Identifying Sites for Offshore Wind Farm Feasibility Studies in Massachusetts

By Eliot Martin
For NUTR 231, Fall 2018, Tufts University Friedman School

Introduction

Wind power is a very promising source of clean energy as one of the most efficient renewable energy technologies currently available. Near-shore locations can be prime locations for wind farms because of high average wind speeds and the availability of space. Off-shore wind has been developed in many places in Europe, but infrastructure is under-developed in the United States. Given the magnitude of the threats posed by climate change, it's imperative near-shore wind-energy resources be better assessed and developed. Identifying coastal regions which may be promising for off-shore wind farms is an important first step to establishing sites for development. This project develops an approach for identifying areas that are most promising for development of near shore wind farms. These regions are identified by combining key pieces of geospatial data which are supportive or restrictive of wind farm development. There are limitations to this approach, but it is intended that the information provided would help in identifying potential sites for further feasibility studies.

Data

Wind Speed

Average annual wind speed determines the energy potential of sites. Wind speeds within the study area were classified according to their relative energy potential. The data used was originally developed under contract for the National Renewable Energy Laboratory using a complex set of measurement and modelling techniques. Last updated in 2008, the data set extends 50 nautical miles from shore in most places, forming the outer limit of the region assessed in this model. Raster data was available in 100m by 100m cells—more than precise enough for identifying large tracts of open water for potential development. It should be noted that this measure does not consider variability in wind speed, which may be important to consider. For instance, it may be problematic if at times there isn't adequate wind for power generation, and at other times there is too much wind, even if the average is ideal.

Water Depth

Water Depth determines ease and cost of both construction and maintenance. Based on convention, areas under 30m in depth were identified as most promising, with those up to 60m considered viable. Depths over 60m are generally considered to be prohibitively expensive. Data was rasterized (100m by 100m cells) from MassGIS bathymetry polygons, current as of late 2013. The data used by MassGIS originally comes from the USGS Coastal Marine Geologic and Environmental Research Program, which compiles a number of rigorous measures of the ocean floor to determine depth. Depths were reported categorically in ranges of 5-10 meters within the depth ranges of interest—meaning some specific locations may be over or under-estimated slightly, which matters more at the edges of depth zones, but shouldn't make a large difference for the purposes of identifying sites for further analysis. The depth numbers used also reflect the deepest depth recorded within each polygon, which may lead to systematic overestimation of the depth for many points within each zone.

Distance from Shore

Distance from shore determines political feasibility (the public may object if sites obstruct coastal views) and cost feasibility (further locations from shore require the laying of more transmission cables). Data was re-classified considering horizon distances as a lower bound, and convention for offshore wind projects as an upper bound. The shoreline used reflects the USGS delineation of the MA coastline current as of 6/30/2011. The actual boundaries may shift slightly over time, but this approach is accurate enough for this relatively arbitrarily delineated spatial mechanism. Certain mediating factors not included may influence political feasibility, such as elevation and buildings along coast. A further limitation is that distance from population centers is not considered. This is not considered to be of critical significance to the decision-making context though, because energy loss over transmission lines in minimal and could be considered during secondary feasibility studies were this hypothetical approach implemented.

Shipping Lanes

Being within 2.5km of shipping lanes has been identified in prior studies as a potential hazard to boat traffic. Shipping lanes were rasterized in 100m by 100m cells from policy regulated polygons denoted weekly by NOAA, likely making this data the most precise data for a spatial mechanism modelled.

Transmission Lines

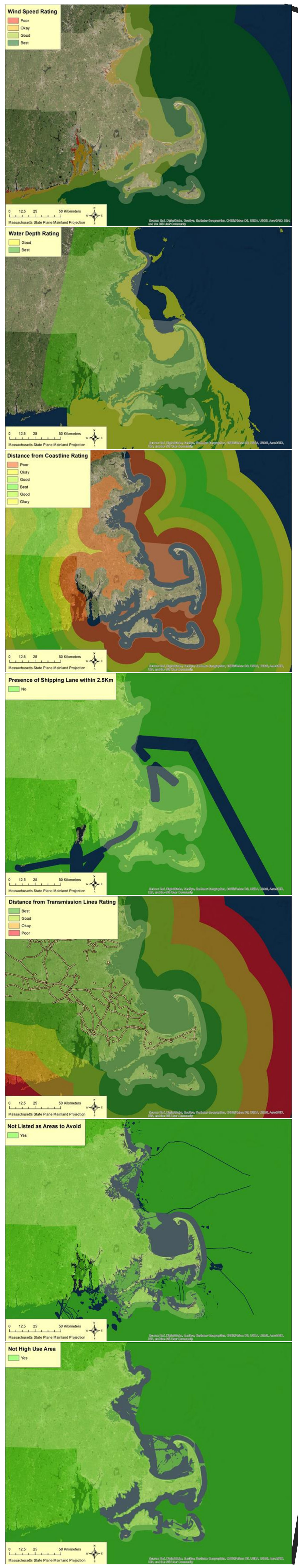
Distance from transmission lines is an important consideration because farther distances from existing transmission lines means a greater amount of transmission infrastructure which must be built to support potential wind farm sites, adding logistical constraints and significant costs. Transmission line data reflects all transmission lines reported by USGS in 2007. The existing data comes with the disclosure that not all lines were necessarily active, and changes may have occurred since publication. Furthermore, there is little information provided by MassGIS about which transmission lines are and are not included in the data set due to potential national security concerns. This Euclidean distances calculated from thetransmission lines don't consider ocean floor conditions or mediating conditions on land which may make transmission lines more difficult or costly to construct. The classifications used for this raster were relatively arbitrary. These considerations would be necessary in follow up feasibility studies.

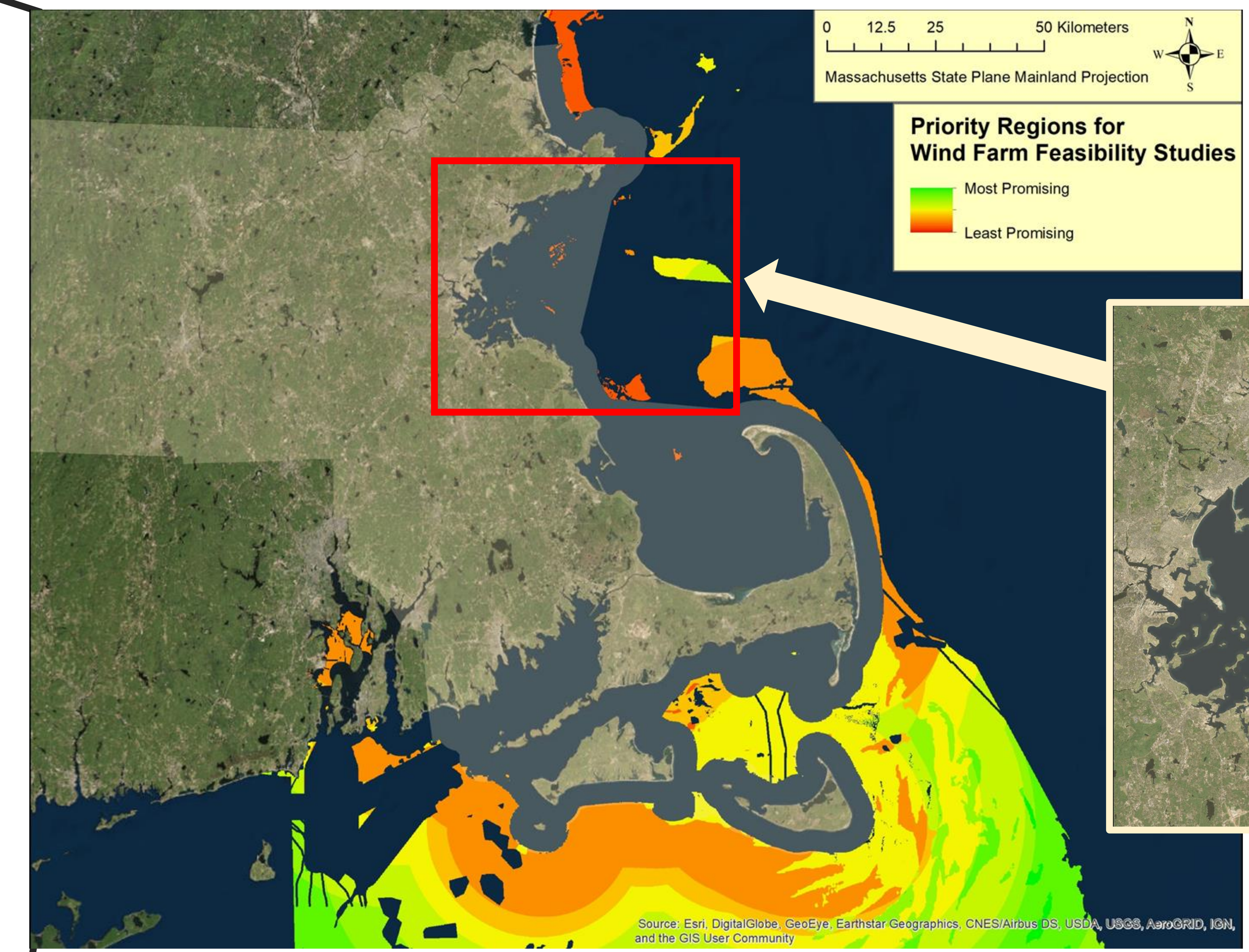
Protected and Unsuitable Locations

Protected habitats can impose practical and legal constraints; and ocean floor conditions that would impair installation can prevent construction. A composite data set available from MassGIS designates ocean areas which may be protected or otherwise inaccessible, including: whale habitats, eelgrass, unsuitable ocean floor conditions, aquiculture sites, disposal sites, existing pipelines and cables, and important fish resources. The individual datasets in the composite measure come from various sources and were compiled as part of the 2015 MA Ocean Management Plan. Polygon size varied. For the raster, a cell size of 10m by 10m was used as opposed to the 100-square meter cell size used elsewhere in order to capture the detail of the dataset which included extremely narrow underwater pipelines. Since it's a composite of many different conditions, its accuracy may vary, but from a practical standpoint, it's likely like what the government would look to in granting leases, making it accurate enough for identifying sites for further feasibility analysis.

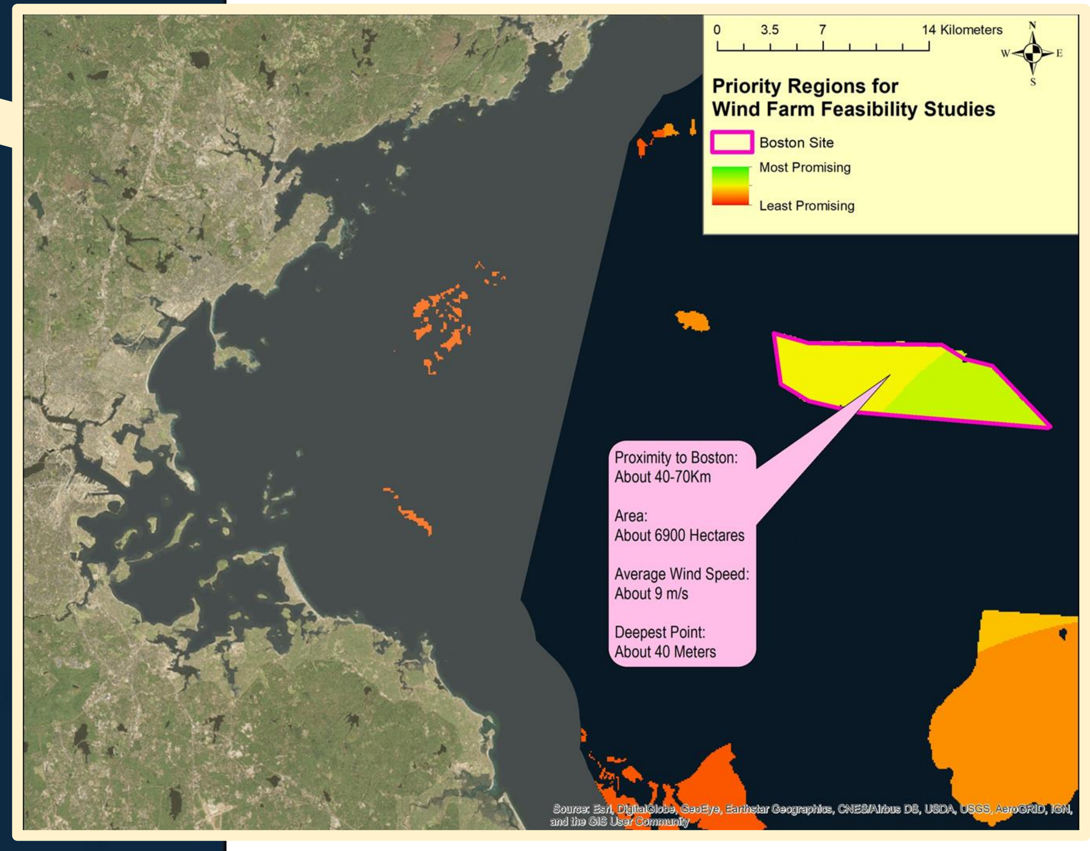
Areas of High Use

Areas of concentrated commercial and recreational activity wouldn't be safe places to have wind turbines or would come with a high opportunity cost if they were to be used for wind farms. Like the prior spatial mechanism included in the model, heavily trafficked areas were merged into a composite layer. Traffic is difficult to model accurately, and the data may just be a snapshot view of commercial and recreational activity. It's difficult to say what sorts of systematic bias may be present though, as this dataset draws from multiple complex sources. This data set may be a good starting point but should be interpreted with caution. The cell size referenced when generating the polygons was 250m by 250m, but polygons ended up varying based on the available data and category of usage. The cell size of the rasterized dataset was again 100m by 100m. A further limitation of this dataset is that it only covers near coastal areas, so further areas in the study area may experience traffic not captured by the dataset.





Note: Highlighted region is Massachusetts state boundaries with existing Coastal Zone Management area. The study area extends beyond this boundary in recognition that possible projects could extend much farther out at sea if financially viable with support from the federal government.



Value	Wind Speed	Water Depth	Distance From Shore	Distance from Shipping Lanes	Distance from Transmission Lines	Protected and Inaccessible Ocean Areas	Heavily Trafficked Areas
4	Best (8.8 m/s-9.8 m/s)	Great (Under 30m)	Best (40-60km)		Best (Under 25km)		
3	Good (7.8 m/s-8.8 m/s)		Good (30-40 & 60-80km)		Good (25-50km)		
2	Okay (6.8 m/s-7.8 m/s)	Good (30m-60m)	Okay (20-30km & 80-92.6km)	Feasible (Over 2.5km)	Okay (50-75km)	Feasible (Not in restricted area)	Feasible (Not in busy area)
1	Poor (5.8 m/s-6.8 m/s)		Poor (5-20km)		Poor (75-100km)		
No Data	Not Feasible (Under 5.8 m/s)	Not Feasible (Over 60m)	Not Feasible (Over 92.6km or under 5km)	Not Feasible (Under 2.5km)	Not Feasible (Over 100km)	Not Feasible (In restricted area)	Not Feasible (In busy area)

Methodology

Seven key spatial mechanisms were identified for the purposes of the model employed: Wind speed, water depth, distance from shore, distance from shipping lanes, distance from transmission lines, proximity of protected and inaccessible ocean areas, and proximity of heavily trafficked areas. The cell values in each raster were re-classified according to the 4-point scale in the provided table, with the associated interpretations. Each re-classified spatial mechanism is presented as an individual map. The overall Priority Areas for Wind Farm Feasibility Studies Map used for the analysis was constructed by using raster algebra to construct a simple additive scale—capturing the variation in scores better than an average. For further analysis, a region was selected for which to present some key information.

Limitations

Identifying locations for wind farms is incredibly complicated. Identifying feasible sites requires extensive economic and political considerations that are well beyond the scope of this modelling. However, many determinants of a site's suitability for a wind farm are easily modeled. As has been mentioned in description of the data, there are key limitations to the precision of the geospatial information which is available for the present model. The modelling employed is likely precise enough to identify regions which warrant further consideration as potential wind farm sites, as is the stated intention of the model. The granularity and biases present in some data, as well as the somewhat arbitrary nature of the classification system warrant that the boundaries of smaller highlighted regions and cutoffs between different scale values should be interpreted as caution. One further limitation highlighted in the composite model is that rasters only reference Massachusetts, but the study area extends into Rhode Island and Maine. Sites in proximity to Rhode Island and Maine may not be appropriate to consider because parameters specific to the states are not included in the model. A closer look at potential sites using the model, as is done in the call-out map, can highlight some of the strengths and weaknesses of different potential sites before considering which ones would be best for more nuanced feasibility studies.

Results and Conclusion

The composite model rating priority regions for wind farm feasibility studies presents several valuable findings. Almost the entire current Costal Zone Management area has been excluded from consideration as potential sites. Using the criteria employed in the model, it appears much of Massachusetts' nearest shore waters would be too costly to develop for harvesting wind energy for several reasons. Much of the region south of the Cape and Islands appears to be suitable for wind energy development according to the spatial mechanisms and data considered, with the area to the southeast having the most highly promising sites for further feasibility studies. However, this area is farthest from the state's largest populations centers, which could be an important cost consideration in further analysis.

One region which stood out in the preliminary analysis identified as promising is the parcel to the east of Boston Harbor. This area was assessed in closer detail to highlight some of the tradeoffs that would need to be considered if further feasibility analysis were conducted. With an area of approximately 6900 hectors, averaging 9 m/s, this site has high potential energy generation capacity. At about 40-70km from shore, with a deepest point of approximately 40m, development may be feasible and cost effective for serving the Greater Boston Area. It's far enough from shore that it may not cause local political challenges but is far enough out that it would require federal sanctioning.

This modelling seeks to illustrate that there are relatively simple methods which can be used to encourage more serious consideration of the U.S.'s significant offshore wind energy potential.

References

"Areas to Avoid and Areas of Concern for Siting of Potential Offshore Wind Transmission Cables Corridors, 2015 Massachusetts Ocean Management Plan." Accessed November 30, 2018. http://maps.massgis.state.ma.us/czm/moris/metadata/moris_om_areas_to_avoid_cables_poly.htm.

"BWEA Briefing Sheet Wind Turbine Technology." The British Wind Energy Association. Accessed November 30, 2018. https://www.nottingham.ac.uk/renewableenergyproject/documents/windturbinetechnology.pdf.

"Concentrated Commerce Traffic, 2015 Massachusetts Ocean Management Plan." Accessed November 30, 2018. http://maps.massgis.state.ma.us/czm/moris/metadata/moris_om_conc_commerce_traf_poly.htm.

"Concentrated Commercial Fishing Traffic, 2015 Massachusetts Ocean Management Plan." Accessed November 30, 2018. http://maps.massgis.state.ma.us/czm/moris/metadata/moris_om_conc_com_fish_traf_poly.htm.

"Concentrated Recreational Boating, 2015 Massachusetts Ocean Management Plan." Accessed November 30, 2018. http://maps.massgis.state.ma.us/czm/moris/metadata/moris_om_conc_rec_boating_poly.htm.

"Concentrated Recreational Fishing, 2015 Massachusetts Ocean Management Plan." Accessed November 30, 2018. http://maps.massgis.state.ma.us/czm/moris/metadata/moris_om_conc_rec_fishing_poly.htm.

"Distance to Shore and Water Depth." Accessed November 30, 2018. http://windmonitor.iee.fraunhofer.de/windmonitor_en/4_Offshore/2_technik/2_Kuestenentfernung_und_Wassertiefe/.

"High Commercial Fishing Effort and Value, 2015 Massachusetts Ocean Management Plan." Accessed November 30, 2018. http://maps.massgis.state.ma.us/czm/moris/metadata/moris_om_high_comm_fishing_poly.htm.

"Massachusetts Document Repository." Accessed November 30, 2018. https://docs.digital.mass.gov/dataset/massgis-data-bathymetry-gulf-maine.

"Massachusetts Document Repository." Accessed November 30, 2018. https://docs.digital.mass.gov/dataset/massgis-data-transmission-lines.

Mekonnen, Addisu D., and Pece V. Gorsevski. "A Web-Based Participatory GIS (PGIS) for Offshore Wind Farm Suitability within Lake Erie, Ohio." *Renewable and Sustainable Energy Reviews* 41 (January 1, 2015): 162–77. https://doi.org/10.1016/j.rser.2014.08.030.

"Shipping Fairways, Lanes, and Zones for US Waters - Data.Gov." Accessed November 30, 2018. https://catalog.data.gov/dataset/shipping-fairways-lanes-and-zones-for-us-waters44831.

"Uelmen - Using Geographic Information Systems to Analyze Su.Pdf." Accessed November 30, 2018. http://www.gis.smumn.edu/GradProjects/UelmenB.pdf.

Uelmen, Brent H. "Using Geographic Information Systems to Analyze Suitable Locations for Water Wind Turbine Farms in Lake Michigan," n.d., 12.

"Wind Data | Geospatial Data Science | NREL." Accessed November 30, 2018. https://www.nrel.gov/gis/data-wind.html.