

Siting a Wind Turbine in Massachusetts:

Using GIS to Demonstrate Fundamentals of Wind Turbine Siting

Cartographer:
James Hughes
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Objectives

The purpose of this mapping project was to use Geographic Information Systems to first demonstrate principles of wind turbine siting, and second, use these principles to determine suitable locations for wind farms in Massachusetts.

Methods

In order to properly site the wind farms, the factors considered were: average wind speed, prevailing wind direction, hill effect, tunnel effect, park effect, zoning, tree cover, surface roughness, and sightlines. For the purpose of constancy, the turbine used to placement and calculations was the Vestas V52-850, an 850kW unit from the world's largest manufacturer of wind turbines. It has 3 blades with a diameter of 52m. It has a cut-in wind speed of 4 m/s (starts generating power), nominal wind speed of 16 m/s, and a stop wind speed of 25 m/s. Unless otherwise stated, turbines were spaced the standard of 7 blade diameters (364m) apart in the prevailing wind direction, and 4 diameters (208m) apart in the perpendicular direction.

Conclusions

- ArcGIS has high potential as a tool for siting and analyzing wind turbines.
- Northwest Massachusetts has too much conservation land, as well as
- Southwest Massachusetts has good potential for small scale wind farms with the ability to provide electricity for 5,000 to 10,000 people
- The best site with the least impact, based on outside studies, is Cape Wind

Hill Effect

When comparing wind speeds with elevation, it appears that the data does not line up – the highest wind speeds are to the west of the mountain ranges instead of at the top. This is a representation of the “hill effect” which occurs when wind hits the windward side of the hill or mountain, building up the air pressure, causing the air to rush over. Here, wind turbines would be better placed off of the ridge in the leeward direction. Figure 3.1 shows the turbines placed approximately 500m from the ridgeline.

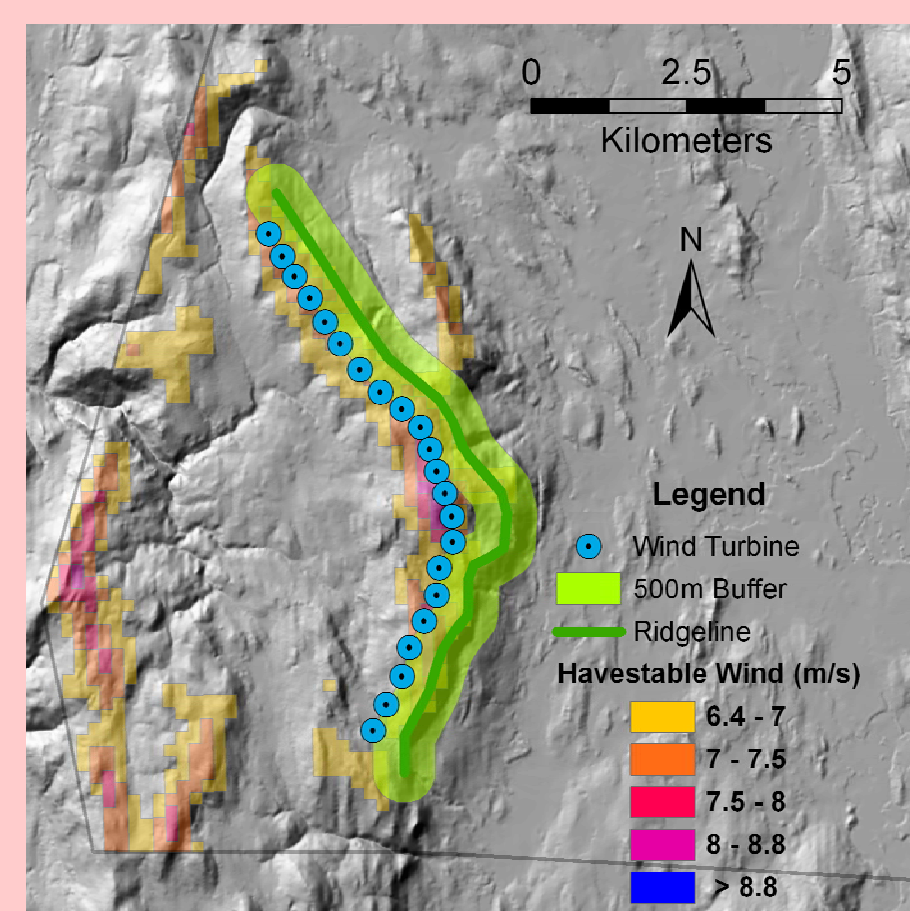
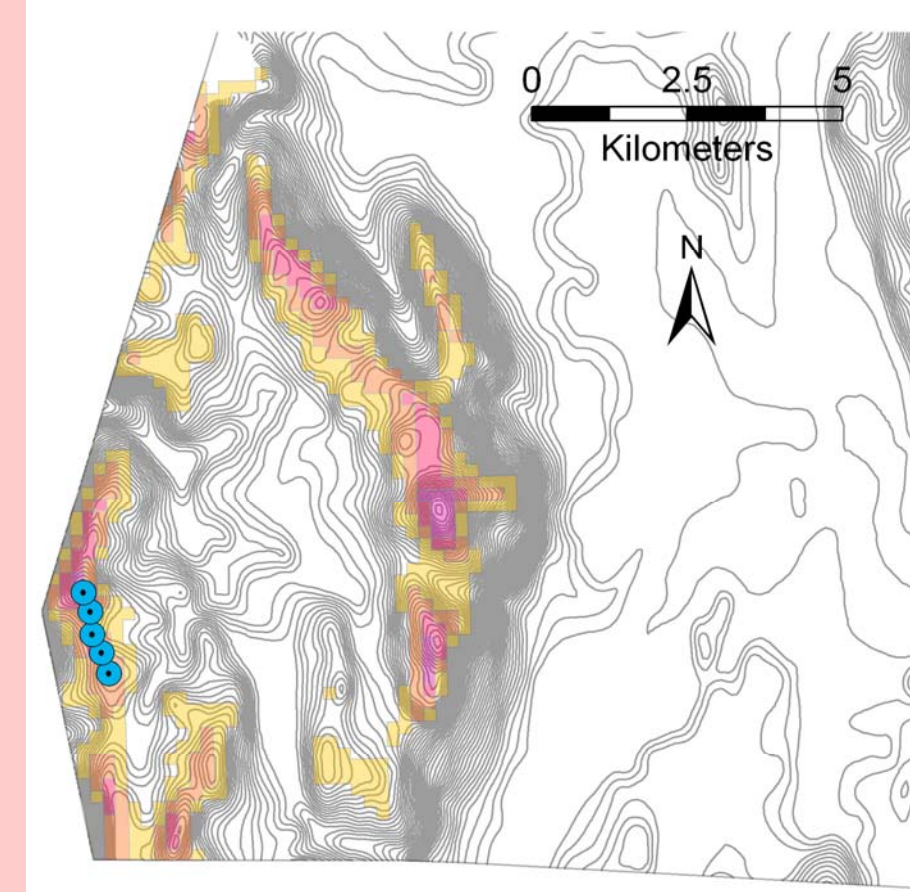


Figure 3.1 - Hill Effect

Tunnel Effect

Conservation of mass can be used to describe wind and to place wind turbines. In areas like narrow valley or mountain passes, the wind speed in that area increases greatly. The two areas highlighted in Figure 3.2a demonstrate good locations of increased wind power in locations of lower elevation.



Park Effect

When one wind turbine is placed too close to or behind another turbine it could result in a high loss of power. This is due to both turbulence and a deduction in wind energy. The turbulence occurs because, by the nature of what a turbine does, of the turbine's giant blades. The loss of energy occurs when the kinetic energy in the wind gets turned into electric potential energy in the first turbine – the principle of wind power. Consequently, standard practice in setting up wind farms is to place turbines 5-9 blade diameters apart in the prevailing wind direction, and 3-5 blade diameters apart in the direction perpendicular to that.

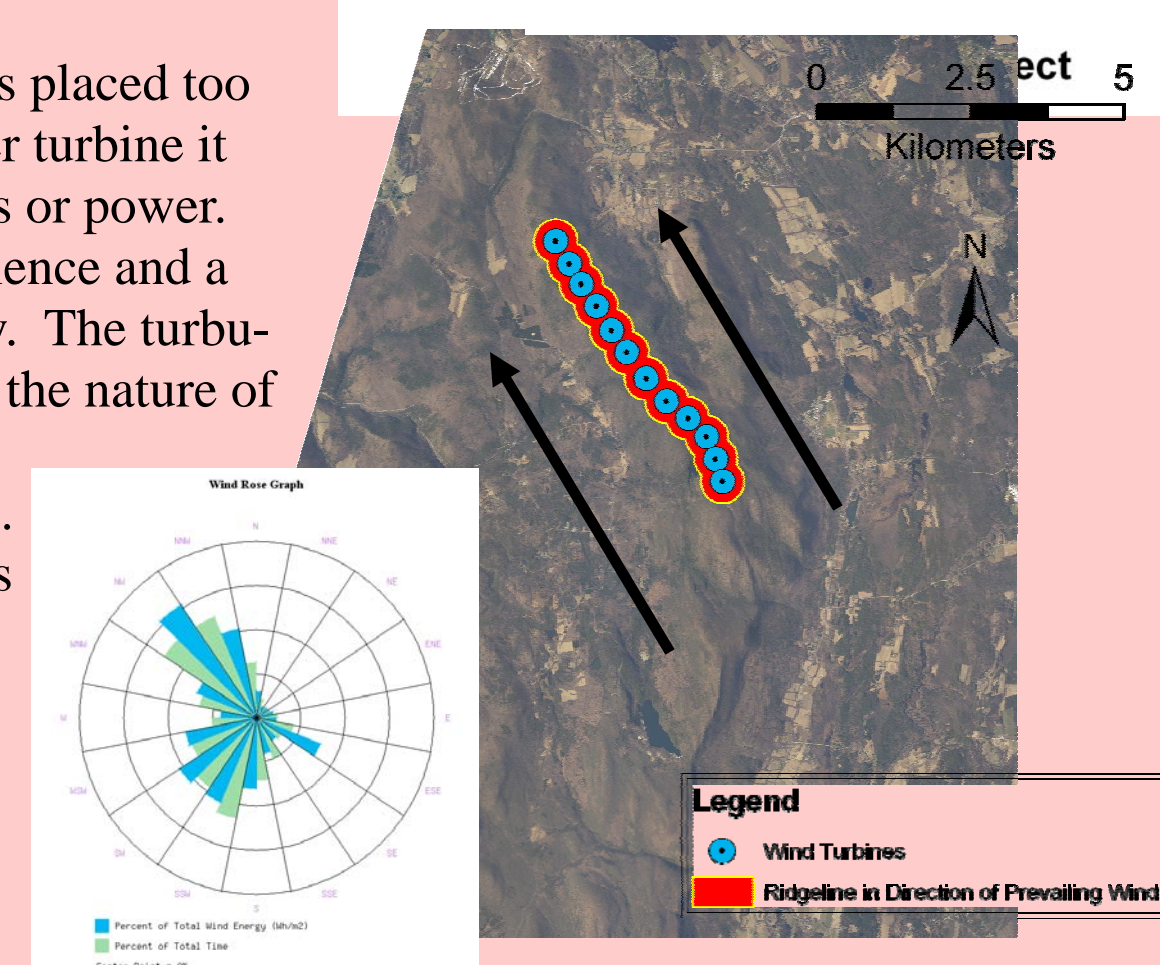


Figure 3.3b—Wind Rose
SOURCE: <http://truewind.teamcamelot.com/ne/>

Figure 3.3 - Park Effect

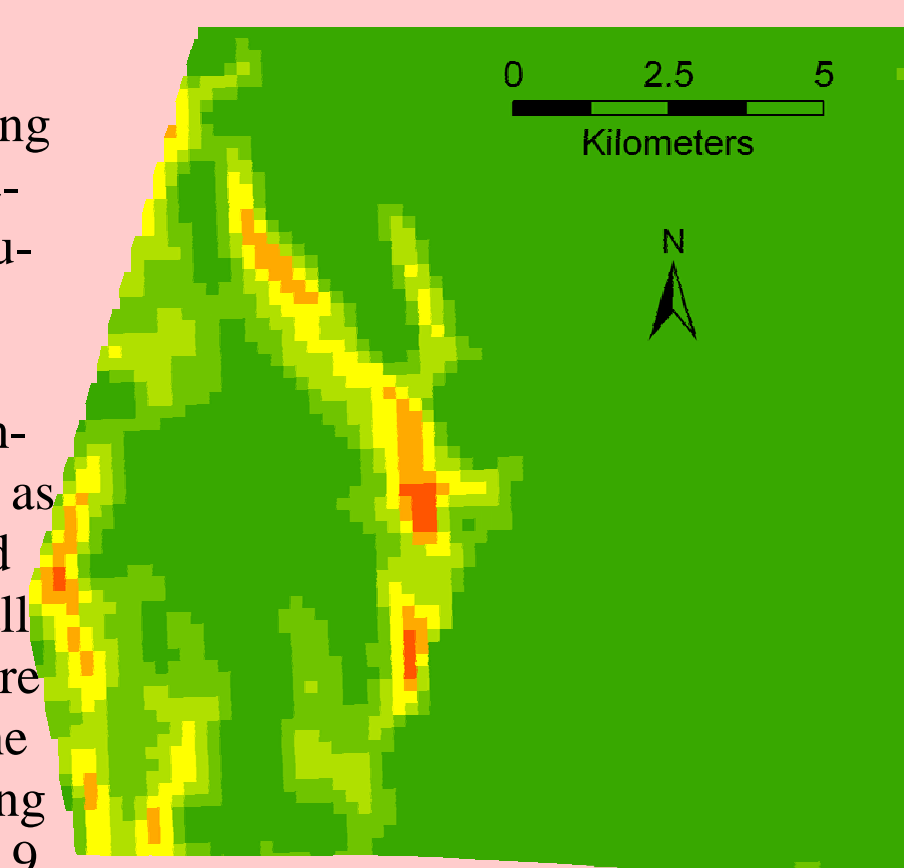


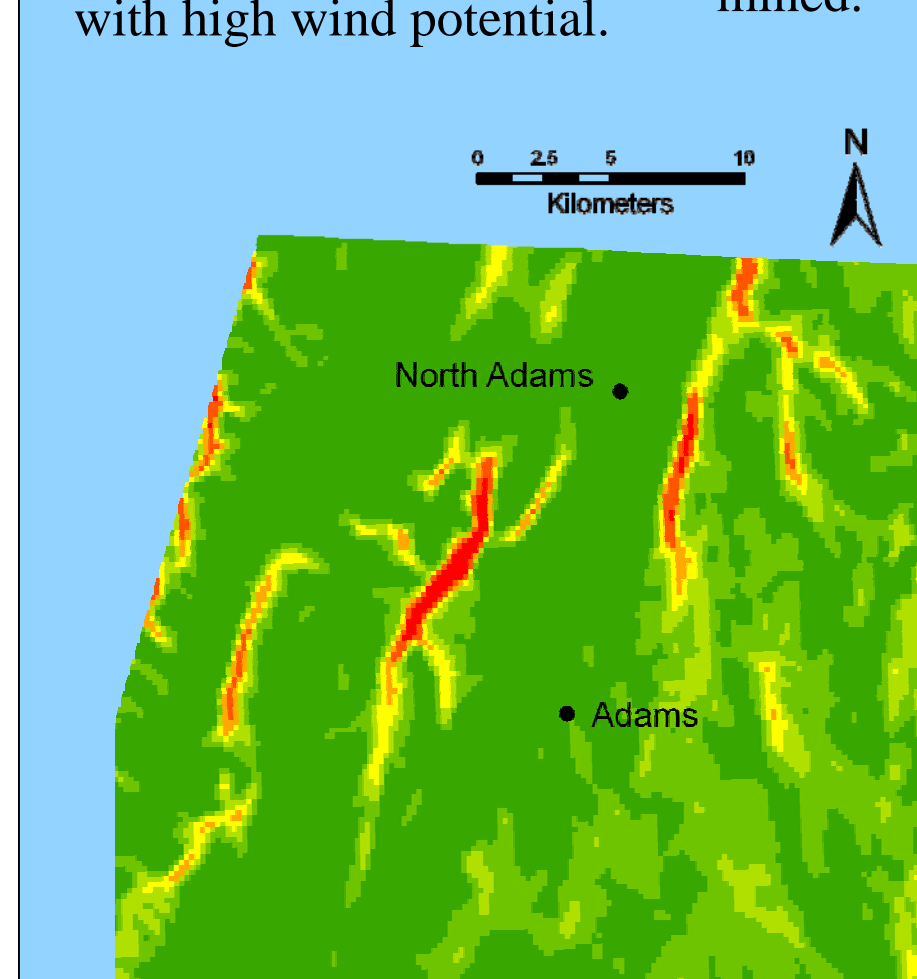
Figure 3.4 - Wind Potential (m/s)

Berkshire Wind

Massachusetts wind resources are very limited. For this reason only a few regions may be studied. Here, in the region around the towns of Adams and North Adams, two small mountain ranges pictured in Figure 2.1 can be used to demonstrate how difficult it is to utilize space with high wind potential.

Surface Roughness

Tree cover is important to determining surface roughness. Surface roughness is a factor that varies based on the land cover and is used as a constant to calculate wind speed more accurately. As a rule, it is good practice to set trees ½ mile back from large tree groves when building wind farms on plains, but in mountains it is hard to avoid building in the trees – a price paid with a higher surface roughness factor. In Figure 2.2a it is possible to see what kind of tree cover is present in an area. However, some of these photos may be taken at different times of the year when growth is taking place or leaves are falling, so tree density cannot be determined.



2.1 - Wind Resources in Northwest Massachusetts

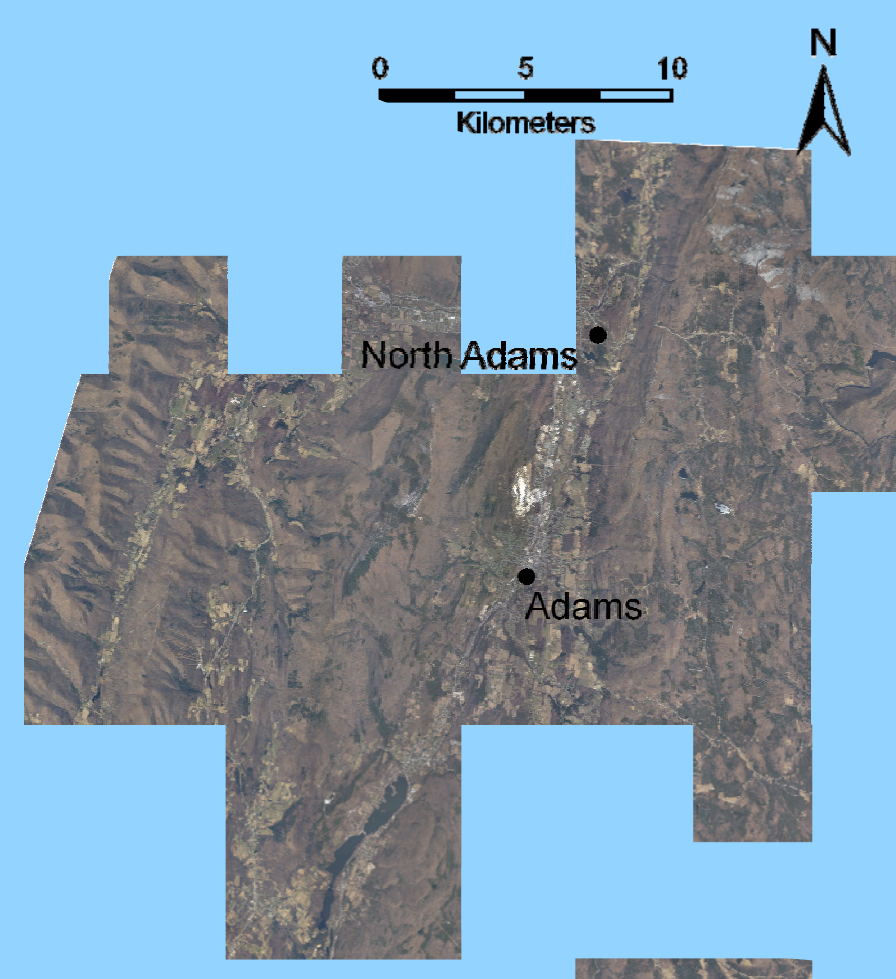


Figure 2.2a - Tree Cover in Orthophotos

Zoning

As of now, through 2007, any electricity generated by a wind turbine generates tax credit for the owner. By the Wind Energy Production Tax Credit, investors in wind make 1.9 cents/kWh generated. Landowners who let wind power investors use their land are also subject to a credit. This is why big, open land like farms is great for placing wind turbines – everyone benefits, and no clearing of trees needs to be done. In the towns of Adams and North Adams, Figure 2.3 demonstrates, most of the land is residential, with one large portion of conservation land atop a mountain and a large commercial area to the northeast.

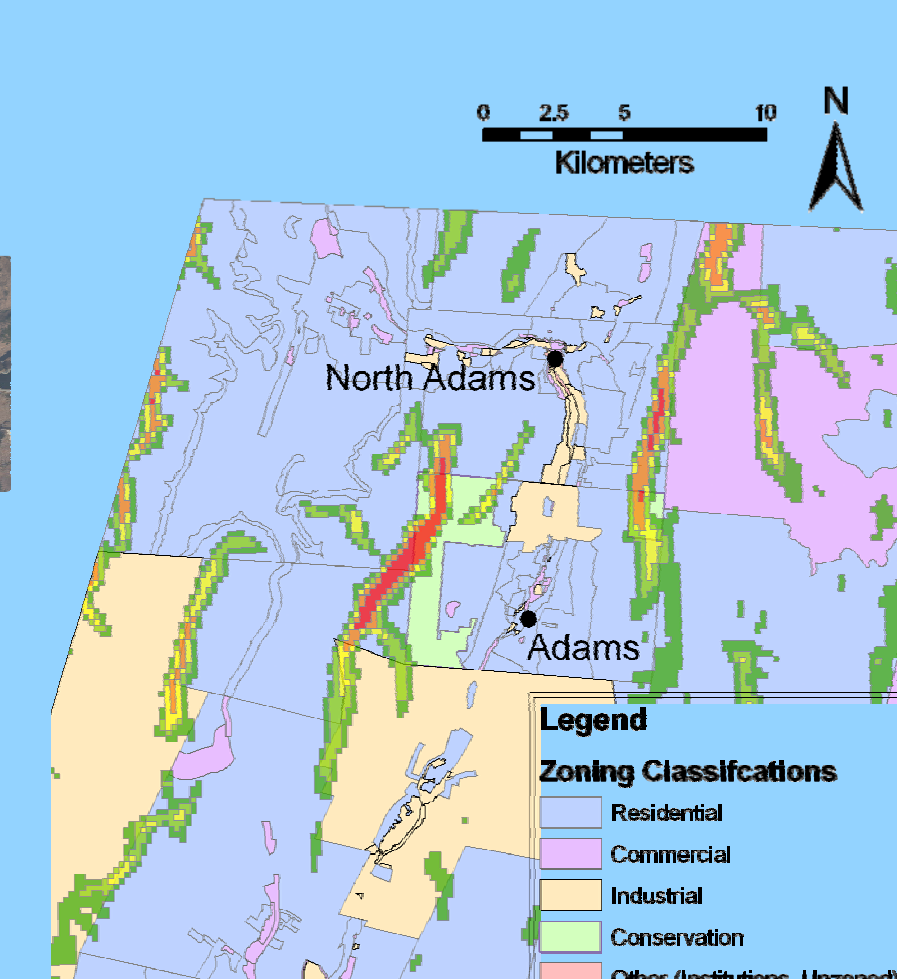


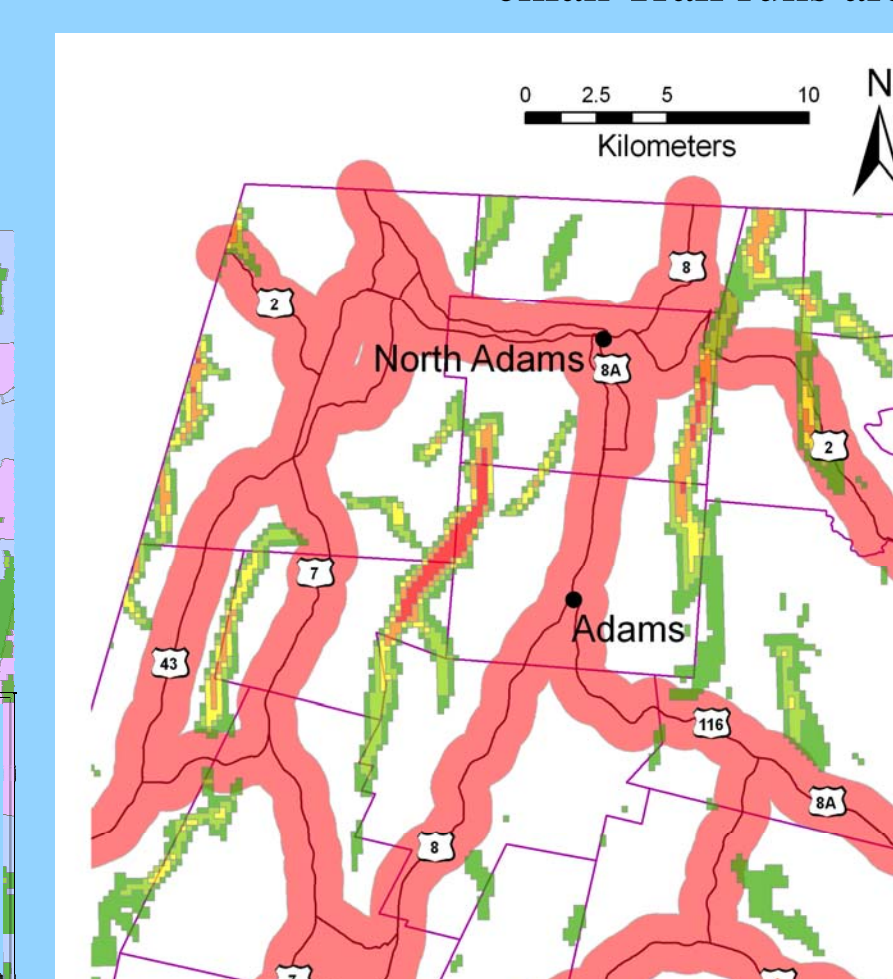
Figure 2.3 - Zoning in Towns of Adams and North Adams

Roads and Structures

It is good practice to build wind farms, and especially single turbines (in case of expansion), away from current infrastructure. Specifically, building along roadways gives rise to potential problems in the future, when the land is developed. For example, structures 40 feet tall and larger create significant losses in wind energy when built close to wind turbines. In Figure 2.4, turbines have been selected to be located one kilometer from the closest major route (Route 8).

Conservation Land

In general, in the Northeast, mountain ranges are protected land designated as state parks, land trust, conservation, or recreation. In Figure 2.5 it is obvious that it would be very difficult to site any wind turbines in this area due solely to the fact that the Appalachian Trail runs along the Western Range.



2.4 - Major Roads

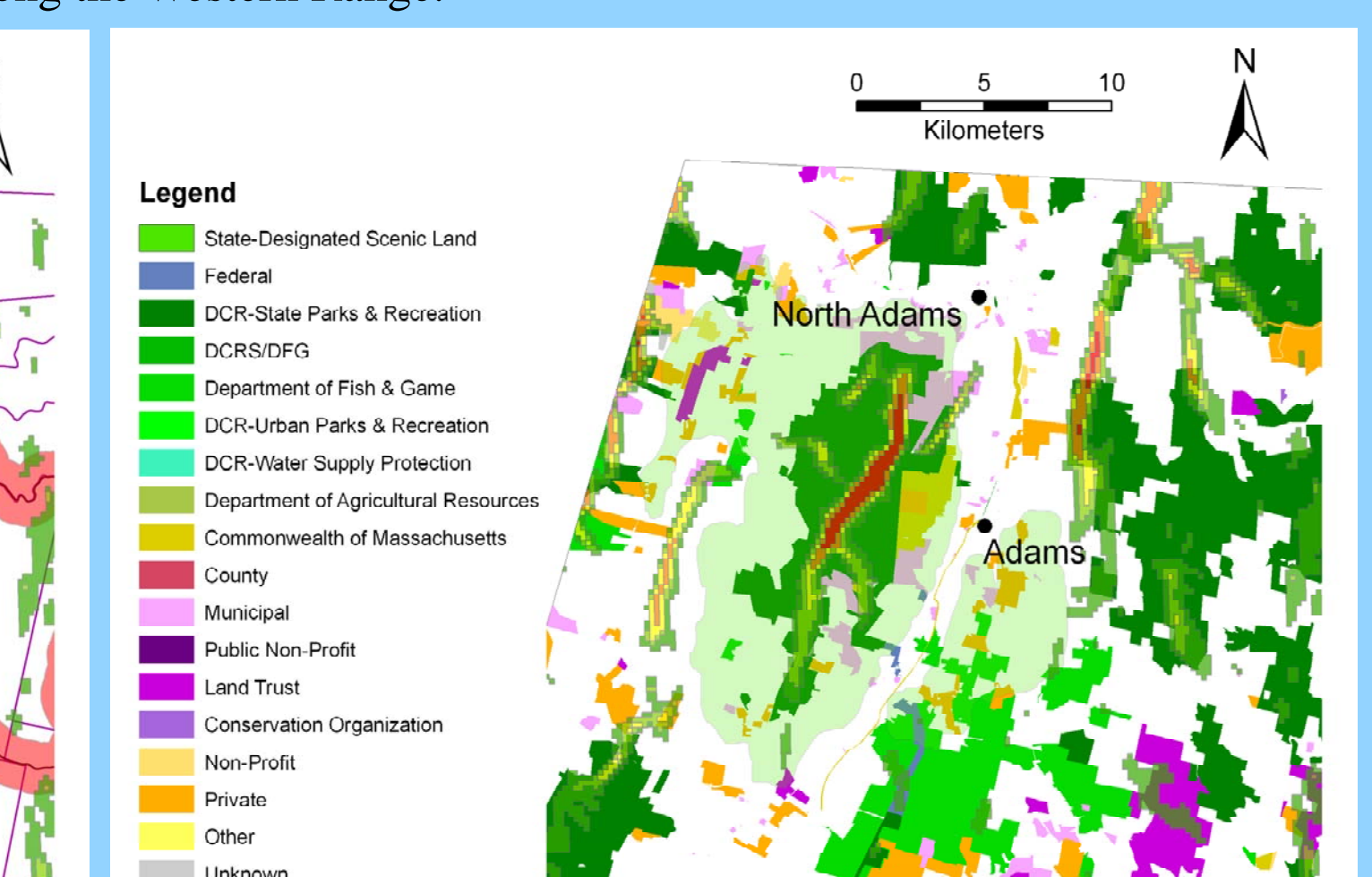


Figure 2.5 - Conservation and Scenic Land

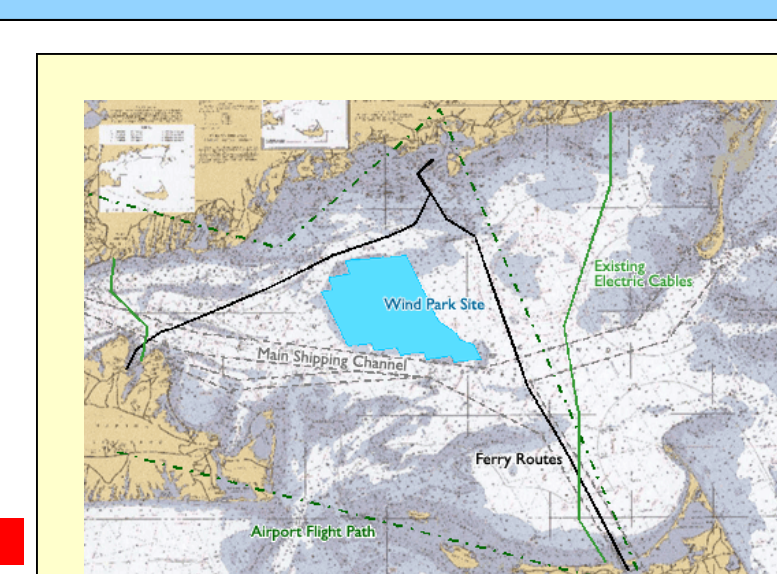
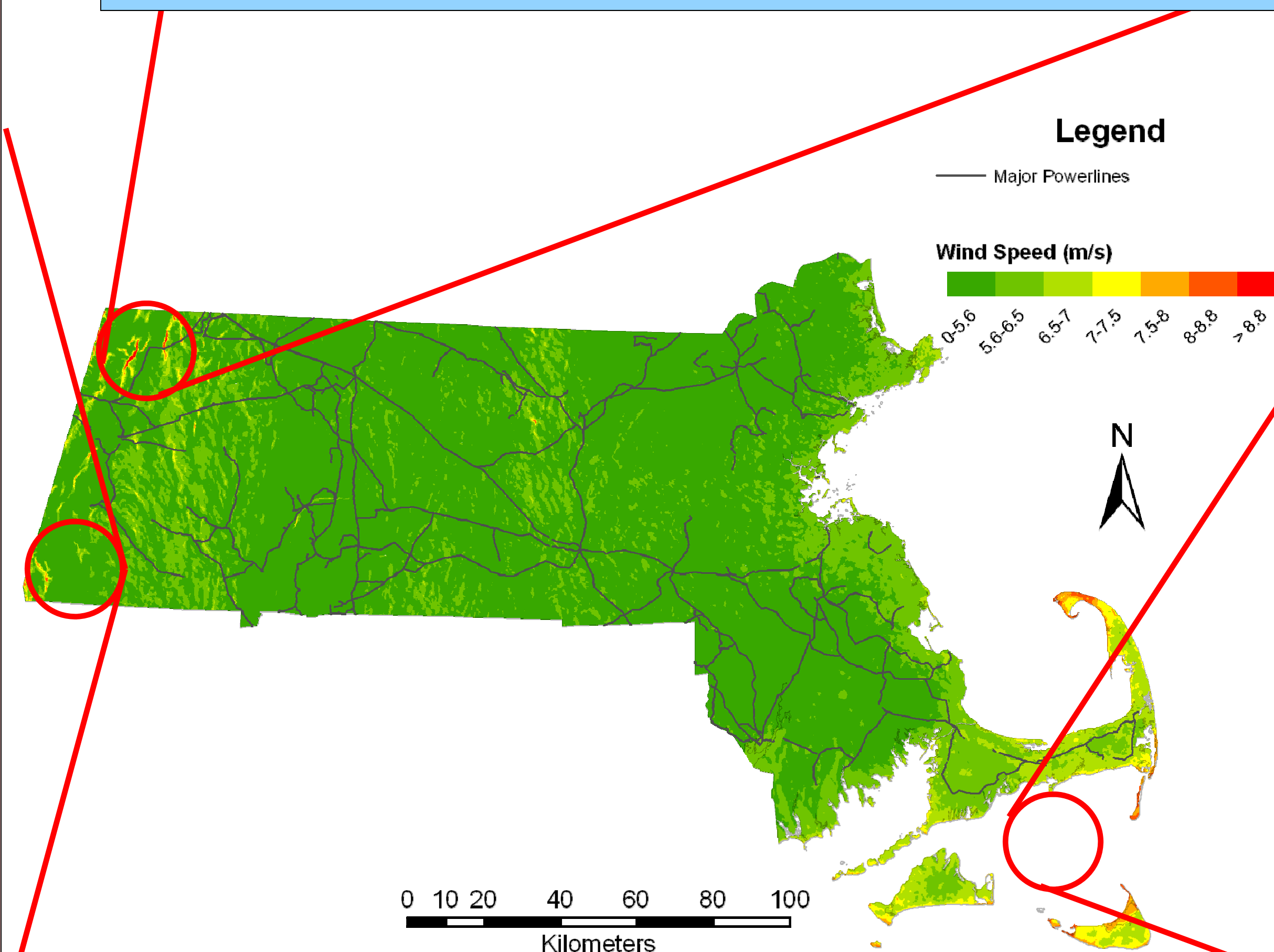


Figure 4.1 — Cape Wind
SOURCE: <http://www.capewind.org/>



Figure 4.2 — Turbine Views
These are renderings of what Cape Wind would look like from Nantucket and Massachusetts Mainland.
SOURCE: <http://www.capewind.org/>

Cape Wind

The United States is the world's 3rd largest generator of wind power, but still only produces less than 1% of its own demand.

Meanwhile, Denmark is the world's 5th largest generator, but produces 20% of its own demand.

Denmark makes up less than 1/2% of the land area of the United States.

SO, how did they produce so much of their own electricity need with wind power?

They use offshore wind farms!

...turbines footed deep in the water, far offshore so that they only appear to be inches high on the horizon. Cape Wind is being proposed as the United States' first offshore wind farm. It consists of 130 turbines that will produce 420 megawatts of clean, renewable energy. Because Cape Wind has been so highly researched and already sited, it has not been placed on this map. Instead, the land area is demonstrated in Figure 4.1. The site is located between shipping routes, ferry routes, electric cables, and airport flight paths, but does not obstruct any of them.



Figure 2.2 — Range Views
These are 3D renderings of the Western Ridge. Mapping programs like GoogleEarth have high potential wind turbine siting.
SOURCE: GoogleEarth

Tufts

Sources

- + The Danish Wind Industry Association – www.windpower.org
- + American Wind Energy Association – www.awea.org
- + National Renewable Energy Laboratory – www.nrel.gov
- + Massachusetts Technology Collaborative – www.mtpe.org
- + Windustry – www.windustry.org
- + Cape Wind – www.capewind.org
- + Global Wind Energy Council – www.gwec.net

GIS Data

- + MassGIS – www.mass.gov/mgis
- + National Renewable Energy Laboratory – www.nrel.gov
- + Massachusetts Technology Collaborative – www.mtpe.org