INL/MIS-15-36549

Procter & Gamble Wind and Solar Analysis Summary

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August 2015

Idaho National Laboratory

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Prepared for the
Procter & Gamble
Box Elder Plant
Tremonton, Utah

EXECUTIVE SUMMARY

This report has been prepared by Idaho National Laboratory as a basic summary of wind data, solar data, and energy production analyses for the Procter & Gamble Box Elder Plant in Tremonton, Utah. Along with this initial analysis report, future development studies/reports may go into more detail and be used to support development of renewable energy projects on Procter & Gamble property. These summaries may be used as supplemental material to support and accelerate further data analysis by other parties involved in the final development and construction of a renewable project.

CONTENTS

ACRONYMS

INL	Idaho National Laboratory
kW	kilowatt
kWh	kilowatt-hour
m	meter
m/s	meters per second
MW	megawatt
P&G	Procter & Gamble

DEFINTIONS

Availability	The percentage of time that a wind turbine is available to operate.
Hub height	The height above ground level to the center of the wind turbine rotor.
Met (tower)	Meteorological tower, with wind data measurement equipment (anemometers).
Net metering	A method of crediting customers for electricity that they generate on-site to offset their own electricity consumption.
Weibull	A mathematical function used to describe frequency distributions of wind speeds.
Wind shear	The increase or decrease in wind speed at higher elevations above the ground.

Procter & Gamble Wind and Solar Analysis Summary

1. INTRODUCTION

This report has been prepared by Idaho National Laboratory (INL) as a basic summary of wind data, solar data, and energy production analyses for the Procter & Gamble (P&G) Box Elder Plant in Tremonton, Utah. Along with this initial analysis report, future development studies/reports may go into more detail and be used to support development of renewable energy projects on P&G property. These summaries may be used as supplemental material to support and accelerate further data analysis by other parties involved in final development and construction of a renewable project.

2. WIND FINDINGS

In the case of the Box Elder Plant, the measured available wind energy resource is poor and not adequate to support an economical, commercial wind energy project at this facility, based on the wind data analysis and National Renewable Energy Laboratory wind maps. At sites with adequate wind, this report data and information would normally be more detailed and would be used to support development of a wind turbine/farm/energy project. However, in the case of the P&G Box Elder Plant, the measured available wind energy is not adequate for supporting an economical wind energy project at this facility.

Based on the wind maps shown below and INL’s historical wind prospecting knowledge in the region, several areas of quality wind resource are available within an approximate 90-mile radius of the P&G facility near Tremonton. Some of the areas we know about are in southeastern Idaho and others in southwestern Wyoming. There could be potential for development of wind energy at another location and wheeling the power over Rocky Mountain Power transmission or other transmission rights (i.e., UAMPS) to service the plant in Utah under a power purchase and transmission service agreements or other mechanisms. Of course transmission wheeling adds to the cost of the electricity from the wind farm; however, if economic analysis shows it to have potential feasibility, these types of options could be further explored. One of the known areas in southeastern Idaho already has an existing small wind farm and substation that is connected to the nearby Rocky Mountain Power transmission. Potential for expansion on that property is likely and enough remaining transmission capacity exists to move the power. In addition, other areas in the region that are not as developed as that one could be explored.

The wind findings to-date are as follows (see Appendices A, B, and C for complete analysis documents):

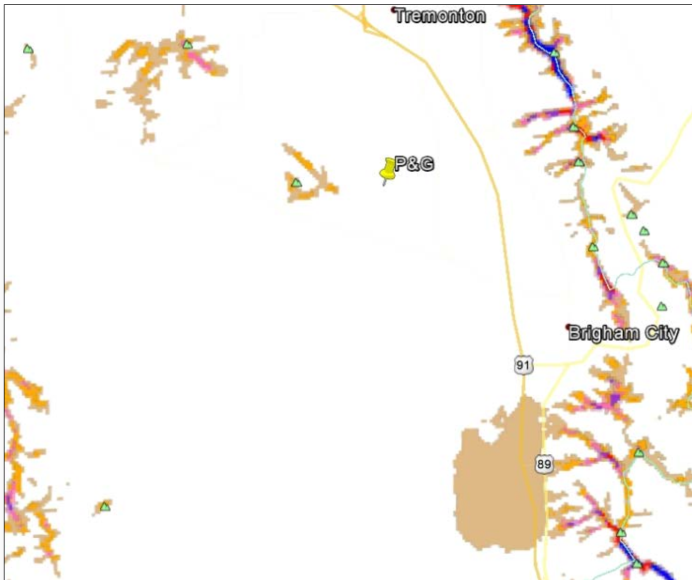
1. 50-m and 80-m National Renewable Energy Laboratory wind maps.

   a. 50-m Utah wind map:

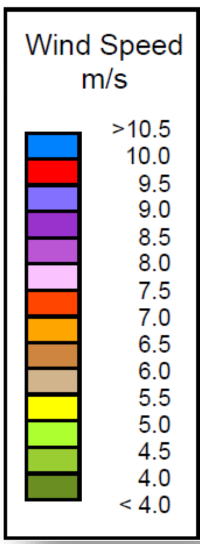
Wind Power Classification

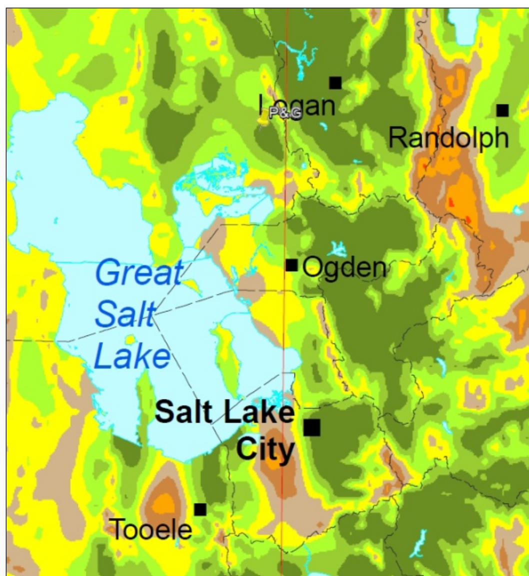
Wind Power Class	Resouce Potential	Wind Power Density at 50m W/m^2	Wind Speed[a] at 50 m m/s	Wind Speed[a] at 50 m mph
1	Poor	0 - 200	0.0 - 5.6	0.0 - 12.5
2	Marginal	200 - 300	5.6 - 6.4	12.5 - 14.3
3	Fair	300 - 400	6.4 - 7.0	14.3 - 15.7
4	Good	400 - 500	7.0 - 7.5	15.7 - 16.8
5	Excellent	500 - 600	7.5 - 8.0	16.8 - 17.9
6	Outstanding	600 - 800	8.0 - 8.8	17.9 - 19.7
7	Superb	> 800	> 8.8	> 19.7

[a]Wind speeds are based on a Weibull k value of 2.0



- 80-m Utah wind map:





2. 15-minute wind data were collected and analyzed at P&G's Campbell Scientific 10-m Met tower from January 2013 to February 2013. A discrepancy was found in the P&G-provided wind data dealing with standard deviation. INL believes the standard deviation found in the wind data was exceptionally high, especially considering the low average wind speed. We believe this average wind speed appears correct and matches the National Renewable Energy Laboratory wind maps. However, it has been noted that this discrepancy in standard deviation will most likely not have enough of an effect to improve the wind classification for this site.

   a. Tower coordinates: N 41° 35.973', W 112° 10.406', surface elevation approximately 4,265 ft (1,300 m) above mean sea level.

3. Long-term estimated annual average wind speed/parameters for the Box Elder plant location are as follows (actual shorter-term annual averages were adjusted for long-term based on available data and estimates):
    a. Long-term annual average wind speed at the P&G 10-m met tower location is estimated at 6.2 mph (2.77 m/s) at 10-m above ground level for the period January 1, 2013 to December 31, 2013.
    b. Estimated wind shear is 0.14 from 10 to 80 m. Based on other data we have in Utah, the wind shear above 30 m likely drops off quickly because much of this wind is cold air drainage from higher ground to the north; therefore, this is a very rough estimate at this time.
    c. The Weibull shape parameter is estimated at 1.6 based on the available data and production estimate comparisons.
    d. A detailed turbulence intensity analysis was not performed for this site due to the questionable standard deviation data, low height of data collection, and because this site does not have commercial development of quality wind. It would be recommended for sites with an adequate wind class to confirm the types and models of wind turbines that may be applied at a project location.
4. Turbines used for initial production estimates: Vestas 2.0-MW, 110-m rotor, 80-m hub height, power curve air density of 1.05 kg/m^3 used. Other turbine brands with available low-wind models are likely to produce similar capacity factors, depending on their relative rotor area versus kW rating ratios and other factors. Other brands with low-wind models include General Electric (1.6 and 1.7-MW models), Siemens, Nordex, Suzlon, and others. However, site suitability studies would still need to be performed by potential turbine suppliers to verify the class of turbines that will be approved for the site based on the climatic/wind conditions. Estimates at other sites with other turbines can be performed and provided upon request, because the models and spreadsheets using the existing wind data have already been developed.
5. Using the parameters outlined above and through multiple energy analysis comparisons using 15-minute data and Weibull production estimates (as well as Weibull parameter adjustments to improve energy content comparison with 15-minute data energy analyses), the long-term projected gross capacity factor for a Vestas V110 2.0-MW wind turbine at the P&G site is 12.3% (see summaries Appendices A, B, and C).
6. Weibull calculations were also performed to compare the various assumptions, energy production estimates based on the 15-minute data, and other aspects to determine if additional adjustments were warranted. The INL long-term energy estimates have used long-term annual wind speed and Weibull shape estimates for distributions that have been adjusted to 3.73 m/s at 80-m hub height and shape factor of 1.6.

    The result is an average annual gross capacity factor of 12.3% for the Vestas V110 (2,149,812 kWh per year for one Vestas 2.0-MW, 110-m rotor, 80-m hub height turbine).
7. For a single turbine, the typical gross-to-net loss percentages would be as follows:
    a. Potential wake losses have been assumed at zero percent for this analysis
    b. Electrical losses are estimated to be 2%
    c. Control (and balance of plant/grid outages/yawing/other) losses at 2%
    d. Wind sector management at 0%
    e. Turbine availability at 4%
    f. Turbulence and high wind hysteresis at 1%
    g. Power curve accuracy deviations at 0%

h. Blade contamination/degradation and icing losses at 1%
i. Other meteorology (e.g., lightning and cold or hot weather) at 0.5%
j. Wind shear reduction effects above hub height at 0.5%.

Because the site has such a low capacity factor, net capacity factor calculations have not been performed at this time; if a project needed other P values, uncertainties would need to be applied to get to P75, P90, and P95 numbers.

8. Energy production estimates for other potential sites and other turbine brands and models can be provided during any follow-on work scope. Scaling of energy production estimates to larger or smaller nameplate MW-rated capacity turbines should provide rough estimates if necessary for request for proposal development, as long as the rotor ratios (i.e., swept area divided by kW rating) and turbine control methodologies and designs are similar.

3. SOLAR FINDINGS

The solar findings to-date are as follows (see Appendix D for complete analysis documents):

1. The solar resource at the Box Elder Plant is very good and an economic photovoltaic (PV) project is achievable. If incentive cost values are considered for energy security and fuel savings in off-grid micro-grid scenarios, the economics for these renewable energy systems can also be improved.
2. For a typical solar PV project, an estimated total project cost used for a life-cycle cost analysis is $2.60/Watt installed or for a 25,000-kW direct current (DC) nameplate, with a total of $6.5M for this size of a system. This cost includes purchase of PV panels and inverters, racking, shipping, warranty, electrical equipment (e.g., conduit, wire, combiner boxes, and breakers), construction, design, and supervision inspection and overhead. Annual maintenance costs are estimated at about 0.005 cents per kWh, which is approximately $193K per year for this size of system.
3. The solar PV equipment that corresponds to the cost range shown in Item 2 includes approximately 14% efficiency PV panels with fixed racking (i.e., no tracking), array tilt of 34 degrees, array azimuth due south, and gross to net derating factor of 0.85. This derate factor accounts for losses, including inverter, wire losses, availability, and soiling and is in a range typical for PV systems of this type. The net energy production from this type of system is estimated at 38,739,004 kWh per year.
4. A single tracking PV system has also been analyzed and an estimated total project cost used for a life-cycle cost analysis is $2.75/Watt installed or, for a 25,000-kW DC nameplate, a total of $6,875,000 for this size of system. This cost includes purchase of PV panels and inverters, racking, shipping, warranty, electrical equipment (e.g., conduit, wire, combiner boxes, and breakers), construction, design, and supervision inspection and overhead. Annual maintenance costs are estimated at about 0.005 cents per kWh, which is approximately $236K per year for this size of system.
5. The single-axis tracking solar PV equipment that corresponds to the cost range shown in Item 4 is approximately 14% efficiency PV panels with single-tracking racking, array tilt of 41.7 degrees, array azimuth due south, and gross to net derating factor of 0.85. This derate factor accounts for losses, including inverter, wire losses, availability, and soiling and is in a range typical for PV systems of this type. The net energy production from this type of system is estimated at 47,363,048 kWh per year.
6. A dual-tracking PV system has also been analyzed and an estimated total project cost used for a life-cycle cost analysis is $2.85/Watt installed or, for 25,000-kW DC nameplate, a total of $7,125,000 for this size of system. This cost includes purchase of PV panels and inverters, racking, shipping, warranty, electrical equipment (e.g., conduit, wire, combiner boxes, and breakers), construction, design, and supervision inspection and overhead. Annual maintenance costs are estimated at about 0.005 cents per kWh, which is approximately $265K per year for this size of system.

7. The dual-axis tracking solar PV equipment that corresponds to the cost range shown in Item 6 is approximately 14% efficiency PV panels with dual-tracking racking, array tilt of 41.7 degrees, array azimuth due south, and gross to net derating factor of 0.85. This derate factor accounts for losses, including inverter, wire losses, availability, and soiling and is in a range typical for PV systems of this type. The net energy production from this type of system is estimated at 52,888,180 kWh per year.

4. ADDITIONAL ANALYSIS

In general, the following table shows typical solar and wind costs:

Solar PV	
Typical total installed cost range per nameplate Watt DC, utility to large industrial/commercial size (>10 MW), fixed tilt	$1.50 to $2.60 per Watt
Typical cost adder range for single or dual-axis tracking systems per Watt DC nameplate	Plus $0.20 to $0.40 per Watt
Annual average net capacity factor range for solar PV in Salt Lake City, Utah area, fixed tilt to dual-axis systems	17.5% to 24.2%
Typical corresponding solar energy power purchase agreement cost ranges (depends on incentives, business model, and financing arrangements)	$0.065 to $0.12 per kWh
Wind	
Typical total installed cost range per nameplate Watt DC, utility to large industrial/commercial size (>10MW), large turbines (1.5 MW or larger)	$1.80 to $2.60 per Watt
Typical annual average net capacity factor range for commercial-grade wind resource	32% to 48%
Typical corresponding wind energy power purchase agreement cost ranges (depends on incentives, business model, and financing arrangements)	$0.035 to $0.09 per kWh

It is possible that the foothills (i.e., Little Mountain) west of the Box Elder plant have a wind class that is slightly better than the lower elevation; however, it is not likely because the topography around the area does not appear to force or pinch the wind over those ridges. Judging by the 50-m wind map, it appears to be in the marginal to fair class. This would need to be further investigated and nailed down with appropriate wind prospecting equipment. If P&G can receive permission from the land owners, INL has a Triton Wind Profiler Sodar unit (see figure below) that can be used to collect wind data on this hill. Or a better probability approach could be to prospect with the Sodar unit in other regional areas where we have more prior knowledge that the wind resource is likely to be good.

The Sodar is a trailer-mounted unit that has an advanced remote sensing system that provides accurate wind measurement data up 200 m into the air. The cost to deploy this unit for 1 year (or possibly longer as needed) would be in the $55 to $80K range, depending on factors such as if the unit is upgraded to the more powerful speaker modules and if it is deployed to more than one location. It is also possible that P&G should consider farther away wind locations and look at renewable energy credits, power purchase agreements, and/or asset ownership and wheeling charges. One of the areas that INL feels has the best potential for this kind of buy in would be in Pocatello, Idaho, either near Rockland and American Falls or by Fort Hall to Firth.

Triton Wind Profiler Sodar unit.

Additional items for discussion include energy storage and power/energy security options for P&G. Many customers are interested in backup power options that may include backup generators, battery/uninterruptible power supply systems, remote sites that do not have utility power service, or others. If P&G has existing backup power/uninterruptible power supply systems, there may be potential to modify these in the future to provide other services such as peak shaving or demand response to help reduce utility bills, while still providing the backup power capability. It is our experience that these types of modifications only make sense economically when the existing systems are old and near replacement or have operational and maintenance or cost issues that push the user into looking for upgraded solutions. In many cases, energy storage costs are challenging to justify when only using the storage for peak shaving or demand response; however, if those demand charge costs are high enough or there is a significant power security need and justification, then energy storage and localized generation should be investigated. Solar power coupled with energy storage can make a good combination for remote sites or reduced fueled generation use at sites where local generation comes on often due to poor utility reliability. Demand charges may only be impacted in cases where the demand charges (or time of use) window is short enough to offset with localized generation, storage, and/or load control. Without baseload power or combined heat/cooling and power assets, longer demand windows are more challenging to compete with.

If there is future interest in these types of analyses and associated economics studies, INL has experience with detailed business model/economics studies and power balance/cost studies for distributed energy systems and can provide examples or discussion as requested. The solar resource study performed in this report utilized regional hourly average solar data. However, for the more detailed studies described above, the onsite data coupled with head-to-head load data (i.e., load and potential generation balance) would allow for more detailed analyses as needed. Comparisons were made between the local and regional data on an annual average basis and they were very close in terms of annual average energy production. Although not analyzed in this preliminary analysis of wind and solar energy, other options involving natural gas generation, biogas, fuel cells, combined heat and power, and others can be considered for analysis in the future if there is continued interest in distributed/local generation.

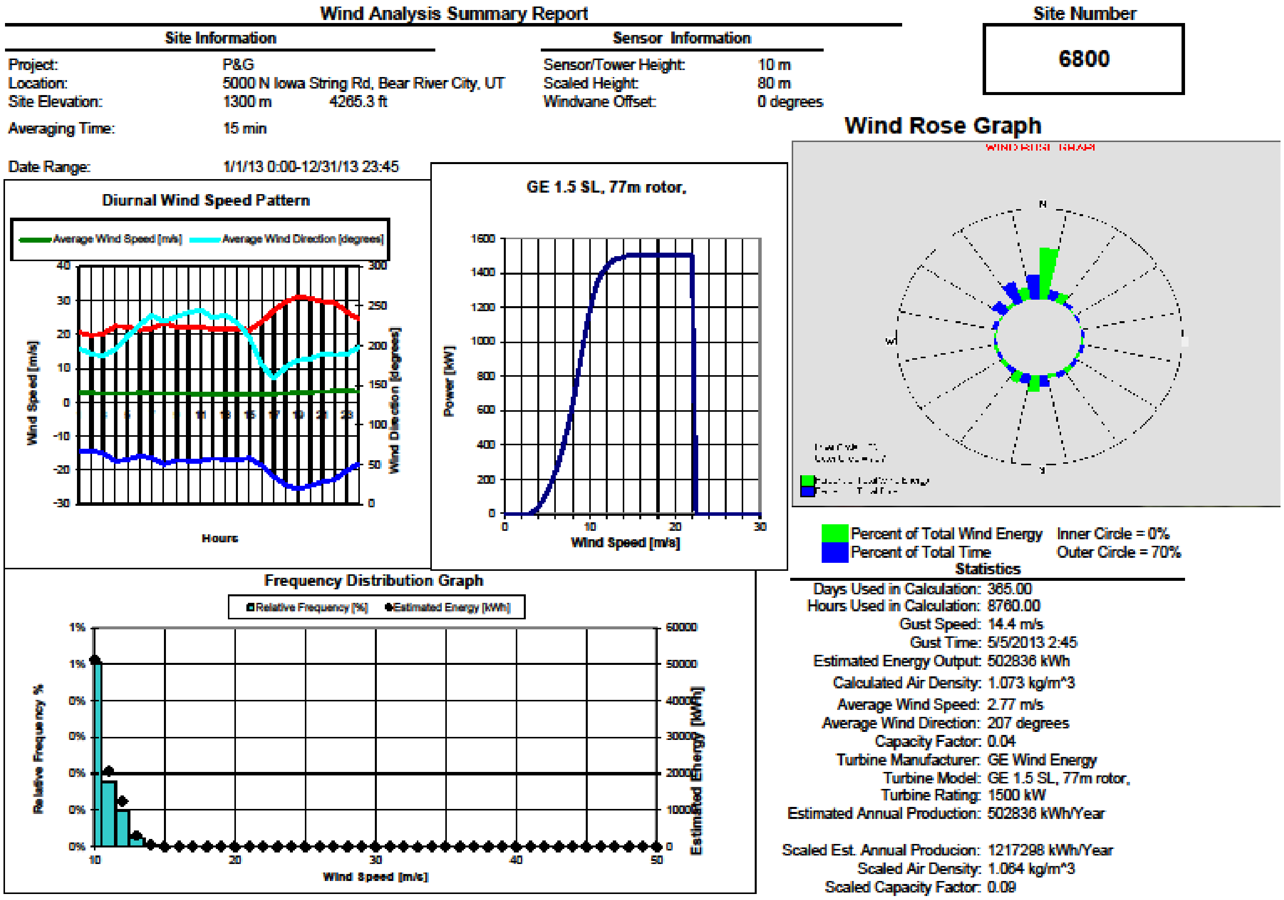
5. ROCKY MOUNTAIN POWER RATE SCHEDULE FINDINGS

The Rocky Mountain Power rate schedule findings are shown in Appendix E:

Final comments include the utility rate/tariff schedules for Rocky Mountain Power. The Schedule 8 and 9 tariffs appear relatively competitive for the region, but the new Schedule 32 for service from renewable energy facilities appears very unfavorable from a demand charge perspective. Our cursory analysis shows that demand charges could double or triple over those in Schedules 8 and 9 for most types of renewable energy generation. We have other federal customers in Utah that have pushed back on being moved to that rate schedule, even though they have onsite renewable generation, because the tariff does not appear to be very reasonable from a regulated utility customer perspective. Those customers have so far elected to just appear as large net meter under their existing rate schedule and sell any excess back under the Public Utility Regulatory Policies Act as a qualifying facility at the avoided cost rate. There may be potential in the future for industry and other customers to push for more reasonable utility tariff structures and incentives for onsite and renewable energy generation through state/public utilities commission involvements and filings, and/or through work with state government and with other options to improve rates, economics, and incentives.

Appendix A

Preliminary Analysis Documents



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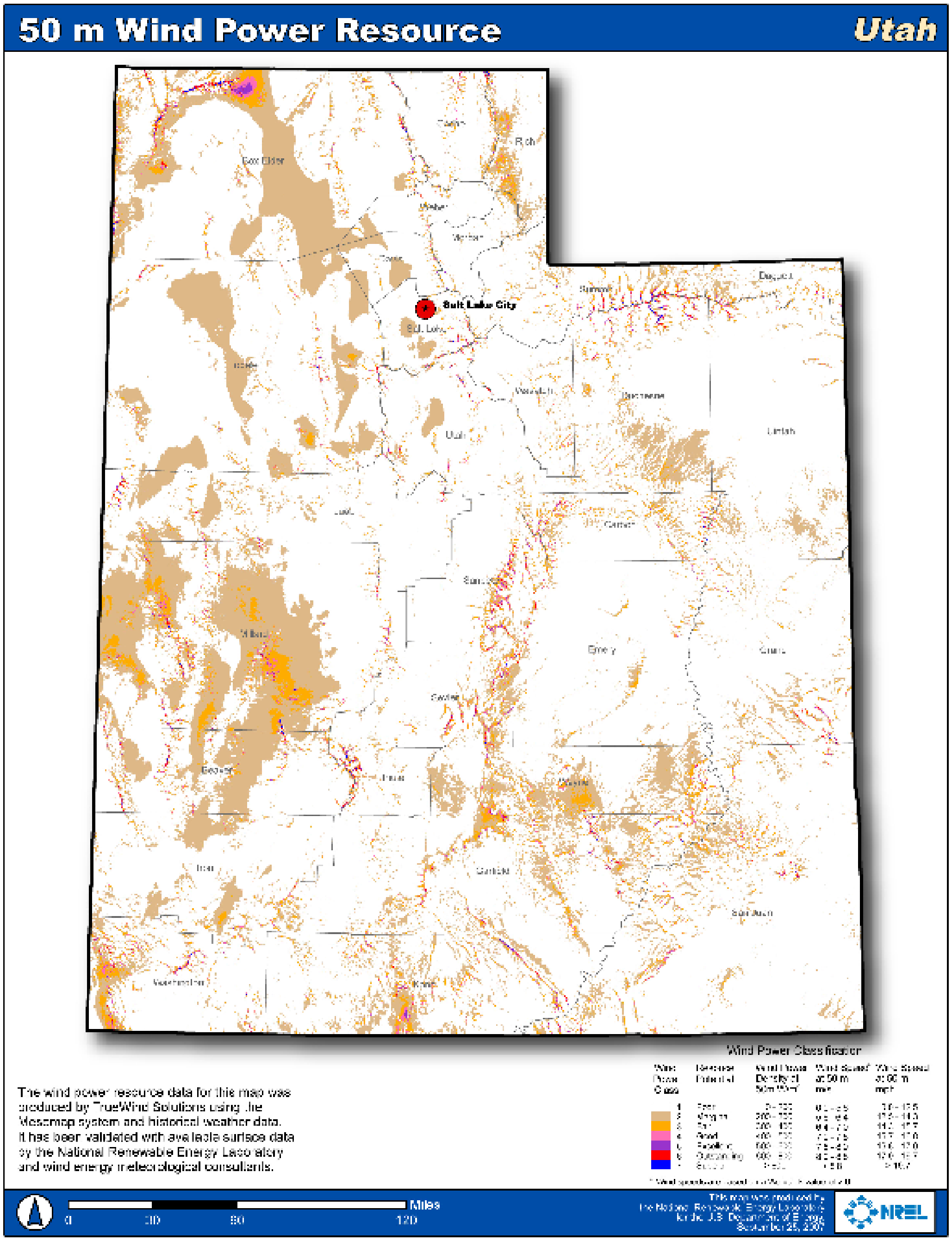
Appendix B

Wind Maps



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Appendix C

Wind Analysis Spreadsheets

Wind Analysis Summary Report

Site Number

6800

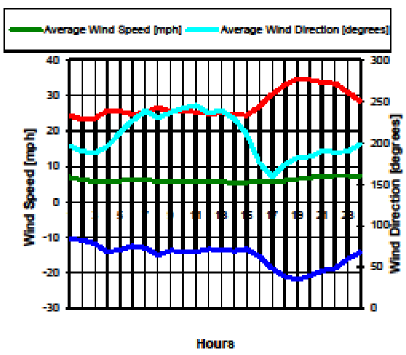
Site Information

Project:	P&G
Location:	5000 N Iowa String Rd, Bear River City, UT
Site Elevation:	4500 ft
Averaging Time:	15 min
Date Range:	1/1/13 0:00-12/31/13 23:45

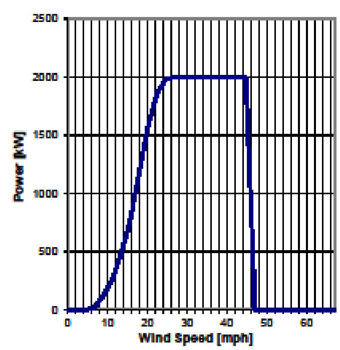
Sensor Information

Sensor/Tower Height:	33 ft
Scaled Height:	262 ft
Windvane Offset:	0 degrees

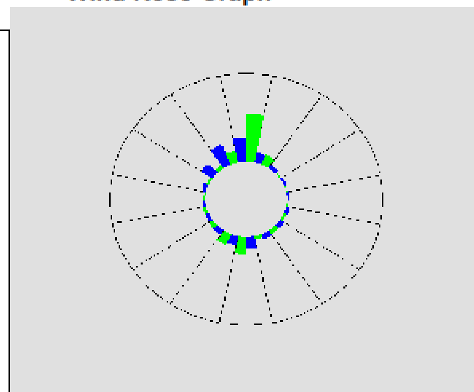
Diurnal Wind Speed Pattern



V110 2.0MW, 110m rotor (1.05 kg/m3)



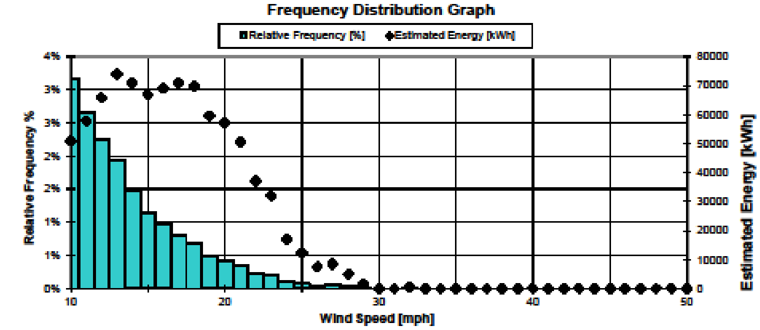
Wind Rose Graph



Percent of Total Wind Energy — Inner Circle = 0%

Percent of Total Time — Outer Circle = 70%

Frequency Distribution Graph



Statistics

Days Used in Calculation:	365.00
Hours Used in Calculation:	8760.00
Gust Speed:	32.2128 mph
Gust Time:	5/5/2013 2:45
Estimated Energy Output:	978163 kWh
Calculated Air Density:	1.065 kg/m^3
Average Wind Speed:	6.2 mph
Average Wind Direction:	207 degrees
Capacity Factor:	0.06
Turbine Manufacturer:	Vestas
Turbine Model:	V110 2.0MW, 110m rotor (1.05 kg/m3)
Turbine Rating:	2000 kW
Estimated Annual Production:	978163 kWh/Year
Scaled Est. Annual Producion:	2149812 kWh/Year
Scaled Air Density:	1.056 kg/m^3
Scaled Capacity Factor:	0.11 — 12.27%

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Appendix D

PVWatts Solar Analysis

NREL

RESULTS

38,739,004 kWh per Year *

Month	Solar Radiation (kWh / m^2 / day)	AC Energy (kWh)	Energy Value ($)
January	3.14	2,106,273	169,134
February	4.34	2,582,847	207,403
March	5.11	3,283,338	263,652
April	5.70	3,450,217	277,052
May	6.75	4,110,684	330,088
June	6.81	3,848,845	309,062
July	7.17	4,078,060	327,468
August	7.13	4,105,460	329,668
September	6.44	3,725,607	299,166
October	5.45	3,352,945	269,241
November	3.80	2,353,173	188,960
December	2.59	1,741,562	139,847
Annual	**5.37**	**38,739,011**	**$ 3,110,741**

Location and Station Identification

Requested Location	tremonton, ut
Weather Data Source	(TMY2) SALT LAKE CITY, UT 66 mi
Latitude	40.77° N
Longitude	111.97° W

PV System Specifications *(Commercial)*

DC System Size	25000 kW
Module Type	Standard
Array Type	Fixed (open rack)
Array Tilt	34°
Array Azimuth	180°
System Losses	13%
Inverter Efficiency	96%
DC to AC Size Ratio	1.1

Initial Economic Comparison

Average Cost of Electricity Purchased from Utility	0.08 $/kWh
Initial Cost	2.60 $/Wdc
Cost of Electricity Generated by System	0.11 $/kWh

Selected Incentives

Capacity Based Incentives (CBI)	Rocky Mountain Power - Solar Incentive Program Rate: $1.55 - Maximum Amount: $4,650.00

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Appendix E

Rocky Mountain Power Rate Schedules

ROCKY MOUNTAIN POWER
A DIVISION OF PACIFICORP

P.S.C.U. No. 50 | **Original Sheet No. 9.1**

ROCKY MOUNTAIN POWER

ELECTRIC SERVICE SCHEDULE NO. 9

STATE OF UTAH

General Service - High Voltage

AVAILABILITY: At any point on the Company's interconnected system where there are facilities of adequate capacity.

APPLICATION: This Schedule is for alternating current, three-phase electric service supplied at approximately 46,000 volts or 69,000 volts or greater, through a single point of delivery. Seasonal service will be available only under other appropriate schedules.

MONTHLY BILL:

Customer Service Charge:
$255.00 per Customer

Facilities Charge:
$2.19 per kW

Power Charge:
Billing Months - May through September inclusive
On-Peak: $13.75 per kW
Off-Peak: None

Billing Months - October through April inclusive
On-Peak: $9.32 per kW
Off-Peak: None

(continued)

Issued by authority of Report and Order of the Public Service Commission of Utah in Docket No. 13-035-184

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