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Module REC-202: Wind Energy Conversion Systems

(Unit-4) Wind Energy Systems: Environment and Economics

Contents

Wind pumps: Performance analysis, Design concept and standard testing Conditions**,** Principle of wind energy electricity generation; Stand alone, grid connected and hybrid applications of WECS, Wind energy in India; Case studies, Matching supply and demand, Control option, Environmental benefits and problems of wind energy, Economics of wind energy: Factors influencing the cost of energy generation, Life cycle cost analysis.

Wind Water Pumping Systems

Wind Water Pumping by windmills is possibly one of man's earliest inventions with wind energy historically being used for a wide range of applications, ranging from grinding grain to sawing wood, with many other applications as well. But there are millions of people throughout the world who do not have access to clean water for all of their daily needs. In many of these situations, water is only available from wells or aquifers, but to be usable it must first be pumped from those sources.

Stand-alone wind based energy systems are an attractive solution to supplying clean electricity to off-grid consumers in remote locations allowing them to be completely independent from any oil price fluctuations. A typical wind energy stand-alone system comprises of: one or more wind energy turbines with its rated power ranging from a few watts to several kilowatts (for micro, mini and small systems) depending on the electricity demand and the available wind potential, and an appropriate energy storage device, generally a lead–acid battery storage array, that is able to guarantee 10-hours of autonomy for when the wind does not blow.

But as well as supplying large quantities of electricity to charge battery banks, wind turbines can also be used to pump water. The vast majority of wind turbines built in the past have been used for non-electrical applications, and historically, wind water pumps were purely mechanical devices siting high up on top of a wooden tower pumping water for watering livestock, land drainage and irrigation, and as wind turbines do not consume water, it makes them ideal for use in dry or drought-stricken areas.

Nowadays, these mechanically driven water pumps are still a good viable option, but with advances in technology there are also a number of other possible wind energy applications that require shaft power as well. These include: wind-electric water pumps and a conventional wind water pump installed in a hybrid power system.

Design Concept

The most common type of wind operated water pumping system is completely mechanical. A typical wind water pumping system includes:

The wind rotor, a tower, a mechanical pump, mechanical linkage, a well full of water (or other such water source), and piping to deliver the pumped water. Also there may be some form of water storage as well as the wind water pump. For example, a large water tank, pond, or reservoirs may be used for water storage, depending on the application.

The key points to consider in a mechanical wind water pump design includes, designing or selecting the turbine rotor and pump so that the pump size and turbine blade design as well as size, are matched to the total head.

Multi-bladed turbines are available in various diameters ranging from 1.5m up to 5 metres, (6 to 16 feet). Water pump shaft diameters ranging from 20mm to 125mm (3/4″ to 5″) for small scale water pumping.

Matching supply and demand

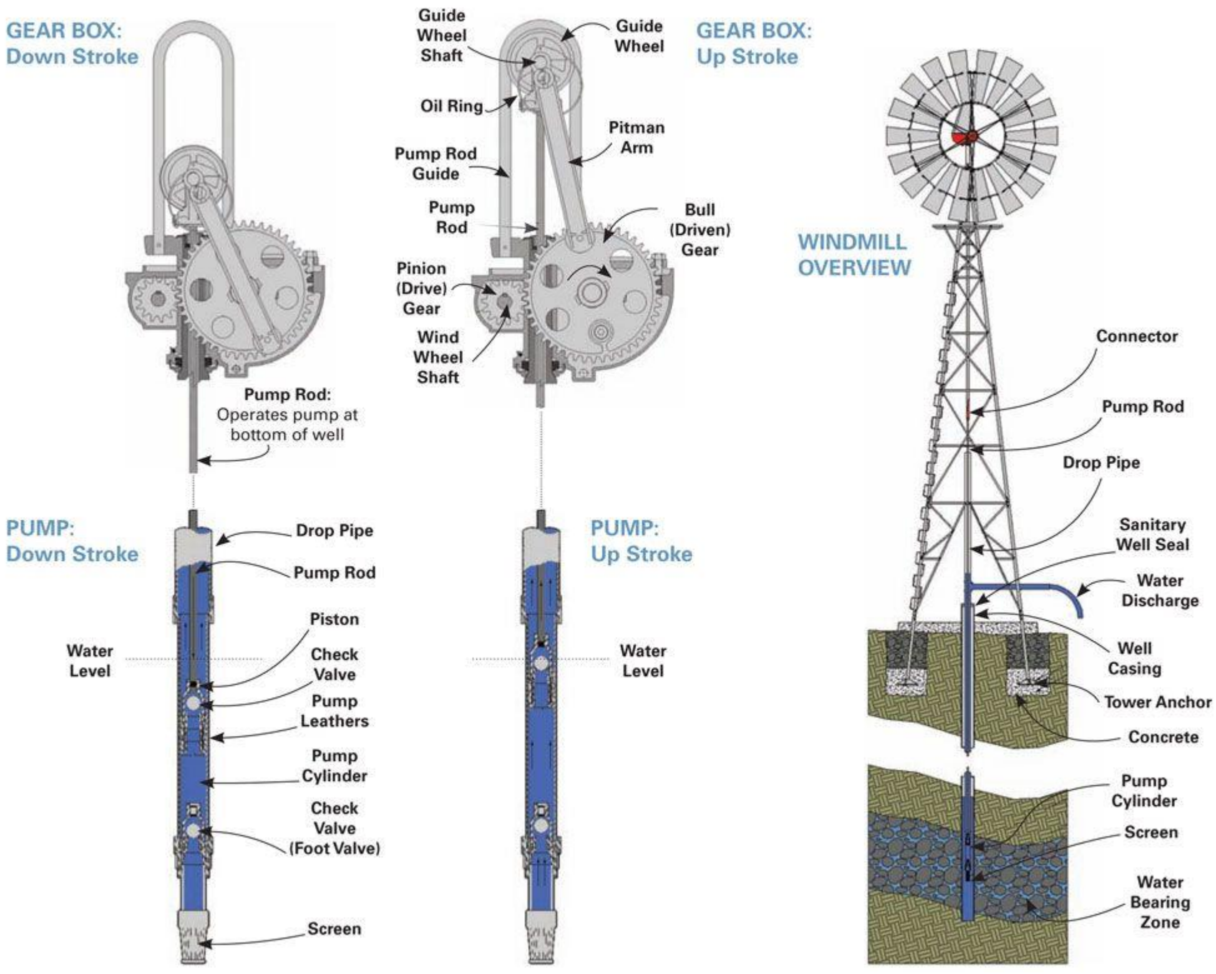
It is important to correctly match the rotor blades to the pump because if we were to put a large diameter water pump on a small diameter turbine over a deepish well, at low wind speed the turbine blades may not be able to produce sufficient torque in order to raise the water to the required level. This mainly due to the fact that the pump acts like a brake up to some very high wind speed where the torque becomes sufficient enough for pumping to occur.

On the other hand, if we were to put a small diameter pump on a turbine with much larger diameter blades, the pump may only supply a small fraction of the required water capacity, when the wind resource is available. Also there is a risk of damaging the pump at high wind speeds.

Then wind water pumping, by its nature, typically requires fairly high torques and low pump operating speeds.

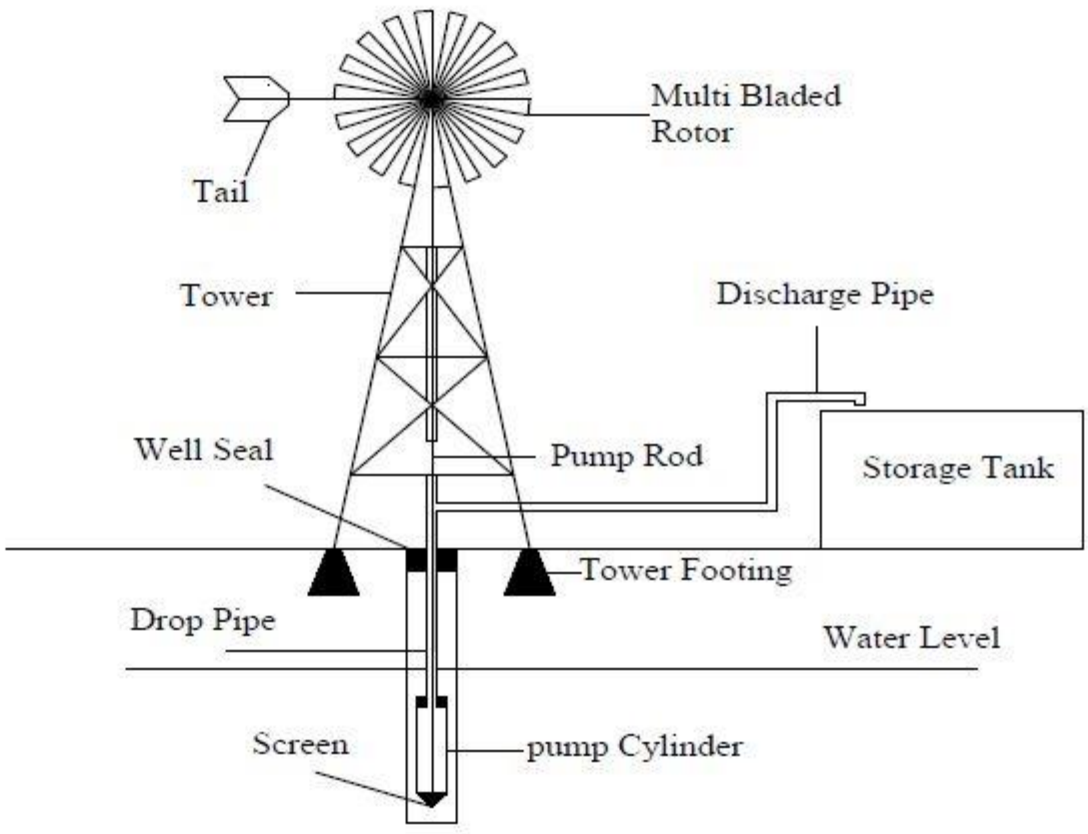
Working

Modern, high tip-speed ratio rotors for generating electrical power have only two or three blades. The conversion of the winds energy into hydraulic energy by a typical wind pumping system requires that the wind speed is greater than about 5-6 mph (9-10 kmph), for pumping to occur. Obviously the force of the wind flowing through the blades of the turbines rotor to lift the water will depend upon the weight of the water being pumped and the speed at which the water flows. Then the weight of the water being lifted and the speed at which the water flows will determine the power that must be delivered by the turbine to the pumping system. A deeper well means a higher head height and a heavier load of water which is why many wind water pumping systems use multi-bladed designs.



The vast majority of wind powered mechanically driven water pumps in operation today is design of reciprocating piston type pumps (Hand Pump).

For a reciprocating piston pump the turbine is connected to a gearbox and crankshaft which converts its rotary motion into reciprocating up-down motion on a pump rod which is connected to a piston in the pump at the bottom of the well pipe.



Wind Water Pumping System

When the piston is lifted by the piston rod, the piston lifts the entire volume of water above it, and the water flows out of a discharge pipe at the top. At the same time, a slight suction or vacuum is formed under the piston, causing water to flow in under the piston refilling the void. During the next half of the cycle, the piston moves down, causing a piston valve to open, and water flows through into the top of the piston ready to be lifted again during the next half-cycle. The volume of water displaced during each stroke depends upon the piston diameter, which is the same as the diameter of the inside of the cylinder and the length of the stroke. This up-down motion of the piston pump means that the flow of water is not constant but will be inherently pulsating due to this reciprocal action.

Principle of wind energy electricity generation

It is defined as the system in which the kinetic energy of the wind is converted to mechanical energy which in turn is used to generate electrical energy. The machines which are used to convert the kinetic energy of the wind into mechanical energy usually consist of sails, vanes or blades radiating from the hub or the central axis. The axis can be horizontal in most of the cases or vertical in some cases. When the wind hits the blade it rotates around the axis and the motion of the blades can be put to useful work .The devices which are used in wind conversion system are known as wind turbines because they convert the kinetic energy of the wind into the rotational energy and the device used for this is known as rotor. These wind turbines are connected to electrical generator to the required electrical energy and the connection of these two devices is known as aero generator. A transmission system is usually used to increase the speed of the rotor with the help of gear system.

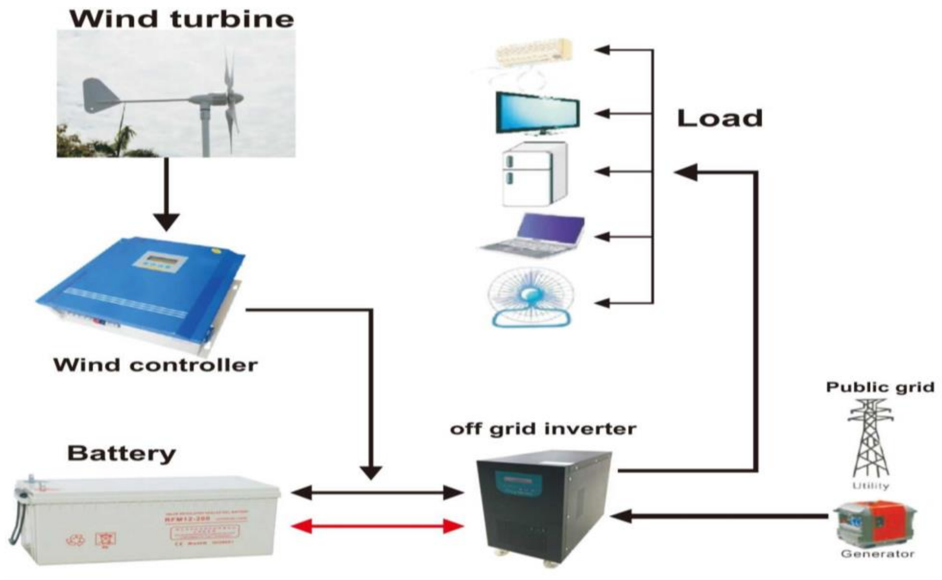
One single wind turbine may not be able to produce the desired level of electricity. Hence, numbers wind turbines are connected together to obtain the desired output. This assembly of wind turbines together is called a wind farm. We must choose the place for constructing a wind farm where the wind speed is sufficient to move the blade of the turbine. When the wind blows through the blades of a turbine, the turbine rotates to run a generator to produce electricity. This electricity flows down through the cable attached to the turbine tower. This cable is also interconnected with cables from other wind turbines in the wind farm.

Hence, electricity from all wind turbines comes to a common node from where it is taken for further ends. After all, this electricity is used directly for domestic or industrial load or is drawn by any grid to fulfill the requirement of electricity.

Wind Energy Conversion System has an application as: Stand-Alone, Grid Connected and Hybrid:

Stand-Alone WECS:

Stand-alone systems (systems not connected to the utility grid) require batteries to store excess power generated for use when the wind is calm. They also need a charge controller to keep the batteries from overcharging. Deep-cycle batteries, such as those used for golf carts, can discharge and recharge 80% of their capacity hundreds of times, which makes them a good option for remote renewable energy systems. Automotive batteries are shallow-cycle batteries and should not be used in renewable energy systems because of their short life in deep-cycling operations.



Stand-Alone WECS

Small wind turbines generate direct current (DC) electricity. In very small systems, DC appliances operate directly off the batteries. If we want to use standard appliances that use conventional household alternating current (AC), must install an inverter to convert DC electricity from the batteries to AC. Although the inverter slightly lowers the overall efficiency of the system, it allows the home to be wired for AC, a definite plus with lenders, electrical code officials, and future homebuyers.

For safety, batteries should be isolated from living areas and electronics because they contain corrosive and explosive substances. Lead-acid batteries also require protection from temperature extremes.

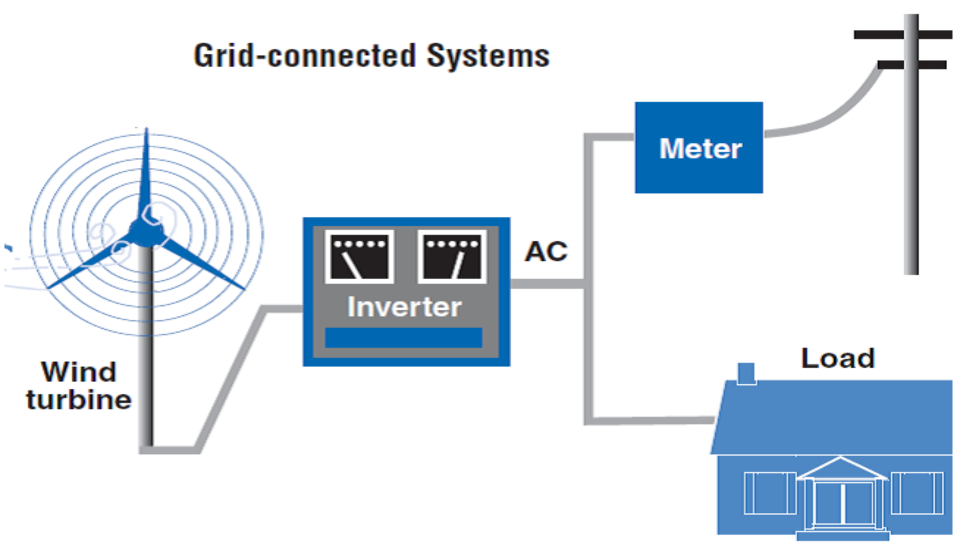
Grid-Connected WECS

Grid-connected systems, the only additional equipment required is a power conditioning unit (inverter) that makes the turbine output electrically compatible with the utility grid. Batteries are usually not required.

Small wind energy systems can be connected to the electricity distribution system. A grid-connected wind turbine can reduce consumption of utility-supplied electricity for lighting, appliances, and electric heat. If the turbine cannot deliver the amount of energy we need, the utility makes up the difference. When the wind system produces more electricity than the household requires, the excess is sent or sold to the utility. These arrangements with the utility company are typically called net metering or net billing, and they address the value of the electricity sold or net excess generation, the time period for valuing the electricity (typically annually or monthly), and any other contractual requirements with the utility.

Grid-connected systems can be practical if the following conditions exist:

- An area with average annual wind speed of at least 10 mph (4.5 m/s).
- Utility-supplied electricity is expensive in that area (about 10 to 15 cents per kilowatt-hour).
- The utility's requirements for connecting system to its grid are not prohibitively expensive.
- There are good incentives for the sale of excess electricity, sale of the renewable energy credit, and/or for the purchase of wind turbines.



A grid-connected wind turbine can reduce your consumption of utility-supplied electricity

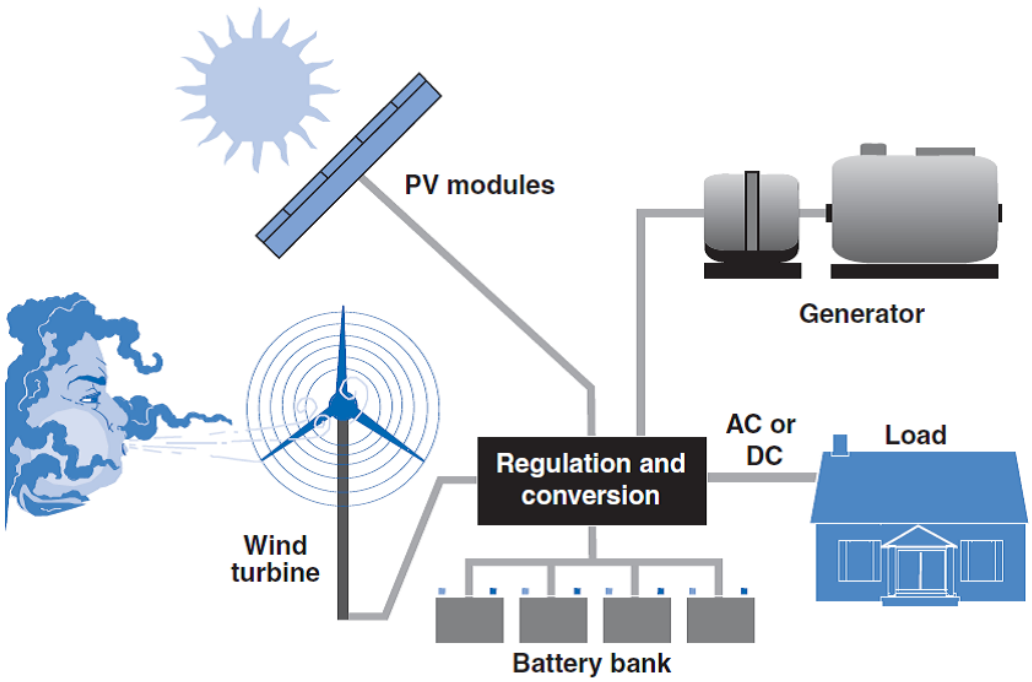
Net Metering

Net metering programs are designed to allow the electric meters of customers with generating facilities to "turn backwards" when their generators are producing more energy than the customers' demand. Net metering allows customers to use their generation to offset their consumption over the entire billing period, not just instantaneously. This offset would enable customers with generating facilities to receive retail prices for more of the electricity they generate.

Net metering varies by state and by utility company, depending on whether net metering was legislated or directed by the Public Utility Commission. Net metering programs specify a way to handle the net excess generation (NEG) in terms of payment for electricity and/or length of time allowed for NEG credit. If the net metering requirements define NEG on a monthly basis, consumers can only receive credit for their excess that month. But if the net metering rules allow for annual NEG, the NEG credit can be carried for up to a year. For people using wind energy to displace a large load in the summer (like air conditioning or irrigation water pumping), having an annual NEG credit allows them to produce NEG in the winter and receive credits in the summer.

Hybrid WECS

Hybrid wind energy systems can provide reliable off-grid power for homes, farms, or even entire communities (for example: a co-housing project) that are far from the nearest utility lines. According to many renewable energy experts, a "hybrid" system that combines wind and photovoltaic (PV) technologies offers several advantages over either single system. In much of the United States, wind speeds are low in the summer when the sun shines brightest and longest. The wind is strong in the winter when less sunlight is available and may be stronger at night compared to the day. Because the peak operating times for wind and PV occur at different times of the day and year, hybrid systems are more likely to produce power when you need it.



Hybrid WECS

For the times when neither the wind turbine nor the PV modules are producing, most hybrid systems provide power through batteries and/or an engine-generator powered by conventional fuels such as diesel. If the batteries run low, the engine-generator can provide power and recharge the batteries. Adding an engine-generator makes the system more complex, but modern electronic controllers can operate these systems automatically. An engine-generator can also reduce the size of the other components needed for the system. Keep in mind that the storage capacity must be large enough to supply electrical needs during non-charging periods. Battery banks are typically sized to supply the electric load for 1 to 3 days.

An off-grid hybrid system may be practical for you if:

- An area with an average annual wind speed of at least 9 mph (4 m/s).
- A grid connection is not available or can only be made through an expensive extension. The cost of running a power line to a remote site to connect with the utility grid can be prohibitive, depending on terrain.
- To gain energy independence from the utility.
- To generate clean power.

Environmental Benefits and Problems of Wind Energy

Environmental Impacts of Wind Energy

Operation of wind power has zero emissions of harmful substances. It does not add to global warming, the “fuel” is free, and is quite evenly distributed around the world. But, as with other sources of energy, wind power does have an environmental impact. The impact on wildlife is likely low compared to other forms of human and industrial activity. However, negative impacts on certain populations of sensitive species are possible, and efforts to mitigate these effects should be considered in the planning phase. Wind energy, like any other industrial activity, may cause impacts on the environment which should be analyzed and mitigated.

Environmental Benefits

Wind energy do not cause water or air emissions, and do not produce any kind of hazardous waste as well. Moreover, wind power does not make use of natural resources like oil, gas or cause and therefore will not cause damage to the environment through resource transportation and extraction and also do not need consequent amounts of water during operation.

Wind energy is not only a favorable electricity generation technology that reduces emissions (of other pollutants as well as CO2, SO2 and NO_x), it also avoids significant amounts of external costs of conventional fossil fuel-based electricity generation.

More and more use of wind energy should be made in order to prevent the problem of global warming.

Wind energy plants are considered a green power technology because it has only minor impacts on the environment. Wind energy plants produce no air pollutants or greenhouse gases.

Wind energy is an ideal renewable energy because:

• It is a pollution-free, infinitely sustainable form of energy

• It doesn't require fuel

• It doesn't create greenhouse gases

• It doesn't produce toxic or radioactive waste.

Environmental Problems

Any means of energy production impacts the environment in some way, and wind energy is no different. Like every other energy technology, wind power plants do have some effects on the environment. Wind turbines cause virtually no emissions during their operation and very little during their manufacture, installation, maintenance and removal. Compared to the environmental impact of traditional energy sources, the environmental impact of wind power is relatively minor.

Wind farms are often built on land that has already been impacted by land clearing. The vegetation clearing and ground disturbance required for wind farms is minimal compared with coal mines and coal-fired power stations. If wind farms are decommissioned, the landscape can be returned to its previous condition.

The major challenge to using wind as a source of power is that the wind is intermittent and it does not always blow when electricity is needed. Wind energy cannot be stored (unless batteries are used); and not all winds can be harnessed to meet the timing of electricity demands. Good wind sites are often located in remote locations, far from cities where the electricity is needed. Wind resource development may compete with other uses for the land and those alternative uses may be more highly valued than electricity generation. Although wind power plants have relatively little impact on the environment compared to other conventional power plants, there is some concern over the noise produced by the rotor blades, aesthetic (visual) impacts, and sometimes birds have been killed by flying into the rotors. Most of these problems have been resolved or greatly reduced through technological development or by properly sitting wind plants.

Economics of Wind Energy:

The wind turbine is the most expensive component of most wind farms. The indicative cost breakdowns for a large offshore wind turbine are given below. The reality is that a range of costs exists, depending on the country, maturity of the wind industry in that country and project specifics. The two most expensive components are the towers and rotor blades, with these contributing around half of the total cost. After these two components, the next largest cost component is the gearbox. But this underestimates the importance of gearboxes, as these generally are an important part of the Operations and Maintenance (O&M) costs, as they can require extensive maintenance. Onshore wind turbines, with their smaller sizes, will tend to have slightly lower shares for the tower and blades.

Tower 26.3% Range in height from 40 metres up to more than 100 m. usually manufactured in sections from rolled steel; a lattice structure or concrete are cheaper options.

Rotor blades 22.2% Varying in length up to more than 60 metres, blades are manufactured in specially designed moulds from composite materials, usually a combination of glass fibre and epoxy resin. Options include polyester instead of epoxy and the addition of carbon fibre to add strength and stiffness.

Rotor hub 1.37% Made from cast iron, the hub holds the blades in position as they turn.

Rotor bearings 1.22% Some of the many different bearings in a turbine, these have to withstand the varying forces and loads generated by the wind.

Main shaft 1.91% Transfers the rotational force of the rotor to the gearbox.

Main frame 2.80% Made from steel, must be strong enough to support the entire turbine drive train, but not too heavy.

Gearbox 12.91% Gears increase the low rotational speed of the rotor shaft in several stages to the high speed needed to drive the generator.

Generator 3.44% Converts mechanical energy into electrical energy. Both synchronous and asynchronous generators are used.

Yaw system 1.25% Mechanism that rotates the nacelle to face the changing wind direction.

Pitch system 2.66% Adjusts the angle of the blades to make best use of the prevailing wind.

Power converter 5.01% Converts direct current from the generator into alternating current to be exported to the grid network.

Transformer 3.59% Converts the electricity from the turbine to higher voltage required by the grid.

Brake system 1.32% Disc brakes bring the turbine to a halt when required.

Nacelle housing 1.35% Lightweight glass fibre box covers the turbine's drive train.

Cables 0.96% Link individual turbines in a wind farm to an electricity sub-station.

Screws 1.04% Hold the main components in place, must be designed for extreme loads.

Factors Influencing the Cost of Energy Generation

The economics of wind energy have changed dramatically over the past twenty years, as the cost of wind power has fallen approximately 90 percent during that period. Despite that progress, the wind industry is still somewhat immature, with production volumes that lesser in comparison to what they will be two decades from now. Thus, the factors affecting the cost of wind energy are still rapidly changing, and wind energy's costs will continue to decline as the industry grows and matures.

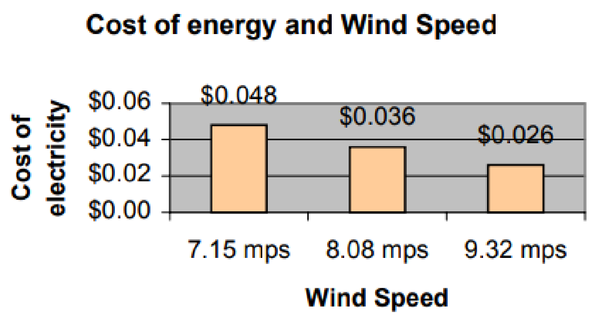
A number of factors determine the economics of utility-scale wind energy and its competitiveness in the energy marketplace.

1. The cost of wind energy varies widely depending upon the wind speed at a given project site: The energy that can be tapped from the wind is proportional to the cube of the wind speed, so a slight increase in wind speed results in a large increase in electricity generation.

Consider two sites, one with an average wind speed of 22.50 kilometer per hour (kmph) and the other with average winds of 25.75 kmph. All other things being equal, a wind turbine at the second site will generate nearly 50% more electricity than it would at the first location.

$$P_{available} = \frac{1}{2}\rho A V_i^3$$

$$P_{available} \propto V_i^3$$



mps = miles per hour

2. Improvements in turbine design bring down costs: The taller the turbine tower and the larger the area swept by the blades, the more powerful and productive the turbine. The swept area of a turbine rotor (a circle) is a function of the square of the blade length (the circle's diameter).

$$P_{available} = \frac{1}{2}\rho A V_i^3$$

$$P_{available} \propto A$$

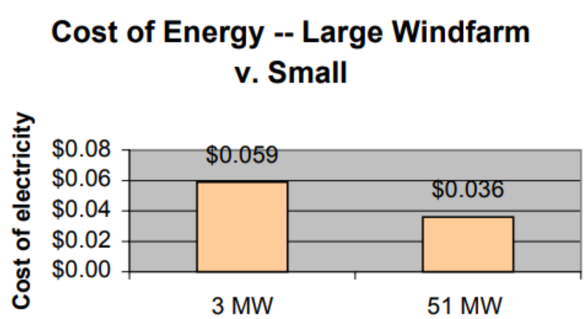
$$P_{available} \propto D^2$$

Therefore, a 5-times increase in rotor diameter (from 10 meters on a 25-kW turbine like those built in the 1980s to 50 meters on a 750-kW turbine common today) yields a 55-times increase in yearly electricity output, partly because the swept area is 25 times larger and partly because the tower height has increased substantially, and wind speeds increase with distance from the ground.

Advances in electronic monitoring and controls, blade design, and other features have also contributed to a drop in cost. The following table shows how a modern 1650-KW turbine generates 120 times the electricity at 20 times the cost of an older 25kW-turbine:

	1981	2000
Rated Capacity	1981: 25 kW	2000: 1,650 kW
Rotor Diameter	10 meters	71 meters
Total Cost ($000)	$65	$1,300
Cost per kW	$2,600	$790
Output, kWh/year	45,000	5.6 million

3. A large wind farm is more economical than a small one: Assuming the same average wind speed of 29 kmph and identical wind turbine sizes, a 3–MW wind project delivers electricity at a cost of $0.059 per kWh and a 51-MW project delivers electricity at $0.036 per kWh—a drop in costs of $0.023, or nearly 40%. Any project has transaction costs that can be spread over more kilowatt-hours with a larger project. Similarly, a larger project has lower O&M (operations and maintenance) costs per kilowatt-hour because of the efficiencies of managing a larger wind farm.



4. Transmission, tax, environmental, and other policies also affect the economics of wind: Transmission and market access constraints can significantly affect the cost of wind energy. Since wind speeds vary, wind plant operators cannot perfectly predict the amount of electricity they will be delivering to transmission lines in a given hour. Deviations from schedule are often penalized without regard to whether they increase or decrease system costs. Interconnection procedures are not standardized, and utilities have on occasion imposed such difficult and burdensome requirement on wind plants for connection to transmission lines that wind companies have chosen to build their own lines instead.

As electricity markets are restructured and long-term power purchase agreements give way to trading on power exchanges, transmission and market access conditions will play an increasingly important role in the economics of a wind project.

The federal tax code, which provides a variety of permanent and temporary incentives for conventional forms of energy, also includes a production tax credit (PTC) for wind energy and a 5-year accelerated depreciation schedule for wind turbines. The 70 Rupees-per-kWh PTC is adjusted for inflation (currently it stands at 80 Rupees/kWh) and supports electricity generated from utility-scale wind turbines for the first ten years of their operation. The PTC, first adopted in 1992, was extended in 1999, and again, after its expiration in 2001, until December 31, 2003. In order to qualify for the credit, generators must now complete installations and start production before the 2003 expiration date. . The PTC may be reduced or cancelled if a project applies for state incentives such as a grant or no-interest loan, under federal "anti-double-dipping" rules.

The PTC, a key incentive, helps level the economic playing field for wind projects in energy markets where other forms of energy are also subsidized. It must be noted, however, that the current “on-again, off-again” status of the credit is hobbling project development and the industry as a whole. Uncertainty also affects relationships with vendors and substantially increases costs as orders are rushed to meet PTC deadlines or as planning grinds to a halt and income is lost while the industry awaits an extension. One major U.S. developer stated that a five-year extension of the PTC would provide enough long-term certainty to squeeze an additional 25 percent out of vendor costs. The wind energy industry is currently seeking a longer-term extension, until 2006.

Stricter environmental regulations enhance wind energy’s competitiveness. Wind power’s environmental impact per unit of electricity generated is much lower than that of mainstream forms of electricity generation, as wind energy neither emits pollutants, wastes, or greenhouse gases, nor damages the environment through resource extraction. The higher the air quality and other environmental standards adopted in a country, the more competitive wind energy therefore becomes in the marketplace. Conversely, a relaxation of standards or failure to internalize environmental costs through pollution charges or other processes makes polluting forms of electricity generation appear deceptively cheap. This is an important economic issue, because the hidden "subsidy" that governments and markets give to polluting energy sources by partially or fully ignoring their health and environmental costs is typically much larger than direct subsidies to such energy sources.

Wind energy provides ancillary economic benefits:

- Less dependence on fossil fuels, which can be subject to rapid price fluctuations and supply problems (the price of natural gas, for example, more than doubled over a period of a few months in 2000);
- Steady income for farmers or ranchers who own the land on which wind farms are built, and for the communities in which they live (in Texas, for example, ranchers have been reaping income from the wind even as their royalties from oil wells have declined);
- An increase in the property tax base for rural counties.

Life Cycle Cost Analysis

The life cycle cost analysis is done with the following assumptions -

i. The analysis period of the project is taken as 20 years.

ii. The rate of interest is considered as 8%.

iii. The plant load factor is taken as moderate i.e. 22.5%, which is the usual practice for turbines of 5 kW rating.

iv. Maintenance cost of small turbines is negligible and hence not taken into account, however provision of one mechanic and one helper at the monthly wage of Rs.8000.00 is considered for the maintenance of system.

v. The life of battery is considered as 5 years i.e. in the entire analysis period the batteries are placed three times.

vi. Maintenance cost of battery is taken as 10% of cost of capital cost.

vii. Residual value of battery is taken as 20% of original cost.

The residual value of turbines installed at first phase is considered as 20%, correspondingly the residual value of turbines in second, third and fourth installation is taken as 30%, 40%, and 50% of capital cost of turbine.

The cash flow diagram with the above stated assumptions is shown in the Figure:

Table-1 shows the demand for household and forcasted value for the period of 5 years.

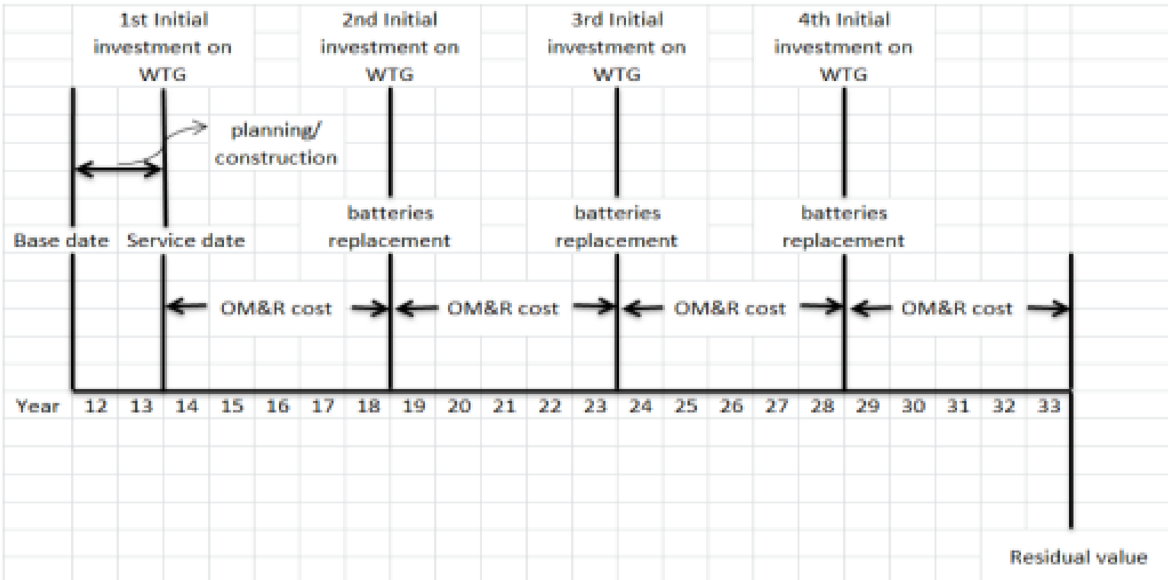


Fig: Cash Flow Diagram

Table-1: Demand Calculations

Description	Lane 1	Lane 2	Lane 3	Lane 4	Lane 5	Lane 6	Lane 7	Lane 8	Lane 9	Lane 10	
Housewise daily consumption in units		0.07	0.07	1.13	1.57	0.53	1.87	4.77	3.07		
		0.07	0.07	1.43	1.27	0.57	1.50	0.97	3.40		
		0.17	2.00	1.37	0.27	1.30	0.80	1.00	3.87		
				1.30	0.30	1.30	0.93	1.07	4.17		
				1.13	0.37	0.60	0.67	1.07			
				1.13	0.27	0.53	0.07	2.07			
					0.3	1.67	0.93	2.10			
					0.43	1.40	0.83	2.23			
					0.53	1.60	1.63	1.13			
					0.57	0.63	1.50	1.13			
					1.37	0.73	1.77	1.13			
					1.57	0.73	1.80	1.13			
					1.7	0.70		2.37			
Actual	0.00	0.31	2.14	7.49	10.52	12.29	14.30	22.17	14.51	0.00	
Facilitated	2.10	0.00	0.00	1.20	0.00	0.00	0.00	0.00	0.00	4.65	
Total	2.10	0.31	2.14	8.69	10.52	12.29	14.3	22.17	14.51	4.65	
Transmission Losses @ 5%	0.105	0.016	0.107	0.435	0.526	0.615	0.715	1.11	0.73	0.23	
Total Consumption/ Day	2.21	0.33	2.25	9.125	11.046	12.90	15.015	23.28	15.24	4.88	
Total Consumption/ Month	66.15	9.77	67.41	273.74	331.38	387.14	450.45	698.35	457.07	146.48	
Total Consumption in 2012	793.80	117.18	808.92	3284.82	3976.56	4645.62	5405.4	8380.26	5484.78	1757.70	34655.04
Forecasted Consumption (2017)	1270.08	187.49	1294.27	5255.71	6362.50	7433.00	8648.64	13408.42	8775.65	2812.32	55448.06
Forecasted Consumption (2022)	1801.93	265.00	1836.25	7456.54	9026.79	10545.56	12270.26	19023.19	12450.45	3989.98	78666.94
Forecasted Consumption (2027)	2381.40	351.54	2426.76	9854.46	11929.68	13936.86	16216.2	25140.78	16454.34	5273.10	103965.10
Forecasted Consumption (2032)	2794.18	412.47	2847.40	11562.57	13997.49	16352.58	19027.01	29498.52	19306.43	6187.11	121985.70

Life Cycle Cost Analysis of Small wind Power Generation–A Case Study

The cost of items appearing in the analysis period of 20 years and the residual values of items at the end of the analysis period is given in Table - 2. Life cycle cost analysis for analysis period 20 years and depreciation @ 8% and the unit cost of electricity produced is calculated in four phases of analysis period of the project, is shown in Table – 3.

Table -2: Life Cycle Cost Estimation

Sr No	Description	Unit Cost	Unit	Quantity	Cost
		Rs			Rs
Initial investment cost					
1	First installation of turbines (5KW)	508000.00	NO.	6	3048000.00
2	Second installation of turbines (5KW)	508000.00	NO.	2	1016000.00
3	Third installation of turbines (5KW)	508000.00	NO.	3	1524000.00
4	Forth installation of turbines (5KW)	508000.00	NO.	2	1016000.00
5	Batteries required in First installation	9000.00	NO.	60	540000.00
6	Batteries required in second installation	9000.00	NO.	20	180000.00
7	Batteries required in third installation	9000.00	NO.	30	270000.00
8	Batteries required in forth installation	9000.00	NO.	20	180000.00
9	Cable(with labour cost) at first installation	62.00	NO.	1500	93150.00
10	Sub meter (with labour cost) at first installation	1525.00	NO.	120	183000.00
Capital Replacement of Batteries					
11	After 5 years	7200.00	NO.	60	432000.00
12	After 10 years	7200.00	NO.	80	576000.00
13	After 15 years	7200.00	NO.	110	792000.00
Operation, Maintenance & Repair Cost					
14	Batteries maintenance first five years from first Installation	900.00	NO.	60	54000.00
15	Batteries maintenance 5 years after second installation	900.00	NO.	80	72000.00
16	Batteries maintenance 5 years after third installation	900.00	NO.	110	99000.00
17	Batteries maintenance 5 years after forth installation	900.00	NO.	130	117000.00
18	Salary of mechanic	5000.00	MONTH	12 months	60000.00
19	Salary of helper	3000.00	MONTH	12 months	36000.00
Residual value					
20	20 % of turbine cost for first installation	101600.00	NO.	6	609600.00
21	30 % of turbine cost for second installation	152400.00	NO.	2	304800.00
22	40 % of turbine cost for third installation	203200.00	NO.	3	609600.00
23	50 % of turbine cost for forth installation	254000.00	NO.	2	508000.00
24	Batteries	1800.00	NO.	130	234000.00
Residual Value at the end of Analysis Period					**2266000.00**

Table -3: Life Cycle Cost Analysis for Analysis Period 20 Years and Depreciation @ 8%

Year	CC (WTG)	CC(BATTERY)	RC (BATTERY)	TCC	EACCF	EACC(2)	EACC(7)	EACC(12)	EACC(17)	AO&MC	ALCC(GROSS)	ALCV	ALCC(NET)	APGC	UNIT COST
	(Rs)	(Rs)	(Rs)	(Rs)		(Rs)	(Rs)	(Rs)	(Rs)	(Rs)	(Rs)	(Rs)	(Rs)	(kWh)	(Rs)
0															
1															
2	3048000.00	540000.00		3588000.00	0.1019	365445.73				150000.00	515445.73	-230797.11	284648.62		
3						365445.73				150000.00	515445.73	-230797.11	284648.62		
4						365445.73				150000.00	515445.73	-230797.11	284648.62	59130	4.81
5						365445.73				150000.00	515445.73	-230797.11	284648.62		
6						365445.73				150000.00	515445.73	-230797.11	492847.12		
7	1016000.00	180000.00	432000.00	1628000.00	0.1168	365445.73	190198.50			168000.00	723644.22	-230797.11	492847.12		
8						365445.73	190198.50			168000.00	723644.22	-230797.11	492847.12		
9						365445.73	190198.50			168000.00	723644.22	-230797.11	492847.12	78840	6.25
10						365445.73	190198.50			168000.00	723644.22	-230797.11	492847.12		
11						365445.73	190198.50			168000.00	723644.22	-230797.11	492847.12		
12	1524000.00	270000.00	576000.00	2370000.00	0.1490	365445.73	190198.50	353199.89		195000.00	1103844.11	-230797.11	873047.01		
13						365445.73	190198.50	353199.89		195000.00	1103844.11	-230797.11	873047.01		
14						365445.73	190198.50	353199.89		195000.00	1103844.11	-230797.11	873047.01	108405	8.05
15						365445.73	190198.50	353199.89		195000.00	1103844.11	-230797.11	873047.01		
16						365445.73	190198.50	353199.89		195000.00	1103844.11	-230797.11	1388954.44		
17	1016000.00	180000.00	792000.00	1988000.00	0.2505	365445.73	190198.50	353199.89	497907.43	213000.00	1619751.54	-230797.11	1388954.44		
18						365445.73	190198.50	353199.89	497907.43	213000.00	1619751.54	-230797.11	1388954.44		
19						365445.73	190198.50	353199.89	497907.43	213000.00	1619751.54	-230797.11	1388954.44	128115	10.84
20						365445.73	190198.50	353199.89	497907.43	213000.00	1619751.54	-230797.11	1388954.44		
21						365445.73	190198.50	353199.89	497907.43	213000.00	1619751.54	-230797.11	1388954.44		
22	RESIDUAL VALUE OF WT & BATTERIES			2266000.00											

CC- Capital Cost, **WTG**- Wind Turbine, **BATT**- Battery, **RC**- Replacement Cost, **TCC**- Total Capital Coat, **EACCF**- Equivalent Annual Capital Cost Factor, **EACC**- Equivalent Annual Capital Cost, **AO&MC**- Annual Operation & Maintenance Cost, **ALCC**- Annual Life Cycle Cost, **ALCRV**- Annual Life Cycle Residual Value, **APGC**- Annual Power Generation Capacity.

Note: Case Study on Life Cycle Cost Analysis of any wind Power Generation Plant in India.