of the turbine as well as the experience of the manufacturer. If we see the list of number of wind turbines installed of different ratings it is observed that the wind turbines of ratings greater than 1 MW are mainly the Suzlon's 1.5 MW turbine with total 869 numbers installed, Vestas wind technologie's 1.65 MW wind turbines with 383 numbers installed and Regen's 1.5 MW wind turbine with 16 numbers installed, other MW range wind turbines are installed in very less numbers. Table 1.15 gives the details of total installed number of all the wind turbines of rating greater than 1 MW which are now having C-WET type test certification in the country. So for this study the three wind turbines 1) S82- 1500 kW, 2) V82- 1650 kW and 3) Regen 1500 KW wind turbines have been selected. The detailed comparison of technical features and the calculations for the ratings of these four wind turbines are given in Annexure II and the score as calculated are given in table 1.16.

Table 1.15 Details of wind turbine installation in India

Manufacturer	Wind turbine rating (kW)	Number of wind turbines installed as on March 2009	Total installed capacity (MW) as on March 2009
Suzlon Energy Limited	1500	869	1303.50
Vestas Wind technology India pvt ltd.	1650	383	631.95

Manufacturer	Wind turbine rating (kW)	Number of wind turbines installed as on March 2009	Total installed capacity (MW) as on March 2009
Regen powertech pvt. ltd	1500	16	24.00
Winwind power energy private limited	1000	2	2.00
Suzlon Energy Limited	2100	1	2.10
M/s Leitner Shriram Manufacturing Limited	1350	1	1.35
Kenersys India Pvt Ltd	2000	--	--

Source: Directory Indian wind power, 2009

Table 1.16 Rating of wind turbines

Turbine manufacturer	Suzlon Energy Limited	Vestas wind Technologies India Pvt. Ltd	Regen Powertech
Model Name	S82-1500	V82-1650	Regen 77-1500
Capacity (kW)	1500	1650	1500
Score	10.18	10.195	10.32

All the above three machines have been considered for the evaluation of the energy generation from the different wind potential sites in the four states

Inputs provided by the wind farm developers in India

The major wind turbine manufacturers in India who too act as wind farm developers have been contacted to take their inputs about the wind turbines offered and the capacity of wind power project which they can offer in the four states. It has been observed that all the developers are active either in all the four states but at different scale of activity. The input from M/s Vestas wind technology India pvt. Ltd, M/s Suzlon Energy limited and M/s Regen Powertech have been received. Based on the details provided it is observed that the total capacity which could be offered in all the four states are as follows

1. In Gujarat the project up to 100 MW capacities can be offered by one bidder of which about 50 MW only capacity can be at single location.
2. In Maharashtra the project capacity up to 50 MW can be offered by one bidder, but it may be in 2 or 3 different locations
3. In Rajasthan the capacity up to 150 MW can be offered by the single bidder and at a single location about 50-60 MW capacity is available
4. In Andhra Pradesh the capacity up to 50 MW can be offered by the single bidder, but this 50 MW may be the combination of capacity in two or more locations.

So the Project capacities available with the developers are higher in the state of Rajasthan and Gujarat and comparatively lower for the states of Maharashtra and Andhra Pradesh.

Selection of state and site

The investment decision on the wind power project depends on the rate of financial return that can be achieved from the wind energy generation. This rate of return from any wind power project depends on various factors that are 1) wind energy output from the wind farm, that is dependent on the wind power density of the site and performance of the wind turbines 2) wind power tariff 3) supporting policies and incentives from the state government as well as central government 3) capital cost of the project 4) Operation and maintenance costs and so on.

In India the states where the good wind power potential exists are Gujarat, Maharashtra, Tamilnadu, Karnataka, Andhra Pradesh, Rajasthan, Madhya Pradesh and Kerala. ONGC have its extraction plant, offices, colonies and institutions in many of these states. In this study the comparison of the investment in wind power projects in the states of Gujarat, Maharashtra, Andhra Pradesh and Rajasthan have been carried out to analyse the potential sites and to select the state where the maximum financial return can be achieved. For this study the sites with good wind power density and are either currently being developed, or planned to be developed in near future by different developers in these four states analysed along with selected sites of power density more than 200W/m^2 with different parameters related to infrastructure in addition to wind resource.

Short listing of sites

The important criteria used for short-listing of the sites are wind power density at 50m heights and the potential available. It is learned form the discussion with major wind farm developers that the locations which are currently being developed or would be developed in very near future are mainly in 1) Kachchh, Jamnagar, Rajkot and Surendranagar districts in Gujarat 2) Satara, Dhule and Nandurbar districts of Maharashtra 3) Kurnool and Anantpur districts of Andhra Pradesh and 4) Jaisalmer and Jodhpur istricts of Rajasthan. The three sites from each states has been selected for the study based on the wind power density and the Estimated MW potential identified based on the micro survey carried out by the C-WET

Based on the above wind resource details given for all the four states and the possible wind farmable sites where the wind farm developers are active or planning their activity, the sites selected for the study and comparison of the returns on investment in wind power projects are given in table 1.17.

Table 1.17 List of the sites selected for the study

State	Sites
Gujarat	1.Dhank
	2.Jamanvada
	3.Surajbari
Maharashtra	1.Gude Panchgani
	2.Vankushawade
	3.Matrewadi
Rajasthan	1.Devgarh
	2.Jaisalmer-1
	3.Phalodi
Andhra Pradesh	1.Kakula Konda
	2. Ramagiri- 1
	3. Kondamithipalli

The reason for selecting these sites is that they cover the various spectrums of sites available in the states and providing the optimistic and average scenarios. Also these site have good potential for wind power installations and the major wind power developers are alresdy working on these sites or are planning to start their activities soon.

Table 1.18 gives the salient features of the sites selected.

Table 1.18 Details of sites selected for the study

State	Site	Latitude	Longitude	Altitude (m)	Mast height (m)	Annual average Air density (kg/m^3)	Annual Average Power Low Index	Annual Average wind speed at 20/25 m (m/s)
	Dhank	21°48’	70°07’	208	20	1.149	0.04	6.97
	Jamanvada	23°25’	68°36’	60	20	1.169	0.26	5.17
Gujarat	Surajbari	23°13	70°42	10	20	1.163	0.39	5.42
	Gude Panchgani	17°07	73°59	903	20	1.072	0.18	5.5
	Vankushawade	17°27	73°50	1100	25	1.052	0.12	5.89
Maharashtra	Matrewadi	17°11	73°56	898	25	1.086	0.07	5.78
	Devgarh	24°03	74°39	520	25	1.11	0.3	5.52
	Jaisalmer-1	26°56	70°54	231	20	1.14	0.22	4.94
Rajasthan	Phalodi	27°06	72°19	250	20	1.14	0.27	4.83
Andhra Pradesh	Kakula Konda	13°43	79°21	981	20	1.061	0.21	6.42
	Ramagiri- 1	14°16	77°31	580	20	1.091	0.13	5.42
	Kondamithipalli	15°03	78°03	449	25	1.114	0.23	5.89

The duration of wind data measurements at these sites in all differs from 1 year to 3 years. The duration of wind data affects the confidence level of generation estimations as a result of possibility of variation in wind resource.

Energy generation analysis

The estimation of the generation has been undertaken for these selected sites and for the three selected turbines. The annual average generation has been estimated based on the annual average wind speed data, wind rose data for each site, power law index, shape factor. The annual average wind speeds along with the annual average power law index have been used. The power law index is used to estimate wind speed at a height different than the height of wind speed measurement that is the hub height of the wind turbine.

Based on the average wind speed and the shape factor 'k' the frequency distribution curve can be plotted. Figure 4 shows the frequency distribution curve with turbine power curve superimposed on it. The area under both these curves is the monthly energy generating, shown as shaded area in figure.

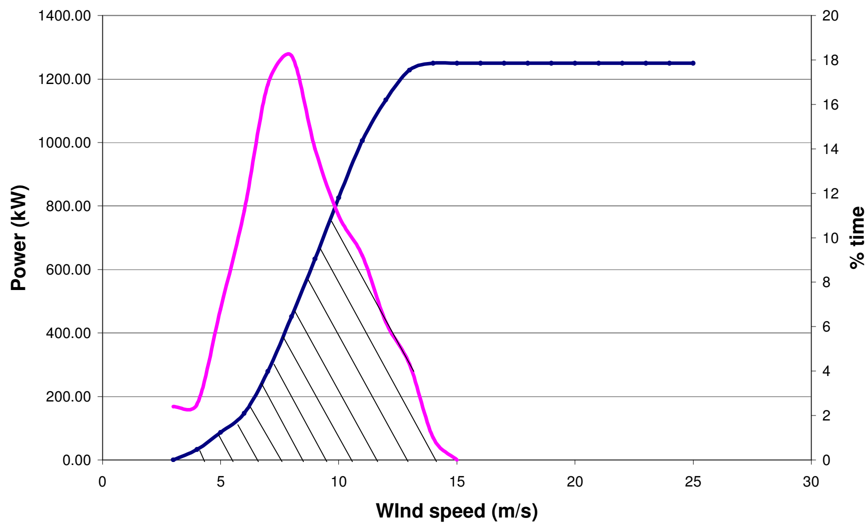


Figure 1.4 Wind power generation

To get the annual average generation by above method, the annual average wind speed with the shape factor and annual average power law index has been used along with the power curves of different turbines. The values of monthly and annual average wind speed, power law index, shape factor and air density values for the selected sites are taken from the wind energy resource survey of India (Volume-I to VII), that is prepared by C-WET under the ministry of new and renewable energy's wind resource assessment program. The annual average values are given in table 1.19 and the monthly average values are given in the Annexure III.

Table 1.19 Average annual wind speed, power law index, shape factor and air density for the selected sites

State	Site	Annual mean wind speed (m/s)	Power law index	Annual average air density (kg/m³)	Shape Factor
Gujarat	Dhank	6.79	0.11	1.153	2.3
	Jamanvada	5.17	0.26	1.169	2.2
	Surajbari	5.43	0.39	1.163	1.7
Maharashtra	Gude Panchgani	5.51	0.18	1.072	2.1
	Vankushwade	5.97	0.12	1.052	1.7
	Matrewadi	5.66	0.07	1.086	1.7
Rajasthan	Devgarh	5.61	0.30	1.110	2.5
	Jaisalmer	4.83	0.22	1.140	1.7
	Phalodi	4.82	0.27	1.140	1.6
Andhra Pradesh	Kakula Konda	6.41	0.21	1.061	1.4
	Ramagiri	5.42	0.13	1.091	1.9
	Kondamithipalli	5.61	0.23	1.114	1.8

A RETScreen model has been used to estimate the annual Capacity Utilisation Factor (CUF) using above method, and based on the CUF, annual energy generation is estimated. Different correction factors are considered for different losses. The correction factors are explained below. A sample RETScreen model sheet is given in Annexure IV

1. Air density correction

The power curves are estimated at standard air density of 1.225kg/m³. The energy generation has been corrected depending upon the air density at the selected site.

2. Array losses

The loss due to other wind turbines is called as array loss. Array loss is the range of 2-6%. The array loss of 5% has been considered for energy estimation.

3. Machine availability

The loss due to machine not available for generation is assumed 5% of total energy generation estimated. The manufacturers provide machine availability guarantee of about 95% to 97%.

4. Grid availability

The loss due to unavailability of grids is considered as 5% based on the general practise in the energy generation estimations.

5. Transmission losses

The metering of energy by the utility is done at the high-tension side of the step up transformer. The transformer losses and the transmission losses are considered at 5%.

6. Uncertainty

As the wind data measured at different sites are quiet old and are measured for 1-3 years only so there is a lot of uncertainty of the wind data used for the estimation of energy generation so an uncertainty correction factor of 10% is applied for energy generation estimation due to uncertainty in the flow of wind.

The annual average net energy generation of different turbines at different sites has been estimated after deducting above-mentioned losses from the estimated gross generation. The net energy generation from all the turbines at different sites are given in table 1.20 and the capacity utilisation factor (CUF) is given below in table 1.21 for all the turbines at these selected sites.

Table 1.20 Annual net energy generation per MW all the sites (MWh/MW)

		Generation (MWh/MW)		
State	Site	S1500	V1650	Reg1500
Gujarat	Dhank	2295	2083	2354
	Jamanvada	1992	1823	2104
	Surajbari	2437	2230	2589
Maharashtra	Gude Panchgani	2160	1977	2203
	Vankushwade	1870	1712	1990
	Matrewadi	1773	1628	1896
Rajasthan	Devgarh	2204	2028	2336
	Jaisalmer	1793	1646	1899
	Phalodi	2042	1878	2177
Andhra Pradesh	Kakula Konda	2395	2184	2538
	Ramagiri	1882	1570	1978
	Kondamithipalli	1946	1623	2095

Table 1.21 Annual average capacity utilization factor (%)

		Average annual CUF (%)		
State	Site	S1500	V1650	Reg1500
Gujarat	Dhank	26.2	23.8	26.9
	Jamanvada	22.7	20.8	24.0
	Surajbari	27.8	25.5	29.5
Maharashtra	Gude Panchgani	24.7	22.6	25.1
	Vankushwade	21.3	19.5	22.7
	Matrewadi	20.2	18.6	21.6
Rajasthan	Devgarh	25.2	23.2	26.7
	Jaisalmer	20.5	18.8	21.7
	Phalodi	23.3	21.4	24.9
Andhra Pradesh	Kakula Konda	27.3	24.9	29.0
	Ramagiri-1	21.5	17.9	22.6
	Kondamithipalli	22.2	18.5	23.9

The CUFs, as mentioned earlier are estimated based on the site wind resource measured over one year and there could be actual +/-10% variation in generation. This aspect has been covered in the sensitivity analysis. Further it is noted that for the same wind turbine CUF achievable is different for different locations, this is because the wind energy generation depends upon the wind characteristics that are the wind speed, variation in wind speed with height, air density of the location and so on. So at the time of making decision on the selection of site for wind farm it is necessary to analyse all these characteristics and to estimate the annual energy generation up to certain accuracy using the good resolution wind data, wind turbine characteristics and a better model for energy estimation for the particular location.

Project cost

Capital cost

The capital cost of wind project along with the break-up is provided in the Table 1.22 below. This cost is based on the present trends and actual project costs offered by different wind turbine manufacturers and developers for projects being developed presently. The broad cost components are described below.

Feasibility, tendering and contracting: This includes the costs for preparation of feasibility report, preparation and evaluation of bids and finalisation of contract.

Project monitoring cost: The proposed model for implementation of the project is through developers. Thus the project needs only monitoring and inspection by ONGC officials and/or project management consultants etc. The actual duration of implementation is expected to be six months.

Technical consultancy: The cost included here is for validation of the energy generation estimations for the proposed projects at about Rs.10.0 lakh per project through independent consultant.

The developer would offer the turnkey costs for the wind power project, which would include following broad elements.

Land: The land costs based on the quotations work out to be Rs 50,000/acre with requirement of 2.0 acres/MW of footprint area for wind power project. Although the area of land required is calculated on the basis of arrangement of wind turbines in arrays. To minimise the loss of energy due to wake effect the wind turbines in a wind farm are arranged in arrays with spacing of 3Dx5D, 5Dx7D, or 4Dx8D etc. (D is the rotor diameter) to optimise the energy generation. Based on this array arrangement the area requirement is calculated approximately as 20 acre per MW. But here only the footprint area of the wind turbines have been taken or the calculations.

Site development and civil work: This includes the costs for levelling of site, development of roads, civil amenities like control room/office/stores/rest rooms/water storage and foundation of wind turbines. This estimate, based on the quotation, is about Rs.45Lakh/MW.

Electrical equipments: This includes the transformers, switchgear etc. for the wind power projects, which is about Rs 49lakh/MW.

Wind turbines: This includes the wind turbine, tower, hub, and generator assembly. Based on the quotes, it is about Rs 490 Lakh/MW.

Erection and Commissioning: This includes the cost for erection of wind turbines and commissioning of the wind turbines. This cost is about Rs 20 Lakh/MW

Evacuation: This includes the cost of evacuation line, from the wind turbines till the substation. The actual cost varies from turbine to turbine depending upon the distance. However, the average cost for a group of turbines is Rs 30 Lakh/MW.

Project Registration cost including cost of application processing charges, PPA signing charges, and other processing charges is taken as Rs. 1.0 lakh per MW.

In the case of proposed wind power project, the implementation is suggested through wind project developer. In this case, the wind project developer undertakes all the activities and there will not be any additional contingency costs to the investor. Summary of the total project cost for 1 MW and 50 MW is given in table 1.22.

Table 1.22 Break-up of capital cost for wind power project of 50 MW capacity

Cost Component	Cost for 1 MW in RS. Lakh	Cost for 51 MW in RS. Lakh
Feasibility, tendering, contract	20	20
Project monitoring cost	50	50
Technical consultancy	10	10
Registration	1	51
Land	1	51
Site development, civil work	45	2295
Electrical equipment #	49	2499
Wind turbines	490	24990
Erection and commissioning	20	1020
Evacuation	30	1530
Total project cost	716	32516

includes cost of SCADA equipment

The insurance during construction is covered in above costs. Further, as the expected construction period is about 6 months (based on the offers given by the developers), for the wind power projects which the developer primarily implements, thus no working capital requirement has been considered in above costs. Though the commissioning time may vary depending on the situations and factors such as delay in land acquisition, delay in clearances and approvals, and some social issues like public opposition etc. but these will not be considered effective in the cost as the process of land acquisition is continuous process by the developers and there are no major problems of these kinds faced by them except few cases in some states.

The operation and maintenance costs

The present model for O&M of wind projects is based on the annual maintenance contracts (AMC) offered by the wind turbine manufacturers. The O&M for the first year is sometimes offered free and for subsequent years the O&M is undertaken based on the AMC. There is about 5% increase in the AMC costs annually. The annual O&M costs, based on the AMCs, are about Rs.11.00 Lakh/MW. In addition, annual insurance of about Rs.1.5 Lakh/MW also has been considered. Along with this the re-certification cost of Rs. 10,000.00 per MW will be included in the O&M cost per year.

Financial analysis

Assumptions

1. 80% accelerated depreciation considered

In case of accelerated depreciation, it was assumed that ONGC has tax liability, which can absorb the depreciation benefit. The tax benefit as a result is shown as revenue inflow in the project. Further, the depreciation benefit can be different depending upon the date of commissioning of the project. If the project is commissioned before 30th September, full benefit of the accelerated depreciation can be availed. In case of project commissioning after 30th September, only 50% of eligible depreciation can accrue in that financial year. It is estimated that the project would be commissioned after September 2009 so half depreciation benefit i.e. 40% depreciation benefit in the first year has been considered for analysis. The year wise accelerated depreciation rate considered is as given in table 1.23

Table 1.23 Rate of accelerated depreciation

Year	Year1	Year2	Year3	Year4	Year5	Year6	Year7
Acc . dep. Rate	40%	48%	9.6%	1.92%	0.38%	0.08%	0.02%

2. The tax benefit under Section 80IA of the Income Tax Act

As per this section, the infrastructure projects can get tax holiday for 10 years. Wind power projects are eligible for

Section 80IA benefit. Here, the Minimum Applicable Tax (MAT) that is applicable along with the surcharge (10%) and Education Cess during the period when Section 80IA benefit is taken and are considered in financial calculation.

3. Costs
The capital cost and the O&M costs as given in the section on Project Cost have been used. Escalation in O&M has been assumed as 5%.

4. Energy generation
The analyses have been carried out with short listed sites and three turbines and the generation in each site from the wind turbine S1500 is used for the financial evaluation considering it as the middle value for all the three turbines.

5. 100 % equity

6. Project life: 20 years

7. Single line depreciation at the rate of 5% per year.

8. Reactive power compensation: Assuming 3% reactive power consumption of net generation.

Financial analysis of the projects

The financial analysis is carried out assuming total capacity of 51 MW (34 nos of 1.5 MW turbines) in one state.

It has been observed that the captive consumption of ONGC is higher in the state of Gujarat (880 lakh units per year) and Maharashtra (236 lakh unit per year), and the low captive consumption in Rajasthan (2.5 lakh units per year) and Andhra Pradesh (46 lakh unit per year). The wind project capacity for captive consumption in all the four states have been calculated based on the 20% capacity utilization factor.. The capacity for Gujarat is calculated about 50 MW, for Maharashtra it is 15 MW, for Andhra Pradesh it is 3 MW and for Rajasthan it is less than 1 MW. So in this study the Rajasthan is not considered for the captive wind power plant.

For estimation of the savings due to the captive consumption of wind energy the retail electricity tariff rates for the HT consumers in the three states Gujarat, Maharashtra and Andhra Pradesh have been considered. For calculating the average HT tariff the total consumption in the state, energy charges for the HT consumer (time of the day tariffs wherever applicable), fuel surcharge, electricity duty, rebate etc are considered, except in case of Gujarat where the C2-C3 extraction plant is located at Special Economic Zone (SEZ) area so the electricity duty is not applicable. The Average HT tariff so estimated and used for the financial evaluation are Rs

4.76/kWh in Gujarat, Rs 5.22/kWh in Maharashtra, and about Rs. 3.70/kWh in Andhra Pradesh.

The state specific parameters considered for the financial evaluation are given in the table 1.24.

Table 1.24 State specific parameters used for financial evaluation

Parameter/Satre	Gujarat	Maharashtra	Rajasthan	Andhra Pradesh
Project capacity for captive use	All 51 MW as captive	15 MW captive + 36 MW sale to grid	No captive capacity	3 MW as captive + 48 MW as sale to grid
Project capacity for grid sale only	All 51 MW	51 MW	51 MW	51 MW
Electricity saving rate for captive consumption (Rs/kWh)	4.76	5.22	---	3.70
Rate for sale of the unused power from captive plant	85% 0f 3.56 = 3.026	3.65 (lowest time of the day tariff)	---	=85% of 3.5 = 2.98
Rate for sale to grid (Rs/kWh)	Rs. 3.56	Rs. 3.5 in the first year and the escalation of Rs 0.15 up to 13th yesr. From 14th to 20th yesr the tariff equal to 13th year is considered	Rs 4.28	3.50
Wheeling abd transmission losses for captive power use	4.0 %	9%	10%	5%
Wheeling/Transmission charges for captive use	Rs 3262.2 per MW per day	Rs 0.25 per kWh	---	Rs 182 per kW per month
Total captive consumption demand	880 lakh kWh	236 lakh kWh	----	46 lakh kWh

IRR values and payback periods have been estimated for a 51 MW total capacity with S1500 wind turbines and at each of the sites. This is summarised in 1) Tables 1.25 for the case of captive use and 2) Table 1.26 for the case of sale of power to the utility

Table 1.25 IRR values and payback periods calculated based on the estimated CUF for all the sites and S1500 wind turbines when generation is used for captive purpose

		Captive Without CDM	
State	Site	IRR%	Payback period (years)
Gujarat	Dhank	11.77	6.40
	Jamanvada	9.82	7.26
	Surajbari	12.62	6.07
Maharashtra	Gude Panchgani	12.91	6.42
	Vankushwade		7.20
	Matrewadi	11.13	7.47
Andhra Pradesh	Kakula Konda	11.19	6.64
	Ramagiri	7.27	8.77
	Kondamithipalli	7.79	8.44

Table 1.26 IRR values and payback periods calculated based on the estimated CUF for all the sites and S1500 wind turbines when all the generation is sold to the grid

		Sale to grid Without CDM	
State	Site	IRR%	Payback period (years)
Gujarat	Dhank	11.12	6.67
	Jamanvada	8.80	7.86
	Surajbari	12.19	6.23
Maharashtra	Gude Panchgani	13.33	6.43
	Vankushwade	11.05	7.42
	Matrewadi	10.22	7.83
Rajasthan	Devgarh	13.80	5.66
	Jaisalmer	10.06	7.14
	Phalodi	12.34	6.18
Andhra Pradesh	Kakula Konda	11.56	6.48
	Ramagiri	7.64	8.54
	Kondamithipalli	8.16	8.22

From above tables it can be seen that for the case of captive purpose the return is higher in Maharashtra among all the three states, followed by the Gujarat. This is because the savings for captive use are higher due to high electricity purchase price and also the rate for selling of surplus energy is higher compared to the other states.

For the case of sale to grid the rate of returns are highest for the Rajasthan followed by the Maharashtra. One of the main reasons for this is that the price for wind power purchase by state electricity utility is highest for the Rajasthan and in Maharashtra there is an escalation of the price up to 13th Year.

The above calculations were based on the estimated energy generation from different sites based on the available wind data and wind turbine characteristics. For easy of comparison an analysis also had been carried out considering if the 23% CUF is achieved in each state. These values are given in table 1.27. It is found that for Rajasthan and Maharashtra the IRR values are good and almost in the same range.

Table 1.27 IRR values calculated based on the 23% CUF for each state when power is sold to the grid

State	IRR (%)	Payback period (years)
Gujarat	9.02	7.44
Maharashtra	12.14	6.88
Rajasthan	12.10	6.27
Andhra Pradesh	8.75	7.89

Further it is observed that the IRR for the case of sale to grid in Maharashtra is higher for the higher CUF site, because the captive project capacity is less compared to the total project capacity and as the generation increases the loss due to the transmission/wheeling losses increases and the amount of surplus energy from captive plant increases which is to be sold at the lower rate than the tariff for the sale to grid.

Possibility of availing CDM benefits

India being a signatory of the Kyoto Protocol of the United Nations Framework Convention on Climate Change (UNFCCC), projects resulting in reduction of CO2 are eligible under the Clean Development Mechanism (CDM). The wind power projects producing clean power thus can result in to generation of additional revenue through sale of Certified Carbon Emissions Reductions (CERs). The detailed procedure for registering the projects with the Executive Board of the UNFCCC and availing the CDM benefits is given in Annex IV. There are various wind power projects which got registered with UNFCCC for availing the carbon benefit. Though during the years the process of registering is becoming tough and various projects failed to register because of the change in the registration process and the requirements to fulfil the additionality of the project. Therefore it is necessary for an organisation investing in the wind farm to decide in the initial stages of the project to start the process for the registration for CDM.

Based on the estimated energy generation per MW as given above, and using the baseline carbon emission factor for the Northern, Eastern, Western North-Eastern regional grids as 0.83 tCo2/MWh of electricity the number of CERs that can be achieved on installing 51 MW wind farm in the selected sites, if the CUF of the level of S1500 is achieved are given in table 1.28.

Table 1.28 Estimated GHG emission reduction (tCO_2) of CERs that can be achieved from different sites using estimated CUF of S1500 turbines for 51 MW wind project

State	Site	GHG emission reduction (tCO_2)
Gujarat	Dhank	97152
	Jamanvada	84174
	Surajbari	103085
Maharashtra	Gude Panchgani	91590
	Vankushwade	78983
	Matrewadi	74904
Rajasthan	Devgarh	93444
	Jaisalmer	76016
	Phalodi	86399
Andhra Pradesh	Kakula Konda	101231
	Ramagiri	79724
	Kondamithipalli	82320

The registration by UNFCCC depends upon the validation of the project by the committee appointed by UNFCCC. This validation depends upon various factors such as 1) Voluntary participation by the parties involved in the project 2) The emission reduction needs to be real and measurable and 3) reductions in emissions from a CDM project need to be additional, that is reductions should not have occurred in the business as usual scenario. The additional GHG reductions are calculated with reference to a defined baseline.

There had been some cases when the wind power projects with smaller wind turbines failed to register for CDM due to the fact that they did not able to proof the additionality and they were considered as business as usual. However there is no specific mention anywhere that the wind projects with smaller wind turbines could not get registered. But considering the estimated energy output and the IRR estimated it would be good to consider the larger wind turbines for the development of wind farm as they would ultimately contribute to the addition in electricity generation and higher values of GHG emission reduction.

In India the investors in wind power projects had faced technical problems such as low generation, lack of proper grid integration etc. In this case the CDM revenue plays a great role and partially recovers the losses. Today apart from the central and state government incentives, the CDM is one of the major factors that encourage the investors to invest in wind farms.

The estimation of possible CDM revenue is carried out based on the possible GHG emission reduction, the current market price of CERs, and the percentage sharing of the CERs by the state distribution licensee. The CERs may either be received for 10 years or for 21 years (in terms of 3 seven years block). Here we have considered that the CERs will be received for the first 10 year of the project life, as there is uncertainty of getting registered the project for CDM for three times of seven years block. So the IRR values and payback period are calculated for each site considering that the CDM benefit will be received for initial 10 years.

The Sale rate for the CERs that is Euro 10 per CER has been taken based on the estimates given by the Carbon management Group of ONGC Limited. This value is almost equivalent to the current market price of the CERs.

The IRR and payback period for both the cases, that is captive use of energy and for sale of electricity to the grid are given in the table 1.29 and table 1.30 respectively.

Table 1.29 IRR values and payback periods calculated based on the estimated CUF for all the sites and S1500 wind turbines when power is used for captive purpose and with CDM benefit

		Captive With CDM	
State	Site	IRR%	Payback period (years)
Gujarat	Dhank	13.22	5.69
	Jamanvada	11.08	6.50
	Surajbari	14.15	5.38
Maharashtra	Gude Panchgani	14.67	5.65
	Vankushwade	12.54	6.35
	Matrewadi	11.68	6.68
Andhra Pradesh	Kakula Konda	12.93	5.79
	Ramagiri	8.83	7.54
	Kondamithipalli	9.23	7.28

Table 1.30 IRR values and payback periods calculated based on the estimated CUF for all the sites and S1500 wind turbines when all the generation is sold to the grid and with CDM benefit

		Sale to grid With CDM	
State	Site	IRR%	Payback period (years)
Gujarat	Dhank	12.58	5.91
	Jamanvada	9.93	6.99
	Surajbari	13.72	5.52
Maharashtra	Gude Panchgani	15.04	5.69
	Vankushwade	12.42	6.56
	Matrewadi	11.52	6.91
Rajasthan	Devgarh	15.23	5.12
	Jaisalmer	11.28	6.45
	Phalodi	13.68	5.59
Andhra Pradesh	Kakula Konda	13.48	5.61
	Ramagiri	9.08	7.36
	Kondamithipalli	9.64	7.09

It has been observed from the above tables that with the CDM benefit the Project IRR increases about 1.5% to 2%. So it can be said that the CDM revenue consideration has a major role in the making of decision for the investment in wind power project. The above values are based on the estimated energy generation based on the site specific parameters measured and published in Wind Energy resource survey of India. As the variation in the wind speed is uncertain and there is variation in average wind speed for different years and also there are inter annual variation in the wind speed the estimated energy generation and hence the amount of CDM benefit may differ for the project depending on the actual generation. This variation in energy generation must be considered during the investment decision for the project.

One of the major issue faced by the wind projects in India under CDM are establishing the benchmark/additionality, serious consideration of CDM revenue, common practice analysis, increased transaction costs and other procedural issues. So it is necessary to see it from all the angles of the investment and make a proper decision at the very beginning of the project.

Voluntary Emission Reductions (VERs)

Voluntary emission reductions are a good alternative for CDM as the rules are not as stringent as for CDM projects. Now an increasing number of people are taking a move ahead with voluntary carbon market. Currently two standards are dominant in the voluntary carbon market namely Voluntary Carbon Standard 9VCS) and the Chicago Climate Exchange (CCX). The only negative point is that the standards are not as high quality as for CDM and hence the price for VERs are quite low, that is in the range of 2 to 4 Euro whereas the price for CERs are in the range of 10 to 12 Euro.

Sensitivity analysis

The IRR achieved depends on 1) capital cost 2) Energy generation and the electricity tariffs. The energy generation may vary depending on the availability of the wind throughout the year, and also the cost of wind machine may be different at the time of project development depending on the raw material cost, equipment cost, site development cost etc. As the wind power tariff is fixed for any state the variation in cost of the project or variation in the energy output from the wind farm will have an impact on the IRR achievable. The variations in generation and cost is considered here and the sensitivity analyses were carried out for Rajasthan and Maharashtra for the case of sale of all electricity to the grid for S1500 Wind turbine, taking into consideration two prominent parameters
a) Generation remaining constant and cost varying by +/- 5%
b) Cost remaining constant and generation varying by +/- 10%

a) Sensitivity analysis for variation in cost of +/- 5% and the generation remaining same

The analysis is carried out considering the sale to utility wind power projects for the states of Maharashtra and Rajasthan. The increase or decrease in total project cost of 5% has been considered for the analysis. The results of the analysis for both the cases are given in the table 1.31 for IRR without CDM and in table 1.32 for IRR with CDM.

Table 1.31 Variation in IRR based on + / - 5% variation in project cost without CDM benefit

State	Site	Original IRR%	IRR with 5% less cost	IRR with 5% high cost
Gujarat	Dhank	11.12	11.88	10.43
	Jamanvada	8.80	9.48	8.18
	Surajbari	12.19	12.98	11.46
Maharashtra	Gude Panchgani	13.33	14.07	12.64
	Vankushwade	11.05	11.72	10.43
	Matrewadi	10.22	10.87	9.62
Rajasthan	Devgarh	13.80	14.64	13.02
	Jaisalmer	10.06	10.79	9.54
	Phalodi	12.34	13.13	11.61
Andhra Pradesh	Kakula Konda	11.56	12.33	10.85
	Ramagiri	7.64	8.28	7.04
	Kondamithipalli	8.16	8.82	7.55

Table 1.32 Variation in IRR based on + / - 5% variation in project cost with CDM benefit

State	Site	Original IRR%	IRR with 5% less cost	IRR with 5% high cost
Gujarat	Dhank	12.84	13.41	11.81
	Jamanvada	10.23	10.68	9.24
	Surajbari	13.97	14.59	12.92
Maharashtra	Gude Panchgani	15.39	15.86	14.28
	Vankushwade	12.81	13.16	11.73
	Matrewadi	11.93	12.24	11.00
Rajasthan	Devgarh	15.53	16.14	14.4
	Jaisalmer	11.63	12.06	10.56
	Phalodi	14.00	14.54	12.9
Andhra Pradesh	Kakula Konda	13.93	14.33	12.69
	Ramagiri	9.62	9.8	8.56
	Kondamithipalli	10.18	10.38	9.1

It is observed that for both the cases i.e. without CDM benefit as well as with CDM benefit there is an increase in IRR of about 0.5 to 1% when the cost becomes 5% less, and there is an increase in IRR of about 0.5 to 1% when the cost of the project becomes 5% higher. So the variations in the project cost have significant impact on the annual return. These aspects can be taken care of by the bidding process and selecting the project proposal which offers higher generation as well as higher rate of return.

b) Sensitivity analysis for variation in generation and cost of the project remains same

The analysis have been carried out to estimate the variation in IRR when there is 10% increase or decrease in the capacity utilization factor or the energy generation from wind farm. For this one site each from each state has been selected to analyse the change in IRR with the variation in energy generation. Table 1.33 and Table 1.34 give the results of the analysis without CDM benefit and with CDM benefit respectively

Table 1.33 Variation in IRR based on + / -10% variation in the electricity generation without CDM benefit

State	Site	Original IRR%	IRR with 10% less generation	IRR with10% high generation
Gujarat	Dhank	11.12	9.44	12.85
Maharashtra	Gude Panchgani	13.33	11.73	14.97
Rajasthan	Devgarh	13.80	11.85	15.65
Andhra Pradesh	Kakula Konda	11.56	9.72	13.31

Table 1.34 Variation in IRR based on + / -10% variation in the electricity generation with CDM benefit

State	Site	Original IRR%	IRR with 10% less generation	IRR with10% high generation
Gujarat	Dhank	12.84	10.62	14.43
Maharashtra	Gude Panchgani	15.39	13.15	16.83
Rajasthan	Devgarh	15.53	13.17	17.2
Andhra Pradesh	Kakula Konda	13.93	11.48	15.37

It is observed the IRR values decreases to about 2% with the decrease in the energy generation of 10%, and the IRR increases to about 2% when the energy generation increases by 10%. It is further observed that the IRR values for Rajasthan and Maharashtra goes below 12% when the generation reduces by 10% for the selected sites, but is more than 12% if the CDM benefit is also considered. So the states of Rajasthan and Maharashtra are showing good returns with CDM benefit even if the generation reduces by 10% of the estimated value.

It is clear from the above analysis that the cost of the turbine as well as the generation estimations has considerable impact on the financial viability of the project.

The IRR increases by approximately 1.0 % point with 5% decrease in the cost and decreases about 1 % with 5% increase in the cost. Similarly for reduction in generation of 10% there is a decrease of approximately 2.0% in IRR and for increase in generation of 10%, there is an increase in IRR of approximately 2.0%.

The issue of fluctuation in cost & generation and resultant lowering IRR is mitigated in project development with developer approach through tendering. The lump sum costs received in the tender would be firm and as the project has very short gestation period, the cost escalation would not arise.

In case of generation, which is function of wind turbine as well as location, the risk on wind turbine part is reduced by putting a requirement of on site power curve testing of the wind turbine and including it as a requirement in bid. Further, while evaluation of the bids, the conditions may be made like sites which give IRR below a fixed value (specified by ONGC) would not be considered for further processing.

Thus through tendering, the best turbine/ site combination, which would meet the financial norms, and give the best result would get selected; there by ensuring required returns even in worst case scenarios.

Financial analysis for the Captive consumption in Gujarat considering the monthly variation in energy generation

The analysis for the IRR calculation for the case of monthly variation in the energy generation has been carried out for the captive power consumption in Gujarat. This is an important due to the fact that the average wind speed varies throughout the month and in any month the energy generation from the wind farm may be higher than the average monthly captive consumption and for the other months the generation may be lower than the captive consumption. And as in Gujarat the banking of electricity is allowed for one month only there may be the variation in IRR due to monthly variation compared to the IRR values calculated for annual average generation.

The monthly generation values are calculated using same methodology as used for annual average generation that is using site specific monthly average values of wind speed, power law index, shape factor, air density and the wind turbine power curve. It has been estimated that if the site Dhank in Gujarat is considered then for the 51 MW captive power projects the IRR for the case of monthly energy generation variation is 11.73 %, which is almost equal to the IRR of 11.77% calculated based on the annual average energy generation for the same site.

Risk analysis

Payment security

In each state the power purchase agreement is to be signed by the wind farm owners and the distribution companies. The distribution company pays to the owner for the electricity fed to the grid against the bill sent by the owner based on the reading of the meter installed at the point as specified in the regulations of different states. The time specified for the payment of bills by discoms is 30 to 45 days for different states. Table 1.35 below gives the time taken by different state discoms for the payment of the bills

Table 1.35 PPA data for different states

State	PPA to be signed with	Payment
Gujarat	GUVNL	Within 30 days from date of receipt of tariff invoice by designated office of GUVNL
Maharashtra	MSEDCL	Within 45 days from receipt of seller's monthly bill
Andhra Pradesh*	APTRANSCO	Within 45 days from receipt of seller's monthly bill
Rajasthan	JVVNL	Within 30 days from date of receipt of tariff invoice by designated office of TNEB

It has been observed that in the state of Rajasthan Gujarat and Maharashtra the realisation of payment from discoms are at faster rate within the time stipulated. For Andhra Pradesh there had been some delays in the payment from the discoms.

There is no additional security mechanism in place for payments for wind energy projects. However, there are some late payment surcharges specified by CERC in its notification dated 16th September 2009, that is for the delayed payment beyond 60 days from the date of billing, a late payment surcharge at the rate of 1.25% per month shall be levied by the generating company.

Entry exit barriers

The wind energy projects are being developed on commercial scale in India and so far there are no major entry barriers. In case of all the states the wind tariff order, renewable purchase obligations, and renewable power/wind power policies have been issued and is applicable for projects set up either for selling power to utility/ for captive purpose.

Technology

The wind turbines presently being offered in India are state of the art for the individual turbine capacities. The individual turbine capacities are increasing world over and reaching the capacity of 6MW. However, these higher capacity turbines are developed a) for offshore wind projects or/and b) for high wind regimes. India being in medium to low wind regime, the maximum turbine capacities would remain about 2.1 MW. The analysis carried out was based on turbines with C-WET certification, thus, reducing technology risk. In addition, while rating different turbines, the years a particular turbine has been operational was considered as one of the criteria.

Further, the 'on-site power curve testing' of turbines would be an essential condition for bidders ensuring the turbine quality.

Risk during construction

Risk during construction may be such as delay in land acquisition, delay in getting approvals and clearances for wind farm development, delay in procurement of materials, labour problem, etc.

In Gujarat and Rajasthan till now no major problems like above have been faced by the developers, which may cause delay in construction work. Generally the developers take all the clearances, well in time. Whereas in Maharashtra the wind farm developers have faced lot of hurdles due to resistance from local tribal community and some times the wind farm developer had to stop their activity due to this risk. In Andhra Pradesh the mostly land which are suitable for wind farm development are under forest land, so there may be a problem in getting the clearance for the acquisition of land for wind farm development activity.

Other energy sources

There would not be any risk as far as other energy sources are concerned, as the project would have a long term PPA with the utility and would not enter into the open market for bidding, whenever it comes into force.

Environmental assessment

Pollution

Wind power is a clean source of energy and does not result into any liquid, land or air pollution. Thus wind projects are exempted from the requirement of carrying out Environmental Impact Assessment (EIA) prior to the project implementation.

There is some noise pollution in the vicinity of the wind projects. However, the wind projects are always in the remote locations away from settlements, making the noise pollution levels insignificant for general population.

Fire /Accident

Standard safety precautions are needed for the O&M personnel since the maintenance involves climbing to the hub of the turbine at 60-80m high. Standard industrial Injury and Illness Prevention Program and fire precaution are required to be followed at wind power project sites.

Steps involved in developing a wind energy farm

The implementation of the proposed wind farm could be done in two ways.

1. **Developer approach**

The developer/manufacturer carries out all the activities on behalf of the client. The project developer procures suitable land, develop the project with necessary permissions and approvals, install turbines, provide grid connection, gets the agreements signed, commission the project, hands over the same to the investor and if required carries out the O&M for contracted period etc.

The advantages of the developer approach are:

1. ONGC will not be required to undertake any of the processes for approvals, contracts, grid extension, site development as well as erection/ commissioning of the turbines etc.
2. Another advantage is the time required to commission the project. With the developer approach, the time required to commission the project is about a year since all the clearances, infrastructure development etc. is already planned/ undertaken by the developer.

The possible disadvantages of this approach are:

1. Limitation on choice of site depending on offers by developers
2. No option for opting Foreign based manufacturers turbines
3. 3.Possible high cost as the developers may charge premium for the sites controlled by them.

2. **Setting up of the project by the ONGC**

The procedure to develop the wind farm in this node is as follows:

- Feasibility studies involving tendering and contract
- Wind resource assessment which requires more than 1years time
- Contour and land survey
- Micrositing study
- Hiring of a technical consultant for validation of micrositing
- Registration with State Nodal Agency (SNA) which are GEDA, MEDA, NEDCAP, and RREC for the states of Gujarat, Maharashtra, Andhra Pradesh, and Rajasthan Respectively.
- Land procurement (18–20 acres/ MW): In case of Government land: Selection of land, Collectors approval, Tehsildar's approval, forest department approval, if necessary. In case of private land: Buying it from the villagers, approval of Tehsildar
- Approval from SNA after filing an application.
- Assessment of power evacuation facilities
- Approval of transmission company after it conducts the load flow analysis
- Power purchase agreement with Discoms
- Application of loan
- Site development and civil construction

- Preparation of bids for machine procurement and O&M arrangements
- Bid evaluation
- Finalization of contract
- Erection and commissioning
- Development of evacuation facilities
- Project commissioning

There are two agreements, one a PPA with discoms and another, a wheeling agreement with Transmission Company, which are required to be entered into.

Advantage of this route:

1. Choice of site from all the declared windy sites. But with the present scenario of most of the high potential sites being captured by prospective developers, the choice can get restricted.
2. Choice of turbines from foreign manufacturers

Disadvantages:

1. Need to undertake all the activities on its own, with little experience, resulting in longer commissioning time.
2. Procurement of land without wind resource assessment can be risky.
3. Doing wind assessment without procurement of land can result in situation where some private developer might take possession of the same before our purchase.
4. The possibility of getting turbines from the manufacturers with the expected cost advantage is less given the current market situation.

Thus, the recommended approach for the development of the proposed wind project is through the developers.

The detailed pert chart for activities under both implementation modes is given below in table 1.36.

Table 1.36 Pert chart for the implementation methodology of the wind power project

Activity chart	MONTHS																					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Activity chart for self development mode																						
Activity																						
Feasibility study	■	■																				
Selection of site and purchase of land with clearances		■	■	■	■	■	■															
Wind resource assessment			■	■	■	■	■	■	■	■	■	■	■	■								
Contour and land survey				■	■																	
Micrositing of wind turbines											■	■	■									
Assessment of evacuation facility with clearance												■	■									

Activity chart	MONTHS																					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Power purchase agreement														■								
Application for loan															■							
Site development, road development													■	■	■							
Preparation of Bids for supply and erection and commissioning of WTGs								■	■													
Bid evaluation									■	■												
Finalization of contract											■											
Erection and commissioning																■	■	■	■	■	■	
Evacuation facility																			■	■	■	
Commissioning of project																						■
Activity Chart for project at sites already being developed by Developers																						
Feasibility study	■	■																				
Preparation of bids			■	■																		
Floating – closing of tender					■	■																
Bid evaluation, validation of micro-siting and contract signing							■	■	■	■												
Power purchase agreement										■												
Application for Loan										■												
Erection and commissioning										■	■	■	■	■	■							

It was noted that with the implementation through the developer mode, the project commissioning would be before September 2008, while as in the case of self-implementation by ONGC, it would take longer to commission the project.

Contractual agreements between wind farm/ mill owners and SEB/power utilities

A model PPA has been developed by discoms for having agreements with the developer for sale of energy to utility. This PPA is signed only after the approval is accorded from SNA. The obligations of the developer and DISCOMS are given below:

Obligations of the developer

i. The developer shall obtain all statutory approvals, clearances and permits necessary for the project at his cost
ii. The developer shall construct, operate and maintain the project during the term of PPA at his cost and risk including the interconnection facilities and the substation.
iii. The developer shall sell all available capacity from identified wind farms to the extent of contracted capacity on first priority basis to the state distribution unit and not to sell to any third party.

iv. The developer shall seek approval of Transmission Company in respect of interconnection facilities and the sending station.

v. The developer shall undertake at its own cost construction/upgradation of (a) the interconnection facilities, (b) the transmission lines and (c) sending station as per the specifications and requirements of Transmission Company as notified to the developer.

vi. The developer shall undertake at its own cost maintenance of the interconnection facilities and the sending station excluding the transmission line beyond the sending station as per the specifications and requirements of Transmission Company as notified to the developer, in accordance with prudent utility practices.

vii. The developer shall operate and maintain the project in accordance with prudent utility practices.

viii. The developer shall be responsible for all payments on account of any taxes, cesses, duties or levies imposed by the state government or its competent statutory authority on the land, equipment, material or works of the project or on the electricity generated or consumed by the project or by itself or on the income or assets owned by it.

ix. For evacuation facility and maintenance of the transmission, the developer shall enter into separate agreement with Transmission Company, if applicable.

x. To procure start up power required for the plant from respective discom.

Obligations of Transmission Company are:

i. To allow the developer to the extent possible, to operate the project as a base load generating station.

ii. To grant must run status to the project subject however to emergency conditions.

List of approvals required for project implementation

i. Consent from Transmission Company for the evacuation scheme for evacuation of the power generated by wind power projects.

ii. Approval of the electrical inspectorate, from state government for commissioning of the transmission line and the wind energy converters installed at the project site.

iii. Certificate of commissioning of the wind farm project issued by SNA.

iv. Permission from all other statutory and non-statutory bodies required for the project.

v. Clearance from the Airport Authority of India, if required.

vi. Clearance from the Department of Forest, Ecology and Environment, if required.

Above are the common things which almost every state follows along with certain state specific and project specific requirements.

Conclusion and recommendation

Recommendation for the project capacity

The captive consumption of ONGC is higher in the states of Gujarat and Maharashtra. But it has been informed that the C2-C3 plant in Gujarat for which the captive consumption was being considered will not be feasible so only Maharashtra remains for the captive consumptions only with a captive wind power project capacity of 15 MW and the rest of the capacity for higher capacity wind power project is to be considered for sale to the state utility.

Based on the detailed study carried out it has been observed that for captive consumption of the power from wind farm the state of Maharashtra gives better return among all the four states when 15 MW project in Maharashtra is considered for captive power use and rest 36 MW is considered for the sale to grid. But again this 15 MW captive capacity is less compared to the 36 MW capacities for sale of power to utility so the investment in wind power project for the purpose of the sale to the state electricity utility may be considered. Also the risk of public agitation in land acquisition being faced by all the wind farm developers in Maharashtra is a constraint.

For the case of sale of power to the utility the states of Rajasthan and Maharashtra produced almost equal returns, followed by the Gujarat. But for Maharashtra the tariff is applicable for 13 years from the commissioning, which can be lower after 13^{th} year if the DISCOMs do not agree to pay the tariff at the same rate, whereas or Rajasthan it is for 20 year, so Rajasthan would be the best state for investment in wind power project or the purpose of sale to utility. Again the available project capacities with the wind farm developers in these states are different. It is up to 150 MW for Rajasthan, up to 100 MW for Gujarat and up to 50 MW each for Maharashtra and Andhra Pradesh.

Considering the above, the investment in wind power project is feasible and recommended to ONGC and based on the financial returns achievable the recommendation for the wind project capacity is as follows

1. 50 to 100 MW capacity in Rajasthan for the purpose of sale of electricity to the state grid
2. Up to 50 MW capacity in the Maharashtra state (But the risk of delay in the project due lo land acquisition problem by the developers)
3. 50 MW captive / sale to grid based wind power plant in Gujarat

Recommendation for the site selection criteria

Based on the financial analysis as well as the site conditions, the sites with low wind resource would provide lower returns as indicated by the lower IRR. There are many sites available in all the four states which have the wind power density greater than 250 W/m². Thus, the wind belts to be focused are medium and high wind resource, with wind power density above 250W/m² at 50 m height.

The generation from the wind turbines depends upon its power performance characteristics and also on the site specific conditions like wind speed, power law index, air density and so on, so while selecting the final developer the technical as well as performance details of the wind turbine offered must be analysed considering the site specific parameters, that is the wind turbines class shall be as per the class of wind farm sites.

The wind turbines of the similar or better characteristics than the selected wind turbines for the study shall be considered for the invitation of bids. The turbines thus selected cover all the major wind turbine manufacturers operating in India.

In the case of implementation of the project through developer, it would not be sure that same sites, as analysed in this study, would be offered. In such a scenario, based on the typical site-wise analysis in the study, sites with wind power density above 250 W/m² at height of 50m could be focused upon, or ultimately the estimated energy generation along with the return on investment are to be considered for the final selection of the wind farm developer.

The developer approach with tendering would mitigate the possible fluctuations in cost and generation and would allow selection of best site and turbine combination offered which would make the project viable.

Recommendation for the methodology of wind farm development

At present the wind turbine manufacturers are offering full services from purchase of land till finalization of the Power purchase agreement as well as long term O&M. These manufacturers have already purchased land at potential sites and started developing projects. So the approach is to invest in a wind farm, which is being developed at any of the sites by the wind manufacturers.

Usually O & M for 1st year is offered free by bidder/ manufacturer in project cost; so no separate contract is required for 1st year. It would be better to have O&M contract for complete 20 year at the start of the project.

Usually the land offered is barren land and is not used for cultivation etc. If the plantation is very close to the wind mill they might affect energy production as roughness of the land changes and it act as obstacles, for the blowing wind. But as the hub height for the wind turbines now are about 75-80 m so there is no much impact if anything grown up to 5-6 m in the wind farm lands. The sites usually face scarcity of water as most of the sites are remote or in the curvy area. The feasibility of making the site for solar power plant has been carried out and it is found that solar PV systems can be installed in the area available between two wind turbines. It would not have any impact on the wind energy generation as the solar PV plants are generally up to height below 10 m and the wind turbines installed are of 78 m hub height.

CHAPTER 2 Technical feasibility study of solar PV power plants at Jakhau, Gujarat

Solar photovoltaic (SPV) technologies are on the verge of large scale deployment across the globe. These technologies use global solar radiation to produce electricity.

Variety of SPV technologies are emerging and some of them are likely to emerge as most efficient and competitive technologies in near future. The SPV market is poised to explode in billion dollars market in coming decade. The Government of India has also identified solar power as one of the important renewable energy resources and its commitment to develop solar power applications is reflected well in the recently announced 'National Action Plan for Climate Change' where in it has announced 'National Solar Mission' as one of the eight missions to tackle the challenges of the climate change. A target of 20,000 MW installed capacity by 2022 across the country has been decided by Ministry of New and Renewable Energy, Government of India.

At this juncture, it is important to understand the market readiness of different SPV technologies, the investment opportunities SPV technologies are likely to create and the overall market development scenario.

This chapter is prepared for the ONGC Ltd. aims to give comprehensive introduction of these technologies and their technological feasibility at their existing 50 MW capacity wind farm in Jakhau, Gujarat. For Jakhau, this report essentially contains the followings:

- Solar radiation resource assessment
- Climate study
- SPV Technology evaluation and
- Technological feasibility

The potential of SPV power plants at the existing wind farm of ONGC requires the comprehensive lay out of the wind farm and appropriate positioning of the wind machines for the determination of area availability where SPV systems could be installed. Further Shading pattern of wind turbines will be carried out over the year towards identification of effective/utilizable area for SPV installation. These points will be summarized in the next report.

Jakhau

Jakhau (latitude 23° 13' 0" N, 68° 43' 0" E) Port is situated in Kachchh (Bhuj), Gujarat. Jakhau is located about 130 km from Bhuj city (Figure 2.1).

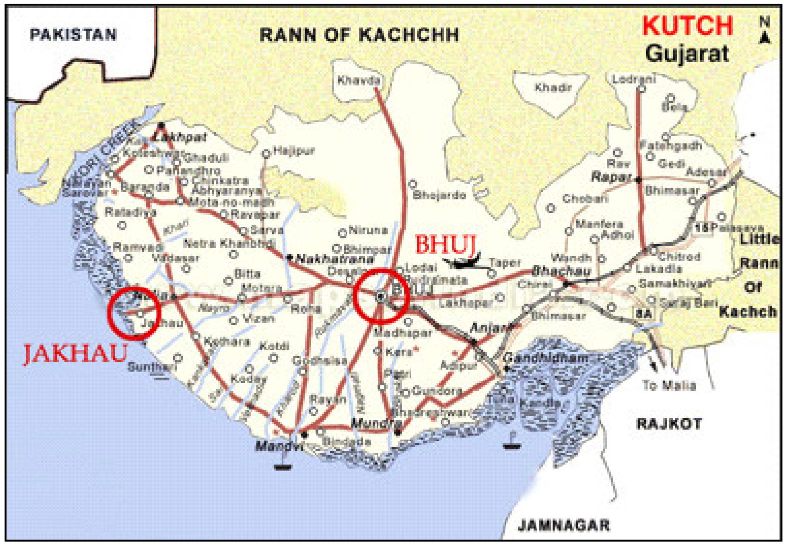


Figure 2.1 Map of Kachchh district of Gujarat

Jakhau is located in the 'Warm and Humid' climatic zone[1] of India and has almost constant ambient temperature over the year. Figure 2.2 presents the annual pattern of ambient temperature and relative humidity at Jakhau. The rain fall at the location is seasonal and the humidity is more than 70 percent from June to August months.

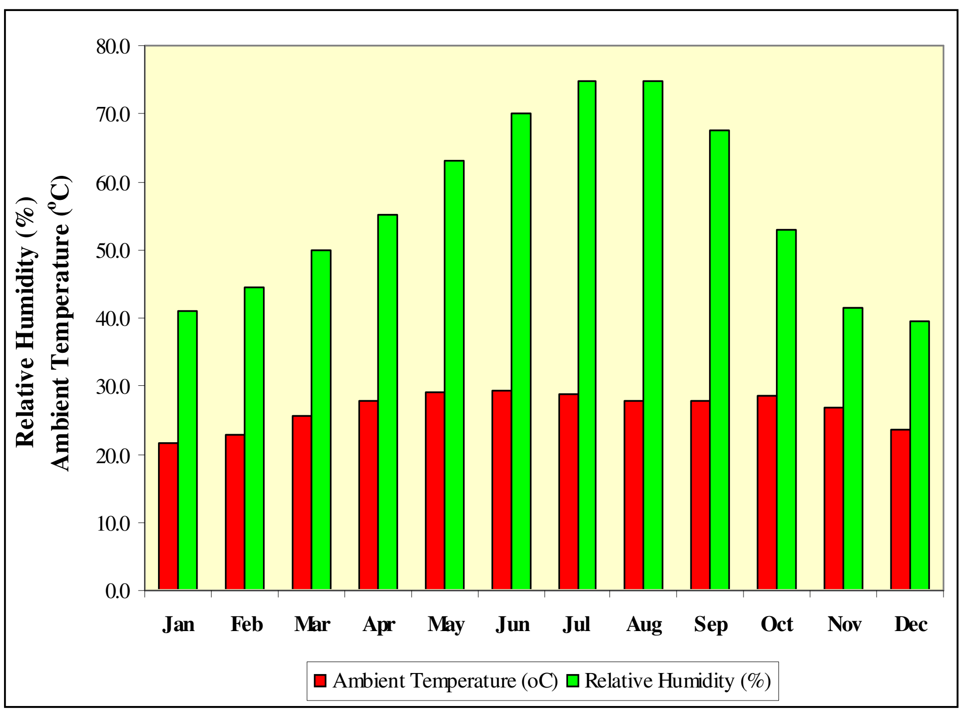


Figure 2.2 Relative humidity and ambient temperature over Jakhau

[1] On the basis of climatic parameters and microclimatic conditions, India has been divided in six major climatic zones namely composite, moderate, hot and dry, warm and humid, cold & sunny and cold & cloudy.

Solar energy resource assessment for Jakhau

Resource assessment is the primary and essential exercise towards project evaluation. In renewable energy projects the resource assessment exercise is important because of the intermittent nature of the resource. In India, the Indian Meteorological Department (IMD) measures the solar radiation and other climatic parameters over various locations across the country however, the measuring stations record only global and diffuse solar radiation on horizontal surfaces. There is weather monitoring station of IMD located in Bhuj. For the present analysis the solar radiation data has been taken from Atmospheric Science Data Centre, NASA Surface Meteorology & Solar Energy and the data measured by IMD is not available.

The sun-path diagrams of the Jakhau has been presented in Figure 2.3(a) and 2.3(b); which indicates that the locations receives good number of sunshine hours (annual daily average >9) through the year.

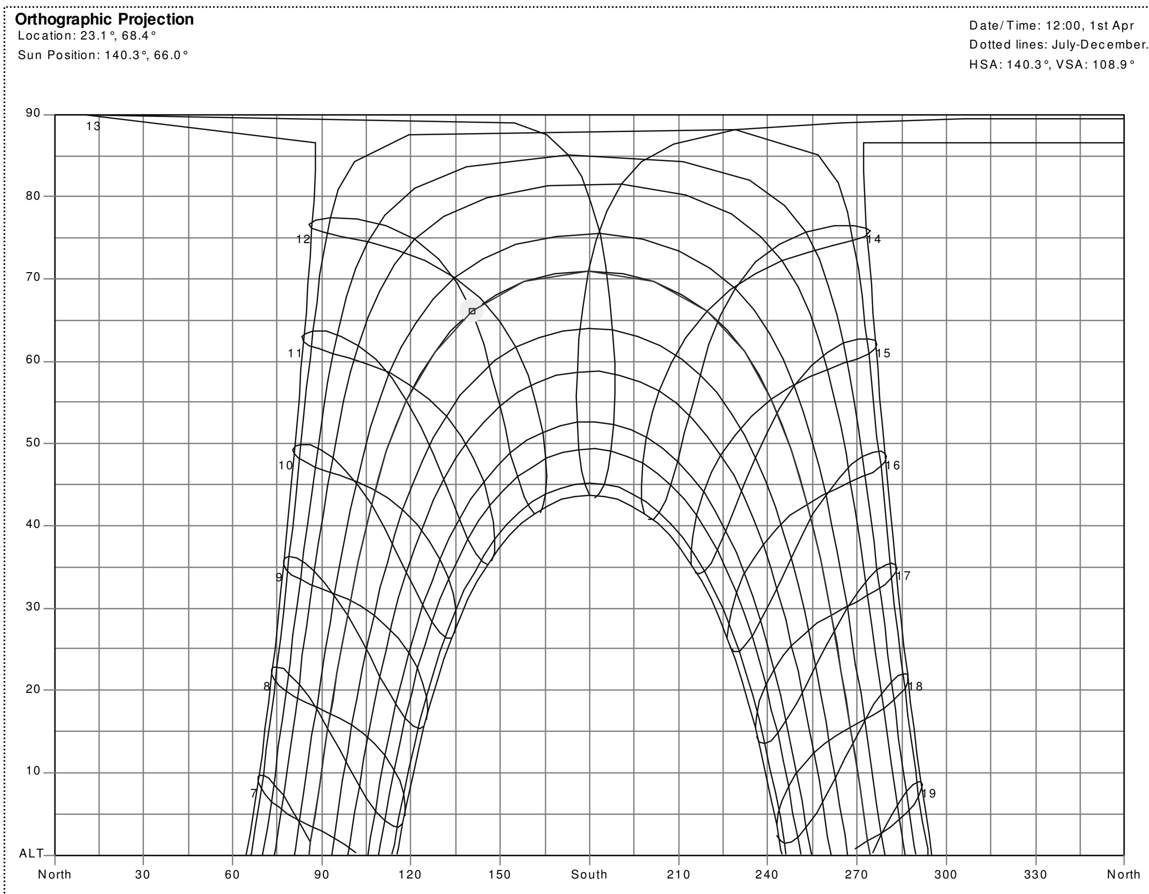


Figure 2.3(a) Sun path (Orthographic) diagram of Jakhau using ECOTECT Software

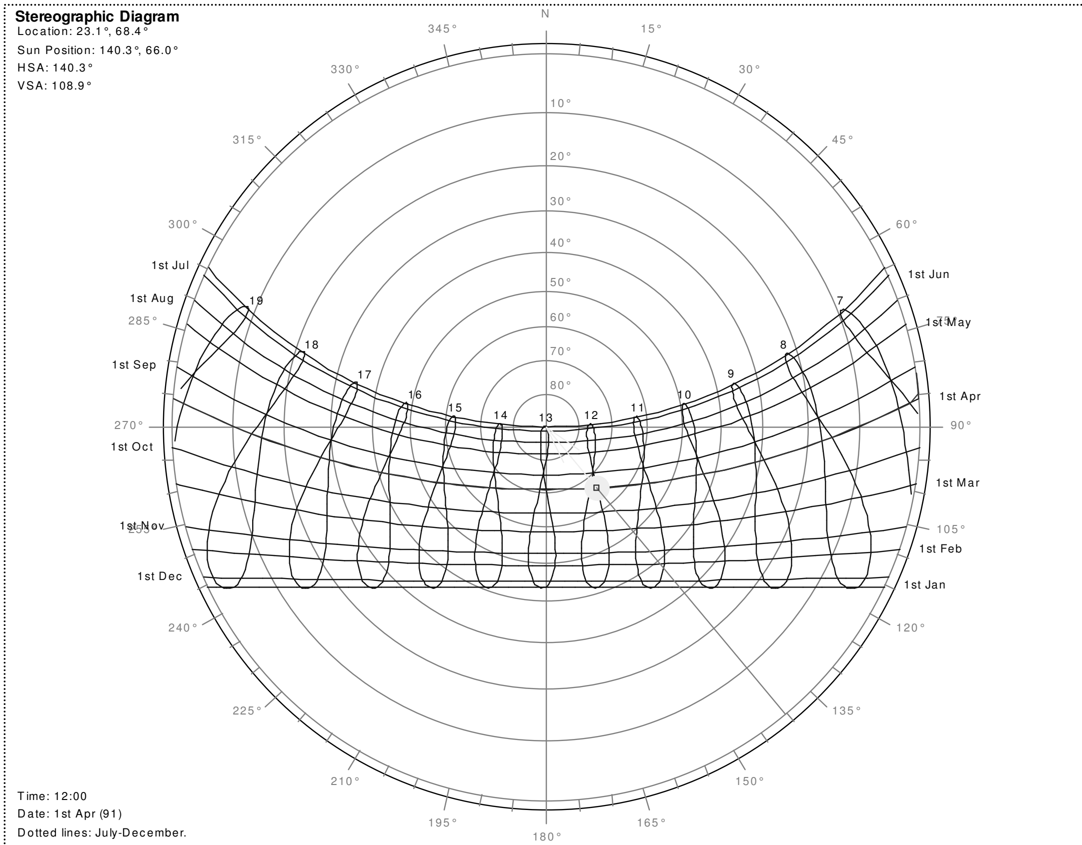


Figure 2.3(b) Sun path (Stereographic) diagram of Jakhau using ECOTECT Software

It has been estimated that Jakhau receives very good amount of solar radiation throughout the year with high number of sunshine hours. Figure 2.4 presents the daily solar radiation pattern over Jakhau for each month. The global solar radiation over Jakhau varies from 4.28 kWh/m^2/Day in the month of December-January to 6.87 kWh/m^2/Day in the months of April and May. Simultaneously the diffuse solar radiation varies from 0.95 kWh/m^2/Day in the month of December-January to 2.45 kWh/m^2/Day during July-August.

As the solar panels are placed on inclined surface (at the latitude of the location); hence the daily global solar radiation over the latitude has been determined for Jakhau and obtained as 6.5 percent that that of horizontal surface. It is maximum in month of April (i.e.6.78 kWh/m^2/Day) and minimum during December month (i.e. 5.96 kWh/m^2/Day).

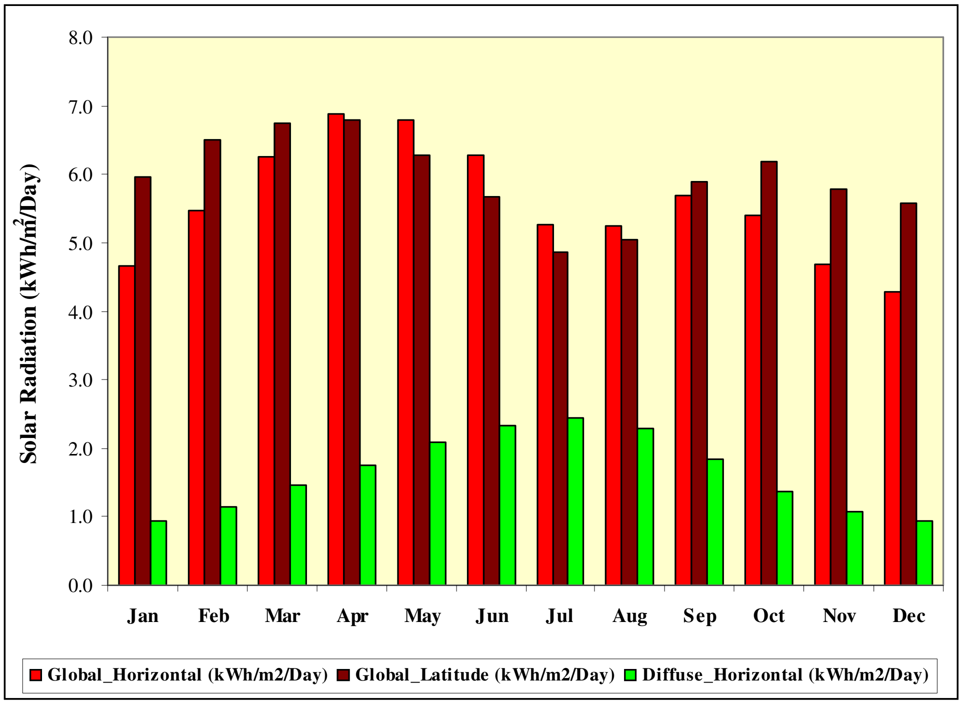


Figure 2.4 Solar Radiation pattern of Jakhau

The annual solar radiation pattern of Jakhau is presented in Figure 2.5. It has been estimated that the location receives 2033 kWh/m² annual global solar radiation on horizontal surface; while 2166 kWh/m² on inclined surface annually. As a part of the analysis the Direct Normal Incidence (DNI)[1] has also been carried out and it has been estimated that Jakhau receives 2320 kWh/m² DNI annually.

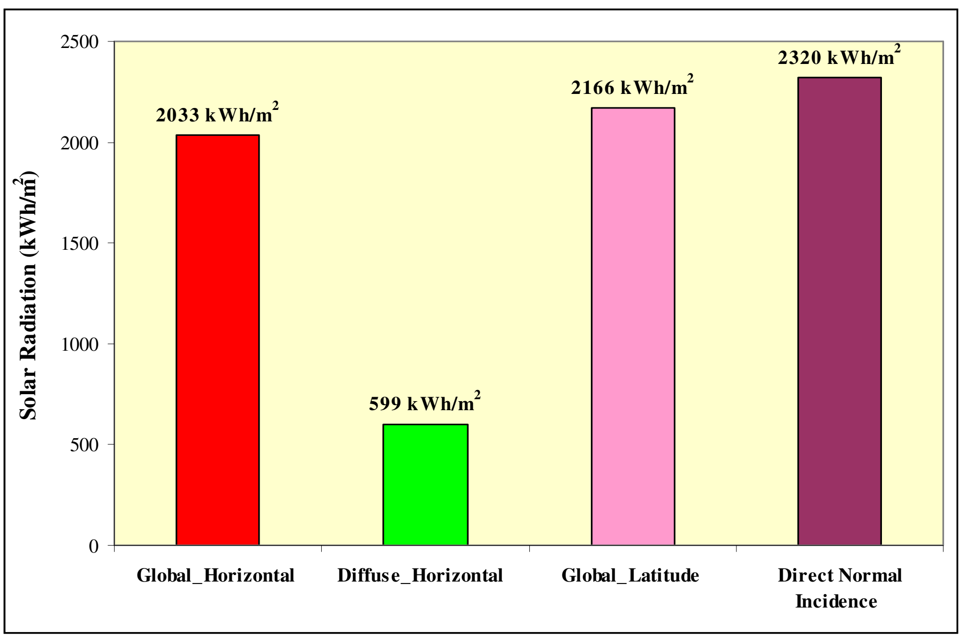


Figure 2.5 Annual solar radiation over Jakhau

[1] DNI is input for concentrating Photovoltaic (CPV) technologies; which comprises two-axis tracking mechanism.

Table 2.1 presents the values of solar global, diffuse and direct solar radiation over Jakhau for one representative day of each month. The monthly values of global, diffuse and direct solar radiation over Jakhau has been presented in Table 2.2; which also includes the monthly total values of DNI.

It has been estimated that the annual global solar radiation availability over Jakhau is 2033 kWh/m²; direct 1434 kWh/m² and diffuse 599 kWh/m² on horizontal surface. On the inclined surface (tilt is equal to latitude of the location) the annual global solar radiation is received as 2166 kWh/m². The annual daily total beam solar radiation over a two axis tracking surface has been estimated to be 2320 kWh/m².

Table 2.1 Monthly average daily values (kWh/m²) of beam solar radiation for Jakhau under horizontal, inclined and two-axis tracking condition

Months	Global Solar Radiation, (kWh/m² Day)	Diffuse Solar Radiation, (kWh/m² Day)	Direct Solar Radiation, (kWh/m² Day)	Global Solar Radiation, on Inclined Surface (kWh/m² Day)	Direct Normal Incidence (kWh/m² Day)
Jan	4.65	0.95	3.70	5.96	7.17
Feb	5.47	1.14	4.33	6.50	7.51
Mar	6.25	1.46	4.79	6.75	7.48
Apr	6.87	1.75	5.12	6.78	7.48
May	6.78	2.09	4.69	6.28	6.72
Jun	6.27	2.33	3.94	5.66	5.65
Jul	5.26	2.45	2.81	4.85	4.02
Aug	5.24	2.29	2.95	5.04	4.26
Sep	5.70	1.83	3.87	5.90	5.85
Oct	5.41	1.36	4.05	6.18	6.75
Nov	4.69	1.07	3.62	5.79	6.81
Dec	4.28	0.94	3.34	5.59	6.71

Table 2.2 Monthly total values (kWh/m²) of solar radiation for Jakhau under horizontal, inclined and two axis tracking condition

Months	Global Solar Radiation, (kWh/m² Day)	Diffuse Solar Radiation, (kWh/m² Day)	Direct Solar Radiation, (kWh/m² Day)	Global Solar Radiation, on Inclined Surface (kWh/m² Day)	Direct Normal Incidence (kWh/m² Day)
Jan	144.2	29.5	114.7	184.8	222.3
Feb	153.2	31.9	121.2	181.9	210.3
Mar	193.8	45.3	148.5	209.3	231.9
Apr	206.1	52.5	153.6	203.4	224.4
May	210.2	64.8	145.4	194.5	208.3
Jun	188.1	69.9	118.2	169.9	169.5
Jul	163.1	76.0	87.1	150.5	124.6
Aug	162.4	71.0	91.5	156.3	132.1
Sep	171.0	54.9	116.1	176.9	175.5
Oct	167.7	42.2	125.6	191.6	209.3
Nov	140.7	32.1	108.6	173.8	204.3
Dec	132.7	29.1	103.5	173.2	208.0
Total	**2033**	**599**	**1434**	**2166**	**2320**

Solar PV system

A PV system essentially consists of modules (array of solar cells generating the electricity) and a balance of system (BoS) including the cabling, battery, charge controller and DC/AC inverter, as well as other components and support.

Most of the systems are in flat-plate (having a fixed orientation) variety but these might be use sun-tracking (single or double axis) concentrators in order to achieve high radiation on a small area and hence higher efficiency.

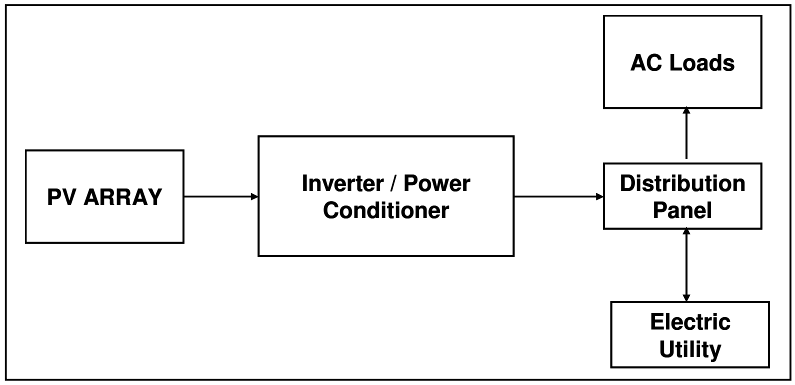


Figure 2.6 Schematic of grid-connected photovoltaic system

Solar PV module is the smallest PV unit that can be used to generate substantial amounts of PV power. Although individual PV cells produce only small amounts of electricity, PV modules are manufactured with varying electrical outputs ranging from a few watts to more than 100 watts of direct current (DC) electricity. The modules can be connected into PV arrays for powering a wide variety of electrical equipment. The system components of SPV Water Pumping System are:

- PV Array
- Battery Bank
- Interface Electronics
- Connecting Cables & Switches
- Support Structure & Tracking System
- Charge Controller Unit
- Electrical loads, such as fans, lights, TV, etc.

In every configuration all these components are not used. Components used depend upon the type of configuration, which in other way depend upon the application. For example: Storage battery is not used in case of direct coupled PV system and inverter is not used for DC load.

Solar cell technologies

Solar cells represent the fundamental power conversion unit of a photovoltaic system, which has much in common with other solid-state electronic devices, such as diodes, transistors and integrated circuits. For practical operation, solar cells are usually assembled into modules. Its operation is based on the ability of semiconductors to convert sunlight directly into electricity by exploiting the photovoltaic effect. In the conversion process, the incident energy of light creates mobile charged particles in the semiconductor, which are then separated by the device structure and produce electricity. Based on the different technologies and materials, the solar cell technology has been grouped in four different generations.

The first generation solar cells are of large area, single-crystal, single layer p-n junction diode, capable to generate usable electricity from light sources with the wavelengths of sunlight. These are typically made using diffusion process with silicon wafers. The silicon wafer-based solar cells are the dominant technology towards commercial production of solar cells accounting for more than 85% of the terrestrial solar cell market.

The second generation photovoltaic cells are based on the use of thin epitaxial deposits of semiconductors on lattice-matched wafers. Epitaxial photovoltaics are of two types namely space and terrestrial. The space cells typically have higher efficiencies (28-30%) in production, but have a higher cost per watt. Their "thin-film" cousins have been developed using lower-cost processes, but have lower efficiencies (7-9%) in production.

There are currently a number of technologies/semiconductor materials under investigation or in mass production mainly amorphous silicon, polycrystalline silicon, micro-crystalline silicon, cadmium telluride, copper indium selenide or sulfide. An advantage of thin-film technology theoretically results in reduced mass so it allows fitting panels on light or flexible materials, even on textiles. Second generation solar cells now comprise a small segment of the terrestrial photovoltaic market, and approximately 90% of the space market.

The third-generation photovoltaic cells are proposed to be very different from the previous semiconductor devices as they do not rely on a traditional p-n junction to separate photo-generated charge carriers. For space applications quantum well devices (quantum dots, quantum ropes, etc.) and devices incorporating carbon nanotubes are being studied - with a potential up to 45% AM0 production efficiency.

The efficiency of basic solar cell unit has further been increased to 42.8% using an altogether novel concept. The credit goes to a group of scientists under the leadership of University of Delaware, USA. The cells achieve this by splitting the incoming light into high, low and medium energy chunks. The light is then directed to different state of the art devices optimized to respective chunks of radiation leading to higher efficiency. The concept is yet to be commercialised.

The fourth generation of photovoltaic cells are the hypothetical generation of solar cells; which may consist of composite photovoltaic technology, in which polymers with nano-particles can be mixed together to make a single multi-spectrum layer. The multi-spectrum layers can be stacked to make multi-spectrum solar cells more efficient and cheaper.

The last two generations of solar cells are still at research and development stage. It will take some more years to understand the underlying science and technology to bring them to commercial level. For terrestrial applications, these new devices include photo electrochemical cells, polymer solar cells, nano-crystal solar cells, dye-sensitized solar cells and are still in the research phase. Dye-sensitized solar cells, which are cheaper than silicon cells, consist of dye-coated titanium dioxide nano-particles immersed in an electrolyte solution, which is sandwiched between glass plates. These solar cells consist of titanium oxide nano-crystals that are coated with light-absorbing dye molecules and immersed in an electrolyte solution, which is sandwiched between two glass plates or embedded in plastic.

The first two generations of solar cells are commercialised. The efficiency of crystalline silicon modules varies from 17-22%, though theoretical limit is around 29%. Efficiency of a solar cell depends on its ability to absorb solar radiation. Larger the fraction of solar radiation it absorbs, larger will be its efficiency and larger power it will generate. Taking this into account, multi-junction solar cells have been fabricated. The efficiency of triple junction, state of the art solar cell of 40.7% has been recorded by Spectrolab, USA. The R&D work to improve efficiency further is going on by using 4, 5 or 6 junction solar cells. Using these high efficiency solar cells and focusing solar light to 500X, high efficiency solar concentrator has been devised to give electrical power of few KWp, enough to light up a household of small family. The use of light reflector have reduced the actual device size of the device, thus reducing the usage and price of much costlier semiconductor materials.

Classification of solar cell technologies

Depending upon the type of absorbing material used, manufacturing technique / process adopted, and type of junction formed etc., the solar cell technologies can be broadly classified as following.

- Wafer based crystalline silicon solar cells
- Thin-film solar cells, which includes, Copper Indium Gallium Diselenide (CIGS), Cadmium Telluride, Amorphous silicon (a-Si) etc.
- Emerging technologies such as thin-film silicon, dye sensitized solar cells; polymer organic solar cells etc.

Figure 2.7 represents the classification of solar cell technologies along with their market share.

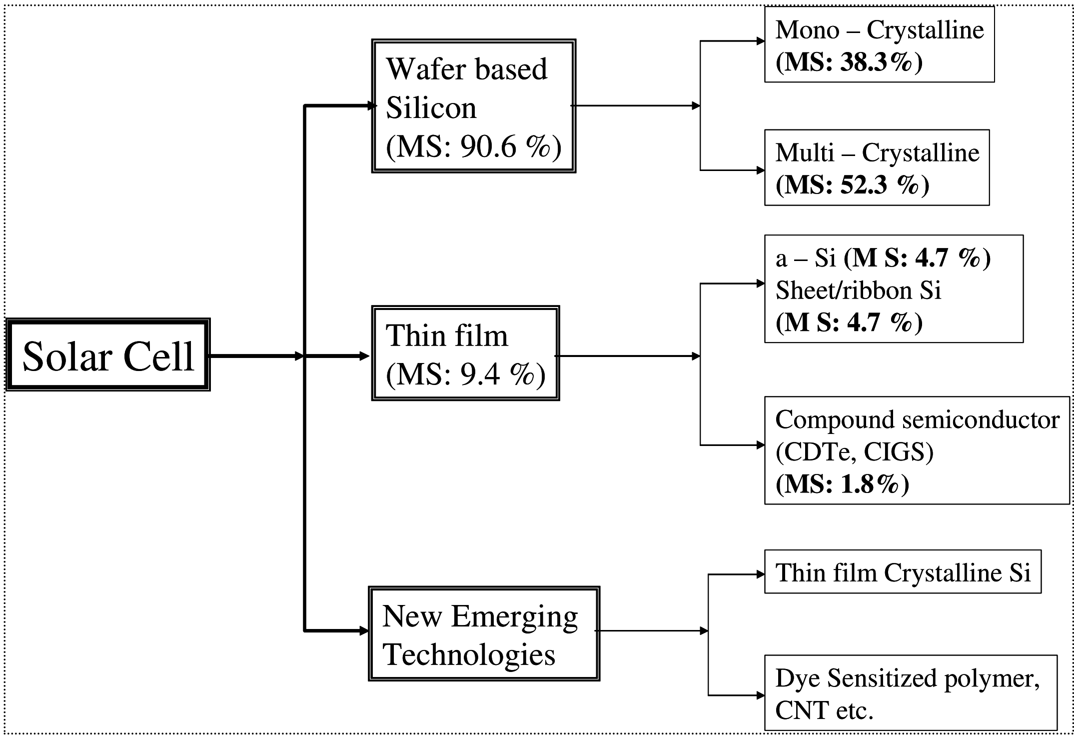


Figure 2.7 Classification of various solar cell technologies

Wafer-based crystalline silicon solar cell technology

The technology used to make most of the solar cells, fabricated so far, borrows heavily from the microelectronics industry; which is further classified into two categories as;

a) Single-/ Mono-crystalline silicon solar cell and
b) Polycrystalline silicon solar cell

Single/mono-crystalline silicon solar cell

This is the most established and efficient solar cell technologies till date, which have the module efficiency of 15-18%. The cell and module fabrication technology is well developed and reliable. These cells are manufactured from single silicon crystal, by process called Czochralski process. During the manufacturing, c-Si crystals are cut from cylindrical ingots, they do not completely cover a square solar cell module.

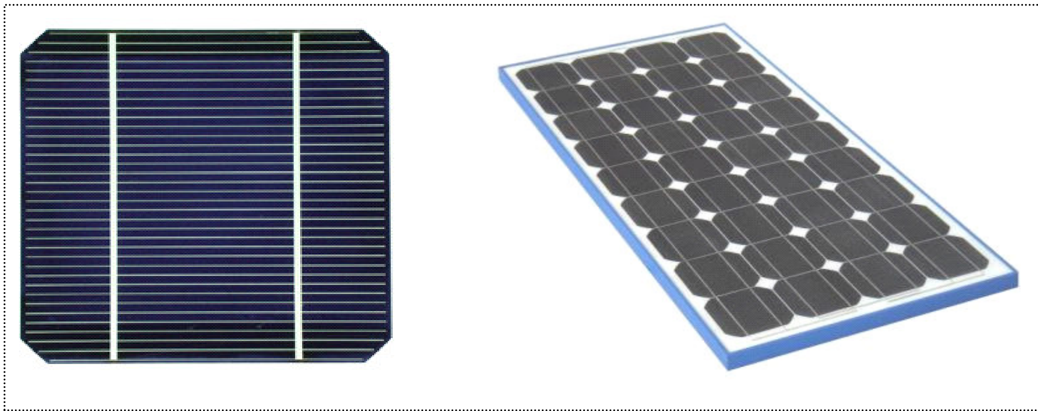


Figure 2.8 Mono-crystalline silicon solar cell and module

Polycrystalline silicon solar cell (poly-Si or mc-Si)

The production of polycrystalline cells is more cost-efficient which are manufactured by cooling a graphite mold filled with molten silicon. In this process, liquid silicon is poured into blocks that are subsequently sawed into plates. During solidification of the material, crystal structures of varying sizes are formed, at whose borders defects emerge. These cells have module efficiency of around 12-14%.

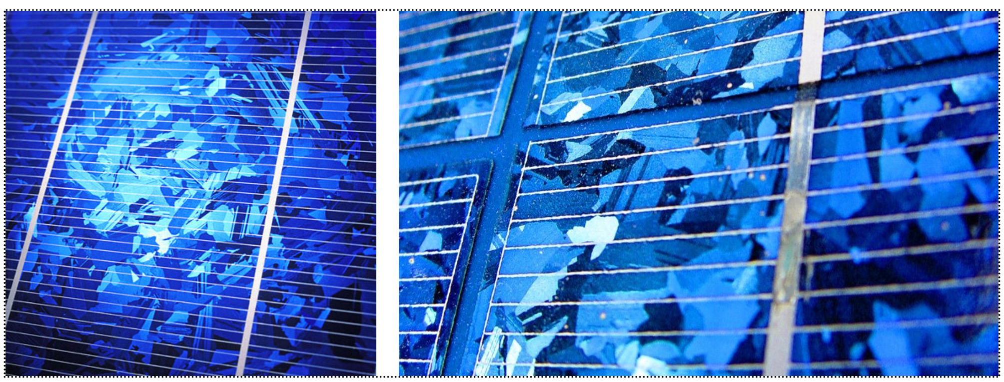


Figure 2.9 Polycrystalline silicon solar cell and module

Thin film solar cell technology

In this approach thin layers of semiconductor material are deposited onto a supporting substrate, such as a large sheet of glass. Typically, less than a micron thickness of semiconductor material is required, 100-1000 times less than the thickness of Silicon wafer. Some of the thin film solar cells in use are as follows;

- a – Si
- CdTe
- CIS, CIGS (copper indium gallium di-selenide)
- Thin film crystalline silicon

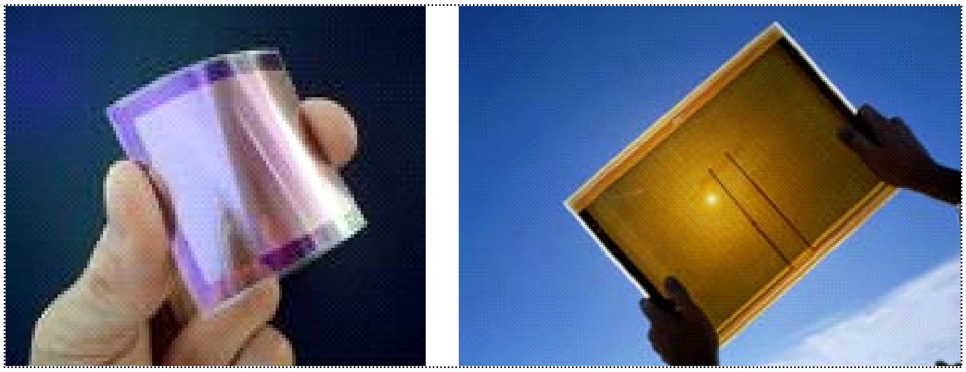


Figure 2.10 Thin film solar cell and module

Amorphous silicon thin film (a-Si) solar cell

Amorphous Silicon (a-Si) modules are the first thin film solar module to be commercially produced and at present has the maximum market share out of all thin film solar cell technologies.

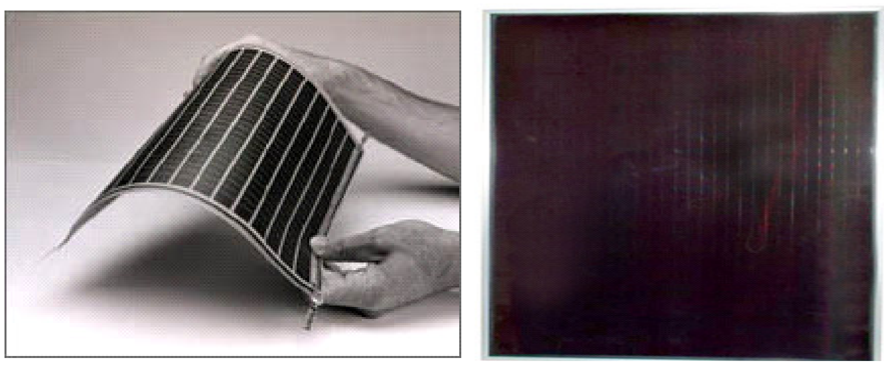


Figure 2.11 Amorphous Silicon (a-Si) solar cell and Module

Amorphous Silicon (a-Si) solar can be fabricated at a lower deposition temperature hence permits the use of various low cost flexible substrates by easier processing technique. The major concern of a-Si solar cells is their low stabilized efficiency. The overall efficiency drops inevitably at module level and at present the efficiencies of commercial modules are in the range of 4-8%.

Cadmium telluride (CdTe) thin film solar cell

Being a crystalline compound Cadmium Telluride is a direct bandgap semiconductor, which is a strong solar cell material. It is usually sandwiched with cadmium sulfide to form a pn junction PV solar cell. CdTe with laboratory efficiency as high as 16% have been developed at NREL.

Figure 2.12 Cadmium telluride (CdTe) thin film solar cell

Multitudes of manufacturing techniques are main advantage of these solar cells which are suitable for large scale production. Limited availability of cadmium and pollution problem associated with Cadmium is main concerns with this technology.

Copper Indium Gallium Diselenide (CIGS) solar cells

This is a new semiconductor material comprising copper, indium, gallium and selenium in a specific order, which is used for solar cell manufacturing. It is one of the most promising thin film technologies due to their high-attained efficiency and low material costs. Amongst thin film solar cells, the advantage of CIGS solar cell is its extended operational lifetime without significant degradation. The inherent properties of CIGS also provide an opportunity for maximizing the efficiency.

Figure 2.13 Copper Indium Gallium Diselenide (CIGS) Solar Cells

Solar cell of materials other then Silicon (viz. CIGS, CdTe etc.) has negligible share in the world market, which implies that, those solar cells are not found to be feasible even at the time of shortage of silicon feedstock. Table 2.3 represents that comparison of various PV commercialised technologies' module efficiencies determined by system area.

Table 2.3 Solar PV Module Efficiency and Forecast (% DC efficiencies for production modules)

Solar Cell Technology	2006	2010	2015
Crystalline Silicon			
Monocrystalline Silicon	14-19	16-22	22-25
Multi-crystalline Silicon Cast Ingot	13-17	16-18	>20
Crystalline-based Silicon			
a-Si/ Mono-crystalline slice (HIT)	16-18	18-20	22-24
Concentrators silicon Cells	24/36	26/37	28/38
Non-Crystalline Silicon			
Amorphous Silicon (a-Si)	6-8	9-10	12
Silicon Film	10	14	16
Non-Silicon			
Copper Indium (G) Diselenide (CIS/CIGS)	8-11	10-12	14
Cadmium Telluride (CdTe)	9-10	11	12

Concentrating solar photovoltaic

CPV systems employ solar radiation concentrated onto photovoltaic surfaces for electricity production. Solar concentrators of all varieties may be used, and these are often mounted on a solar tracker in order to keep the focal point upon the cell as the Sun moves across the sky. Additionally, increasing the concentration ratio improves the performance of general photovoltaic materials. There are four types of CPV technologies;

- Dish CPV
- Lens CPV
- Low concentration CPV and
- Non-Tracking CPV

Dish CPV

The parabolic dishes are now being coupled with photovoltaics in dish CPV systems. Dish CPV systems are available in a range of sizes and configurations from large systems that resemble Dish-Engines with the engines replaced with a CPV receiver to several small dishes combined together in a tracking panel. Dish concentrators coupled with PV to form Dish CPV systems are taking shape in three main forms namely –

- ***Large Dish* CPV*:*** These are essentially Dish-Engine systems with the engine replaced with a PV receiver. These are systems are stand-alone systems consisting of a 2-axis tracking dish and a CPV receiver
- **Medium *Dish CPV:*** These systems are typically made up of sets of dish-PV assemblies that track in unison. Medium sized dishes have lower wind exposure than large dishes,

reducing the wind loading and strain on the tracking systems.

- ***Small Dish CPV:*** These systems consist of several small dishes with small PV receiver placed together in a panel that tracks as a panel. Small Dishes are also being used to focus sunlight onto very small areas of PV material. Small Dish CPV systems consisting of a very small dish, a secondary reflector, and a PV receiver are assembled together in a panel that tracks the sun.

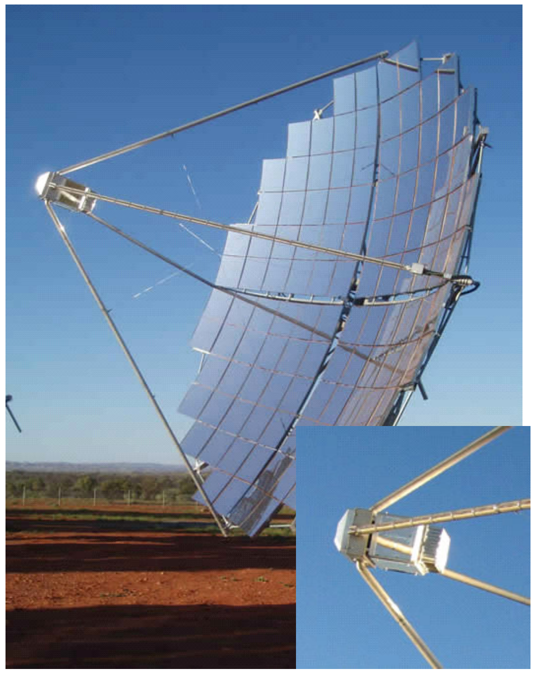


Figure 2.14 Large parabolic dish CPV

Lens CPV

Lens CPV technology is most popular CPV technology among the entrepreneurial community, with several start-ups springing up with various solutions for products that promise lower costs than standard PV. The technology comprises full tracking panels of lens-CPV assemblies, and arrays of individually tracking facets.

Lens CPV modules with individually tracking facets have a lower profi le than Lens CPV tracking panels as the panel is mounted fl at and only the small assemblies track. This results in many moving parts and high potential for mechanical failure and high O&M costs. The tight packing of the facets within one panel can also lead to shading between the facets as they track the sun.

Figure 2.15 Lens CPV

Low concentration PV (LCPV)

LCPV is the most accessible and available CPV technology presently which applies simple flat reflective surfaces to reflect light onto conventional solar panels. While these systems do require tracking, they can tolerate only single-axis tracking, and they do not require the accuracy that higher concentration CPV/CST technologies. Different configurations of LCPV systems have been developed or commercially deployed, but all are based on the same basic principle of combining low-cost and low-precision reflectors and trackers with a PV panel to increase its performance.

Figure 2.16 Low concentration CPV

Non-tacking CPV

This technology is an approach to developing a product with a lower cost than conventional PV is to develop a CPV panel that looks and acts almost exactly like a conventional PV panel, but contains a third to half of the PV used in a conventional PV panel. Non-Tracking CPV technologies use a variety of internal optical devices that can accept light at a range of angles and direct it toward a small amount of PV. NTCPV offer promising market application as they can be installed and operated like conventional PV panels, with low O&M costs, with a fraction of the PV material used to create PV panels. Furthermore, because these technologies accept light at a range of angles, they are not limited to DNI, but can take advantage of a greater range of the solar resource.

A comparative matrix of CSP and SPV technology is presented in Table 2.4.

Table 2.4 Technology matrix of conventional SPV and CPV technologies

CSP Technology Type	System	Concentration Technology	Power Conversion	Concentration Ratio	Tracking Required	Insolation required	Footprint (Acres/ MW)	Status of Commercialization
Conventional Photovoltaic	Mono-crystalline	Not used	Silicon	1	Stationary	Global	6	Commercialized
	Poly-crystalline	Not used	Silicon	1	Stationary	Global	7	Commercialized
	Thin Film	Not used	a-Si, CIS, CdTe, CIGS	1	Stationary	Global	8	Commercialized
Concentrating Solar Photovoltaic	Dish CPV	Parabolic dish	Multi-Junction or Silicon PV	500-1500	Double-axis	Direct Normal Incidence	8.0	Prototype/ commercial
	Lens CPV	Lens or Fresnel Lenses	Multi-Junction PV	500-1000	Single /Double-axis	Direct Normal Incidence	8.0	Prototype/ commercial
	LCPV	Low concentration reflectors	Silicon PV	1.5 – 3.0	Single /Double-axis	Global	11.0	Commercial
	Non-Tracking CPV	Non-tracking concentrators	Multi-Junction or Silicon PV	> 2	Stationary	Global	NA	Early manufacturing

Estimation of Utilizable area for SPV projects at ONGC site Jakhau: Shade Analysis

The solar PV based projects comprises complete shadow free area for installation. The feasibility of solar PV projects depends mainly on the following parameters;

- Annual solar radiation availability
- Climatic parameters
- Technological advancements
- Land availability and
- Power evacuation facility

It is clear from above section(s) that Jakhau location receives good amount of global solar radiation through out the year. Simultaneously the climatic parameters are also favourable for installation of SPV projects. In addition well mature and established SPV technologies of high efficiency are commercially available in Indian market. Further the ONGC wind farm at Jakhau already has the power evacuation facility. Hence only estimation of utilizable land is the essential dimension towards execution of SPV projects in the wind farm.

In order to estimate the utilizable land area for SPV projects at Jakhau, Gujarat following considerations have been made;

- Foot prints of existing 35-wind turbines (Model S-82)
- Area covered by roads (village)
- Area covered by the connecting road
- Building and
- Existing Water bodies in the wind farm

The foot prints of the wind turbines are seems most effective as compared with other assumptions. Hence a simulation program has been developed for a single S-82 wind turbine in order to asses its shading patter using ECOTECH and Goggle-Sketch computer software. The technological specifications of the wind generator (S-82) have been taken from the supplier; which indicates that the hub height of the wind energy generator is 82 m, rotor diameter is 40 m and bottom diameter is 8 m.

From solar geometry it is clear that the minimum and extreme shading of any obstacle is on 21 June and 21 December due to variation of solar declination angle which is respectively $+23.45^{o}$ and -23.45^{o} for above days. In addition the geography (latitude and longitude) of the place plays an important role towards shading. Taking in to account the extremes days and geographical parameters the shading pattern of respective wind energy generator is estimated during the sun shine hours (9:00 am to 4:00 pm) of these days. Figure 2.1 presents the shading pattern of a representative S-82 wind energy generator on 21-December over the day. Simultaneously similar pattern for 21-June is also presented in Figure 2.2 (8:00 am to 6: pm)[1].

[1] The daylength at any location is governed by the declination angle. When declination is negative the daylength is smaller than when it is positive.

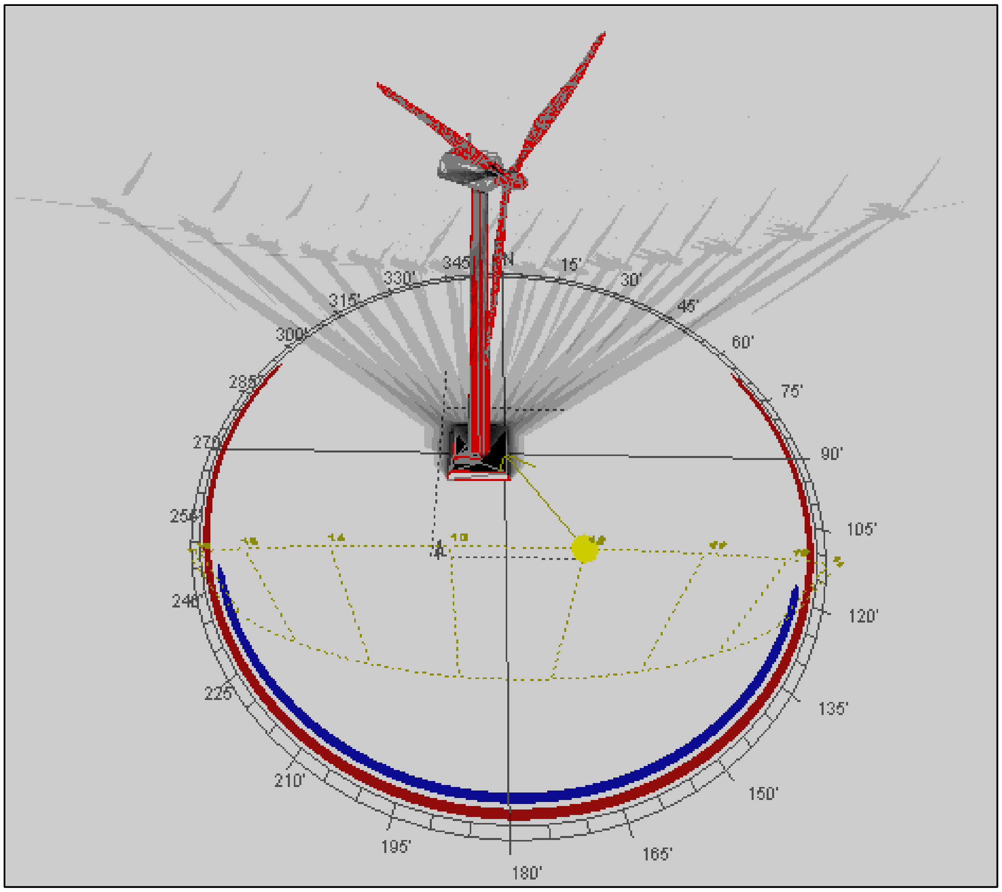


Figure 2.17 Shading pattern of S-82 wind turbine at Jakhau on 21-December

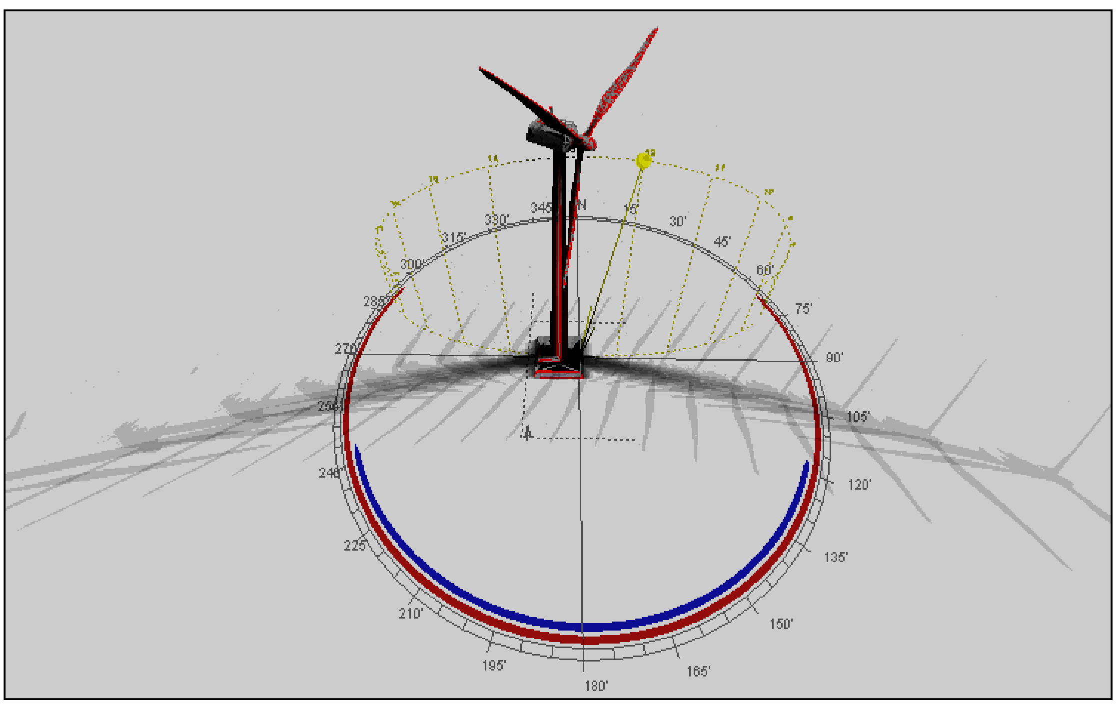


Figure 2.18 Shading pattern of S-82 wind turbine at Jakhau on 21-June

As the solar PV projects complete shade free area hence an approach has been adopted that subtract the complete shading area of the wind energy generator throughout the area. The shading of the WEG-S82 except the 21-June and 21-December lies with in the ranges of these days. Figure 2.19 presents the shading pattern of the WEG-S82 on horizontal surface. The area of shading contour of a typical WEG-S82 has been determined as 40757.6 m².

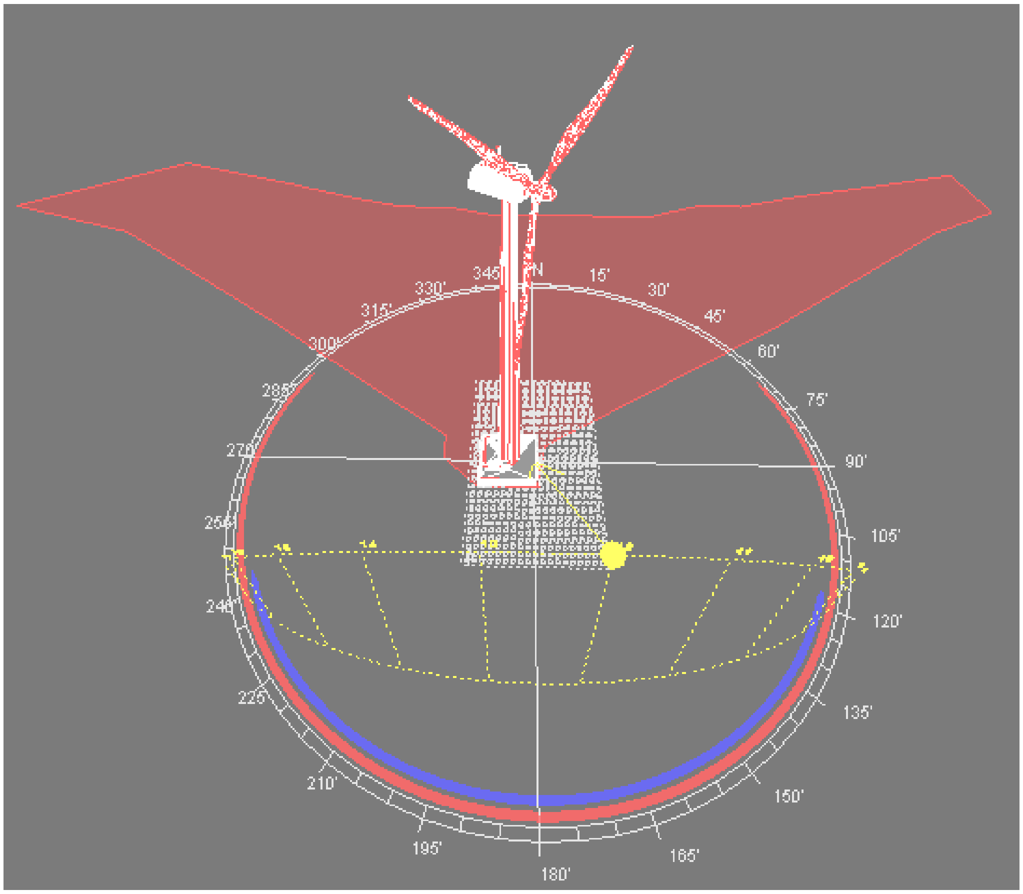


Figure 2.19 Shading contour of S-82 wind turbine at Jakhau on 21-December

Similarly Figure 2.20 presents the shading of a typical WEG-S82 over the day on 21-June. As explained above the shading is the least on this day. The shading area has been determined as 25798 m² at Jakhau.

The combine shading pattern of the WEG-S82 is presented in Figure 2.21; which indicates that the overall area of shading is 64927.6 m². Hence in order to explore the potential of installation of solar PV power plants in the existing wind farm the shading area of all wind energy generators will be subtract from the overall area. In fact the average shading pattern of all WEG-S82 will be symmetrical. The details of shading analysis are presented in Annexure-VI.

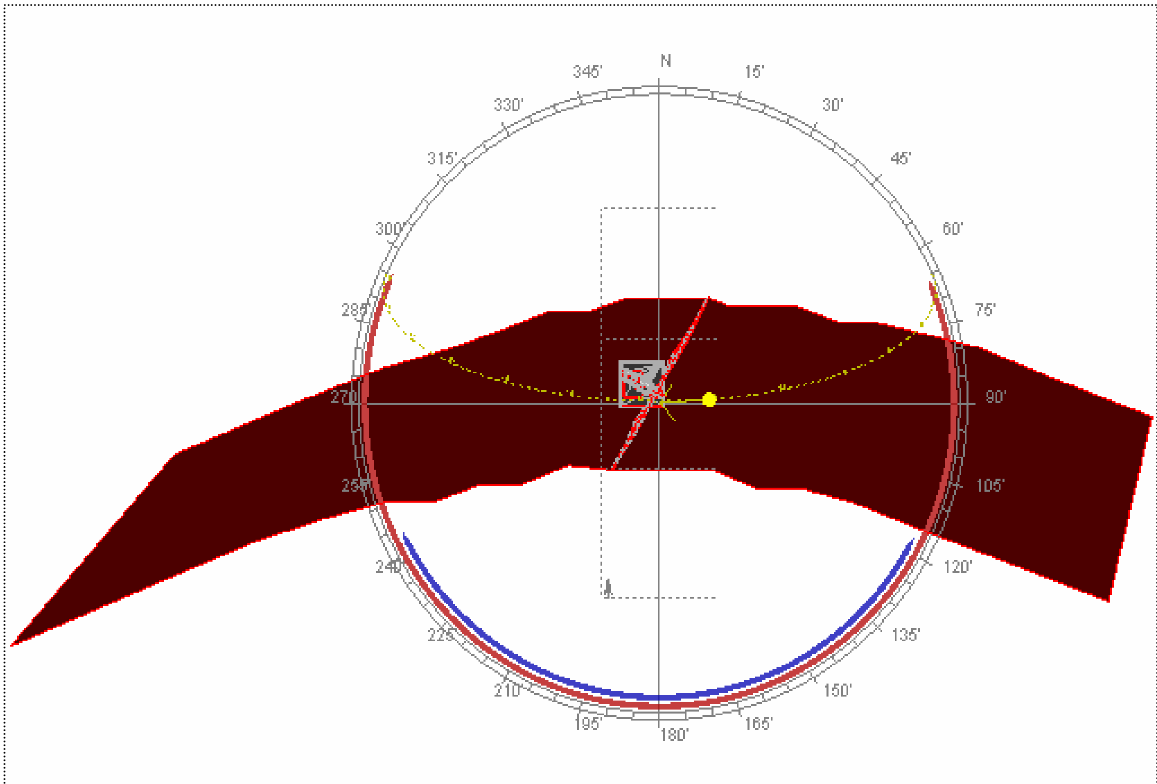


Figure 2.20 Shading contoor of S-82 wind turbine at Jakhau on 21-December

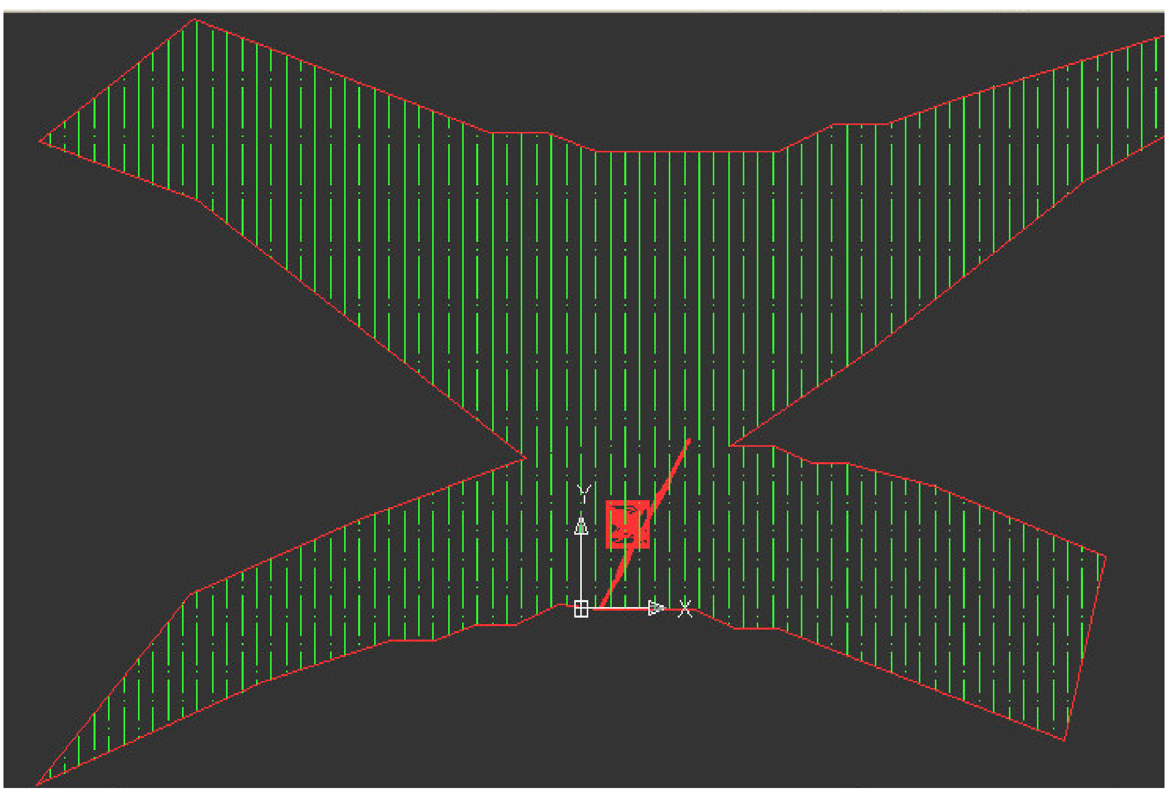


Figure 2.21 The combined shading pattern of S-82 wind energy generator at Jakhau on 21-June and 21-December

Potential of SPV power plants at ONGC wind farm, Jakhau

In order to estimate overall land availability the standard practices of installing the WEG has been considered. Table 2.5 presents the observations has been carried out from the analysis.

Table 2.5 Feasibility of solar PV power plants at ONGC wind farm at Jakhau

Total Land Availability at wind farm	(app.) 1964 acres (7945800 m^2)
Footprint of WEG (S-82)	2.47 acres (9996 m^2)
Gross area of WEG (S-82)	57.7 acres (233700 m^2)
Shaded area of WEG (S-82)	16.04 acres(68928 m^2)
Total shaded area at wind farm	545.4 acres (2207138 m^2)
Area for roads, control, etc	490 acres (25% of the land)
Utilizable/Effective area for SPV	928 acres (3755454 m^2)

Hence from the shading analysis and standard methodology of area determination it has been determined that 928 acres land area is available at the wind farm which can effectively be use for installation of solar PV based power plants.

Taking in to account the area required for setting up a mono-crystalline solar cell SPV based power plant (5 acres/MW), it has been determined that there is a potential of setting up solar PV based project(s) of 186 MW.

In order to check the technological feasibility of solar PV based power plant(s) of 186 MW capacity a computer program has been developed in RETScreen software.

Taking the climatic (ambient temperature), operating and technical parameters from the above analysis, it has been observed that a SPV based solar power plant of the capacity of 186 MW will generate approximately **300,000** MWh electricity annually. The technological feasibility of 186 MW solar PV based power project(s) has been given in Table 2.6. The details (sample calculation for 1 ME SPV power plant on mono-crystalline solar cells) of the simulation program of RETScreen are given in Annex VII.

Table 2.6 Technical Feasibility of solar PV power plants at ONGC wind farm at Jakhau

Annual Average Solar Radiation	2033 kWh/m^2
Annual average solar radiation (latitude)	2166 kWh/m^2
Annual Average Ambient Temperature	26.64^{o}C
Annual Average Relative Humidity	56.2 %
Potential of SPV power plants at Site (5 acres/MW)	186 MW
Annual Electrical Output (mono-crystalline)	300,000 MWh
Approximate cost (per MW)	15-17 crores/MW

ANNEX I Guidelines for scheme on Generation Based Incentives (GBI) for Grid Interactive Wind Power Projects issued on 16 Dec 2009

The following are the broad guidelines for submission of proposals by the interested project developers, details of incentives and other related guidelines.

1. Objectives:

(i) To broaden the investor base and create a level playing field between various classes of investors.

(ii) To incentivise higher efficiencies with the help of a generation/outcome based incentive.

(iii) To facilitate entry of large independent power producers and foreign direct investors to the wind power sector.

2. Incentive and Duration:

2.1 Under the scheme, a GBI will be provided to wind electricity producers @ Rs. 0.50 per unit of electricity fed into the grid for a period not less than 4 years and a maximum period of 10 years in parallel with accelerated depreciation on a mutually exclusive manner, with a cap of Rs. 62 lakhs per MW. The total disbursement in a year will not exceed one fourth of the maximum limit of the incentive i.e. Rs.15.50 lakhs per MW during the first four years. The scheme will be applicable to a maximum capacity limited to 4000 MW during the remaining period of 11th Plan period. The provision of GBI will continue till the end of 11th Plan period. However, provision of accelerated depreciation in parallel with GBI will continue till the 11th Plan period or introduction of Direct Tax Code, whichever is earlier.

2.2 Detailed Guidelines for implementation arrangements will be issued shortly. GBI would be available for wind turbines commissioned after the issue of this scheme and commissioned on or before 31.3.2012 and would be governed by the Guidelines.

3. Eligibility:

3.1 The GBI scheme would be implemented in parallel with existing fiscal incentive including that of accelerated depreciation, for grid connected wind power projects in a mutually exclusive manner, so that companies can avail either accelerated depreciation or GBI, but not both. Once a Company has opted for one benefit, it cannot change the option later. As GBI promotes higher generation, it is intended that the first claim of beneficiary should be on GBI.

3.2 In case of a company which amalgamates, changes its form or name or transfer assets to another company, the GBI may be released only when the claimant produces a proof that it has intimated the concerned Commissioner of Income Tax of the changed position of ownership and henceforth, the new company will not claim the benefit of accelerated depreciation.
3.3 The GBI will cover grid connected generation from wind power projects set up for sale of electricity to grid at a tariff fixed by SERC and/or State Govt. and also include captive wind power projects, but exclude third party sale, (viz. merchant power plants).

4. Implementation Arrangements:
4.1 The GBI would be implemented through Indian Renewable Energy Development Agency (IREDA). IREDA will also assist the Ministry in organizing business meets, awareness programmes and other related activities, as considered necessary for promotion of the scheme.
4.2 The funds provided in the budget of MNRE will be released upfront as advance to IREDA to ensure timely release and flow of funds to the projects. The existing system followed by various state utilities for data collection/metering and billing on the generation of electricity for the purpose of payment to the power producers with modification, if any as deemed necessary, would be followed as the basis for disbursal of the amount due to the power producer for the new turbine(s) to be set up under the GBI.
4.3 All the wind power producers (whether availing AD or GBI) will be required to register with IREDA. IREDA will give an acknowledgement of the registration, which would become a part of the documents required for claiming the AD. An instruction to this effect will be issued by the Department of Revenue shortly. Through this registration mechanism, the turbine owners will provide the required details of the machines including generation data to the IREDA.
4.4 As the GBI scheme would be applicable only for those wind power producers who do not avail the accelerated depreciation benefit under the Income Tax Act, investors would be required to furnish documentary proof to this effect that no accelerated depreciation has been availed. Apart from other required documents for disbursement, the company will also submit a copy of their Tax returns duly certified by the same Chartered Accountant who conducted statuary audit under section 44AB of Income Tax Act that no accelerated depreciation has been claimed. IREDA will build safeguards into the implementation /disbursal process of the scheme to avoid the misuse of the GBI incentive.
4.5 The IREDA would disburse the GI to the developers through their designated bank account periodically through e-payment.

4.6 This incentive is over and above the tariff that may be approved by the State Electricity Regulatory Commissions in various States. In other words, this incentive that is sanctioned by the Union Government to enhance the availability of power to the grid will not be taken into account while fixing tariff by State Regulators.

4.7 The mechanism of Unique Identification (UI) number developed by IREDA will have to be followed by all the wind power developers to claim the GBI. This will also be used to monitor the performance of the projects including those availing AD, in respect of quantity of electricity fed to the grid and comparative performance etc.

4.8 IREDA would provide feedback to the Ministry regarding implementation of the scheme and would suggest modification to make the implementation more effective. The Ministry will also obtain feedback from other stakeholders in regular intervals and take steps to modify the modalities of implementation, if required.

5.0 Financial Outlay

The financial liability during the 11th Plan is estimated to be Rs.380 crore, which would be met by the Ministry from its existing Plan allocation.

6. Evaluation of the Scheme:

6.1 The GBI would be evaluated during the last year of the 11th Plan and if the response of the GBI exceeds the expectations, further up-scaling would be considered based on the evaluation.

7.0 This issues with exercise of delegated powers of the Ministry and with the IFD's concurrence dated 11.12.2009 vide their diary no. IFD-1536/2009.

ANNEX II Technical evaluation of wind turbines

The Turbine related parameters, which can be analyzed, are of two types, namely (i) those related to the experience of the offered turbine in India, its certification etc. and (ii) those related to salient features (electrical/ mechanical/safety etc) of the turbine. An evaluation matrix was generated to rate the turbines.

Turbine features

The turbine features, which were included in the evaluation matrix, are explained below.

Turbine size

Turbines with size 500 have been given minimum score of 1 and maximum size 2.1 MW was given score of 1.15. Different capacities in this range ware given score with increment of .005 for every 50kW increase above 500kW. The logic of scoring is based on the fact that there is about 15% reduction in land requirement with increase in size of turbines.

Generator type

The induction generator was give score 1. The synchronous generators have definite advantages like higher energy capture, and easier grid integration. The synchronous generators have about 5% higher energy capture thus were given score 5% higher than that of induction generator

Single speed/ variable speed

The variable speed machines have highest energy capture, about 5%, than the single speed machines and the variable speed turbines were given 5% higher score than singe speed machines. The double speed machines are have better energy capture than that of single speed and thus were given 2.5% higher score.

Geared/gearless

The gearless turbines have highest energy capture, about 2%, thus given higher score by 2% than the geared turbines. This is based on the fact that wind machines, which have synchronous generators, have no gearboxes since they could be designed for high speeds or for low speeds and have continuous variation according to the speed of the wind. These machines have an added advantage over induction machines because it is inherently variable speed and it has been proved that variable speed increases the energy capture and hence more energy could be generated. In this respect it has been found from various methods that there would be increase of 4-18% in energy capture by variable speed than the fixed speed machines.

Reactive power control

The turbines with the dynamically varying control systems were given score of 1.02since these systems have better reactive power control than the mechanically switched control systems. The intelligent switching systems, which basically have time delay with mechanical switching is given intermediate score of 1.01. The turbines with purely mechanical switching were given the lowest score of 1.

Cut in wind speed

The lower cut in wind speed results in higher energy capture, though the amount of energy capture depends on wind resource at the site. Thus the maximum cut in wind speed was given minimum score of 1, and lowest cut in wind speed of 4m/s was given score of 1.02. The other cut in wind speeds were given scores in the range of 1 to 1.02.

Rated wind speed

The rated wind speeds of turbines vary in the range from 11m/s to 17 m/s. The lower rated wind speeds, depending upon the sites and for similar rating of turbines, would lead to higher energy capture. Thus following scores were given to the different rated wind speeds

Rated speed	Score
11 m/s	1.06
12 m/s	1.05
13 m/s	1.04
14 m/s	1.03
15m/s	1.02
16 m/s	1.01
17 m/s	1

Class of turbine

The class of turbines is an indicator of whether the wind turbine is designed to operate in that class of wind regime. The definition of the wind turbine classes is given in IEC safety standards (IEC 61400). A wind turbine class in IEC 61400 is defined by its basic parameter of reference wind speed (Vref). Based on the reference wind speed a wind turbine is designed to withstand climate, for which the extreme ten minute average wind speeds, with a recurrence period of fifty years at a certain hub-height is lower than or equal to reference wind speed (Vref). From the table below, shows various wind turbine class, based on their reference wind speed. Along with the other parameters the class is also defined by the annual average wind speed at the hub height as given in table below.

WTG class	I	II	III	IV
Reference wind speed (Vref) in m/s	50	42.5	37.5	30
Annual avg. wind speed (m/s)	10	8.5	7.5	6

Thus class I turbines were given score of 1.02, followed by class II with score of 1.01 and class III with score of 1.00.

Power regulation

The active pitch/stall has better control on output and was given highest score of 1.02 followed by the pitch control with score 1.01 and stall control with score 1.

Technical feature comparison of turbines

Features/ Turbine manufacturer	Suzlon Energy Limited	Vestas wind Technologies India Pvt Ltd	ReRegen powertech
Capacity (kW)	1500	1650	1500
Score	10.19	10.2075	
Make	Suzlon	Vestas	Regen
Model No.	S.82/1500*	NM-82/1650*	VENSYS 77
Rating in kW	1500	1650	1500
Rotor Diameter (m)	82	82.0	77
Highest hub height (m)	78	78.0	85
Type of tower (Tubular/Lattice)	Tubular	Tubular	Tubular
No. blades	3	3	3
Power regulation (Pitch/Stall)	Pitch	Active Stall	Pitch
Rotor speed (RPM)	16.3	14.4	9-17.3
Type of generator (Synchronous/Asynchronous)	Asynchronous	Asynchronous	Synchronous
Single speed/Dual speed/ Variable speed (Generator)	Single Speed	Single Speed	Variable
AC/DC/AC system (Yes/No)	No	No	Yes
Protection/ insulation class	IP 54 class H	IP 56 class F	IP 23Class F
Rated Voltage	690V	690V	620 V
Geared/Gearless	Geared	Geared	Gearless
Cut-in-wind speed	4 m/s	4 m/s	3 m/s
Cut-out wind speed	20 m/s	20 m/s	22 m/s
Rated wind speed	14 m/s	14 m/s	13 m/s
Survival wind speed	52.5 m/s	52.5 m/s	52.5 m/s

Calculation of Rating of Turbines
1. For S82-1500 kW and S82-2100kW

		Machine	Suzlon S82-1500 kW	
				Score for machine
	Parameter	Defined Score		
Machine size				
	500 kW	1	1500	1.1
	2000 kW	1.15		
Generator type				
	Induction	1	Induction	1
	Synchronous	1.05		
Geared Gearless				
	Gearless	1.02	Geared	1
	Geared	1		
Singe speed/variable speed				
	Single speed	1	Single Speed	1.00
	Double speed	1.02		
	Variable speed	1.05		
Reactive power control				
	Mechanically switched	1	Intelligent	1.01
	Intelligent switching	1.01		
	Dynamically variable	1.02		
Cut in wind speed				
	2	1.05	4 m/s	1
	4	1		
Rated wind speed				
	11	1.06	14 m/s	1.03
	12	1.05		
	13	1.04		
	14	1.03		
	15	1.02		
	16	1.01		
	17	1		
Tower type				
	Lattice	1	tubular	1.01
	Tubular	1.01		
Class of machine				
	Class I	1.02	Class II	1.01
	Class II	1.01		
	Class III	1		
Power regulation				
	Active pitch/Active stall	1.02	pitch	1.01
	Pitch control	1.01		
	Stall	1		
Total score				**10.18**

2. For Vestas82-1650 kW and Regen 77-1500 kW turbines

		Machine	Vestas82-1650 kW		Regen 77-1500 KW	
				Score for machine		Score for machine
	Parameter	Defined Score				
Machine size						
	500 kW	1	1650	1.115	1500	1.1
	2000 kW	1.15				
Generator type						
	Induction	1	Induction	1	Synchronous	1.05
	Synchronous	1.05				
Geared Gearless						
	Gearless	1.02	Geared	1	Gearless	1.02
	Geared	1				
Singe speed/variable speed						
	Single speed	1	Single Speed	1.00	Variable speed	1.05
	Double speed	1.02				
	Variable speed	1.05				
Reactive power control						
	Mechanically switched	1	Intelligent	1.01	Fully controlled	1.02
	Intelligent switching	1.01				
	Dynamically variable	1.02				
Cut in wind speed						
	2	1.05	4 m/s	1	3 m/s	1.025
	4	1				
Rated wind speed						
	11	1.06	14 m/s	1.03	13 m/s	1.04
	12	1.05				
	13	1.04				
	14	1.03				
	15	1.02				
	16	1.01				
	17	1				
Tower type						
	Lattice	1	tubular	1.01	tubular	1.01
	Tubular	1.01				
Class of machine						
	Class I	1.02	Class II	1.01	Class III	1.0
	Class II	1.01				
	Class III	1				
Power regulation						
	Active pitch/Active stall	1.02	Active Stall	1.02	pitch	1.01
	Pitch control	1.01				
	Stall	1				
Total score				**10.195**		**10.325**

ANNEX III Monthly average wind speed, power law index, shape factor and air density for the selected sites

1. Dhank, Gujarat

Month	Monthly mean wind speed (m/s)	Power law index	Monthly average air density (kg/m3)	Shape Factor
Jan	6.55	0.11	1.191	3.4
Feb	6.27	0.12	1.179	2.9
Mar	6.91	0.13	1.159	2.7
Apr	6.74	0.11	1.144	2.5
May	7.63	0.1	1.132	2.6
Jun	8.67	0.03	1.124	2.7
Jul	8.58	0.09	1.131	2.8
Aug	7.68	0.14	1.136	2.6
Sep	6.01	0.12	1.143	2.4
Oct	5.07	0.15	1.148	2.6
Nov	5.60	0.12	1.166	3
Dec	5.77	0.11	1.185	3.7
Annual Avg	**6.79**	**0.11**	**1.153**	**2.3**

2. Jamanvada, Gujarat

Month	Monthly mean wind speed (m/s)	Power law index	Monthly average air density (kg/m3)	Shape Factor
Jan	4.31	0.28	1.205	1.5
Feb	4.09	0.34	1.192	1.2
Mar	4.48	0.35	1.175	2.1
Apr	5.48	0.32	1.161	2.3
May	6.82	0.27	1.149	3.2
Jun	7.31	0.17	1.142	3.8
Jul	6.59	0.18	1.145	2.5
Aug	6.77	0.22	1.151	2.8
Sep	4.76	0.3	1.158	2.1
Oct	3.73	0.3	1.164	2.1
Nov	3.61	0.29	1.181	2.4
Dec	4.12	0.29	1.202	2.3
Annual Avg	**5.17**	**0.26**	**1.169**	**2.2**

3. Surajbari, Gujarat

Month	Monthly mean wind speed (m/s)	Power law index	Monthly average air density (kg/m3)	Shape Factor
Jan	3.64	0.57	1.203	2
Feb	4.00	0.54	1.189	1.7
Mar	4.36	0.44	1.172	1.9
Apr	5.68	0.31	1.155	1.8
May	7.45	0.2	1.14	2.7
Jun	7.91	0.21	1.134	2.8

Month	Monthly mean wind speed (m/s)	Power law index	Monthly average air density (kg/m3)	Shape Factor
Jul	7.76	0.26	1.136	2.6
Aug	6.36	0.29	1.142	2.4
Sep	5.06	0.33	1.148	1.9
Oct	3.56	0.43	1.157	1.3
Nov	3.70	0.64	1.177	2
Dec	3.66	0.66	1.199	1.7
Annual Avg	**5.43**	**0.39**	**1.163**	**1.7**

4. Gude Panchgani, Maharashtra

Month	Monthly mean wind speed (m/s)	Power law index	Monthly average air density (kg/m3)	Shape Factor
Jan	4.16	0.16	1.082	2
Feb	4.03	0.15	1.076	1.9
Mar	4.41	0.15	1.064	2.7
Apr	4.66	0.15	1.058	2.8
May	5.83	0.17	1.058	2.7
Jun	7.10	0.19	1.067	3.4
Jul	8.26	0.21	1.072	3
Aug	7.05	0.2	1.075	3.1
Sep	5.40	0.21	1.074	2
Oct	4.11	0.27	1.073	2.3
Nov	5.44	0.15	1.078	2.2
Dec	5.66	0.12	1.082	2.7
Annual Avg	**5.51**	**0.18**	**1.072**	**2.1**

5. Vankushwade, Maharashtra

Month	Monthly mean wind speed (m/s)	Power law index	Monthly average air density (kg/m3)	Shape Factor
Jan	4.39	0.12	1.060	1.7
Feb	4.43	0.13	1.053	1.7
Mar	4.80	0.13	1.044	1.7
Apr	5.32	0.13	1.040	1.7
May	6.41	0.11	1.039	1.7
Jun	7.96	0.11	1.051	1.7
Jul	10.90	0.13	1.055	1.7
Aug	8.05	0.12	1.057	1.7
Sep	6.11	0.11	1.058	1.7
Oct	4.40	0.12	1.054	1.7
Nov	4.06	0.13	1.057	1.7
Dec	4.84	0.11	1.061	1.7
Annual Avg	**5.97**	**0.12**	**1.052**	**1.7**

6. Matrewadi, Maharashtra

Month	Monthly mean wind speed (m/s)	Power law index	Monthly average air density (kg/m3)	Shape Factor
Jan	3.58	0.1	1.097	1.7
Feb	3.99	0.1	1.09	1.7
Mar	4.33	0.09	1.079	1.7
Apr	5.05	0.09	1.073	1.7
May	6.78	0.06	1.073	1.7
Jun	7.91	0.05	1.083	1.7
Jul	10.25	0.04	1.088	1.7
Aug	9.47	0.05	1.089	1.7
Sep	5.58	0.06	1.089	1.7
Oct	4.00	0.11	1.086	1.7
Nov	3.20	0.13	1.092	1.7
Dec	3.80	0.11	1.099	1.7
Annual Avg	**5.66**	**0.07**	**1.086**	**1.7**

7. Devgarh, Rajasthan

Month	Monthly mean wind speed (m/s)	Power law index	Monthly average air density (kg/m3)	Shape Factor
Jan	5.91	0.31	1.148	2.5
Feb	5.22	0.31	1.136	2.5
Mar	5.29	0.3	1.114	2.5
Apr	5.33	0.26	1.093	2.5
May	6.90	0.27	1.076	2.5
Jun	6.90	0.25	1.078	2.5
Jul	6.56	0.27	1.092	2.5
Aug	5.93	0.27	1.099	2.5
Sep	4.41	0.29	1.102	2.5
Oct	4.36	0.36	1.111	2.5
Nov	4.71	0.42	1.131	2.5
Dec	5.83	0.3	1.144	2.5
Annual Avg	**5.61**	**0.30**	**1.11**	**2.5**

8. Jaisalmer, Rajasthan

Month	Monthly mean wind speed (m/s)	Power law index	Monthly average air density (kg/m3)	Shape Factor
Jan	3.19	0.33	1.193	1.1
Feb	3.61	0.27	1.175	1.4
Mar	4.23	0.25	1.15	1.8
Apr	4.32	0.24	1.129	1.9
May	5.94	0.2	1.108	2.3
Jun	7.44	0.17	1.101	2.5
Jul	7.64	0.16	1.108	3.1
Aug	6.43	0.16	1.115	2.5
Sep	6.08	0.2	1.122	2.7
Oct	3.60	0.28	1.137	2.7
Nov	2.73	0.39	1.166	1.9
Dec	2.87	0.38	1.186	1.5
Annual Avg	**4.83**	**0.22**	**1.14**	**1.7**

9. Phalodi, Rajasthan

Month	Monthly mean wind speed (m/s)	Power law index	Monthly average air density (kg/m3)	Shape Factor
Jan	3.56	0.35	1.193	1.3
Feb	4.05	0.31	1.175	1.7
Mar	4.42	0.28	1.15	1.6
Apr	4.57	0.27	1.129	2
May	5.67	0.21	1.108	2.2
Jun	7.12	0.19	1.101	2.3
Jul	7.34	0.17	1.108	2.7
Aug	5.63	0.1	1.115	2.2
Sep	5.34	0.19	1.122	2.6
Oct	3.60	0.3	1.137	2.7
Nov	3.04	0.38	1.166	2.5
Dec	3.08	0.4	1.186	1.2
Annual Avg	**4.82**	**0.27**	**1.14**	**1.6**

10. Kakula Konda, Andhra Pradesh

Month	Monthly mean wind speed (m/s)	Power law index	Monthly average air density (kg/m3)	Shape Factor
Jan	4.25	0.49	1.08	1.7
Feb	4.20	0.32	1.07	1.8
Mar	4.62	0.21	1.058	1.8
Apr	4.90	0.17	1.048	1.8
May	6.41	0.15	1.043	1.6
Jun	9.71	0.09	1.048	2.2
Jul	10.36	0.09	1.054	2.4
Aug	10.71	0.09	1.054	2.6
Sep	6.05	0.15	1.057	1.7
Oct	4.55	0.35	1.064	1.1
Nov	5.30	0.5	1.075	2.5
Dec	5.01	0.58	1.083	2.9
Annual Avg	**6.41**	**0.21**	**1.061**	**1.4**

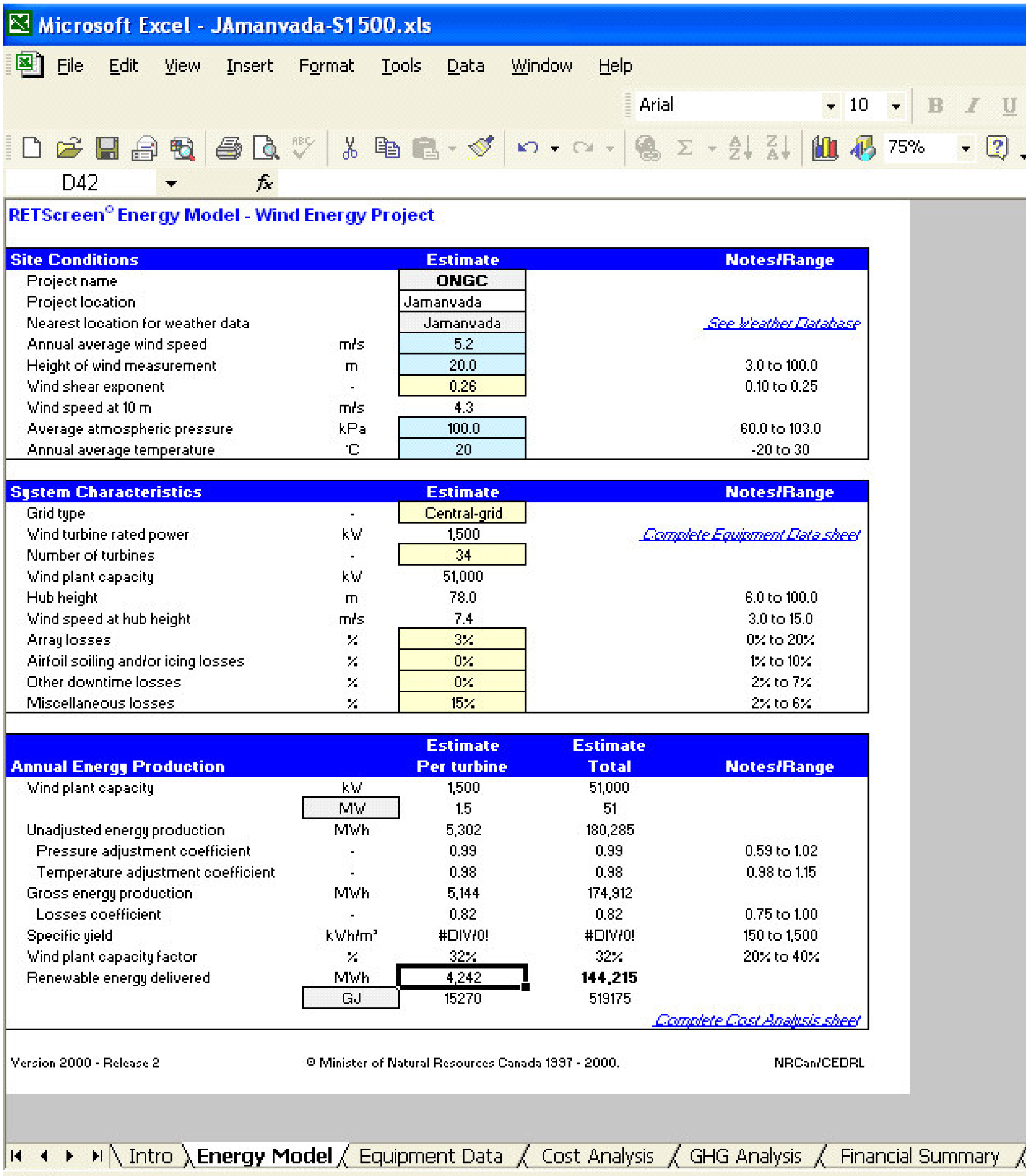
11. Ramagiri-1, Andhra Pradesh

Month	Monthly mean wind speed (m/s)	Power law index	Monthly average air density (kg/m3)	Shape Factor
Jan	3.66	0.15	1.11	2.1
Feb	4.01	0.15	1.1	2.1
Mar	4.26	0.14	1.086	2.4
Apr	4.43	0.15	1.073	1.9
May	6.22	0.15	1.071	2.3
Jun	8.17	0.17	1.078	3.1
Jul	9.16	0.16	1.085	3.3
Aug	8.98	0.14	1.086	4.3
Sep	5.88	0.13	1.088	2.7
Oct	3.74	0.11	1.094	1.8
Nov	3.58	0.07	1.106	2
Dec	3.71	0.11	1.113	2.6
Annual Avg	**5.42**	**0.13**	**1.091**	**1.9**

12. Kondamithipalli, Andhra Pradesh

Month	Monthly mean wind speed (m/s)	Power law index	Monthly average air density (kg/m3)	Shape Factor
Jan	4.24	0.27	1.133	1.8
Feb	4.58	0.23	1.123	1.8
Mar	4.31	0.21	1.109	1.8
Apr	4.51	0.2	1.096	1.8
May	5.60	0.22	1.094	1.8
Jun	9.19	0.22	1.101	1.8
Jul	9.61	0.22	1.108	1.8
Aug	7.86	0.21	1.109	1.8
Sep	5.26	0.23	1.111	1.8
Oct	3.90	0.25	1.117	1.8
Nov	3.90	0.25	1.129	1.8
Dec	4.39	0.29	1.136	1.8
Annual Avg	**5.61**	**0.23**	**1.114**	**1.8**

ANNEX IV Sample RETScreen model used for energy estimation



Microsoft Excel - JAmanvada-S1500.xls

RETScreen® Energy Model - Wind Energy Project

Site Conditions		Estimate	Notes/Range
Project name		ONGC	
Project location		Jamanvada	
Nearest location for weather data		Jamanvada	See Weather Database
Annual average wind speed	m/s	5.2	
Height of wind measurement	m	20.0	3.0 to 100.0
Wind shear exponent	-	0.26	0.10 to 0.25
Wind speed at 10 m	m/s	4.3	
Average atmospheric pressure	kPa	100.0	60.0 to 103.0
Annual average temperature	°C	20	-20 to 30

System Characteristics		Estimate	Notes/Range
Grid type	-	Central-grid	
Wind turbine rated power	kW	1,500	Complete Equipment Data sheet
Number of turbines	-	34	
Wind plant capacity	kW	51,000	
Hub height	m	78.0	6.0 to 100.0
Wind speed at hub height	m/s	7.4	3.0 to 15.0
Array losses	%	3%	0% to 20%
Airfoil soiling and/or icing losses	%	0%	1% to 10%
Other downtime losses	%	0%	2% to 7%
Miscellaneous losses	%	15%	2% to 6%

Annual Energy Production		Estimate Per turbine	Estimate Total	Notes/Range
Wind plant capacity	kW	1,500	51,000	
	MW	1.5	51	
Unadjusted energy production	MWh	5,302	180,285	
Pressure adjustment coefficient	-	0.99	0.99	0.59 to 1.02
Temperature adjustment coefficient	-	0.98	0.98	0.98 to 1.15
Gross energy production	MWh	5,144	174,912	
Losses coefficient	-	0.82	0.82	0.75 to 1.00
Specific yield	kWh/m²	#DIV/0!	#DIV/0!	150 to 1,500
Wind plant capacity factor	%	32%	32%	20% to 40%
Renewable energy delivered	MWh	4,242	**144,215**	
	GJ	15270	519175	
				Complete Cost Analysis sheet

Version 2000 - Release 2 © Minister of Natural Resources Canada 1997 - 2000. NRCan/CEDRL

Intro | Energy Model | Equipment Data | Cost Analysis | GHG Analysis | Financial Summary

Microsoft Excel - JAmanvada-S1500.xls

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E33

RETScreen® Equipment Data - Wind Energy Project

Wind Turbine Characteristics		Estimate	Notes/Range
Wind turbine rated power	kW	1,500	See Product Database
Hub height	m	78.0	6.0 to 100.0
Rotor diameter	m	82	7 to 72
Swept area	m²		35 to 4,075
Wind turbine manufacturer		Suzlon	
Wind turbine model		S82-1500	
Energy curve data source	-	Custom	Weibull wind distribution
Shape factor	-	2.2	1.0 to 3.0

Wind Turbine Production Data

Wind speed (m/s)	Power curve data (kW)	Energy curve data (MWh/yr)
0	0.0	-
1	0.0	-
2	0.0	-
3	0	249.4
4	1	980.5
5	99	2,142.8
6	263	3,509.2
7	466	4,863.7
8	709	6,066.2
9	974	7,032.4
10	1219	7,720.2
11	1382	8,128.6
12	1438	8,289.4
13	1473	8,251.5
14	1500	8,066.7
15	1500	7,781.5
16	1500	-
17	1500	-
18	1500	-
19	1500	-
20	1500	-
21	0	-
22	0.0	-
23	0.0	-
24	0.0	-
25	0.0	-

Power and Energy Curves

Power — Energy

Intro / Energy Model / Equipment Data / Cost Analysis / GHG Analysis / Financial

Ready

ANNEX V Procedure for registering the projects with the Executive Board of the UNFCCC and availing the CDM benefits

What is CDM?

Kyoto Protocol and CDM

The world community first came together to address the threat of climate change through the UNFCCC (Box 1). This treaty was opened for signatures in June 1992 at the Rio Earth Summit. The UNFCCC came into force on 21 March 1994, and had been ratified by 198 countries as of May 2004. While the UNFCCC did not lay down legally binding emissions reduction targets for countries, it recognized the need for an agreement with emissions reduction commitments with a specific timetable.

Box 1: Scientific evidence of climate change

Climate change was first recognized as a problem of global magnitude and of immediate concern in the 1980s with the occurrence of unusually warm summers in the United States. It became apparent that the atmospheric 'greenhouse' phenomenon studied by the Swedish scientist Svante Arrhenius a hundred years ago was actually changing climatic patterns across our planet. Severe storms, floods, and droughts in the last decade have served as a reminder that urgent action is required to control the increase in the concentrations of GHGs (greenhouse gases).

In order to better understand the processes by which we are altering the earth's climate system, the IPCC (Intergovernmental Panel on Climate Change) was established jointly by UNEP (United Nations Environment Programme) and WMO (World Meteorological Organization) in 1988. The scientific output of this body has helped to define more clearly the range of possible impacts, to determine which locations and systems may be most vulnerable, and to identify mitigation and adaptation measures. The IPCC, in its Third Assessment Report, has confirmed that the evidence of human interference in the climate is stronger than ever. Atmospheric concentrations of carbon dioxide, methane, and nitrous oxides have grown by about 31%, 151%, and 17%, respectively, over the period 1750–2000. Specifically, carbon dioxide concentrations have increased from about 280 PPMV (parts per million by volume) in pre-industrial times to 360 PPMV in 2000. At the same time, the mean global surface temperature

has increased by 0.6 °C (+0.2 °C) over the twentieth century. Scenario-based projections reported in Third Assessment Report indicate a higher rate of warming (1.4 °C–5.8 °C) over the period 1990–2100, while the sea level is projected to rise by 9–88 cm. Changes in the surface air temperature and the sea level could change precipitation quantity and pattern, vegetation cover, and soil moisture. The impact on the natural and managed systems will depend critically on the rate of climate change. The predicted changes in global temperature are greater than any seen in the last 10 000 years. Further, regional temperature changes could be substantially different from the global average and the frequency, intensity, and duration of storms and other extreme weather events could increase. The impacts of climate change could include the dieback of tropical forests and grasslands, tremendous reductions in the availability of water from rivers, decline in cereal yields, and increased incidence of heat stress, malaria, and other vectorborne and water-borne diseases. Rise in the sea level could have a number of physical impacts on coastal areas, including loss of land due to inundation and erosion, increased flooding, and saltwater intrusion. These could adversely affect coastal agriculture, tourism, freshwater resources, fisheries and aquaculture, and human settlements and health.
Source IPCC (2001)

This was achieved in the form of the Kyoto Protocol in 1997. The Protocol covers the following six GHGs.

- CO_2 (carbon dioxide)
- CH_4 (methane)
- N_2O (nitrous oxide)
- HFC_s (hydrofluorocarbons)
- PFC_s (perfluorocarbons)
- SF_6 (sulphur hexafluoride)

Annex I Parties agreed to reduce their overall emissions of these six GHGs by an average of 5.2% below the 1990 levels by the first commitment period 2008–12. Among Annex I countries, the Protocol allowed for differentiated targets depending on the country's circumstances; for instance, Japan and the United States were required to reduce emissions by 6% and 7%, respectively, while Australia was allowed an increase of 8% over the 1990 levels. The condition for the coming into force of the Kyoto Protocol was ratification by 55 countries accounting for 55% of Annex I 1990 carbon dioxide emissions. Since the United States, responsible for about 35% of Annex I 1990 carbon dioxide emissions, refused to ratify the Kyoto Protocol in early 2001, the fulfilment of this condition became contingent on ratification by Russia (accounting for 17% of emissions). With this achieved, the Protocol has been ratified by 141 countries, as of 2 February 2005, including 37 Annex I countries accounting for 61.6% of 1990 carbon dioxide emissions (Figure 1).

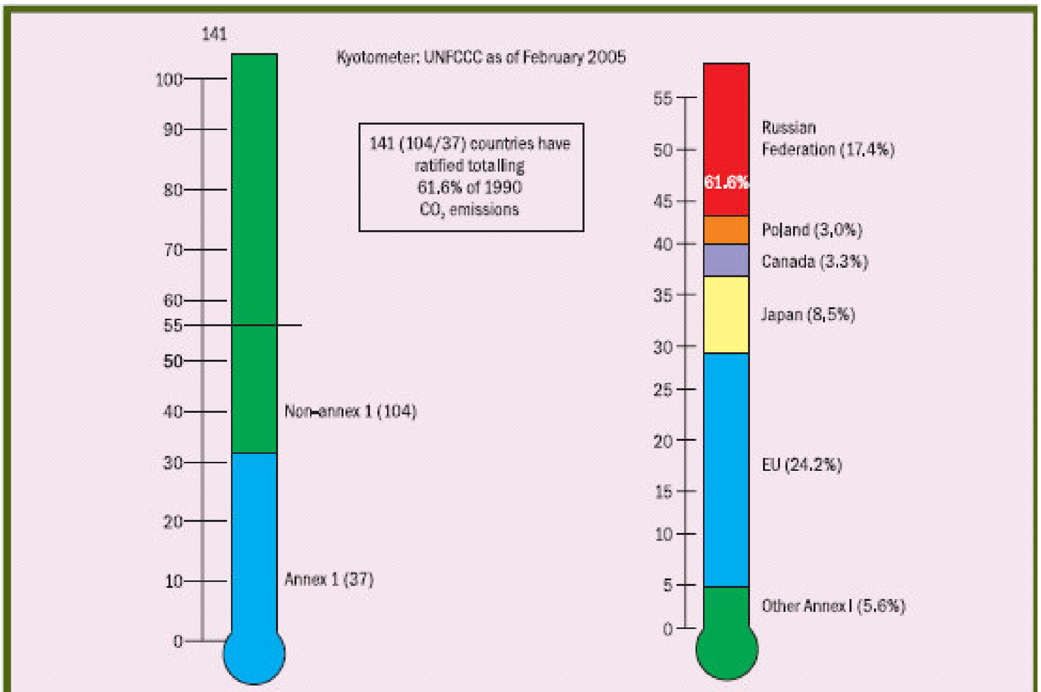


Figure 1 Kyoto Protocol ratification

To enable countries meet their reduction commitments in a flexible and cost-effective manner, the Protocol established three market-based mechanisms (ET, JI, and CDM). In particular, CDM allows Annex I countries to meet part of their Kyoto Protocol targets by using credits from projects that reduce GHG emissions in developing countries. The underlying rationale is that cutting GHG emissions in any part of the world can contribute towards reducing global atmospheric concentrations of GHGs. While the Annex I Parties benefit by obtaining reductions at costs lower than those in their own countries, the gains to the host Parties are in the form of finance, technology, and local sustainable development benefits.

Value of carbon

As a result of the Kyoto Protocol, carbon has become a tradable commodity with an associated value. One tonne of carbon dioxide reduced through a CDM project, when certified by a designated entity, is known as a CER (certified emission reduction), which can be traded. Revenue from CERs can form part of a project's annual cash inflow, equity, or debt. There are varying estimates of the potential opportunities under CDM. Early studies of the demand for CDM had predicted impressive amounts of more than 4000 MT CO2eq per year. However, the refusal of the US and Australia to ratify the Kyoto Protocol citing adverse economic impacts has severely shrunk the carbon market. Also, instead of investing in CDM, Annex I countries can more cheaply buy the excess quota of countries like Russia and Ukraine.

Nevertheless, in recent years a small market for carbon has started to emerge. Even in the anticipation of the coming into force of the Kyoto Protocol, some European countries, multilateral

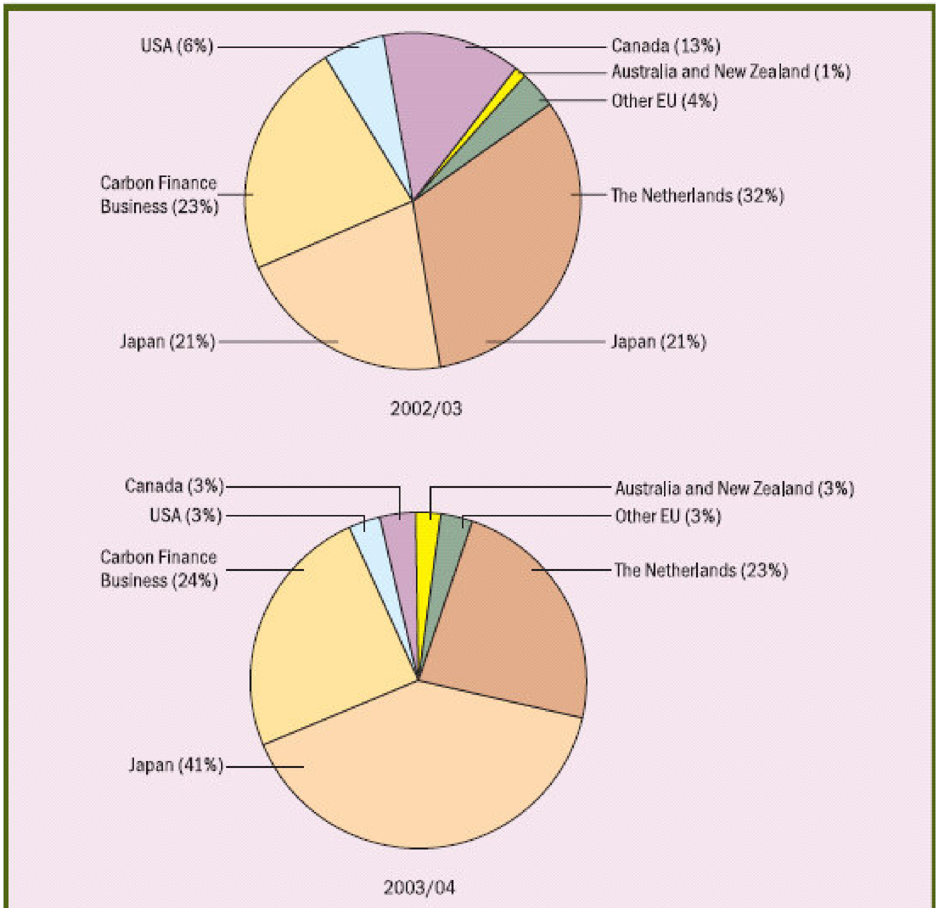


Figure 2 Share of market buyers (in terms of volume of emission reductions purchased)
Source Lecocq (2004)

Fast-tracking CDM in Indian States organizations, and corporates took the lead by launching CDM tenders, carbon funds, and emissions trading schemes (Box 2). Figure 2 shows the main buyers in the market. While the pioneers were the Prototype Carbon Fund of the World Bank and the CERUPT (Certified Emission Reduction Unit Procurement Tender) programme of the Netherlands, the year 2004 saw the emergence of Japan as the largest buyer, and the launch of the Japan Carbon Fund (jointly managed by the Japan Bank for International Cooperation and the Development Bank of Japan). In this evolving market, brokers and consultants are also playing matchmaking roles between buyers and sellers. As a result of these activities, in 2004, 127.2 MTCO2eq were contracted, of which the share of CDM was 82 MTCO2eq at an average weighted price of 4.2 Euros/TCO2eq (Point Carbon 2005).

Box 2 Emissions trading

Despite the delay in entry of the Kyoto Protocol into force, many countries have started implementing regulations for reducing and trading GHG (greenhouse gas) emissions. Foremost among these is the European Union's Emissions Trading System (EU ETS), which in January 2005 commenced operation as the largest multi-country, multi-sector GHG emissions trading scheme worldwide. In addition to this regional trading system, some countries like the United Kingdom and Denmark have launched domestic trading schemes. Even in countries like the US and Australia, which have decided not to ratify the Kyoto Protocol, some policy initiatives are emerging at the state level. Massachusetts and New Hampshire have planned state cap-and-trade of carbon dioxide emissions starting in 2006, while Oregon already possesses a GHG emissions reduction procurement initiative. The New South Wales trading system covers electricity retailers and aims to reduce emissions by 5% in 2012. The corporate sector too is not far behind. Companies from seven US states, Canada, Brazil, and Mexico participated in CCX (Chicago Climate Exchange), and have committed to reduce their GHG emissions by 4% below their average 1998–2001 baseline by 2006. Companies like BP and Shell have also experimented with internal trading systems. In January 2005, the prices in the EU ETS were about ¤7.20 / TCO2eq for vintage 2005 allowances (Carbon Finance 2005).

Source: *Babu and Bhandari (2004) 1 Under the Kyoto Protocol, countries like Russia and Ukraine were set targets according to their 1990 emission levels.*

Due to the ongoing economic slowdown, their emission levels were already 30% below their 1990 levels, giving rise to what has been termed as 'hot air'.

The prevailing carbon prices are too low to excite large-scale CDM project development activity. However, the EU ETS (European Union Emissions Trading System), which became operational in January 2005, creates a significant new market for CDM as a result of its Linking Directive. Furthermore, prices can be expected to rise as the deadline for meeting the Kyoto Protocol targets draws nearer, and countries/companies save carbon credits to meet stricter targets in the future.

CDM Project Cycle

As defined in Article 12 of the Kyoto Protocol, CDM is defined as a mechanism to address the following objectives.

- Assist non-Annex I countries in achieving sustainable development

- Help Annex I countries comply with their emissions reduction commitments
- Contribute to the ultimate goal of the UNFCCC, i.e. stabilization of GHG concentrations in the atmosphere

Projects in developing countries are eligible under CDM if they help meet the above objectives by reducing GHG emissions relative to the 'baseline'. In other words, to qualify for credits, GHG emissions from a project activity must be reduced below those that would have occurred in the absence of the project. The project itself should not be part of the baseline scenario but should be 'additional' to what would have happened anyway. Without this 'additionality' requirement, there is no guarantee that CDM projects will create incremental environmental benefits, contribute toward sustainable development in the host country, or play a role in the ultimate objective of stabilizing atmospheric GHG concentrations. Some examples of CDM projects are listed below.

- Carbon dioxide displacement through utilization of renewable energy for power generation and thermal energy
- Carbon dioxide reduction through energy efficiency improvement
- Carbon dioxide sequestration through afforestation and reforestation
- Landfill gas capture and energy generation
- Hydrofluorocarbon decomposition

In December 2001, negotiators worked out the detailed modalities and procedures of the international climate change policy regime, including the rules and regulations of the CDM, which were formulated as the Marrakech Accords (Box 3).

The CDM Executive Board was established as part of the UNFCCC framework to oversee the CDM process. CDM projects have to undergo the series of steps illustrated in Figure 3. The glossary of CDM terms is given in Annexe 2.

Box 3 Clean development mechanism participation requirements as specified in Marrakech Accords

1. Participation in a CDM project activity is voluntary.
2 . Parties participating in the CDM shall designate a national authority for the CDM.
3. A Party not included in Annex I may participate in a CDM project activity if it is a Party to the Kyoto Protocol.
4 . A Party included in Annex I* with a commitment inscribed in Annex B* is eligible to use CERs
(certified emissions reductions), issued in accordance with the relevant provisions, to contribute to compliance with part of its commitment under Article 3, paragraph 1, if it is in compliance with the following eligibility requirements.

(a) It is a Party to the Kyoto Protocol;
(b) Its assigned amount pursuant to Article 3, paragraphs 7 and 8, has been calculated and recorded in accordance with decision -/CMP.1 (Modalities for the accounting of assigned amounts);
(c) It has in place a national system for the estimation of anthropogenic emissions by sources and anthropogenic removals by sinks of all greenhouse gases not controlled by the Montreal Protocol, in accordance with Article 5, paragraph 1, and the requirements in the guidelines decided thereunder;
(d) It has in place a national registry in accordance with Article 7, paragraph 4, and the requirements in the guidelines decided thereunder;
(e) It has submitted annually the most recent required inventory, in accordance with Article 5, paragraph 2, and Article 7, paragraph 1, and the requirements in the guidelines decided thereunder, including the national inventory report and the common reporting format. For the first commitment period, the quality assessment needed for the purpose of determining eligibility to use the mechanisms shall be limited to the parts of the inventory pertaining to emissions of greenhouse gases from sources/sector categories from Annex A* to the Kyoto Protocol and the submission of the annual inventory on sinks;
(f) It submits the supplementary information on assigned amount in accordance with Article 7, paragraph 1, and the requirements in the guidelines decided thereunder and makes any additions to, and subtractions from, assigned amount pursuant to Article 3, paragraphs 7 and 8, including for the activities under Article 3, paragraphs 3 and 4, in accordance with Article 7, paragraph 4, and the requirements in the guidelines decided thereunder.

Refer Annexe 3

Source UNFCCC (2001)

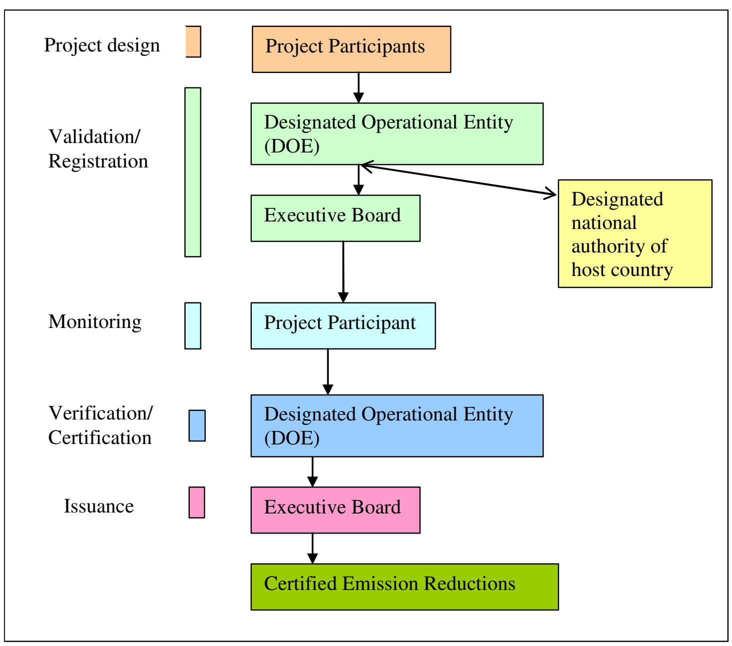


Figure 3: CDM cycle

Step 1: Project formulation

The first step in the CDM project cycle is identifying an eligible project. As per the Marrakech Accords, projects that reduce any of the six GHGs covered in the Kyoto Protocol are eligible for CDM if 'anthropogenic emissions of GHG by sources are reduced below those that would have occurred in the absence of the registered CDM project activity'. Carbon sequestration projects in the forestry sector are limited to afforestation and reforestation. Nuclear energy projects have been deemed ineligible under CDM. Further, three types of small-scale project categories have been defined, which are entitled to simpler and faster procedures (Box 4).

Box 4 Small-scale clean development mechanism project categories

Renewable energy projects up to 15 MW (megawatt)
Energy efficiency projects reducing energy consumption by up to 15 GWh (gigawatt hour) annually
Other project activities that reduce emissions and directly emit less than 15 KTCO2eq (kilo tonnes)
Afforestation and reforestation project activities sequestering less than 8 KTCO2 annually

The project has to be formulated as a PDD (project design document), which has the following key elements.

- General description of project activity
- Baseline methodology (including boundary and leakage aspects)
- Duration of project activity / crediting period
- Monitoring methodology and plan
- Calculation of GHG emissions by sources
- Environmental impacts
- Stakeholder comments.

Probably the most important element is the establishment of the baseline and the calculation of emissions reductions. The Marrakech Accords allow for the following three baseline approaches.

'Existing actual or historical emissions data.'
Emissions from a 'technology that represents an economically attractive course of action, taking into account barriers to investment.'

'The average emissions of similar project activities undertaken in the previous five years, in similar… circumstances, and whose performance is in the top 20% of their category.'

Details of PDD requirements are available at <http://cdm.unfccc.int>.

Step 2: Approval by designated national authority

Each participating country is required to set up a DNA (designated national authority) for CDM. Each project must get approval from the relevant DNA that it assists the host country in achieving sustainable development.

Step 3: Validation

Validation of the PDD is carried out by third-party agencies known as DOEs (designated operational entities) accredited by the Executive Board. As part of validation, the DOE checks the following points.

- The host and Annex I countries involved in the CDM project have ratified the Kyoto Protocol.
- Stakeholder comments have been accounted for.
- Environmental impact analysis/assessment has been done.
- GHG emissions reduction is additional.
- Approved baseline and monitoring methodologies have been used; or a new methodology has to be submitted to the Executive Board.

Step 4: Registration

After validation, the DOE forwards its report to the Executive Board, which normally registers the project as a CDM project within eight weeks. An administrative fee is charged, which differs according to the size of the project (Table 1).

Table1: Administration fee for CDM projects

Volumes of CERs generated annually (tCO_2)	Fee (US dollars)
<=15,000	5,000
>15,000 and <=50,000	10,000
>50,000 and <= 1,00,000	15,000
>100000 and <= 2,00,000	20,000
>2,00,000	30,000

Step 5: Monitoring

Monitoring is the systematic surveillance of project performance by the project participants. For this purpose, a transparent and reliable monitoring plan must be specified to collect and archive all data needed to estimate GHG emissions occurring within the project boundary, determine the baseline GHG emissions, and determine leakage.

Step 6: Verification

Verification is the periodic independent review and ex post determination by the DOE of the monitored emissions reductions resulting from the CDM project. The DOE which has performed the validation cannot normally perform verification for the same project.

Step 7: Certification

Certification is a written assurance by the DOE that the project has achieved emissions reductions as verified.

Step 8: Issuance of CERs

Project developers can choose between the following two options for the period of receiving credits.
1. Ten years without any revision to the baseline
2. Twenty one years with a reassessment of the baseline after every seven years.

Within 15 days of the DOE making its certification report public, the Executive Board issues the necessary CERs. The only exception is if there is an objection by a project participant or by three Executive Board members. A registry for the issuance and the tracking of CERs is under development by the Executive Board. Further, two per cent of the share of the proceeds from CDM projects is retained for the Adaptation Fund created under the Kyoto Protocol.

Table 2 summarizes the roles and responsibilities of the various agencies and stakeholders involved in the CDM project cycle.

Table 2 Roles and responsibilities in CDM project cycle

Activity	**Definitions**	**Responsible entity**
Project development	Developing a CDM project	Project promoter
Project design document	Developing a PDD	Project promoter
Validation	Independent evaluation of PDD including calculations of baseline emissions and estimated project emissions	DOE
Most country approval	Approval from host government is mandatory	Project promoter and host government
Registration	Formal acceptance of a validated PDD	Executive Board
Project implementation and monitoring	Commissio9ning and operation of the CDM project and measuring and recording project performance related indicators/parameters	Project promoter
Verification	Periodical independent review of monitored GHG reductions	DOE
Certification	Written assurance on the actual GHG reductions verified	DOE
Issuance of CERs	Issuance of CERs based on DOEs certification	Executive Board

Where CDM = clean development mechanism, PDD = project design document, DOE = designated operational entities, CERs = certified emission reductions, GHG = green house gas

Special consideration for small-scale projects

Recognizing the high sustainable development impacts of small projects, efforts have been made to encourage such projects by reducing the costs of going through the CDM project cycle. These measures include the following.

- Simplified baseline and monitoring methodologies approved by the Executive Board, which can be applied directly, thereby saving project development costs.
- PDD has simpler requirements related to sustainable development.
- The same DOE can undertake validation, verification, and certification for a small-scale project.
- Bundling of small projects is feasible, provided the bundle does not violate the small-scale project eligibility limit (e.g. 15 MW [megawatt] for renewable energy projects).
- A lower registration fee is charged.
- CERs are issued in four weeks, instead of the eight weeks taken for other projects.

Updated details are available at <http://cdm.unfccc.int/pac/howto/smallscalePA/index.html>.

ANNEX VI Details of Shading Analysis of WEG-S82 at Jakhau

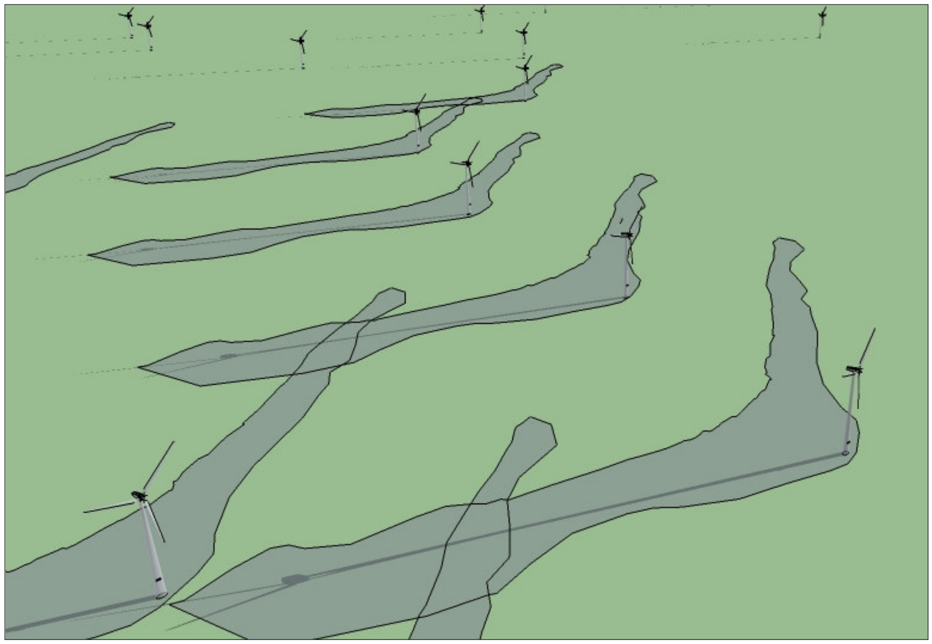


Figure A-VII.1 Shading of WEG-S82 at 9:00 am (21st December) at Jakhau

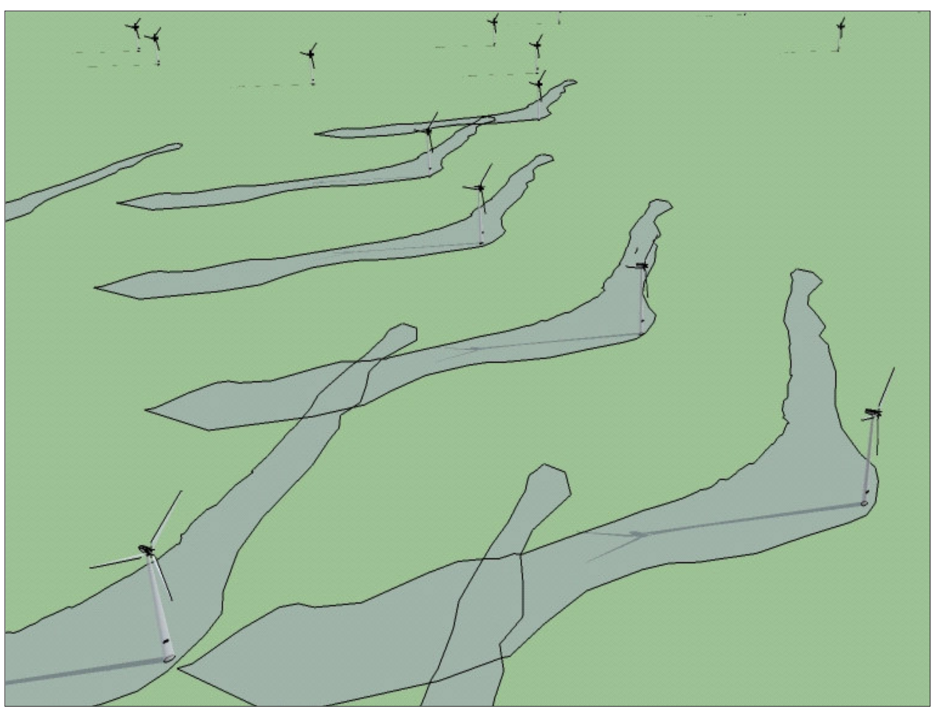


Figure A-VII.2 Shading of WEG-S82 at 10:00 am (21st December) at Jakhau

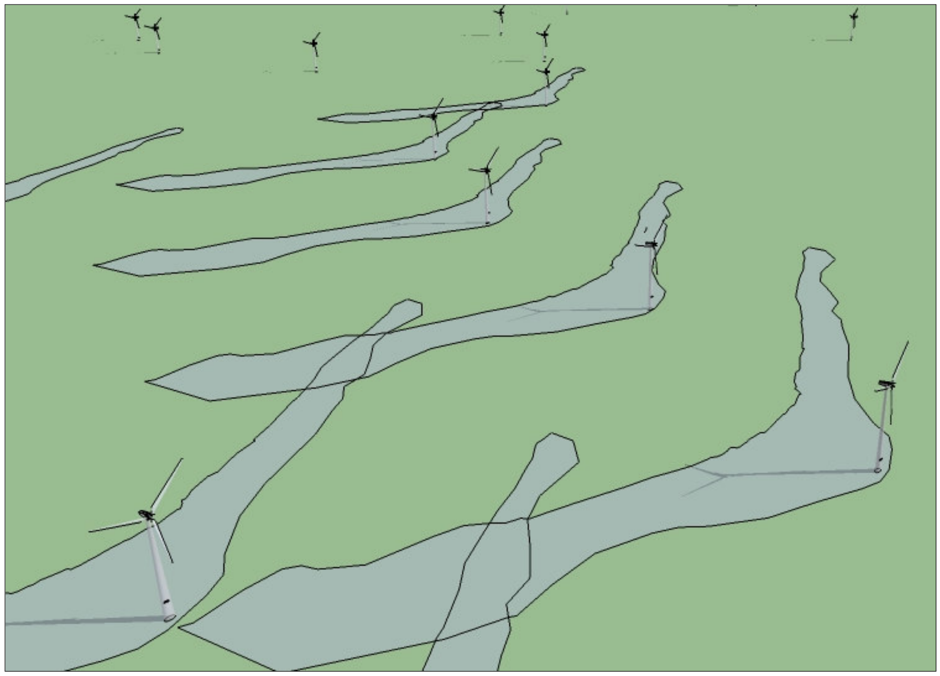


Figure A-VII.3 Shading of WEG-S82 at 11:00 am (21st December) at Jakhau

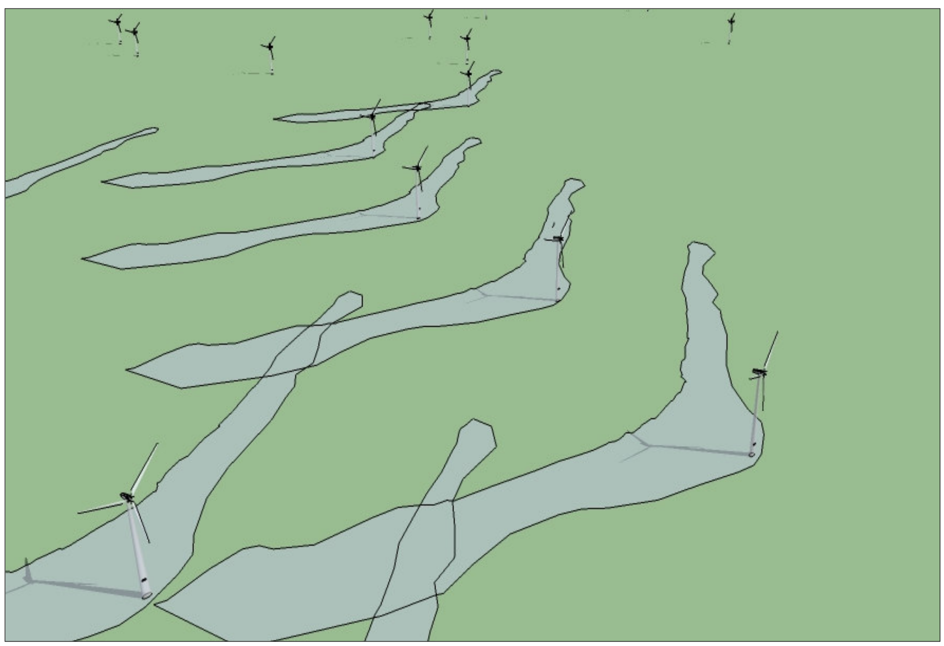


Figure A-VII.4 Shading of WEG-S82 at 12:00 am (21st December) at Jakhau

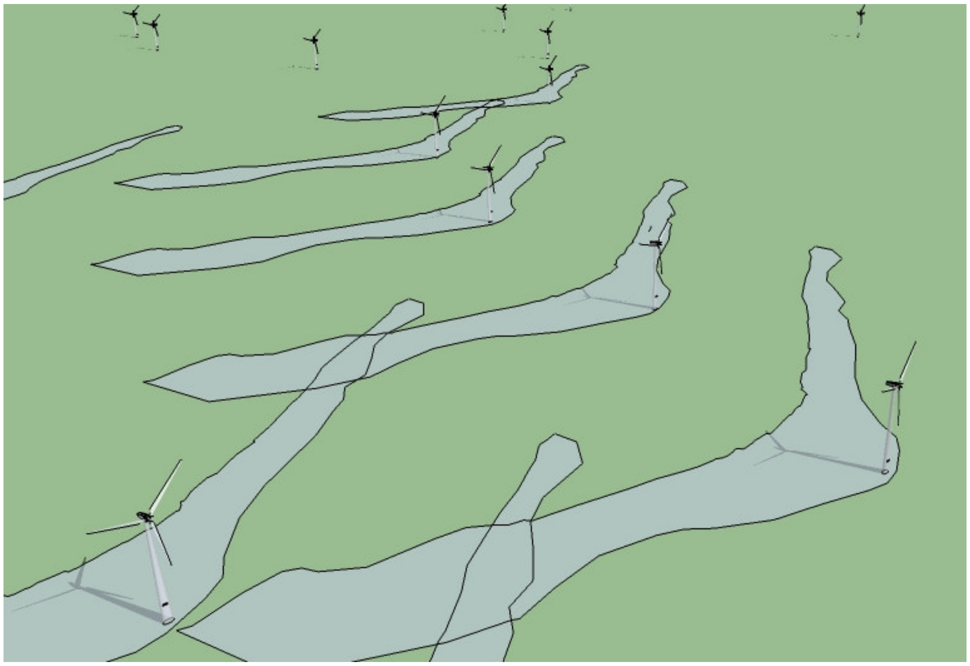


Figure A-VII.5 Shading of WEG-S82 at 1:00 pm (21st December) at Jakhau

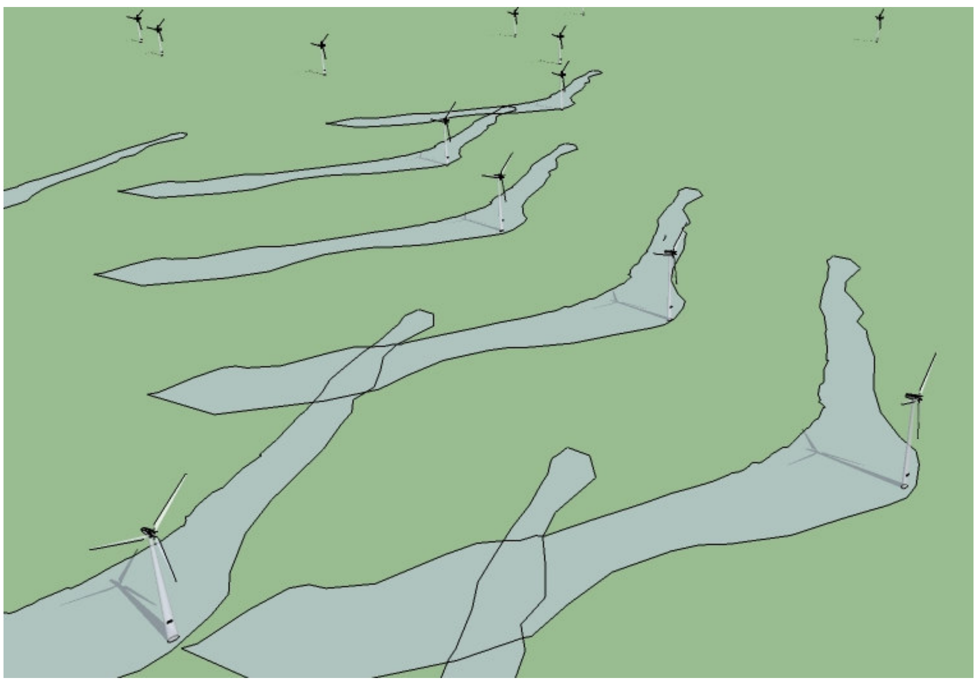


Figure A-VII.6 Shading of WEG-S82 at 2:00 pm (21st December) at Jakhau

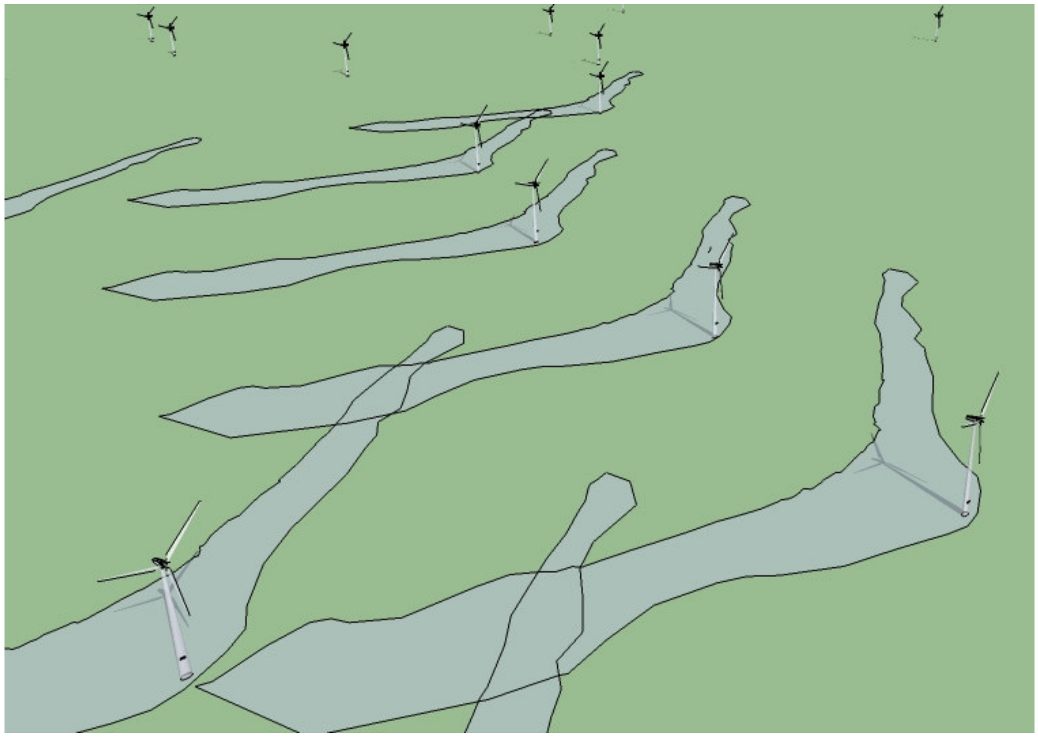


Figure A-VII.7 Shading of WEG-S82 at 3:00 pm (21st December) at Jakhau

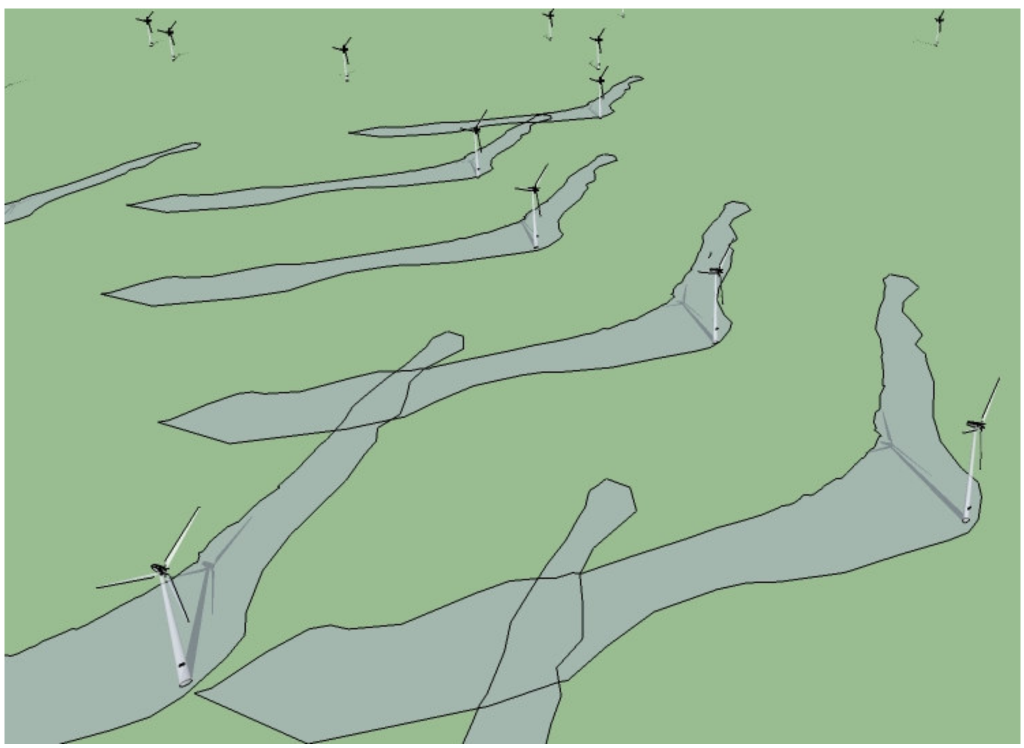


Figure A-VII.8 Shading of WEG-S82 at 4:00 pm (21st December) at Jakhau

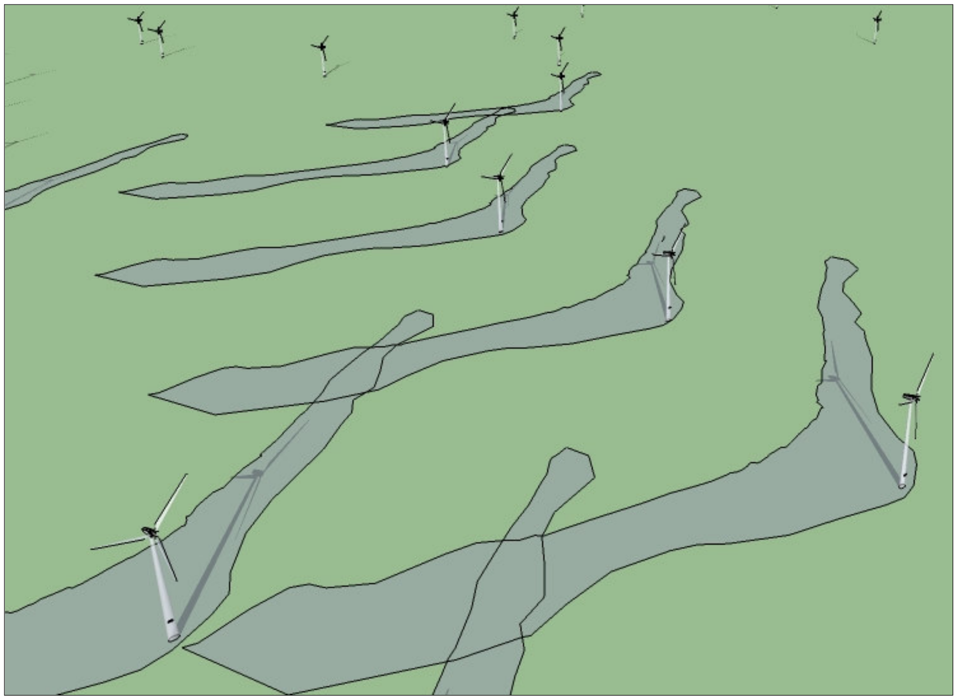


Figure A-VII.9 Shading of WEG-S82 at 5:00 pm (21st December) at Jakhau

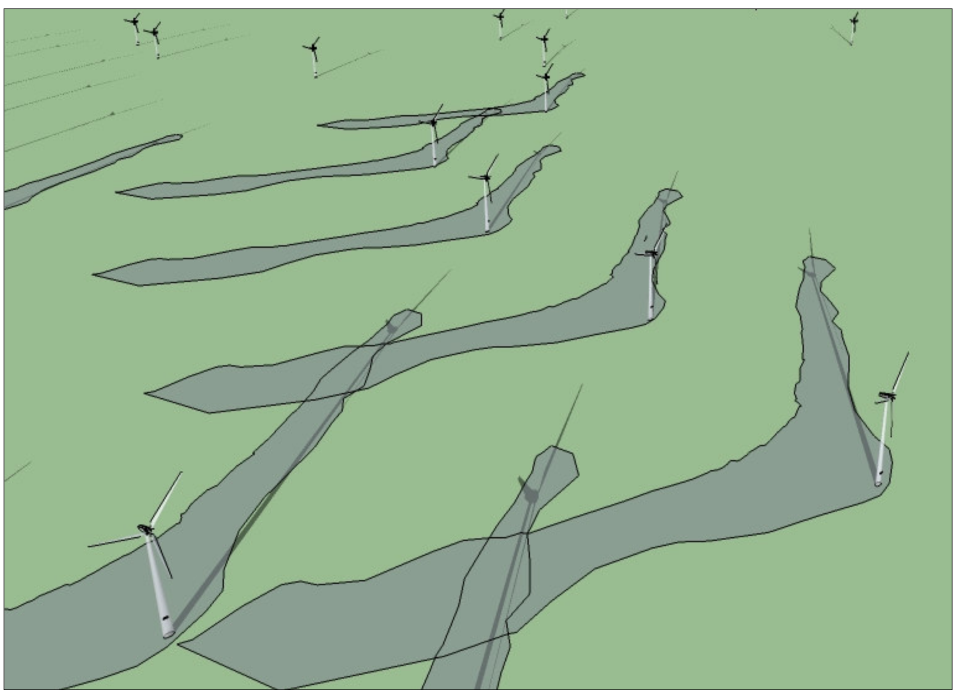


Figure A-VII.10 Shading of WEG-S82 at 6:00 pm (21st December) at Jakhau

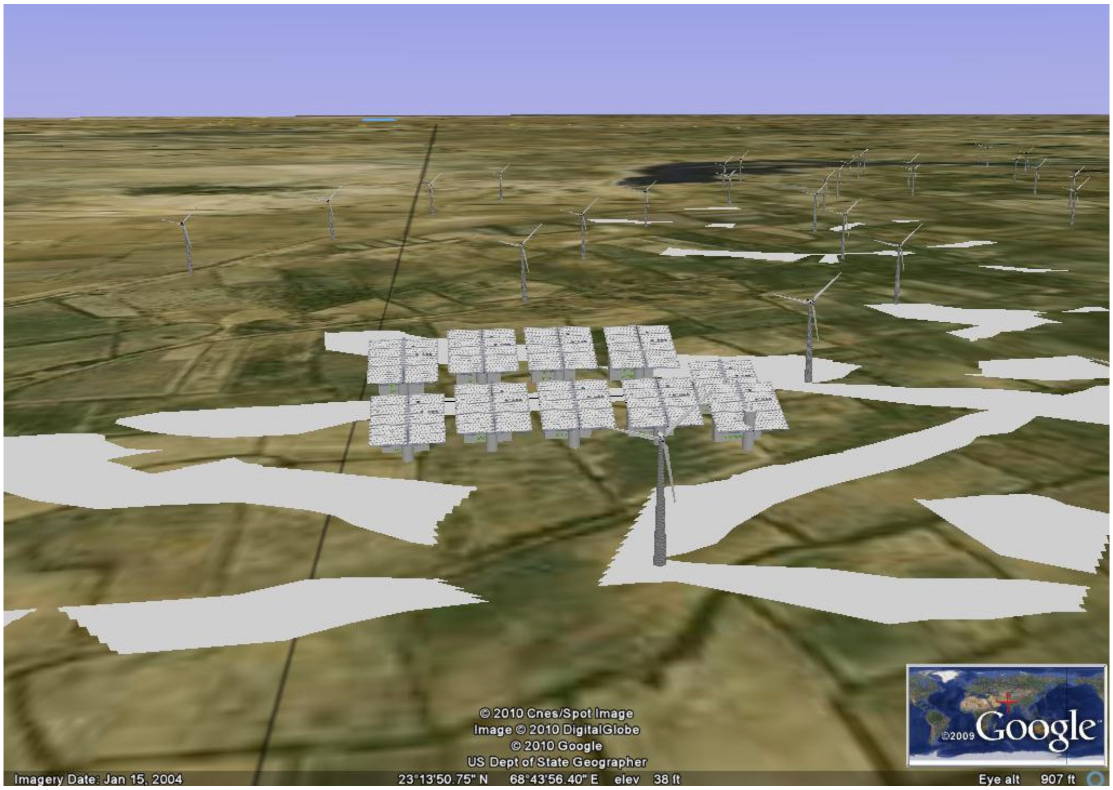
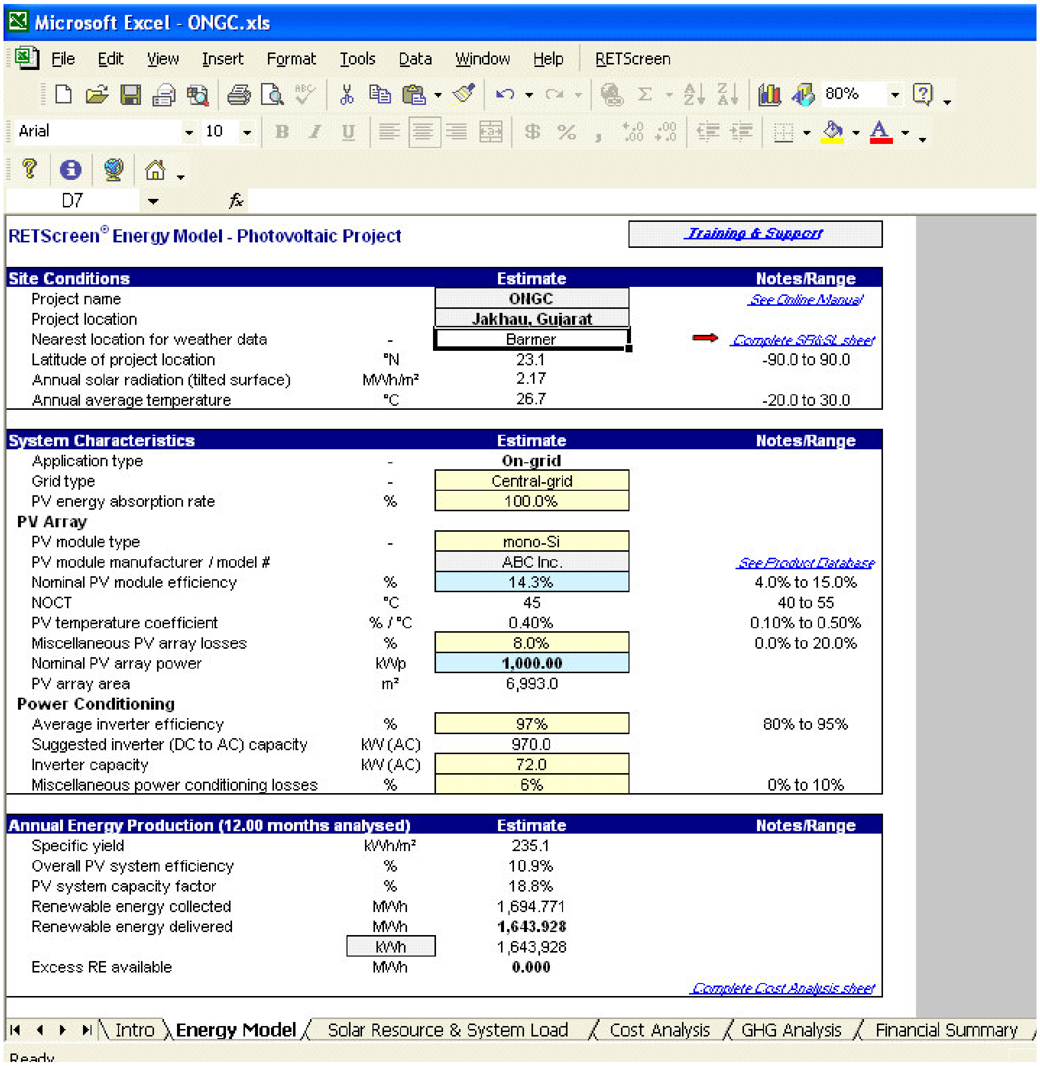


Figure A-VII.11 Proposed sample Layout of solar PV power project in between of ONGC Wind Power Project

ANNEX **VII** RETScreen Worksheets for 1 MW SPV project at Jakhau, Gujarat



Microsoft Excel - ONGC.xls

RETScreen® Energy Model - Photovoltaic Project

Training & Support

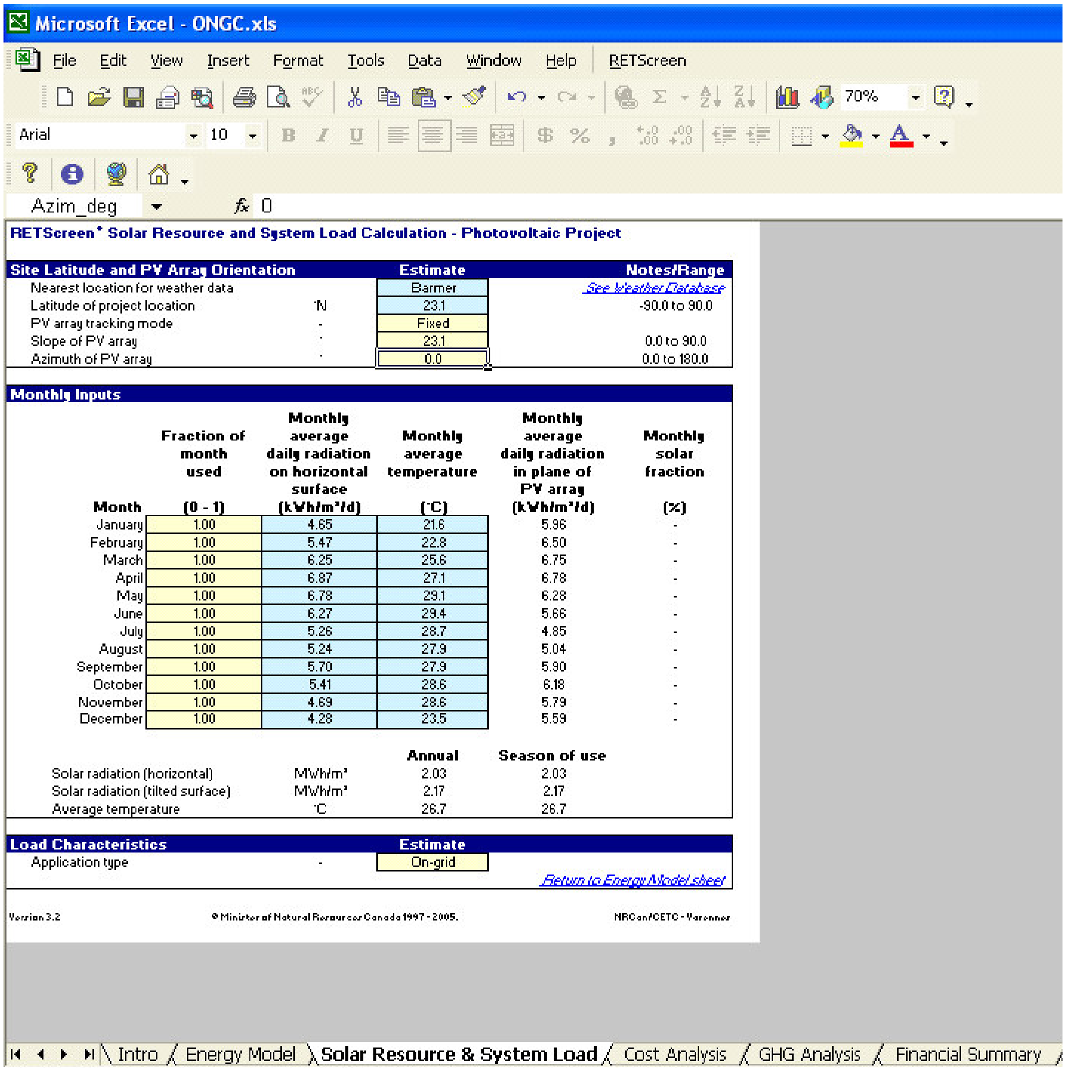
Site Conditions		Estimate	Notes/Range
Project name		ONGC	See Online Manual
Project location		Jakhau, Gujarat	
Nearest location for weather data	-	Barmer	Complete SR&SL sheet
Latitude of project location	°N	23.1	-90.0 to 90.0
Annual solar radiation (tilted surface)	MWh/m²	2.17	
Annual average temperature	°C	26.7	-20.0 to 30.0

System Characteristics		Estimate	Notes/Range
Application type	-	On-grid	
Grid type	-	Central-grid	
PV energy absorption rate	%	100.0%	
PV Array			
PV module type	-	mono-Si	
PV module manufacturer / model #		ABC Inc.	See Product Database
Nominal PV module efficiency	%	14.3%	4.0% to 15.0%
NOCT	°C	45	40 to 55
PV temperature coefficient	% / °C	0.40%	0.10% to 0.50%
Miscellaneous PV array losses	%	8.0%	0.0% to 20.0%
Nominal PV array power	kWp	1,000.00	
PV array area	m²	6,993.0	
Power Conditioning			
Average inverter efficiency	%	97%	80% to 95%
Suggested inverter (DC to AC) capacity	kW (AC)	970.0	
Inverter capacity	kW (AC)	72.0	
Miscellaneous power conditioning losses	%	6%	0% to 10%

Annual Energy Production (12.00 months analysed)		Estimate	Notes/Range
Specific yield	kWh/m²	235.1	
Overall PV system efficiency	%	10.9%	
PV system capacity factor	%	18.8%	
Renewable energy collected	MWh	1,694.771	
Renewable energy delivered	MWh	1,643.928	
	kWh	1,643,928	
Excess RE available	MWh	0.000	
			Complete Cost Analysis sheet

Intro / Energy Model / Solar Resource & System Load / Cost Analysis / GHG Analysis / Financial Summary

Ready



Microsoft Excel - ONGC.xls

RETScreen® Solar Resource and System Load Calculation - Photovoltaic Project

Site Latitude and PV Array Orientation		Estimate	Notes/Range
Nearest location for weather data		Barmer	See Weather Database
Latitude of project location	°N	23.1	-90.0 to 90.0
PV array tracking mode	-	Fixed	
Slope of PV array	°	23.1	0.0 to 90.0
Azimuth of PV array	°	0.0	0.0 to 180.0

Monthly Inputs

Month	Fraction of month used (0 - 1)	Monthly average daily radiation on horizontal surface (kWh/m²/d)	Monthly average temperature (°C)	Monthly average daily radiation in plane of PV array (kWh/m²/d)	Monthly solar fraction (%)
January	1.00	4.65	21.6	5.96	-
February	1.00	5.47	22.8	6.50	-
March	1.00	6.25	25.6	6.75	-
April	1.00	6.87	27.1	6.78	-
May	1.00	6.78	29.1	6.28	-
June	1.00	6.27	29.4	5.66	-
July	1.00	5.26	28.7	4.85	-
August	1.00	5.24	27.9	5.04	-
September	1.00	5.70	27.9	5.90	-
October	1.00	5.41	28.6	6.18	-
November	1.00	4.69	28.6	5.79	-
December	1.00	4.28	23.5	5.59	-

		Annual	Season of use
Solar radiation (horizontal)	MWh/m²	2.03	2.03
Solar radiation (tilted surface)	MWh/m²	2.17	2.17
Average temperature	°C	26.7	26.7

Load Characteristics		Estimate
Application type	-	On-grid

Return to Energy Model sheet

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Intro / Energy Model / Solar Resource & System Load / Cost Analysis / GHG Analysis / Financial Summary

ANNEX **VIII** Detailed financial calculation sheets

The financial models used for all the four states for both the cases that is for captive use of power and for sale of power to utility are given in following pages.