Technical and Financial Feasibility for Small Scale Wind Turbines in Urban Areas of Jaipur

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Abstract:- **Wind energy is one of the most abundant renewable energy resources on the earth and has been targeted for centuries. Interest among general people is increasing for adopting Renewable energy technologies for energy generation, due to various reasons including depleting energy sources, saving in energy bills, investment subsidies, net metering and other government policies supporting renewable energy sources. There is a great need to generate environment friendly energy and adopt the alternative or renewable energy sources for not only to increases energy efficiency but also to promote sustainable development. This paper discusses the small-scale building level application of Wind energy system with this technical and financial feasibility. Energy consumption in residential buildings is increasing day by day due to extensive use of HVAC and other electrical equipment for more comfort with changing lifestyle. In this study, a sample survey of about 60 Household is conducted in the old city of Jaipur and after analyzing their energy; consumption suitable Wind turbine system capacity is calculated with their costing and payback period. The main objective of this article is to present the financial feasibility of Small-scale wind turbine systems. The study concluded that thought initial cost of the wind energy system is very high but if we consider its long-term feasibility & the payback period with net metering and Govt. incentives, it is a viable option.**

Keywords**: Renewable energy, Wind Energy, Wind turbines, Energy efficiency, Sustainable development**

I. INTRODUCTION

This article is about wind energy application in urban areas. The main renewable energy sources are solar energy, wind energy, hydro energy, geothermal energy and Biomass energy. Out of all these solar energy and wind energy are being used from ancient times. Though wind energy system are less developed than solar system. Wind is air in motion formed due to the Earth's rotation and the uneven heating of Earth's surface by sunrays. Wind is an infinite, natural, and restorable source and a popular form of non-conventional energy. Conventionally, it is utilized for drawing water, which is an essential requirement in watering agricultural lands in the rural areas. The commercial use of wind energy for electrical power generation started in 1970s. Presently, it can be utilized for electricity generation.

Wind speed is the key determinant of power, Hence performance of wind turbines depends on their location, time and direction. Wind speeds vary in nature and the annual mean speed of one year may differ significantly to that of the next. Hence, to calculate the wind speed of a site, its long-term annual mean wind speed, averaged over several decades shall be accounted.

Wind has emerged as the most promising renewable energy source for India as well as Rajasthan. The gross wind energy potential in the Rajasthan is about 5400 MW out of which 1825.995 MW wind power capacity already existing.

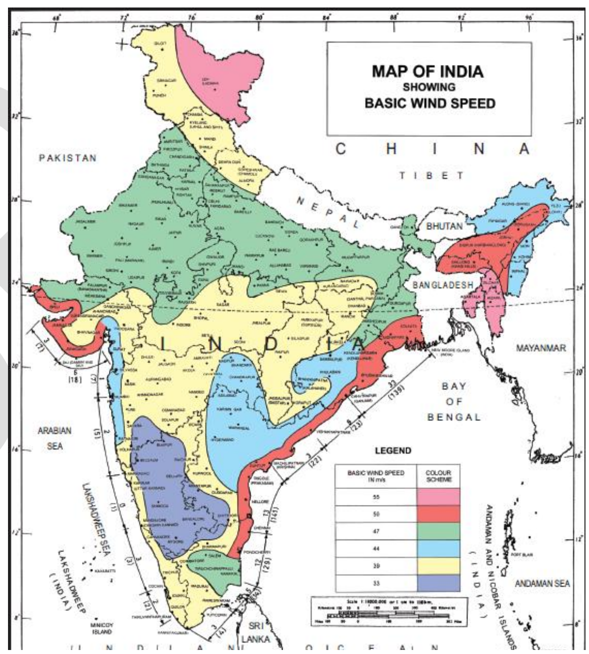

Figure 1Basic wind speed map of India [12]

The Basic wind speed map of India shows that the wind speed all over India ranges from 33 m/S to 55 M/s while in Rajasthan the basic wind speed is 47M/s. Hence, For Jaipur also Basic wind speed is 47m/s As per National Building codes. Rajasthan is India's leading state for tapping energy from wind resources.

II. WIND TURBINES

A wind turbine is a system, which transforms the kinetic energy available in the wind into mechanical or electrical energy to use for any required applications including water pumping and to utilize locally or transport to the electric grid. Wind turbines convert the kinetic energy of the moving wind into electricity. Two wind laws govern the energy generated by wind turbines:

- Power generated is proportional to wind speed cubed. Doubling the wind speed gives eight times the power. Therefore wind speed at the turbine location is very important; and
- Power generated is proportional to the swept area of the blades. Doubling the rotor diameter yields a fourfold increase in swept area with a corresponding increase in power generation.

Wind speeds increase with height above ground, so the higher a turbine is mounted, the greater the power that can be generated. Obstacles such as buildings and trees can cause sheltering and turbulence, depending on their distances to the turbine and relative heights. However, New Technologies can overcome wind turbulence and noise problems in urban use.

Types of Wind Turbines

There are mainly two types of turbines based on their axis of rotation, first is **Horizontal Axis Wind Turbines (HAWT),** in which the axis of rotation is vertical with respect to the ground and almost perpendicular to the wind stream. Second is **Vertical Axis Wind Turbines (VAWT),** in which the axis of rotation is horizontal with respect to the ground and parallel to the wind stream.

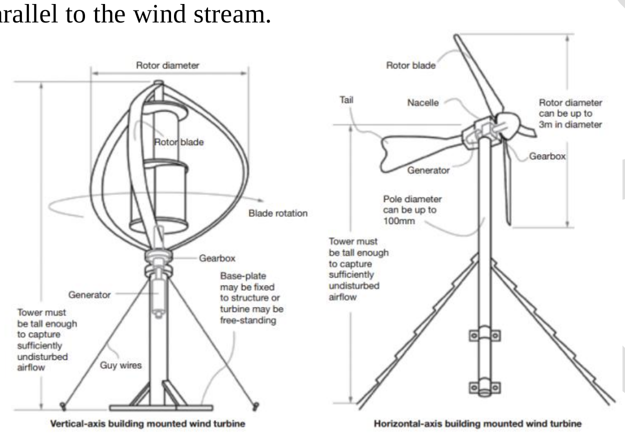

Figure 2 Components of Roof mounted Horizontal and vertical axis wind turbines [6]

Horizontal axis wind turbines are most common for power generation, although design of some vertical axis wind turbine has been developed and tested. The vertical axis turbines have structural as well as aerodynamic limitations hence, are not commercially used. The wind power generation is simple conversion of kinetic energy in the wind into electrical energy. However, the mechanism to capture, transmit, and convert the energy into electrical energy involves several stages, components, and controls.

Technology and Components of wind turbines

Basic Components of wind turbines includes Tower, Rotor Hub, Rotor Blades, Shafts, Gear Box, Brake, Generator, Controller, Nacelle, Pitch, Wind vane, Yaw drive, Anemometer or sensor and Batteries for energy storage etc. Batteries have been used for stand-alone renewable energy systems for many decades. New developments mean they can be included in grid-connected renewable energy systems as well, with the use of advanced inverters. Lead-acid batteries, traditionally used for storage, require careful management; abuse, such as repeatedly discharging them beyond around half charge, can dramatically shorten their lives. While lead-acid batteries are improving, emerging alternatives, including lithium ion batteries (as used in many electric vehicles) are becoming cheaper and better. Given the rapid rate of change in this area, consult experts when considering battery purchases.

However, New Technologies can overcome wind turbulence and noise problems in urban use. There are mainly four type of system for connecting the electrical energy received from renewable energy source to the electrical system, Direct Connection, Off-grid system, Grid Interactive system and hybrid system.

Basic components of Horizontal and vertical axis wind turbines are same except yaw mechanism. However, the major difference lies in the shape and structure of components and its installation.

Table 1 Comparison between HAWT and VAWT

Component/Feature	**Horizontal Axis Wind Turbines**	**Vertical Axis Wind Turbines**	**Remarks**
Axis of Rotation	Horizontal Axis of Rotation the blades move horizontally, i.e., perpendicular to the wind and they receive power throughout the rotation due to minimum drag	Vertical axis of rotation In VAWT's, additional drag is produced due to vertical rotation of blades	VAWTs' have lower efficiency as compared to HAWTs' due to additional drag
Wind Direction	Needs to be Pointed into the wind as Air strikes from one direction only. Does not cope well with frequently changing wind direction	Need not to be pointed into the wind as Air strikes from both directions and, can turn regardless of the direction of the wind. Not affected with Wind direction, less sensitive to turbulence as compared to HAWT	Suitable for Urban areas having variable wind speed/ direction and turbulence
Location/ Tower	It needs to be installed on high tower to get access to higher wind speed in heights	Tower structure is not compulsory as it is mounted closer to the ground. VAWT's are often installed on a relatively flat piece of land, nearer to the base on which they rest, such as the ground or a building rooftop.	It can be installed on building rooftops on small scale Cost of VAWT's are reduced as compared to HAWT as tower is not needed.
Rotor/ Hub /Blades /Shaft	Main rotor shaft and electrical generator at the top of tower, In HAWT there is single hub at rotor	Main rotor shaft arranged vertically as the Blades are vertical In VAWT's there are two hubs upper and lower	VAWT's are Advantageous for the sites where the wind direction is highly variable or

		because blades are attached at two points.	has turbulent winds.
Pitch/Yaw Mechanism	HAWT's have Variable blade pitch, which gives the turbine blades the optimum angle of attack. By Changing the angle of attack towards wind generation can be maximized. But this needs an additional yaw control mechanism to turn the blades toward the wind.	As the rotor blades are vertical, a yaw device is not needed,	Reducing the need for yaw mechanism reduces the cost of VAWT's. VAWT's are useful in sites where wind direction is random or there is presence of large obstacles like trees, houses etc.
Noise	Wind turbine operation often leads to production of electronic noise which affects radar sites.	These have a lower noise as compared to HAWT's.	VAWT's more Suitable for urban areas
Operation and Maintenance	Regular Maintenance is required which increases lifecycle cost Generator, Gearbox cannot be placed on the ground.	Maintenance frequency is low hence low cost & Easier to maintain Generator, Gearbox etc., can be placed near the ground with/without tower	VAWT's are easier to maintain as they are located closer to the ground.
Efficiency	High efficiency in open and exposedRural sites, which are largely free of obstacles in all directions installed on a tall tower.But Less efficient in areas with obstacles like building trees etc with variable and turbulent winds. Also Regular turbulence produced may leads to structural failure.	VAWT's are very efficient for the sites where the wind direction is highly variable or has turbulent winds. These have lower startup speeds and can start at speeds as low as 10Kmph. Does not need to be pointed into the wind	Hawt's are advantageous for open rural sites while VAWT's are advantageous for urban sites
Vibrations	Does not cope well with buffeting	Create fewer vibration than HAWT	VAWT's more Suitable for building rooftops
Market position	HAWT's has seen technological and economical growth and it has become the commonly used commercial turbines on large scale	VAWT's are more used in small scale applications.Though VAWT's are in use from ancient times, but they are not as famous as the horizontal axis turbines because they do not utilize the higher wind speeds above the ground	VA's are more suitable for small scale applications located on poles from the ground or rooftops

Source : Compiled by Author

The Comparison table concludes that Horizontal axis wind turbines are more suitable for large open areas with consistent winds. A HAWT can work well on roof tops or in open spaces but it does not cope well with frequently changing wind direction, it is generally heavier and it does not produce well in turbulent winds also regular turbulence produced in urban areas may leads to structural failure. Hence for small-scale application in urban areas VAWT's are more suitable because of its ability to produce energy in tumultuous wind conditions. In addition, Vertical axis turbines receive power by wind coming from all 360 degrees, and even some turbines when the wind blows from top to bottom. Because of this versatility, vertical axis wind turbines are ideal for installations where wind conditions are not consistent.

Figure 3Small scale vertical axis wind turbines (Compiled by Author)

Technology for wind power system

The energy in the wind turns two or three propeller-like blades around a rotor. The rotor is connected to the main shaft, which spins a generator to create electricity. At 100 feet (30 meters) or more above ground, they can take advantage of faster and less turbulent wind. Wind turbines can be used to produce electricity for a single home or building, or they can be connected to an electricity grid (shown here) for more widespread electricity distribution.

Wind generators or turbines use the wind to turn a rotor that drives a generator. A wind turbine produces an alternating voltage and current, which is rectified to provide direct current (DC) at the correct voltage to charge batteries. It is similar to the system in a motor vehicle. Generators connected to the grid feed the DC power through an inverter which converts it to grid compatible alternating current (AC) power.

However, New Technologies can overcome wind turbulence and noise problems in urban use. There are mainly four type of system for connecting the electrical energy received from renewable energy source to the electrical system; Direct Connection, Off-grid system, Grid Interactive system and hybrid system.

Direct connection: In this, the Generated energy is connected directly to the load it is supplying. An example of this is modern street lighting, in which, the turbines are fixed to the street lighting column and supply the individual street light only.

Stand-alone (Off-grid) System: in this no mains electricity is available; a renewable energy source can be used to replace or supplement the existing local electricity supply similar to a diesel generator. In this the system is connected to the fuse board or dedicated load via the controller and inverter. Batteries can be used to store the generated energy, for use later in absence of generator or other electricity supply.

Grid Interactive system: in this the generated energy can be used to complement main electricity, providing the security of an uninterrupted power supply. In this case there are two inputs to the fuse board, one from the energy source and one from the mains. Whenever, due to some reasons, there is less energy generation, mains electricity can be used. If more than, needed electricity is generated than the excess can be connected to the national grid. This Building-sited renewable energy systems generating electricity and connected to the electrical utility grid system is known as distributed generation (DG) systems

In this two meters are required, one to measure the amount of imported electricity and the other to measure the generated electricity by the system to be exported. Net metering allows for the flow of electricity between a grid-connected DG system and the customer with the help of a single and bi-directional meter. This optimize the electricity consumed by the customer at a different time during the same billing cycle or is carried over as a credit on future billing cycles.

Hybrid System (wind electric&solar electric): Because the peak operating times for wind and solar systems occur at different times of the day and year, hybrid systems are more likely to produce power when you need it. Wind generators used in combination with a solar PV system present a good mix for year round power generation: in summer, the solar resource is at its best, and in winter, the wind resource is usually at its best. When used in combination with rooftop solar panels, a house could run off grid. "When there is wind you use the energy produced by the wind turbine; when the sun is shining you use the solar cells to produce the energy.

Table 2 Comparison of Standalone and grid connected system

	Grid connected wind turbine systems	**Stand-alone wind turbine systems**	**Remarks**
Batteries	Can work without Batteries	Stand-alone wind turbines systems work with batteries.	batteries require replacement once in every 3 -5 years
Location	Suitable for Urban areas having grid connectivity	More suitable for remote areas without grid supply or with unreliable grid supply	More suitable for urban areas
Installation	Comparatively easier to install as they do not require a battery system	Battery installation in needed also a back-up generator is usually required for power back up	Battery makes the system more complex with Diesel generator noisy and produce a lot of fumes
Costing	Reduce the power bill as it is possible to sell surplus electricity produced to the local electricity supplier under net metering	life cycle costing of the wind turbine system installation cost, battery replacement cost and Maintenance & operation cost will be added to initial cost with price inflation	High cost of standalone system
Reliability	In case of low wind speed electricity can be imported from grid	Emergency back is completely dependent on battery performance or diesel generator	Good quality battery may be costly, Diesel generator noisy and produce a lot of fumes
Efficiency	Advantage of effective utilization of generated power because there are no storage losses involved	Loss of energy during storage and transfer resulting less efficiency	Grid interactive is more efficient
Power uses	Can use on all types of power system	It is neither practical nor cost effective to operate high power-demand equipment's on standalone system	Stand alone Can work only as supplementary power supply
Operation & Maintenance	Low maintenance required	More maintenance required due to battery system	Simple system with less maintenance is preferable

Compiled by Author

The comparative analysis of these system results that for grid connected urban areas, wind turbine system with grid connectionis option that is more preferable. Therefore, costing and payback calculation of the grid interactive system for feasibility of wind turbine installation with and without battery backup, in old buildings of Jaipur is essential.

The capacity of small wind turbines: Small-scale vertical axis wind turbines are easily available in the market with various specifications. The amount of electricity a wind turbine generates will depend on the wind speed at the site and the turbine's capacity rating. If a model has a rated capacity of 1 kW, it means it will produce one kWh of electricity per hour when exposed to a specific rated wind speed.

Actual generating rates: Although capacity ratings are a useful guide, in the real world a turbine will not expose to ideal conditions or the 'rated wind speed' at all times. This means turbines will typically generate, on average, only 10-40% of their rated capacity every hour over a year.

To work out roughly how much electricity a turbine will generate on an average day, multiply the rated capacity by 24 hours, and then multiply it again by percentages ranging from 10 to 40, to reflect the typical range of wind available.

For example, a one kW wind turbine might generate between 2.4 kWh and 9.6 kWh a day on average (i.e., 1 x 24 hours x 10% = 2.4 kWh/day; or 1 x 24 hours x 40% = 9.6 kWh/day).

Production of energy depends on capacity factor of that area. Capacity factor is a way to measure the productivity of a wind turbine; it compares the plant's actual production over a period with the amount of power the plant would have produced if it had run at the full capacity for the same amount of time. Typical capacity factors are 15–50%; values at the upper end of the range are achieved in favorable sites and are due to wind turbine design improvements. The capacity factor is affected by several parameters, including the variability of the wind at the site and the size of the generator relative to the turbine's swept area. For Rajasthan the capacity utilization factor is 20-21%.

Table 3 Average Energy generation from Small Wind turbines

SI	Capacity of Wind turbine installation	Avg. energy generation / day
1	1 KW	4.8 KWH
2	1.5 KW	6.75 KWH
3	2 KW	9.6 KWH
4	3 KW	14.4 KWH
5	4 KW	19.2 KWH
6	5 KW	24 KWH
11	10 KW	48 KWH
12	50 KW	240 KWH
13	100 KW	480 KWH

Compiled by author (Assuming average 20% capacity)

How Much power is needed?

For calculation of power requirement for residential units in walled city Jaipur from renewable energy sources, the data was collected from primary and secondary sources. A household survey of around 100 Household has been conducted and based on the survey the average consumption of electricity is analyzed. The findings of survey show that there originally there were mainly three types of Havelis/ residences but now there is a lot of change in use of many building.

- House for High income groups - Large, spacious, multistoried Havelis with more than one courtyard covering 50% of Haveli area
- House for Middle class - small houses G+2 structures, small inner courtyards covering 25% of plinth area
- House for low income groups - Occupied by artisans & laborers, usually single or two room tenements, mostly semi- pucca, over crowed with no open spaces

Among all these types major transformation in structure and use is happened in large & middle class Havelis. Similar kind of houses have different use pattern of traditional Havelis as follows:

- Haveli residential use continued as original with no change in structure but partly/fully dilapidated
- Haveli residential use continued but with major changes in building structure renovation/ addition/ alternation as per modern life style
- A large Haveli size plot subdivided into various residential units without planning
- Havelis subdivided or rented out with partly modification or use changed as commercial
- Haveli Partly converted to commercial (small Manufacture/retail/wholesale /storage) use
- Havelis completely converted to commercial (small Manufacture /retail/wholesale /storage) use

With all these categories the electricity consumption in different buildings varies from 150 KWH to 6000KWH per Month.

Application of Small Scale Vertical axis Wind Turbines

Turbine with a capacity of 20W to 100 kW are known as small scale wind turbines and these are generally intended to supply electricity to buildings, and which may or may not be connected to the grid. Small wind turbines generally have higher capital costs and achieve lower capacity factors as compare to large-scale wind systems, but they can meet important unmet electricity demands of individual homes, farms, small businesses and villages or small communities and can offer local economic and social benefits.

Although small, building-mounted systems wind turbines give less output in urban areas due low wind speed and turbulence but it could be very effective if carefully placed in a suitable wind resource location. A small wind turbine system can be located onto various existing urban structures including building rooftops, flagpoles, light poles, building corners, and walls, among others. Indeed, one of the central features of this system is its flexibility in mounting, ensuring that the user can optimize the placement of their small wind turbine in order to maximize its performance.

Before Application of small-scale wind turbines in Traditional Havelis of Walled city Jaipur, it is important to know the potential of system installation in these Havelis. Developments in the wind energy harvesting technology as of now have been mainly concentrated towards the large-scale power production. This is mainly due to the economy of scale that justifies the installation and operational costs of LSWTs. However, it is a rapidly expanding field.

Table 4 Installation of Wind (energy) Turbines - (Building or Cluster Level)

Orientation	In order to generate the optimum annual electricity yield, a wind turbine should face in the direction of the prevailing wind. This is normally south-west, but can vary from place to place.
Location	Wind turbines are more commonly located away from the building but can be fixed onto the building. The performance of the turbine may reduce when fixed to a building or in a densely populated area.
System Installation	Wind turbines work by converting the wind's kinetic energy into electrical energy. The turbine is mounted on a pole, which is fastened with brackets to an external wall, high enough to project above the building. In general, the higher the turbine above the roof the greater the power output will be as it will be affected less by turbulence. When fixing a turbine to the building the additional structural load shall be assessed and wall brackets must be fixed strongly enough not only to support the turbine itself, but also to withstand the force exerted on it. Where a building is framed, for the best support the fixing must be to the frame, not to infill panels. If the frame is not exposed, it is generally possible to fix into the frame through the external finish. An essential elements in this is a wind-turbine controller, to stop the turbine if the wind becomes strong enough to damage it
Visual Aspect	Wind turbines are the most contentious, as they have the greatest visual effect on the landscape. Wind turbines may cause zoning issues or problems with neighbors and an unwanted visual impact on a property, as it needs to be fit on tall towers.
Potential	As Havelis in the walled city of Jaipur is planned on a large plot and structure is very strong as stone is the main building material, thus it can sustain the load of small turbine system, hence a good condition to fit the turbines.
Maintenance	A turbine may fix directly to a flat roof, but care should be taken that brackets do not compromise the weatherproofing. Equipment should be located to permit easy access for maintenance and repair. All parts of the installation should be indicated on a working drawing. Where equipment is to be fixed to building walls, the number of fixing points should minimized by the use of a wooden patters or frame system.

Compiled by Author

Policies and Government Interventions for Wind power in Rajasthan

Central & state Governments have launched many policies and incentives scheme in the field of energy for development of renewable energy sources in Rajasthan. The Ministry of New and Renewable Energy (MNRE) provides Central Financial Assistance (CFA) in the form of capital subsidy and financial incentives to the renewable energy projects in India. CFA is allotted to the projects on the basis of its installed capacity, energy generation and its application etc. Financial support will be made available selectively through a transparent and competitive procedure. Policies and schemes providing financial support for wind power projects are as follows:

Table 5 Policies and Government interventions for wind energy system installation

<table>
<tr><th>Policy intervention</th><th>Incentives/ Financial Support for Wind turbine</th></tr>
<tr><td>Policy for promoting generation of electricity through non-conventional energy sources 2004
(promotes generation of power from non-conventional energy sources)</td><td rowspan="2">• Exemption from Electricity Duty On electricity generated for captive use
• Exemption for entry tax on equipments required for wind projects
Incentives available Same as for industrial unit viz;
• Reduction in VAT on related Products from 14% to 4%
• Exemption on Stamp duty and land tax @ 50% for a period of 7 years
• Investment subsidy up to 30% of the tax deposited
• Employment subsidy 20% of the tax deposited
• Single Window Clearance, Availability of Water for Power Generation, Availability of Land on Concessional Rate, and Clearance from Pollution control board
• It is notified under green categories.</td></tr>
<tr><td>Policy for promoting generation of electricity from wind, 2012</td></tr>
<tr><td>Rajasthan Electricity Regulation Committee Net Metering Regulations, 2015
(Credits for excess energy generation for Renewable energy for more than 50 units)</td><td><table>
<tr><th>Connected load of Eligible Consumer</th><th>Connectivity level</th></tr>
<tr><td>Up to 5 kW</td><td>240 V- single phase</td></tr>
<tr><td>Above 5 kW and up to 18.65 kW</td><td>415 V-Three phase</td></tr>
<tr><td>Above 18.65 kW and up to 50 kW/kVA</td><td>415 V-Three phase</td></tr>
<tr><td>Above 50 kW/kVA</td><td>HT/EHT level</td></tr>
</table>Exemption from banking and wheeling charges and cross subsidy surcharge.
The CDM benefits arising from renewable energy generation from will pass to consumers through distribution licensee</td></tr>
<tr><td>Renewable Energy Certificate and Renewable Purchase Obligation</td><td>Provision of Renewable Energy Certificates to fulfill renewable purchase obligation to demonstrate compliance with regulatory requirements (RECs) for excess energy. REC represent 1MWh of renewable energy generated.</td></tr>
</table>

Compliance Framework) Regulations, 2010	

Rajasthan Electricity Regulation Committee Renewable energy Tariff Regulations, 2014	The operators of such systems will also be eligible to receive the feed-in tariff fixed by the Electricity regulatory commission both on the wind power consumed by the operator and the wind power fed into the grid.
	• Accelerated Depreciation (AD) benefit (Rs/kWh) 80%
	• Levelised Tariff for District other than Jaisermer, Barmar& Jodhpur[30]
	  ○ Rs. 5.93/kWh without AD
	  ○ Rs. 5.57/kWh with AD

Source: Compiled by author based on various Govt policies and schemes

Utilities will debit/credit the operator for the net saving on conventional power consumed and the wind power fed into the grid, as applicable. A Generation Based Incentive will be payable to the utility to cover the difference between the wind tariff determined by CERC, less the base price of Rs. 5.50/kWh with 3% p.a. escalation. The metering and billing arrangements between the utility and the wind turbine operator will be as per guidelines/regulations of the Appropriate Commission. Thus, it is necessary that uniform principles for applicable tariff, standard guidelines for metering/billing/energy accounting are adopted; to the extent feasible, across States to facilitate smoother implementation of the Programme.

There are also various incentives being given by the state government so as to encourage the development and use of wind power. To begin with, the land for establishing wind power projects is being provided by the state government at 10 per cent of the DLC rate of that area. Also the energy consumed by the power producer for his own captive use shall be exempted from payment of electricity duty. The generation of electricity from renewable energy sources is treated as eligible industry under the schemes administered by the industries and incentives available to industrial units under such schemes are also available to these power producers.

Incentives from Central Government

The Central government too has been taking measures to further the usage of renewable energy. Depreciation benefits are being given by the Central Government to investors in wind energy sector. However it is pertinent to note that since 30 March 2012, depreciation benefit has been restricted to up to 15 per cent as compared to the earlier figure of 100 per cent. This is likely to hamper the wind energy programme.

Costing of Wind Turbines

Like other renewable energy technologies, wind is capital intensive, but has no fuel costs. The key parameters governing wind power economics are the:

- Investment costs (including those associated with project financing);
- Operation and maintenance costs (fixed and variable);
- Capacity factor (based on wind speeds and turbine availability factor);
- Economic lifetime; and
- Cost of capital.

Although capital intensive, wind energy is one of the most cost-effective renewable technologies in terms of the cost per kWh of electricity generated.

The upfront capital cost (often referred to as CAPEX) for the wind turbines (including towers and installation) dominates the installed cost of a wind power project and this can be as much as 84% of the total installed cost. Similarly, to other renewable technologies, the high upfront costs of wind power can be a barrier to their uptake, despite the fact there is no fuel price risk once the wind farm builds. The capital costs of a wind power project can be broken down into the following major categories:

Table 6 Cost share (%) for wind turbines system

SI	Component	% Share
1	Turbine cost (blades, tower and transformer, production, transportation and installation of the turbine)	30-50%
2	Civil works (construction costs for site preparation and the foundations for the towers, Development and engineering costs)	15-25%
3	Grid connection costs (cabling, substations, buildings, transformers and connection to the local distribution or transmission network	15-30%
4	Other capital costs (construction of buildings, control systems, project consultancy costs, licensing procedures, consultancy and permits with Supervisory, Control and Data Acquisition and monitoring systems etc.	8-30%
	Total	100%
	Operation & Maintenance cost(Approx 2% per year)	20-25%

Source: Wind Power, Renewable energy technologies: Cost analysis series, 2012, International Renewable Energy Agency

The amount of electricity a wind turbine generates will depend on the wind speed at the site and the turbine's capacity rating. If a model has a rated capacity of 1 kW, it means it will produce one kWh of electricity per hour when exposed to a specific rated wind speed. At present imported Small Wind turbines of about 100W capacity cost around Rs50,000[1].

Table 7 Costing of small Scale (1 KW) wind turbines

Components	Costing of 1 KW capacity system (Rs)	
	Stand Alone	Grid Connected
Turbine Cost (Blade, Tower & Transformer)	22500	22500
Civil Works (Transportation, site preparation, Installation, Development	7500	7500

and engineering costs)		
Power Conditioning unit (Inverter, controller, Grid Charger/battery charger cost)	12000	12000
Grid connection costs (cabling, substations, buildings, transformers and connection to the local distribution or transmission network	Not Required	8000
Batteries	8000	Not Required
Total	50000	50000

Source: Compile by Author based on cost sharing % and capital cost

Here calculation is done for both stand alone and grid interactive system. However, for small scale, stand-alone turbines system is more suitable due to no excess energy generation to transfer.

Net cost after incentives and subsidy

Table 8 Calculation of wind turbine system cost after subsidy and Accelerated depreciation

Component	Cost Rs (INR)
Cost of 1 KW Wind Turbine	**50000**
Accelerated Depreciation @80%	40000
Tax rate @32.45%	12980
Net cost after accelerated depreciation	**37020**

Source: Rajasthan Renewable Energy Corporation

Table 9 Calculation of Life cycle cost of Wind turbine

Life cycle cost @ 20 Year	**Cost**
Initial Capital cost after subsidy	**37020**
operation and Maintenance costs @ 2% for 20 years of operation	**15000 (Approx)**
Life cycle cost	**52020**

Source: Rajasthan Renewable Energy Corporation

Calculation of Payback Period

Calculation of Payback period is derived from Total Lifecycle costing, Life cycle output energy and electricity billing. Existing and Approved Tariff for FY 2014-15 for Residential users for electricity consumption above 250 units is as follows:

Table 10 Electricity tariffs (2014-15) Rajasthan

Energy Consumption Per Month	**Energy charges (Rs/Unit)**	
	Existing	**Proposed (2015-16)**
For Consumption Up to First 50 Units	3.00	3.5
For Consumption above 50 Units and up to 150 units	4.65	5.45
For Consumption above 150 units Up to 300 Units	4.85	5.7
For Consumption above 300 units Up to 500 Units	5.15	6.00
For Consumption above 500 Units	5.45	6.40

Source: Rajasthan Electricity Regulatory Commission, Jaipur, Tariff Regulations 2014

Generation of bill to pay for monthly electricity consumption for 250 KWh (Units) based on rates prescribed by RERC.

Table 11 Calculation of Payback period for 2KWp Small Wind Turbine System

2KWp wind turbine is calculated for electricity consumption of		250 units
Units /Month generation by 1KWpturbine system		1X9.6X30 = 288
Electricity billing	0 - 50 units = Rs. 3.5 / kWh 50 - 150 units = Rs. 5.45 / kWh 150 - 300 units = Rs. 5.7 / kWh	So, total electricity bill = Rs. 1290
Net Saving	Meter billing + Excess energy generation (Monthly)	1290 + (288-250)X6.63* = 1542
Annual Saving	1542X 12	18504
Payback period for the investment	**Lifecycle cost/ Saving per year**	
	Without Battery	104040/ 18504 = **5.6Years**

* As per RERC, the Levelised Tariff (Rs/kWh) with Accelerated Depreciation is 6.63 (Compiled by Author)

Table 12 Lifecycle costing and payback period calculation for wind turbine System

SI	**KWH / Month**	**SWT System Capacity**	**Energy generation / Month**	**Lifecycle costing (Lakh)**	**Generated units @6.63/unit**	**Savings per Month (Rs) on Electricity bill**	**Total Saving Per Year**	**Payback Period (Years)**
1	150	1.5	216	78030	438	720	13896	5.6
2	250	2	288	104040	252	1290	18504	5.6
3	500	4	576	208080	504	2775	39348	5.3
4	600	5	720	260100	796	3345	49692	5.2
5	1000	10	1440	520200	2917	5975	106704	4.9
6	1500	12	1728	624240	1512	9175	128244	4.9
7	2000	15	2160	780300	1061	12375	161232	4.8
8	4000	30	4320	1560600	2122	25175	327564	4.8
9	5000	40	5760	2080800	5039	31575	439368	4.7

Compiled by author based on previous calculations

This table gives the simple payback period i.e., the number of years needed for a system to pay itself off. Considering the modern, high quality wind turbines having an expected life of approximately 20 years or more; in this case the simple payback calculation may not be enough because it does not take in to account the time value of money and does not measure profitability, price inflation or escalation in electricity billing, hence the actual calculation may vary from this. Also many incentives like Exemption from banking and wheeling charges and cross subsidy surcharge, CDM benefits and renewable energy certificates adds to its advantages.

III. FINDINGS

Conventional or horizontal-axis wind turbines are most common in the wind industry. It produces lot of energy in ideal conditions However; it is less productive in turbulent wind. Whereas, vertical-axis wind turbines (VAWT), can capture wind energy when it is inconsistent or turbulent.
There are some issues in installing a wind turbine in urban areas like lower annual mean wind speeds as compared to rural areas due to different elevation created by buildings, street furniture etc, which causes wind speed to decrease. The turbulent flow of wind in urban area produces extra stress on the turbine blades and slow energy production. Rooftops, open grounds and playing fields can be a good location as the wind flow there could be substantially greater as it gets concentrated by passing around and over the building. However, before selecting system component and sizing a wind turbine system for existing building, evaluation of energy consumption pattern in essential. In addition, it is important to reduce buildings energy consumption.

IV. CONCLUSION

Wind energy is a rapidly expanding field. Currently, developments in the wind energy harvesting technology have been mainly concentrated towards the large-scale power production. This is mainly due to the economy of scale that justifies the installation and operational costs of Large Scale Wind Turbines. The main reasons for the low adaptability of the Small Scale Wind Turbines are their high rated wind speed and poor aerodynamic performance giving low power output. The low wind speed small scale wind turbines (SSWTs) are generally ignored because of their poor performance that does not allow justifying their installation and operational cost. Although small wind turbines are a proven technology, further advances in small wind turbine technology and manufacturing are required in order to improve performance and reduce costs. Wind is highly variable, both geographically and temporally. Moreover, this variability exists over a very wide range of scales, both in space and time.
Wind energy is a very attractive energy resource because it is virtually inexhaustible supply, distributed over complete and pollution free nature. Extensive research activities are being conducted across the globe in this area, with the goal of improving the efficiency of wind turbines. The overall contribution of wind power in the global total electricity generation is still a small fraction. More efficient installation and maintenance techniques will also help improve the economics and attractiveness of small wind turbines.
However, it is very important to reduce energy consumption in the building and save energy by limiting the use of high power-demand electrical appliances and use various energy efficiency techniques in buildings. We need to increase application of alternative energy sources for electricity generation wherever possible for sustainable development.

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