IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

STUDY ON AIR BORNE WIND TURBINE

Dipankar Chatterjee, Student of VIT Vellore

Mayank Mani, Student of VIT Vellore

Mukul Pandey, Student of VIT Vellore

Nabarun Dutta, Student of VIT Vellore

Abstract

As population is increasing at high pace, so does our energy demand. Non-renewable energy possess a high risk for the population and the surrounding with their emissions and being one of the biggest reason for the surge towards global warming and pollution. Each and every one of us is energy consumer. We consume energy in nearly every day-to-day activities. Our dependence on energy has increased steeply with our ease of living. We are in the midst of unprecedented changes, where meeting energy demands sustainably is not an option, but an only way to get through the societal and environmental concerns. It's high time to shift from conventional to clean energy sources. One of the source is – Wind Energy. Wind energy can be harnessed by converting the Kinetic energy of wind to Mechanical energy via wind turbines, which can be converted to the electrical energy by means of generator. It is a consistent source of renewable energy with less variability.

The limitation of wind turbine is its height, average height of wind turbine is around 100-120 meters. Wind energy is available most vastly on the upper atmosphere. Speed of wind increases with height, and we are restricted to limited height when we can harness more energy at the same place in same time limit just by increasing height. Increasing the wind turbine height additionally will incur an addition to capital cost, as wind turbines are primarily made of steel and are supported on base. To improve this constraint, Air-Borne wind turbine are find suitable, as they are clean, there height can be varied with tether cable, and they do not require high setup cost and expensive materials. Designing an AB-Wind turbine after assessing the wind speeds at various locations can generate more electricity, more cheaply and more cleanly. Clean energy follows the rule of 3R's- 'Reduce, Reuse, and Recycle '. AB-Wind Turbine reduces emissions, it can be reused in various cycles, and Wind Energy is a form of inexhaustible recyclable energy.

Introduction

An airborne wind turbine is a design concept for a wind turbine with a rotor supported in the air without a tower, thus benefiting from more mechanical and aerodynamic options, the higher velocity and persistence of wind at high altitudes. There has been a significant push to shift our energy sources from fossil and nuclear fuels to renewable technologies. A relatively new generation of energy systems aims to harness atmospheric winds that can't be reached by traditional wind turbines. Atmospheric winds tend to be faster and more consistent than surface winds, which poses an interesting opportunity to harvest energy at higher rates with atmospheric winds than with surface winds. Wind speed increases with height due to certain reasons

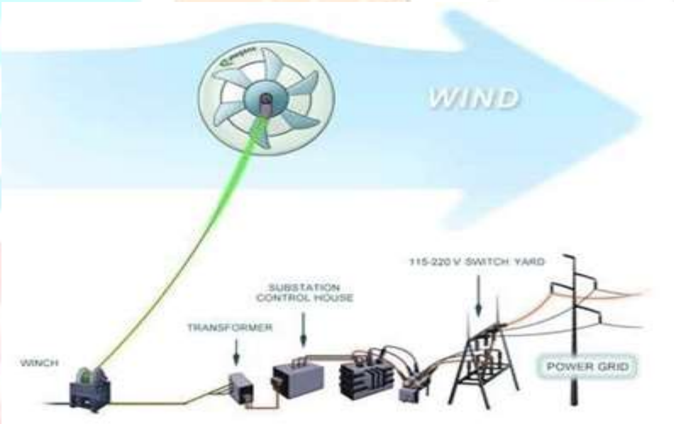
(i) As the height increases, pressure gradient also increases from surface to troposphere, less dense warmer air occupies greater volume above, this leads to an increased pressure gradient with height between the warmer air and colder air

(ii) Wind speed is less along the ground due to surface friction, where wind has increased collision with trees, rocks and structures, this does not happens at increased height (iii) Air density decreases with height, being highest on the surface. Less dense air has more impact of force, as it has less mass and can pass more easily.

In fact, a recent global climate model suggests that high- altitude wind power devices could extract more than 1,800 TW, which is approximately 100 times greater than the present global power demand (~18 TW). By contrast, surface winds can only provide 400 TW.

Working

Air borne wind turbines works on the principle of using aerodynamic forces to displace a generator to produce mechanical work. They use a tether to extend into the atmosphere. Due to which they are able to extract kinetic energy from the atmospheric winds. Air borne wind turbines are mainly of two types i.e ground-gen and fly-gen systems. In ground-gen the energy conversion is achieved with a two phase cycle composed by a generation phase, in which electrical energy is produced and a recovery phase in which a smaller amount of energy is consumed. In this systems ropes which are subjected to traction forces are wound on winches that in turn are connected to motor generators axes. During the generation phase, the aircraft is driven in a way to produce a lift force and consequently a traction force that induce the rotation of the electrical generators. In the recovery phase motors rewind the ropes bringing aircraft back to its original position from the ground. Positive balance is maintained by the control system which adjusts the aerodynamic characteristics of the aircraft and controls its flight path in a way to maximize the energy the energy produced in the generation phase and to minimize the energy consumed the recovery phase. For fly gen energy can be produced in many ways, one of the ways is in which Airborne Wind Turbine takes off with the wing plane in a vertical position driven by propeller thrust. The flight mode is similar to quadcopter flight and rotors on Airborne Wind Turbine are used as engines. Once all the rope length has been unwound, the Airborne Wind Turbine changes flight mode becoming a tethered flight airplane. In this second flight mode a circular flight path is powered by the wind itself and rotors on the Airborne Wind Turbine are used as generators to convert power from the wind. During this phase the cable length is fixed. In order to land, a new change of flight mode is performed and the Airborne Wind Turbine lands as a quadcopter.



Methodology

Airborne wind energy systems generate electricity from the wind. Hence, India should at least have a certain demand for electricity and some wind resources which can be harvested by the wind turbine. Then wind climate of India would be determined.

The `wind climate' is split into two sub criteria,

(1) local wind power density.

(2) the national wind energy potential.

The local wind power density is a measure of the wind resources at one specific location, whereas the national wind energy potential is a measure of the entire country's technically possible wind resources, which can be harvested. After collecting data for the above metrics we can safely estimate about the feasibility of the Airborne Wind Energy Systems in India.

Tables and Graphs

<u>Wind potential at 100m</u>

High altitude wind devices are all about trying to access that additional high altitude power.

Airborne Wind Turbine focus is at present is to tap into the layer between 500 and 2000 m.

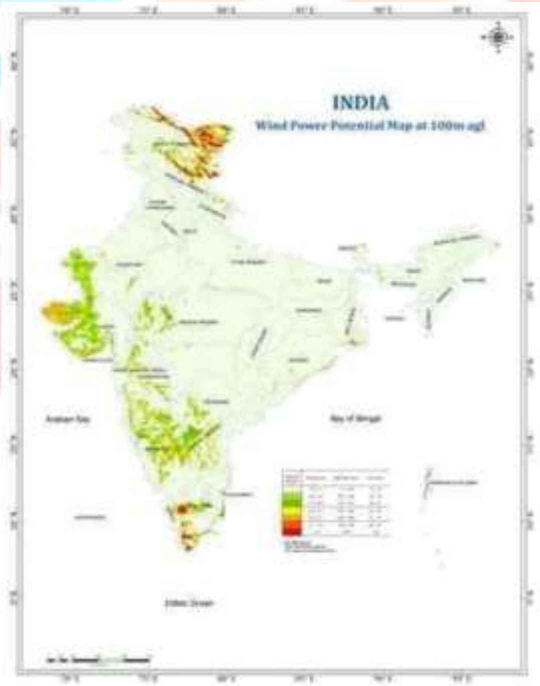
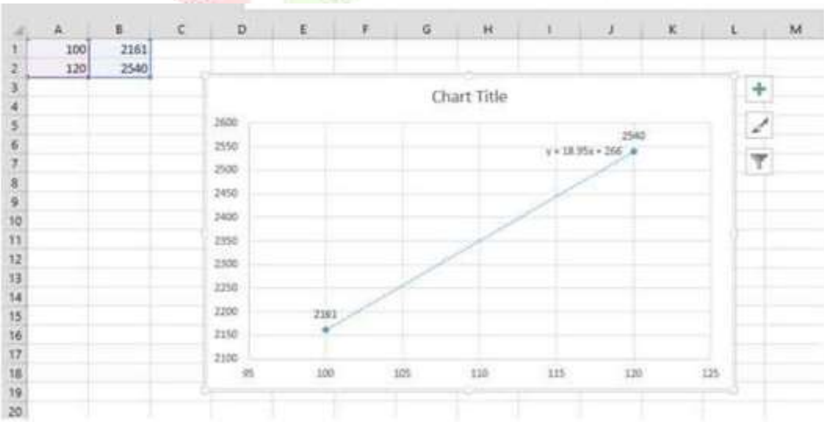


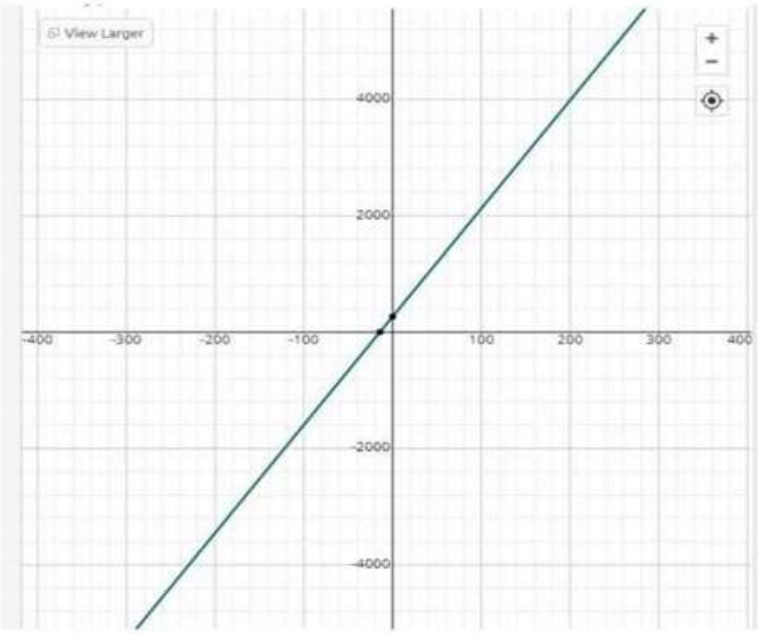
Table 8: Wind Potential at 100 m (GW)

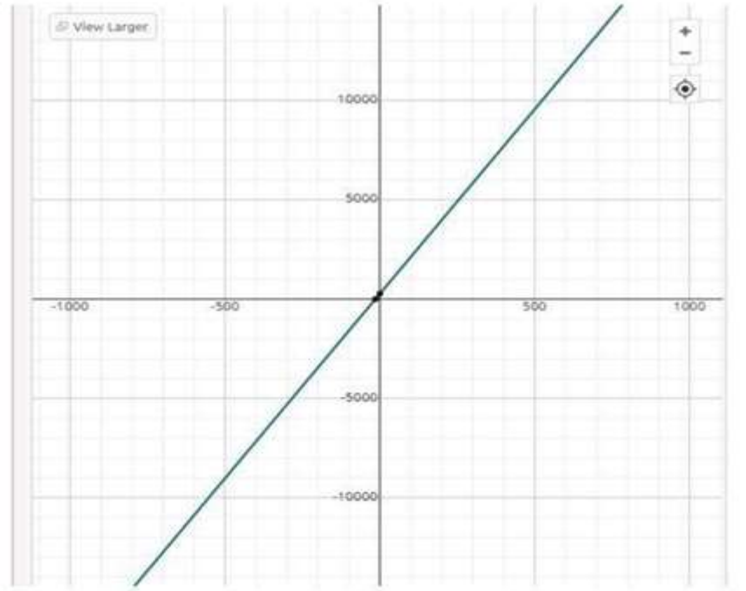
	Area (sq.km)			5D x 7D Potential (GW)				3D x 5D Potential (GW)			
STATES	Rank 1	Rank 2	Rank 3	Rank 1	Rank 2	Rank 3	Total	Rank 1	Rank 2	Rank 3	Total
Maharashtra	40.552	100.135	27.618	92	228	63	384	216	533	147	895
Karnataka	34.785	85.109	30.807	79	194	70	344	185	453	164	802
Madhya Pradesh	16.220	103.690	9.360	37	236	21	295	86	552	50	688
Gujarat	36.039	72.914	11.709	82	166	27	275	192	388	62	642
Rajasthan	51.541	41.011	11.507	118	94	26	237	274	218	61	554
Andhra Pradesh	42.174	39.565	21.561	96	90	49	236	224	210	115	550
Telangana	18.439	43.113	9.237	42	98	21	161	98	229	49	377
Tamil Nadu	13.542	34.292	14.780	31	78	34	143	72	182	79	333
Kerala	2.751	5.006	12.946	6	11	30	47	15	27	69	110
Orissa	2.615	6.865	2.399	6	16	5	27	14	37	13	63
Uttar Pradesh	170	3.008	549	0	7	1	8	1	16	3	20
Chhattisgarh	88	575	521	0	1	1	3	0	3	3	6
West Bengal	53	450	77	0	1	0	1	0	2	0	3
Haryana	75	119	15	0	0	0	0	0	1	0	1
Total	259,043	535,855	153,085	591	1222	349	2,161	1378	2851	814	5,043

Table 9: Wind Potential at 120 m (GW)

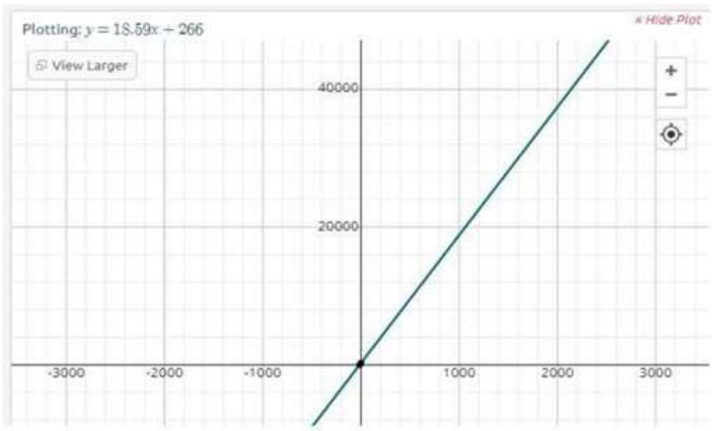
	Area (sq.km)			5D x 7D Potential (GW)				3D x 5D Potential (GW)			
STATES	Rank 1	Rank 2	Rank 3	Rank 1	Rank 2	Rank 3	Total	Rank 1	Rank 2	Rank 3	Total
Maharashtra	44515	114697	36272	101	262	83	446	237	610	193	1040
Madhya Pradesh	21372	126208	13748	49	288	31	368	114	671	73	858
Karnataka	36340	88508	31612	83	202	72	357	193	471	168	832
Rajasthan	60098	59389	14505	137	135	33	306	320	316	77	713
Gujarat	36725	75923	12553	84	173	29	285	195	404	67	666
Andhra Pradesh	43550	46783	25382	99	107	58	264	232	249	135	616
Telangana	19845	48514	14864	45	111	34	190	106	258	79	443
Tamil Nadu	14443	37896	16204	33	86	37	156	77	202	86	365
Chhattisgarh	1524	9312	13821	3	21	32	56	8	50	74	131
Kerala	2778	5077	13160	6	12	30	48	15	27	70	112
Orissa	4017	10858	5475	9	25	12	46	21	58	29	108
Uttar Pradesh	561	4609	843	1	11	2	14	3	25	4	32
West Bengal	87	943	135	0	2	0	3	0	5	1	6
Haryana	137	285	23	0	1	0	1	1	2	0	2
Jharkhand	59	237	95	0	1	0	1	0	1	1	2
Himanchal Pradesh	149	52	0	0	0	0	0	1	0	0	1
Total	286200	629291	198691	653	1435	453	2540	1523	3348	1057	5927







Not only would airborne technology do without the concrete foundations which drive up the cost of offshore wind but winds at high-altitude have, on average, twice the velocity of those near ground level, with up to eight times the power density. There is enough energy in high altitude winds to power civilization 100 times over , wrote Professor Ken Caldeira of Stanford University in his research paper. Other peer-reviewed papers estimate it could reduce the cost of wind energy ten-fold. So if this technology arrives in earnest, it will make a serious impact on the global energy market.



Turbines are taller now than they were in previous decades. Since 2012, the average height of wind turbines installed in the United States has been about 280 feet, or 80 meters. Before 2006, few wind turbines were as tall as 280 feet.Wind speed typically increases with altitude and increases over open areas without windbreaks such as trees or buildings. Favorable sites for wind turbines include the tops of smooth, rounded hills; open plains and water; and mountain gaps that funnel and intensify wind.

Graphical Calculation

Wind energy potential at 100m: 216 GW

Wind energy potential at 500m: 9500GW

Wind energy potential at 2000m: 37000GW

Limitations

One of the major limitation of wind turbine is it needs to be shut down when the wind speed gets very high, to prevent the damages as they are rigid structures. However, this doesn't happen in the case of AB-Wind Turbine, They can even operate in hurricane type of situations. At most the damage can happen to the tether cable, when it gets cut off. The damage done will be very less as compared to the conventional wind turbines.

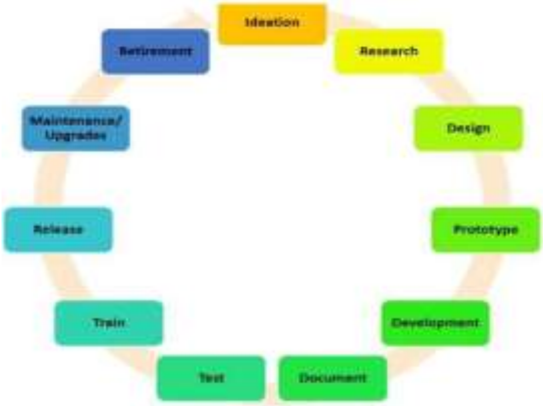
Secondly, the offshore wind has more speed than anywhere on the surface. Capital cost for building an offshore-wind turbine is very high, as the tower needs to be strong enough to hold the frame, rotor must be strong enough to resist rotational and bending motion from wind, and all of these has to be supported by base which is underwater. In the case of AB-Wind Turbine, we only require a base that is strong enough to hold the thrust of tether. The ground station need to be heavy enough to prevent the lifting. The ground station can either be a floating structure or rigid structure. This makes designing the AB-Wind turbine significantly cheaper.

Business Model Development

(1). Product description: -

This model proposes intelligent and smart Irrigation system which can be used for controlling the watering or irrigation of flowering plants and fields. It controls the irrigation of plants automatically where the need of human intervention can be reduced. This mainly focused on wastage of water, which is a major concern of modern era. It also aids time saving, cost effectiveness, environmental protection, low maintenance and operating cost and efficient irrigation service. Arduino (open source) is used in the design of the prototype model in making the system compact and sustainable. The system has sensor which measures the moisture of the soil and switches motor which gives water as per requirement. Along with the system also send message to the user regarding moisture level through GSM module. This irrigation automation system provides a most modern solution with phones for those persons who want to do agriculture without physically present on that place.

(2).Business locations: - As our product can be used both on large scale (i.e. farmer's field in villages) as well as small scale (gardens in urban areas houses). Also considering the raw materials transport cost, business area can be located in cities, as Chennai, along with various small branches in villages across Tamil Nadu. Initial survey will be done for review of product.



Product development life cycle

Break even Analysis

Fixed cost= 3,98,000 Variable cost per unit =2050

The break-even analysis shows that business model will start getting profit after selling nearly 275 units.

Detailed Data Table :-

Units Sold	Sales Revenues	Variable Costs	Fixed Costs	Operating Profit
0	$0	$0	$398,000	$-398,000
68	240,757	141,257	398,000	-298,500
137	481,514	282,514	398,000	-199,000
206	722,271	423,771	398,000	-99,500
275	963,028	565,028	398,000	0
344	1,203,785	706,285	398,000	99,500
413	1,444,542	847,542	398,000	199,000
482	1,685,298	988,798	398,000	298,500
551	1,926,055	1,130,055	398,000	398,000
620	2,166,812	1,271,312	398,000	497,500

Calculation for Payback Time estimation

Energy Audit Report of Cost Savings by implementing Airborne Wind Turbine System for the farming purposes: -

This analysis is done for a field (1 hectare) i.e. for rice which is one of the main staple food in India

Water used by 1kg of rice on an average= 5000 litres.

Amount of rice grown in 1 hectare of land = 1800 kg (approx..)

Pump power = 1920 watts (approx..) = 1.920 Kw

RPM = 2750

Discharge rate of pump = 21 lit./s = 0.021 klit./s = (0.021 × 3600) klit./hr = 75.6 klit./hr

Water used by farmer for approx. 6 months = (1800 × 5000) lits = 9000 klits.

Power used by pump in the 6 months = (1.920) × ((9000 klits.)/ (75.6 klit./hr) =228.5714 kWhr. (approx.)

If it is assumed that the aforesaid specified pump runs for on an average 8 hours throughout the 6 months. Then the total power consumed by the pump for 6 months will be:-

Total power of the pump for 6 months = (228.5714 ×8) kWhr = 1828.5714 kWhr

If the efficiency of the specified pump is assumed to be about 70 % then the actual power required by the pump is

Actual power required by the pump in 6 months = (1828.5714)/0.7) kWhr. = 2612.2448 kWhr.

If 10 pumps are of same kind are used for watering then power required by them in 6 months = (7 × 2612.2448) kWhr. = 18285.7136 kWhr.

Let the air borne wind turbine is set up at the height of 50 m approximated and of blade length diameter of about 3 m.

Therefore change in wind speed at 100 m/s if the wind speed at the ground is assumed to be about 4 m/s (approx.) at about 2 m.

$V_{100} = V_4\,(50/2)^{0.245}$ (since wind shear exponent is taken as 0.245)

$V_{100} = 4\,(50/2.5)^{0.245}$ m/s = 8.80 m/s (approx.)

Therefore power generated by the turbine for efficiency let 75 % for 1 hour if 0.3 then

Power of the turbine = $0.5 \times 0.3 \times 1.225 \times (\pi/4) \times (3)^2 \times (8.80)^3 \times 0.75 \times 3600$ kWhr = 2389.8548 kWhr

If the wind turbine is run for only 2 hrs keeping the surrounding in mind then average power generated by the turbine = (2 ×2389.8548) kWhr. =4779.7096 kWhr.

The turbine will be made be used for consideration of birds lets say for 10 days in 6 months. Then the power generated will be

Power of the turbine =47797.096 kWhr.

Then, months of electricity saved by the farmer = (47797.096 – 18285.7136)/ 18285.7136 = approximately, 1.61 times of 6 months. = 9.68 months of power.

Since we know that winter crop farming takes less power then, months of electricity saved by the farmer can be taken as 11 months. Then, (11 +6) = 15 months of power if the pessimistic approach is applied:

Cost saved by farmer on electricity = 8 (₹/kWhr) ×(18285.7136 /6) kWhr =₹ 24380.9515 (approx.) / month.

Then cost saved by the power by the excess of power = 8 (₹/kWhr) × {(47797.096 – 18285.7136) / 6} kWhr.

= 8 (₹/kWhr) × (29511.3824 / (1.61× 6) kWhr. = ₹ 24440.0682(approx.) /month.

where unit cost of electricity is taken to be ₹ 8/unit i.e., ₹ 8/kWhr.

Let say the power the farmer spends ₹ 6,000 on the petrol and generator in 1 month if the power is not there at the time of watering then total cost save by the farmer is :

Total cost saved by farmer on electricity =₹ (24380.9515 + 24440.0682 + 6000) = ₹ 54821.0197 / month

Since, the above calculation is mainly based on the assumption so the above profit gained by subtracted with the 5% of its value keeping the losses and unevenness in the wind pattern and speed into consideration. Therefore the predicted profit gained by the farmer is given as:

Total actual cost saved by the farmer = ₹ {(1-0.05) × 69729.4614 }

= ₹ 0.95 × 54821.0197 = ₹ 52079.9687 /month =₹ 52000 /month (approx.)

Since, the cost of the airborne wind turbine along with the set-up, installation charges and maintenance charges for a year is given as:

Total cost of the airborne wind turbine = ₹ (250000 + 100000)

= ₹ 350000 (approx.)

Therefore, payback time = { (₹ 350000)/ (₹ 52000 / month) = 6.73 months = 7 months (approx.) }

Amount of coal saved = ((18285.7136) /(6 × 8)) kg

= 380.95 kg of coal / month = 381 kg of coal/ month.

Since, 1 kg of coal produces about 8 kWhr of electricity if complete combustion occurs.

Cost of coal saved = ₹3.50* 380.95

= ₹ 1333.33 / month = ₹ 1300 /month.

Amount of CO_2 saved =((18285.7136 × 0.4483) /6)kg

=1366.247 kg of CO_2 / month = 1350 kg CO_2 / month. (approx.)

However, the aforesaid calculated payback time can increase or decrease very minutely as amount of time in which the turbine over the course of time is very less as it may change due to the natural factors like varying crop season and according to which water and fuel consumption.

Result taken from the Report:

- Since, there are about 12 crore farmers living in the country in which about only 1.3-1.5 crore owns a land of about 1 hectare or more. So electricity saved by the farmers due the implementation of the airborne wind turbine saves upto ₹ 52000 per month which is significant value. Since, in our calculation amount of time in which the turbine over the course of time is assumed to be very less. So, there is much possibility that the profit may increase.

- Since, for the farmers of the country the payback time may vary from (0.6 -1.3) year which is acceptable.

- Cost of coal saved by the government is about ₹ 1300 per month/per farmer. If large number of farmers are implementing, then about ₹ 2000 crores will be saved by the government per month.

- Huge amount of coal as well as CO_2 which is mainly responsible for the present global climatic changes are being cut-off due to the proposal of this system. However, discrepancies or slight exaggeration may be felt but about 381 kg of coal and 1350 kg of CO_2 is being taken off per farmer per month then million ton of coal and CO_2 can be held off from going into the environment per month i.e., quality is being preserved and positive impact towards the flora and fauna.

- The all-over quality of life-style of the farmers as well as the climate of the region is simultaneously increased. This wind turbine system provides an all-over sustainable development on every aspect. Due to this economic sector is positively affected due to the large saving of the power and electricity.

- Less depletion of natural resources helps us to plan for the near future where the sustainable use of these resources can be used. And the J-shaped increasing population doesn't reach to the point of crisis or not collapse.

Conclusion

At 500m Wind potential is 4.4 times compared to 100m and at 2000m Wind potential is 17.1 times compared to 100m. Airborne wind energy devices pose significantopportunitiesforincreasing our reliance on renewable energies.There is enough wind energy to satisfy global power demands and deployedairbornewindenergy devices do not impose significant environmental or societal pressures. In order to commercialize more airborne wind energy devices, more research and development needs to bedonetomake the multitude of Ground-Gen and Fly-Gen concepts a reality. Replacing the large and bulky structure of a turbines tower with a lighter and more efficient tethered wing allows us to generate energy not only at ground level but high up in the skies. The wind resource in high altitudes is very promising when compared to the conventional wind energy height and wind speed, because at higher altitudes there is significantly higher wind speeds and more consistent wind resources. The success and on-going development of renewable energy resources including wind energy will benefit greatly from advances in new technologies, ideas and the control systems being introduced getting more mature as they evolve. Airborne wind energy is a relatively young technology and industry but the ideas and concepts already developed seem to have a promising potential playing a vital role in the renewable energy sector. Maybe one day there will be many airborne kites, balloons and wings flying in the skies generating electricity from a free and sustainable high altitude wind energy. AB-Wind Turbine can be setup within a day, and can be very useful in disaster relief situations, to meet the energy requirements.

References

1.https://www.eia.gov/todayinenergy/detail.php?id=33912

2.http://large.stanford.edu/courses/2018/ph240/chang1/

3.http://www.alternative-energy-tutorials.com/energy-articles/airborne-windenergy.html

4.https://cyberleninka.org/article/n/965116

https://www.researchgate.net/figure/Rice-production-levels-kg-per-hectare-per-year_fig3_282851804

https://claroenergy.in/5-most-water-intensive-crops/

https://www.researchgate.net/publication/265253578_Estimating_Pump_Capacity_and_Power_requirement_at_Farm_Level/link/5406c4740cf23d9765a8044f/download

https://www.pumpsandsystems.com/pump-efficiency-what-efficiency

https://www.quora.com/What-is-the-length-and-diameter-of-blades-and-rotor-in-small-wind-turbines

https://websites.pmc.ucsc.edu/~jnoble/wind/extrap/

https://brainly.in/question/12264926

https://carbonfund.org/calculation-methods/