Ocotillo Wind Resource Study*

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Summary

The levelized cost of electricity is central to both private developers and public regulators. For wind powered electricity, it is inversely proportional to the capacity factor (CF). Our study of the Ocotillo project seeks to determine whether the 34% CF claimed by the developer is reasonable.

We first look at the design of the Ocotillo wind project and its geographical location. Since turbines are located in a valley instead of a ridge and are packed too close, we may categorize the design as suboptimal. As a consequence, the project will likely achieve a capacity factor significantly below an estimate derived from a mathematical model.

Secondly, we assess the quality of the wind resource at Ocotillo and find it to be low. Most notably, the projected site does not belong to *Wind Power Class #3*, the minimum efficiency level used all over the world to determine whether a particular location is fit for erecting a wind project.

Next, we assess the wind speed at Ocotillo against historical data from California, Ireland and Germany. All methods concur to predict a capacity factor between 20% and 23%. The Californian data from individual modern wind projects clearly shows that the Ocotillo project with a *Wind Power Class #2* is far from the famed projects found in the Tehachapi or San Gorgonio passes which all belong to *Wind Power Classes #6 and #7*.

These technical findings have a direct monetary implication: wind powered electricity generated at the Ocotillo project will be 30% to 50% more expensive than the current US average. Since renewables sources of energy are supported by public monies, it is the duty of the regulator to watch over their efficient use. In that particular case, we may safely conclude that the Ocotillo Wind Project fails to meet these standards of stewardship.

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1 Objective

The economic comparison of electric generation technologies is based on the concept of *levelized cost*. For a given technology, productive units are compared across space and time using again the same concept which is thus central to both profit making developers and regulators. In the particular case of wind powered electricity, the absence of variable cost makes the levelized cost inversely proportional to the *capacity factor* (CF). The latter, expressed as a percentage, measures the availability of wind all along the year.

The Ocotillo developer claims an output of 891GWh per year for a nameplate capacity of 315MW i.e., $CF = \frac{891}{315 \times 8.760} \approx 32.2\%$ while later on it directly claims a CF of 34%.[1] This estimated value is usually obtained by applying wind speed data recorded on site to the power curve of the best wind turbine currently available on the market. Our study of the Ocotillo wind resource seeks to determine whether this claim is warranted or not and offers some basic policy considerations.

2 Layout Design

As can be checked from the documents lodged with the Bureau of Land Management (BLM) by the developer, the Ocotillo wind project site lies inside a valley and is cut across by a highway and a high voltage transmission line.[2] These features reduce the cost of transporting turbines on site and the cost of connecting the project to the state electricity grid. Yet, by renouncing the greater winds found on the ridge of nearby mountains, the developer has purposely chosen a lesser capacity factor. This prediction will be borne out by the analysis of wind density in the next section.

Beyond the site choice, we can also inquire about the distribution of turbines within the select area. This is warranted by the so-called *shadowing* phenomena: the fact that each turbine perturbs the wind flow when extracting kinetic energy and therefore leaves less energy to be extracted by all

[1] Resolution E-4458 (p2 and p21) from the energy division of the public utilities commission of the state of California.

[2] Using Google StreetMap, one need not visit the site to check these elementary facts.

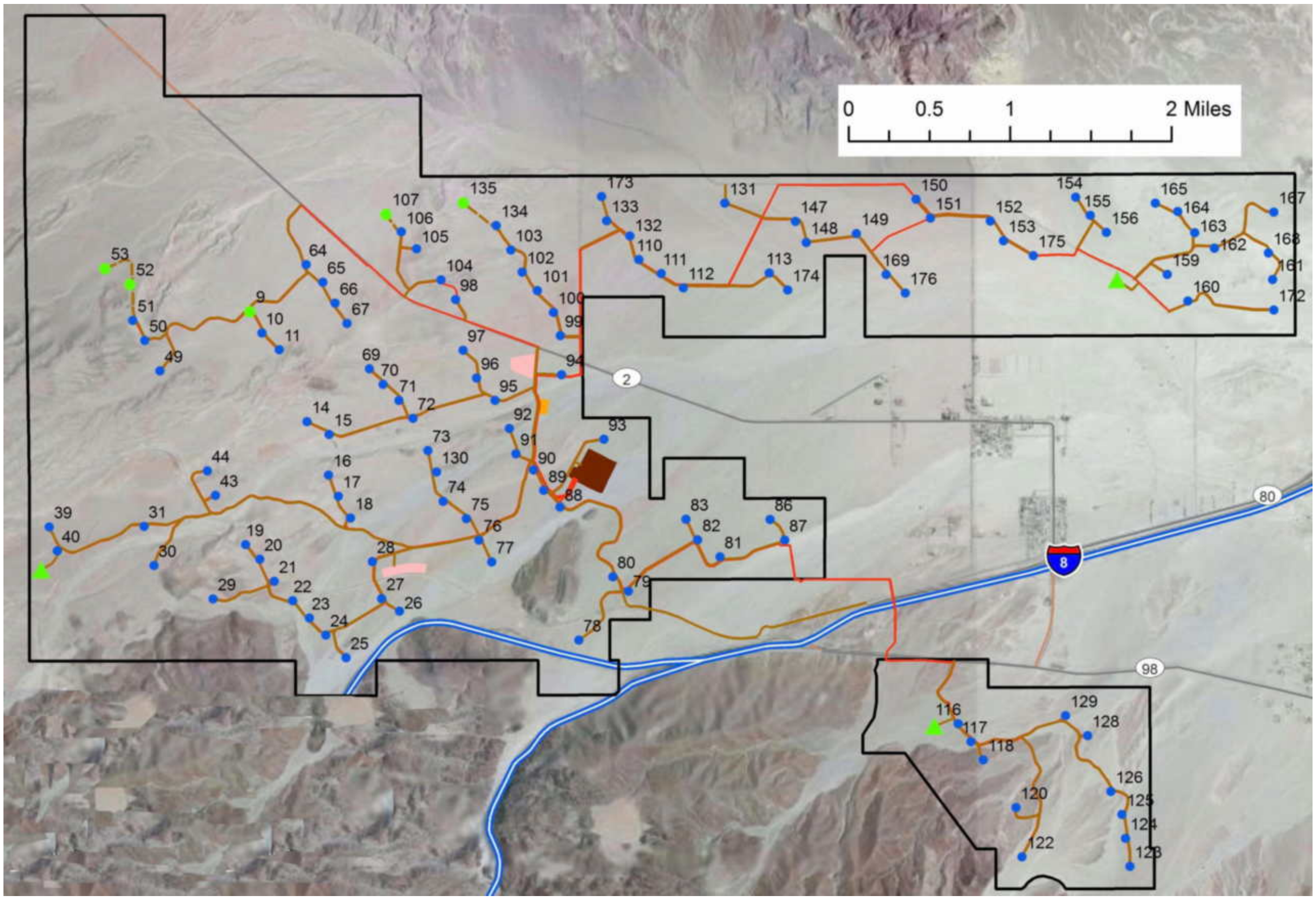

Figure 1: Turbine Layout at the Ocotillo Project

turbines sitting behind. As seen on Figure 1, an average of 6 turbines are packed along a one mile line i.e., they stand at a maximum distance of $\frac{1609}{5} = 322$ meters while successive lines are distant by about half a mile i.e., 804 meters. As reported by the authoritative book of Kaltschmitt et al. (2007), the section on optimal sitting states: "Depending on the specific site conditions, between 8 and 10 times the rotor diameter is required with regard to the main wind direction, and between 4 and 5 crosswise". The Ocotillo project comprises 112 turbines totaling 315MW of power i.e., 2.8MW per turbine.[3] The rotor diameter for that class of turbine being 110 meter, the optimal distances should then be at least 440 and 880 meters. We thus see that the Ocotillo design comes short of respecting the standard guidelines for building an efficient wind project.

Our findings regarding *valley sitting* and *shadowing* lead us to a first conclusion: the Ocotillo design is suboptimal and will therefore achieve a capacity factor significantly below an estimate derived from a mathematical model.

[3]Since the developer intends to use "commercially proven wind turbines", he must be planning to use the latest 3MW models whose rotor diameter is 110 meters.

3 Wind Density Map

To assess more precisely the intrinsic quality of the Ocotillo project, we use wind density mapping. The Pacific Northwest Laboratory (PNL), a federal research center, created a national wind resource assessment for the Department of Energy (DOE) in 1986. PNL classifies wind power by class, with #1 consisting of very light winds and #7 the strongest ones. It is customary for regulators around the world to limit wind project development to locations classified #3 or more.[4]

The developer claims in its application for funding to the North American Bank an average of $6.2ms^{-1}$ across the entire site at 80 meters of hub height. Now, power class #2 is defined as power per square meter below 300 Watts at 50m hub height which in turn is equivalent to wind speed of $6.4ms^{-1}$. The conversion to 80 meters height is done using the 1/7 power law $\left(\frac{80}{50}\right)^{1/7} \approx 1.069$ i.e., speeds greater by 7% or $6.84ms^{-1}$. We thus come to our second conclusion: the Ocotillo project squarely belongs to *Wind Power Class #2*. If one is to follow the standard rule, this site should be listed as "unsuitable for the development of wind powered electricity".

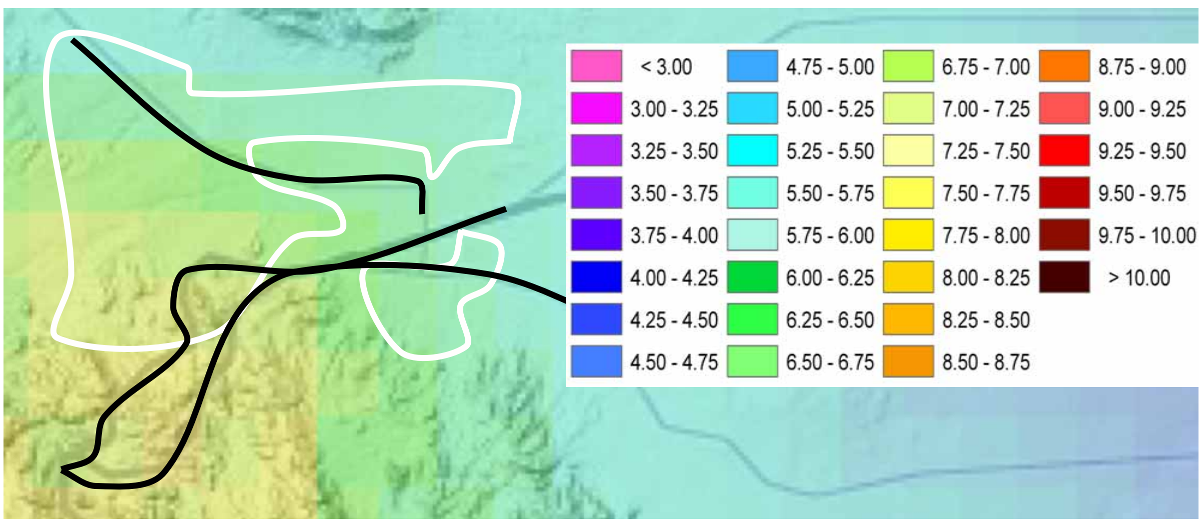

Figure 2: Ocotillo Wind Speed at 60 m hub-heigth

This conclusion is graphically confirmed on Figure 2 which overlays the Ocotillo project outline upon a wind density map of the area created by AWS Truepower (freely available online).[5] The project area shown with a heavy white line goes from yellow to blue. Since the 112 turbines are evenly spread over the entire site, the average green color is a good proxy of the average wind speed over the wind project. The color scale indicates an approximate average speed of $6.5ms^{-1}$ at 60 meter elevation which puts the project at the limit between Power Classes #2 and #3.

[4]Equivalently, feed-in tariffs are set so as to make class #3 break even i.e., earn a fair return.

[5]As recalled by Brower (2010): "AWS has worked with the National Renewable Energy Laboratory (NREL) to produce the only seamless, high-resolution wind resource dataset for the US".

4 Capacity Factor

In this section, we assess the wind speed at Ocotillo against historical data. For that task we use the extensive information that is available for California, the Republic of Ireland and Germany regarding wind powered electricity. In order to carry a meaningful comparison, it is important to use states with a long experience because wind not only varies during the hour, the day and the year but also across years. Having a decade of observation guarantees that we are looking at the true capacity factors of these countries or territories.

Whatever the degree of error that may exists in the following identification strategies, they all concur to put a very low upper bound upon the capacity factor that may be achievable at Ocotillo. Our third conclusion follows: the 34% capacity factor claimed by the Ocotillo developer is far off the mark and shall never be achieved.

4.1 California

Using EIA reports from 1996 until 2011 relative to power plant characteristics and generation, we have have been able to build a table of "post 1990" Californian wind projects with the individual capacity factors for as many years as available. Next, we use information from EIA and BLM documents to infer the precise geographical location of each project. Lastly, we use the 2003 GIS data from NREL for California to attach a power class to each project. We are then able to produce Table 1 and Figure 3. Power class outliers were either confirmed or corrected using AWS' wind navigator which is based on their latest wind speed data and mathematical modeling (cf. Brower (2010)). Extending the linear fit towards Power Class #2 reveals the likely 21% capacity factor for the Ocotillo project.

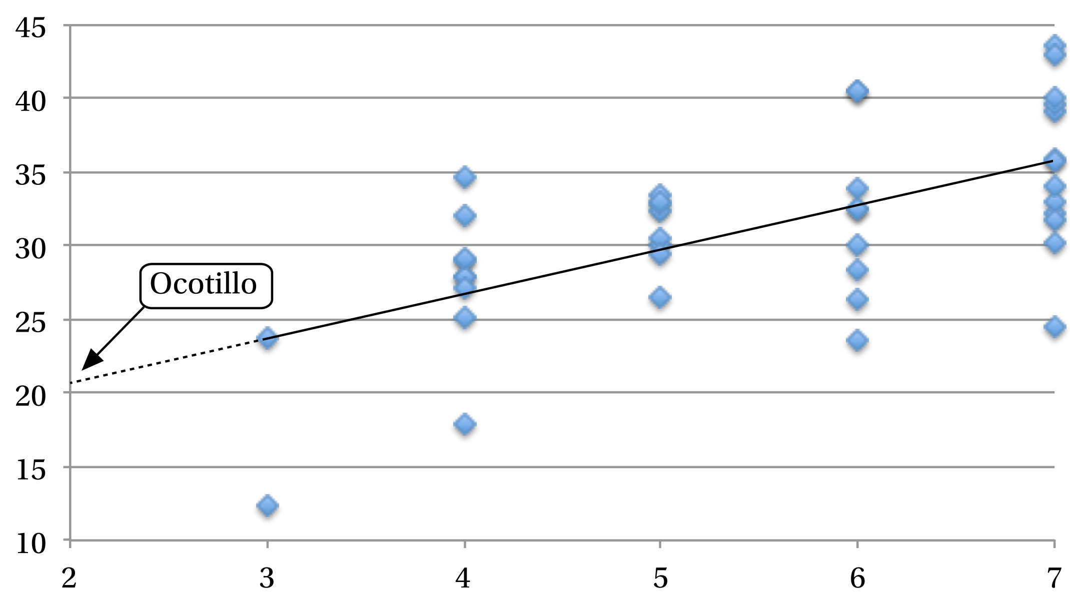

Figure 3: Power Class vs. Capacity Factor in California

Name	MW	PWC	CF
Coram Energy LLC	3	7	43.6
Coram Energy LLC (ECT)	8	7	43.0
Mountain View I	44	7	40.0
Mountain View III	22	7	39.6
Dillon Wind LLC	45	7	39.1
Mountain View II	22	7	35.8
Ridgetop	47	7	35.8
Mojave 5	23	7	34.0
Mojave 3	24	7	33.0
Garnet Wind Energy Center	7	7	32.2
Mojave 4	29	7	31.7
Coram Tehachapi	7	7	30.2
Cabazon Wind Farm	40	7	24.5
Oak Creek Energy Systems I	23	6	40.4
Oak Creek Energy Systems I	4	6	40.4
San Gorgonio Westwinds II LLC	43	6	33.9
Karen Avenue Windfarm	12	6	32.5
Oasis Wind	60	6	32.5
Sky River LLC	77	6	30.0
Dutch Wind Energy	8	6	28.3
Tehachapi Wind Resource II	14	6	26.3

Name	MW	PWC	CF
Tehachapi Wind Resource II	8	6	23.5
Kumeyaay Wind	50	5	33.5
Cabazon Wind Partners	41	5	32.9
Shiloh I Wind Project	150	5	32.8
Shiloh Wind Project 2 LLC	150	5	32.3
Hatchet Ridge Wind Project	101	5	30.5
Alta Wind Energy Center I	150	5	30.1
Buena Vista Energy LLC	38	5	29.4
Victory Garden Phase IV LLC	22	5	26.5
Diablo Wind LLC	20	4	34.7
Whitewater Hill Wind Partners	62	4	32.0
High Winds LLC	146	4	29.1
FPL Energy Montezuma Winds LLC	37	4	28.9
Solano Wind	24	4	27.9
Solano Wind	63	4	27.9
High Winds LLC	16	4	27.1
Pine Tree Wind Power Project	135	4	25.1
ENXCO Wind Farm V	60	4	17.9
Edom Hills Project 1 LLC	21	3	23.8
Tres Vaqueros Wind Farms LLC	28	3	12.4

Table 1: Modern California Wind Projects

Notation: "MW" stands for the installed capacity in MW, "PWC" for the Power Class and "CF" for the average capacity factor over all years posterior to either 1996 or the project first full year of operation.

4.2 Republic of Ireland

Our first international comparison builds on a country with an excellent wind resource, the republic of Ireland (located in the Atlantic west of Britain).

Zooming over individual projects on Figure 4 (cf. Original) allows to identify the wind speed at each location. We have repeated this operation for the projects with the largest capacity and found that on average, Irish wind projects sit at yellow locations. The corresponding wind speed is 9ms^{-1}.[6] Hence, the Ocotillo average wind speed is at least $\frac{9-6}{9} \approx 33\%$ lesser than in Ireland. Lastly, the capacity factor for the whole of Ireland is 30% on average during the last decade (similar to US value), so that the Ocotillo capacity factor cannot be greater than $0.30 \times 0.67 = 20\%$.[7]

[6] Being conservative, we are also accounting for the 3% reduction needed to convert wind speed measured at 75 meters down to a 60 meters height.

[7] Wind power is a function of the cube of wind speed. By performing a linear interpolation, we are minimizing the Ocotillo drawback.

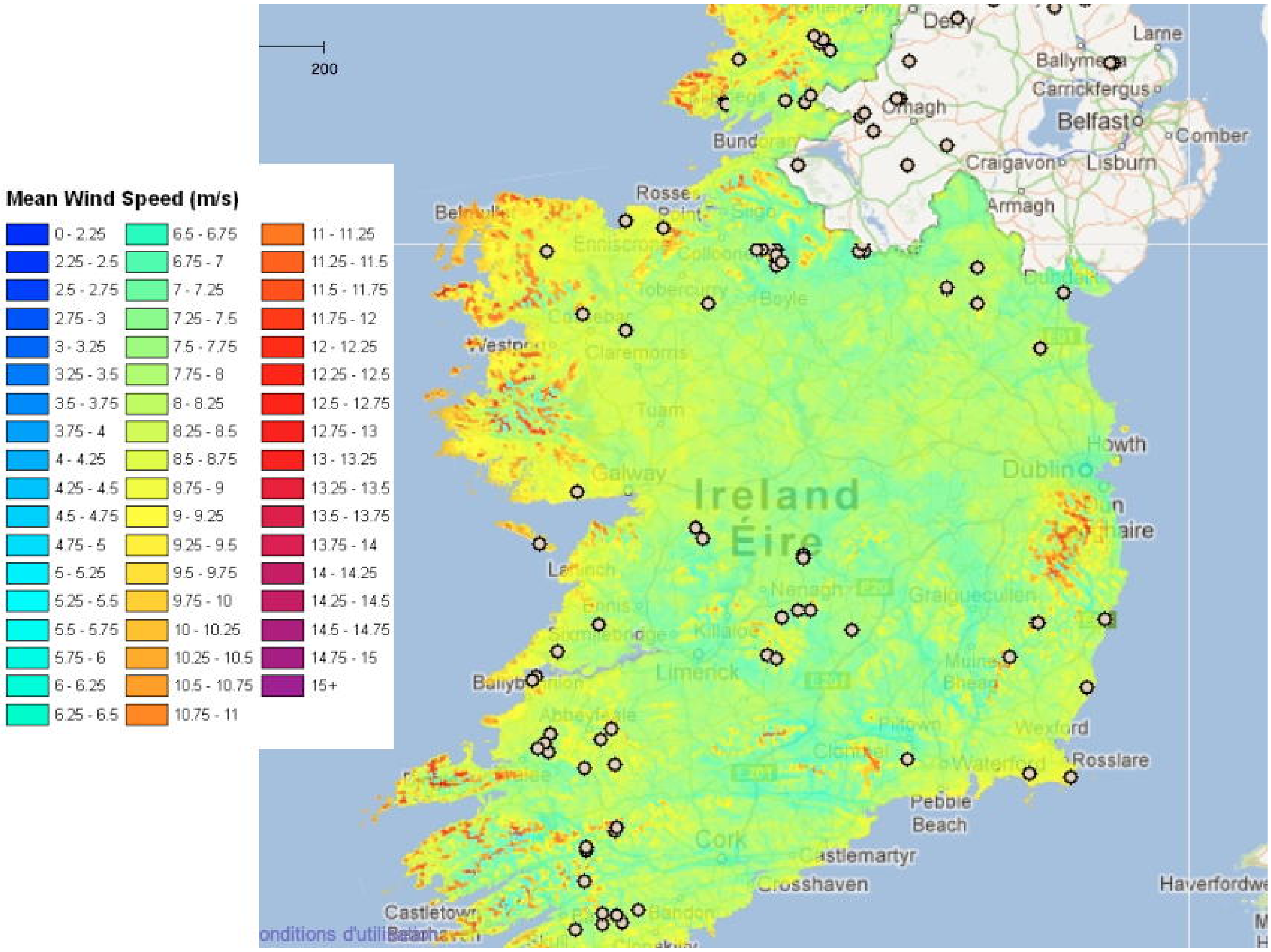

Figure 4: Irish wind map at 75m with wind projects locations

4.3 German Lander of Schleswig-Holstein

Germany is a leader in wind powered electricity with a capacity of 29GW even though it is endowed with a poor wind resource; its capacity factor over the last decade has systematically remained below 21%. Within the country, the northern lander of Schleswig-Holstein with an installed capacity of 3.3GW enjoys the best wind resource ($CF = 23.2\%$) along the north sea shores as shown on Figure 5 (cf. Deutscher Wetterdienst).

As shown on Figure 6, nearly three thousands turbines are scattered over the lander mostly near the shores where wind is stronger (cf. source).[8] This concentration implies that the geographical average of wind speeds (average color) is an acceptable proxy for the wind speed enjoyed on average by wind projects in Schleswig-Holstein. Color coding informs us that the average wind speed is above 7.5ms^{-1}. The corresponding value at 60m height is 7.2ms^{-1} which is clearly greater than the Ocotillo average wind speed. Even if we account for the poor quality of our estimate, the regional capacity

[8] Many areas of the lander achieve a density of more than 5 one MW turbine per km^2.

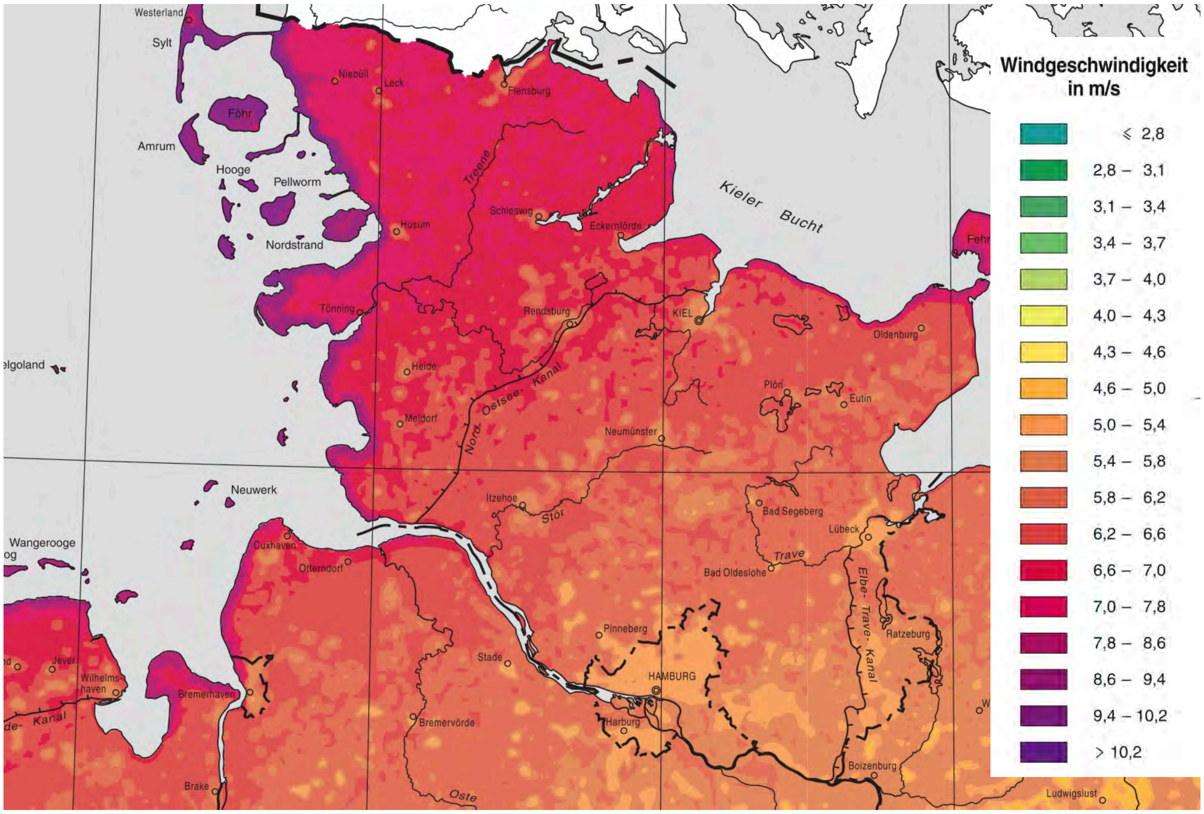

Figure 5: Schleswig-Holstein Wind Map at 80m

factor of 23% appears to be a valid upper bound for the Ocotillo project.

5 Economics

Recall that the levelized cost of wind powered electricity is inversely proportional to the capacity factor. Since the latter is 30% on average in the US but likely to range between 23% and 20% at Ocotillo, the cost of electricity at the Ocotillo project is likely to be 30% to 50% more expensive.[9] This is bad news for the financing institutions behind the project since their profit may be cut or even turned into a loss. Next, as that the electricity generated at Ocotillo is to be paid by clients of the regulated San Diego Gas & Electric Company, the Californian authorities are warranted to demand the outmost efficiency in the management of this renewable project, all the more as the developer will enjoy tax rebates and/or public subsidies. In our opinion, the Ocotillo project fails to meet these standards of stewardship and should not be allowed to continue.

[9]The ratio is between $\frac{30}{23} \approx 1.3$ to $\frac{30}{20} = 1.5$.

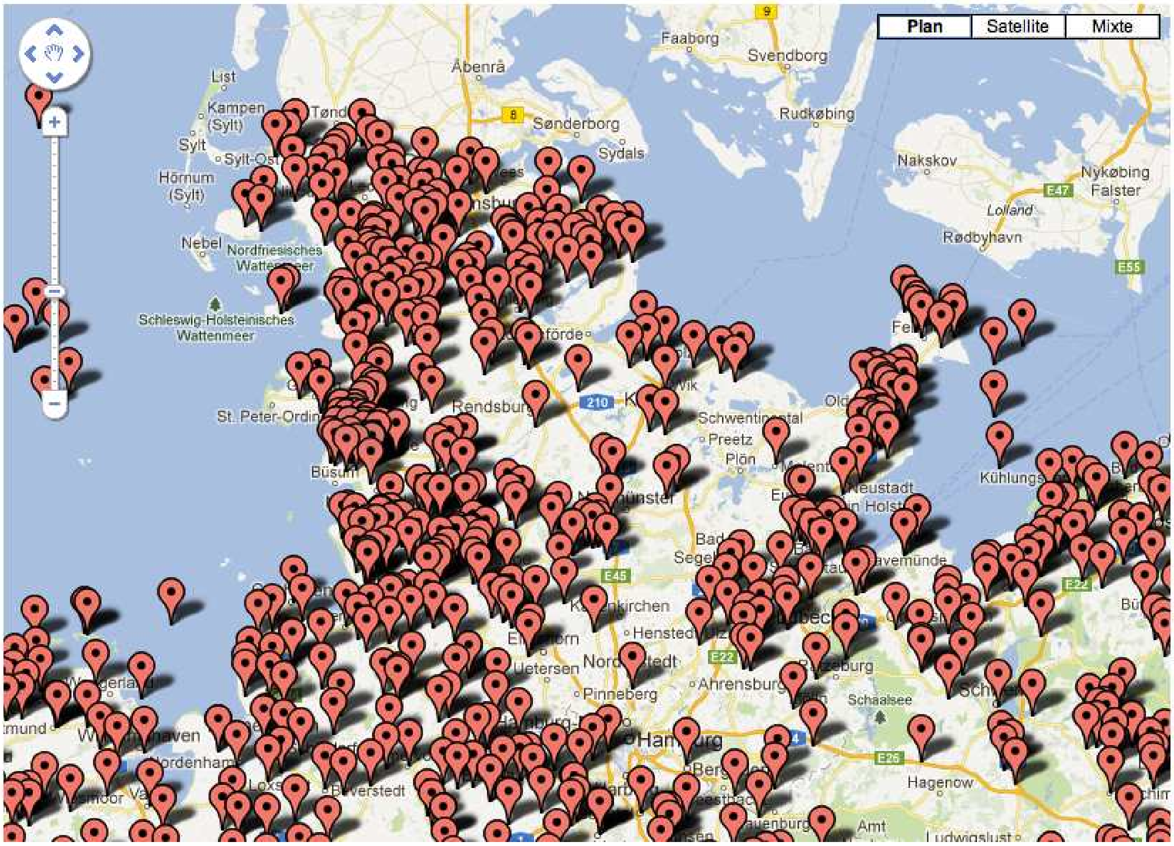

Figure 6: Wind Project Locations in Schleswig-Holstein

References

Boccard N. Economic properties of wind power, a European assessment. *Energy Policy*, 38(7):3232–3244, 2010.

Boccard N. Capacity factor of wind power: Realized values vs. estimates. *Energy Policy*, 37(7):2679–2688, 2009.

Boccard N. The economic implications of wind power intermittency, chapter 100. Elsevier, 2012.

Brower M. New us wind energy potential estimates. Technical report, AWS, 2010.

Kaltschmitt M., Streicher W., and Wiese A. Renewable energy, technology, economics and environment. Springer, 2007.