A Visibility Analysis of the Cape Wind Project

Caitlin G. Casey and Patrick J. Roche

Colby College Environmental Studies Program, Spring 2008

Abstract

A wind farm of 130 turbines has been proposed for Horseshoe Shoal in the center of Nantucket Sound, Massachusetts. Since the impact of turbine visibility is a prominent concern, we have assessed the extent to which Cape Cod, Martha's Vineyard, and Nantucket will be visually affected by the wind farm. We performed viewshed analysis with ArcMap software, from the three observation heights on the turbines. These viewsheds were combined to give a comprehensive perspective of the percent of the wind farm visible from shore. Finally, a weighted land use value was applied to the viewshed to account for the impact of land use on the ability to see the project. The objective of this analysis is to provide a visual representation of how great an influence the wind farm will have on Cape Cod's residents and tourists. We find that the wind farm will visually impact approximately 50% of the total land area, 41.5% of residential area, and 55.95% of water-based recreation (WbR) area in Nantucket Sound from the highest observation point.

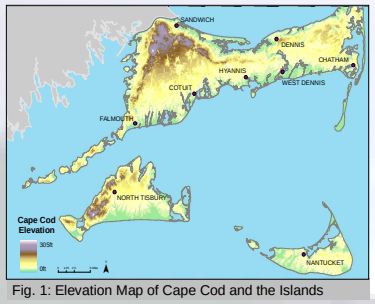

Fig. 1: Elevation Map of Cape Cod and the Islands

Introduction

The Cape Wind project, America's first proposed offshore wind farm, will be located on Horseshoe Shoal in Nantucket Sound off the coast of Cape Cod, Nantucket, and Martha's Vineyard[1]. Located at least 4.5 miles from shore, the project has stirred controversy among residents and the tourism industry, concerned that the 130 wind turbines will spoil the pristine coastal views that have made the region one of America's premier tourism destinations[2].

Energy Management Inc., the project's developer, has committed itself to minimizing the impact of the project on coastal activities. The turbines have been painted in neutral tones that are intended to blend in with the ocean views. They believe that the wind farm will appear to be about one half of an inch high from the coast[1]. Additionally, the 3,800 page Draft Environmental Impact Statement, completed by the Army Corps. Of Engineers in 2004, found the project would have positive environmental impacts[3]. A final Environmental Impact Statement is still pending.

The Cape Cod region is a site of natural heritage and beauty. 130 wind towers will undoubtedly impact it - visually, environmentally and economically. In this study, we asses the overall visual impact of the project for Cape Cod, Martha's Vineyard, and Nantucket. From this, we will quantitatively analyze the visibility impact on residential and water-based recreation (beach) (Wbr) areas.

Methods

The visibility analysis in this model was conducted from observation points on each tower looking toward the land. We first built an elevation model of Cape Cod and the Islands by merging 3-meter elevation contour-line tiles available from the Massachusetts Office of GIS (MAGIS) and using them to create a raster Digital Elevation Model with 20m resolution. The contour data from MAGIS lacked spatial reference information; we reprojected the contour-line and turbine shapefiles to Lambert Conformal Conic, based upon MAGIS parameters.

Assisted by Colby's GIS Specialist Manny Gimond, we developed a model to compute the visible area from each of the 130 turbines and one meteorological tower (See Fig. 2). In order to account for Earth's curvature in the analysis, we reprojected the DEM and turbine files to UTM Zone 19N. The model ran at three different observation heights: 0, 129, and 258ft, representing the bottom, middle and top of the turbine shaft, respectively. We used turbine shaft height, as opposed to total height with blades, because the blades are almost indistinguishable from the shoreline due to their movement and width. The model returned 393 individual viewsheds, with values of 0 (not visible) and 1 (visible). We summed these and converted the output to a percentage, with values from 0 (no towers visible at any height) to 100% (all towers visible at all heights) (See Fig. 4):

SUM([viewshed0_1]…[viewshed0_130]…[viewshed129_1]…[viewshed129_130]…[viewshed259_1]…[viewshed258_130]) = [viewshed_total]) / 393 * 100

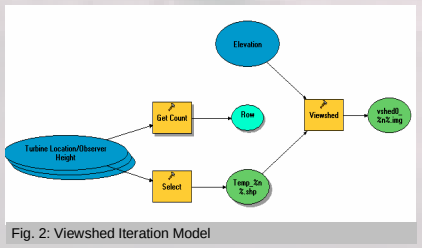

Fig. 2: Viewshed Iteration Model

To account for the effect of vegetation and buildings on visibility, we created a weighted visibility map. We first developed a raster land use map from a 1999 vector land use map from MAGIS. Then, we weighted each type of land use according to it's visibility probability, using 0.1, 0.4, 0.6 and 0.9 (See Fig. 5). For example, forests and residential areas had low probabilities, while shorelines and fields had high probability. We multiplied the visibility and land use rasters together, outputting values from 0 to 90% (See Fig. 3):

[viewshed_total] * [land_use_weighted] = [viewshed_weighted]

Lastly, we calculated the total and percent of residential areas and WbR areas that were impacted visually by the wind farm. We first calculated total area of residential and WbR land uses using the land use 1999 raster. Then we created three new rasters, showing the areas visible for each of the observation heights. We overlayed this layer with the landuse layer to find all residential and WbR areas visible from the turbines. Total area was calculated with this raster, as well as percentages, using a conversion factor of 1 cell = $20m^2 = 1.54*10^{(-4)}mi^2$.

We would like to thank and acknowledge the following people for their invaluable help on our project: Manny Gimond, Philip Nyhus, the Oak Foundation, Gordon Perkins and Environmental Design and Research, and Cape Wind for permission to use their data layer.

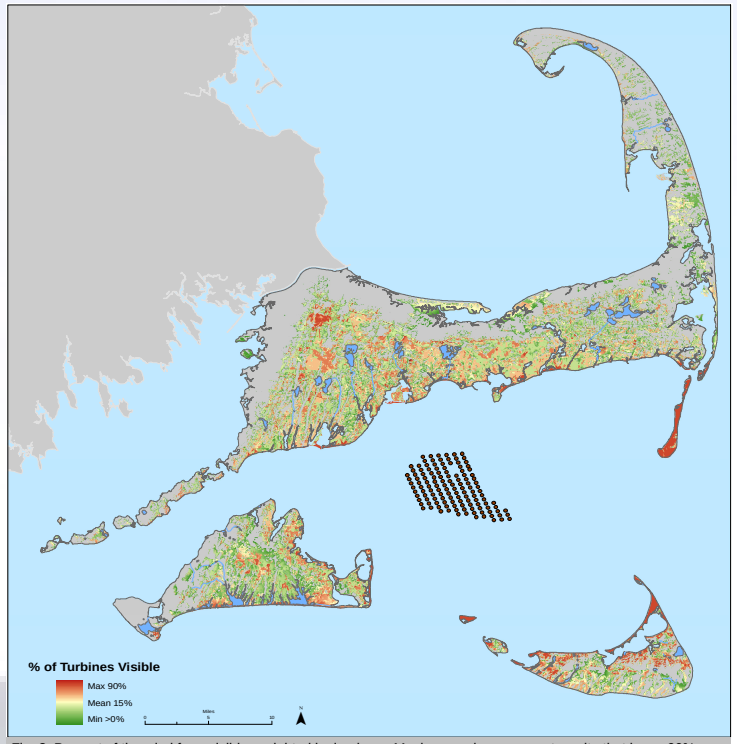

Fig. 3: Percent of the wind farm visible, weighted by land use. Maximum value represents a site that has a 90% probability of viewing the entire height of all 130 wind turbines and meteorological tower.

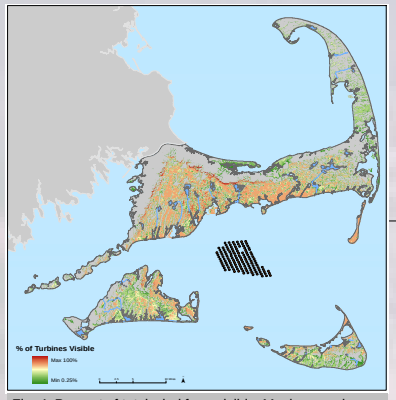

Fig. 4: Percent of total wind farm visible. Maximum value represents a site that can see the entire height of all 130 turbines and meteorological tower.

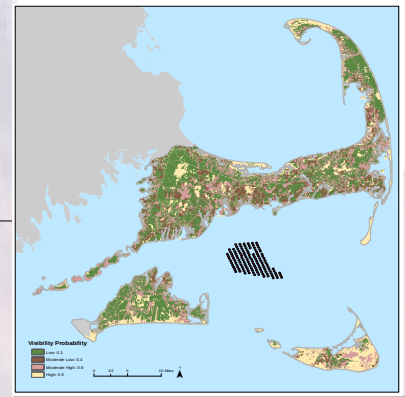

Fig. 5: Weighted land use categories for Cape Cod and the Islands. Values represent the probability that the wind farm is completely visible from the site.

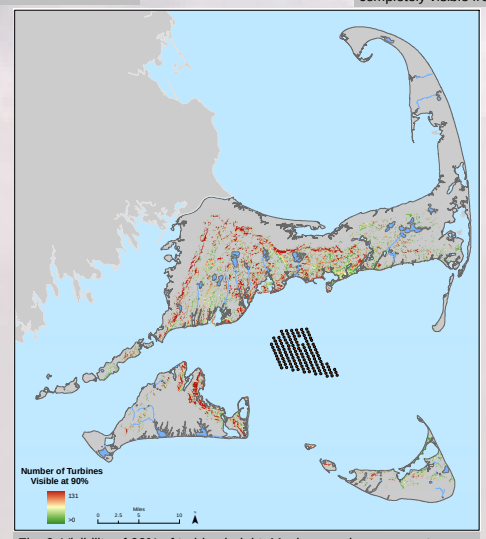

Fig. 6: Visibility of 90% of turbine height. Maximum value represents a site that can see 90% of each of the 130 turbines and meteorological tower.

Results

Our results indicate that the proposed wind farm will visibly affect a significant portion of Cape Cod and the Islands, including residential and water-based recreation (WbR) areas (See Fig. 7 and 8). The top of the wind turbine shaft is theoretically visible from approximately 50% of Cape Cod, 56% of residential areas and 42% of WbR areas.

Due to the curvature of the Earth and distance to shore, only 0.02% of the WbR and 4.4% of the residential areas will be able to see the entirety of at least one tower. However, 24.78% of WbR and 41.25% of residential areas will be able to see 90% of at least one tower.

The turbines have such a far-reaching visual impact because the shaft height, 258ft, is higher than the 99.91% of the land of the Cape and Islands. Including the blades, the turbines measure 440ft, 135ft higher than the maximum elevation of 305ft.

Using an observation height of 25.8ft (90% of tower visible), we calculated the areas that various numbers of towers are visible (See Table 1 and Fig. 6).

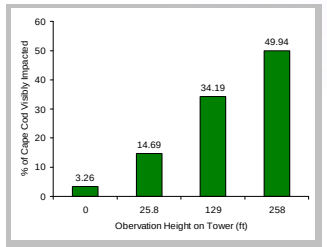

Fig. 7: Percent of total Cape Cod and Islands area visually impacted by wind farm.

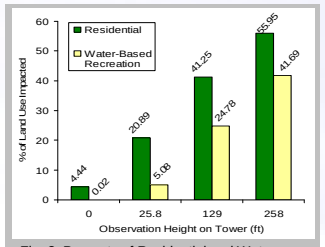

Fig. 8: Percents of Residential and Water-based Recreation area visually impacted by wind farm.

Table 1: Total Sq. Miles and Percent of Total Land Area Impacted by 90% of Turbine

Number of Turbines Visible	0	1 - 25	26 - 50	51 - 75	76 - 100	101 - 130	131
Square Miles	473	21.36	12.08	10.53	9.16	14.43	12.69
Percent of Total Land Area	86.6	3.91	2.21	1.93	1.68	2.64	2.32

Image 1: View from Craigville – 6.5 miles

Discussion

In reality, the visual impacts of the wind farm are likely much lower than our model predicts. First, buildings and vegetation heavily obscure the visibility in such a flat area. To account for this, we weighted each theoretically visible area according to its land use. This weighting does not reduce the number of areas visible, but it does reduce the visibility probability. Additionally, our analysis did not account for the visual effects of haze. Therefore, correct interpretation of the results considers that all areas deemed "visible" are potentially obscured by a structure, vegetation, and/or haze.

Thus, we expect the wind farm to affect much less than 56% of total residential area. We do expect, however, that nearly 42% of WbR areas will be affected, because they border water which presents no obstruction.

Conclusion

Although there is no way to quantify the personal impact of visibility of the wind farm, based on percentages and raw area, analysis suggests it will have a significant impact on the Cape's residents' and tourists' views. Our analysis does not advocate a stance for or against the Cape Wind Project but merely predicts the results of its presence on the viewshed of Cape Cod and the Islands. A previous study prepared for the Cape Wind Project has focused analysis solely on shoreline points[4]. Additionally, the Cape Wind website discusses visibility impacts primarily from a shoreline perspective. In our study, we have shown that the impacts may reach much further inland.

Literature Cited

[1] Cape Wind. 2007. Cape Wind home page. <www.capewind.org>. Accessed 2007 April 7.

[2] Firestone, Jeremy and Willett Kempton. Public Opinion About large Offshore Wind Power: Underlying Factors. Energy Policy 35: 3, March 2007. Pp 1584-1598.

[3] Army Corps of Engineers. 2004 Nov 8. Executive Summary of the DEIS [Draft Environmental Impact Statement]. <http://www.nae.usace.army.mil/projects/ma/ccwf/section1.pdf>. Accessed 2008 April 15.

[4] Environmental Design & Research, P.C. 2006 July. Seascape and Shoreline Visibility Assessment: Cape Cod Energy Project. <http://www.mms.gov/offshore/PDFs/CWFiles/31.pdf>. Accessed 2008 April 7.

Data Sources

Massachusetts Office of GIS. www.mass.gov/mgis.

Environmental Design and Research, P.C. with permission from Cape Wind.