Predicted Performance of Planned Renewable Energy Systems
At the WCROC Dairy
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Introduction

Grants have been secured to provide wind and solar renewable energy systems in an effort to convert the WCROC dairy parlor into a 'Net Zero' operation generating as much energy as it uses on an annual basis. Specifically, funding has been obtained to procure and install two 10 kW wind turbines, one with 4 kW of solar PV panels mounted to the tower base, and a 50 kW ground-mount solar PV system. This document provides a prediction of the expected electrical generation of the planned systems.

The WCROC dairy milks between 200 and 280 cows twice daily and is representative of a mid-size Minnesota dairy farm. The cows are split almost evenly between conventional and certified organic grazing herds and all cows also spend the winter outside in confinement lots near the milking parlor. The WCROC dairy provides an ideal testing opportunity to evaluate and demonstrate the effect of on-site renewable energy generation and energy efficient upgrades on fossil fuel consumption and greenhouse gas emissions.

Wind Data

A utility-scale Vestas V-82 wind turbine was installed on the WCROC farm site in 2005. Prior to installation, Sustainable Automation LLC was contracted to perform a yearlong wind resource assessment. The contractor constructed a 60 meter meteorological tower with wind data logging equipment in July of 2003 and monitored wind data for one year submitting a final report in January of 2005. All wind data used to predict the output of the planned turbines is taken from this final report.

Average wind speeds at heights other than those directly measured can be found using the following power law for wind shear:

$$\frac{v_{hub}}{v_{meas}} = \left(\frac{Z_{hub}}{Z_{meas}}\right)^{\alpha}$$

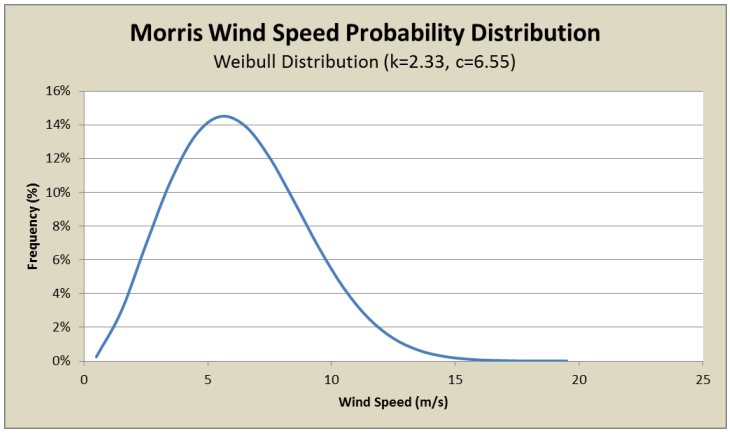
Where:

v_{hub}= Average wind velocity at tower hub height
v_{meas}= Average wind velocity measured at known height
Z_{hub}= Tower hub height
Z_{meas}= Known height of measured wind velocity
α= Power Law exponent

The power law exponent was empirically determined to be 0.244 at the WCROC site and the average wind speed for each month at a 30 meter (98.4') height is shown in the following table along with the calculated value at the proposed hub height of 70 feet.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVE
30 m data (m/s)	6.54	6.07	7.02	6.55	6.63	5.03	4.16	4.73	5.9	5.79	6.43	6.76	5.96
@70'(m/s)	6.02	5.58	6.46	6.03	6.10	4.63	3.83	4.35	5.43	5.33	5.92	6.22	5.48

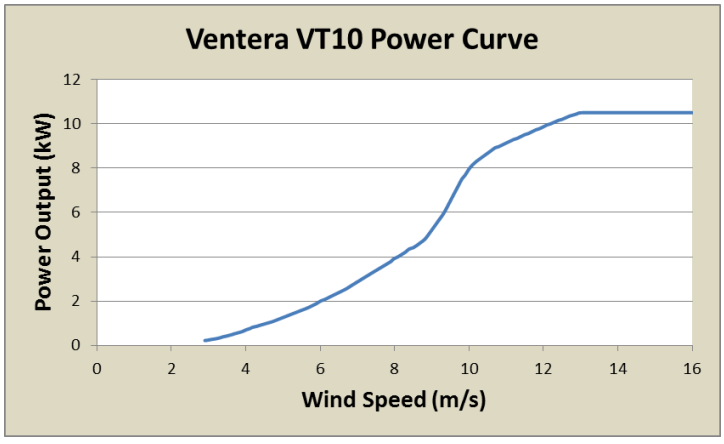
Wind speed distribution is often characterized by a two-parameter Weibull distribution because it has been found to match measured wind data well. The two parameters are a shape factor, k, and a scale factor, c, which were found to be 2.33 and 6.55, respectively. The following chart shows the empirically determined Weibull distribution for the WCROC site. The wind speed distribution curve determines how much time is spent at any given wind speed.



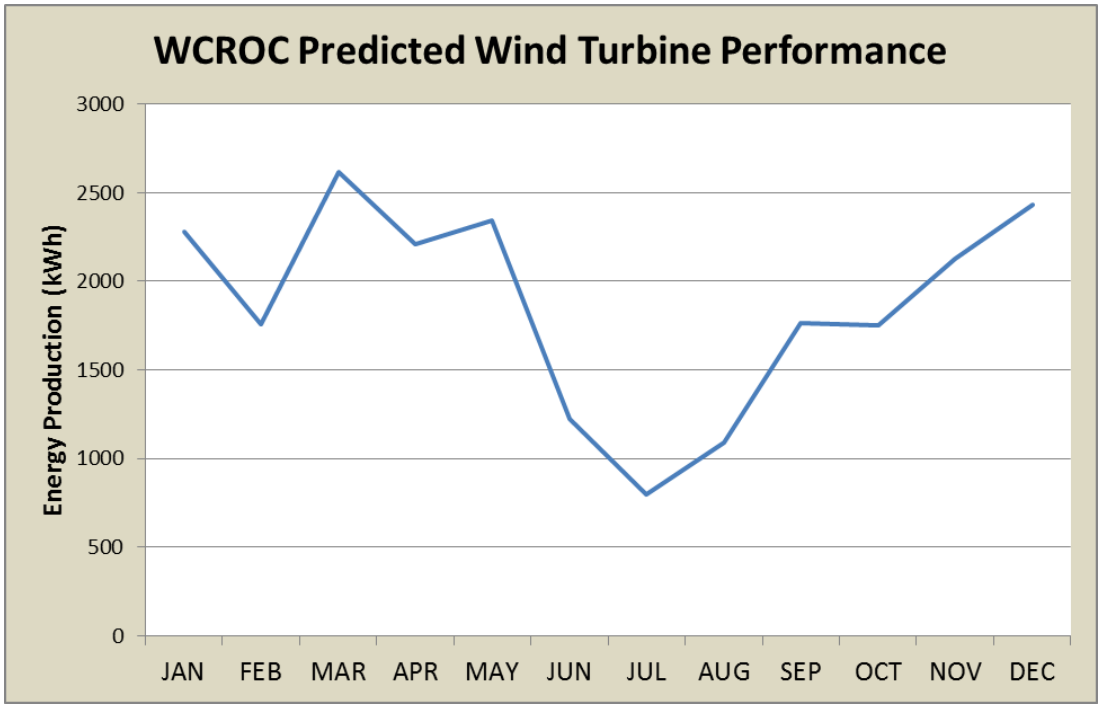
Wind Turbines

The planned wind turbines are model VT10 made by Ventera Wind, Inc. in Duluth, MN. The turbine is a downwind design using an injection molded, 3 blade rotor design 22 feet in diameter. The turbines will be mounted on tilt-down monopole towers, model AFS 1100, made by ARE Telecom & Wind in St. Paul, MN. The tower is 62' tall and sits on an above ground, assembled foundation that will put the turbine hub 70 feet above ground. One of the foundations will also include a specially engineered mount to hold 4 kW of solar PV panels making one of the towers a hybrid wind/solar system.

The following chart shows the VT10 power curve. The power curve indicates how much power is produced for a given wind speed. From the power curve it can be seen that the turbine starts to produce power at a wind speed of about 3 m/s and produces a maximum power of about 10.5 kW at 13 m/s. Due to the turbine design and simple blade governing system, the turbine will continue to produce its maximum power up to its rated survival speed of 130 mph (58 m/s).



Combining the power curve with the wind speed distribution produces a prediction of the expected energy output from the turbine. The following chart shows the predicted energy output of a VT10 turbine with the hub 70 feet above the ground at the WCROC site in Morris, MN. The predicted performance has been reduced by 1% to account for scheduled maintenance as suggested by the manufacturer. The total annual output for one turbine is predicted to be 22,396 kWh.



Solar Photovoltaic (PV)

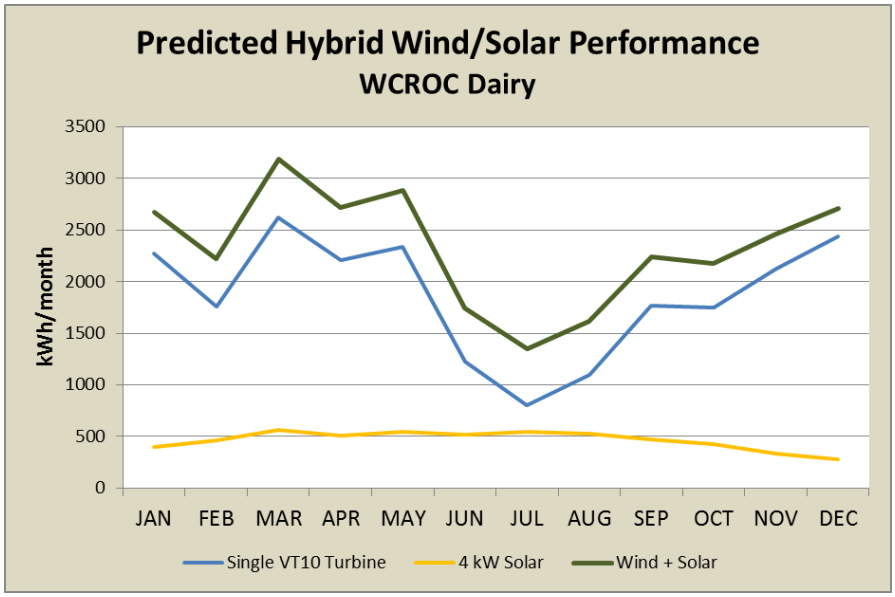
The output from solar PV panels can be reliably predicted using an online tool developed by the National Renewable Energy Labs (NREL) called PVwatts. It is freely available on the NREL web site (http://pvwatts.nrel.gov/pvwatts.php) and only requires the user to enter a location, panel orientation, and DC system size.

The panels mounted to the wind turbine tower (4 kW) will be mounted at 45 degrees facing south and the ground mounted array (50 kW) is a tenKsolar product with a fixed mounting angle of 26 degrees also facing due south.

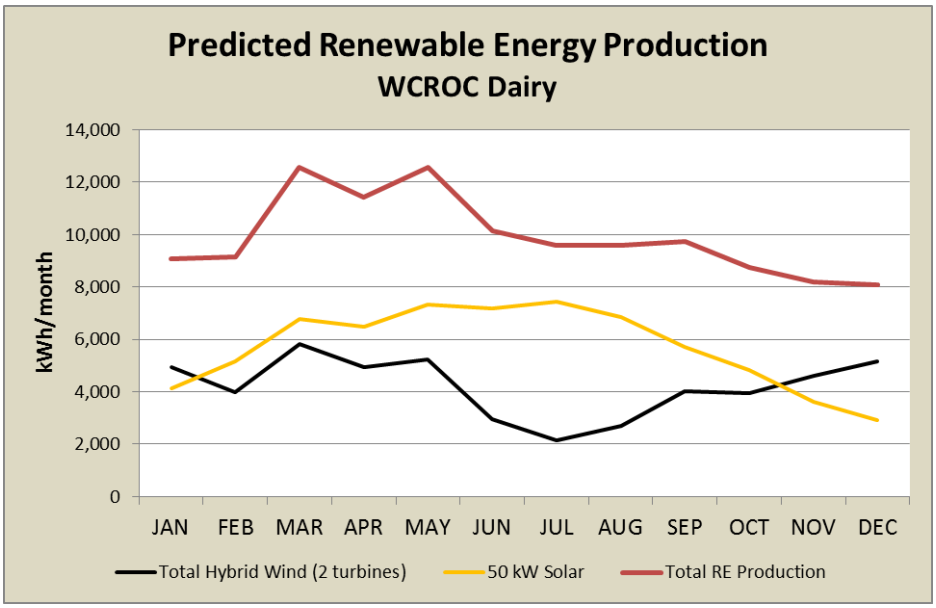
The predicted annual output of the tower mounted array is 5,564 kWh, and for the ground mounted array, 68,441 kWh.

Combined Renewable Energy System Production

The following chart shows the expected monthly production from one of the wind turbines, the tower mounted solar array, and the combined total from the hybrid wind/solar tower.



The following chart shows the expected monthly production from the total hybrid wind system (2 turbines and 4 kW solar), from the ground mounted solar array (50 kW nameplate), and the total combined production from all renewable electric systems for the WCROC dairy. The total annual electricity produced is predicted to be 118,796 kWh.



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