Richard Barad
ENMG 5020 - Introduction to Energy Policy
Professor Shelley Welton
Final Policy Memo

Policy Memo
Date: 12/17/2023
To: The Office of Josh Shapiro, Governor of Pennsylvania
From: Richard Barad
Subject: Mapping Wind Suitability in the State of Pennsylvania

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Summary

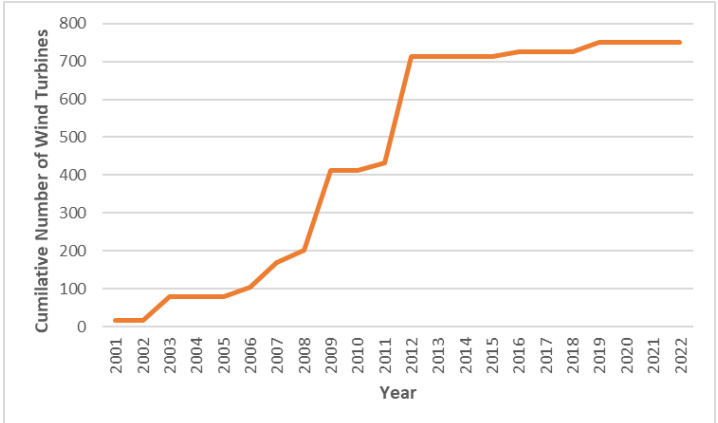
Renewable Energy sources account for just 6.1 percent of energy consumption in Pennsylvania – this ranks the state as 42 out of 50 when looking at the percent of energy consumption generated by renewables[i]. Transitioning to renewable energy is a challenge in Pennsylvania because the state is home to a large shale formation, and fracking this shale has become increasingly common and is lucrative. During your campaign for governor your team set a pledge to ensure Pennsylvania generates 30% of its electricity from renewable sources by 2030[ii]. Achieving this goal will require a rapid expansion of renewable energy, including hydropower, solar power, and wind power.

The brief examines the role that wind energy can play in the transition to renewable energy. It begins by outlining the status of wind energy in Pennsylvania and outlines some of the major challenges to expanding wind energy in the state. Next, it presents my work leveraging Geographic Information Systems (GIS) analysis and open geospatial data to map areas that are suitable for wind energy development in the commonwealth. The geospatial methods leverage a set of established techniques called multi-criteria decision making (MCDM). MCDM involves considering multiple different criteria to determine if an area is suitable for a purpose of interest. The criteria which are examined for wind energy suitability include wind speed, distance to roads, distance to existing transmission infrastructure, land cover, population density, distance from airports, and the presence of national parks. The mapping methodology will be discussed in greater detail in the methods section of the brief. Lastly, the brief explores some of the key policy implications of the mapping work and provides recommendations on how the map can be used to inform policy decision making around the shift to renewable energy in Pennsylvania.

The State of Wind Energy in Pennsylvania

On shore wind is an important resource for Pennsylvania to consider in its shift towards renewable energy. While average wind speeds in Pennsylvania are lower than states in the mid-west, average winds speed in Pennsylvania are higher than those in neighboring east coast states[iii]. Average annual wind speeds above 6.5 m/s at 80 meters above ground level are typically considered to be suitable area for wind turbine development[iv]. A report published by Saint Francis University in

Figure 1: Cumulative Number of Wind Turbines in Pennsylvania



Source: United States Wind Turbine Database

2017 noted that there is 4,192 km^2 of land in the Commonwealth that meets the criteria for wind development of which 35% is located on public land[v]. Despite this, there has been minimal growth in the Pennsylvania wind sector in recent years. Over the past ten years only two new wind farms have come online in the state[vi]. This stagnation is shown in figure one. Available literature identifies multiple challenges that have contributed to this stagnation including community opposition, restrictions to wind development on public lands, and concerns about environmental impacts. Anti wind energy advocacy campaigns have played a major role in stopping wind projects in Pennsylvania. Save Our Allegheny Ridges, a non-profit organization, has led multiple lawsuits that have halted wind farm developments in the commonwealth[vii]. Also, local rural communities have increasingly developed ordinances which prevent wind farm developments in their communities. Wind energy tends to be much more heavily criticized and receives greater community scrutiny from Pennsylvania residents when compared to traditional fossil fuels[viii].

Using public land for wind farm developments is also currently not an option in Pennsylvania. As mentioned, 35 percent of the area suitable for wind farm development is on public lands like state parks, state forests, and state game lands. However, there are currently no wind farms on state-owned land. The Department of Conservation and Natural Resources (DCNR) and the Pennsylvania Game Commission (PGC) are both not willing to issue permits for wind turbine development on state owned lands due to a lack of clear guidelines from the state government. However, permits for coal mining and oil and gas extraction are permitted on state lands[ix]. There are also limited state and federal incentives to encourage the development of wind in Pennsylvania. Environmental concerns for endangered species have played a role in preventing wind farm development in the Commonwealth. Specifically, there has been notable concern about the endangered Indiana bat which resides in rural Pennsylvania[x]. As of 2021 there had been 31 documented deaths of bats from wind turbines of which one death was in Pennsylvania[xi].

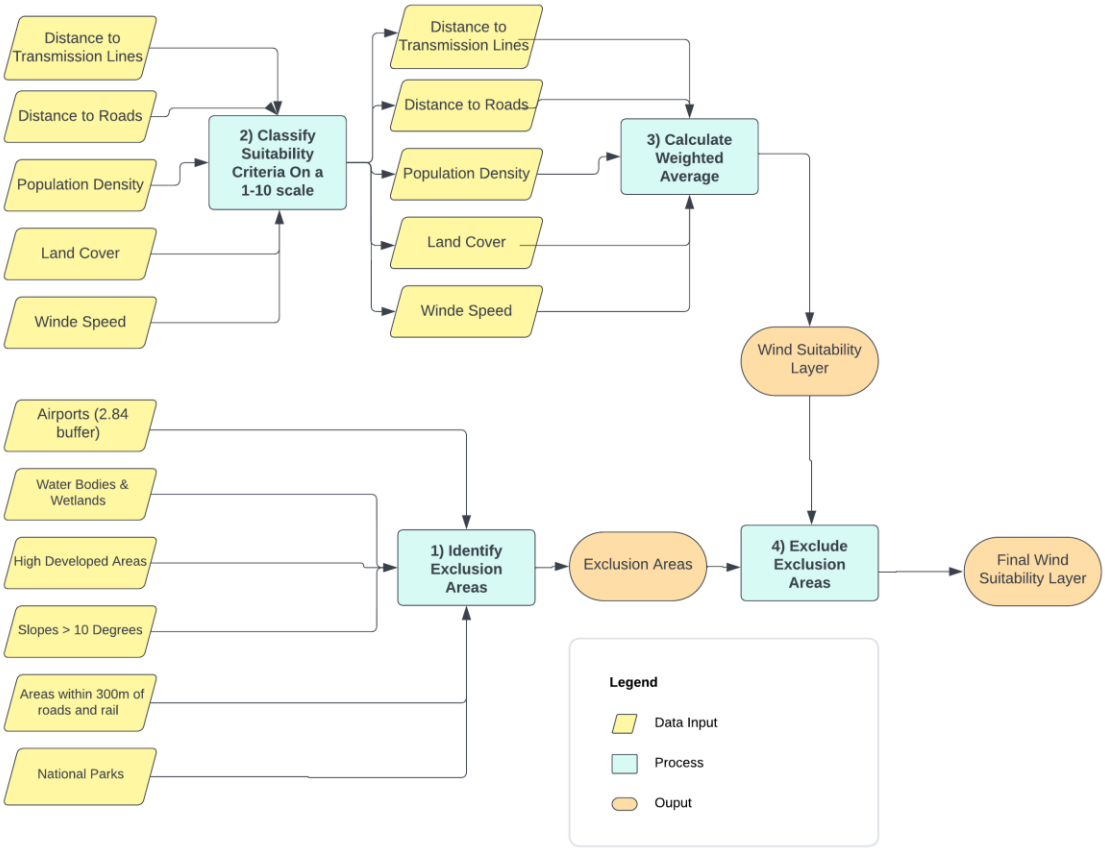
However, there is evidence that responsible curtailment can reduce the number of bird and bat deaths by 44% to 93%[xii].

Wind Suitability Mapping Methods

Prior to developing a map of wind suitability for Pennsylvania an extensive literature review was carried out to better understand the methods that other researchers have used to map wind turbine suitability. The literature review involved reviewing four analyses. Two are state level analysis in the United States and two focus on a sub-region of a European country. I intentionally choose to focus on analysis conducted in Europe and the United States to ensure that there are geographic and economic similarities between my geographic area of focus (Pennsylvania) and the geographic areas of focus of the reviewed studies. The four analyses I reviewed are: Vinessi work Mapping of wind suitability in Bristol, United Kingdom[xiii], Hansing, Hennings mapping of wind suitability in Northern Jutlans, Denmark[xiv], Angela Luciano's work mapping wind suitability in Texas[xv], and Rob Van Harren and Vasilis Fthenakis mapping of wind suitability in New York State[xvi]. The approach used here draws on the lessons learned from reviewing the work of these four researchers.

The methods used require working with raster datasets – raster data analysis involves dividing the study area into grid squares and each grid square is assigned a value according to each suitability criterion. This analysis for Pennsylvania uses a raster grid which is 30 meters by 30 meters, and all data was resampled to this grid size prior to proceeding with the analysis. Additionally, all datasets used in the analysis were projected into the NAD 1983 State Plane Pennsylvania North coordinate system, the standard coordinate system for Pennsylvania. The wind suitability mapping methodology involves four general steps: 1) identify Exclusion Areas, 2) identify suitability criteria and classify suitability criteria on a

1-10 scale, 3) calculate weighted average for suitability criteria, and 4) exclude exclusion areas. The graphic below provides a high-level overview of the data inputs and processing steps.



1) Identify Exclusion Areas

The first step is to identify exclusion areas, these are areas where it is likely not possible to build wind turbines due to land use regulations and/or land use constraints. It is important to note that local ordinances vary by county and there is likely variability in land use regulations between counties – the work presented here is based on general thresholds identified through a review of literature. The exclusion areas include:

1. **All areas located within 2.84 miles of airports**, research suggests wind turbines can be a hazard to aviation if build within 2.84 miles of airports[xvii].
2. **Water bodies and wetlands** identified using the 2019 National Land Cover Database[xviii] are excluded as environmental regulations likely prohibit building in these areas.

3. **High and Medium developed areas** identified using the 2019 National Land Cover database are considered unsuitable for the development of wind energy turbines due to urban land use regulations and the high likelihood of encountering complaints over noise in urban areas.
4. **Slopes greater than 10 degrees** are considered unsuitable as available research of literature indicates that slopes greater than 10 degrees are not suitable for wind turbines[xix]. Slope is calculated using elevation data published by the U.S Geological Survey (USGS) downloaded from the Pennsylvania Spatial Data Access (PASDA) portal[xx].
5. **Areas within 300 meters of roads and railways** are excluded based on local ordinances from Antis Township, Pennsylvania which indicate that wind turbines must be setback 1,000 feet (approximately 300 meters) from public roads[xxi]. Road data includes all primary and secondary roads in Pennsylvania based on U.S Census Bureau Roads dataset[xxii].
6. **National Parks** are also excluded as federal regulations prohibit wind turbines in national parks. Spatial data on National Parks was obtained through ESRI[xxiii].

2) Identify suitability criteria and classify on a 1-10 scale.

The second step is to identify our suitability criteria and classify them on a 1-10 scale in which ten represents the highest suitability and one represents the lowest suitability. Each grid square is assigned a 1-10 score for each suitability criteria. The suitability criteria included in the analysis are wind speed, land cover, population density, distance to existing roads, and distance to transmission lines. The selected criteria are based primarily on cost considerations. The cost of building wind turbines increases as you move further from existing roads due to the need to build more new roads to access the wind turbine site. Similarly, the cost increases as you move further from existing transmission lines due to the need to build new transmission lines to connect the wind turbine to the grid. Land cover is another cost consideration, as certain types of land such as forests are likely to require clear cutting of forests to build turbines which presents an additional cost. Wind speed is the most important consideration because

wind turbines built in areas with higher wind speeds can produce greater amounts of wind energy resulting in higher profits. Wind speeds above 6.5 m/s at 80 meters above ground level are typically considered to be suitable areas for wind turbine development. The last consideration is population density. Population density is included as a decision criterion because wind turbines in densely populated areas are more likely to experience opposition for noise or visual concerns. Population density uses population data at the census block group level from the 2020 decennial U.S Census Bureau survey.

The table below shows how each suitability criteria is classified on a 1-10 scale. Distance to roads and distance to transmission lines use a fuzzy classifier. The fuzzy classifier assigns the highest value in a dataset a value of one, while the lowest is assigned a value of ten. In the case of distance to roads, the area with the largest distance from a road in a state is assigned a value of one, while areas right next to roads are assigned a value of ten. The classified values for all other areas are spread out in between one and ten based on their rank in the state, with larger distances getting values closer to ten. The same approach is used for distance to transmission lines. The table below also includes the weight for the variable which will be discussed in more detail in the next step.

Variable	**Classifier**	Weight
Wind Speed	• <6m/s (Least Suitable) = 1 • 6m/s - 6.5m/s = 3 • 6.5m/s - 7m/s = 5 • 7m/s - 7.5m/s = 7 • 7.5m/s – 8m/s = 9 • >8m/s (Highest Suitable) = 10	45%
Land Cover	• 10 (Highest Suitability): Barren Land, Grasslands, Pasture, Croplands • 5 (Medium Suitability): Shrub • 2 (Low Suitability): Deciduous Forest, Mixed Forest, and Evergreen Forest	5%
Population Density	Divide data into deciles (i.e: 10 equally sized groups based on population density). The census blocks in the densest decile are assigned a value of 1, while the least dense census blocks are assigned a value of 10.	10%
Distance to Roads	Fuzzy Classifier	15%
Distance to Transmission Lines	Fuzzy Classifier	25%

3) Calculate Weighted Average

The next step is to calculate a weighted average of the five suitability criteria. A weighted average is used because some suitability criteria are more important than others. A higher weight results in a criterion having greater influence on the final calculated suitability. For example, if one variable has a weight of 10% and another has a weight of 20% the variable with a weight 20% will have twice the influence on the final suitability score. The analysis considers wind speed to be the most important criterion, followed by distance to transmission lines. Land Cover and Population density are given a lower weight. If there is interest, the analysis can easily be repeated using different weights – the only requirement is that the weights add up to 100%.

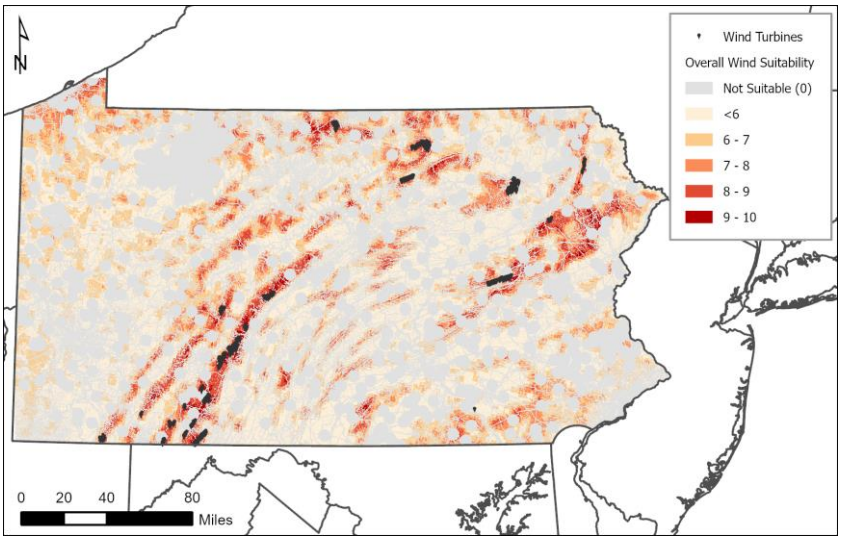
4) Remove Exclusion Areas

The last step is to remove the exclusion areas from the map. Exclusion areas are assigned a value of 0 because the analysis considers them unsuitable for wind turbine development.

Final Map

The results of the mapping process are shown in figure two, with areas deemed more suitable for wind turbine development visualized in a dark shade of red. The map below also shows existing wind turbine infrastructure as black dots.

Figure 2: Results of Wind Suitability Mapping for Pennsylvania



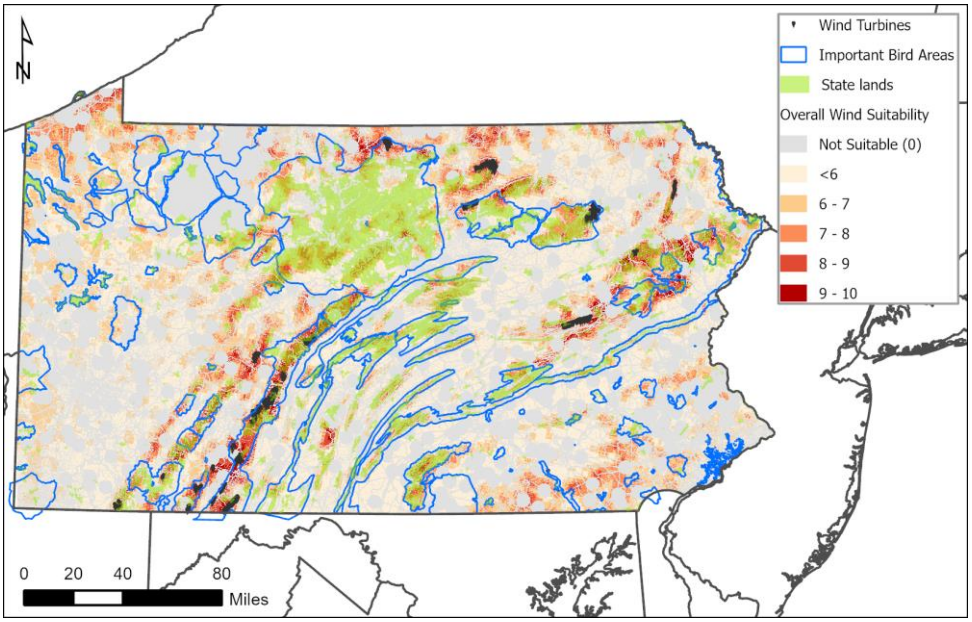
The high degree of overlap between areas identified as highly suitable for wind turbines and existing wind turbine infrastructure helps validate the accuracy of the mapping work. However, the mapping work highlights that there are still many areas that have high

suitability for wind turbines that have not yet been developed. Examples of such areas include the Poconos in northeastern Pennsylvania and localized areas of the Allegheny Mountains, although there is a larger amount of existing infrastructure in the Allegheny region. Areas around South Mountain near the border with Maryland and areas near Lake Erie are also suitable for wind turbine development and currently do not have any wind turbine infrastructure.

Policy Implications

One key element which was not considered in the mapping work is environmental and conservation concerns. As noted previously, environmental pushback has been one of the barriers to expansion of wind turbine infrastructure in the state. To better understand the overlap between important bird areas and areas suitable for wind turbine development, we can overlay important bird areas on top of the wind turbine suitability map. The data on important bird areas is obtained from the National Audubon Society[xxiv]. The resulting map is shown on the right. The map also includes state lands in green.

Figure 3: Wind Suitability Areas with state lands and important bird areas overlay.



A clear takeaway is that there is a large amount of overlap between important bird areas and areas that are suitable for wind turbines. However, there are areas that are suitable for wind turbine development and are not located within important bird areas – examples include costal areas along Lake Erie, areas along the border with New York state, parts of the Poconos Mountain range, and areas in

Southeastern Pennsylvania along the border with Maryland. It is recommended that these areas be prioritized for wind turbine development, as they are less likely to receive pushback from environmental groups. Environmental groups like the Audubon society have shown a willingness to support wind turbine infrastructure if they are properly sited and consider the impacts on bird communities[xxv]. Given the high degree of overlap between state lands and wind suitable lands, it is also recommended that the state legislature pass legislation allowing for the development of wind turbines on state lands. This legislation can include regulations that require developers to implement protocols to mitigate the deaths of birds and bats since many state lands also overlap with important bird areas. Additionally, any legislation should also require developers to hire local populations to work on building new wind turbine infrastructure. Implementing such measures will help mitigate concerns from local communities and is consistent with approaches recommended by the Regional Greenhouse Gas Initiative (RGGI) Working Group[xxvi].

Building wind turbines on public lands is not the only one piece of the puzzle. Private landowners can also help play a role by having wind energy turbines installed on their land. As discussed previously, there is high skepticism of wind energy in Pennsylvania in part because of concerns that wind jobs will replace the fossil fuel industry. However, states in the mid-west like Texas, Oklahoma, and Iowa have shown that green energy and fossil fuels can coexist and will likely continue to coexist in the short to medium term. Texas has achieved success in expanding wind turbines by offering a 100% tax exemption on the appraised value of a wind power generating device[xxvii]. Similar laws could be implemented in Pennsylvania, and private lands could be overlaid on top of the wind suitability map to determine areas where there is high potential to build wind turbines on private lands.

To add support for the mapping work presented here, it is recommended that the mapping work be independently reviewed and endorsed by the Pennsylvania Department of Environmental Protection (DEP). Getting an authoritative seal to the mapping work from a state government agency could help

with broader acceptance of the suitability map. Any DEP comments can be incorporated into the methodology. Once endorsed, the map could also be shared via an online interactive mapping tool providing decision makers, local governments, and wind turbine developers with easy access to the map to help with sitting decision making. In discussions of the map, it should be reiterated that the map is intended to just be a screening tool and a full environmental and land use assessments would still be needed before a project begins.

While on shore domestic projects can help achieve Pennsylvania's energy transition goals the mapping work also highlights that there are limitations to how much on shore wind energy can help as a large portion of land in the commonwealth is not suitable for wind turbine development. To meet clean energy goals, it is also recommended that the commonwealth explore offshore wind energy options in partnership with other members of PJM. This could include investing in offshore wind off the cost of New Jersey and/or offshore wind projects in Lake Erie. The opportunities are likely higher in New Jersey where three permits for offshore wind developments have already been issued[xxviii].

Conclusions

This memo provides an overview of how data and modern mapping tools can be used to help inform wind turbine sitting decisions in the commonwealth of Pennsylvania. I hope your office will consider sharing this memo and map with the Pennsylvania Department of Environmental Protection (DEP) and encourage them to use it as a reference for wind turbine sitting decision making and request a state seal of approval on the map. The map inputs and weights can be revised based on feedback from the DEP and other state government stakeholders. Once the map has a state government seal of approval, it also recommended the map be shared with the state legislature to encourage passing legislation that would allow for wind turbine developments on state lands. Additionally, the state legislature should be encouraged to revise the tax code to allow for 100% tax exemptions on the

appraised value of a wind power generating device – such exceptions could help spur wind power generation on private lands in Pennsylvania.

Thank you for your consideration.

Sincerely,

Richard Barad

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