Wind Energy

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Executive Summary

Total Potential

Energy Source	Electricity (GWh)	Percent of Total 2008 Electricity Demand
Wind Energy Potential		**127%**
Small-scale Wind	39.9	
Medium-scale Wind	649.7	
Large-scale Wind	302.2	
Total	**991.8**	
2008 Community Demand	779.3	

Major Assumptions

	Small-scale Wind	Medium-scale Wind	Large-scale Wind
Turbine Size/Type	1-25 kW, Bergey Excel 10 10kW model, 30 m hub height	25-500 kW, EWT DW54 500kW model, 50 m hub height	>500 kW, Vestas V100 1.8MW model, 80 m hub height
Land Included	Agricultural, Residential, Commercial/Industrial, and Public property class designations, Parcels with at least a 2 acre circle free of human occupied structures and property lines	Agricultural, Forest, Recreation, Vacant, Commercial and Industrial property class designations, Parcels >6.5 acres	Agricultural, Barren or Disturbed, Brush, Grassland and Forest property class designations, Parcels with at least a 35 acre circle free of property lines, land within 6 miles of a high voltage transmission line
Land Excluded	Unique natural areas (UNAs), slopes >15%, Important Bird Areas, Publicly owned open space, Critical Environmental Areas, Airport approach and clear zones, Cornell natural areas	Residential property class designations, publicly owned land,	Unique natural areas (UNAs), slopes >15%, Important Bird Areas, Publicly owned open space, Critical Environmental Areas, Designated Distinctive scenic viewsheds, Airport approach and clear zones
Number of Turbines	1 per tax parcel	1 per tax parcel	n/a
Min. Wind Speeds	5.25 m/s at 80m	5.25 m/s at 80m	6.5 m/s at 80m

The overall objectives of this section are 1) to quantify the generation potential of implementing wind power, for large-, small- and medium-scale energy production within Tompkins County, and 2) to identify challenges and opportunities for future implementation of wind power in the

County. In this report, wind power systems have been divided into three categories based on their potential to create energy and probable uses. The distinctions between the different scales of wind power were chosen because of how net metering laws are structured in New York State. The maximum amount of power allowed to be net metered on residential properties is 25 kW, so that was the upper bound used for small-scale wind power. Agricultural land can be net metered for up to 500 kW of power, so that was the limit used for medium scale power[1]. More concisely, we defined the categories as follows:

- *Small-scale wind power*: turbines with a rated capacity between 1 kW and 25 kW. These will likely be used by individual homes.
- *Medium-scale wind power*: turbines with a rated capacity between 25 kW and 500 kW. These will likely be used for small businesses, especially agriculture, or for community-shared turbines.
- *Large-scale wind power*: turbines with a rated capacity above 500 kW. These will likely be used as wind farms with the electricity sold to utilities.

We used a Geographic Information System (GIS)-based model to determine potential wind power sites using information relating to wind speeds, parcel size and other considerations. Once we determined the number of turbines that could be erected in the county, we used the average wind speed, its standard deviation, and other information specific to the turbines to determine the probable Annual Energy Output (AEO) of wind-generated electricity in the county. The table below summarizes the end results of this analysis assuming continuous operation with no degradation in efficiency. Thus, the numbers below do not include downtime for maintenance, and other similar occurrences.

Table 1: Total power, capacity, and annual energy output for 3 scales of turbines.

Scale	Installation Capacity	Capacity Factor	Annual Energy Output
Small-scale	38.6 MW	11.81%	39.9 GWh
Medium-scale	295.5 MW	22.54%	649.7 GWh
Large-scale	120 MW	28.61%	302.2 GWh

Wind turbines have many opportunities for growth in the future if a concerted effort is made. Current siting laws in local municipalities could prevent the growth of wind power. Changes to these laws, particularly around medium-scale wind, would open up a new segment of wind turbines to public use. Maintenance costs of wind turbines are manageable at present and are poised to decrease as wind power becomes more ubiquitous. Wind power to some extent complements solar power and could make both renewable options more attractive. Recent studies have found that wind power has only slight effects on bat and bird ecology, and minimal

[1] http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=NY05R&re=0&ee=0

to no effects on human health[2][3]. Additionally, community owned wind power as a concept has begun to spread and will allow wind power to enter into an entirely new subset of the market.

1. Introduction

Wind turbines convert energy from the wind into usable electrical energy. As wind speeds vary diurnally and seasonally, the electricity generation from wind turbines is inherently intermittent. Currently, the majority of wind power systems are grid tied, meaning they are interconnected with the electrical grid. In most of the small- and medium-scale systems, the grid can act as a kind of battery, accepting any extra electricity that wind power system produces that is higher than the demand, and supplying electricity if the wind power system does not meet the demand.

Wind power is governed by one important equation. The equation describes the power that can be extracted from the wind:

$$P = \frac{1}{2} C_P \rho \pi r^2 u^3$$

where P is the power (in the wind), C_P is the efficiency of the turbine, ρ is the density of the wind, r is the radius of the wind turbine, and u is the speed of the wind. Essentially the equation measures the flow rate of the wind using the area, density and the velocity. By multiplying the flow rate by velocity squared we get a formula for total power in the wind. The efficiency factor takes the power in the wind and determines how much power can be extracted by a specific turbine. Because wind power scales with the cube of wind speed, finding sites with high wind speeds is of utmost importance to creating successful wind turbines.

Wind turbines can come in a variety of shapes. They have blades that spin either on a horizontal or on a vertical axis as seen in Figures 1a and 1b. They can vary based on hub height (i.e., how high the tower the turbine sits on is), and blade radius (i.e., the length of the blades). Since wind speeds increase as height above the ground increases and as described above power is related to the cube of wind speed, electricity generated is related to the hub height at a site. Since wind can only be used if it passes through the sweep of the blades, a longer blade radius allows more power to be generated.

It is important to note that rated capacity does not necessarily correspond to energy generated at any given time. Unlike rated capacities for thermal power plants that can run at maximum capacity any time, a wind turbine's rated capacity instead represents a maximum power that can be generated if the wind is blowing sufficiently fast. Because of this, wind turbines will generally generate less than their rated capacity. While this intermittency cannot be foreseen on a day-to-day basis into the future, the yearly output of a turbine can be generally predicted based on the mean wind speed of a site and the variation of that speed.

[2]Knopper, Loren D., Christopher A. Ollson, Lindsay C. McCallum, Melissa L. Witfield Aslund, Robert G Berger, Kathleen Souweine, and Mary McDaniel. Wind Turbines and Human Health (2014). Retrieved from: http://journximityal.frontiersin.org/Journal/10.3389/fpubh.2014.00063/full

[3]Minderman, Jeroen, Chris J. Pendlebury, James W. Pearce-Higgins, Kristy J. Park. Experimental Evidence for the Effect of Small Wind Turbine Proximity and Operation on Bird and Bat Activity. 2012. Retrieved from: http://www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0041177

Figure 1. (a) A horizontal axis wind turbine; (b) A vertical axis turbine

There are three characteristic wind speeds for wind turbines: the cut-in speed, the rated wind speed and the cut-out speed. The cut-in wind speed is the lowest possible wind speed, measured at hub height, which the turbine can use to generate power. The rated wind speed is the wind speed at which the turbine produces the output it is rated for. The cut-out wind speed is the maximum wind speed at which the turbine can generate power. In between the cut-in speed and the rated wind speed, the power output of the turbine increases. Figure 2 shows a typical output of a wind turbine for several speeds.

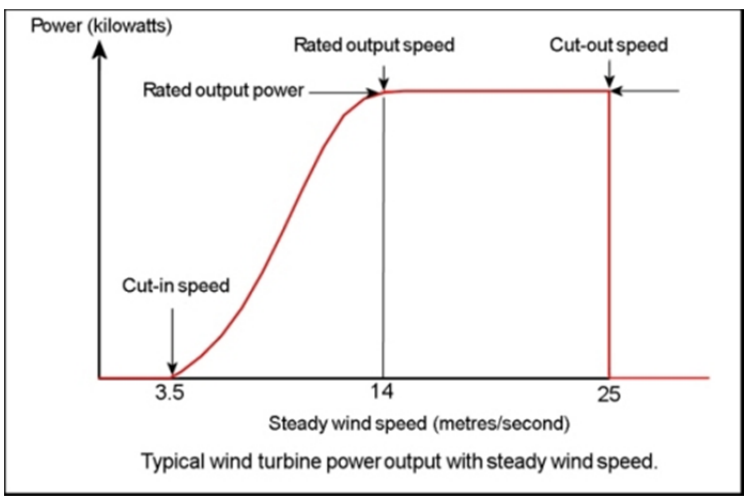

Figure 2: A typical power curve for a wind turbine[4].

Recently, wind power has experienced an increase in public interest. The US Department of Energy has made studies into the efficacy of wind power. Their conclusion is that the US could move to 20% wind power within the next 30 years[5].

[4]http://www.wind-power-program.com/Images/turbine_characteristics.htm/Typical%20power%20output%20(500%20x%20330).jpg

There has been one major development in the state of wind power in Tompkins County. The Black Oak Wind Farm in Enfield, NY is slated to start construction in 2016. The 16.1 MW wind farm will use seven GE 2.3 MW turbines and is projected to provide the equivalent of 5,000 homes with electricity. Black Oak is the first community owned wind farm to be built in New York State and may serve as a model for future community owned wind farms in New York.[6]

The rest of the report is organized as follows. First, we will elaborate the methodologies and results in estimating the wind power potential in Tompkins County (Section 2). Then, we will discuss the opportunities and challenges (Section 3) in future wind power development in the County.

2. Wind Power Potential of Tompkins County

In order to calculate the wind power potential of the County, we used GIS software to determine areas with sufficient wind speeds to spin turbines. In order to determine the wind speeds throughout the county, we used a wind resource map of Tompkins County at 80m created by AWS Truewind that we received through the Cornell University Geospatial Information Repository.[7] The map was generated using MesoMap, which used a series of measurements and a simulation of atmospheric physics to predict average wind speeds at every point in the county. The map was uploaded into our GIS program and used for the rest of the project. This map was chosen over a similar one made with 100m high data because the process of scaling down the wind speeds to lower heights introduced an approximation, which can be a source of error. By choosing a map at a lower elevation, we were able to minimize the error from such an approximation. Other GIS map data was taken from CUGIR, the GEDDeS lab at Cornell University, the Tompkins County Planning Department and the Audubon Society of New York.

In order to look at the wind resource of Tompkins County, we adopted several general criteria based off the physics of wind turbines, and local and federal laws:

- Locations with wind speeds lower than 5.25m/s at 80m of elevation were omitted for small- and medium-scale wind as they are unsuitable for those types of wind power. Similarly, wind speeds lower than 6.5m/s at 80m were omitted for large-scale wind development. According to American Wind Energy Association (AWEA), “Installers recommend sites with average wind speeds of at least 12 mph(5.36m/s)”[8] Lands with 5.25m/s of wind were chosen despite being beneath the AWEA recommended limit to account for potential improvements to wind technology.
- We omitted lands deemed to be sensitive to wind development, as summarized in the table in the Executive Summary.
- Areas with slopes greater than 15% were omitted as they would make installation of wind turbines impractical.[9]

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[5] 20% Wind Energy by 2030. Retrieved from: http://www.20percentwind.org/
[6] Black Oak Wind Farm (2014). Retrieved from: http://www.blackoakwindny.com/
[7] http://cugir.mannlib.cornell.edu/bucketinfo.jsp?id=7878
[8] http://www.awea.org/Issues/Content.aspx?ItemNumber=4638&navItemNumber=727
[9] http://www.nrel.gov/gis/data_wind.html

- Areas within 20,000 feet of the airport were omitted because of federal laws requiring Federal Aviation Administration approval for any projects exceeding a 100:1 horizontal distance to vertical height within 20,000ft of a runway of more than 3,200ft, which Ithaca-Tompkins County Airport has.[10]
- We further assumed that there would only be one turbine installed per tax parcel for small and medium scale. This is because of net metering limits and practical constraints involved with a private residence or small business buying more than one turbine.

There were other considerations for each unique scale of wind power. Those will be dealt with in their individual sections.

2.1 Wind Calculations Methodology

In order to calculate the wind potential for the county, we needed to establish all of the equations needed. Since the wind data that we gathered was for an elevation of 80m, the wind data had to be scaled down to the hub height. Wind speeds have a relation to height that follow the general formula:

$$\frac{u_1}{u_2} = (\frac{h_1}{h_2})^{\alpha}$$

where u_1 and h_1 are the wind and height at one height, u_2 and h_2 are the wind and height at a second height, and α is the power law exponent. Inputting the appropriate values for α, u_1, h_1 and h_2, we found the proper wind speeds for a wind turbine for any height.

Once we had the wind data for the county, we could find a way to approximate energy production. With these values, we could find the annual energy output (AEO) produced by each turbine with the following formula:

$$E = P_{ave} \times 8760$$

where E is the total energy produced in a year, P_{ave} is the rated power of the turbine, and 8760 is the number of hours in a year. Power from the wind turbine follows the following equation:

$$P_{avg} = \int_{u_{cut-in}}^{u_{rated}} \mathbb{P}(u) * P(u)du + \int_{u_{rated}}^{u_{cut-out}} \mathbb{P}(u) * P(u_{rated})du$$

Where P_{ave} is the average power, $u_{cut\text{-}in}$ is the cut-in speed of the turbine, u_r is the rated speed for the turbine, $u_{cut\text{-}out}$ is the cut-out speed for the turbine, $\mathbb{P}(u)$ is the probability of a given wind speed based on the Weibull distribution and P(u) is the power in the wind based on the power curve (such as that illustrated in Figure 2). The Weibull distribution follows the formula:

$$\mathbb{P}(u) = (\frac{k}{c})(\frac{u}{c})^{k-1} e^{-(\frac{u}{c})^k}$$

where k is the shape parameter of the Weibull Distribution, c is the scale parameter of the Weibull Distribution, and the rest of the symbols are defined above. k can be determined through the following formula:

$$k = (\frac{\sigma_u}{u_{ave}})^{-1.086}$$

[10] Aviation and Airport Development Law Blog. ―Wind Farms Run Into Turbulence with the FAA.‖ http://www.aviationairportdevelopmentlaw.com/2010/01/articles/faa-1/regulatory/wind-farms-run-into-turbulence-with-the-faa/ (25 January, 2010). Retrieved January, 2012.

where σ_u is the standard deviation of wind speed, and u_{ave} is the average wind speed. c can be determined by:

$$c = \frac{u_{ave}}{\Gamma(1+\frac{1}{k})}$$

where Γ describes the gamma function, a special mathematical function, and k is the shape parameter listed above. Thus the performance of a wind turbine can be calculated using only the average wind speed, the standard deviation of that wind speed, and factors relating to the specific wind turbine.

For ease of use, we can combine the above formulas into a single formula for the capacity factor. Capacity factor tells the percentage of power that can be produced by the turbine relative to the maximum, or rated, power of the turbine. The conglomerate formula for capacity factor is seen below:

$$CF = \frac{e^{-(\frac{u_{cut-in}}{c})k} - e^{-(\frac{u_{rated}}{c})k}}{(\frac{u_{rated}}{c})^k - (\frac{u_{cut-in}}{c})^k} - e^{-(\frac{u_{cut-out}}{c})^k}$$

where CF is the capacity factor and the remaining components are listed above.

For this equation, we needed to determine the proper value for the α parameter in the power law equation. The typical value for the power law parameter is 1/7, however we did not feel that value was appropriate for Tompkins County. The hilly terrain of the county combined with the high degree of tree cover meant that we needed a higher value for α. In the end, the power law parameter was set equal to .22 which is appropriate for the hilly, woody conditions of Ithaca.[11]

We also ran a sensitivity analysis on the power law parameter to see the effect the choice of power law exponent had on the scaled down wind speed. For a change from 80m to 30m, which is the change needed to find the average wind speeds for small-scale turbines, we found that a 1% change in the alpha factor resulted in a .22% change in the calculated average wind speed. For a change from 80m to 50m, the change needed to find average wind speeds for medium scale turbines, a 1% change in the alpha factor resulted in a .1% change in the calculated average wind speed. From this analysis, we can deduce that even if the choice in alpha factor is slightly incorrect, the results will not be overly swayed by this error. Further, we can feel comfortable moving forward using the value of .22 for this parameter.

The standard deviation of the wind speed was determined to be 43% of the average wind speed based off wind data recorded at Ithaca College in 2009.[12] The Ithaca College measurements were taken at a height of 50m and were extrapolated to fit an 80m height. There was another set of data taken at Ithaca Airport that could have been considered. This data was taken at an elevation of 10m and found the standard deviation of the wind speed to be 72%. Because of the low height of the data collection and the relatively high value of the power law exponent in

[11] Ray M, Rogers A, McGowan J (2006) Analysis of wind shear models and trends in different terrains. In: Proceedings of the AWEA windpower 2005 conference, Pittsburgh, 4–7 June 2006

[12] Ithaca College Wind Power Project. (2009). Retrieved from http://faculty.ithaca.edu/bclark/icwindpowerproject/

Tompkins County, we decided to not consider the Ithaca Airport data in our analysis. Thus value of a 43% standard deviation in wind speed was used for all of our calculations.

2.2 Small-Scale Wind Power

Small-scale wind power is defined as turbines designed for home energy production. Because of the typical needs of homes, we capped this category at 25 kW rated turbines. In addition to the constraints listed above, we also added several more considerations. In order to determine the minimum amount of land needed to incorporate a fall zone for small-scale turbines, we determined that a sufficient area would be a circle with a radius calculated by the turbine height plus a 50 foot setback for the property and an extra 10 feet of fall zone setback. This is based off the "Model Municipal Ordinance for Utility-Scale Wind Energy Conversion Systems (U-SWECS)" which, while not drafted into law, has provided many of the baseline assumptions for our wind analysis.[13] Given the power needs of a typical home, we used a 105 ft turbine height for our calculations. This meant that the additional criteria to be added to the GIS model were as follows:

- Parcels with at least a 2 acre circle free of human occupied structures and property lines were included because they have sufficient area to accommodate the calculated fall zone.
- Wind speeds that were not excluded in the previous parts of the analysis were separated into 'bins' which each contain a range of wind speeds. They were then given a value within the bin range. All wind speeds in that bin are approximated to that given value.

[13] http://tompkinscountyny.gov/files/emc/news/FINALwindordinance2005.pdf

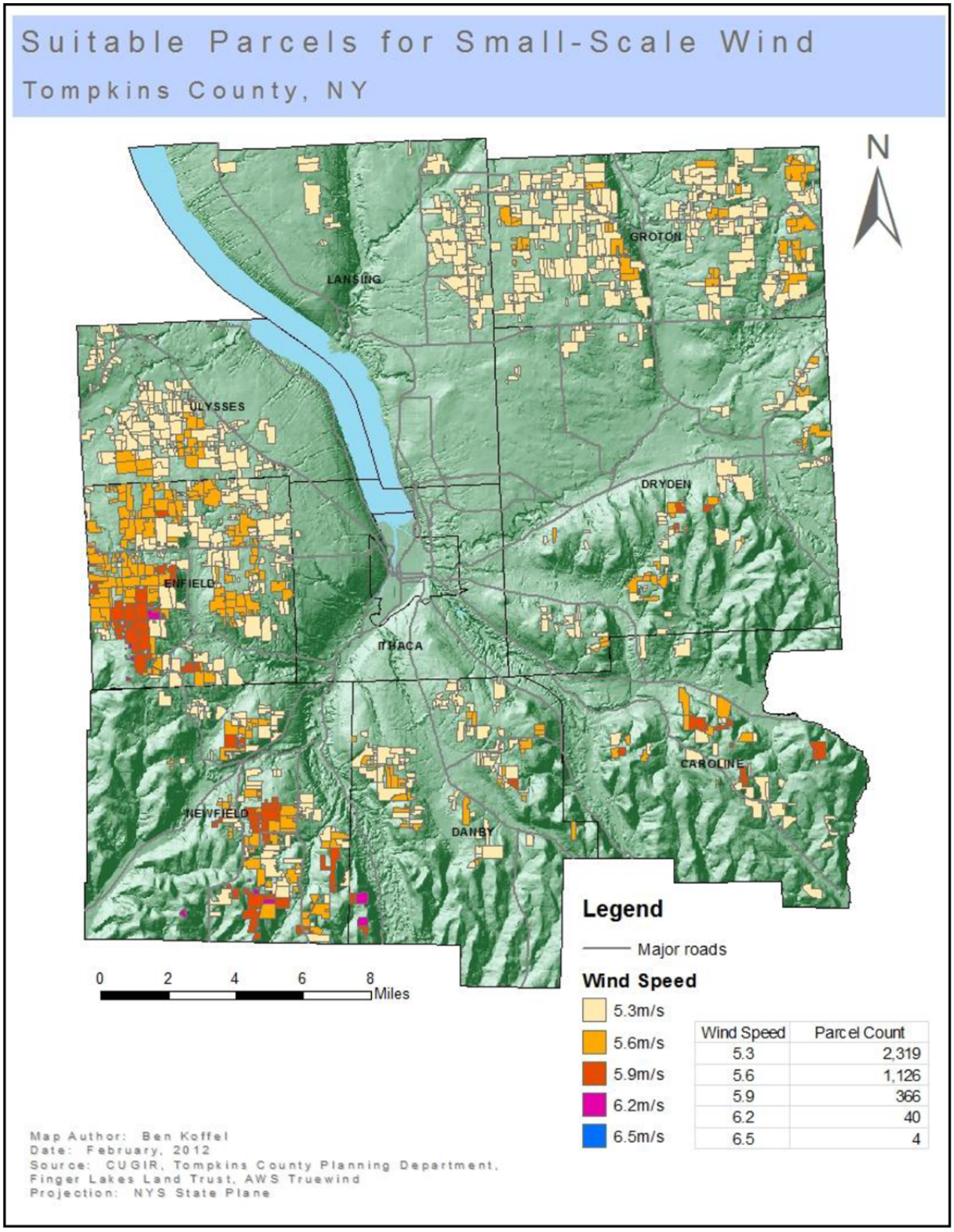

Figure 3: Suitable parcels for small-scale wind

For this analysis, we needed to choose a specific wind turbine to get specific numbers for power and energy production. We used the Bergey Excel 10 wind turbine[14] which has a rated power of 10 kW to model the average of all small-scale turbines that could be installed within the county. The turbine represents a typical example of a wind power unit that a home might install. This specific turbine has a cut-in speed of 2.5m/s, a rated speed of 11m/s, and no cut-out speed. It has a blade radius of 3.5m and a hub height of 30m.

Based on our analysis and calculations described above, we estimated the potential for small-scale wind turbines as 38.6 MW and the corresponding annual energy output as 39.9 GWh. The results are summarized in Table 2. It should be noted that the wind speeds appear in Table 2 as those at 80 m to be consistent with medium-scale and large-scale results, even though the hub height is ~30 m.

Table 2: Small-scale wind power breakdown

Wind Speed at 80m [m/s]	Number of Parcels	Capacity Factor	Total Power [MW]	AEO per Turbine [MWh]	Total AEO [MWh]
5.3	2319	10.90%	23.19	10	22,144
5.6	1126	12.46%	11.26	11	12,288
5.9	366	14.99%	3.66	13	4,805
6.2	40	16.79%	.4	15	588
6.5	4	18.69%	.04	16	65

2.2 Medium-Scale Wind Power

Medium-scale wind power was defined to exist in the range between large-and small- scale power. This would entail turbines that collect more energy than a typical home would use but not enough energy to be worth investment by a utility. Energy production on this scale is perfect for businesses, especially farms. This range of turbine size represents a large store of untapped potential within the county.

In order to collect more energy than small-scale wind turbines, medium-scale wind turbines will have larger hub heights and bigger blade radii. Because of this height difference, medium- scale wind power requires larger parcel sizes to allow for bigger fall zones. To reflect this, we made several changes to the ArcGIS model:

- Larger fall zones mean that larger parcels are needed. All parcels sized 6.5 acres or less were omitted from the model.
- Residential land is only eligible for 25 kW of net metering. So they are unlikely to install turbines large enough to be considered medium scale. All tax parcels classified as residential land were omitted.

[14] http://bergey.com/products/wind-turbines/10kw-bergey-excel

- Wind turbines are not allowed to be installed on most state owned public land. Unfortunately, we could not differentiate the public land based on ownership with our GIS files, so in the interest of making a conservative analysis, all public lands were removed.
- We looked at building data and removed the area of buildings from the parcel area. The reason for doing this is because several laws prohibit turbines within a certain radius of an inhabited building. We wanted to see how a constraint like this would affect the analysis. Since this removed two possible parcels from the final map, we can conclude that laws of this nature are unlikely to affect installation at eligible sites.

For the purposes of this analysis, we modeled all medium-scale wind turbines after EWT's DW54, a 500kW Wind Turbine. This turbine was chosen because it has a low cut-in speed, which means that it can collect a wide range of wind, and a large hub height, which means that it has access to higher elevation, and thus faster, wind speeds. This turbine has a 27m blade radius and a 50m hub height. It also has a rated wind speed of 10m/s, a cut-in wind speed of 3m/s and, a cut out wind speed of 25m/s.[15]

Based on our analysis and calculations, we estimated the potential for medium-scale wind turbines as 295.5 MW and the corresponding annual energy output as 649.7 GWh. Figure 4 illustrates the potential sites for deploying medium-scale wind turbines.

Table 3: Medium-scale wind power breakdown

Wind Speed at 80m [m/s]	Number of Parcels	Capacity Factor	Total Power [MW]	AEO per Turbine [MWh]	Total AEO [MWh]
5.5	14	13.64%	7	597	8364
5.8	19	16.71%	9.5	732	13,905
6.1	47	18.88%	23.5	827	38,876
6.5	95	22.31%	47.5	977	92,821
6.7	108	24.67%	54	1,080	116,686
7.1	306	28.28%	153	1,239	379,008

Table 3 shows that there is the potential for medium-scale wind power to generate large amounts of energy for the county. One might further wonder about the current land use of these properties. Table 4 shows that the vast majority of the land we identified as viable for medium-scale wind turbines is either listed as Vacant or Agricultural, both types work well for wind power.

[15] http://newgen.uk.net/wind/commercial-agricultural/ewt-500kw-wind-turbine/

Table 4: Medium-scale wind power parcel designations

Parcel Designation	Vacant	Agriculture	Forest	Commercial	Recreation	Industrial
Total Parcels	367	165	24	21	8	5
Total Power [MW]	183.5	82.5	12	10.5	4	2.5

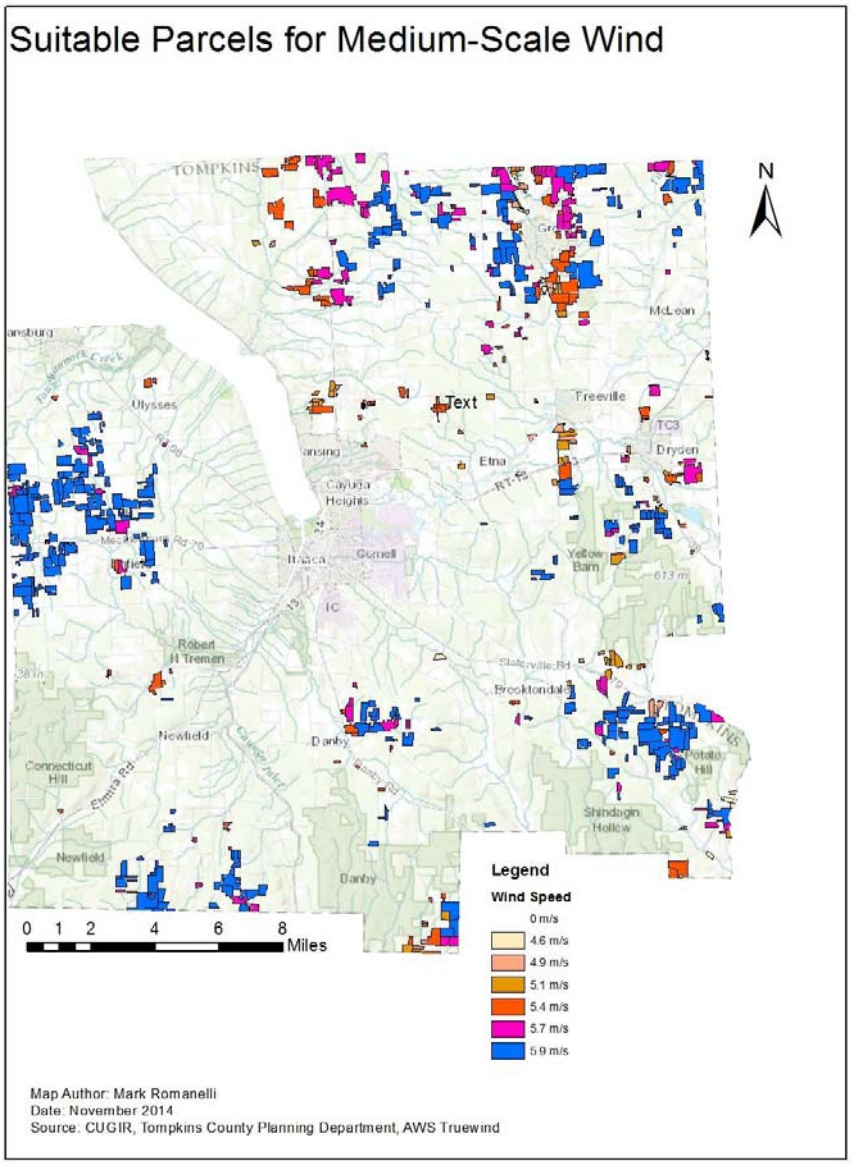

Figure 4: Suitable parcels for medium-scale wind

2.3 Large-Scale Wind Power

We defined large-scale wind power as turbines with rated capacity greater than 500 kW usually used for utility scale generation of energy.

Because their capacity exceeds 500kW, many of the constraints used in our analysis are based on the 2005 Tompkins County Environmental Management Council's "Model Municipal Ordinance for Utility-Scale Wind Energy Conversion Systems". Per the ordinance, large-scale wind development requires several additional criteria to be met for installation:

- Turbines must be separated from inhabited structures and public roads by 1.25 times their height.
- Turbines must be separated from property lines by 2 times their total height unless the owner can get written consent from the affected neighbors.
- Turbines must also be separated from power lines, telephone lines and designated scenic highways by 2 times their height.[16]

There were several other considerations that were added to the GIS analysis as well:

- Because these turbines will be used to generate large amounts of energy, 5.25 m/s wind speed would not be sufficient to make the turbines feasible. Instead, we decided to use a minimum of 6.5 m/s average wind speed.
- We had to consider the fact that these turbines will be used for utility scale power generation. This consideration made proximity to transmission lines a point of major importance. Proximity to transmission lines allows energy to be delivered out of the system and reduces the cost of installing high voltage transmission lines, which can be a major expense. Studies suggest that 10 km may be the maximum distance large-scale wind turbines can be placed from transmission lines.
- Large-scale wind turbines cannot be placed in locations that would interfere with the Tompkins County Public Safety Communication System. The turbines could not be placed within a certain radius of a receiver or transmitter in this system and especially not within the lines of sight between receivers and transmitters. Although this aspect was considered, it was not incorporated into the analysis, but is noted as an important consideration in future large-scale wind siting.

The final results of the large-scale wind analysis can be seen in Figure 5.

For the energy generation analysis of these sites, we used the Vestas V100 1.8MW Turbine[17]. This turbine was chosen because it was designed to work in areas of comparably lower wind speeds than turbines of comparable rated powers. The turbine has a rotor radius of 50m, a hub height of 80m, a cut in speed of 3m/s, a rated speed of 12m/s and a cut out speed of 20m/s. Because the hub height was the same height as the wind data we used, we did not need to scale down the wind speeds for large-scale wind.

[16] http://tompkinscountyny.gov/files/emc/news/FINALwindordinance2005.pdf
[17] "V100-1.8 MW - Vestas." 2012. 10 Nov. 2014 <http://www.vestas.com/files%2Ffiler%2Fen%2Fbrochures%2Fvestas_v_100_brochure.pdf>

The end result of this analysis is that there are three main areas that have the potential to be used for large-scale wind power. Of these, the largest site is in Enfield which has the potential for the installation of 51 turbines. Part of this site is currently being developed by the Black Oak Wind Farm. The second major site is in Danby. It consists of only one parcel, but has the potential to house 3 turbines. Finally, there is a site in Dryden that could house 13 turbines. In all, we could install 67 turbines in these sites for an installed capacity of 120MW and a total annual power generation of 302.2 GWh. These sites and their maximum outputs are summarized in the chart below.

Table 5:The three main l and their large-scale wind potential.

Site Location	**Maximum Number of Turbines**	**Average Wind Speed at Site [80m]**	**Capacity Factor**	**Installed Capacity [MW]**	**Total Annual Output [MWh]**
Enfield	51	6.76	28.60%	91.8	230,010
Danby	3	6.64	27.41%	5.4	12,965
Dryden	13	6.79	28.90%	23.4	59,240

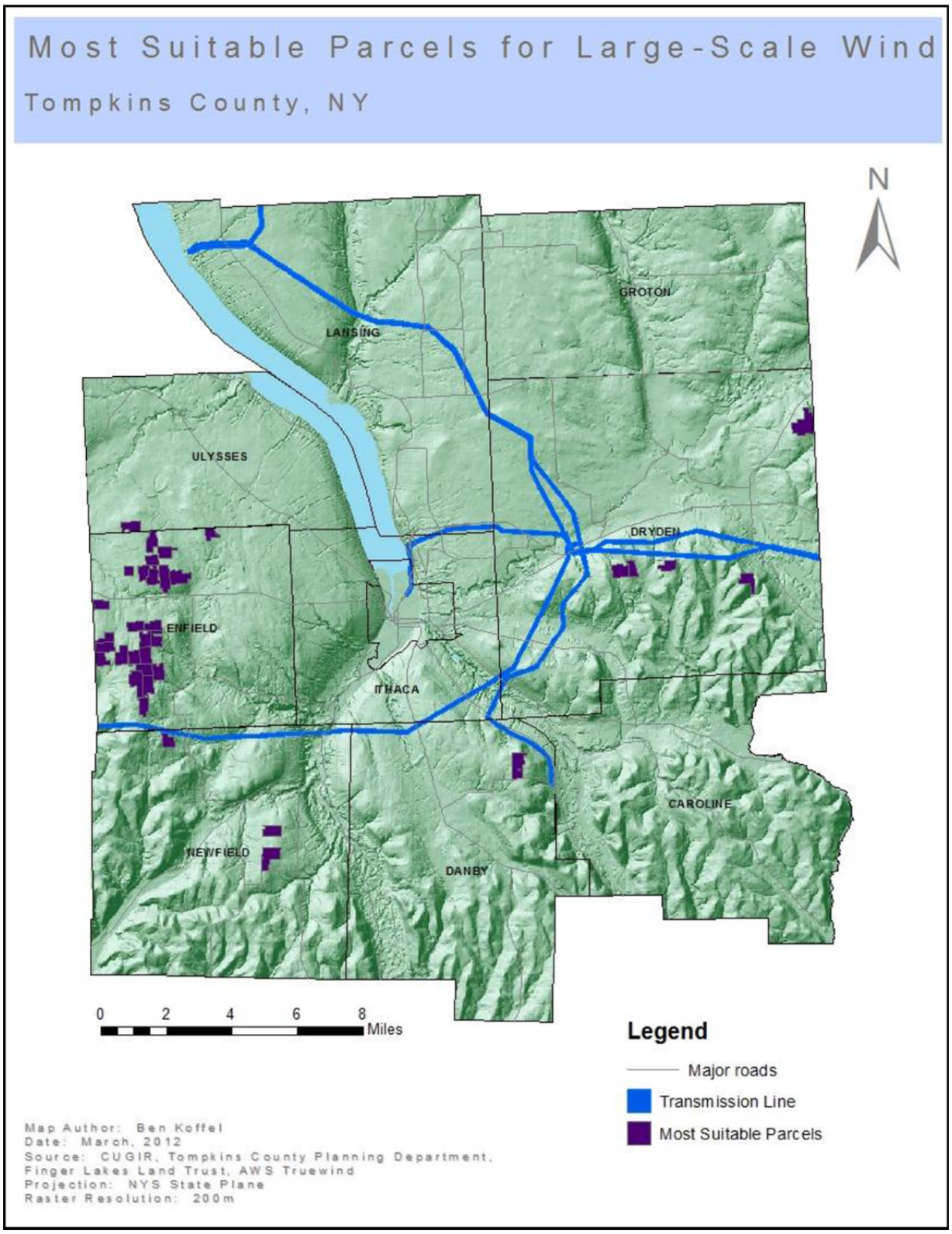

Figure 5: Suitable parcels for large-scale wind

3. Challenges and Opportunities

3.1 Challenges

The regulatory structure for wind turbines is governed primarily at two levels – the state and local level. For large-scale wind installations, the state is significantly involved in siting through the Power Facilities Siting Act, also known as Article X,[18] and the State Environmental Quality Review Act (SEQR).[19] For small-scale turbines, the primary government entity is the municipality, which may create their own regulations for height restrictions, zoning, and special use permits.

3.1.1 Regulations

3.1.1.1 State Regulations

The regulations on large-scale energy development in New York State changed with the Power NY Act of 2011 and the reinstatement of Article X. Under Article X, a multi-agency Siting Board was formed and charged with streamlining the permitting process for power plants of 25 MW or greater, centralizing authority for site approval of large projects with the state. Facilities with an installed capacity of less than 25 MW are permitted under the SEQR process, granting more authority for smaller projects with local governments.[20]

Article X requires any project with a capacity of 25 MW or more to submit an application to the state siting board. This application must discuss potential health and safety impacts, emissions, demographics of the host community, alternative locations for the power source, measures needed to be taken to minimize environmental impact, a list of additional studies to be conducted and required permits. There is also a fee of $350/MW to cover costs of the approval process. This has no effect on small or medium scale wind power and per this law large scale wind power is subject to the same rules as every other large capacity power source. Additionally, Enfield is the only site that has the potential to have 25 MW of capacity and thus is the only site potentially affected.

SEQR addresses some of the environmental aspects of new energy projects. SEQR requires an environmental review of projects. It grants local municipalities, state agencies and other involved entities the right to request modifications, such as relocation of turbines or reduction in the number of turbines, and even grants them the right to halt the project at any point in development if necessary. Again, this process is only likely to affect large-scale wind farms.

3.1.1.2 Local Regulations

The greatest control that a local community can exercise over wind power development is through its zoning, land use provisions, and permitting procedures. By creating regulations that address wind turbines and provide an efficient and easily understandable permitting process,

[18] "Article 10 Regulations." 2012. 10 Nov. 2014 <http://www.dps.ny.gov/SitingBoard/SBArticle10Regs.html>
[19] "SEQR Handbook - New York State Department of ..." 2009. 10 Nov. 2014 <http://www.dec.ny.gov/permits/47636.html>
[20] Morris, Jackson. The Pace University Energy & Climate Center. Personal correspondence, February 2012.

municipalities can encourage more development of small, medium and large-wind in their jurisdictions, and restrict certain types of development to specified districts.

Each of the towns within Tompkins County have the authority to enact local laws defining the limitations on the implementation of wind power within town borders. As of early 2012, the status of these laws are as follows:

- Ithaca: Small-scale wind facilities are permitted in all zones provided they are under 145 ft tall and operate within a defined decibel range.
- Groton: Small-scale wind power is permitted provided the installed capacity is less than 10 kW, the height is less than 120 ft, and the turbine falls within a property line setback of 1.5 times the height of the turbine.
- Dryden: Small-scale wind turbines may be installed provided they are under 50 ft in total height and under 10 kW in capacity. All projects larger than that require special use permits.
- Lansing: Wind turbines require special considerations and a special use permit, except within areas zoned for medium density residential and all commercial districts where they are not permitted.
- Newfield: No provisions for wind turbines could be found.
- Ulysses: No provisions for wind turbines could be found.
- Caroline: No provisions for wind turbines could be found, however the Comprehensive Plan for the town identifies renewable energy technologies as an area of interest for the town. Additionally, Caroline does not have any zoning laws.[21]
- Danby: No provisions for wind turbines could be found.[22]
- Enfield: According to the Enfield Wind Ordinance, a Wind Energy Permit is required in order to construct any wind turbine, regardless of size, or any meteorological tower.[23] The only exception to this rule is for turbines that are exclusively used in an agricultural zone. For turbines larger than 100kW a Wind Energy Permit Application must include a description of the project, site plans, turbine information, decommissioning plan, landscaping plan, Part 1 of a Full Environmental Assessment Form (EAF) with visual impact addendum, and a construction schedule. For a turbine under 100 kW, the Wind Energy Permit application must include turbine information, a visual analysis, evidence that the utility provider has been informed of the electrical interconnection, electrical diagrams, and evidence that the primary use of the turbine will be for reducing on-site electric demand. For both permits, the fee schedule appears below:
    - WTG Wind Energy Permit: $250 per WTG.
    - Wind Measurement Towers Wind Energy Permit: $200 per tower.
    - Small WTG Wind Energy Permit: $150 per WTG.
    - Wind Measurement Tower Wind Energy Permit renewals: $50 per WTG.
    - Additionally, the town may charge the project owner any fees associated with the inspection by an expert. The town reserves the right to negotiate a PILOT with the owner of a turbine. As Enfield does not have zoning, there are no specifications on the allowable locations of wind turbines.

[21] Town of Caroline, New York. "Town of Caroline Comprehensive Plan." 2006. http://carolinetown.powweb.com/wp-content/uploads/2007/11/comprehensive-plan-2006.pdf

[22] Town of Danby, New York. "Zoning Ordinance, Town of Danby, New York." May, 2005. http://town.danby.ny.us/Documents/ZoningOrdinance.pdf

[23] Town of Enfield. "Wind Energy Facilities Local Law.: 14 January, 2009. http://townofenfield.org/content/Laws/View/8:field=documents;/content/Documents/File/184.pdf

In these cases, the lack of standardized laws regarding wind power within the county may be impeding its development. If vendors must navigate very different processes depending on which town the turbine is being built in, it may increase the time it takes to complete the process and increase the overall cost of the project.

An example for future consideration could come from Europe. A release from the European Wind Energy Association gives a practical guideline for wind turbine siting. While it does list considerations made for auditory, visual, and environmental impact, it is notably silent on setback recommendations.[24] Instead, it recommends that turbines be placed so they do not have undue impact on the noise in the area. This does add a little work for installers, but could give potential sites for wind turbines the leeway they need to install a turbine. Further investigation would be needed to determine if this change in requirements would appreciably impact small-scale wind power adoption within the county.

3.1.2 Net Metering and Grid Integration

Net metering allows the owners of wind power systems to generate power, and gain credit for energy they generate but do not use. This allows the owner to be billed only for net energy used. At present there are 3 different segments that have different net metering limits in New York:

- Residential: <25 kW
- Farm-based: <500 kW
- Non-residential: <2 MW

These net metering limits provide a practical limit to the installed capacity of a property. For many properties this may present no issue because the wind resource is not strong enough to warrant larger installations, but for large farms within Tompkins County, this may limit the amount of wind power capacity that can be installed.[25]

3.1.3 Maintenance

One point that is brought up when comparing wind power to solar power is the maintenance costs associated with wind power. Maintenance represents an unavoidable issue with wind power because turbines require moving parts to operate. An installed turbine can be expected to last more than 20 years and in that time will require annual to semi-annual maintenance. This maintenance may involve changing oil or filters, torqueing bolts, and inspecting other components. Some parts involved in wind turbines may need to be replaced every 5 to 15 years.[26]

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[24] http://ec.europa.eu/energy/res/sectors/doc/wind_energy/best_practice.pdf

[25] New York Incentives/Policies for Renewables & Efficiency. Retrieved from: http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=NY05R

[26] Wind Turbine Operations & Maintenance. Retrieved from: http://awea.files.cms-plus.com/FileDownloads/pdfs/O-M-PPR_1-pager-3.pdf

Maintenance can be expected to cost about 20 to 25 percent of the total cost per kWh over the lifetime of a turbine.[27] Other sources place this number closer to 1.5 to 2 percent of the initial investment per year, with the cost rising as the turbine ages.[28] The AWEA lists the cost of a small wind turbine to be $30,000 on average.[29] With this number as the installation cost, maintenance should cost between $6,000 and $7,500 over the lifetime of the turbine or between $450 and $600 each year. As wind power grows in prominence and more workers are trained to maintain turbines, maintenance costs are likely to decrease.

3.2 Opportunities

3.2.1 Complementary Relationship with Solar Power

A major boon to wind power is its relationship to potential solar power. By analyzing four years of data from the Western Regional Climate Center, we have determined that wind and solar power reach their maximum annual values at different periods.[30] These data comes from Harford, NY, which while technically located in Cortland County, is the closest location to Tompkins County that records both wind speeds and solar insolation. Wind speed reaches a maximum in mid-February. Solar insolation on the other hand reaches a maximum in the beginning of July, while wind speeds are approaching a minimum. While these variances do not exactly compensate for each other, it does suggest that using a combination of wind and solar power could help overcome one of both power sources' biggest weaknesses, their variable nature. Figure 6a below shows a visual representation of this trend.

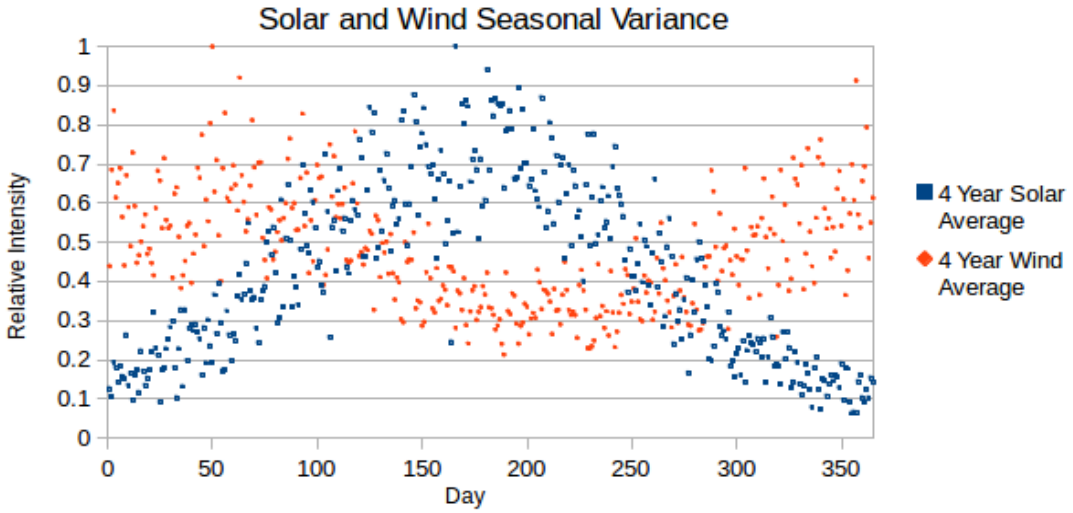

Figure 6(a) Relative wind intensity vs. relative solar intensity for Harford, NY

[27] Operation and Maintenance Costs of Wind Generated Power. Retrieved from: http://www.wind-energy-the-facts.org/operation-and-maintenance-costs-of-wind-generated-power.html
[28] Operational and Maintenance Costs for Wind Turbines. Retrieved from: http://www.windmeasurementinternational.com/wind-turbines/om-turbines.php
[29] http://www.awea.org/Issues/Content.aspx?ItemNumber=4638&navItemNumber=727
[30] Western Regional Climate Center. 2014. Retrieved from: http://www.wrcc.dri.edu/cgi-bin/rawMAIN.pl?idRITH

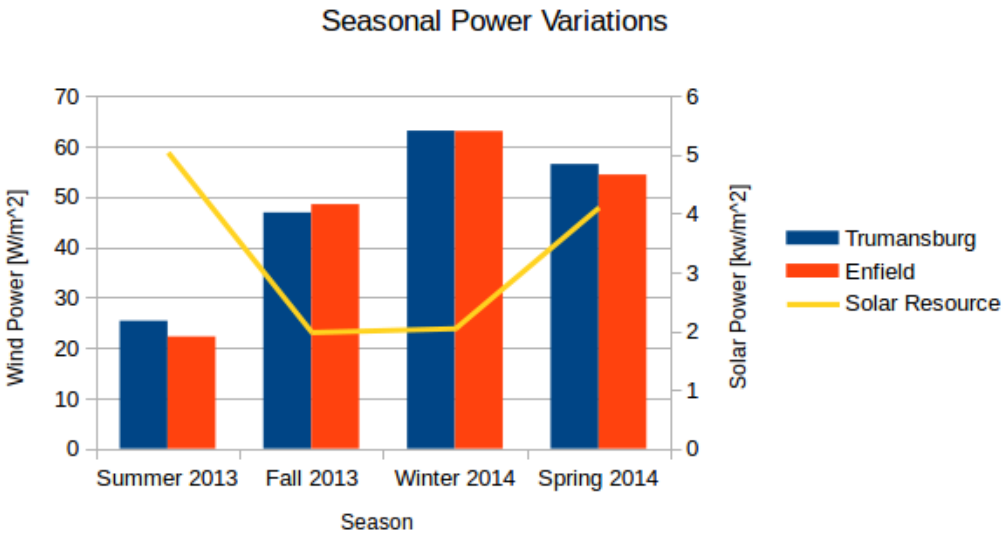

Figure 6(b) Solar power seasonal variations represented by the yellow line compared to wind power seasonal variations represented by the two bar graphs at two locations.[31]

We then performed analysis of the data to determine the correlation coefficient between solar and wind power. Correlation coefficients show the level to which a change in one data set can be observed in another. A coefficient of 1 would describe two data sets that are completely correlated, and a coefficient of -1 would describe two data sets that have a complete negative relationship, that is one rises while the other falls. Finally a coefficient of 0 would describe two data sets that are completely unrelated. In order to properly compare these data sets, we had to make sure both data sets had a linear relationship with power. Solar insolation values already had a linear relationship with power, but wind speed has a cubic relationship with power. This means that in order to compare like values we had to compare the cube of wind speed with solar radiation. The wind and solar data sets have a correlation coefficient of -.28 which denotes a weakly negative correlation between solar and wind power.

Because wind power varies so much with location, we also did an analysis for two locations within Tompkins County. Using seasonal average wind speeds provided by Weaver Wind Energy, we found the average seasonal wind power for Trumansburg and Enfield. We compared these data to the solar data from the Harford station. While Harford is not within the county, solar intensity varies by location to a much smaller degree than wind does so solar data from Harford is valid for our analysis. Figure 6b shows that solar power peaks in the summer and reaches a minimum in fall and winter while wind power peaks in winter and reaches a minimum in the summer.

[31] Art Weaver, personal communication, 4 October 2014

3.2.2 Effects on Populations

Numerous studies have been done to examine the effects of wind turbines on human health. A meta-analysis of existing data published in Frontiers in 2014 found: "The available scientific evidence suggests that electromagnetic fields, shadow flicker, low-frequency noise, and infrasound from wind turbines are not likely to affect human health"[32] The article looked at almost 60 studies related to the effects of wind power on audible noise, low-frequency noise, infrasound, electromagnetic fields and shadow flicker. The studies were not filtered based on date so the majority of them have come from the current decade as wind power has come into prominence. The methods and results of all of these studies were compared, questioned and analyzed.

The same article found that some people may be annoyed by the noise produced by turbines, but the majority of issues connected with turbines can be explained by the nocebo effect, where the mere suggestion of side effects can bring on negative symptoms. This finding suggests that most reported negative health effects from wind turbines can be overcome with proper planning and development guidelines and thus they should not be regarded as an insurmountable problem with wind power. The article lists some general guidelines for wind development to overcome the nocebo effect, including: the setting of sound level based rather than distance based setbacks, and closer monitoring of projects in development to make sure noise levels stay within acceptable limits.[33]

Another point of concern has been the effect of wind turbines on bird and bat populations. A paper published in PLOS ONE studied the effect of turbines on these populations. The end result of the study showed that the installation and operation of turbines had no threat to survival on overall bird populations. Bat populations were affected only if turbines were placed within very close proximity to their habitats. The study recommended that turbines be placed no closer than 20 m to known bat habitats.[34]

3.2.3 Community Invested and Community Owned Wind Power

Community owned wind power presents several opportunities. A brochure from the National Renewable Energy Laboratory spells out the following advantages for wind projects that are either owned by the municipality or by groups of local individuals:

- Community wind projects allow local control over projects. Communities can be sure that their best interests are being served by the projects because they are in full control over them.

[32] Knopper, Loren D., Christopher A. Ollson, Lindsay C. McCallum, Melissa L. Witfield Aslund, Robert G Berger, Kathleen Souweine, and Mary McDaniel. Wind Turbines and Human Health (2014). Retrieved from: http://journximityal.frontiersin.org/Journal/10.3389/fpubh.2014.00063/full

[33] Knopper, Loren D., Christopher A. Ollson, Lindsay C. McCallum, Melissa L. Witfield Aslund, Robert G Berger, Kathleen Souweine, and Mary McDaniel. Wind Turbines and Human Health (2014). Retrieved from: http://journximityal.frontiersin.org/Journal/10.3389/fpubh.2014.00063/full

[34] Minderman, Jeroen, Chris J. Pendlebury, James W. Pearce-Higgins, Kristy J. Park. Experimental Evidence for the Effect of Small Wind Turbine Proximity and Operation on Bird and Bat Activity. 2012. Retrieved from: http://www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0041177

- Community wind projects can stabilize the price of energy in a region. Wind power requires no fuel and small maintenance costs so the price of electricity from wind power is fixed and predictable.
- Community wind projects can be easily connected to the grid compared to utility-scale wind farms. This is because they tend to be smaller in size than utility-scale wind projects and often do not require transmission line upgrades.[35]

The Black Oak Wind Farm in Enfield represents a new opportunity in community wind power. Typically in the US, wind energy tends to be project financed. In project finance, the initial capital for the project is borrowed against the future revenue streams. This financing option often requires extra diligence in assessing sites but is often chosen because it shifts much of the risk from the developer to the creditors. In Europe, groups of citizens will share equity in a more modest scale turbine and sell the power to the grid. This system does not allow for the same economies of scale that the current US model does. On the other hand, it does allow wind developers to interact with private investors, a largely new market. It also places more power in the hands of individuals in the community thereby increasing public support for planned projects. The Black Oak Wind Farm appears to be financed in a hybrid between these two models possibly opening the door to future ventures with similar models.[36]

3.2.4 Incentives

3.2.4.1 Federal Tax Incentives

There are two main federal tax incentives relating to small-scale wind energy. The Business Energy Investment Tax Credit (ITC) is designed for small wind turbine owners. It grants owners of turbines with 100 kW of capacity or less tax credits worth up to 30% of the value of the project. The American Recovery and Reinvestment Act allows select wind power projects to receive direct payments from the US Treasury instead of ITCs. There was no end date written into the Recovery Act because, while many of Recovery Act projects were focused on jumpstarting the economy, others are expected to contribute to economic growth for many years. Eligibility standards for the act are available at recovery.gov[37]

3.2.4.2 NYSERDA On-Site Wind Turbine Incentive Program

The New York State Energy Research and Development Authority's (NYSERDA) program, "On-Site Wind Turbine," offers incentives to individuals or organizations that are interested in installing wind turbines. $13.8 million in funds are available. As a consequence, not all applicants who express interest will receive incentives. Furthermore, all applicants must meet the eligibility requirements designated by NYSERDA. These requirements are available online at NYSERDA's website. The maximum equipment size shall be 2 MW per site/customer. NYSERDA's incentive shall not exceed 50% of the total installed cost of the system. The program will continue through December 31, 2015 or until funds are fully committed, whichever

[35] Community Wind Benefits. 2012. Retrieved from: http://www.nrel.gov/docs/fy13osti/56386.pdf

[36] Bolinger, Mark. Community Wind Power Ownership Schemes in Europe and their Relevance to the United States. 2001. Retrieved from: http://emp.lbl.gov/sites/all/files/REPORT%2048357.pdf

[37] Federal Incentives for Wind Power Deployment. 2011. Retrieved from: http://www1.eere.energy.gov/wind/pdfs/51452.pdf

comes first. To date, the program has been relatively successful. Thus far, NYSERDA has achieved half as many megawatts as planned. Although the program has only reached half of its intended goal, there is room for growth. More certainty surrounding whether a project will win a NYSERDA grant, at what price, and how to finance the project would help to encourage wind turbine development. Some of these issues reflect general difficulties in developing wind in New York State that are not unique to NYSERDA [17].

NYSERDA offers incentives in the form of rebates, or discounts on the purchase of a wind turbine. Rebates are determined by the expected annual energy output (AEO) of the proposed wind energy system, as calculated by the Wind Professional Wind Resource Report (NYSERDA, 2014). Those who wish to partake in the program are expected to use eligible installers and equipment manufacturers listed on NYSERDA's website. This requirement ensures the wind turbine and its installation will be successful. Incentives are as follows:

- If the AEO is 10,000 kWh or less, the NYSERDA incentive is $3.50 per kWh.
- If the AEO is greater than 10,000 kWh, but not greater than 125,000 kWh, the NYSERDA incentive is $35,000 plus $1.00 per kWh for every kWh greater than 10,000 kWh.
- If the AEO is greater than 125,000 kWh, but not greater than 1,000,000 kWh, the NYSERDA incentive is $150,000 plus $.30 per kWh for every kWh greater than 125,000 kWh.
- If the AEO is greater than 1,000,000 kWh, the NYSERDA incentive is $412,500 plus $.15 per kWh for every kWh greater than 1,000,000 kWh.

There are limitations to the "On-Site Wind Turbine Program." First, the maximum incentive available is $1,040,000 per site/customer and the maximum equipment size is 2 MW per site/customer. NYSERDA incentives shall also not exceed 50% of the total installed cost of the wind energy system. Systems should be sized such that the expected AEO (kWh/year) by the system will not exceed 110% of the customer's annual electric energy usage, including eligible remote meters. (NYSERDA, 2014). Incentives are only available for the installation of new equipment and are only available to eligible Installers. Incentives will not be provided directly to customers who purchase and install their own wind energy systems. For instance in which multiple turbines will be installed at a site, the NYSERDA incentive is based on the AEO of all turbines combined. For example: If two turbines are installed and the AEO for each turbine is 10,000 kWh, the NYSERDA incentive will be $45,000 and not $70,000. [15]

3.2.4.3 Property Tax Incentive

Section 487 of the New York State Real Property Tax Law provides a 15-year real property tax exemption for solar, wind energy, and farm-waste energy systems constructed in New York State. The law is a local option exemption, meaning that local governments are permitted to decide whether or not to allow it. The option is available in Tompkins County for several of the towns and school districts. The exemption applies to systems that are (a) existing or constructed prior to July 1, 1988 (mandatory), or (b) constructed subsequent to January 1, 1991, and prior to January 1, 2025 (local option). The law intends to encourage the installation of solar, wind and farm-waste energy equipment systems and to ensure property owners that their real property

taxes will not increase as a result of the installation of these systems. The amount of the exemption is equal to the increase in assessed value attributable to the solar, wind or farm-waste energy system. The exemption applies only to general municipal and school district taxes; it cannot be applied to special assessments or special ad valorem levies. Sec. 487 was reauthorized this past year by the NYS Legislature for 10 more years. [16]

Figure Sources

Figure 1(a): http://www.yougen.co.uk/i/blog/125042938409762.jpg
Figure 1(b):http://plainswindeis.anl.gov/images/photos/wind_450KW_turbine_IA_V_13764.jpg