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# Regional Field Verification – Case Study of Small Wind Turbines in the Pacific Northwest

## Preprint

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# Regional Field Verification - Case Study of Small Wind Turbines in the Pacific Northwest[1]

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**Abstract**

The U.S. Department of Energy/National Renewable Energy Laboratory's (DOE/NREL) Regional Field Verification (RFV) project supports industry needs for gaining initial field operation experience with small wind turbines and verify the performance, reliability, maintainability, and cost of small wind turbines in diverse applications. In addition, RFV aims to help expand opportunities for wind energy in new regions of the United States by tailoring projects to meet unique regional requirements and document and communicate the experience from these projects for the benefit of others in the wind power development community and rural utilities.

Under RFV, six Bergey 10-kW wind turbines were installed at a number of sites in the Pacific Northwest. Each installation was instrumented with Data Acquisition Systems to collect a minimum of two years of operating data. In addition, a detailed understanding of the turbine system and balance of system (BOS) costs will be calculated for each site.

Between August 2003 and August 2004, six turbines were installed at different host sites. At least one year of data has been collected from five of these sites. This paper describes DOE/NREL's RFV project, reviews some of the lessons learned with regards to small wind turbine installations, summarizes operations data from these sites, and provides preliminary BOS costs.

**Purpose**

The purpose of this paper is to provide lessons learned from installing small wind turbines in the Pacific Northwest (PNW) and detailed operation and cost information collected from small wind turbines installed in one region. Lessons learned in the PNW could be helpful in improving the penetration of small wind turbines in other U.S. regions.

This paper will 1) highlight the importance of site selection for small wind turbines by comparing and contrasting operational characteristics from 6 sites, 2) summarize the range of issues encountered during the site permitting process for small wind turbines, and 3) provide preliminary cost information for a number of different site installations. Because of the preliminary nature of these data, no conclusions will be drawn in this paper regarding these small wind turbine systems.

**Regional Field Verification**

In 2000, U.S. Department of Energy/National Renewable Energy Laboratory's (DOE/NREL) issued a Regional Field Verification (RFV) project Request for Proposal (RFP). The purpose of the RFP was to solicit projects that would support industry needs for gaining initial field operation experience with small

[1] Information taken from reports provided to NREL from NWSEED.

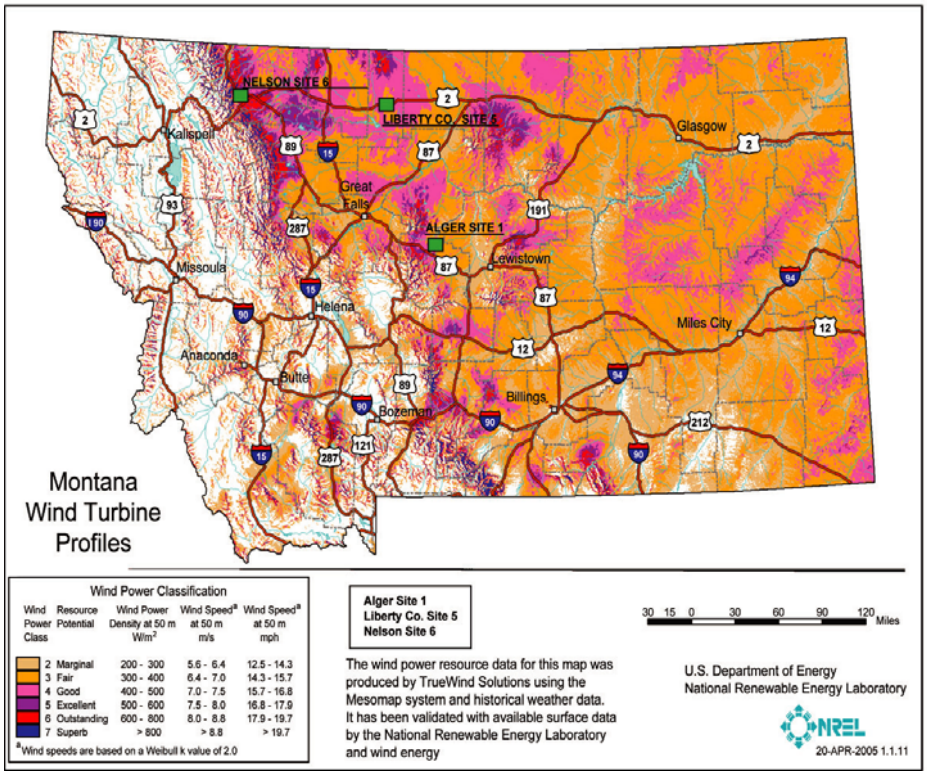
wind turbines and verify the performance, reliability, maintainability, and cost of small wind turbines in diverse applications. The RFV project was also envisioned as a way to help expand opportunities for wind energy in new regions of the United States by tailoring projects to meet unique regional requirements and document and communicate the experience from these projects for the benefit of others in the wind power development community and rural utilities.

Of the proposals submitted in response to the RFP, NREL ultimately executed a subcontract with Northwest Cooperative Development Center (NWCDC). Under this subcontract, Bergey 10-kW wind turbines would be installed at a number of sites in the Pacific Northwest (PNW). Each installation was to be instrumented with Data Acquisition Systems (DAS) to collect a minimum of two years of operating data. In addition, a detailed understanding of the turbine system and balance of system (BOS) costs was to be calculated for each site.

Northwest Sustainable Energy for Economic Development (NWSEED), a lower-tiered subcontractor for NWCDC, is responsible for the actual project installations and data collection/analysis. NWSEED has expanded this project, known as Our Wind Cooperative (OWC), partnering with numerous other organizations including Bonneville Environmental Foundation (BEF), Last Mile Electric Cooperative (LMEC), United States Department of Agriculture (USDA), Bullitt Foundation, Climate Solutions, Renewable Northwest Project, host utilities, and others to assist with lowering the project cost to hosts and supporting outreach activities. For information on OWC, go to http://ourwind.org/windcoop/

**Host Sites**

All six systems ultimately installed under the RFV subcontract have a Bergey XL 10 wind turbine that is connected to the utility grid. They are located in Montana and Washington, as shown in Figure 1. The turbines were commissioned between October 2003 and October 2004 (Table 1). Because of the involvement of the Federal Government in this project, a National Environmental Policy Act (NEPA) determination from DOE was required. Ultimately, DOE determined that a categorical exclusion B5.1 applied to each site.



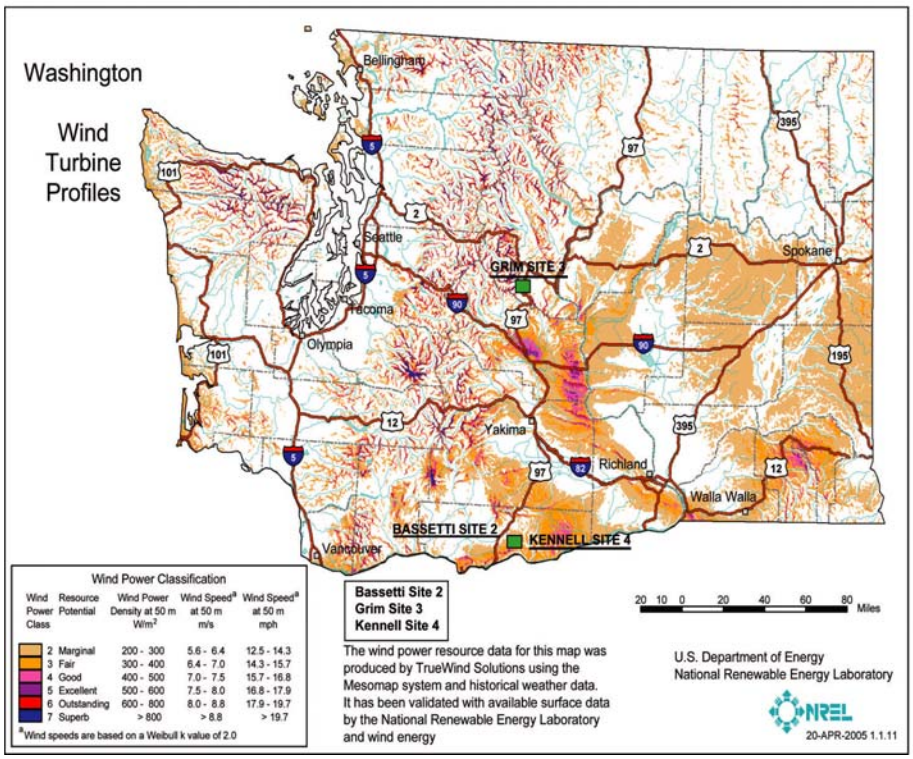




Figure 1. Location of six RFV host sites (MT and WA maps).

Table 1. RFV Host Sites – Location and Commissioning Dates

| | Host | Location | Lat/Long | Elevation | Tower Type | Assumed Wind Class | Commission Date |
|---|---|---|---|---|---|---|---|
| 1 | Alger, Jess | Stanford, MT | 47.265/ -110.234 | 1219m | 100-ft guyed | 3 | 10/2/2004 |
| 2 | Bassetti, Gwen & Fred | Goldendale, WA | 45.83/ -120.65 | 632 m | 120-ft guyed | 3 | 10/30/2004 |
| 3 | Grim, Don & Bev | Peshastin, WA | 47.547/ -120.639 | 610 m | 100-ft latticed free standing | 2 | 10/7/2003 |
| 4 | Kennell, Ed | Goldendale, WA | 45.82/ -120.628 | 670 m | 80-ft guyed | 3 | 12/29/2003 |
| 5 | Marble, Don (Liberty County Commissioner) | Chester, MT | 48.51/ -110.995 | 969 m | 80-ft tilt up | 3 | 2/24/2004 |
| 6 | Nelson, Doug | Browning, MT | 48.55/ -113.197 | 1474 m | 60-ft guyed | 5 | 2/24/2004 |

Source: NWSEED

## 1. Alger (Stanford, Montana)

With a concern for the environment and an interest in self-sufficiency, Jess Alger installed a wind turbine on his 1200-acre cattle ranch and wheat farm (Figure 2) in Stanford, Montana, in September 2003. Located in Judith Basin County, no building or land use permits were required. Alger did most of the site preparation and some of the installation himself, significantly reducing the overall cost of the project. Alger's system has one of the lowest cost of all the systems installed under RFV (Table 11). A certified Bergey dealer was hired to assist with some of the wiring and turbine installation.

The turbine was commissioned on October 2, 2004. It initially experienced some inverter faults but has consistently produced energy for Alger. Mounted on a 100-ft guyed tower, wind speeds have averaged 13 mph, measured at 80 feet. Over an eighteen-month period, Alger's turbine has produced over 17,000 kWh, averaging over 950 kWh/month (Table 2).

Technical Issues

- Anemometer did not function for first 2.5 months of data gathering
- Data card was damaged in March 2004; only partial data recovered
- Logger accidentally reset when host was replacing logger batteries in August 2004. Averaging rate was set to hourly instead of 10 minutes. Issue resolved in October when Term Reader was sent to host.

Figure 2: Turbine installed at Alger ranch in Stanford, MT. Source: NWSEED

Table 2. Alger Site Production

| | Stanford, MT (Alger) | | |
|---|---|---|---|
| | Wind Speed (mph) | Monthly Energy (kWh) | Cum. Energy (kWh) |
| October, 2003 | | 1154.0 | 1154.0 |
| November, 2003 | | 876.0 | 2030.0 |
| December, 2003 | 12.9 | 1006.0 | 3036.0 |
| January, 2004 | 13.8 | 1206.0 | 4242.0 |
| February, 2004 | 11.6 | 728.0 | 4970.0 |
| March, 2004 | 16 | 1383.0 | 6353.0 |
| April, 2004 | 12.3 | 761.0 | 7114.0 |
| May, 2004 | 11.6 | 1018.0 | 8132.0 |
| June, 2004 | 12.5 | 901.0 | 9033.0 |
| July, 2004 | 11.2 | 490.0 | 9523.0 |
| August, 2004 | 11.3 | 550.0 | 10073.0 |
| September, 2004 | 11.7 | 550.0 | 10623.0 |
| October, 2004 | 11.9 | 710.0 | 11333.0 |
| November, 2004 | 13.9 | 1178.0 | 12511.0 |
| December, 2004 | 17.1 | 1518.0 | 14029.0 |
| January, 2005 | 14.2 | 1000.0 | 15029.0 |
| February, 2005 | 12.4 | 861.8 | 15890.8 |
| March, 2005 | 14.9 | 1465.1 | 17355.9 |
| Average | 13.1 | 964.2 | |

Source: NWSEED

## 2. Bassetti (Goldendale, Washington)

Seeing their neighbor's (Kennell) wind turbine go up inspired the Bassetti's to install their own turbine to support residential electric load requirements and offset their electricity costs on their ranch in Klickitat County, Washington. Mounted on a 120-ft guyed tower (Figures 3 – 6), the Bassetti turbine is the last turbine installed under NREL's RFV project. Installed in September 2004, the turbine generated an

average of 731 kWh per month during the first seven months of operation (Table 3) from winds that average 9 mph measured at 100 feet.

The Klickitat County Planning Department required a Conditional Use Permit. A Washington State Environmental Policy Act checklist was also submitted. Although no building permit was required by the Klickitat County Building Department, an electrical work permit was required and obtained from the State of Washington Department of Labor & Industries.

Technical Issues

- Inverter cut-outs caused by extra output from new turbine blades

Figure 3: Bergey turbine being installed at Bassetti site. Source: NWSEED

Figure 4: Turbine installed in field behind Bassetti ranch. Source: NWSEED

Figure 5: Bassetti ranch with turbine in background. Source: NWSEED

Figure 6: Turbine in background behind Bassetti residence. Source: NWSEED

Table 3: Bassetti site production

| | Goldendale, WA (Bassetti) | | |
|---|---|---|---|
| | Wind Speed (mph) | Monthly Energy (kWh) | Cum. Energy (kWh) |
| September, 2004 | 9.9 | 1137 | 1137 |
| October, 2004 | 9.7 | 1079 | 2216 |
| November, 2004 | 7.1 | 590 | 2806 |
| December, 2004 | 6.8 | 250 | 3056 |
| January, 2005 | | 572 | 3628 |
| February, 2005 | | 357 | 3985 |
| March, 2005 | 11.5 | 1129 | 5114* |
| Average | 9 | 730.6 | |

* 3/1 - 3/8 based on estimate from Kennell data
Source: NWSEED

## 3. Grim (Peshatin, Washington)

With a site situated on the top of a hill, surrounded by trees, Don and Beverly Grim were the first to install a turbine as part of NREL's RFV project. Interested in reducing their dependence on their local utility and in installing renewable energy technology to meet their electric needs, the Grim's began talking to a local solar/wind dealer. Based on conditions observed during a few visits to the site and tree flagging, the dealer recommended a small wind turbine to meet their needs.

The Grim's went through the local permitting process, which required a conditional use permit from the Chelan County Planning Department, a building permit and electrical work permit from the State of Washington Department of Labor and Industries. The hosts were also required to paint the tower and turbine green to help it blend in to the surrounding landscape (Figure 8).

With the help of Randy Brooks of Brooks Solar, the turbine was mounted on a 100-ft latticed freestanding tower. It was installed in May 2003 (Figure 7) and commissioned in October 2003. The DAS was installed in July 2003.

A faulty inverter caused problems early on. The default parameters of the inverter caused it to go into standby mode if the wind dropped below cut-out speed for more than 10 seconds. Once the wind reached a speed above the cut-in speed, the inverter would start a two-minute countdown before going into active mode. NWSEED believes this situation resulted in the loss of power production on this low-wind, gusty site. The unloaded turbine was very noisy during this period.

Bergey Windpower provided new software, changing the cut-out time to prevent the inverter from going into standby mode so quickly. The inverter now waits 10 minutes before going into standby mode. This means that in the presence of gusty winds, all of the energy will be captured and that the turbine will be much quieter because it is under load most of the time.

The lack of wind has rendered the turbine minimally operable, producing 732kWh from November 2003 – August 2004 (Table 4). The cell phone service used to transmit data to NWSEED also failed. Because NREL dropped this poorly performing wind site from its project, cell service has not been continued and data is not being reported to NWSEED (Table 2, September 2004 – March 2005).

Technical Issues

- Inverter faults
- Lack of wind
- Failure of cell phone service

Figure 7: Foundation pad for Grim site.
Source: NWSEED

Table 4: Grim Site Production

| | Peshastin, WA (Grim) | | |
|---|---|---|---|
| | Wind Speed (mph) | Monthly Energy (kWh) | Cum. Energy (kWh) |
| May, 2003 | | | |
| June, 2003 | | 40* | 40 |
| July, 2003 | 6.5 | 40* | 80 |
| August, 2003 | 6.0 | 40* | 119 |
| September, 2003 | 4.4 | 40* | 159 |
| October, 2003 | 3.5 | 40* | 199 |
| November, 2003 | 2.5 | 40* | 239 |
| December, 2003 | 1.7 | 40* | 279 |
| January, 2004 | 1.6 | 13 | 292 |
| February, 2004 | 1.8 | 0 | 292 |
| March, 2004 | 4.1 | 75 | 367 |
| April, 2004 | 5.0 | 62 | 429 |
| May, 2004 | 5.6 | 70 | 500 |
| June, 2004 | 5.6 | 59 | 558 |
| July, 2004 | 6.5 | 123 | 681 |
| August, 2004 | 5.9 | 51 | 732 |
| September, 2004 | | | |
| October, 2004 | | | |
| November, 2004 | | | 1118 |
| December, 2004 | | | |
| January, 2005 | | | |
| February, 2005 | | | |
| March, 2005 | | | |
| Average | 4.3 | 49.4 | |

* DAS was offline, therefore this is average estimated production

Source: NWSEED

Figure 8: Painted green, Grim's tower/turbine blends in with surrounding trees.
Source: NWSEED

4. Kennell (Goldendale, Washington)

Ed Kennell has been involved with the small wind industry for over 30 years. Purchasing property in Klickitat County, Washington, Kennell planned to build his retirement home and integrate the use of renewable energy technology into the design. The Conditional Use Permit (CUP), issued by Klickitat County Planning Department, required that Kennell install security measures, including fencing the entire property and bird flight diverters on the guy wires.

Kennell also obtained a Building Permit and an Electrical Permit from the State of Washington Department of Labor & Industries. Although his home has not yet been built, the turbine was installed in November 2003 and commissioned in August 2004 (Figure 9). Energy from the turbine, mounted on an 80-ft guyed tower, is currently fed into the local utility grid.

Averaging more than 1000 kWh/month during the first 16 months of operation, which included a period where the system was off line because of a fault (Dec 2004 – Jan 2005), the Kennell site has produced over 16,000 kWh from average wind speeds of 12 mph, measured at 60 feet (Table 5).

Technical Issues

- Fencing entire property was required for CUP
- Bird flight diverters were required on guy wires
- Improper switching of data card resulted in loss of data in February 2004
- Anemometer stopped working in March 2004

Figure 9: Turbine at undeveloped Kennell site.
Source: NWSEED

Table 5: Kennell Site Production

| | Goldendale, WA (Kennell) | | |
|---|---|---|---|
| | Wind Speed (mph) | Monthly Energy (kWh) | Cum. Energy (kWh) |
| December, 2003 | 6.0 | 1796.0 | 1796.0 |
| January, 2004 | 7.0 | 485.0 | 2281.0 |
| February, 2004 | 12.3 | 1133.5 | 3414.5 |
| March, 2004 | 17.6 | 1133.5 | 4548.0 |
| April, 2004 | 13.8 | 1045.0 | 5593.0 |
| May, 2004 | 16.6 | 1668.0 | 7261.0 |
| June, 2004 | 15.9 | 1551.6 | 8812.6 |
| July, 2004 | 16.1 | 1463.0 | 10275.6 |
| August, 2004 | 15.3 | 1275.0 | 11550.6 |
| September, 2004 | 15.2 | 1320.0 | 12870.6 |
| October, 2004 | 12.7 | 942.0 | 13812.6 |
| November, 2004 | 9.8 | 613.0 | 14425.6 |
| December, 2004 | 8.0 | 250.0 | 14675.6 |
| January, 2005 | 9.4 | 168.0 | 14843.6 |
| February, 2005 | 9.2 | 494.4 | 15338.0 |
| March, 2005 | 13.7 | 1191.3 | 16529.3 |
| Average | 12.4 | 1033.1 | |

Source: NWSEED

## 5. Don Marble, Liberty County Commissioner (Chester, Montana)

Viewed as an opportunity to reduce operating costs for the county's maintenance building, Don Marble, as one of Liberty County's Commissioners, spearheaded the installation of a small wind turbine under the RFV project. The county required no building or land use permit.

Employees from Liberty County maintenance and Independent Power Systems, a certified Bergey dealer, installed the turbine. Using an 80-ft tilt-up tower, installation of the Bergey turbine was completed in December 2003, and the turbine began operating on January 8, 2004 (Figure 10).

The turbine system experienced a faulty fan in the inverter (subsequently replaced). The system shut down after continuous periods of operation because the fan was not cooling the inverter.

Averaging 10.1mph, measured at 60 feet, the site has produced over 9000 kWh over a 15-month period, producing an average of 617 kWh/month (Table 6).

Technical Issues
Faulty fan in inverter

Table 6: Liberty County Site Production

| | Liberty County, MT (Marble) | | |
|---|---|---|---|
| | Wind Speed (mph) | Monthly Energy (kWh) | Cum. Energy (kWh) |
| January, 2004 | 8.0 | 277.5 | 277.5 |
| February, 2004 | 6.8 | 328.0 | 605.5 |
| March, 2004 | 13.5 | 1107.5 | 1713.0 |
| April, 2004 | 11.2 | 680.0 | 2393.0 |
| May, 2004 | 12.6 | 960.8 | 3353.8 |
| June, 2004 | 10.7 | 666.0 | 4019.8 |
| July, 2004 | 10.6 | 577.0 | 4596.8 |
| August, 2004 | 9.4 | 437.0 | 5033.8 |
| September, 2004 | 9.1 | 397.0 | 5430.8 |
| October, 2004 | 8.7 | 419.0 | 5849.8 |
| November, 2004 | 10.0 | 662.2 | 6512.0 |
| December, 2004 | 11.0 | 846.9 | 7358.9 |
| January, 2005 | 7.6 | 439.0 | 7797.9 |
| February, 2005 | 9.8 | 502.0 | 8299.9 |
| March, 2005 | 11.8 | 951.0 | 9250.9 |
| Average | 10.1 | 616.7 | |

Source: NWSEED

Figure 10. Liberty County site; turbine production used in county maintenance building
Source:NWSEED

6. Doug Nelson (Browning, Montana)

Looking to the future when long-term purchase contracts expire, Doug Nelson wanted to position himself to control the cost of his electricity. Located on the Blackfeet Reservation in Glacier County, Montana, Nelson's Mad Wolf Ranch uses a lot of electricity. By installing a wind turbine, he will be able to control those costs.

Glacier County did not require either a building or land use permit. The ranch is subject to the Blackfeet Nation laws and regulations; the tribe did not oppose the project. Nelson was required to obtain a Business License from the Blackfeet Tribe to participate in the NWSEED OWC program.

Mounting his turbine on a 60-ft guyed two-tier tower (Figure 11), the turbine was initially installed October 7-9, 2003. When a severe storm came through on October 17, one of the guy wires dislodged causing the tower to fall and the turbine was damaged. It was determined that the guy wires had not been completely tensioned and the safety cables had not been installed. The turbine was shipped back to Bergey Windpower for a complete refurbishment, which occurred during Dec 2003 – Jan 2004. The turbine was reinstalled February 20, 2004. Because Nelson had included the turbine under his homeowner's insurance policy, the cost of the refurbishment (almost $9,000) was covered.

Nelson's site experienced wind speeds that averaged 12.6 mph measured at 40 feet over a 13-month period. Producing almost 9000 kWh during this period, the turbine generation has averaged 689 kWh/month (Table 7). Although Nelson expected greater production based on his site's wind resources, NWSEED suggests the underproduction may be due to inverter software using an outdated RPM cut-out

setting and that the turbine is not furling properly. According to NWSEED, these two issues cause "…the RPMs of the turbine to max out the inverter at high wind speeds causing a series of faults which shut down the inverter in such a way that a manual reset is required to restart the system."[2]

Technical Issues

- Tower failure due to incomplete initial installation
- Underproduction of generation
- Furling issue

Figure 11: Doug Nelson with turbine at ranch
Source: NWSEED

[2] Source: NWSEED (3rd Quarter Data Report)

Table 7: Nelson Site Production

| | Browning, MT (Nelson) | | |
|---|---|---|---|
| | Wind Speed (mph) | Monthly Energy (kWh) | Cum. Energy (kWh) |
| March, 2004 | 14.3 | 738.6 | 738.6 |
| April, 2004 | 9.7 | 419.0 | 1157.6 |
| May, 2004 | 11.3 | 650.8 | 1808.4 |
| June, 2004 | 9.4 | 356.0 | 2164.4 |
| July, 2004 | 9.7 | 431.0 | 2595.4 |
| August, 2004 | 8.5 | 310.0 | 2905.4 |
| September, 2004 | 11.8 | 696.0 | 3601.4 |
| October, 2004 | 12.1 | 868.0 | 4469.4 |
| November, 2004 | 16.9 | 1253.0 | 5722.4 |
| December, 2004 | 17.8 | 657.0 | 6379.4 |
| January, 2005 | 14.1 | 920.0 | 7299.4 |
| February, 2005 | 13.1 | 631.0 | 7930.4 |
| March, 2005 | 14.5 | 1030.0 | 8960.4 |
| Average | 12.6 | 689.3 | |

Source: NWSEED

**System Costs**

In addition to collecting operational data, another objective of the RFV project is to understand the overall costs of installing small wind turbine systems. Overall system costs are comprised of two major categories - hardware (turbine/tower) costs and BOS costs. BOS costs comprise 3 major areas: 1) permitting/fees; 2) site preparation; and, 3) miscellaneous.

The majority of the variability of overall system costs occurs in BOS. For our six sites, the permitting/fees category varied from no costs (Chester, Liberty County, MT) to approximately 2,000 (Peshastin, Chelan County, WA). Table 8 summarizes the actual permitting/fee costs incurred at each site.

Table 8: Regional Field Verification BOS Costs – Permitting and Fees

| Host Sites | **Alger** | **Bassetti** | **Grim** | **Kennell** | **Marble** | **Nelson** |
|---|---|---|---|---|---|---|
| Location | Stanford, MT | Goldendale, WA | Peshastin, WA | Goldendale, WA | Chester, MT | Browning, MT |
| County | | | $110.00 | | | |
| Building | | | $654.50 | $115.88 | | |
| CUP | | $475.00 | $300.00 | $475.00 | | |
| SEPA | | | $180.00 | | | |
| Geologist review | | | $650.00 | | | |
| Electrical permit | $45.00 | | | $76.30 | | |
| Plan Review Fee | | | | | | |
| Business License | | | | | | $50.00 |
| Utility (meter inspection) | | | $74.30 | | | |
| Total | **$45.00** | **$475.00** | **$1,894.50** | **$667.18** | **$0.00** | **$50.00** |
| Legal (pro bono) | | | $387.50 | | | |

Source: NWSEED

Costs related to site preparation comprise the majority of the BOS costs. Site preparation includes activities such as excavating, trenching, foundation, wiring and erection-related materials and labor. Across the six RFV host sites, site preparation costs ranged between $5,900 (Bassetti) and $18,100 (Grim). Table 9 summarizes the site preparation costs experienced by each host.

Table 9: Regional Field Verification Balance of System Costs – Site Preparation Costs

| Host Sites | **Alger** | **Bassetti** | **Grim** | **Kennell** | **Marble** | **Nelson** |
|---|---|---|---|---|---|---|
| Location | Stanford, MT | Goldendale, WA | Peshastin, WA | Goldendale, WA | Chester, MT | Browning, MT |
| Site Preparation | | | | | | |
| Grading/Backfill | | | | **$510.00** | **$171.00** | |
| Trencher rental | | | **$129.60** | **$642.00** | | |
| Trenching, backhoe, & pipe installation labor | **$333.00** | | **$986.36** | | **$983.08** | |
| Excavating | | | | **$1,620.00** | | |
| Conduit | | | **$787.00** | | | |
| Concrete for foundation | **$595.50** | **$401.98** | **$4,147.20** | **$612.50** | **$1,380.00** | **$500.00** |
| Rebar | **$56.25** | **$82.85** | | **$25.98** | **116.15** | **119.06** |
| Misc foundation materials | | | | | **417.68** | |
| Erection | | | | | | |
| Crews/Crane, contractors | **$875.00** | **$642.00** | **$4,353.00** | | **$4,432.43** | **$1,050.00** |
| Electrical | | | | | | |
| Materials (wire, conduit,etc) | **$1,563.50** | | **$1,350.00** | **$266.12** | **$340.79** | **$858.62** |
| Hook up/inverter | | **$3,980.00** | | **$3,425.52** | | **$1,350.00** |
| Contractor Labor | **$3,405.00** | **$800.00** | **$5,460.00** | **$260.00** | **$5,000.00** | **$4,500.00** |
| Contractor's Travel Time | | | **$885.00** | | | |
| Total Site Preparation | **$6,828.25** | **$5,906.83** | **$18,098.16** | **$7,362.12** | **$12,841.13** | **$8,377.68** |

Source: NWSEED

Miscellaneous costs related to turbine installation ranged from the requirement to install bird flight diverters on guy wires (Bassetti and Kennell) to a requirement to install a fence around the turbine (Kennell and Marble). Table 10 summarizes miscellaneous expenses.

Table 10: Regional Field Verification BOS Costs – Miscellaneous Costs

| Host Sites | **Alger** | **Bassetti** | **Grim** | **Kennell** | **Marble** | **Nelson** |
|---|---|---|---|---|---|---|
| Location | Stanford, MT | Goldendale, WA | Peshastin, WA | Goldendale, WA | Chester, MT | Browning, MT |
| Misc | | | | | | |
| Bird Flight Diverters | | $163.20 | | $158.04 | | |
| Paint | | | $415.13 | | | |
| Oil Off fee | $9.00 | | | | | |
| Contractor Trade | $80.00 | | | | | |
| Site Recovery | | | | $350.00 | | |
| Fencing materials | | | | $6,145.04 | $1,496.54 | |
| Inverter shed | | | | $265.00 | | |
| Freight | $1,379.00 | $1,400.00 | $1,637.00 | $1,134.00 | $1,523.70 | $1,073.00 |
| Total Misc Costs | **$1,468.00** | **$1,563.20** | **$2,052.13** | **$8,052.08** | **$3,020.24** | **$1,073.00** |

Source: NWSEED

Table 11 reflects the overall system costs accrued at the six different RFV host sites. As a partner to NWSEED in the RFV project, Bergey Windpower arranged a hardware discount for hosts participating in the project. This discount is identified in Table 11 as Bergey Matching Fund, and may not be available to others interested in installing this small wind turbine model. Thus, we also included the cost of the system without the discount to give readers a better idea of what the true system cost may be. Costs *not* reflected in this table include any host-provided labor and administrative costs incurred by a wide range of agencies and organizations[3] involved in supporting the development of each site.

The BOS variability (ranging from a low of $7,945 [Bassetti] to a high of $22,169 [Grim] plays a big role in determining overall system costs. Overall system costs range from a low of $38,601 (Nelson) to a high of $57,599 (Grim).

For more information on how these costs were reduced for the hosts through OWC, contact NWSEED.

Table 11: Regional Field Verification – Total System Costs, by Host

| Host Sites | **Alger** | **Bassetti** | **Grim** | **Kennell** | **Liberty Co. (Marble)** | **Nelson** |
|---|---|---|---|---|---|---|
| TOTAL BOS | **$8,341** | **$7,945** | **$22,169** | **$16,081** | **$15,861** | **$9,501** |
| Turbine | **$22,900.00** | **$22,900.00** | **$22,900.00** | **$22,900.00** | **$22,900.00** | **$22,900.00** |
| Tower | **$6,900.00** | **$8,100.00** | **$11,600.00** | **$6,000.00** | **$8,700.00** | **$5,400.00** |
| Tower Raising Kit | | | | | **$1,800.00** | |
| Tower Wiring Kit | **$930.00** | **$990.00** | **$930.00** | **$860.00** | **$860.00** | **$800.00** |
| **Total Turbine/Tower** | **$30,730.00** | **$31,990.00** | **$35,430.00** | **$29,760.00** | **$34,260.00** | **$29,100.00** |
| **TOTAL Turbine/Tower/BOS** | **$39,071** | **$39,935** | **$57,599** | **$45,841** | **$50,121** | **$38,601** |
| **Bergey Matching Fund** | **$7,746.00** | **$7,552.00** | **$1,600.00** | **$7,552.00** | **$8,528.00** | **$7,552.00** |
| **System Cost W/O Discount** | **$46,817** | **$47,487** | **$59,199** | **$53,393** | **$58,649** | **$46,153** |

[3] Agencies/organizations include NWCDC, NWSEED, NREL, BEF, LMEC, and others

**Lessons Learned**

Learning from the experiences of installing small wind turbines in a regional sector is a key component of NREL's RFV. From these first six installations, several lessons can be highlighted, and are summarized here.

1. Follow manufacturer's installation guidelines. Failure to follow the manufacturer's guidelines can lead to serious problems, such as occurred at the Nelson site. Damage to the newly installed turbine could likely have been averted if the guy wires had been completely tensioned and the safety cables had been installed. The resultant damage lead to a 4-month delay in electricity production from the turbine.
2. Use high-resolution wind resource maps only as a proxy for site evaluation. Evaluation of individual sites, which may include the use of an anemometer, should be done to adequately determine the expected wind resource. Both the Grim and Nelson sites are experiencing wind resources that are below those expected, resulting in a turbine production that is far below expected levels.
3. Avoid siting turbine where obstructions or turbulence will impede energy production. Trees and other obstructions block the wind, such as those found at the Grim site. Careful consideration of the placement of a turbine on a site should be made to maximize output from the turbine.
4. Find out permitting requirements and fees as early in the process as possible. As a percentage of total BOS costs, permitting and fees varied from 0% to 9% (Table 12). While actual costs were fairly low, the variability of these costs can add to uncertainty for prospective owners. In the case of the six RFV projects, the number of permits/fees that were required varied from 0 to 6 (Table 8).
5. Minimize installation costs. Site preparation costs can be minimized if the owner does some or much of the work (Table 9). Site preparation costs ranged from a low of 46% to a high of 88% of BOS.

Table 12. BOS Categories; Totals and As A Percentage of BOS

| Host Sites | **Alger** | **Bassetti** | **Grim** | **Kennell** | **Marble** | **Nelson** |
|---|---|---|---|---|---|---|
| TOTAL BOS | $8,341 | $7,945 | $22,169 | $16,081 | $15,861 | $9,501 |
| Total Permits/Fees (Table 8) | $45 | $475 | $1,895 | $667 | $0 | $50 |
| Permits/Fees as Percent of BOS | 1% | 6% | 9% | 4% | 0% | 1% |
| Total Site Prep (Table 9) | $6,828 | $5,907 | $18,098 | $7,362 | $12,841 | $8,378 |
| Site Prep as Percent of BOS | 82% | 74% | 82% | 46% | 81% | 88% |
| Misc (Table 10) | $1,468 | $1,563 | $2,052 | $8,052 | $3,020 | $1,073 |
| Misc as Percent of BOS | 18% | 20% | 9% | 50% | 19% | 11% |

6. Seek to realistically estimate energy production to better understand system payback opportunity. Under the RFV project, initial estimates of energy production were far greater than has been experienced thus far, although some of the shortfalls may be due to early technical issues that, once resolved, will result in increased production (Table 13).

Table 13. Actual Annual Production Compared to Estimated Annual Production

| Host Site | Estimated Annual Production (kWh)[4] | Actual Annual Production (kWh) | Months of data |
|---|---|---|---|
| Alger | 18,000[5] | 11,600 | 18 |
| Bassetti | 13,000 | 8,800 | 7 |
| Grim | 8,000 | 600 | 15 |
| Kennell | 13,000 | 12,400 | 16 |
| Marble | 10,000 | 7,400 | 15 |
| Nelson | 18,000 | 8,300 | 13 |

**Conclusion**

Under NREL's RFV project, all sites were developed with host support and enthusiasm. Site selection for small wind turbines is a critical parameter in the successful production of electricity. While permitting requirements vary across local jurisdictions, the overall cost impacts of these requirements are a very small percentage of the final costs of a system. Site preparation costs are by far the largest component of the BOS costs and can be minimized if the turbine owners are able to do some of the work themselves.

Operating data from the RFV host sites are skewed due to project start-up issues. Resolution of these issues should lead to better operations. Lessons learned under RFV should lead to easier small wind turbine installations, both in the Pacific Northwest and in other regions of the country.

[4] Source: Site Development Letter Reports submitted by NWSEED to NREL
[5] Source: Independent Energy Quarterly, Winter 2003

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The U.S. Department of Energy/National Renewable Energy Laboratory's (DOE/NREL) Regional Field Verification (RFV) project supports industry needs for gaining initial field operation experience with small wind turbines and verify the performance, reliability, maintainability, and cost of small wind turbines in diverse applications. In addition, RFV aims to help expand opportunities for wind energy in new regions of the United States by tailoring projects to meet unique regional requirements and document and communicate the experience from these projects for the benefit of others in the wind power development community and rural utilities. Between August 2003 and August 2004, six turbines were installed at different host sites. At least one year of data has been collected from five of these sites. This paper describes DOE/NREL's RFV project, reviews some of the lessons learned with regards to small wind turbine installations, summarizes operations data from these sites, and provides preliminary BOS costs.

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