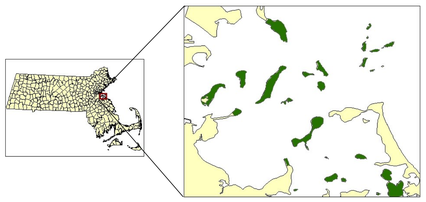
Evaluating the Boston Harbor Islands and World's End for Wind Energy Potential

Introduction

The potential for large-scale development of offshore wind farms has been well established — high wind speeds and wide open areas along the coast create ideal conditions for wind energy. As a coastal state, Massachusetts has the potential to significantly invest in this technology and fulfill Governor Charlie Baker's executive order to mitigate the Commonwealth's greenhouse gas emissions.[1] Offshore wind farms offer a source of renewable, clean energy for the state that could produce relatively consistent levels of electricity due to the near-constant high wind speeds along the coast. However, studies sponsored by the state have identified only two areas south of Cape Cod as potential wind farm sites.[2] These limited findings suggest that offshore wind farms may be more difficult for Massachusetts given mitigating factors such as endangered species and high boat traffic.

In order to fill this gap and widen the scope of wind farm siting in Massachusetts, previously ignored areas need to be taken into consideration. The Boston Harbor Islands and World's End represent potential areas for onshore wind farm development, given their relative lack of residential communities and high velocity wind regimes. Additionally, much of the area on these islands is federally owned and could be leased to the state for wind farm development. While the islands are a protected national park and World's End is a conservation area, their potential value cannot be ignored or underestimated. The need for carbon-free technology could be significant enough to override this concern and encourage a utilitarian, rather than conservationist approach to this land.

Boston Harbor Location on Massachusetts Coastline



Methodology

To evaluate the wind farm potential of these islands, seven factors were chosen based on their relevance given previous wind farm studies and the availability of data[3], including:

1) Wind speed
2) Slope
3) Land use
4) Building locations
5) The presence of roads for ease of construction
6) The presence of docks for ease of construction
7) Important bird nest locations

Proximity to transmission lines was also considered, as it has been shown to be an important factor in connecting wind energy to the electric grid,[4] but due to a lack of available data it was not included in the final analysis. Previous studies of wind farm placements have typically been large, state-wide projects, making this analysis uniquely focused and small. For this reason, buffer sizes used in previous studies—which often range in the thousands of meters—were downsized to accommodate the smaller surface area of the islands under consideration.

An overall suitability range was created for the area by evaluating each factor and assigning a suitability score on a 0 to 4 scale, see Table 1. Slope was calculated in percent given available elevation data. Roads were hand digitized for certain islands using World Imagery due to a lack of data, and multi-ring buffers were created around them. Data for residential buildings, various structures, and National Parks Services' owned facilities were merged and a 50 meter buffer was created around them. Other factors needed little manipulation other than clipping. All factors were then converted into raster data with a cell size of 2x2 meters to capture the smallest features—thin roads—and each was reclassified to fit the suitability scale. In the raster analysis, factors were weighed based on previous studies[5] to assign their proper value.

Wind Energy Suitability Analysis for Boston Harbor Islands & World's End

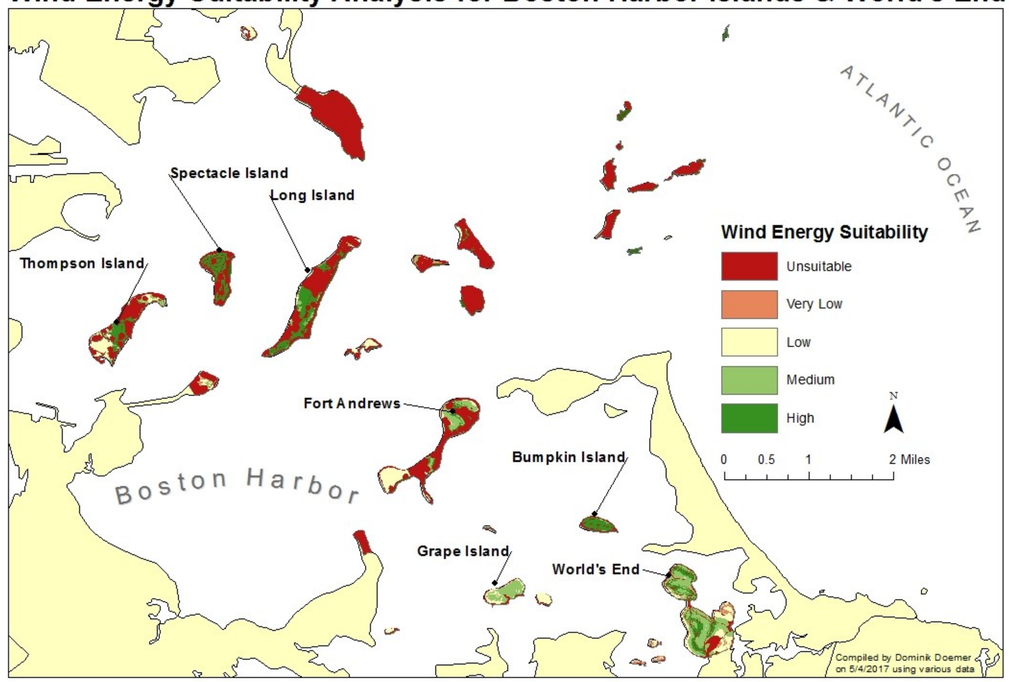


Table 1. Suitability scale and assigned weight by factor

Suitability Score	Wind Speed at 100m (m/s)	Slope (%)	Land Use	Buildings Buffer (m)	Roads Multi-Buffers (m)	Docks (presence)	Roads (presence)	Bird Nests (presence)
High (4)	>7.5	0 - 7	Agriculture, Open	/	50	/	/	/
Medium (3)	7 - 7.5	7 - 16	Forests	/	100	/	/	/
Low (2)	6.4 - 7	16 - 30	Recreational, Transitional	/	200	Yes	/	/
Very Low (1)	5.6 - 6.4	30 - 40	Very low density residential	All other areas	500	No	No	No
Unsuitable (0)	0 - 5.6	>40	Wetlands, beaches, water, low to high density residential	50	/	/	Yes	Yes
Weight	3	2	2	1	2	1	1	1

Conclusion and Limitations

The reclassification of individual factors produced multiple maps that showed factor-specific suitability distributions on the islands. Wind speed for example was shown to be either highly suitable or suitable on all islands, see Map 1. This is not surprising given the reclassification scheme based on previous onshore wind energy projects[6] which rarely see the high wind velocities typical for the Massachusetts coast. Similarly, most of the area on the islands was shown to have a suitable slope for wind energy, see Map 3. Factors that most limited the overall suitability then included land use—with wetlands, beaches, and residential areas marked as unsuitable, see Map 2.—the presence of roads, see Map 4., and the presence of bird nesting areas and docks, not featured.

The weighted raster analysis combined these factors and produced areas ranging from unsuitable to highly suitable for wind energy. Thompson Island, Spectacle Island, Long Island, areas around Fort Andrews, Bumpkin Island, Grape Island, and World's End all showed somewhat to highly suitable conditions for wind turbine placement. This is likely because they are some of the larger islands in the Boston Harbor with open spaces and roads and docks for construction. The outer islands, including the Brewster Islands, were mostly found to be not suitable given the high presence of colonial water bird nesting locations, while other areas such as Deer Island were excluded for their land use. Overall, the analysis showed that a wind farm development on the Boston Harbor Islands could be feasible given their conditions, though it would be small in scale.

Distances between the suitable areas on the islands were also measured and were consistently above 1,300 meters. This is important because wind turbines create a wake around them that make dense placement of turbines ill-advised. Given that wind turbines are usually spaced 5 to 9 rotor diameters apart,[6] with each rotor diameter at around 100 to 150 meters, the distance measurements allows for the placement of one turbine per suitable island.

Table 2. Distances between suitable areas on Boston Harbor islands

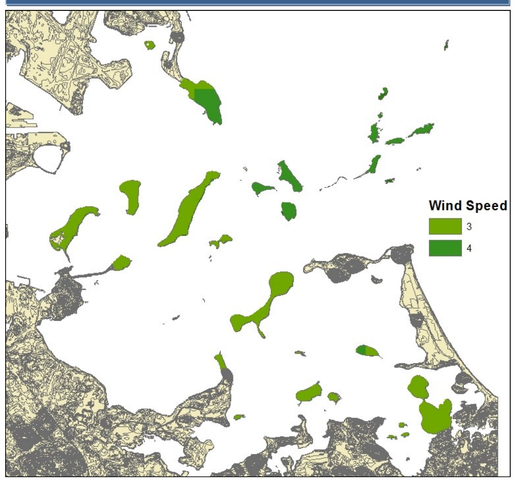
Islands	Thompson & Spectacle	Spectacle & Long	Long & Fort Andrews	Fort Andrews & Bumpkin	Fort Andrews & Grape	Bumpkin & Grape	Bumpkin & World's End
Measured Distance (m)	~2,000 m	~1,400 m	~3,200 m	~2,600 m	~3,000 m	~1,700 m	~1,300 m

The lack of transmission line data is a significant limitation of this study as this factor is critical in connecting the electricity produced by wind farms to consumers. However, given the presence of national parks buildings and residential areas, these wind turbines could instead be used to power the buildings on the islands, avoiding costly transmission line construction through the Boston Harbor. Since an average onshore wind turbine can produce between 2.5 and 3 MW of electricity per year,[7] however, there is likely too little demand on the islands themselves for this energy production. Future analysis should look at the feasibility of constructing transmission lines to provide Boston area residents with this source of clean energy. Additionally, future analysis must ask whether Boston residents and the American public would be willing to disrupt their national park in order to promote the development of clean energy. While this project shows that land conditions make such a development feasible at a small-scale, previous wind farm developments have been called off due to public concerns and outrage over the proposed construction.

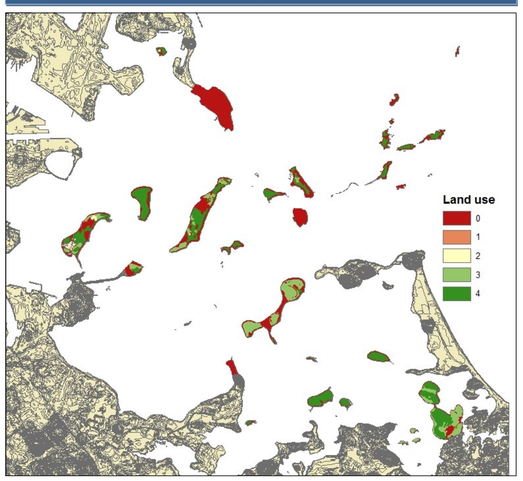
Citations

1. "Gov Baker Signs Climate Change Strategy Executive." *Governor of Massachusetts. Commonwealth of Massachusetts, 16 Sept. 2016.*
2. "Offshore Wind." *Energy and Environmental Affairs. Commonwealth of Massachusetts, 20 Oct. 2009. Web. 02 May 2017.*
3. Miller, Adam, and Ruopu Li. "A Geospatial Approach for Prioritizing Wind Farm Development in Northeast Nebraska, USA." *ISPRS International Journal of Geo-Information 3.3 (2014): 968-79. Web.*
4. Ibid.
5. Ibid.
6. Ibid.
6. Samorani, Michele. "The Wind Farm Layout Optimization Problem." *Handbook of Wind Power Systems Energy Systems (2013): 21-38*
7. "Wind Energy Frequently Asked Questions" *EWEA RSS. European Wind Energy Association, 2016.*

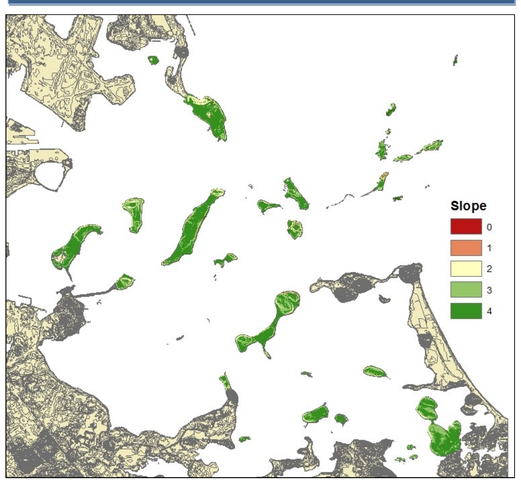
Map 1. Wind Speed Suitability



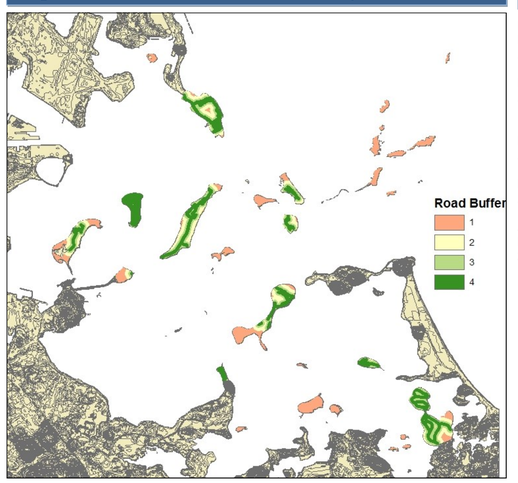
Map 2. Land Use Suitability



Map 3. Slope Suitability



Map 4. Roads Multi-Buffer Suitability



Data

National Parks Services, Integrated Data Management Resources
Island Extent, NPS Buildings

MassGIS MORIS
Land use, Wind speed, Roads, Digital Elevation, Colonial Waterbirds Nesting Areas

Boston Open Data
Buildings, Infrastructure

Boston Dept. of Innovation & Technology
Docks

All data were projected into NAD_1983_StatePnae_Massachusetts_Mainland_FIPS_2001, using meters as the linear unit.

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