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Eugene Wind Power

A Business Proposal

Proposal Overview:

In order to supply energy to the city of Eugene for the next 50 years we propose the construction of a 6.5 square mile wind farm in eastern Oregon. Assuming these 800 2.7MW GE wind turbines produce only an average of .81MW, this plant will supply the expected energy demand of Eugene in 2054. Our flow battery energy storage unit will allow the plant to provide peak energy for 48 hours without wind. This is a stable and reliable energy plan for the city of Eugene that will provide consistently low costs for many years to come with minimal environmental impact.

Capital costs are estimated at $3.82 billion. Assuming complete turbine and battery system replacement every 20 years and full electrolyte replacement after 50,000 cycles we can offer the city a levelized cost of 3.06 cents/kWh: a significant savings over current costs and not subject to the volatility of the spot market and fossil fuel costs. When the value of the loan is paid back revenue from the turbines can go directly to the continued maintenance of the turbines to continually provide this energy beyond 50 years.

Levelized Cost Approximation Spreadsheet

2054 peak MW	~1100
2054 ave MW	~550
Years planned for	50

Generation

		yrs loan	B$ RAW (	**interest**	B$ CAPIT	cts/KWh	Levelized	**unit cost**	# units	**capacityMW/unit**	ave MW output/unit	**$/acre**	**units/acre**
Turbines alone		50	1.13	0.05	3.09		3.20	3510000	679.012	2.7	0.81	2000	0.2
w/ flow batteries	**/MW**	**30**	**1.29**	**0.05**	**2.95**		**3.06**	**3510000**	**792.181**	**2.7**	**0.81**	**2000**	**0.2**
w/ flywheels		**30**	**1.25**	**0.05**	**3.26**		**3.38**	**3510000**	**763.889**	**2.7**	**0.81**	**2000**	**0.2**
w/ c hydrogen		30	3.85	0.05	11.64		8.06	4680000	1018.52	3.6	1.8	10000	0.2
w/ l hydrogen		30	3.85	0.05	11.61		8.04	4680000	1018.52	3.6	1.8	10000	0.2
w/ cables & flow batt		30	0.00	0.05	0.00		#DIV/0!	8000000	0	3.6	1.8	10000	0.2
w/ cables & flow batt		30	0.00	0.05	0.00		#DIV/0!	8000000	0	3.6	1.8	10000	0.2

Storage

								unit cost		**MWh/unit**	efficiency	**$/acre**	**units/acre**
for offshore	FlowBatt		50	0.00	0.05	0	per MWh	34199	0	1	0.75	50000	1
for on land	**FlowBatt**		**30**	**0.23**	**0.05**	**0.45**	**per L:**	**34.2**	**5.3E+07**	**0.001**	**0.75**	**2000**	**100000**
	Flywheel		**30**	**0.43**	**0.05**	**0.84**	**per flywheel**	**100000**	**105600**	**0.5**	**0.8**	**2000**	**500**
	compr Hy	sea	30	0.81	0.05	1.564	per kW:	124.5	5301205	0.00083	0.3	10000	50000
		land	30	1.37	0.05	2.643	per L:	50	6.4E+07	0.00083		50000	150000
	liq Hydrog	sea	30	0.81	0.05	1.567	per kW:	330	2000000	0.0022	0.3	10000	50000
		land	30	1.35	0.05	2.61	per L:	50	2.4E+07	0.0022		50000	150000

Inputs

Outputs

acres land	$/MWh opera	life (yrs)	ave MW needed	ave MW produced	ave MW deliverable	peak MW deliv	life MWh proc	life MWh delive	% stored	portion E on land
3395.1	6.5	20	550.00	550.00	550	1100	96360000	96360000	0	1
3960.9	**6.5**	**20**	**641.67**	**641.67**	**550**	**1100**	**1.12E+08**	**96360000**	**0.5**	
3819.4	**6.5**	**20**	**618.75**	**618.75**	**550**	**1100**	**1.08E+08**	**96360000**	**0.5**	
5092.6	6.5	30	1833.33333	1833.333333	550	1100	4.82E+08	1.45E+08	1	
5092.6	6.5	30	1833.33333	1833.333333	550	1100	4.82E+08	1.45E+08	1	
0	6.5	30	0	0	0	0	0	0	0	
0	6.5	30	0	0	0	0	0	0	0.8	

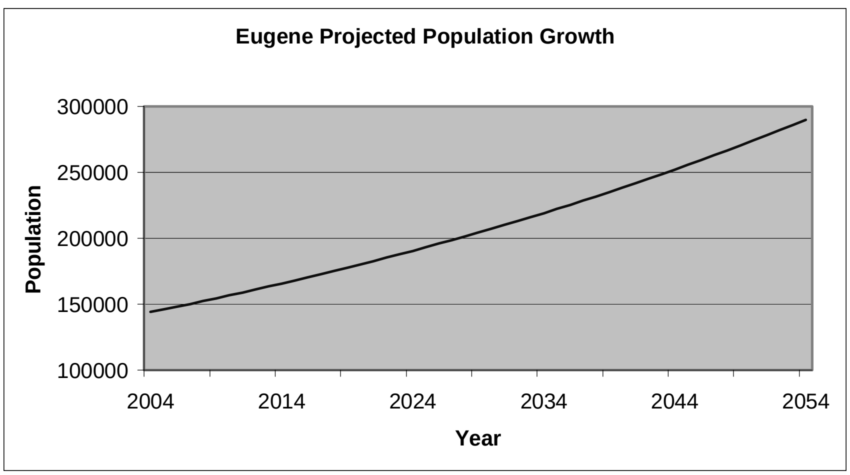
acres land	$/MWh oper	life (yrs)	$/L elcryt	life (chrg cycles)	ncsry storable MWh	life MWh stored
0	1	30			0	0
528	**1**	**30**	**50**	**50000**	**52800**	**1.12E+08**
211.2	**1**	**80**			**52800**	**2.71E+08**
106.02	0.5	30			4400	1.61E+09
424.1	0.5	50			52800	2.68E+09
40	0.5	30			4400	1.61E+09
160	0.5	50			52800	2.68E+09

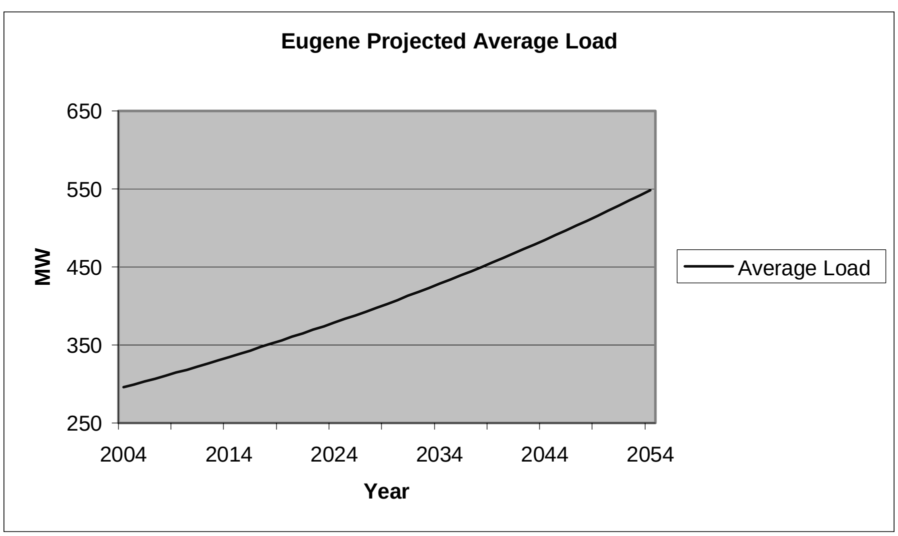
Inputs

Outputs

1 Population Projection

We assumed a constant 1.5% annual growth rate in the number of both residential and commercial customers, with a linear 5% reduction in energy used per customer over the 50-year period. We also assumed that the average load is the product of population and efficiency (i.e. 100% now, 95% in 50 years), that the current average load is 300 MW, and that the peak to average load ratio is two (an intentional overestimate). This gave us an average load of just under 550 MW in 2054, which we rounded up to an average of 550 MW and a peak of 1100 MW.





2 Location

2.1 Wind Resources

Team Wind proposes to utilize Oregon's plentiful wind resources to our utmost advantage in providing adequate energy to supply Eugene for at least the next fifty years. Currently, Oregon has seven wind projects in commission and we believe it is extremely feasible to construct another one that would clearly generate enough wind power for the Eugene-area. To date, Oregon has currently 260.06 installed Mega Watts with the potential for: 4870 MW and 43 Billion annual kWh.

As for location, Oregon has excellent wind resources in portions of the state, especially in the northeastern and southeastern half of the state. Oregon has many class 4 wind regions within the state. If we were to develop all the available land, excluding land with urban development, environmentally sensitivity & other conflicts, this would results in 1.5% of the state with good winds able to generate power for the state. However, one main benefit to using wind farms is the fact that they use a very small portion of land, so the actual amount of state land used would only be .15%. Oregon has enough wind resources that if all this potential land was developed, we could produce 43,252,500 kW – or 92% of the entire state's electricity consumption.

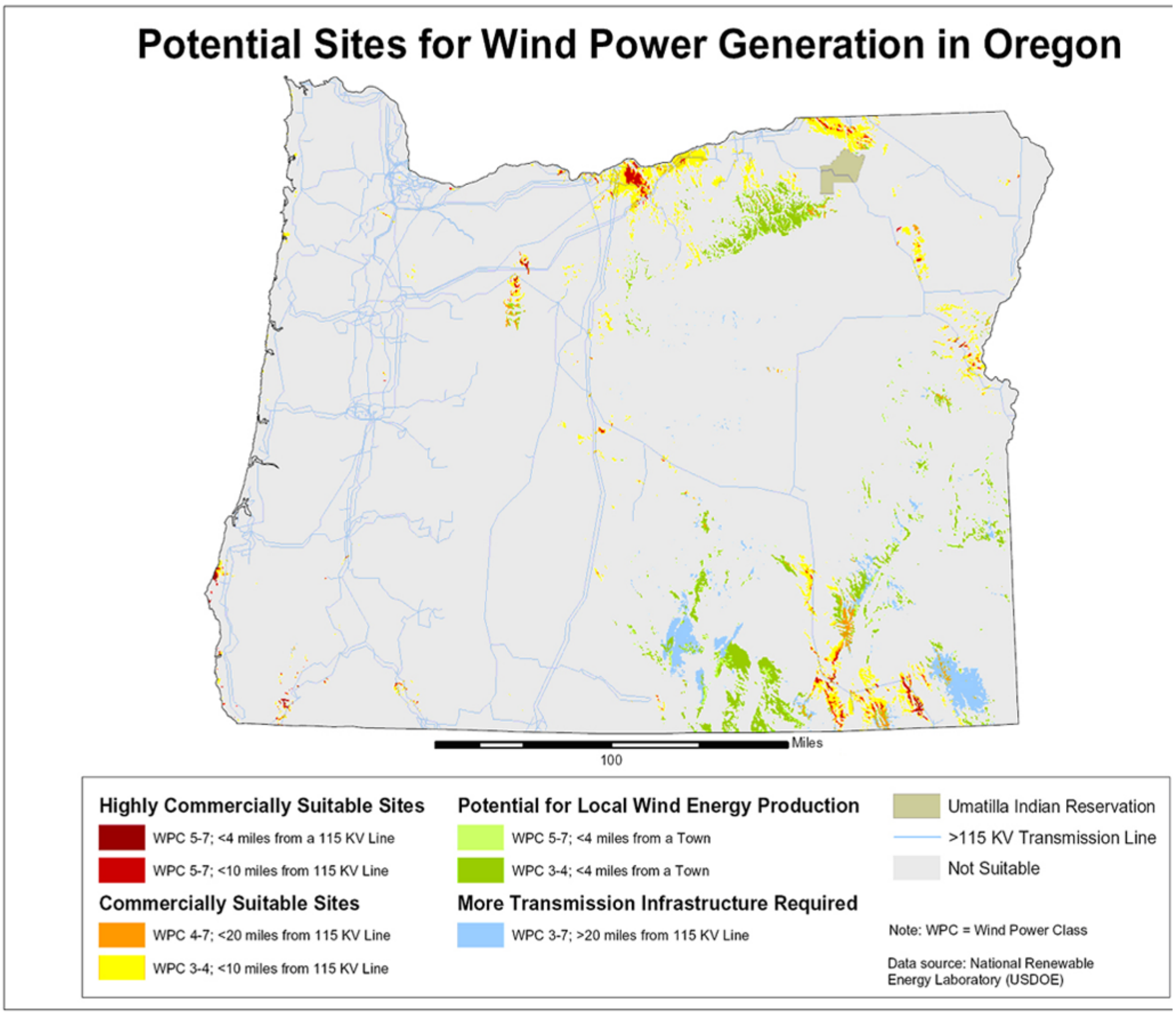
2.2 Location and Land Turbines

We propose to utilize the eastern half of the state to construct our on-shore wind farm. Through calculations, we found that, in order to power the entire city of Eugene, it is necessary to build 800 2.7 MW wind turbines on land. Due to size and space requirements, we will situate 1 every 5 acres. Currently, we are examining ideal topography within the northeastern quarter of Oregon. We have noted that Union county, southern Harney County and southwestern Malheur County have sufficient wind output and futher research will allow more specific site selection to best meet Eugene's needs without posing a hindrance to the existing community.

Through building these wind turbines at 1 every 5 acres, only 6.25 square miles will be needed for the site of our wind farm. Another advantage is more and more farmers are willing and seeking to utilize their land for the development of wind farms. Clearly, we will account for the specific topography of our chosen site. It is more beneficial to place wind turbines on top of ridgelines, depending on the land will determine our final wind farm site.

Team Wind has also researched extensively the possibility of constructing an offshore wind farm off the coast of Oregon. While not in our immediate plans, there is ample supply of wind resources and the proposal will remain an available option.

The map below shows potential sites for wind facility construction in Oregon, with the degree of suitability determined by land use, Wind Power Class (WPC), and proximity to existing major transmission lines (>115 KV). The red and yellow hues depict lands most suitable for large commercial projects, such as the one that we propose. All land uses except those designated as Agricultural, Range, Rural Commercial, and Rural Industrial have been designated "not suitable." The vast majority of the suitible sites remaining are designated Agricultural or Range Land. (Note: the members of the Umatilla Indian Reservation have requested that WPC data on their reservation not be released.)



3 Turbine Technology

General Electric has made great strives in the production of large-scale, efficient wind technology. With the development of the 2.X Series for onshore use and their 3.6MW offshore specific turbine, wind energy is no longer just a dream because of its high cost. Using the new technology it will be possible to generate electricity at costs that will be competitive in the current market and with advanced technology still developing, efficiency continues to rise (now up to 40%). The limits of wind energy have yet to be seen.

3.1 Onshore Wind Turbines

The 2.X Series just recently developed by GE provides the best option for electricity generation using wind energy. Coming in 2.3, 2.5, and 2.7 MW models, the 2.X Series is adaptable to a wind range of wind conditions, thus allowing us to produce electricity with higher efficiency in a larger number of areas where before, efficiency was a major issue. Variable speed turbines allow for automatic adjustments to changes in wind speed, further increasing the efficiency at all times and aiding in increasing the life of the turbines themselves. With a variety of heights, rotor diameters, and operating speeds, the 2.X Series demonstrates an adaptable and efficient method of providing consumers with clean renewable energy that can compete with the prices of electricity provided by hydroelectric and fossil fuel-based power plants. Furthermore, all new GE wind turbines are equipped with the WindVAR system, which allows for easy connection with existing power grids.

All of the GE turbines are designed to operate at similar wind speeds to provide for fluctuations in wind patterns and speeds in any given area. But, the differences between the turbines will be taken into account when deciding which turbines to place in certain areas, based on the general wind patterns, with the goal of providing maximum energy production from any given site.

All GE turbines of the 2.X Series are equipped with features such as an onboard crane in order to simplify service requirements and minimize costs. Also, each turbine in the 2.X Series has an easy-to-transport design. No major changes will need to be made in installation for each size, allowing turbines of variable sizes to be constructed fairly easily in the same general area. For these onshore turbines, the estimated lifespan is 20 years, but it could also be higher.

2.3MW Turbine

The 2.3MW GE wind turbine is the tallest of the series and is designed to operate efficiently on sites with lower wind speeds. With a rotor diameter of 94m, it sweeps an area of 6940m^2 at a height of 100 to 120 meters. The 2.3MW turbine operates at winds between 3.0m/s and 25m/s, optimally working at the low end of that range. Finally, the variable speed rotor allows it to rotate anywhere between 6.0rpm and 16.5rpm for maximum efficiency.

2.5MW Turbine

The 2.5MW GE wind turbine is designed for use in areas with wind speeds that generally fall in the mid-range between 3.5m/s and 25m/s. Standing at a height of 80m, it sweeps an area of 6082m^2 with a rotor 88m in diameter. Rotating from

5.5rpm-14.9rpm, the 2.5MW turbine is able to provide maximum efficiency on sites with medium wind speed.

2.7MW Turbine

Finally, the 2.7MW GE wind turbine is designed for maximum efficiency at sites with higher wind speeds. At a height from 58-70m, the rotor, 84m in diameter, sweeps an area of 5542m^2 and the rotor speed of 6.5-18.0rpm provides for the maximum efficiency seen on the higher end of the 3.5m/s to 25m/s wind speed scale.

3.2 Offshore Wind Turbines

Although at this point it appears that it will be most cost-effective to place all of our wind turbines onshore, the development of offshore wind power is still a possibility for the future. GE has designed and built the first wind turbine specifically for offshore use, capable of producing large amounts of power efficiently, particularly at sites with higher average wind speeds.

3.6MW Offshore Turbine

The 3.6MW GE Wind Turbine is designed for maximum efficiency at sites with higher average wind speeds. With a rotor diameter of 104m, the offshore turbine sweeps an area of 8495m^2. The 3.6MW turbine can be built at a variety of heights, depending on the location in order to ensure maximum power production and efficiency. Like the 2.X Series, the 3.6MW turbine operates at speeds from 3.5m/s to 25m/s, with an optimum operating speed of 14m/s. This generates rotor speeds from 8.5-15.3rpm using GE's variable speed turbine technology. The 3.6MW turbine is also equipped with onboard cranes if necessary and can even be outfitted with a helicopter-hoisting platform for easy maintenance access. Furthermore, the lifespan of these offshore turbines is estimated to be upwards of 30 years because of more consistent wind conditions that will mean that fewer adjustments will need to be made, prolonging the life of the internal parts. However, it remains to be seen what effects constant exposure to the ocean salt-water atmosphere will have on the longevity of the turbines.

3.3 Unit Costs

The cost of individual turbines onshore generally follows the pattern of $1 million per MW plus 30% of the cost of the turbine for installation costs. This cost includes infrastructure like service roads and transportation of materials. The estimated costs to build individual 2.3, 2.5, and 2.7MW turbines are:

- **2.3MW—$2.99 million per turbine**
- **2.5MW—$3.25 million per turbine**
- **2.7MW—$3.51 million per turbine**

Offshore costs are typically greater because of the greater cost of infrastructure. The cost of building grids connecting the turbines to the shore is much greater than onshore grid costs. However, cost estimates include the building of offshore platforms and grid costs. The estimated cost for the 3.6MW Offshore wind turbine is:

- **3.6MW—$6.12+ million per turbine**

Operating costs for wind turbines are very minimal. The bulk of the cost is in the actual construction of the turbines. Once they are built, operating costs are estimated at $6.50 per MWh. At first maintenance costs are minimal as well, but as the turbines get older, the costs begin to go up. However, even with full replacement every 20 years maintenance costs are low compared to coal/natural gas, which require extraction and transport of materials on a highly variable market. The biggest additional cost for the turbines during our 50-year outlook will be the refurbishing or replacement costs after 20-25 years.

4 Transmission

With any renewable energy plan, transmission lines must be included to transport the harvested energy. Current means of electrical transmission are in either buried underground cables or overhead cables. For this project the most practical are the overhead transmission wires, which are priced at $200,000 per mile; this figure includes both cables and transmission towers. For our land plot of 4000 acres, which is a 6.3 square mile lot, we would be able to channel the energy from turbine generators to the storage system using overhead cables.

Once the energy is harvested and stored in the storage systems, then the task is to efficiently transport the energy to the city of Eugene. In order to utilize already existing transmission grid systems in Eastern Oregon, the wind power group plans to hook into the existing transmission infrastructure. It will be necessary to upgrade the transmission lines when there is a higher demand for energy in the future. Due to the technology of wind power, a large-scale operation is highly attainable, and with that, a larger transmission system can be constructed, but for the current wind needs, the Eastern Oregon transmission is an efficient means to transport the energy from the site to Eugene, where it is needed.

5 Energy Storage

Half of the generated energy will be stored, planning for enough storage to supply a peak demand of 1100 MW for 48 hours. Due to the weight of lead-acid batteries and the inefficiency of hydrogen power, the two smarter alternatives to wind storage are flow batteries and flywheels.

4.1 Flow Batteries

The fist, flow batteries, are a simple, renewable, and cost efficient means of storage. Flow batteries provide a flow of electrons between two salt solutions to generate a current. Those electrons can then are recharged and go through another cycle to maintain energy output. The polysulfide bromide (PSB) flow battery will be used for wind storage, with a 75% efficiency rate. The PSB batteries do regenerate their own energy but the electrolyte fluid must be replaced when the vanadium ion charge becomes deplete. The electrolyte solutions are priced at $50 per liter, and that given amount of solution can withstand 50,000 cycles of charge and discharge. This rate yields a lifetime of 20 years for the battery stations. By allowing for maintenance on the electrolyte solutions and replacement of the solutions when necessary, the storage facilities can store the energy efficiently for 20 years.

5.2 Flywheels

The other very real storage possibilities are flywheels. The site requires roughly 106,000 flywheels of 0.5 MWh (or 500 KWh) capacity, each at a cost of $100,000. They would be constructed on 210 acres at $2,000/acre, with an operating cost of $1/MWh. All of this harvested energy could be stored in times of excess production and delivered in peak times. By means of flow batteries or flywheels, around the clock reliable energy is stored and ready for use at all times.

6 Cost of Land

Cost of land in Eastern Oregon is moderate and should not exceed $5,000 per acre. Our team is still conducting research concerning the exact location of our wind farm, and we are considering the possibility of developing mutually beneficial contracts with farmers so that we can use their land. If our team purchases land, onshore turbines will require a land area of 3,400 acres, so total costs will not exceed $17 million.

7 Environmental Impact

Relative to solar and hydropower, the environmental impact of wind turbines is negligible. Turbines do not necessitate the paving of land with PV panels, nor do they obstruct the flow of a river. Turbine construction is the only aspect of wind-power that could potentially negatively affect the environment, and if it were conducted with sensitivity to ecological concerns, it would not have to.

7.1 Noise Pollution

The Noise pollution that wind-farms produce is virtually insignificant and equivalent to a rural nighttime background (a sound pressure level of about 35-45 decibels). Developing technology is continually reducing noise levels, which could be reduced to nothing by 2020.

7.2 Visual Impact

There are many ways in which our team will curb the visual impact of wind-turbines. First, turbines will not be built in scenic areas. Popular lookout points and heavily forested/populated areas will be avoided. Refection can be minimized with the aid of matte paint, and turbines can be painted a gray color that blends with the sky. Calming fractal patterns derived from nature can be printed on turbines, so that they can exacerbate the calming effect of nature’s patterns. The spacing, design and uniformity of turbines are aesthetically pleasing. Since turbines are such a novel technology, they will serve as tourist attractions similar to the Hoover Dam or the Empire State Building.

7.3 Impact on Bird Migration

Additionally, turbines have little affect on bird populations. One third of first year bird deaths result from collision with man-made objects, and .02% of these deaths are caused by wind turbines. Studies conducted in California have found that turbines have a virtually insignificant effect of birds; each turbine accounting for about 1.83 bird deaths per year. Air pollution and destruction of natural habitat by humans are far more serious threats to bird populations than wind turbines. Wind-turbines, as a clean energy source, can abate the effects of air pollution.

To obtain planning permission from the government, our team will complete a comprehensive Environmental Impact Statement, which includes a landscape assessment. The projected effects of turbine construction on wildlife and natural ecosystems will be researched carefully.