# A Windy Future?

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## 1 Goal

The goal of this program is to manipulate data and determine where the most suitable locations for wind farms are in the United States. The program was written in Mathematica and chooses optimal locations based on three parameters: wind speed, population density, and average value of land. The program should provide a starting point for those who want to delve further into the topic of wind farm development.

## 2 Parameters

The three factors chosen for this program are hardly a dent in the myriad influences on the development of this form of alternative energy. What is hoped is that these three parameters are important enough to provide an estimate.

1. Average Wind Speed: This is the most obvious parameter. The data was taken from the National Climactic Data Center. It is the wind speed of many large cities averaged over the years 1930 to 1996.

2. Population Density: A clear factor when determining where to locate even one turbine, as they are quite large. While much of California is quite windy, creating energy from it is highly impractical in parts of the state because of the high population density. It is hard to imagine trying to put a wind turbine in the middle of San Francisco. This data was taken from the U.S. Census Bureau.

3. Land Value: This parameter is an attempt to factor in the variable costs of building a turbine in specific parts of the country. The data was taken from the Lincoln Institute for Land Policy, and estimates the average value of land in the year 2000 for each state. This parameter is the broadest of the three and is used only as a crude estimate of the financial aspect of development. An estimate of cost is obviously necessary; regardless of its population density or average wind speed, building turbines in Hawaii, some of the most expensive land, is unfeasible.

## 3 Data Manipulation

In order to have numbers that could be used to make sense of the problem, the acquired data was manipulated in a specific way using Mathematica. After importing the data, five lists were extracted: Cities, States, Average Wind Speed, Population Density, and Land Value. The three numerical lists, average wind speed, population density, and land value, were then standardized. Standardizing the data represented the data as number of standard deviations from the mean. Thus, after standardization, all data can be compared to other data on the same scale. An average wind speed of -3, a population density of 1, and a land value of 0 describes a city with very low wind speed, above average population density, and a land value that costs about average for the United States. Because the values were all standardized, the result will give locations that are good locations relative to other locations in the United States. Even the best location for the U.S. may be a poor location relative to the entire world or the contrary.

Importing, extracting, and standardizing data is relatively easy in Mathematica and was performed in the following way.

```
data = Import["Data.csv", "Data"];
Cities = data[[All, 1]];
States = data[[All, 2]];
WindSpeeds = data[[All, 3]];
PopDensities = data[[All, 4]];
LandValues = data[[All, 5]];
StandWindSpeeds = Standardize[WindSpeeds];
StandPopDensities = Standardize[PopDensities]
StandLandValues = Standardize[LandValues]
```

To use the standardized values to determine the prospects of wind energy creation for each location, all three standardized lists were shifted by the minimum value to ensure all numbers were positive. The standardized land value and population density values were then both subtracted from the standardized wind value, as the two aforementioned values detract from a locations suitability. Each location then had a ”score” as shown below.

```
Scores = StandWindSpeeds - StandPopDensities - StandLandValues;
```

## 4 Results

Plotting scores by location using the code shown below gave the graph shown in Fig. 1. The exponential of the scores was taken in order to increase the sensitivity–making smaller scores smaller and larger scores larger–in order to create a better visual representation.

```
PointsToPlot2 =
  Table[{PointSize[Exp[ShiftedScores[[j]]]*0.000001],
    Point[Reverse[CityData[CityList[[j]], "Coordinates"]]]}, {j, 1,
    176}];
Graphics[{Brown, CountryData["UnitedStates", "Polygon"],
  Opacity[0.3, Blue], PointSize[Large], PointsToPlot2}]
```

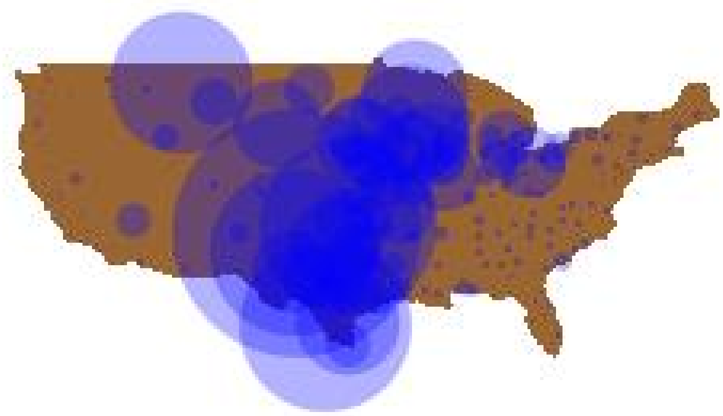

Figure 1: Suitability of wind energy development by U.S. location

This graph shows that, conforming to traditional opinion, the midwest region is significantly more suitable than other regions. However, the results become more interesting when a manipulation feature is added, allowing the user to place different weighting on each of the three parameters. The user can make adjustments so that one parameter is up to three times more important than the others. The following code shows how this is done.

```
f[x_, y_, z_] :=
```

```
Module[{\[Alpha] = x, \[Beta] = y, \[Gamma] = z},
 Scores = \[Alpha]*StandWindSpeeds - \[Beta]*
    StandPopDensities - \[Gamma]*StandLandValues;
 ShiftedScores = 8.7 + Scores;
 PointsToPlot2 =
  Table[{PointSize[Exp[ShiftedScores[[j]]]*0.000001],
    Point[Reverse[CityData[CityList[[j]], "Coordinates"]]]}, {j, 1,
    176}];
 Graphics[{Brown, CountryData["UnitedStates", "Polygon"],
   Opacity[0.3, Blue], PointSize[Large], PointsToPlot2}]]

   Manipulate[
f[WindSpeed, PopDensity, LandValue], {WindSpeed, 0, 3}, {PopDensity,
 0, 3}, {LandValue, 0, 3}]
```

Notice the differences between Fig. 1 and Fig. 2, the plot when land value is factored out by placing the slider all the way to the left at 0.

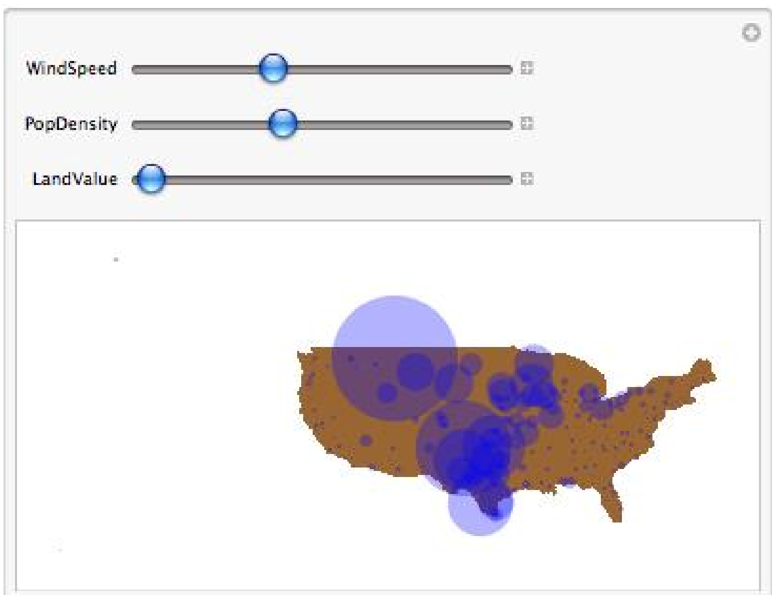


Figure 2: Suitability of wind energy development by U.S. location when cost of land is not factored.

While there are plenty of difference to notice, the most obvious is the drop in suitability in the eastern part of the midwest, hinting that relatively low cost of land is what makes that part of the country apt towards development. Also, parts of the western edge of the midwest clearly grow when land value is removed, indicating lowering land costs may allow for easier development.

# 5 Applications

While this program is meant to be only skeletal at best, the applications for such a program are where its potency rests.

## 5.1 Business

Businesses that specialize in alternative energy development can use programs like this to choose locations for their developments. Moreover, the program can be modified by changing or adding parameters for the users specific goals. International businesses can expand the program to cover the entire world.

## 5.2 Public Policy

Public policy experts, likewise, can use this program or programs similar or more developed than this to examine how individual factors influence development in various regions.

# 6 Data Sources

”Census 2000 Summary File 1.” 2000. U.S. Census Bureau. ¡http://www.census.gov¿

”Climatic Wind Data for the United States.” National Climactic Data Center. November, 1998. U.S. Department of Commerce ¡http://www.ncdc.noaa.gov¿

Davis, Morris A. and Jonathan Heathcote, 2007, ”The Price and Quantity of Residential Land in the United States,” Journal of Monetary Economics, vol. 54 (8), p. 2595-2620; data located at Land and Property Values in the U.S., Lincoln Institute of Land Policy http://www.lincolninst.edu/resources/