An Evaluation of the Power Predictor 1.0™

A low-cost anemometer, vane and pyranometer used to determine energy potential at a given site

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Alaska Energy Authority, April 2011

Acknowledgments: Many thanks to Bruce Wright and Aleutian Pribilof Islands Association for loaning a Power Predictor 1.0™ for this study. Thanks to James Jensen, Kat Keith, Doug Vaught and Bruce Wright for reviewing the technical content of this report.

Abstract: The Alaska Energy Authority has completed a six-month evaluation of a Power Predictor 1.0™ in near side-by-side testing with a Second Wind anemometer and NRG Symphonie™ datalogger. The purpose of the evaluation was to determine if this ~$300 product could serve as an alternative to the Authority's standard meteorological configuration. The results show that the Power Predictor 1.0™ may be a viable alternative during the reconnaissance stage of wind energy exploration and site development and serve as a useful tool to evaluate many potential sites in a fast and economical fashion. The performance of the unit's pyranometer was not deemed acceptable, but a future evaluation of the Power Predictor 2.0™ with upgraded polysilicon PV sensor is warranted.

Figure 1 – Power Predictor 1.0 vane and anemometer

Figure 2 – Datalogger

Background: The Power Predictor 1.0 unit tested is actually the third system used here in the state by Alaska Energy Authority. The unit tested was graciously loaned to the Authority by Bruce Wright, senior scientist with Aleutian Pribilof Islands Association. The first unit was installed on a 7-meter portable PVC tower above the village of Tatitlek in eastern Prince William Sound. This unit failed early due to water in the datalogger. It is possible that the water-tight seal popped open or was knocked open. No physical

damage can be seen on the unit to explain the leak. Testing back at AEA indicated no pinholes in the seal. The second unit was wrapped in plastic and electrical tape with no moisture inside the datalogger. The third unit tested at the AEA warehouse and the AEA roof had electrical tape wrapped around the seal with no problems occurring.

The goal in evaluating this unit is to find a low-cost anemometer that can be deployed by one or two people in the field in locations that are difficult to access with pickups, four-wheelers or other off-road equipment. Data collection from multiple potential wind sites early in the reconnaissance phase of a project could allow for better siting of our standard 30/34m NRG Tall Tower™ system. The Authority's standard configuration costs $8,160 at the time of publication, weighs 1240 pounds and takes a crew of 5+ to erect utilizing robust anchors and a winch. A portable tower used for wind-site prospecting, however, could be carried in and erected by two people and cost around $800, including anchors, PVC pipe, fittings and guy wires.

General product and purchase information can be found at http://www2.powerpredictor.com/

Literature search: All online information that can be found regarding the Power Predictor™ online is promotional sales information or testimonials. Product specifications and manuals can be found online, but no independent testing or comparisons with other anemometers are present.

First AEA set up: A tower was installed in the afternoon of Friday, Oct. 24 along the north fence line of the AEA warehouse at 2601 Commercial Drive in Anchorage. The tower consisted of two 2" ID PVC pipe sections (10' long) with 1.5" ID sleeves (2' long) connected with 3" 5/16 dia. Galvanized bolts, washers and nuts. (Figure 3) A ½" crescent wrench was used to tighten bolts. These materials were purchased by the author due to delays in reinstating the Authority's wind assessment fund. An Air-X tower kit, including t-base, top collar and guy wires, was not purchased for this reason, but would be part of a standard test configuration.

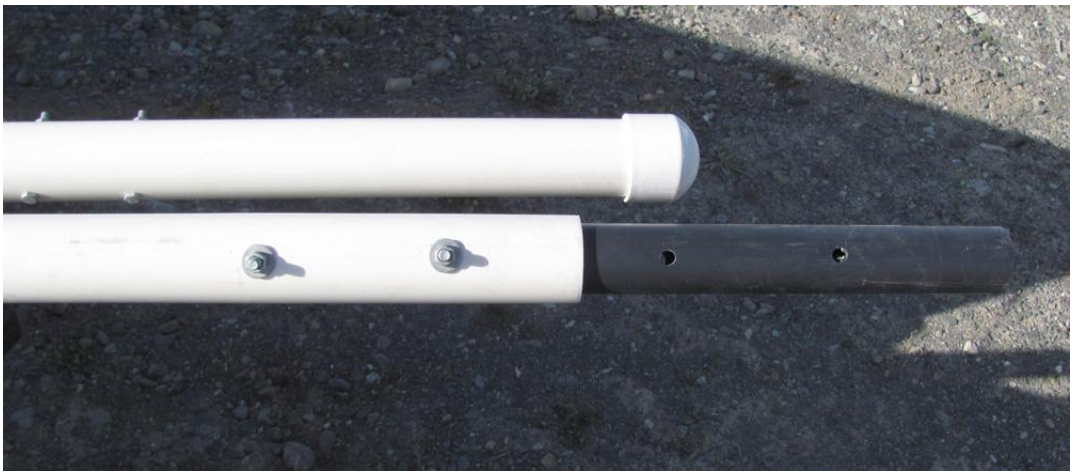

Figure 3 – Pipe section detail

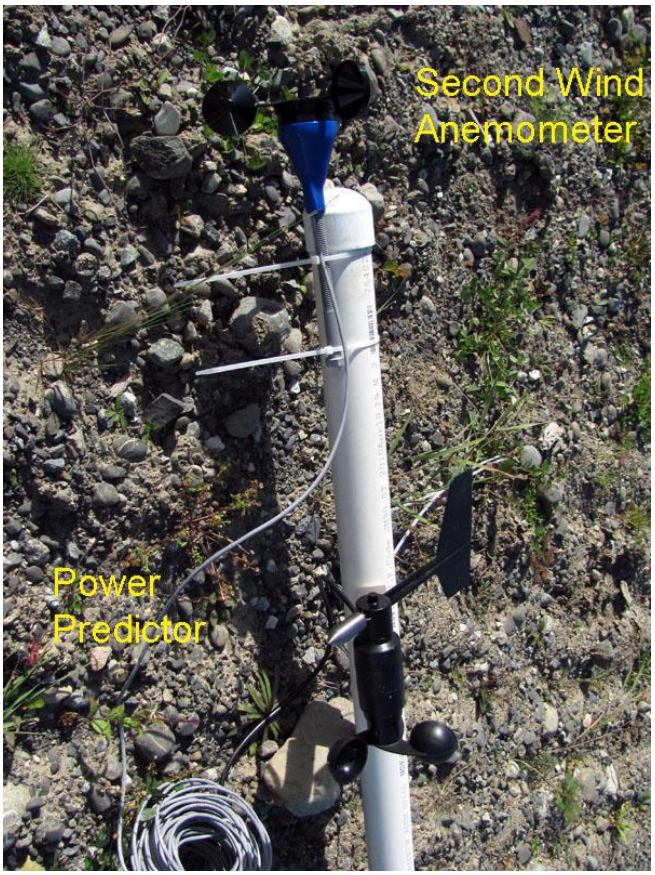

Figure 4 – Top of pole configuration

The Power Predictor™ was mounted onto the top section of PVC pipe with two 3”-long ¼”-dia. galvanized bolts, plus nuts and washers. The Second Wind anemometer was mounted on a galvanized bolt extending from the top of the PVC pipe. A PVC cap was placed over the top of the PVC to prevent birds trying to nest and getting stuck inside. (Figure 4)

The Power Predictor™ datalogger was taped to the PVC pole around chest height with the NRG Symphonie™ datalogger sat in a shelter box at the tower base.

An attempt was made to attach the 20’ tower to the fence, but the lack of a top collar anchored to the ground resulted in too much flex in strong winds and the tower was reduced to 10’. (Figure 5)

The purpose of the test was not to assess the wind resource at the warehouse, but to place the two sensors as close to each other as possible to determine how closely they track during wind events.

Under the test configuration, the two anemometers were approximately 1.5 feet apart. The fact that the Second Wind anemometer is placed higher and extends from the top of the pole, while the Power Predictor™ is side mounted introduces variation due to shadowing of the latter from the 2” ID PVC pipe. The Power Predictor™ cup diameter is approximately 5 inches versus 7.5 inches diameter for the Second Wind sensor.

An initial inspection showed that instantaneous readings on the two systems varied in gusty conditions, but steady state looked fairly close. Both loggers will record 10-minute data, their clocks synched up. The recorded time period, however, did not match up with the NRG recording at :00, :10, :20, etc. and the Power Predictor™ recording at :06, :16, :26, etc. It is not clear how to correct this offset.

Figure 5 – 20’ pole assembly

Sensor specs:

Power Predictor™ 3-cup pulse anemometer with data logger
• Wind speeds accurate to +/- 3% in independently verified tests
• 10 second recording interval, average taken every 10 minutes
• Wind vane for measuring prevailing wind direction and turbulence (requires due south orientation)
• Solar sensor for measuring solar irradiation (also requires due south orientation)
• Self-contained waterproof data logger engineered for low power operation
• LCD screen provides live wind speed and solar indication
• 512 MB SD memory card included with USB adaptor
• Power Predictor Web application works through your browser - works with PC or Mac
• Requires USB 1.0 or 2.0 port on your computer
• Minimum 30 days data required before Power Report generated
• PP3 9V battery supplied
• 5m cable (6m extension available)
• Rugged UV resistant ABS plastic
• RoHS compliant and fully CE certified
http://www.bettergeneration.com/power-predictor/introducing-the-power-predictor-anemometer.html

Second Wind C3™ Conical cups measure 51 mm (2 inches) in diameter
• Rotor diameter is 190 mm (7.5 inches)
• Standard AC output, frequency proportional to cup rotational speed
• Shielded AC pickup coil, 4100 turns of #41 wire
• Four-pole Indox 1 magnet rotates with the cup assembly
• Fully hardened beryllium-copper shaft running in self-lubricating modified Teflon bearings, with protective boot to make the system dirt and water resistant
• Rated bearing PV (pressure-velocity) factor is 20,000
– At 15 mph PV is approx. 500.
– At 100 mph PV is approx. 2,000.
• Rotor assembly moment of inertia = 68 x 10–6 S-ft2 (or 92.2 x 10–6 kg-m2)
• Distance constant = 10 feet (3.0 meters)
• Transfer Function: m/s = (Hz x 0.766) + 0.324 [miles per hour = (Hz x 1.714) + 0.725]
• Accuracy: within 0.1 m/s (0.2 mph) for the range 5 m/s to 25 m/s (11 mph to 55 mph). *This equates to max 2% error.*
http://www.secondwind.com/Sensors/C3-anemometer.html

Results from AEA Warehouse Site: After one month, data for the two sensors was compared. Even though there had been some severe wind events in Anchorage, the highest 10-minute average seen during the month was 6.5 meters per second. Prevailing winds are likely blocked by nearby buildings and vegetation even though the immediate several hundred feet around the site is clear. At the end of the first month, it was noticed that the anemometer channel on the NRG datalogger did not have a .350 offset value as is apparent in the presence of values less than .4 m/s. (Figure 6)

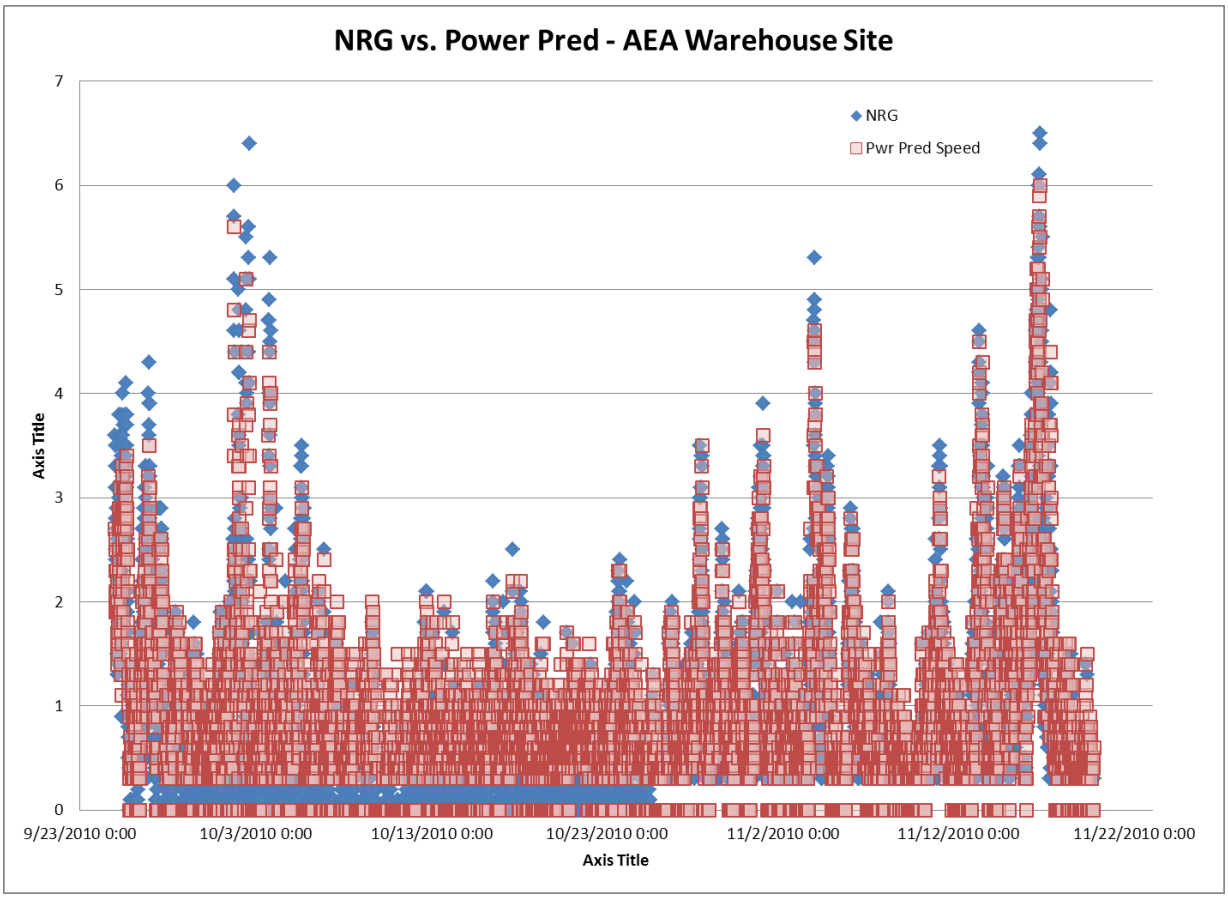

Figure 6 – Trend Chart from AEA Warehouse Site

This offset value was corrected on Oct. 25. The data trend shows several key observations.

- Null readings on the NRG/Second Wind sensor default to 0.4m/s while the Power Predictor™ will read zero unless the wind speed is at least 0.4 m/s at which point the anemometer begins to spin.
- Both sensors move with each other – each wind peak can be detected by the Second Wind and the Power Predictor™ anemometers. The correlation coefficient (Excel™ CORREL procedure) is 0.929 for all data pairs and .952 for all data after the NRG offset value was corrected.
- With one low-speed spike as an exception, the Second Wind anemometer always peaks higher than the Power Predictor by ~ 0.5 m/s.

A high-wind event was analyzed to get better visual resolution on how well the two sensors track each other. (Figure 7) The two sensors appear to track very closely.

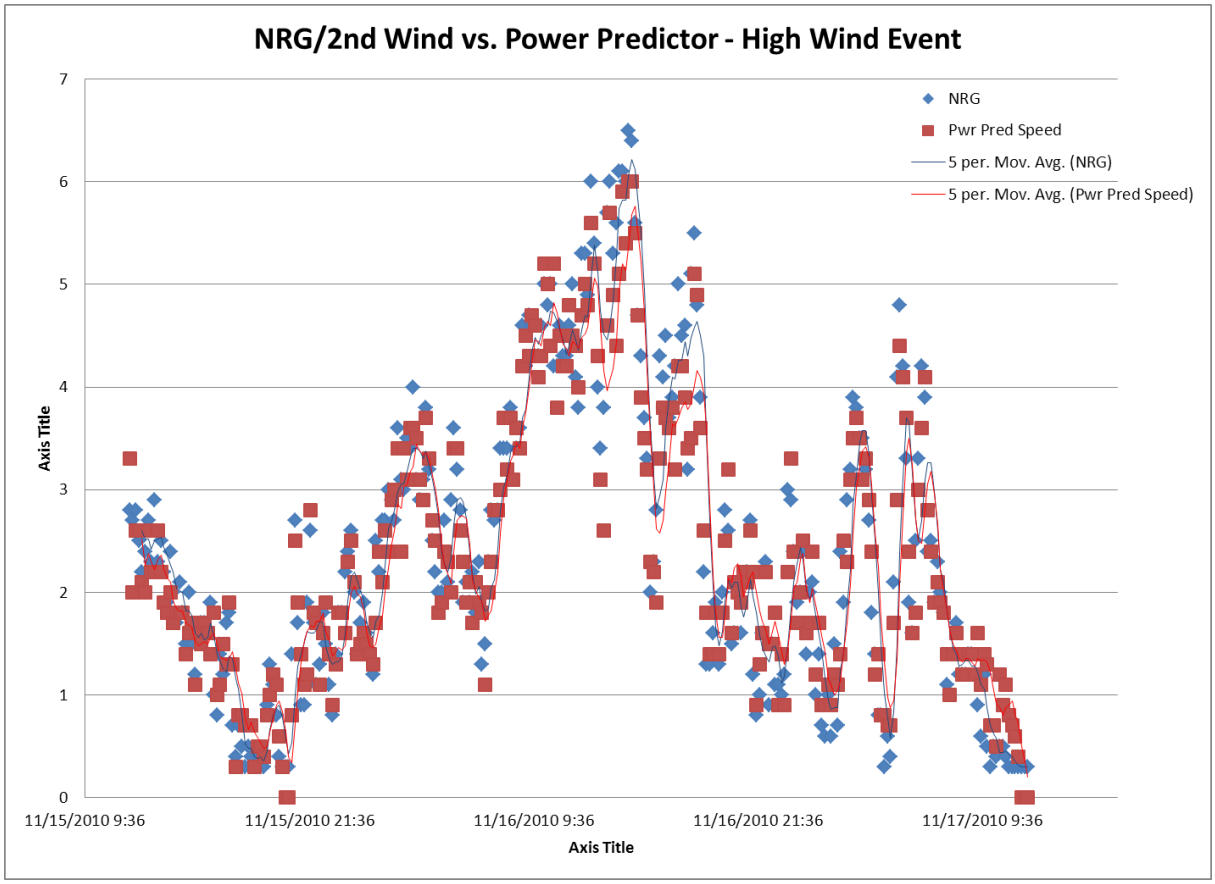

Figure 7 – "High" wind event – AEA warehouse location

Probability plots for the two datasets show the Second Wind anemometer to be consistently higher reading than the Power Predictor. The smoothness of the curves depends on which data column was sorted. (Figures 8 and 9)

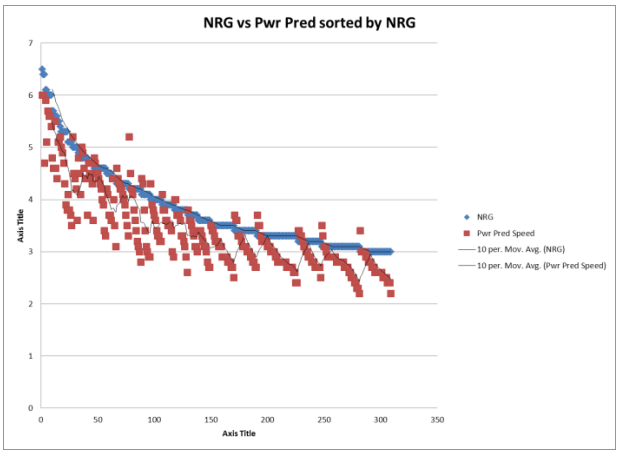

Figure 8 – Prob plot NRG sort

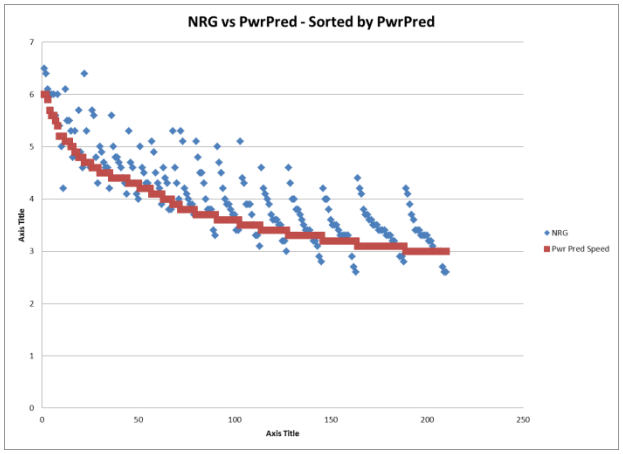

Figure 9 – Prob plot PwrPred sort

To test the theory that the 2”-dia. PVC pipe is blocking some of the wind, radial graphs were printed. The Power Predictor™ has to be mounted on the south side of the pole to provide accurate wind direction values and solar irradiance values. Thus, one would expect a 2” pipe approximately one foot from the anemometer to interfere with wind readings from the north and possibly other directions. A radial graph of average wind speeds by direction show very low readings coming from the north (Figure 10) and possible interaction with winds out of the south due to a pressure increase on the windward side of the PVC pipe.

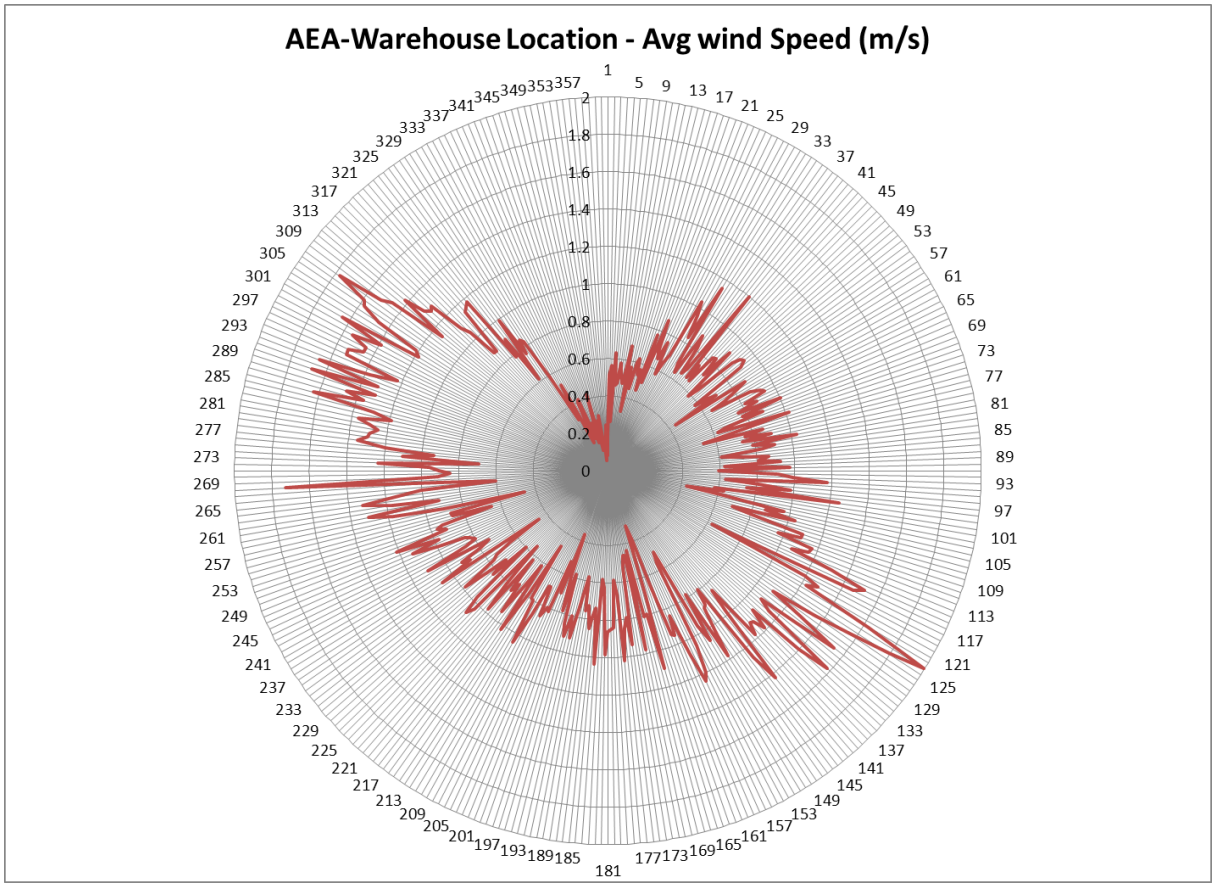

Figure 10 – Radial graph of average wind speed by wind direction – Warehouse site

A similar radial graph, but plotting the maximum observed wind speed for a compass direction exhibits an even stronger effect of lower wind readings coming from the north (pole blocking) and south (pole pressure buildup) sides of the test configuration. (Figure 11)

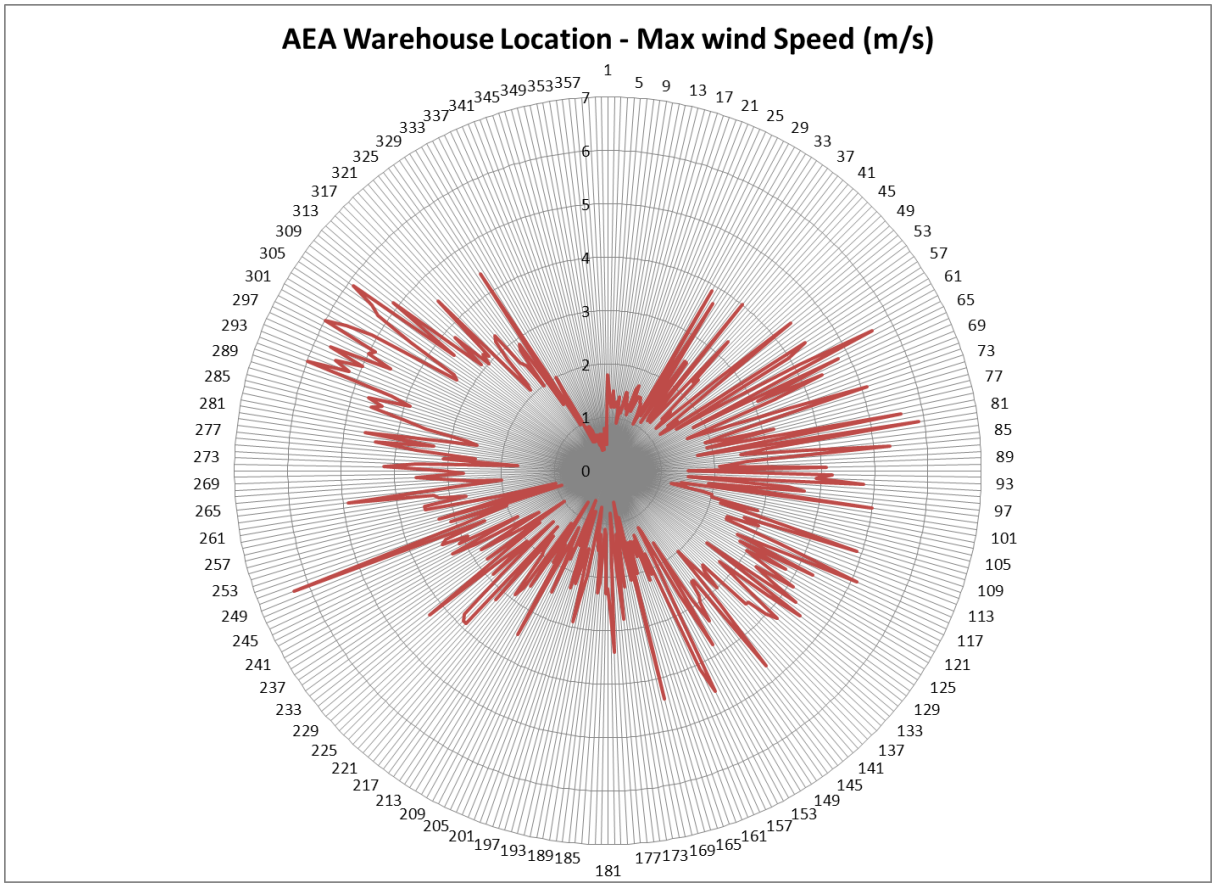

Figure 11 – Radial graph of maximum wind speed by wind direction – Warehouse site

Because no higher wind events were seen at the warehouse site, the test tower was moved to the roof of the Alaska Energy Authority building located at 813 W. Northern Lights Blvd in Anchorage in early December. This new site also allowed for correlation of solar irradiance data since a Li-Cor LI-200SZ pyranometer had been collecting data on the AEA roof since late February 2010.

Results from AEA Main Office Site: After four months, data for the two sensors was compared again. This time there had been four periods where the 10-minute average peaked out around 7.5 meters per second. Due to the placement of the test tower, there was interaction with part of the building roof and the Second Wind/NRG instruments would have been less impacted by the roof than the Power Predictor™. As was seen before, both units track well with high-wind events, but the Power Predictor™ never reads as high for wind speed. (Figure 12)

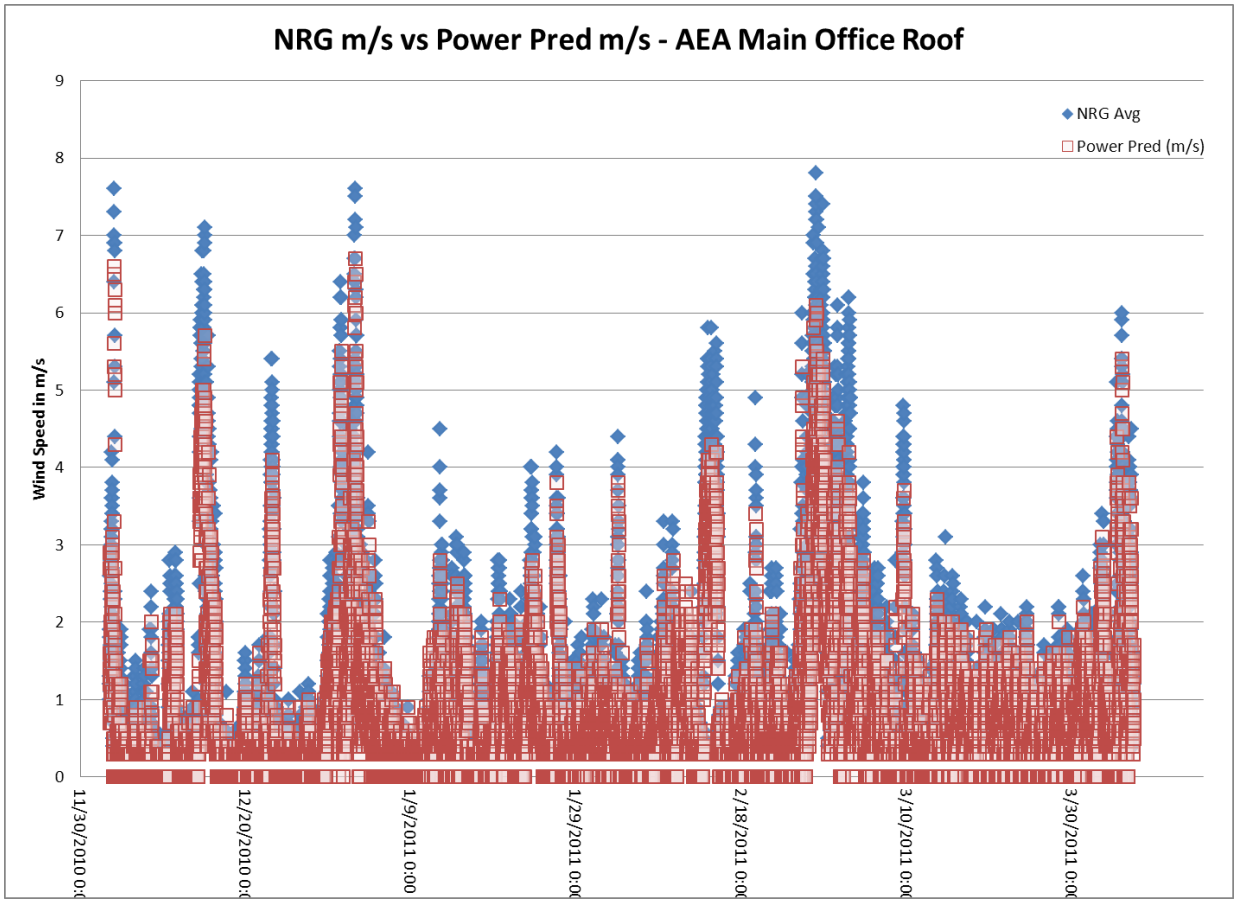

Figure 12 – Trend Chart from AEA Main Office Roof Site

The correlation coefficient (Excel™ CORREL procedure) is 0.9002 for all data pairs and the delta between the average of each data set is .255 meters per second with the Second Wind/NRG configuration having the higher average. Median delta is only .1 meters per second.

As before, probability plots for the two datasets show the Second Wind anemometer to have consistently higher readings than the Power Predictor™. The smoothness of the curves depends on which data column was sorted. (Figure 13) This time, the delta between the two moving-average curves is higher – 1 meter per second of higher. Radial graphs of the average and maximum speeds (Figures 14 and 15) indicate additional shadowing from the nearby roof on the east side of the test configuration. The Power Predictor's lower position on the test pole would make it more susceptible to interference from this sloping roof. After seeing this impact, it is recommended that the AEA office roof site not be used in future studies. If higher wind regimes are needed, the author has a cabin east of Chickaloon with some exposed hills. Data could be collected each weekend. Also, technical reviewer Bruce Wright has property north of Palmer that is being used to test and compare two Power Predictors.

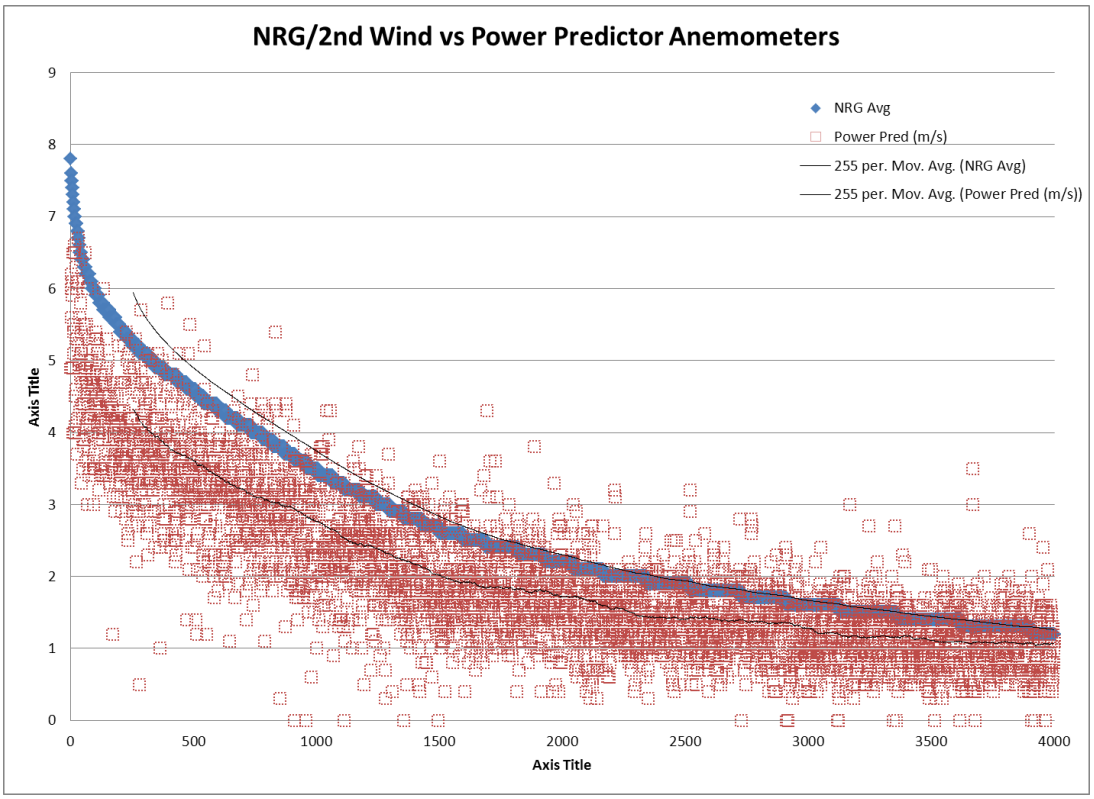

Figure 13 – Probability plot (sorted by NRG value)

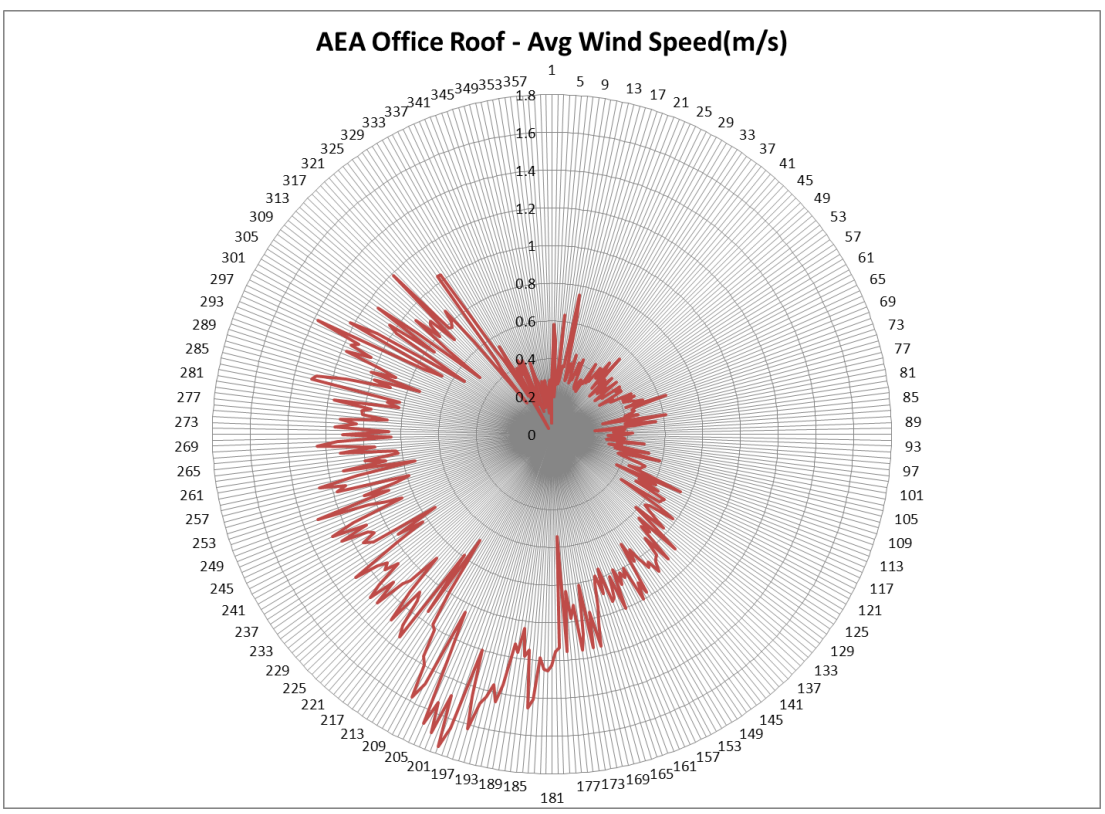

Figure 14 - Radial graph of average wind speed by wind direction – AEA roof site

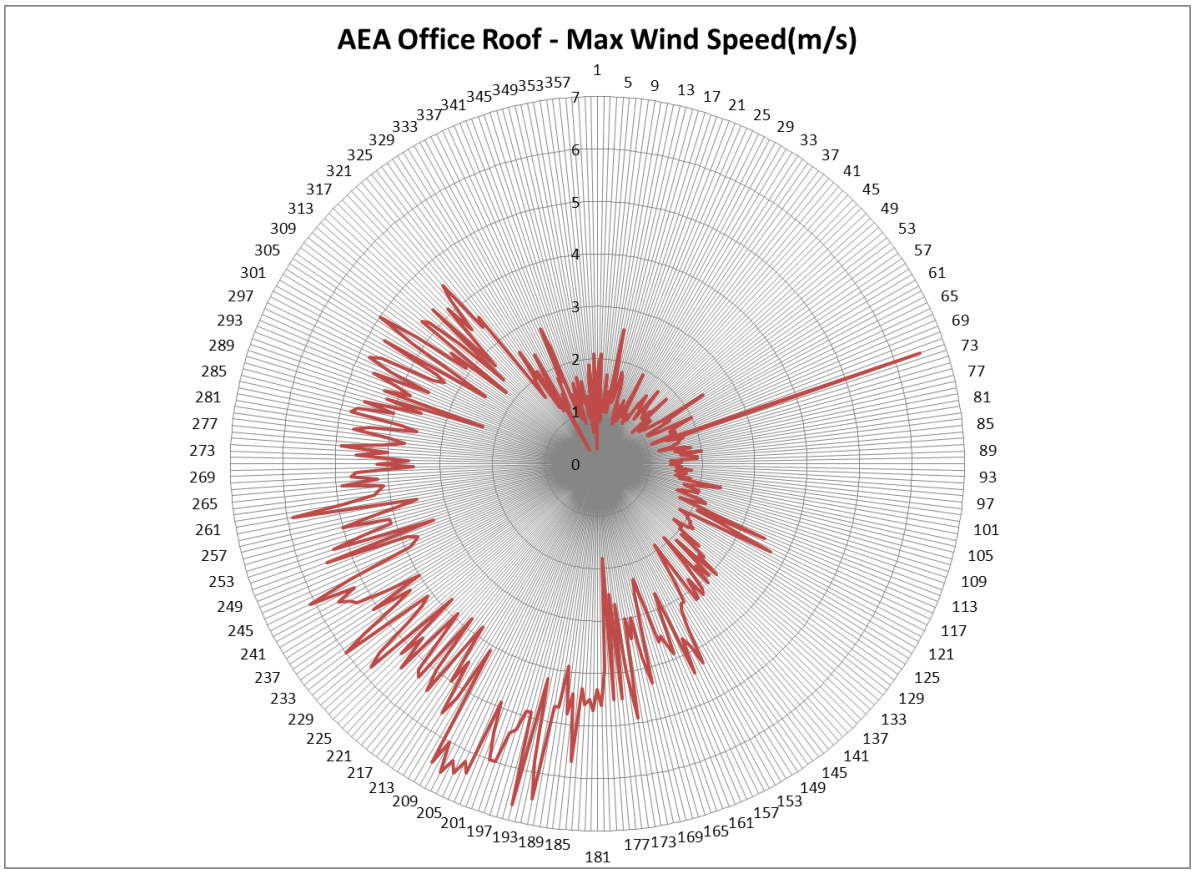

Figure 15 - Radial graph of maximum wind speed by wind direction – AEA roof site

Comparison of solar irradiance sensors: With the test pole moved to the AEA roof, a near side-by-side comparison could be made between the Power Predictor 1.0™ solar sensor which has a vertical, south-facing placement and the LiCor-200 pyranometer that sits at a latitude tilt, south-facing. The Power Predictor 1.0™ sensor was not blocked by any building components or by any part of the test configuration. This pole was anchored within 50 feet of AEA's pyranometer, which has been collecting solar irradiance data since late Feb. 2010.

Detailed specs for the Power Predictor 1.0™ solar sensor are not available. Specs for the Li-Cor LI-200SZ are in Figure 16. This model is one of the standards used by the National Renewable Energy Laboratory to measure solar irradiance.

Product Specifications
Product #: 1948
http://www.nrgsystems.com/sitecore/content/Products/1948.aspx

Date: 5/5/2011

Li-Cor #LI-200SZ Pyranometer

Excellent general purpose solar radiation sensor measuring direct and reflected solar radiation. Compatible with all NRG data loggers: Symphonie*PLUS*, Symphonie, 9300, and 9200 data loggers.

SPECIFICATIONS

Description	
Sensor type	total solar radiation sensor - cosine corrected
Applications	• solar resource assessment • meteorological studies • environmental monitoring
Sensor range	0 W/m^2 to 3000 W/m^2
Instrument compatibility	• NRG Symphonie PLUS w/ Solar SCM • NRG Symphonie w/ Solar SCM • Logger measurement range 0 to 1300 W/m^2, typical
Output signal	
Signal type	microamp current proportional to total solar radiation
Transfer function	• included on calibration certificate • typical is 90 µA per 1000 Watts/m^2
Accuracy	maximum deviation of 1% for sensor range
Calibration	• calibration sheet included with each sensor defines output in microamps per 1000 Watts/square meter • calibrated against Eppley Precision Spectral Pyranometer under natural daylight conditions.
Output signal range	0 µA to 270 µA (typical)
Drift	+/- 2% change over a 1 year period
Response characteristics	
Threshold	0.1 W/m^2
Installation	
Mounting	mounts to tower with custom NRG side mounting boom and hose clamps
Tools required	• sheet metal shears or similar for hose clamps • 5/16 inch hex driver or flat blade screwdriver • 0.05 inch hex key (included); metric #4 allen wrench for level adjustment
Environmental	
Operating temperature range	-40 °C to 65 °C (-40 °F to 149 °F)
Operating humidity range	0 to 100%
Physical	
Connections	2 bare wire leads from coaxial cable
Cable length	3 m (10 feet)
Weight	28 g (1.0 ounces)
Dimensions	• 23.8 mm (0.94 inches) diameter • 25.4 mm (1 inch) length
Materials	
Cable	shielded coaxial
Detector	high-stability silicon photovoltaic
Enclosure	weatherproof anodized aluminum case with acrylic diffuser and stainless steel hardware

Figure 16 – Pyranometer specifications

Results from Power Predictor 1.0 solar sensor are severely inadequate. The trend graph in Figure 17 clearly shows that the Power Predictor™ is binning to discrete values while the Li-Cor 200 outputs continuous data values. The 255-point moving average trend lines appear to move together and the correlation coefficient (Excel™ CORREL procedure) is a surprising .8567. The actual values output from the solar sensor, however, do not allow for any detailed analysis. The average solar irradiance for the study period from 12/3/10 to 4/6/11 is 92.50 watts per square meter for the Li-200 and 60.89 watts per square meter for the Power Predictor 1.0™. The Power Predictor1.0™ is also limited by its fixed vertical mount.

It should be noted that the Power Predictor 2.0™ has incorporated a completely different style of solar sensor – a photovoltaic cell mounted at a near horizontal orientation.

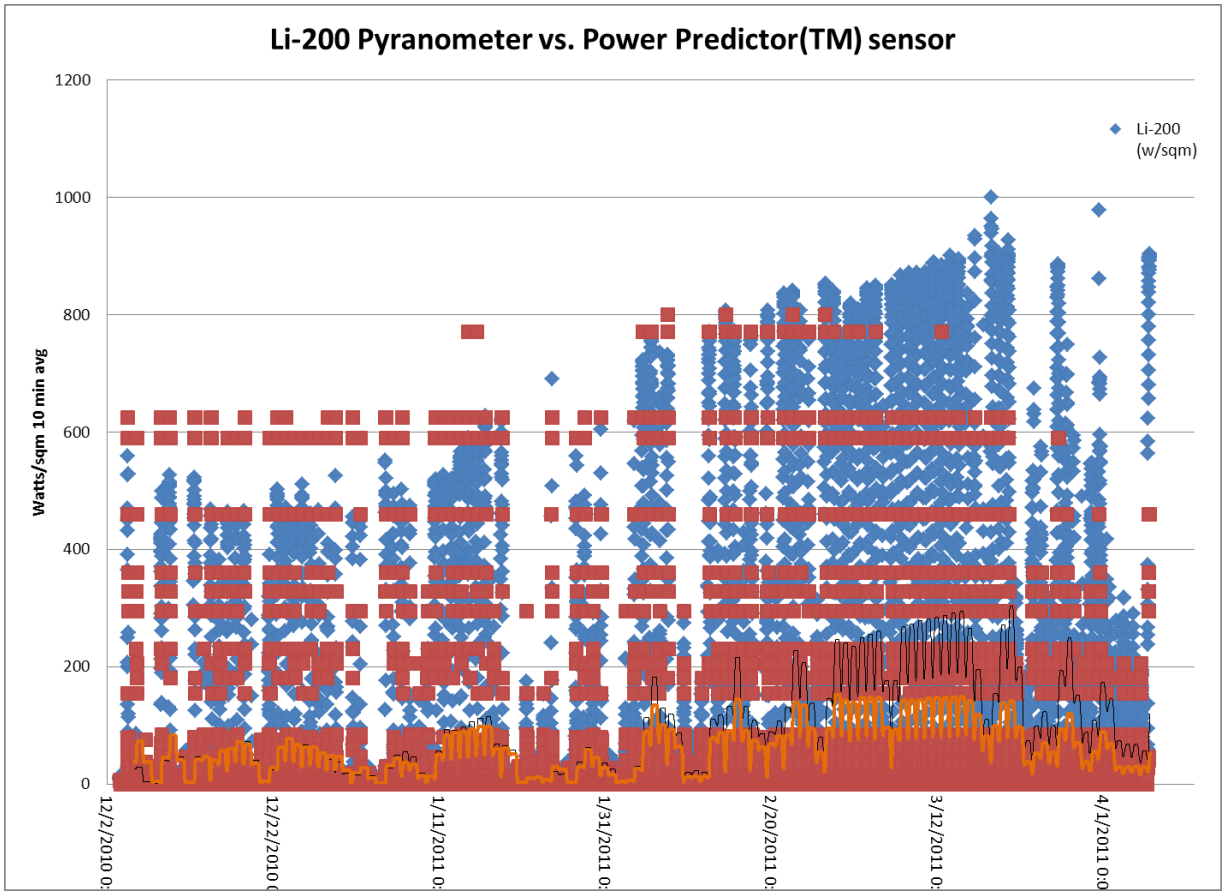

Figure 17 – Pyranometer vs. solar sensor comparison

Conclusions/Recommendations: Data from the evaluation was reviewed by Douglas Vaught, professional engineer with V3 Energy, LLC, Bruce Wright senior scientist with Aleutian Pribilof Islands Association and James Jensen, wind program manager with Alaska Energy Authority. The consensus was that the Power Predictor™ could be used for low-cost reconnaissance work throughout Alaska to identify sites for possible wind energy development. Based on this study, we would assume the Power Predictor™ underestimates the average wind speed by 0.5 meters per second.

Additional wind data collection with a 34-meter NRG Tall Tower™ would be required before any large-scale development were to take place, but the Power Predictor™ data may suffice in locations where small turbines (< 10-kilowatt rated capacity) were to be installed. The Power Predictor™ could also be used in a fleet of as many as five sensors in the vicinity of a proposed wind farm to identify the best location to set up a large meteorological tower for longer-term data collection.

Follow-on studies are recommended to assess the solar photovoltaic sensor in the 2.0 model as well as to compare multiple units side-by-side to verify data consistency from one unit to the next.

In the future, the AEA office roof will only be used to compare solar irradiance sensors. Further wind studies will be conducted at AEA's warehouse site or potential rural locations in the Matanuska Valley.