Investigating Spatial Variation of Renewable Energy Potential in the UK

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1 Introduction

Gordon Brown did it two years ago, and David Cameron did it last March, to great interest. What have they both done? They've both installed means of harnessing natural energy at their private residences. To break opinion down, they've either taken steps towards contributing to a greener future, leading the way in advocating the use of natural energy sources, or they've blindly jumped on the green bandwagon, and become caught up in increasingly popular "eco-cons". Somewhere in between lies the truth, and in finding the truth lies the investigation of the spatial distribution of natural energy.

The statistics are overwhelming and seem to contradict each another more often than agreeing. On December 13th, 2007, *The Times* printed numbers stating that Mr Brown will have recouped his solar panel investment in 100 years, while Mr Cameron is looking at 60 years before he's recouped the cost of his wind turbine (*The Times, 13/12/07*). The next day, the public had picked apart these numbers; the numbers had ignored wind gusts, inflation of energy prices and life spans of the systems (*Political Penguin 14/12/07, R Kyriakides's Weblog 14/12/07*). The varying statistics are in reality a direct result of the wide range of variables inherent in calculating available wind and solar energy.

With such varying landscape in the United Kingdom, the location variable cannot be ignored when considering natural energy production. The estimated energy outputs for a wind turbine on the shores of western Scotland are obviously not going to be applicable to a turbine on a roof in suburban London. Indeed, solar panel customers are warned to de-rate manufacturer's power ratings by 20-40%, based on local atmospheric conditions (*Kemp, p240*). Unfortunately, in order to simplify things for public consumption, small scale natural energy harnessing installations are generally described in very broad terms, which they shouldn't be. With so many variables in flux, attributing a benchmark value to a natural energy system will always be fraught with uncertainty.

This paper investigates a means of advanced geovisualization and user interaction in giving the public a service to determine the potential natural energy that exists in their community, allowing them to see beyond the often inaccurate benchmarked values of small scale solar panels and wind turbines.

2 The Data

2.1 The Stations

The UK Met Office has a system of stations based at sites that are representative of an area up to several tens of km from the station (*Met Office*). In all, the Met Office has almost 60,000 records in their stations table. From this total, 220 stations were used: 141 stations for wind recordings, and 79 stations for solar recordings. Stations were chosen on their recording status being current, and their recordings being made consistently throughout the year. Four wind stations with good readings were removed from the study due to their high elevations, which heavily influenced their readings.

2.2 Recordings at Stations

Stations used in this study had at least 8000 recordings throughout 2006. In ideal circumstances the stations would all have 8760 recordings (24hr x 365 days), and deterministic calculations for 2006 *potential* wind power at each station would be calculated based on hourly wind speed mean averages, and hourly max gust speeds. However, the drawbacks to this technique are numerous; few stations recorded weather stats for every hour of every day, and at none of the stations is gust duration recorded. To deterministically record a site's potential wind power, greater details than the Met Office's hourly recordings would be needed.

3 Means of Calculations for Potential Energy

When considering wind speed distribution, it is more accurate to look at a PDF, or probability distribution function (Barnsley, 2007). Instead of attempting to calculate deterministic wind and solar energy using each individual hourly recording, histograms were created and probabilistic potential energy values were calculated. Analysis using gnuplot allowed fitting of the histogram data to a Weibull curve which allows for the consideration of wind speeds that might occur at less than yearly frequencies by extrapolating values in the curve's tail.

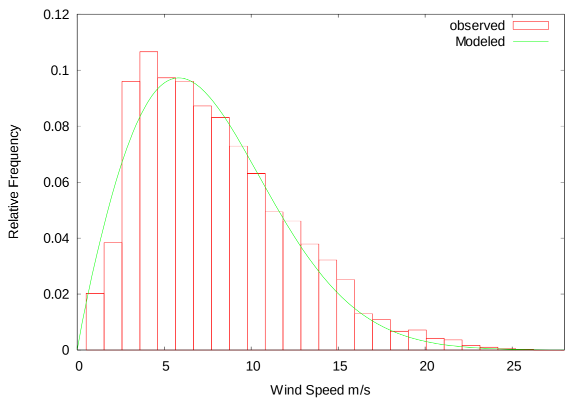

Figure 7: Wind frequency distribution at the UK's highest potential wind energy location, Credenhill, Hereford.

Yearly wind energy output based on mean wind speeds was generated from the histogram. Energy output from wind is proportional to the cube of the wind speed (equation 1); consequently, steady winds produce less power over time than winds prone to gusts (Gipe, 1999). Doubling the wind speed produces 8 times more energy:

Wind Speed (v) = 2 m/s $v^3 = 2*2*2 = 8$
Wind Speed (v) = 8 m/s $v^3 = 4*4*4 = 64$

Ignoring wind gusts implies that less energy can be extracted than it is available in the wind. This extra energy is represented by a factor known as the "energy pattern factor" (Gholam, 2007). This value was found to range from 1.6 to 3.0 in the UK.

The energy potential at each station is calculated by multiplying the energy pattern factor against *P*, where:

$$P = \frac{1}{2}\alpha\rho\pi r^2 v^3 \quad \text{(equation 1)}$$

Probabilistic solar energy values are more easily calculated than wind, as the Met Office records irradiance energy as power in KW·H. Solar cell efficiency of 15% is applied to yearly values to give resulting potential energy values for each station location.The resulting energy values for each solar and wind station are added as an extra field to the two station tables.

4 Local Weather Stations

In order for a user to get the most accurate idea of potential natural energy resources in their region, the system must take the user's location and consider the network of stations to determine which station from each of the solar and wind station networks is closest. In figure 2, Thiessen polygons help visualize which solar station a location would use.

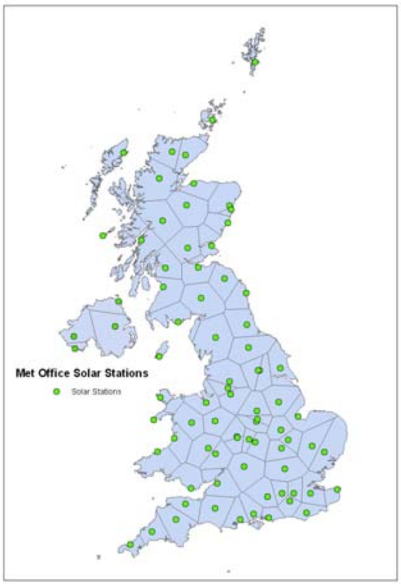

Figure 8: UK solar station regions

The user navigates in the Google Earth geo-browser environment which acts as the interface where the user will identify the location of their residence. Google Earth passes WGSS84 latitude and longitude coordinates to a PHP script. This lat/long value is converted to British or Irish National Grid, to perform distance calculations to determine each of the nearest wind and solar stations.

5 System Functionality

The user is delivered the KML file which opens in Google Earth. The client then enters their postcode in the "find address" toolbar. Within the KML file, a <networklink> tag points towards a PHP script that resides on a server. Apart from a pointer to the PHP script, this <networklink> tag also nests an attribute that determines when the PHP script will be called. In this case, the PHP is called two seconds after the camera has come to a rest, after zooming into the user's postcode. The <networklink> tag passes the bounding box coordinates of the user's view to the script, and these coordinates form the basis of the appropriate solar and wind station selections. Once the nearest solar and wind stations are determined, the total KJ output at both locations is queried for. The data is house in a MySQL database, in two separate tables for wind and solar stations.

The energy values returned from the database are wrapped within KML and sent back to the user's Google Earth browser. These results are displayed in a placemark callout box, styled with text that advises the user of the amount of savings that could have been achieved over the 2006 year.

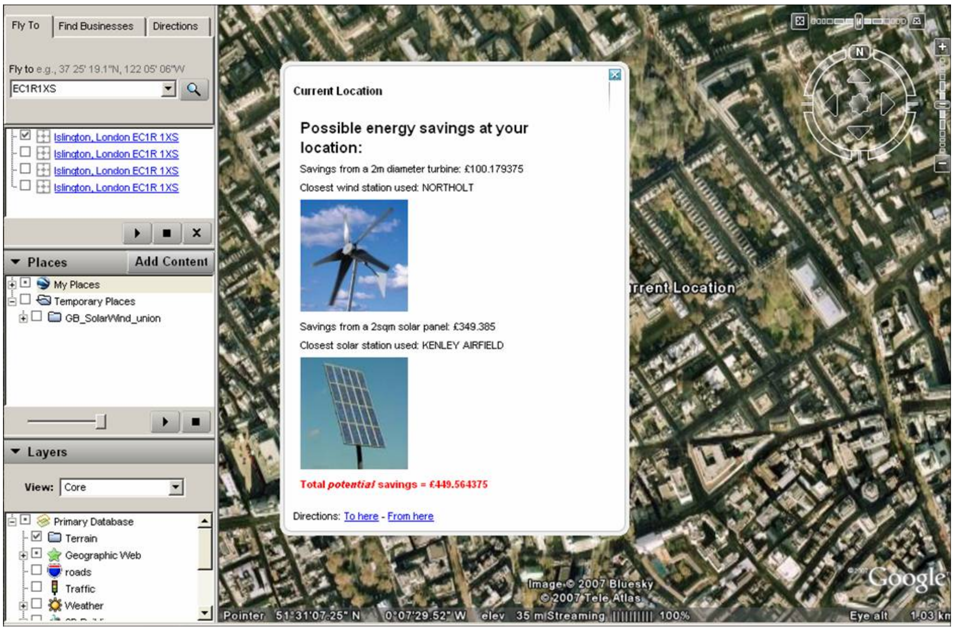

Figure 9: The call-out balloon displays natural energy potential results.

6 Visualizing Energy Potential throughout the UK

The system created in this project allows querying for local information regarding natural energy potential, but it is also beneficial to visualize energy potential across the UK in order to determine trends and potential errors over a larger area.

Potential solar and wind energy values were extruded to create thematic 3d displays to assist in the visualization process. Anomalies can be studied and their possible explanations considered. The polygons shown in figure 2 are shown extruded in figure 4, viewed in Google Earth. ESRI's 3d analyst toolbox contains a *lyr to kml* converter which transforms the shapefile to the open source kml format, viewable in any virtual globe.

To no surprise, the south parts of England provide the greatest return from solar energy panels, while Western Wales contains the best return from wind turbine investment. It was also clearly seen that wind stations at higher elevations reported higher potential energy, and locations along the coast tend to provide more hours of sunshine in addition to generally higher energy-density winds.

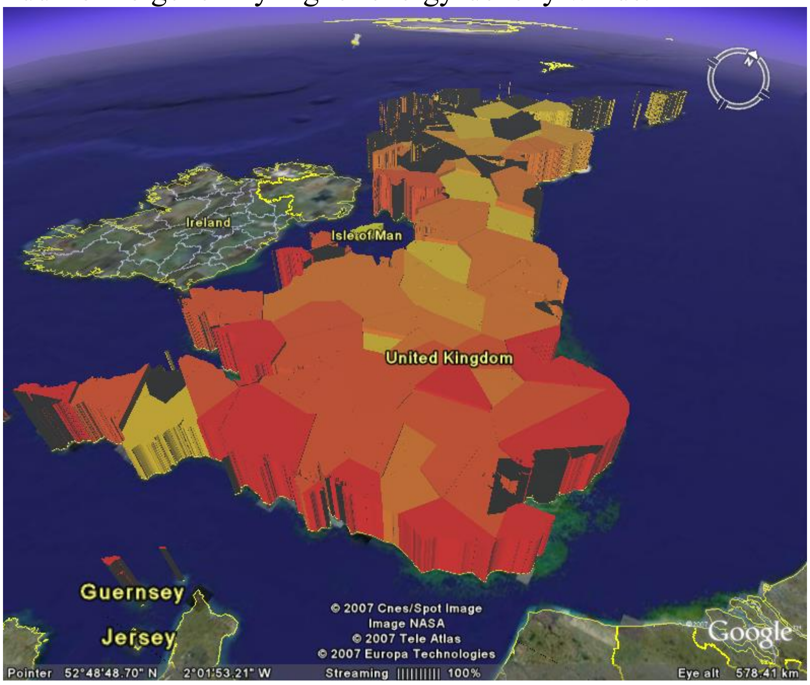

Figure 10 : Potential solar energy throughout Great Britain.

7 Conclusion and Recommendations

Virtual globes provide a lightweight geo-browser to enhance GIS visualization. The benefits of their usability and accessibility have been utilized in this case to provide insightful and enlightening information to the public who are inundated with natural energy statistics that might not necessarily be relevant to their locale. By allowing the user to enter their postcode, natural energy information that is region specific can be obtained to give a better understanding of the estimated amount of natural energy that is available to be harnessed from the wind and sun.

While aggregating all UK locations to 141 wind or 79 solar stations improves localisation of renewable energy information, in order to get the highest level of precision measurements, meteorological instruments would be required installed on individual rooftops throughout the UK to consider neighbouring building structures, nearby trees, and other impediments to wind and solar energies. There is potential here for user generated meteorological data to contribute to even higher resolution datasets.

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Biography

Michael Blom has most recently worked at Willis at a GIS developer, supporting catastrophe management teams. He has also worked as part of the London Cycling Network. His main interest in GIS is using the numerous emerging geographic technologies to better visualize trends in helping to make more informed decisions.