9.0 City of Ellensburg Site Tests

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The City of Ellensburg, Washington, is an historic municipality that serves about 10,000 electric and 5,500 gas customers. Starting in 2006, the city launched the first community solar project in the United States. Through their participation in the Pacific Northwest Smart Grid Demonstration (PNWSGD) Project, the city added renewable generation capacity of 153 kW to the existing renewable energy park, including both renewable solar and wind generation. The solar generators are shown installed at the renewable energy park in Figure 9.1 from high above the park. The array on the left is polycrystalline panels, and the array on the right is the thin-film panels.

Figure 9.1. Polycrystalline (left) and Thin-Film (right) Solar Panel Arrays at the City of Ellensburg Renewable Energy Park, Ellensburg, Washington[1]

The site's wind generators are shown in Figure 9.2. From left to right, the nine wind generators are the Ventera Wind, Urban Green Energy, Tangarie, Bergey, Windspire, Honeywell WindTronics, Wing Power, Energy Ball, and Southwest Windpower Skystream wind turbines.

[1] Courtesy City of Ellensburg, e-mail from S Rowbotham to DJ Hammerstrom, January 12, 2015.

Figure 9.2. Wind Generators at the City of Ellensburg Renewable Energy Park, Ellensburg, Washington (City of Ellensburg 2013a)

The community renewable energy park consolidates citizens' efforts to test and use more renewable resources. Residents may buy into the projects without having to construct and operate the generators themselves. The residents can take advantage of economies of scale by building larger and more cost-effective generators than they might construct on their own properties. Furthermore, the city believes that the centralized park generation resources are safer and are more safely managed than would be the case with many, more distributed renewable generators located randomly throughout the city. The city and its residents may learn about and compare the renewable generator technologies that will inform their future energy decisions (City of Ellensburg 2013a). As shown in Figure 9.3, the park is close to and highly visible from Interstate Highway 90. The site is at a multipurpose community park that is publicly accessible. The diagram in Figure 9.3 labels the four installation phases for the arrays of solar panels and indicates the approximate locations of the solar arrays and nine wind turbines. The weather metrology tower was installed just beyond the upper right corner of this diagram. Public walkways lie to the north of and among the wind generator sites and lead to more park land on the other side of the highway.

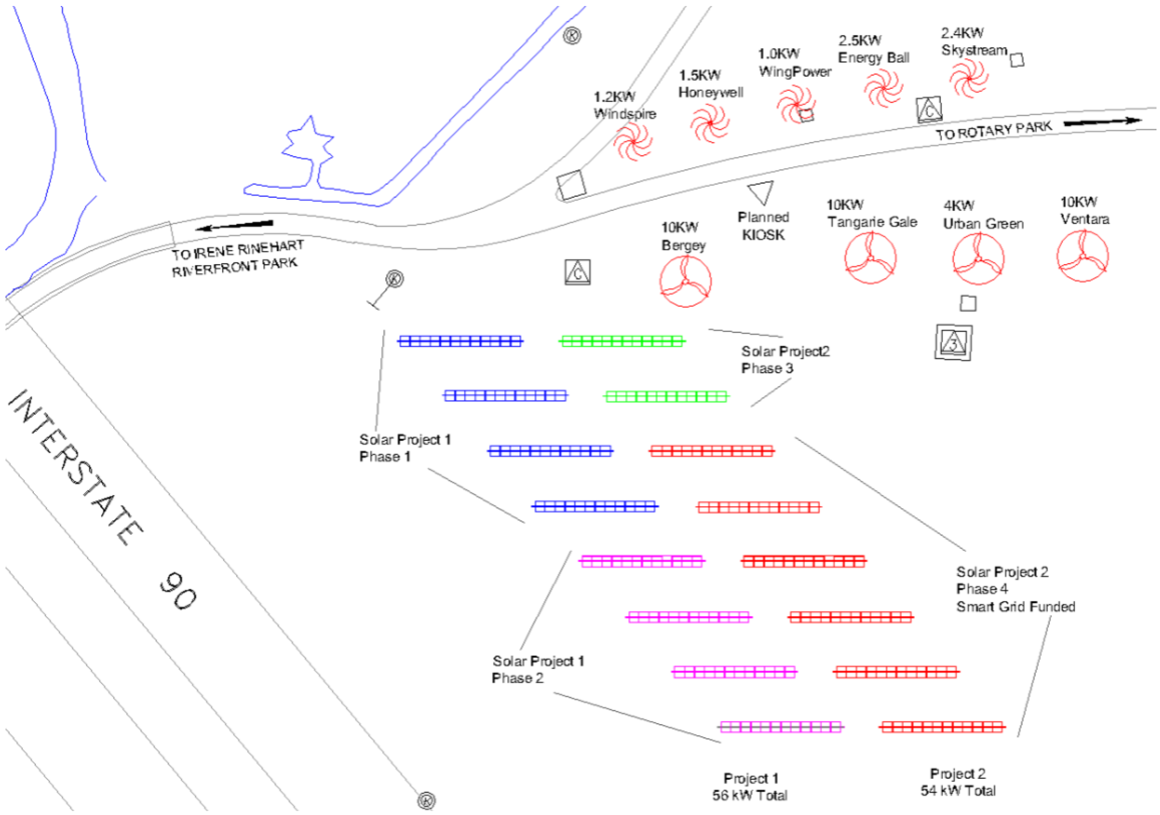


Figure 9.3. Layout of Renewable Generation at the Ellensburg Renewable Energy Park (City of Ellensburg 2013b)

The city had intended to make the data created by the project at the renewable park available to its residents, to researchers at Central Washington University, which resides in Ellensburg, and even to local teachers and their K–12 curricula, but these features were not successfully implemented in the city's supervisory control and data acquisition (SCADA) system by the city's chosen vendor. The City of Ellensburg received some qualitative value from its very visible investment in green energy resources and describes the park as an "eco-tourism" site. (City of Ellensburg 2013a)

The City of Ellensburg installed metrology equipment and made SCADA and other general site improvements. The major focus of their project participation was the installation and testing of two renewable solar photovoltaic (PV) generation systems, five residential-class wind turbine systems, and four larger commercial-class wind turbine systems. The new and existing solar and wind generation resources have been listed in Table 9.1. In this list, the names of the city's data metering points (e.g., "MP-1") have been mapped to each metered renewable generator. These renewable generation systems and their performance will be described in detail in the remainder of this chapter. The assets' corresponding chapter sections have been included in Table 9.1.

Table 9.1. Existing and New Renewable Solar and Wind Generation

Type/Make/Model	Meter Point	Section	Existing	New
Solar PV arrays:			69.5 kW	40.5 kW
Polycrystalline	MP-1	8.2	56.0	-
Thin-film	MP-2	9.3	13.5	40.5
Residential wind turbine generator systems:				8.6 kW
Honeywell WindTronics	MP-5	9.4	-	1.5
Windspire	MP-4	9.5	-	1.2
Energy Ball V200	MP-6	9.6	-	2.5
Skystream	MP-15	9.7	-	2.4
Wing Power	MP-7	9.12	-	1.0
Commercial wind turbine generator systems:				34.0 kW
Bergey	MP-8	9.8	-	10.0
Tangarie	MP-9	9.9	-	10.0
Urban Green Energy	MP-10	9.10	-	4.0
Ventera Wind	MP-11	9.11	-	10.0

The city was unable to establish and operate a transactive node and participate in the project's transactive system. None of its assets were represented in the transactive system. The City of Ellensburg was one of three utility sites that elected to design its own transactive node according to project specifications and using a proxy server instead of the software platform that was offered from project participant IBM. This effort proved more challenging than had been anticipated and was not completed. The city and project jointly decided to terminate the activity after it became seriously delayed.

9.1 Recloser Switch for Reliability and Outage Prevention

The City of Ellensburg purchased and installed a remote recloser switch at the interface between all the renewable generators and the city distribution system. The switch could be remotely opened using the site's SCADA. During an unlikely regional overgeneration event, the City of Ellensburg offered to use SCADA-level metering and control to quickly disconnect its renewable generators at the renewable energy park, thus improving system grid reliability. Fiber optic cable was installed to tie the renewable energy park communications to the city's electricity distribution operations center.

The Bonneville Power Administration (BPA) occasionally encounters overgeneration scenarios when wind generation is high, electric load is small, and base-load generation cannot be further reduced. During these scenarios, "dec" (decreased) balancing reserves can become depleted, and the region becomes challenged to manage frequency and enforce its exchange obligations.

It was determined early in the project that the project would not engage this disconnect switch through the project's transactive control system. Because the transactive system was only weakly connected to the region's operational objectives and was not aligned with real energy costs and incentives, the project could not reimburse the city for its loss of generation.

The project was not successful in its request to connect the operation of the switch with mitigation of overgeneration events. There was no signal or program available to the city for that purpose. In 2013, BPA solicited participation in a demonstration of commercialized demand response that might have dispatched this resource during overgeneration events. The city did not engage in this solicitation.

Recloser switch operation was successfully tested by the City of Ellensburg via the SCADA system in December 2012.

9.2 Polycrystalline Flat-Panel 56 kW PV System

The 56 kW polycrystalline flat-panel PV system, shown in Figure 9.4, at the Ellensburg community renewable energy park, Ellensburg, Washington, existed prior to the PNWSGD project, but the City of Ellensburg offered its data for evaluation by the project. The City of Ellensburg supplements its power and energy requirements, and thereby displaces its need for BPA energy supply with the power generated by the existing PV system.

Figure 9.4. Arrays of Standard Polycrystalline PV Panels at the Ellensburg Renewable Energy Park (City of Ellensburg 2013a)

The city chose not to include the expense of the existing PV panels in its estimation of annualized system costs. The remaining annualized costs, summarized in Table 9.2, were for site improvements and for improved monitoring of the generator and local weather conditions.

Table 9.2. Annualized Costs of the 56 kW Polycrystalline Flat-Panel PV System

	Shared Usage of Component (%)	Annualized Component Cost ($K)	Allocated Annual Component Cost ($K)
SCADA and Monitoring	8	33.2	2.7
Fiber Optic Communication	8	16.4	1.3
Climate Data Equipment	8	6.7	0.5
High-Voltage Equipment Installation	8	13.1	1.0
Low-Voltage Equipment Installation	8	7.8	0.6
Project Signs	8	7.4	0.6
Fencing	8	4.6	0.4
Consultants	8	18.5	1.5
56 kW PV Polycrystalline Solar Panels (existing)	100	0.0	0.0
Total Annualized Asset Cost			**$8.6K**

9.2.1 Baseline Approach

The baseline for this renewable generation system is the hypothetical absence of the system. The system is given credit for the value of the energy that is being generated at the times of active generation.

9.2.2 Data and Data Collection for the Polycrystalline PV Panels

The City of Ellensburg submitted 5-minute SCADA data concerning this PV system from its metering point “MP-1.” The raw generation data from the city stated the energy generated every 5 minutes. The project converted this data into average power for each 5-minute interval. The data period began August 2, 2012, and continued through August 31, 2014, the end of the project’s data collection period. Analysts removed obvious outliers—very negative generation values, for example. They also removed nonzero “stuck” data values from five time periods that ranged from 8 hours to over 17 days in duration. From March 31 to April 18, 2014 (17 days, 16 hours), no data was received while fiber optic cable was being changed. Most of the analysis used averaged power and will therefore be minimally degraded by the removal of these few periods when the data was questionable.

The city also collected and submitted meteorological data from its onsite weather station, including solar irradiance data. This onsite weather data, which was never calibrated, was supplemented by data from nearby Ellensburg weather stations. The data collected by the project permitted a characterization of the average hourly production from the 56 kW PV system as a function of measured solar irradiance. Figure 9.5 plots the average hourly power as a function of the average hourly solar irradiance.

Each point on Figure 9.5 represents the average power output for a solar irradiance range that is 1.0 W/m^2 wide (e.g., from 431–432 W/m^2). Considerable variability is evident, but some of this variability must be attributed to the irradiance meter. There is some evidence that birds perching on or near the meter influenced its output. Furthermore, the meter was not perfectly colocated with the PV system and therefore could be differently affected by intermittent cloud cover. The metrology tower was approximately 400 feet northeast of the center of the PV array, and the arrays themselves span about 350 feet from their northwest corner to their southeast corner.

The maximum hourly generation from the PV system was about 50 kW, somewhat less than the 56 kW nameplate capacity. This correlation provides some insight concerning the fixed orientation, quality, and design of the PV system, but it was not directly used for benefit analysis.

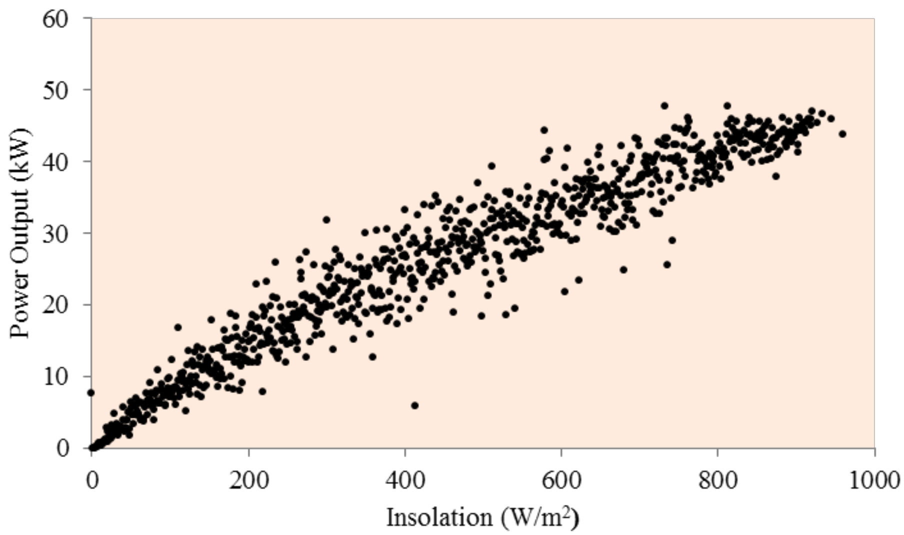


Figure 9.5. Power Curve Calculated for the 56 kW Polycrystalline PV Generator System. (This calculation used available averaged hourly production data from August 2, 2012, through March 14, 2014.)

9.2.3 Performance of the Polycrystalline PV System

The value of the displaced energy supply may be assessed from costs described within the BPA load-shaping service. This service differentiates unit energy costs by month and by heavy-load hour (HLH) and light-load hour (LLH). The BPA tiered-rate methodology is discussed in Appendix C.

The component HLH and LLH energy usages and their average impact on the city's energy supply costs are listed by calendar month in Table 9.3. The average energy usages were calculated for each calendar month from the average power generation for each of the two hour types that month and the numbers of HLHs and LLHs in the months of 2013. The variabilities in these energy calculations were estimated from the differences between the average power levels generated in the same calendar month but in different project years. The totals are simply the sums of the results from the HLHs and LLHs, but their variability is the square root of the squares of the variability in the data for the two hour types.

Table 9.3. Average Monthly Power Generation and Value of Displaced Supply According to BPA Load-Shaping Rates for the Polycrystalline PV Array

	HLH		LLH		Total	
	(kWh)	($)	(kWh)	($)	(kWh)	($)
Jan	2,300 ± 400	87 ± 15	460 ± 190	14 ± 6	2,800 ± 450	101 ± 16
Feb	4,300 ± 850	160 ± 31	610 ± 150	19 ± 5	4,900 ± 870	179 ± 32
Mar	5,700 ± 200	170 ± 6	1,300 ± 190	32 ± 5	7,000 ± 280	204 ± 8
Apr	7,600 ± 1,600	190 ± 41	1,300 ± 220	26 ± 4	8,800 ± 1,600	220 ± 41
May	7,800 ± 580	160 ± 12	1,200 ± 53	16 ± 1	9,000 ± 580	179 ± 12
Jun	7,400 ± 600	170 ± 14	1,700 ± 140	24 ± 2	9,100 ± 620	193 ± 14
Jul	8,200 ± 360	250 ± 11	1,500 ± 220	37 ± 6	9,700 ± 420	287 ± 12
Aug	8,000 ± 500	270 ± 17	1,300 ± 110	34 ± 3	9,200 ± 510	304 ± 17
Sep	6,300 ± 1,100	210 ± 36	1,600 ± 220	45 ± 6	8,000 ± 1,100	259 ± 36
Oct	5,900 ± 1,500	190 ± 48	800 ± 180	22 ± 5	6,700 ± 1,500	209 ± 48
Nov	2,900 ± 1,200	100 ± 42	770 ± 340	24 ± 11	3,700 ± 1,200	127 ± 43
Dec	2,500 ± 980	98 ± 38	460 ± 270	15 ± 9	3,000 ± 1,000	114 ± 39

As shown in Figure 9.6, most of the solar energy is generated during HLHs. Almost 4 times as much energy is generated in the summer months, when the sun is high in the sky and daylight is longer, as in winter, when the sun remains low and is often hidden by clouds. Based on the calculated energy values in Table 9.3, this array of polycrystalline PV panels could be expected to generate 81.9 ± 3.3 MWh each year. The sum value of the annual generated energy from the PV system was found to be $2,377 ± $104, based on the value of the energy supply that the city would otherwise need to purchase for this energy and using the most recent BPA load-shaping rates.

The variability in the stated value (i.e., $104) was estimated by comparing monthly values from one year to the next. By the end of the project, two complete years' data were collected. The total variability should be the square root of the sum of the squared variabilities for the 12 calendar months. The total energy and total value of the energy produced each calendar month was remarkably similar from year to year during the project.

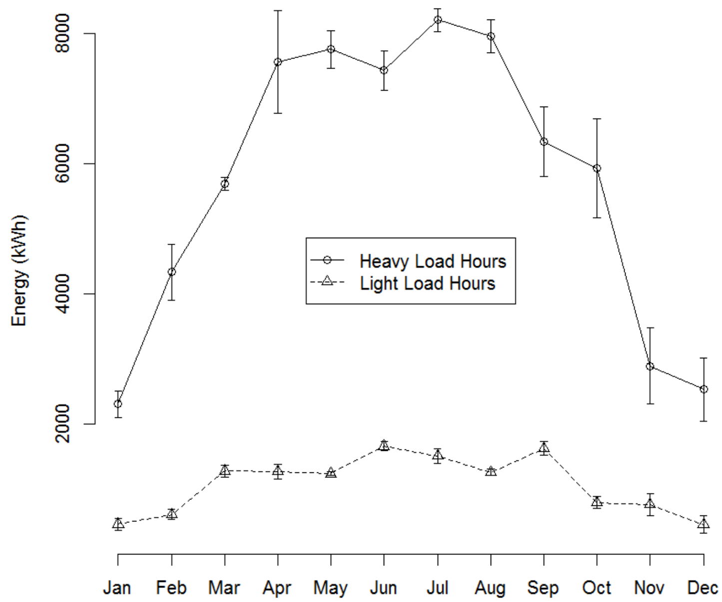


Figure 9.6. Average HLH and LLH Energy Production for the Polycrystalline PV Array by Calendar Month

Figure 9.7 shows the average generated renewable power by hour for all hours of the project. In this figure, the x-axis lists the Pacific Time hour on which the hour-long interval began. The pattern of power generation is quite symmetrical from 06:00 until 19:00 Pacific Time. One should expect production of about 30 kW during the hour that begins at noon.

The variability shown by the error bars represents the distribution range from the 16th percentile to the 84th percentile. This range was chosen because, for a normal distribution, it would represent the span between one standard deviation above and below the average. The distributions of hourly power production are not normal distributions, but this representation of variability is useful to analysts who have worked often with standard populations.

Even in this figure that has aggregated all the project hours, one can see that the variability of production in the afternoon is greater than that in the morning. This trend will be more evident for individual seasons.

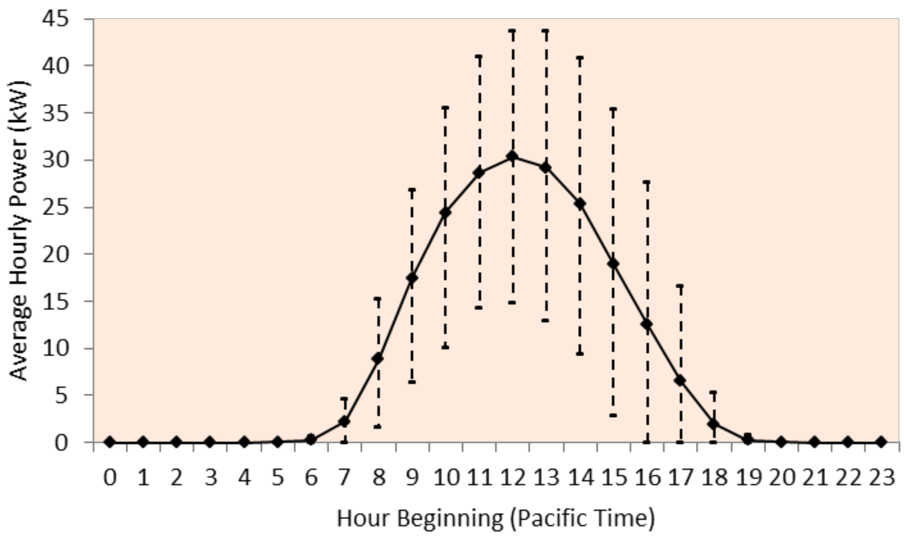
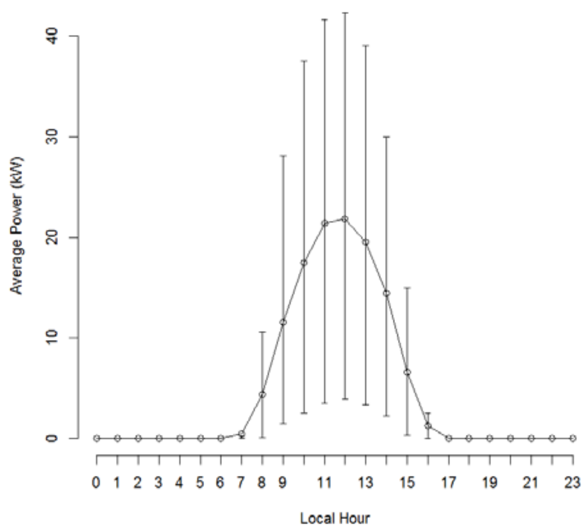


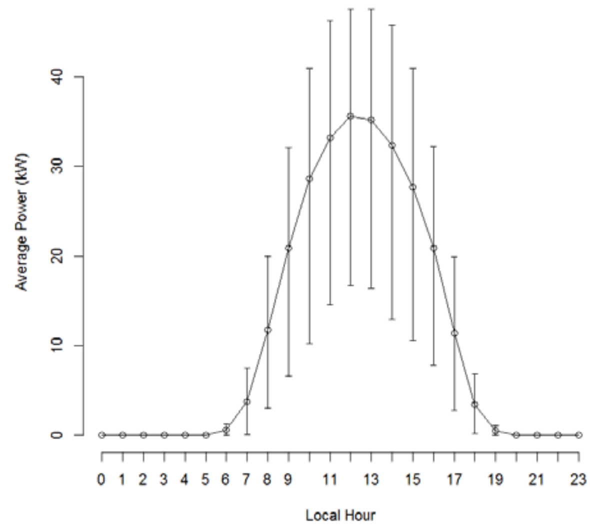
Figure 9.7. Average Hourly Power Production of the 56 kW Polycrystalline PV System for All Project Hours. The error bars represent the data range of the hourly production from the 16th through the 84th percentiles.

Figure 9.8 separates hourly generation by hour for winter (Dec.–Feb.), spring (Mar.–May), summer (Jun.–Aug.), and fall (Sep.–Nov.) seasons. The production differs by numbers of hours during which energy is produced—about 11 hours during winter compared to about 15 hours during summer. The average peak power production ranges from about 22 kW in the winter to about 39 kW in the summer.

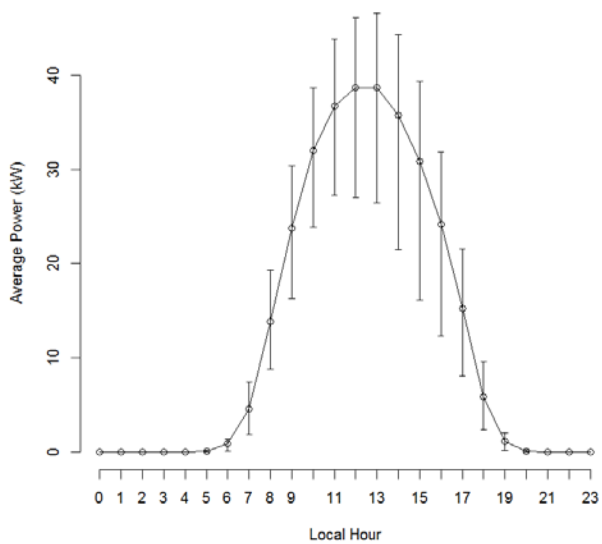
The variability represented by the 16th and 84th percentile error bars also differs significantly from season to season. Generation during the summer is relatively reliable, with average hourly production relatively narrowly distributed around the average. The distribution of average hourly production is wider in the other three seasons. During winter, the variability is especially large compared to the relatively small expected generation. It is fall that drives the trend of having more variability in the afternoon than in the morning.



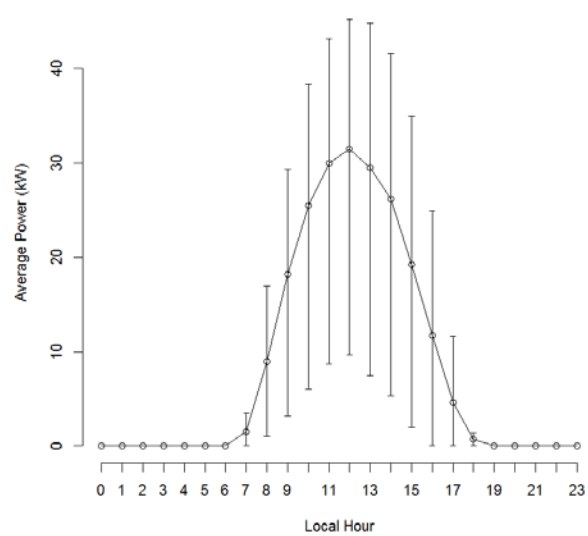
(a) Winter



(b) Spring



(c) Summer



(d) Fall

Figure 9.8. Average Hourly Production and Variability of Production of the 56 kW Polycrystalline PV System by Season. The error bars represent the range between the 16th and 84th percentiles.

The City of Ellensburg is subject to BPA demand charges that are determined at the conclusion of each month from the city's peak HLH, the average hourly HLH load, and a contract demand quantity allowance that has been calculated for the month. Generation from renewable sources may affect two of these—the month's peak load during the peak HLH and the average load during all HLHs that month. BPA's bills to its customers are complex. There may be other corrections in the complete billing method that are not accounted for here.

To estimate the impact on peak load in a month, one must know or infer the utility's peak hours. The City of Ellensburg submitted to the project a history of their months' peak hours. The project used the most recent 24 months to represent typical peak hours by calendar month. Analysts determined how the generation resource during an example peak hour would have affected the demand for that particular hour. This was performed for each calendar month. The result is therefore a statistical result and does not necessarily reflect the outcome during any specific month or year. As was shown in Figure 9.7, actual production for any given hour is highly variable. The variability was estimated by propagating the standard deviations of the exemplary peak hours each month.

Because the formula for determining BPA demand-charge determinants also subtracts average HLH power (i.e., “aHLH”), the impact of generation from the 56 kW polycrystalline PV system on average HLH power must be addressed. Renewable solar energy production decreases the city’s average HLH energy consumption and therefore slightly increases the determinant on which the demand charges are based. Referring now to Table 9.4, the formula for the billing determinant yields significant reductions in the demand charges during hot months when the sun shines for many hours and can affect peak load. In the other months, the PV site may actually *increase* the city’s demand charges. This is possible because the solar generation continues to displace HLH energy supply throughout much of the day, but the sun is not shining brightly during the months’ peak demand hours.

The overall cost impact of this system on BPA demand charges was calculated to be only $15 ± 37 per year. Solar renewable generation has a negligible influence on peak demand and peak demand charges at this site.

Table 9.4. Typical Monthly Impacts on Demand Charges Based on Example Peak Hours Each Month for the Polycrystalline PV Array

	Δ Demand (kW)	Δ aHLH (kWh/h)	Δ Demand Charges ($)
Jan	0.8 ± 3	5.5 ± 1.0	53 ± 3
Feb	4.7 ± 8.7	11 ± 2	72 ± 9
Mar	4.5 ± 7.3	14 ± 1	82 ± 7
Apr	18 ± 12	18 ± 4	−1 ± 13
May	24 ± 13	19 ± 1	−31 ± 13
Jun	22 ± 14	19 ± 2	−25 ± 14
Jul	40 ± 14	20 ± 1	−180 ± 14
Aug	27 ± 14	18 ± 1	−87 ± 14
Sep	26 ± 15	17 ± 3	−98 ± 15
Oct	4.3 ± 6.4	14 ± 4	87 ± 7
Nov	0.4 ± 2.2	7.2 ± 2.9	71 ± 4
Dec	0 ± 0.3	6.3 ± 2.5	72 ± 2

9.3 Thin-Film Solar Panel 54 kW Array

During the project, the City of Ellensburg added 40.5 kW of nameplate generation capacity to its existing 13.5 kW thin-film PV power generation. The city refers to the added thin-film technology as its Phase-4 expansion. The array grew to 54 kW. As with the other renewable generation at this site, the city installed this resource to reduce demand from its energy supplier. A portion of the completed array is displayed in Figure 9.9.

Figure 9.9. Arrays of Thin-Film PV Panels at the Ellensburg Renewable Energy Park (City of Ellensburg 2013a)

Table 9.5 lists the system's components and their annualized costs. The majority of the costs were for purchasing and installing the new 40.5 kW generation capacity at the renewable energy park. Remaining annualized costs were for SCADA system upgrades, consultants, fiber optic communication, outreach, and miscellaneous upgrades to the site. The total annualized system cost for the incremental set of thin-film solar panels was $39.4K. Many of the components' costs were shared with the other renewable generator systems that the city installed and tested during the project. The costs of the existing panels were not included in the estimate of annualized system costs.

Table 9.5. Annualized Costs of the Flat Thin-Film Solar Panel System

	Component Allocation (%)	Annualized Component Cost ($K)	Allocated Annual Component Cost ($K)
40.5 kW Thin-Film Nanotechnology Solar Panels (new)	100	29.0	29.0
SCADA and Monitoring	8	33.2	2.7
Consultants	8	18.5	1.5
Fiber Optic Communication	8	16.4	1.3
Outreach and Education	8	15.9	1.3
High-Voltage Equipment Installation	8	13.1	1.0
Low-Voltage Equipment Installation	8	7.8	0.6
Project Signs	8	7.4	0.6
Climate Data Equipment	8	6.7	0.5
Fencing	8	4.6	0.4
Administrative	8	5.1	0.4
Customer Service	8	1.0	0.1
13.5 kW Thin-Film Nanotechnology Solar Panels (existing)	100	0.0	0.0
Total Annualized Asset Cost			**$39.4K**

In a report to the City of Ellensburg city council, the one-time cost of the city's Phase-4 installation of thin-film solar generation was stated as $291,787. This is probably not directly comparable to the annualized system costs listed in Table 9.5 because the two sums might not include exactly the same subcomponents.

9.3.1 Data from the Thin-Film Solar Panel System

The City of Ellensburg submitted the energy that was generated every 5 minutes for a period from the beginning of July 2012 to the end of the project's data collection at the end of August 2014. The city referred to the site metering point for the thin-film solar panel array as "MP-2." The project converted these data into average power for the 5-minute intervals. Obvious outliers, such as large negative values, for example, were removed by the project. The project also removed from analysis several time periods that exhibited "stuck" data values—nonzero values that remained constant for many data intervals. About five periods with missing data were received, and these empty data periods ranged from 8 hours to more than 17 days. The project was informed that the longest period of missing data (beginning March 31, 2014) resulted from required maintenance. A fiber optic cable was being replaced.

9.3.2 Performance of the Thin-Film Solar Panel System

The City of Ellensburg evaluated their Phase-4 installation of additional thin-film PV generation and concluded that the unit cost of the energy produced by the solar system was $0.28 (City of Ellensburg 2013b). This is expensive energy compared to inexpensive wholesale electricity in the Pacific Northwest.

The remainder of this section presents independent analysis conducted by the project concerning the entire array of thin-film PV at the Ellensburg renewable energy park.

The generation by this system was found to be quite similar to that of the similarly sized 56 kW polycrystalline PV system (Section 9.2). Table 9.6 estimates the monthly energy generated by this system and the value of the energy according to recent BPA load-shaping rates, which are provided in Appendix C. The calculations of yearly energy production used in this chapter are based on average power generation during each calendar month’s HLHs and LLHs. That is, the energy reported by the project is not simply the sum energy that was reported to the project for a given time period. The calculated energy is a statistical result that is based on average power generation each calendar month, which may include data from multiple years. This approach may overstate generation somewhat when data were unavailable. Often the loss of data may be attributable to power metering or data collection, but the solar generator operates well. Conversely, the method overstates energy generation when outages are genuine and no energy is, in fact, generated. The project rarely possessed accurate information concerning the specific nature of data outages.

Table 9.6. Displaced HLH and LLH Supply Energy Consumptions and Costs, Based on BPA Load-Shaping Rates for the Thin-Film PV Array

	HLH		LLH		Total	
	(kWh)	($)	(kWh)	($)	(kWh)	($)
Jan	2,200 ± 410	83 ± 15	440 ± 160	13 ± 5	2,600 ± 440	97 ± 16
Feb	4,200 ± 790	150 ± 29	580 ± 140	18 ± 4	4,700 ± 810	171 ± 30
Mar	5,600 ± 140	170 ± 4.3	1,300 ± 180	31 ± 5	6,800 ± 230	201 ± 6
Apr	7,600 ± 1500	200 ± 39	1,300 ± 230	26 ± 5	8,900 ± 1500	222 ± 39
May	7,800 ± 510	160 ± 11	1300 ± 45	16 ± 1	9,100 ± 520	181 ± 11
Jun	7,600 ± 510	170 ± 12	1,700 ± 120	25 ± 2	9,300 ± 520	197 ± 12
Jul	8,100 ± 510	250 ± 15	1,600 ± 150	40 ± 4	9,700 ± 530	286 ± 16
Aug	7,700 ± 170	260 ± 5.8	1,200 ± 140	33 ± 4	8,900 ± 220	295 ± 7
Sep	6,100 ± 1100	210 ± 37	1,600 ± 230	44 ± 6	7,700 ± 1100	250 ± 37
Oct	5,900 ± 1300	190 ± 41	790 ± 160	22 ± 4	6,700 ± 1300	208 ± 41
Nov	2,800 ± 1100	100 ± 38	720 ± 300	23 ± 10	3,500 ± 1100	123 ± 39
Dec	2,400 ± 800	92 ± 31	440 ± 220	15 ± 7	2,800 ± 830	106 ± 32

Based on the data in Table 9.6, total annual energy generation is estimated by the project to be 80.7 ± 3.0 MWh. The total annual HLH and LLH energy usages are expected to be 68 ± 3 MWh and 12.9 ± 0.6 MWh, respectively. The annual displaced energy supply costs for HLHs and LLHs are $2,031 ± 92 and $305 ± 18, respectively, with a total displaced supply value of about $2,335 ± 94 per year.

The city estimated that the overall unit cost of the solar energy generated by its Phase-4 assets (that include only the added 40.5 kW of the thin-film PV system) was $0.28 per kWh. Of course, this does not yet compare favorably with either the cost of the city's BPA energy supply or even the average retail energy rate that Ellensburg residents now pay for their electricity (City of Ellensburg 2013b).

The generated HLH and LLH energy for each calendar month has been plotted in Figure 9.10. This figure emphasizes that most of the energy is generated during HLHs. Nearly four times more energy is generated in the summer when the sun is high in the sky than is generated during winter months, when the sun remains low on the horizon and is often hidden by clouds.

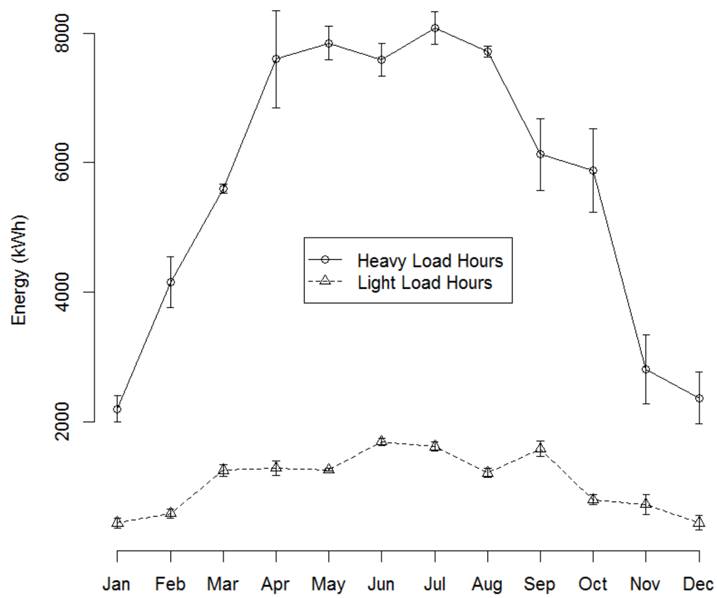
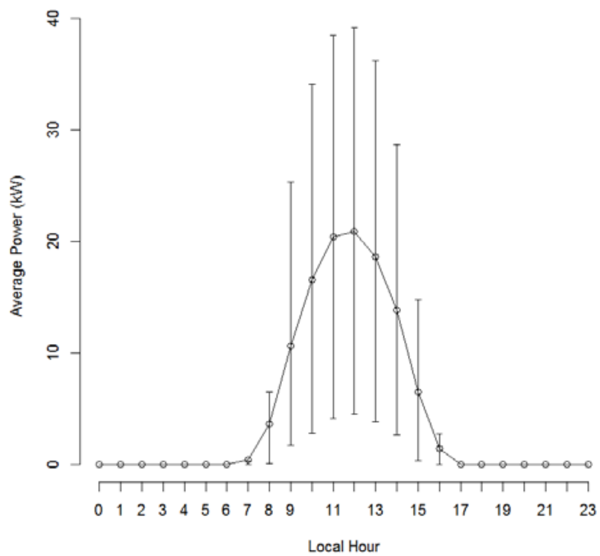


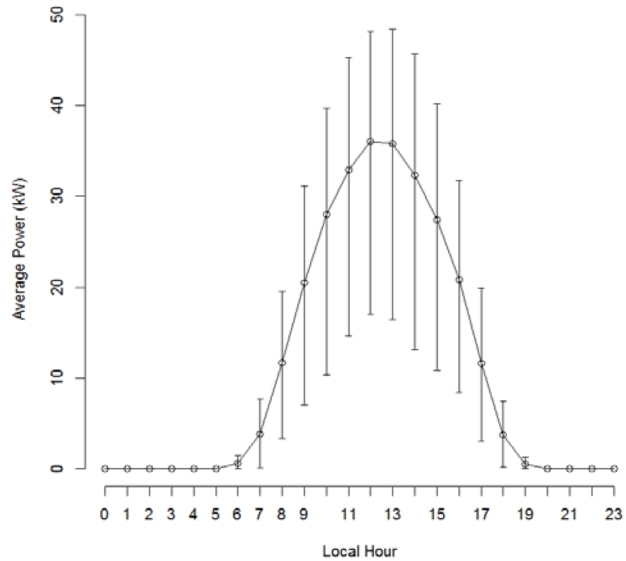
Figure 9.10. Average HLH and LLH Energy that is Generated each Calendar Month by the Thin-Film PV Array. Error bars are estimates of standard year-to-year variability.

Figure 9.11 shows average hourly diurnal patterns of the power that was generated by the complete system of thin-film solar panels. The hours are numbered such that "0" is the hour that began midnight, local Pacific Time. The error bars expand from the 16th to the 84th percentile of the data for these hours.

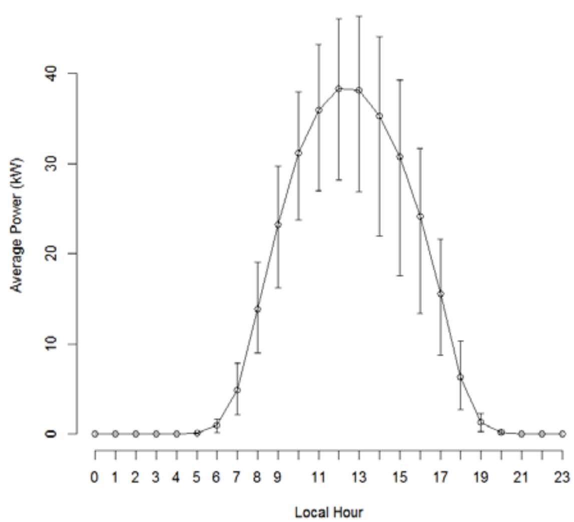
As was observed for the polycrystalline panel array in Section 9.2, summer peak power generation is approximately twice that of winter. The productive summer day includes more morning and evening hours than in other seasons. Power generation in the summer is more predictable than for other months. The error bars are shorter. The variability of generation is somewhat greater in the afternoon than during the morning hours, but this variability is perhaps not as pronounced as was observed for the polycrystalline panel array (Section 9.2).



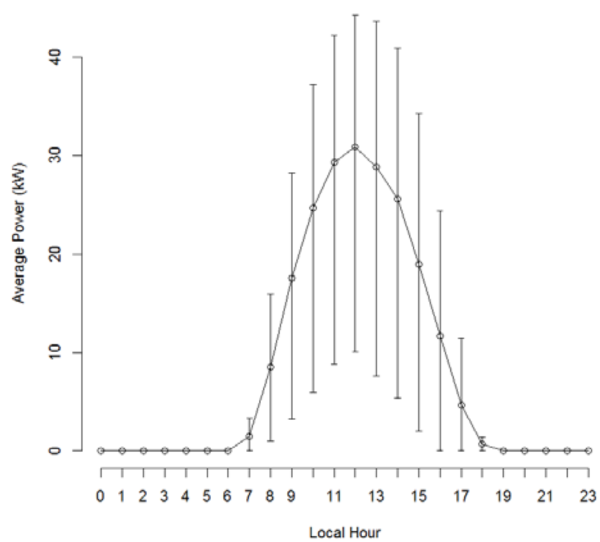
(a) Winter



(b) Spring



(c) Summer



(d) Fall

Figure 9.11. Average Solar Power Generation by Hour and Season for the Thin-Film PV Array

Table 9.7 presents the change in aHLH and the change in peak-hour demand that may be attributed to this thin-film system's power generation. These are the two main components of the demand-charge determinant from which a change in monthly demand charges may be calculated.

The city incurs demand charges nearly every month. The project received from Ellensburg a history of their peak hours. The most recent 24 of these examples (i.e., two years' worth) were used to estimate typical hours of the city's peak electrical load. The normal generation and variation of generation for these hours were used to estimate the impacts during peak hours. The aHLH component is simply the average generated power during HLHs each month with an estimate of how this average might change from year to year.

Finally, the total monthly impact was estimated from these analysis results and the BPA demand rate (Appendix C). This monthly impact is shown in Table 9.7. The negative values that occur primarily during summer months represent *reductions* of the city's demand charges those months. The demand charges are *increased* for many other months because the solar power generation is unimpressive during the (typically) morning peak hours those months.

Table 9.7. Impact on Peak Demand Determinants and Demand Charges from Thin-Film PV System

	Δ Demand (kW)	Δ aHLH (kWh/h)	Δ Expense ($)
Jan	0.6 ± 1.7	5.3 ± 1.0	52 ± 2
Feb	4.2 ± 7.7	11 ± 2	71 ± 8
Mar	4.6 ± 6.8	13.5 ± 0.3	80 ± 7
Apr	18 ± 1	18 ± 4	2 ± 12
May	24 ± 13	19 ± 1	−31 ± 13
Jun	23 ± 14	19 ± 1	−26 ± 14
Jul	39 ± 15	19 ± 1	−173 ± 15
Aug	26 ± 13	17.9 ± 0.4	−83 ± 13
Sep	25 ± 14	16 ± 3	−94 ± 14
Oct	4.2 ± 6.3	14 ± 3	87 ± 7
Nov	0.4 ± 1.9	7.0 ± 2.7	70 ± 3
Dec	0.0 ± 0.4	5.9 ± 2.0	67 ± 2

The total impact of the solar generation from the thin-film PV system on the municipality's demand charges is only $22 ± 36 per year. Note that this is an overall *increase* in the demand charges the city would pay. Regardless, the magnitude is relatively insignificant.

9.4 Honeywell WindTronics 1.5 kW Model WT6500

The City of Ellensburg hoped to supplement its power and energy requirements (effectively reducing its demand from its supplier) with the power generated by a 1.5 kW Honeywell WT6500 wind generator (WindTronics, Inc. 2013) located at its renewable energy park. This is among the set of five residential-class wind systems tested by the city. This turbine has a unique design with the generator's stator and rotor located distal from the turbine's hub. The turbine is shown installed in Figure 9.12.

Figure 9.12. Residential-Class Honeywell 1.5 kW Turbine Installed at the Ellensburg Renewable Energy Park (City of Ellensburg 2013a)

Electrical generation from this wind turbine stopped January 12, 2013, and was not restored. A wing failed due to an object (perhaps a bird) passing through the spoked generator wheel, which bent it enough to prevent it from rotating. The unit was de-energized as repair parts were not available. In a November 1, 2013, city report, the cause was attributed to "wing failures" (City of Ellensburg 2013c).

The annualized costs of the system and its components are listed in Table 9.8. The total system cost $16.0K per year on an annualized basis. The greatest cost was for the turbine generator, followed by the costs of communication upgrades, consultancy, electrical hardware upgrades, and other site upgrades.

Table 9.8. City of Ellensburg Costs of 1.5 kW Honeywell WindTronics System

	Shared Usage of Component (%)	Annualized Component Cost ($K)	Allocated Annual Component Cost ($K)
1.5 kW WindTronics Wind Turbine	100	5.6	5.6
SCADA and Monitoring	8	33.2	2.7
Consultants	8	18.5	1.5
Fiber Optic Communication	8	16.4	1.3
Outreach and Education	8	15.9	1.3
High-Voltage Equipment Installation	8	13.1	1.0
Low-Voltage Equipment Installation	8	7.8	0.6
Project Signs	8	7.4	0.6
Climate Data Equipment	8	6.7	0.5
Fencing	8	4.6	0.4
Administrative	8	5.1	0.4
Customer Service	8	1.0	0.1
Total Annualized Asset Cost			**$16.0K**

9.4.1 Data for the Honeywell WindTronics System

Power data from mid-November 2013 until mid-March 2013 was received from the city. The city's source for this data was their site metering point "MP-5." The power generation data in Figure 9.13 from this period is discretized because the raw data was reported to the nearest watt-hour each 5-minute interval. Therefore, the power is represented by whole-number products of 12 W. Maximum generation seldom, if ever, approached the nameplate value of the wind turbine—1.5 kW.

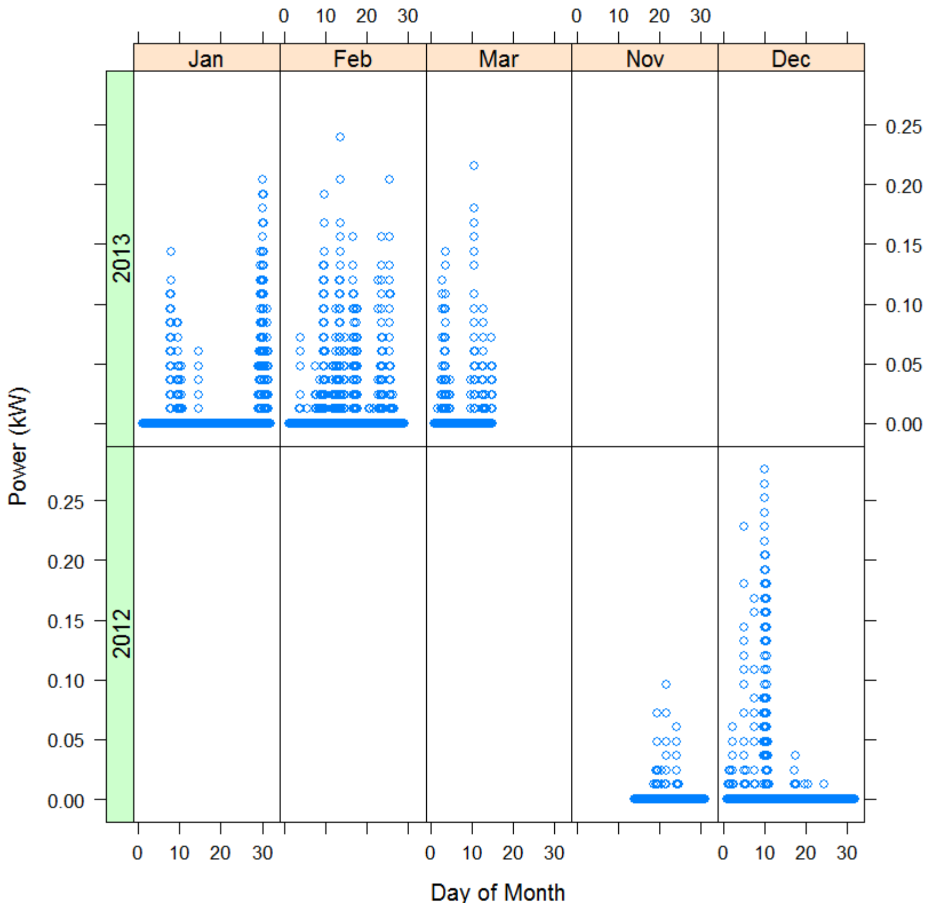


Figure 9.13. All Data Received Concerning Power Generation for the Honeywell WindTronics System

9.4.2 Performance of the Honeywell WindTronics System

The characteristic power generation as a function of wind speed was calculated and is presented in Figure 9.14. This calculation used all the power data that was available from 5-minute intervals and compared that power against the corresponding wind speeds that were reported 36 feet above ground at the site's weather metrology tower. The wind speeds from this sensor were found to have been discretized into the irregular set of wind speeds that were plotted in this figure. The error bars again represent the range of generated power data between the 16th and 84th percentiles at each wind speed. The characteristic curve shape is interesting, but the project is not confident that the meter source of the reported wind speeds had been calibrated.

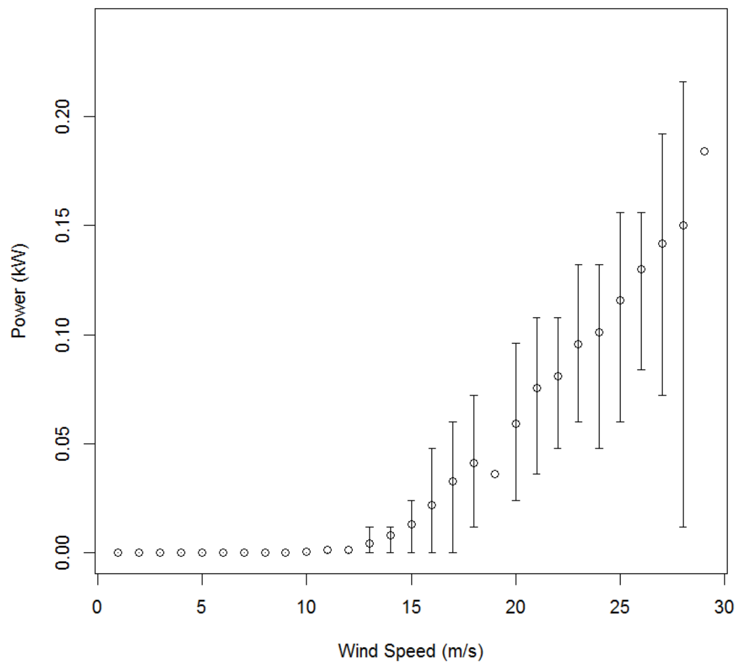


Figure 9.14. Generated Wind Power from the Honeywell WindTronics Wind System as a Function of the Wind Speed that was Measured at the Site at Height 36 Feet

The monthly energy generation each month is shown separately for HLHs and LLHs in Figure 9.15. The uncertainty of these monthly sums cannot be determined because the system ran less than one full year. Because generation was intermittent and was somewhat randomly distributed over time, the generation could occur during either HLHs or LLHs each month.

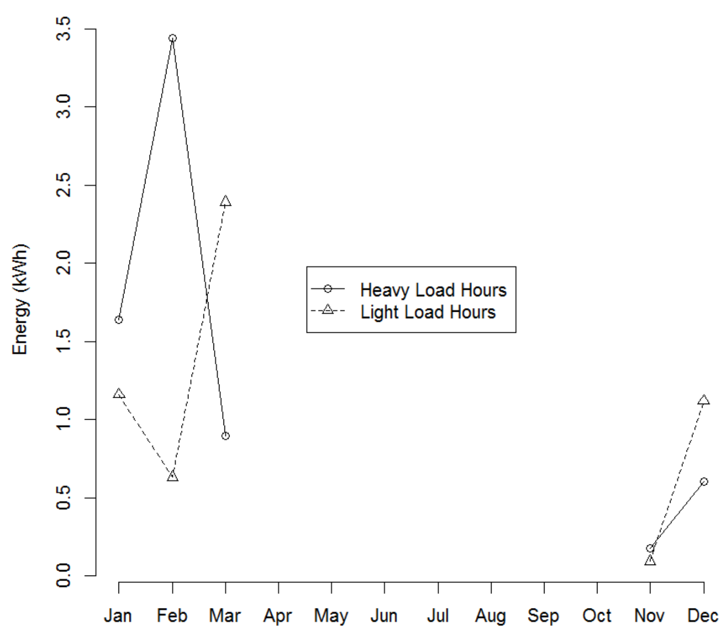
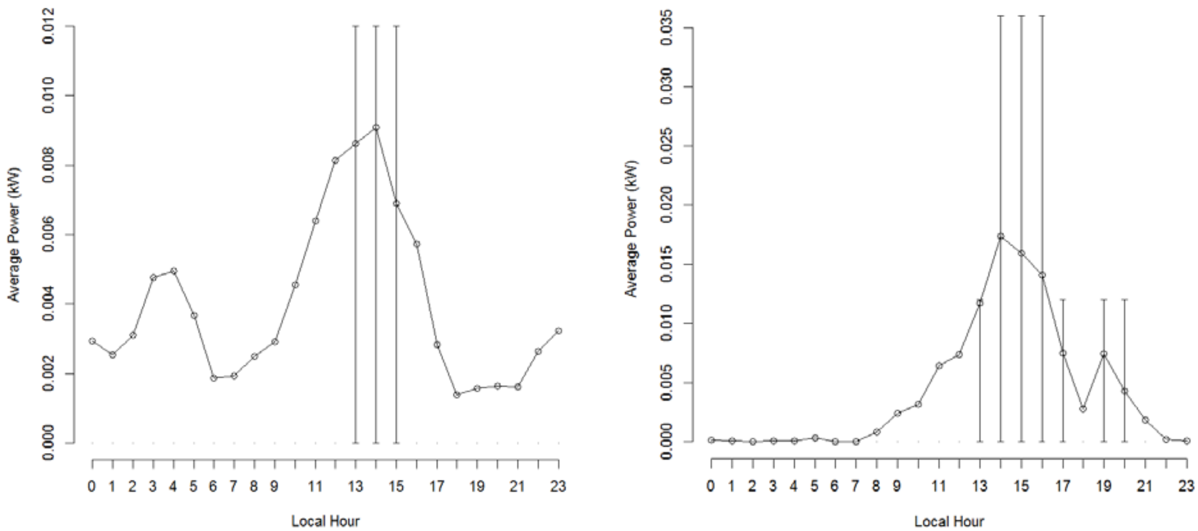


Figure 9.15. Average HLH and LLH Energy by Calendar Month for the Honeywell WindTronics System. Data was collected during five of the calendar months.

The diurnal power generation patterns were determined for winter and spring seasons and are shown in Figure 9.16. Wind generation is strongest during early afternoons. The error bars again represent samples between the 16th and 84th percentiles in this figure. The average power generation was very small.



(a) Winter (b) Spring

Figure 9.16. Average Power Generation by Hour and Season for the Honeywell WindTronics System. Seasons summer and fall had inadequate data and are not shown.

The average monthly energy generation and the values of the amounts of supply energy displaced by the renewable resource are listed in Table 9.9. Data was received during only five calendar months. The monthly energy generation and the values of these quantities of energy, according to BPA load-shaping rates, are miniscule. Even if the generator had operated similarly for a full year, all the energy produced over a year would be expected to displace no more than about $1 of energy that the City of Ellensburg would otherwise have purchased.

Table 9.9. Energy Generated Each Month and the Value of Supply Energy that it Displaced for the Honeywell WindTronics System

	HLH		LLH		Total	
	(kWh)	($)	(kWh)	($)	(kWh)	($)
Jan	1.6	0.06	1.2	0.04	2.8	0.10
Feb	3.4	0.13	0.6	0.02	4.1	0.15
Mar	0.9	0.03	2.4	0.06	3.3	0.09
…	-	-	-	-	-	-
Nov	0.2	0.01	0.1	0	0.3	0.01
Dec	0.6	0.02	1.1	0.04	1.7	0.06

The project analyzed the impact that this asset system had on peak demand; the value was inconsequential. The typical power generation during peak hours was small. Because the resource is intermittent, generation was unlikely to be coincident with a month's peak demand hour.

9.5 Windspire® 1.2 kW Wind Turbine

The City of Ellensburg further complemented its power and energy requirements (effectively reducing its demand from its supplier) with the power generated by a 1.2 kW Windspire wind generator (Windspire Energy Inc. 2010) located at its renewable park. This is among the set of residential-class wind systems tested by the city. The turbine is shown installed in Figure 9.17.

This wind turbine was declared failed on March 15, 2013. In a report November 1, 2013, posted on the city website, the cause was described as a generator and inverter failure. The turbine eventually would not rotate. The city understood the manufacturer to no longer be in business (City of Ellensburg 2013c). Late July that same year, vandals damaged a $1,500 meter that had been used to monitor this turbine system.

The annualized costs of the system and its components are listed in Table 9.10. The total system cost $15.4K per year on an annualized basis. The greatest cost was for the turbine generator, followed by the costs of communication upgrades, consultancy, electrical hardware upgrades, and other site upgrades.

Figure 9.17. 1.2 kW Windspire Wind Turbine at the Ellensburg Renewable Energy Park (City of Ellensburg 2013a)

Table 9.10. City of Ellensburg Costs of 1.2 kW Windspire Wind Turbine System

	Shared Usage of Component (%)	Annualized Component Cost ($K)	Allocated Annual Component Cost ($K)
1.2 kW Windspire Wind Turbine	100	5.0	5.0
SCADA and Monitoring	8	33.2	2.7
Consultants	8	18.5	1.5
Fiber Optic Communication	8	16.4	1.3
Outreach and Education	8	15.9	1.3
High-Voltage Equipment Installation	8	13.1	1.0
Low-Voltage Equipment Installation	8	7.8	0.6
Project Signs	8	7.4	0.6
Climate Data Equipment	8	6.7	0.5
Fencing	8	4.6	0.4
Administrative	8	5.1	0.4
Customer Service	8	1.0	0.1
Total Annualized Asset Cost			**$15.4K**

9.5.1 Data for the Windspire System

Data was collected at 5-minute intervals from the beginning of July 2012 to January 12, 2013, at which time the generator and inverter failed and the turbine would not rotate. The city's source for this data was their site metering point "MP-4."

All this data is shown in Figure 9.18. Observe from the scale of the power axis that the generator never generated more than 1 kW. Generation was very intermittent, as might be expected.

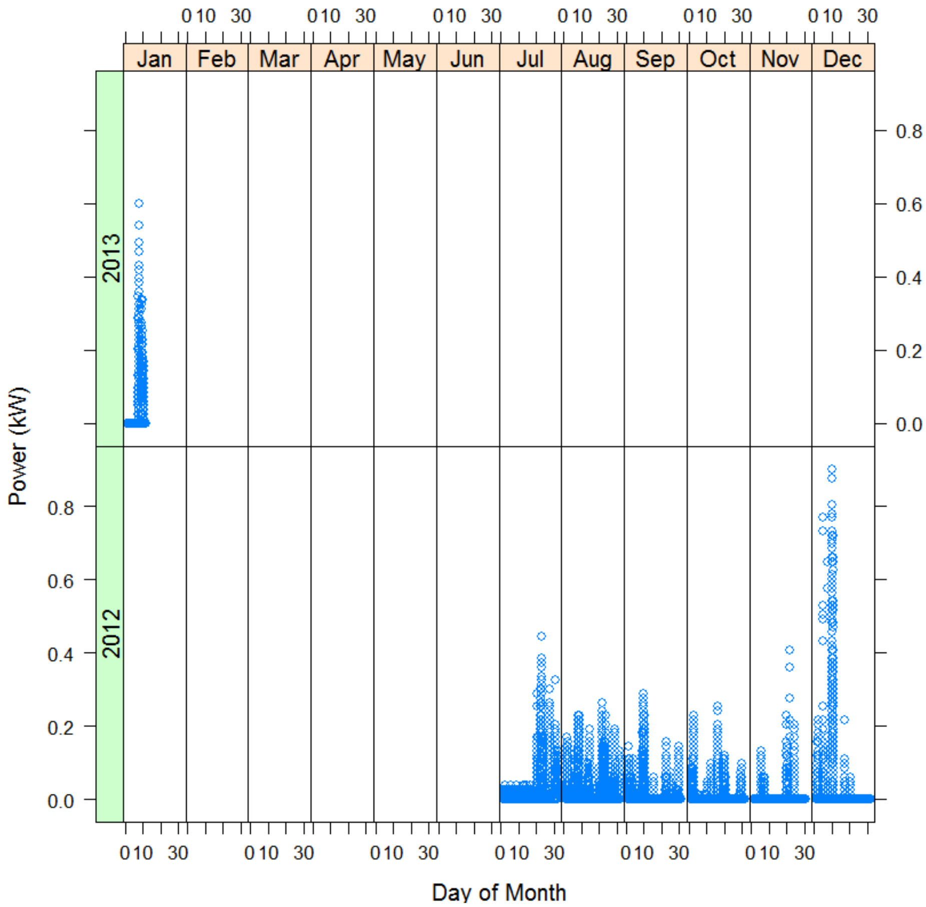


Figure 9.18. Power Generation from July 2012 through January 2013 for the Windspire System

9.5.2 Performance of the Windspire Turbine System

The project calculated the characteristic power generation by this system as a function of the wind speed measured 36 feet above ground at the renewable energy park's weather tower. The result is summarized by Figure 9.19, which includes all the 5-minute data received by the project. The error bars represent the range of measured power intervals from the 16th to 84th percentile at each wind speed.

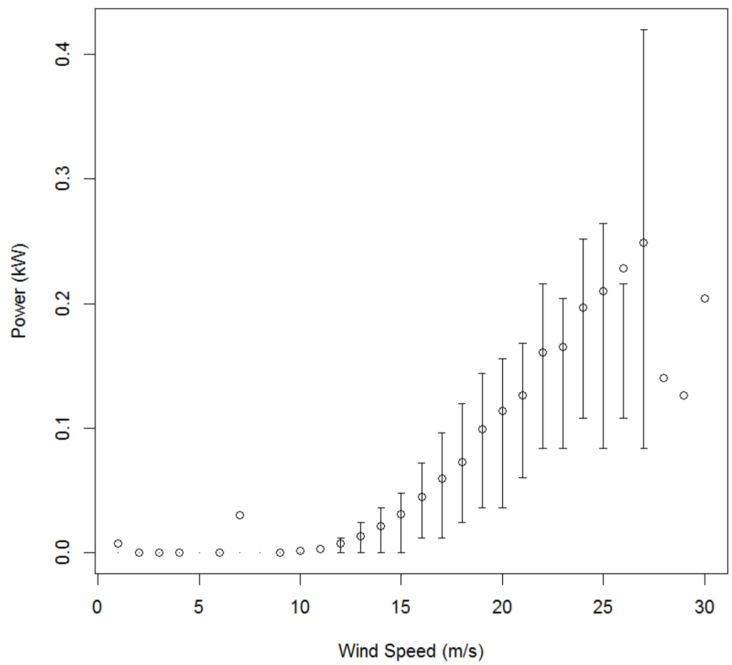
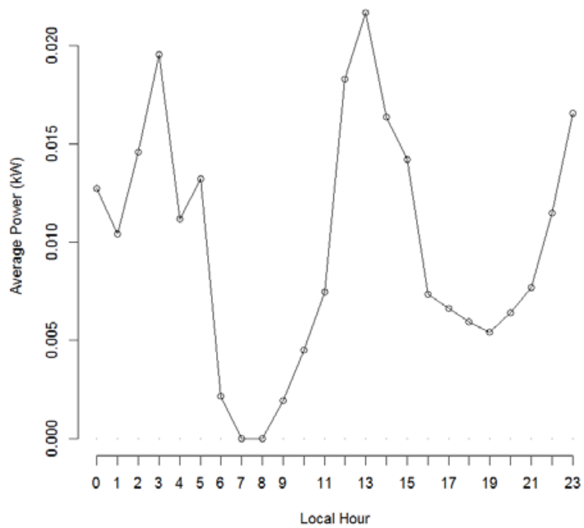


Figure 9.19. Characteristic Power Generation as a Function of Metered Site Wind Speed 36 Feet above the Ground for the Windspire System

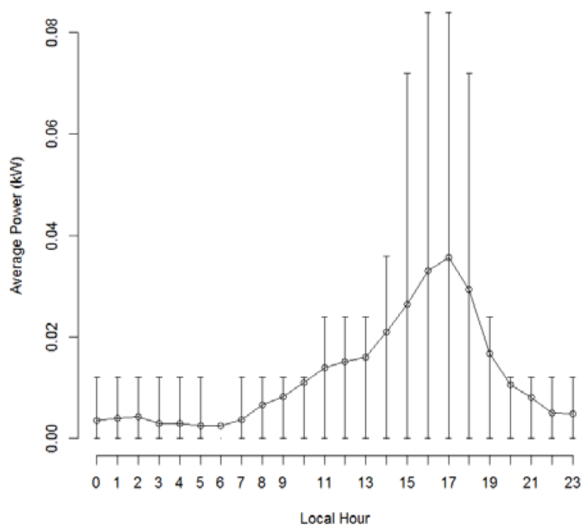
The average diurnal power generation patterns are shown for each season in Figure 9.20. Wind generation typically peaked in the early afternoon, but the typical average power was never more than 50 W for any hour of any season. Data was not reported for spring because generator data was unavailable those months. The error bars estimate the standard range of the data from the 16th to the 84th percentile. Because the generation was very intermittent, the 84th percentile generation was often zero for many of the hours and seasons. That simply means that the wind generator produced power less than 16% of the time.



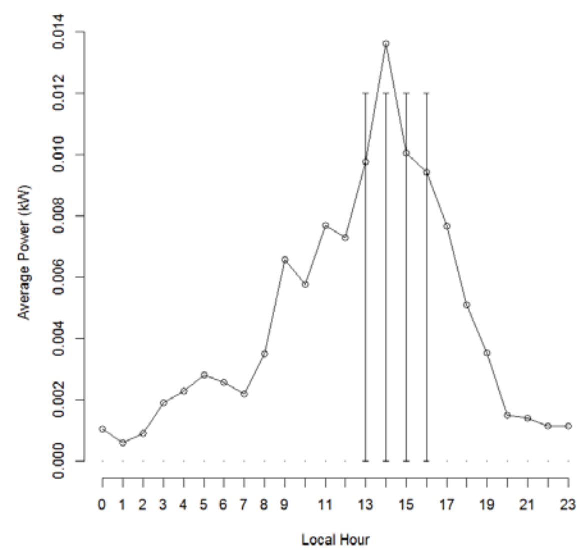
(a) Winter

NA

(b) Spring



(c) Summer



(d) Fall

Figure 9.20. Average Power Generation by Season and Pacific Time Zone Hour for the Windspire System. There was inadequate spring data to create a figure.

Table 9.11 lists the amounts of HLH, LLH, and total energy production and the monetary values of these quantities of energy by calendar month. The value of displaced supply was based on BPA's most recent load-shaping rates. Of the seven months for which generation data was received, none included impressive quantities of energy production. No generation data was available for five calendar months, from February through June. The total value of the energy in monitored months was less than $1.00. The total projected value of the yearly generated energy would be on the order of $2.50. The project did not estimate the variability in these values because less than one year's data was collected.

Table 9.11. Monthly Energy Production and the Monetary Value of the Energy Supply Displaced by the Windspire Generator

	HLH		LLH		Total	
	(kWh)	($)	(kWh)	($)	(kWh)	($)
Jan	7.0	0.26	2.6	0.08	9.6	0.34
…	-	-	-	-	-	-
Jul	6.4	0.20	2.8	0.07	9.3	0.27
Aug	8.0	0.27	0.7	0.02	8.7	0.29
Sep	2.8	0.09	2.5	0.07	5.3	0.16
Oct	2.7	0.09	0.4	0.01	3.1	0.10
Nov	1.2	0.04	0.4	0.01	1.6	0.06
Dec	2.7	0.10	3.9	0.13	6.6	0.23

The project reviewed the impacts that this generator would have on peak demand charges. Like the values of the displaced energy supply above, these impacts never exceeded a dollar for any calendar month.

9.6 Home Energy International 2.25 kW Energy Ball® V200

The City of Ellensburg further complemented its power and energy requirements with the power generated by a 2.25 kW Energy Ball wind generator (Home Energy International 2013) located at its renewable energy park. This is among the set of five residential-class wind systems tested by the city. The turbine is shown installed in Figure 9.21.

Figure 9.21. 2.25 kW Home Energy International Energy Ball V200 at the Ellensburg Renewable Energy Park (City of Ellensburg 2013a)

The City of Ellensburg decided quickly to not continue with the Energy Ball turbine system. In a November 1, 2013, report to its city council, it was reported that the system typically consumed more energy than it generated.

In Table 9.12, the annualized cost of the system and its components is estimated at $15.3K. Most of this expense was for the 2.25 kW Energy Ball wind turbine and upgrades to the SCADA monitoring subsystem. The next greatest costs were for consultancy, outreach, and equipment upgrades at the site.

Table 9.12. City of Ellensburg Costs of 2.25 kW Home Energy International Energy Ball V200 System

	Shared Usage of Component (%)	Annualized Component Cost ($K)	Allocated Annual Component Cost ($K)
2.25 kW Energy Ball Wind Turbine	100	4.9	4.9
SCADA and Monitoring	8	33.2	2.7
Consultants	8	18.5	1.5
Fiber Optic Communication	8	16.4	1.3
Outreach and Education	8	15.9	1.3
High-Voltage Equipment Installation	8	13.1	1.0
Low-Voltage Equipment Installation	8	7.8	0.6
Project Signs	8	7.4	0.6
Climate Data Equipment	8	6.7	0.5
Fencing	8	4.6	0.4
Administrative	8	5.1	0.4
Customer Service	8	1.0	0.1
Total Annualized Asset Cost			**$15.3K**

9.6.1 Data for the Energy Ball System

The City of Ellensburg monitored and submitted data from this wind generation system from the middle of September 2012 through October 2013. It remained functional until the city opted to stop testing wind systems altogether and removed it. The city’s source for this data was their site metering point “MP-6.” They submitted the energy generated in each 5-minute interval, and the project converted this data to average power for each interval. All the data received by the project has been plotted in Figure 9.22. Although the generator capacity is rated at 2.25 kW, it never appears to have generated more than about 0.9 kW during the project period.

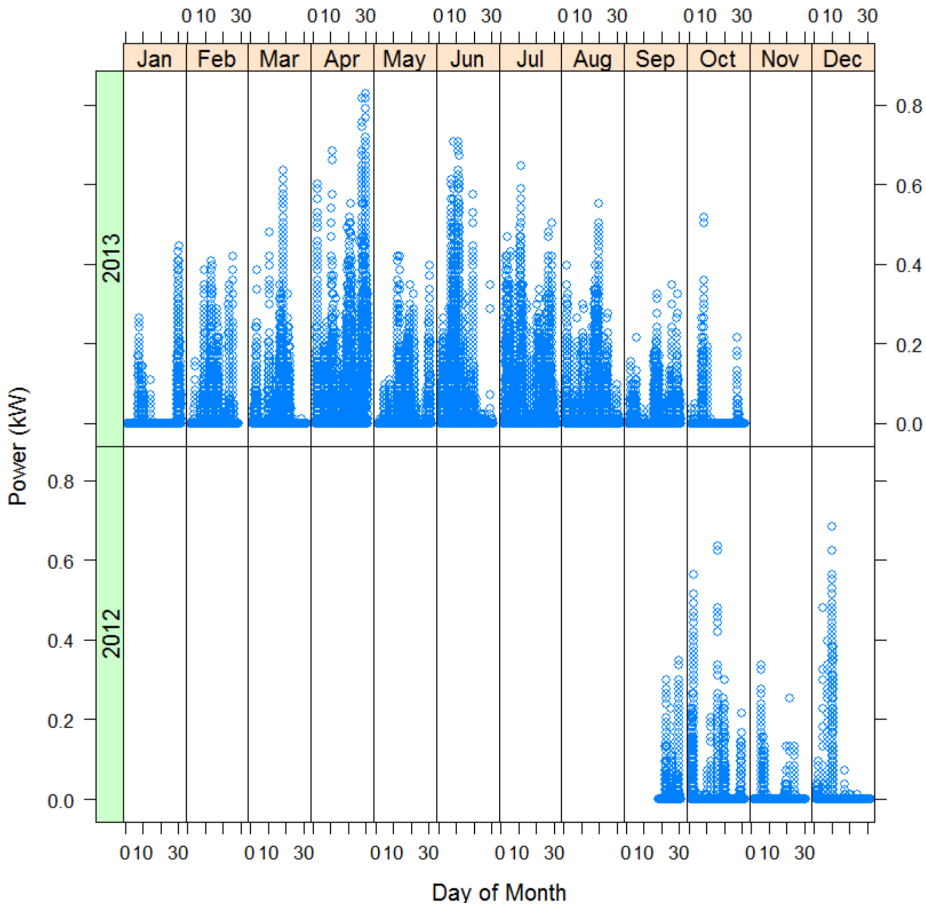
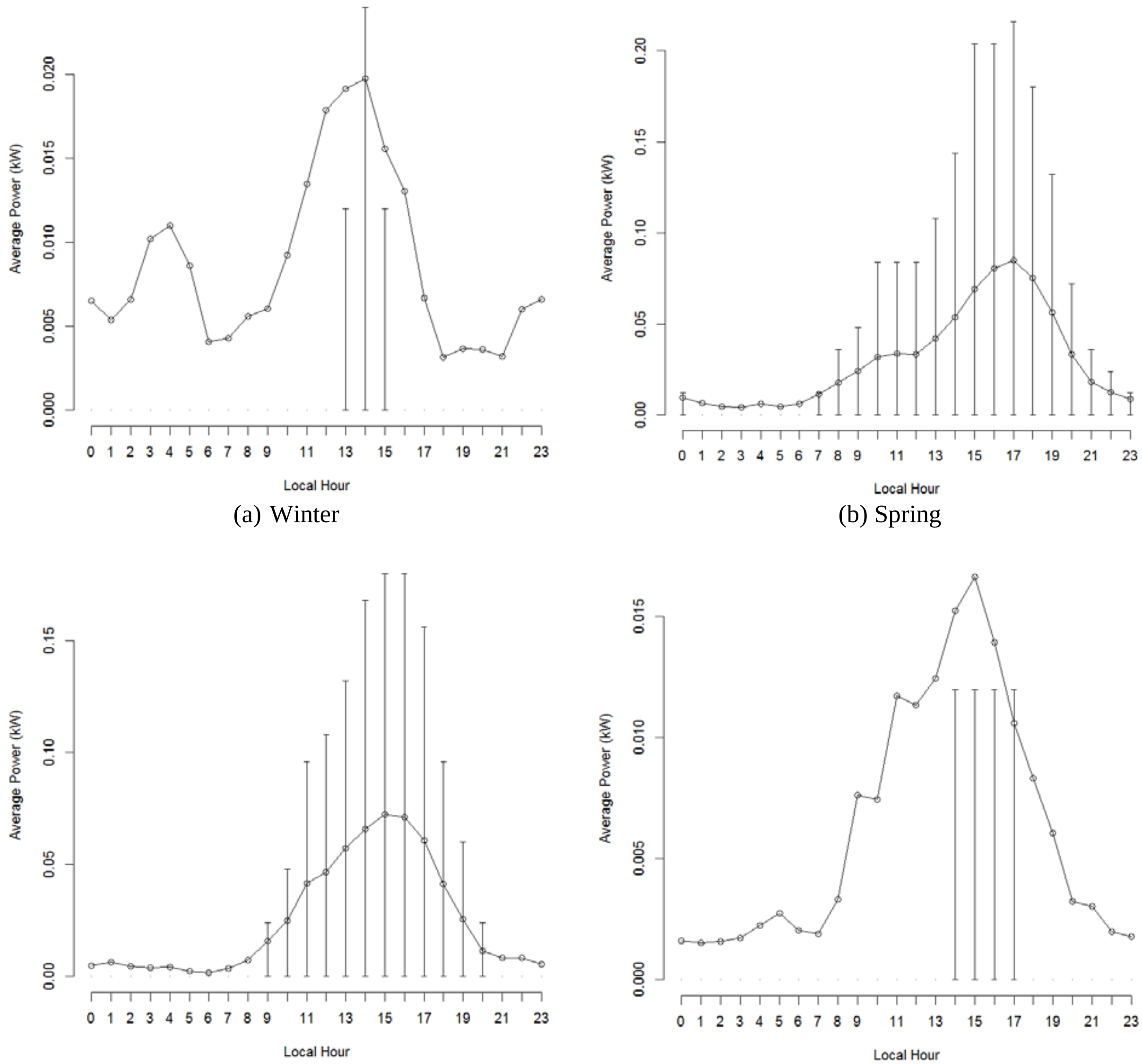


Figure 9.22. Power Generated by the Energy Ball V200 Wind Generator by Month

9.6.2 Performance of the Energy Ball Wind Generation System

The average seasonal diurnal power generation from this wind generator has been plotted in Figure 9.23. The generation is greatest in the afternoon during each of the four seasons. On average, 20 W is generated in winter during the hour that starts at 14:00 Pacific Time. Fall production is similar in magnitude. The other seasons' winds tend to produce more power, and the peak generation is somewhat later in the afternoons. The generation during winter and fall is so intermittent that the average generation does not often fall within the 16th to 84th percentiles. Generation in spring and summer is more predictable, so the average lies within this standard range.



(a) Winter (b) Spring (c) Summer (d) Fall

Figure 9.23. Diurnal Wind Power Generation Patterns for the Four Seasons for the Energy Ball System

The typical HLH and LLH energy generated each calendar month has been plotted in Figure 9.24. The uncertainty from one year to another could be estimated only for September and November because data was collected in both 2012 and 2013 for only these calendar months. The quantities of LLH and HLH energy track one another. The curves are quite jagged, which is probably due to natural wind variability within the year. The curve would likely have been smoother if data had been collected over multiple years.

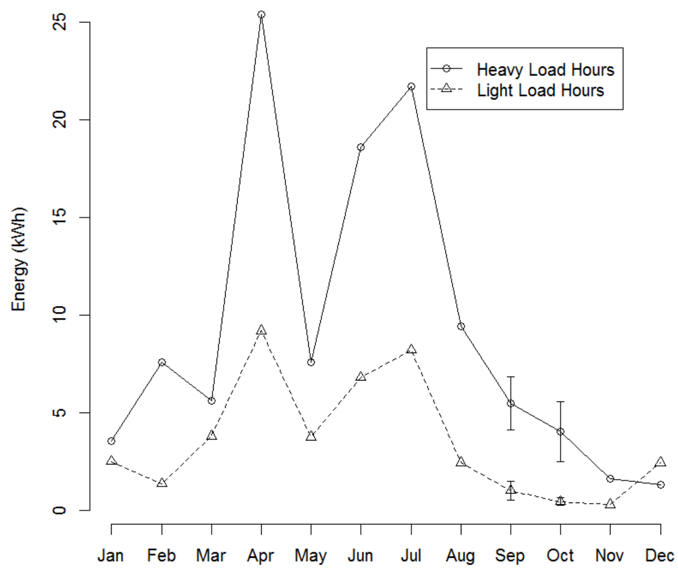


Figure 9.24. HLH and LLH Energy Generated Each Calendar Month by the Energy Ball V200 Wind Generation System

The energy generation from this wind generator has been summarized in Table 9.13. The value of the energy has been estimated using the HLH and LLH BPA load-shaping rates. Based on the 14 project months that this wind generator was monitored, it should be expected to generate 153 ± 10 kWh and thereby displace only about $4.16 ± 0.35 worth of electrical energy supply during a year, based on the BPA load-shaping rates and the energy supply that was displaced by the generator each month. The uncertainty in this calculation was estimated by extrapolating the uncertainty that was estimated for the two calendar months—September and October—that had data in both 2012 and 2013.

Table 9.13. Typical Calendar Month Energy Generation and its Monetized Value for the Energy Ball System

	HLH		LLH		Total	
	(kWh)	($)	(kWh)	($)	(kWh)	($)
Jan	4	0.13	3	0.08	6	0.21
Feb	8	0.28	1	0.04	9	0.32
Mar	6	0.17	4	0.10	9	0.26
Apr	25	0.66	9	0.19	35	0.84
May	8	0.16	4	0.05	11	0.21
Jun	19	0.42	7	0.10	25	0.52
Jul	22	0.66	8	0.20	30	0.86
Aug	9	0.32	2	0.07	12	0.39
Sep	5 ± 3	0.18 ± 0.09	1 ± 1	0.03 ± 0.03	6 ± 3	0.21 ± 0.10
Oct	4 ± 3	0.13 ± 0.10	0.5 ± 0.4	0.01 ± 0.01	4 ± 3	0.14 ± 0.10
Nov	2	0.06	0.3	0.01	2	0.07
Dec	1	0.05	2	0.08	4	0.13

The impact of this wind generation system on peak demand was evaluated, but it was determined that the impact was inconsequential—less than $1 per year.

9.7 Southwest Windpower 2.4 kW Skystream 3.7®

The City of Ellensburg still further complemented its power and energy requirements with the power generated by a 2.4 kW Southwest Windpower Skystream 3.7 wind generator (Southwest Windpower 2012) located at its renewable energy park. This is among the set of five residential-class wind systems tested by the city during the project. The turbine is shown installed in Figure 9.25.

The Windpower Skystream wind system remained functional until the city opted to stop testing wind systems altogether and removed it in late 2013.

The annualized costs of the system and its components are listed in Table 9.14. The total system was estimated to cost $14.9K on an annualized basis. The greatest cost was for the turbine generator itself, followed by the costs of communication upgrades, consultancy, electrical hardware upgrades, and other site upgrades.

Figure 9.25. 2.4 kW Skystream Wind System at the Ellensburg Renewable Energy Park (City of Ellensburg 2013a)

Table 9.14. City of Ellensburg Costs of the 2.4 kW Southwest Windpower Skystream 3.7 System

	Shared Usage of Component (%)	Annualized Component Cost ($K)	Allocated Annual Component Cost ($K)
2.4 kW Skystream Wind Turbine	100	4.5	4.5
SCADA and Monitoring	8	33.2	2.7
Consultants	8	18.5	1.5
Fiber Optic Communication	8	16.4	1.3
Outreach and Education	8	15.9	1.3
High-Voltage Equipment Installation	8	13.1	1.0
Low-Voltage Equipment Installation	8	7.8	0.6
Project Signs	8	7.4	0.6
Climate Data Equipment	8	6.7	0.5
Fencing	8	4.6	0.4
Administrative	8	5.1	0.4
Customer Service	8	1.0	0.1
Total Annualized Asset Cost			**$14.9K**

In a report dated November 1, 2013, posted on the city's website, the one-time cost of the Skystream system was $24,770 (City of Ellensburg 2013b).

9.7.1 Data for the Southwest Windpower System

All the power data collected by the city from site metering point "MP-15" are shown in Figure 9.26. Data became available for the period from late August 2012 into October 2013. The power achieved and even exceeded the 2.3 kW nameplate rating many times over this period. However, only a fraction of the nameplate power rating was achieved during the first three months of data collection. If this was a problem with the early installation that was later fixed, this data may have caused the project to understate the energy production that should be expected during fall months.

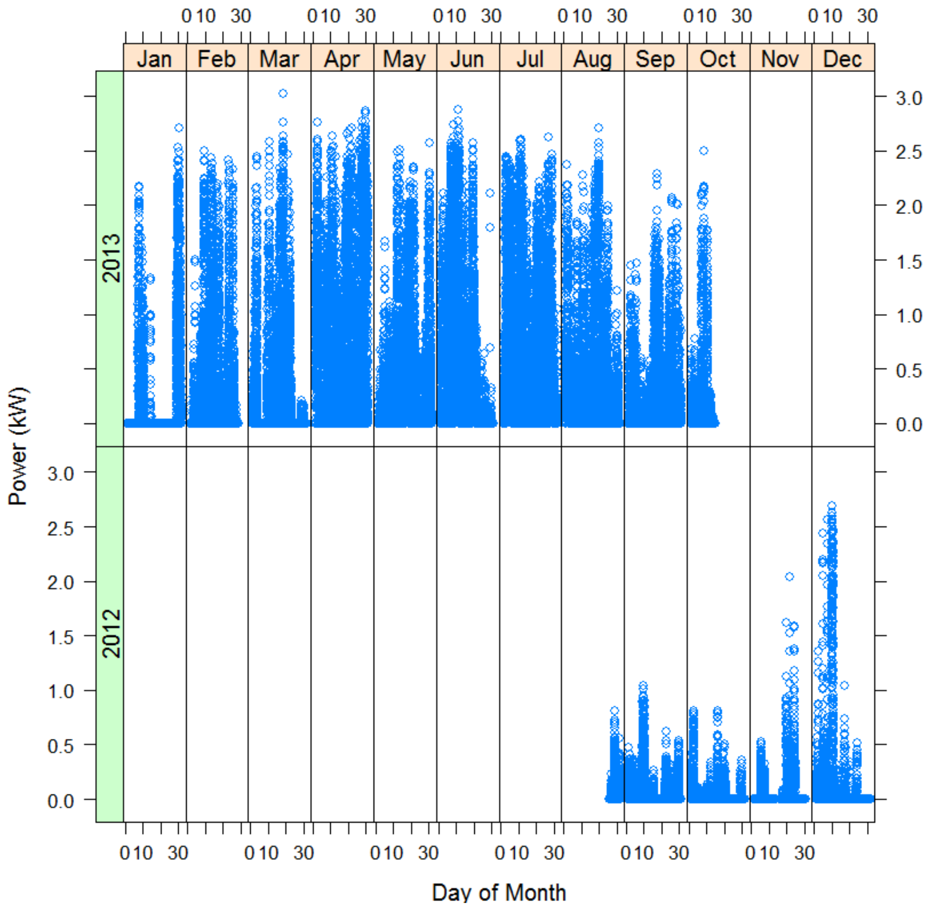


Figure 9.26. Wind Power Data Submitted by the City of Ellensburg for the Southwest Windpower System

9.7.2 Performance of the Southwest Windpower System

The power generated by the wind turbine system is plotted as a function of wind speed in Figure 9.27. All the project's 5-minute power data for this wind system was plotted against the corresponding wind speed data from the 85-foot metrology tower at the renewable energy park near the turbines. The error bars represent the range of power measurements from the 16th to 84th percentile at each wind speed. The wind speeds were found to have been discretized at the plotted wind-speed magnitudes. The characteristic curve is informative, but the project does not believe the wind speed sensors to have been thoroughly calibrated to ensure wind speed accuracy.

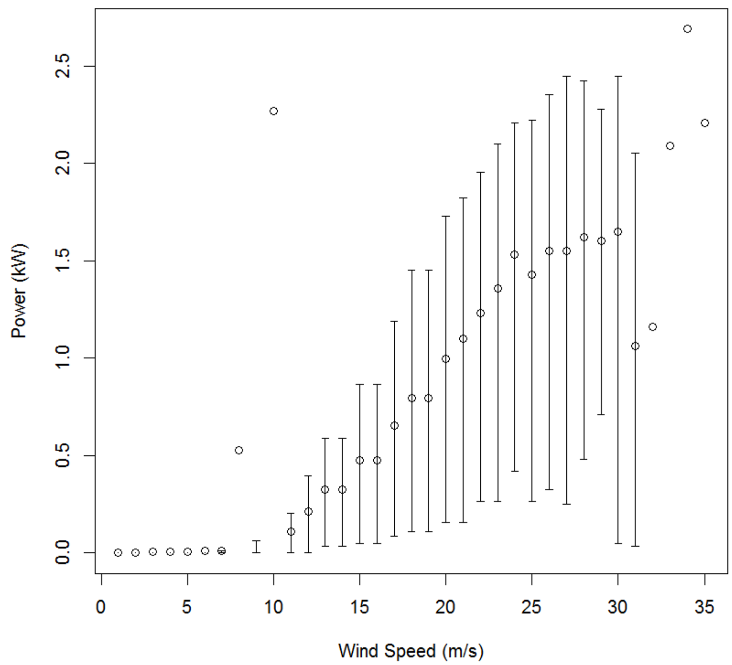
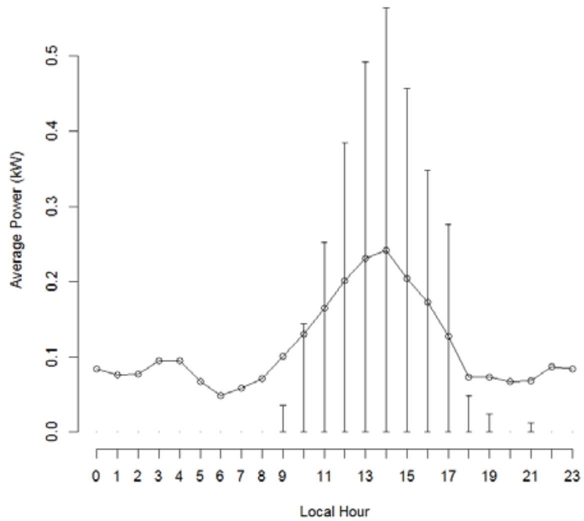
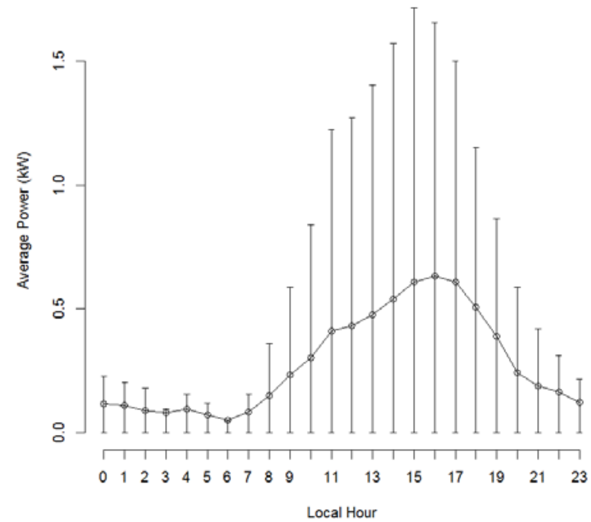


Figure 9.27. Power Generated by the Southwest Windpower Skystream 3.7 System as a Function of Wind Speed at 85 Feet

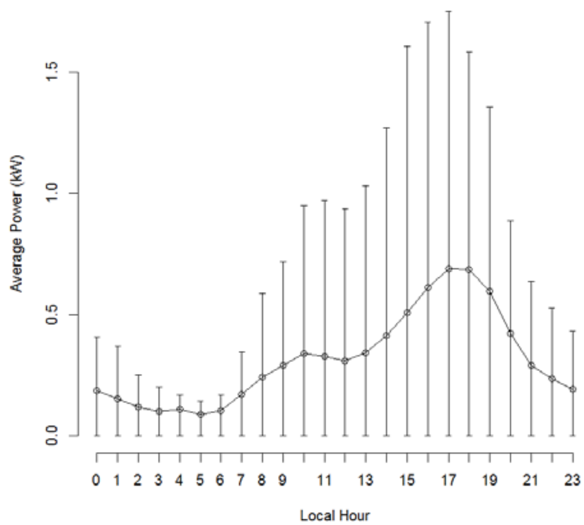
The typical hourly generation patterns for this wind turbine system are shown for each season in Figure 9.28. In this figure, Hour 0 is the hour that begins at midnight local Pacific Time. As has been shown for other of the site's wind turbine systems, wind production at the site peaks in the afternoon. Nighttime and morning wind generation are less reliable than afternoon generation.



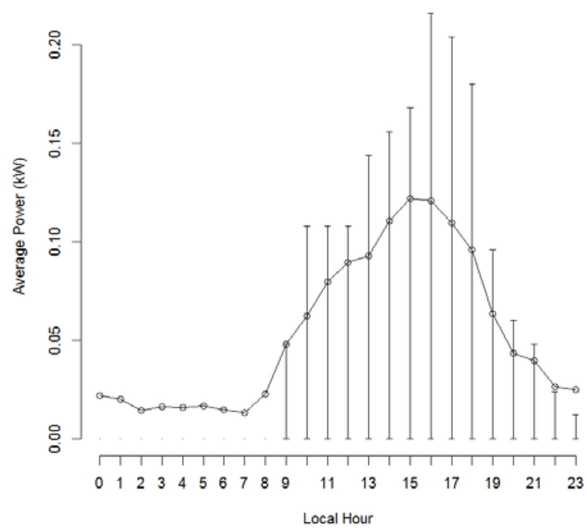
(a) Winter



(b) Spring



(c) Summer



(d) Fall

Figure 9.28. Average Diurnal Wind Power Generation by Season for the Southwest Windpower Generator

Figure 9.29 shows the impact of these diurnal generation patterns on the total monthly HLH and LLH energy production by this wind system. For those several calendar months for which the project collected data for more than one year, the standard error bars have been included. It would be interesting to learn whether a longer data collection period would smoothen the pattern that is observed here during spring and summer months.

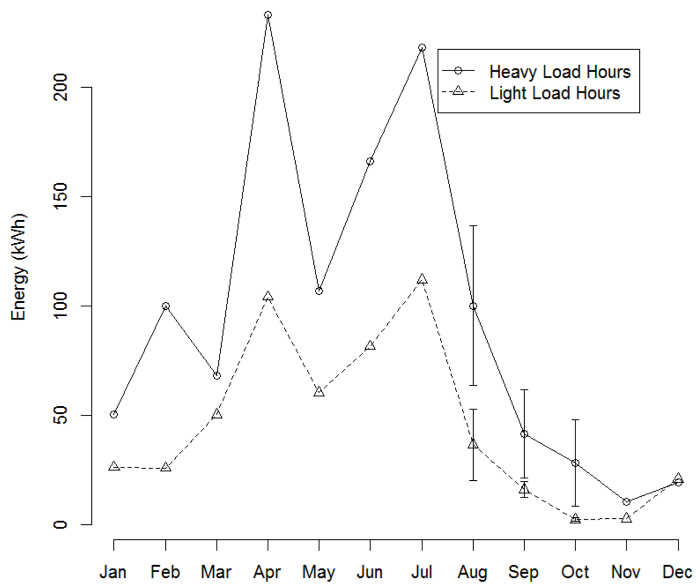


Figure 9.29. Observed HLH and LLH Energy Generated Each Calendar Month by the Southwest Windpower Generator

Energy generation each calendar month was compiled and is reported in Table 9.15 for HLH, LLH, and both hour types. Based on the monthly energy summary in this table, the wind generator system should be expected to generate about 1.7 ± 0.2 MWh per year. The annual value of this energy, based on the unit costs of HLH and LLH energy that would otherwise be supplied by BPA at its load-shaping rates is $45.13 ± 6.44.

The city's analysis led them to conclude that this turbine system would produce 1.33 MWh per year, somewhat less than what the project concluded (City of Ellensburg 2013c).

Table 9.15. Typical Energy Generated Each Month and the Monetary Value of the Displaced Energy for the Southwest Windpower System

	HLH		LLH		Total	
	(kWh)	($)	(kWh)	($)	(kWh)	($)
Jan	50	1.90	26	0.81	77	2.71
Feb	100	3.69	26	0.79	126	4.48
Mar	68.3	2.07	50	1.26	118	3.32
Apr	233	6.01	104	2.1	338	8.11
May	107	2.24	60	0.79	167	3.03
Jun	166	3.78	82	1.19	248	4.97
Jul	218	6.66	112	2.74	330	9.40
Aug	100	3.41 ± 2.48	37 ± 32	0.99 ± 0.87	137 ± 80	4.40 ± 2.63
Sep	41 ± 40	1.39 ± 1.35	16 ± 7	0.45 ± 0.2	58 ± 41	1.84 ± 1.37
Oct	28 ± 40	0.89 ± 1.25	2 ± 2	0.06 ± 0.05	31 ± 40	0.96 ± 1.26
Nov	10	0.37	3	0.09	13	0.46
Dec	20	0.76	21	0.69	40	1.45

As has been shown for other wind systems being tested by the City of Ellensburg, the impact of the generation on peak demand and demand charges is negligible. The monthly impacts are summarized in Table 9.16. Negative dollar values in this table represent reductions in the estimated demand charges that the city would incur. The sum impact is an increase in the total yearly demand charges by $0.60 ± 2.00.

Table 9.16. Typical Monthly Impact of Generation on Peak Demand for the Southwest Windpower System. Negative expenses are reductions in BPA demand charges.

	Δ Demand (kW)	Δ aHLH (kWh/h)	Δ Expense ($)
Jan	0.1 ± 0.5	0.1	0.11
Feb	0.2 ± 0.5	0.3	0.65
Mar	0.1 ± 0.4	0.2	0.30
Apr	0.3 ± 0.6	0.6	2.24
May	0.3 ± 0.8	0.3	−0.55
Jun	0.6 ± 1.1	0.4	−1.02
Jul	0.6 ± 1.1	0.5	−0.32
Aug	0.3 ± 0.8	0.2 ± 0.2	−1.04 ± 0.85
Sep	0.2 ± 0.5	0.1 ± 0.1	−0.59 ± 0.50
Oct	0 ± 0.1	0.1 ± 0.1	0.33 ± 0.16
Nov	0 ± 0.1	0	0.17
Dec	0 ± 0.1	0	0.32

9.8 Bergey WindPower 10 kW Excel 10

The City of Ellensburg further complemented its power and energy requirements with the power generated by a 10 kW Bergey WindPower Excel 10 wind generator (Bergey WindPower 2012) located at its renewable energy park. This is one of the four commercial-class wind systems tested by the city. The system was functioning well at the time the city chose to remove all the site's wind generator systems in late 2013. The turbine is shown installed in Figure 9.30.

The annualized costs of the system and its components are listed in Table 9.17. The total system costs $29.9K per year on an annualized basis. The greatest cost was for the turbine generator, followed by the costs of communication upgrades, consultancy, electrical hardware upgrades, and other site upgrades.

Figure 9.30. 10 kW Bergey Wind System at the Ellensburg Renewable Energy Park (City of Ellensburg 2013a)

Table 9.17. City of Ellensburg Costs of 10 kW Bergey WindPower Excel 10 System

	Shared Usage of Component (%)	Annualized Component Cost ($K)	Allocated Annual Component Cost ($K)
10 kW Bergey Wind Turbine	100	15.2	15.2
SCADA and Monitoring	11	33.2	3.7
Consultants	11	18.5	2.0
Fiber Optic Communication	11	16.4	1.8
Outreach and Education	11	15.9	1.7
High-Voltage Equipment Installation	11	13.1	1.4
Low-Voltage Equipment Installation	11	7.8	0.9
Climate Data Equipment	11	6.7	0.7
Project Signs	11	7.4	0.8
Administrative	11	5.1	0.6
Fencing	11	4.6	0.5
Customer Service	11	1.0	0.1
Total Annualized Asset Cost			**$29.9K**

In a report dated November 1, 2013, posted on the city website, the one-time cost of the Bergey system was stated as $96,350 (City of Ellensburg 2013c).

9.8.1 Data for the Bergey WindPower System

All of the project's power generation data from the Bergey WindPower wind system is shown in Figure 9.31. The data was collected from the site metering point "MP-8." The system achieved and even exceeded its 10 kW nameplate power generation capacity often during this data collection period. Data was collected for almost a year, from mid-November 2012 until the end of October 2013.

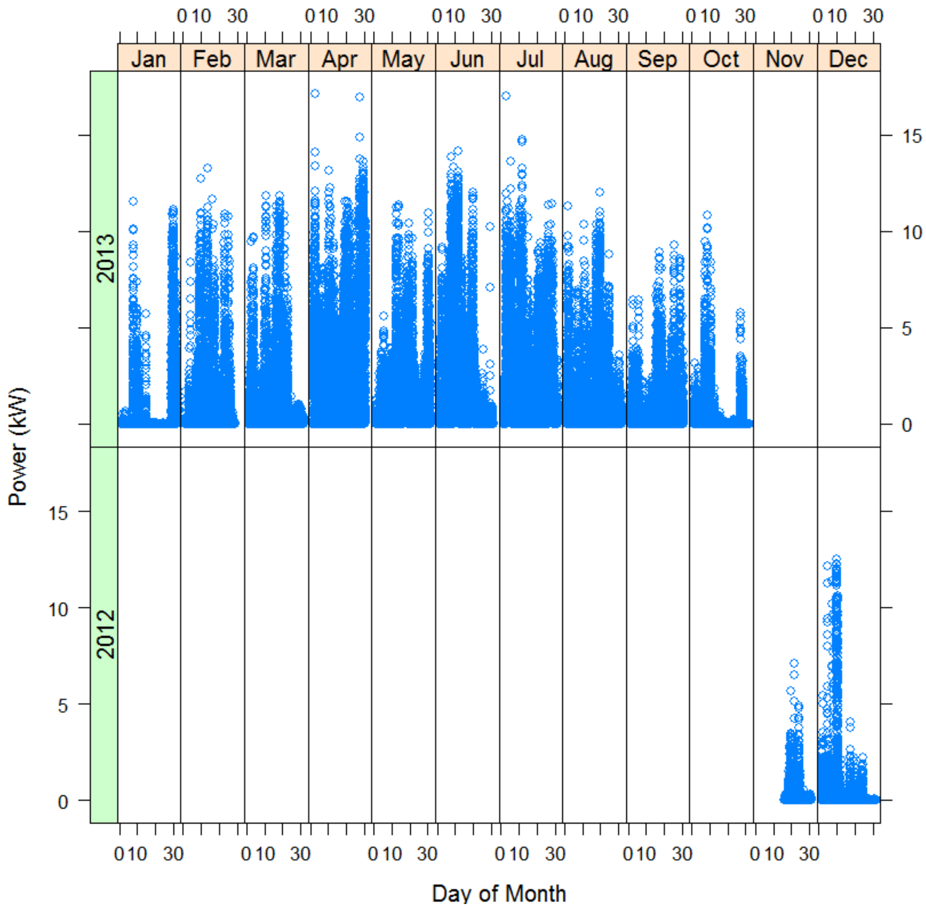


Figure 9.31. Power Generation Data for the Bergey WindPower Excel 10

9.8.2 Performance of the Bergey WindPower System

The project calculated the characteristic power generated by the Bergey wind generator as a function of wind speed. Figure 9.32 shows the result of this calculation. All the project's 5-minute interval power data was used along with the corresponding wind speeds that were measured 85 feet above ground at the project's metrology tower at the renewable energy park near the turbine. The markers are at the average generated power for the given wind speeds. The error bars represent the range of power data from the 16th through the 84th percentile. Wind speeds were found to have been discretized at 1 m/s increments.

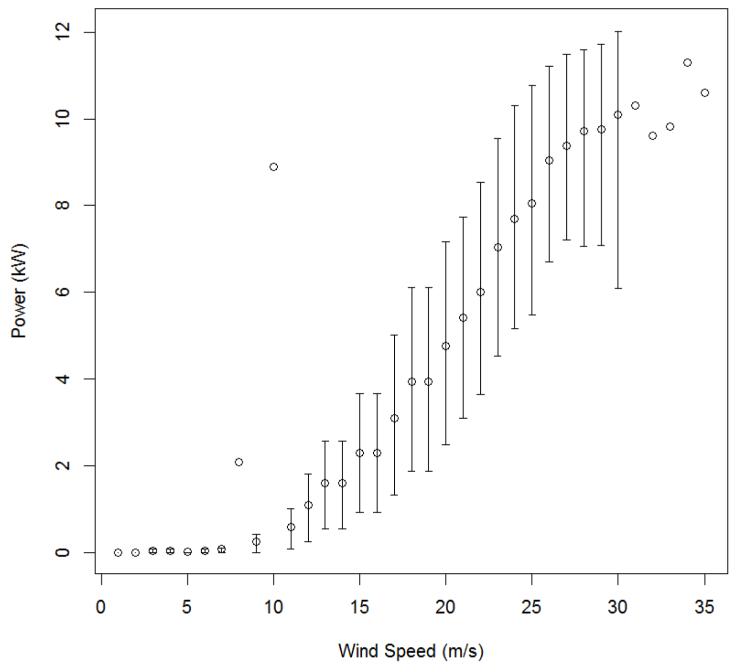


Figure 9.32. Characteristic Power Generation of the Bergey Windpower System as a Function of Wind Speed Measured at 85 Feet

The average diurnal power generation patterns and variability of the output power have been plotted for each season in Figure 9.33. The hour value 0 represents the hour that begins midnight local Pacific Time. Morning power generation during winter and fall is so sporadic that those hours' average power generation magnitudes do not fall within the 16th and 84th percentile data range. Power generation is much more predictable the other months. Peak generation often occurs during afternoon hours. The average power generation is about 3 kW at the 17:00 hour during summer.

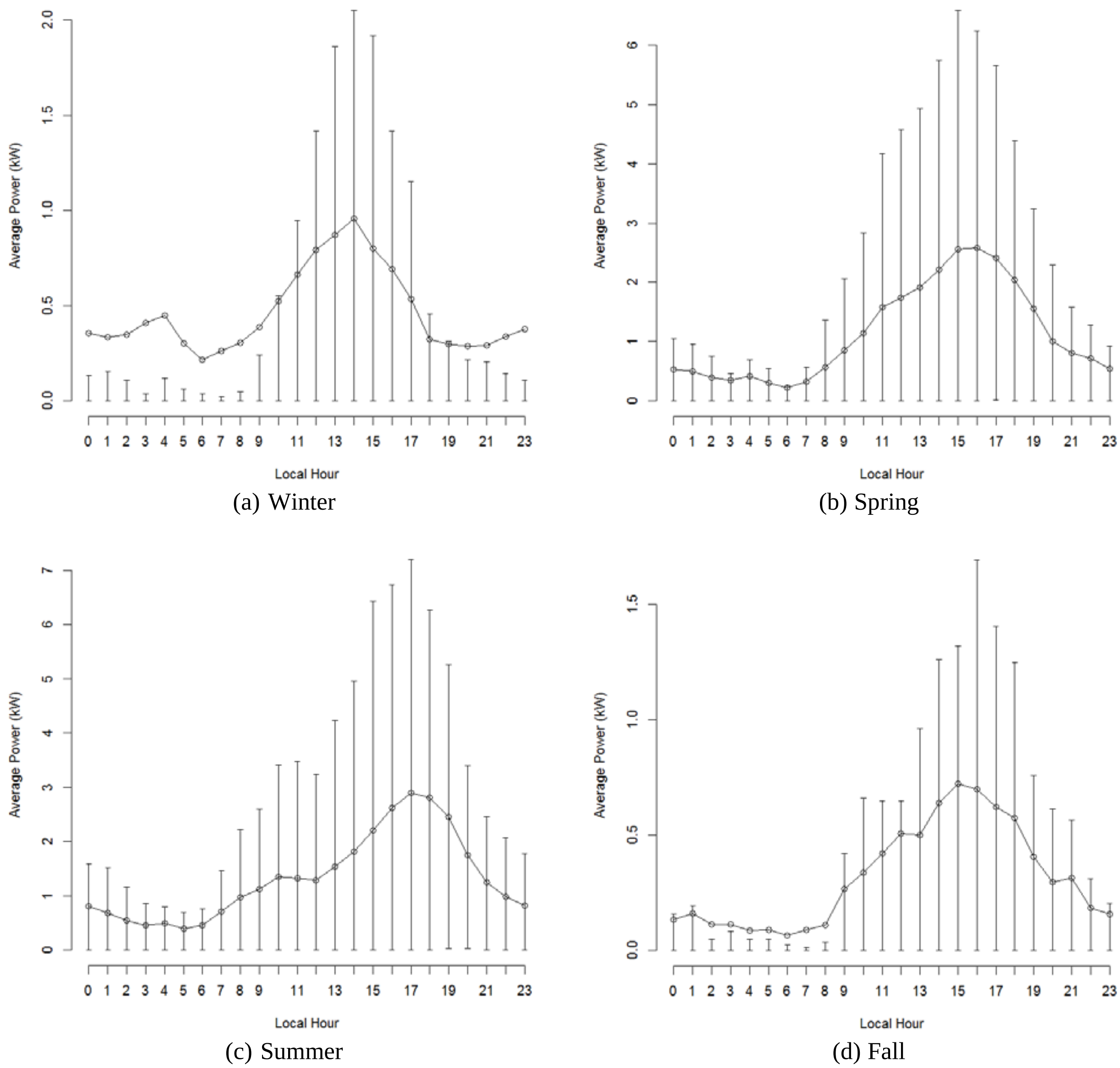


Figure 9.33. Hourly Power Generation of the Bergey Windpower System for Each Season

Figure 9.34 shows the impact of these diurnal generation patterns on the total monthly HLH and LLH energy production by this wind system.

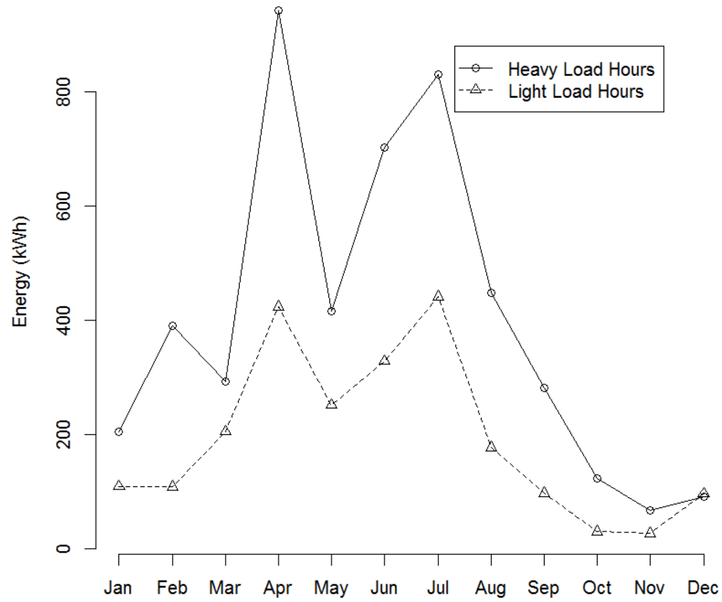


Figure 9.34. Amounts of HLH and LLH Energy Generated each Calendar Month by the Bergey Windpower System

Using the average power generation during HLHs and LLHs each month and the numbers of these hours each month of 2013, the project calculated the HLH, LLH, and combined energy generation for each calendar month. Based on the almost full year of operation that is represented in Table 9.18, this generator would generate 7.1 MW and thereby displace $191 worth of supply energy that the city would have otherwise purchased from BPA. The variability of this estimate from one year to another cannot be estimated well because less than one year of data was collected from the operation of this generator.

Table 9.18. HLH and LLH Energy Generation for Each Month and the Value of the Energy Supply that it Displaced for the Bergey Windpower System

	HLH		LLH		Total	
	(kWh)	($)	(kWh)	($)	(kWh)	($)
Jan	205	7.76	109	3.35	315	11.11
Feb	390	14.39	108	3.31	498	17.70
Mar	292	8.82	205	5.14	497	13.96
Apr	942	24.27	423	8.50	1360	32.77
May	415	8.71	251	3.29	666	12.00
Jun	702	15.95	328	4.78	1030	20.73
Jul	829	25.26	441	10.80	1270	36.07
Aug	447	15.18	177	4.78	623	19.96
Sep	281	9.45	97	2.70	378	12.15
Oct	123	3.89	30	0.82	153	4.72
Nov	68	2.41	27	0.84	94	3.24
Dec	92	3.56	96	3.21	188	6.77

In summer months, the operation of the wind turbine tended to reduce the determinant on which demand charges are applied, but the overall yearly net impact of the generation on incurred demand charges was estimated to be only $0.13. The use of wind generation neither helps nor hurts the calculation of demand charges throughout the entire year, as summarized in Table 9.19 for each calendar month.

Table 9.19. Estimated Monthly Impact on Peak Demand for the Bergey WindPower System

	Δ Demand (kW)	Δ aHLH (kWh/h)	Δ Expense ($)
Jan	0.5 ± 2.1	0.5	0.19
Feb	0.8 ± 2.1	1.0	2.54
Mar	0.6 ± 1.9	0.7	1.31
Apr	1.0 ± 2.3	2.3	9.82
May	1.4 ± 3.1	1.0	−2.36
Jun	2.6 ± 4.9	1.8	−5.55
Jul	2.1 ± 4.0	2.0	−1.10
Aug	1.5 ± 3.5	1.0	−4.52
Sep	1.1 ± 2.3	0.7	−4.15
Oct	0.1 ± 0.6	0.3	1.34
Nov	0.0 ± 0.3	0.2	1.30
Dec	0.1 ± 0.6	0.2	1.31

9.9 Tangarie Alternative Power 10 kW Gale® Wind Turbine

The City of Ellensburg further complemented its power and energy requirements with the power generated by a 10 kW Tangarie Alternative Power Gale wind generator (Tangarie Alternative Power 2013) located at its renewable energy park. This is one of the four commercial-class wind systems tested by the city. The turbine is shown installed in Figure 9.35.

Figure 9.35. 10 kW Tangarie Wind System Installed at the Ellensburg Renewable Energy Park (City of Ellensburg 2013a)

The last credible data from this wind turbine was received August 8, 2012. The wind turbine's tower was blown over on April 29, 2013. See Figure 9.36. After this event, the City of Ellensburg chose to entirely halt its testing of wind systems and removed all its wind systems due to its concerns for the safety of pedestrians near the site.

Figure 9.36. Collapsed Tangarie Wind System

The annualized costs of the system and its components are listed in Table 9.20. The total system costs $34.2K per year on an annualized basis. The greatest cost was for the turbine generator, followed by the costs of communication upgrades, consultancy, electrical hardware upgrades, and other site upgrades.

Table 9.20. City of Ellensburg Costs of 10 kW Tangarie Alternative Power Gale Wind Turbine System

	Shared Usage of Component (%)	Annualized Component Cost ($K)	Allocated Annual Component Cost ($K)
10 kW Tangarie Wind Turbine	100	20.0	20.0
SCADA and Monitoring	11	33.2	3.7
Consultants	11	18.5	2.0
Fiber Optic Communication	11	16.4	1.8
Outreach and Education	11	15.9	1.7
High-Voltage Equipment Installation	11	13.1	1.4
Low-Voltage Equipment Installation	11	7.8	0.9
Project Signs	11	7.4	0.8
Climate Data Equipment	11	6.7	0.7
Administrative	11	5.1	0.6
Fencing	11	4.6	0.5
Customer Service	11	1.0	0.1
Total Annualized Asset Cost			**$34.2K**

9.9.1 Data for the Tangarie System

Useful data were collected at site metering point “MP-9” during only two months of 2012. This power data is shown in Figure 9.37 for July and August 2012.

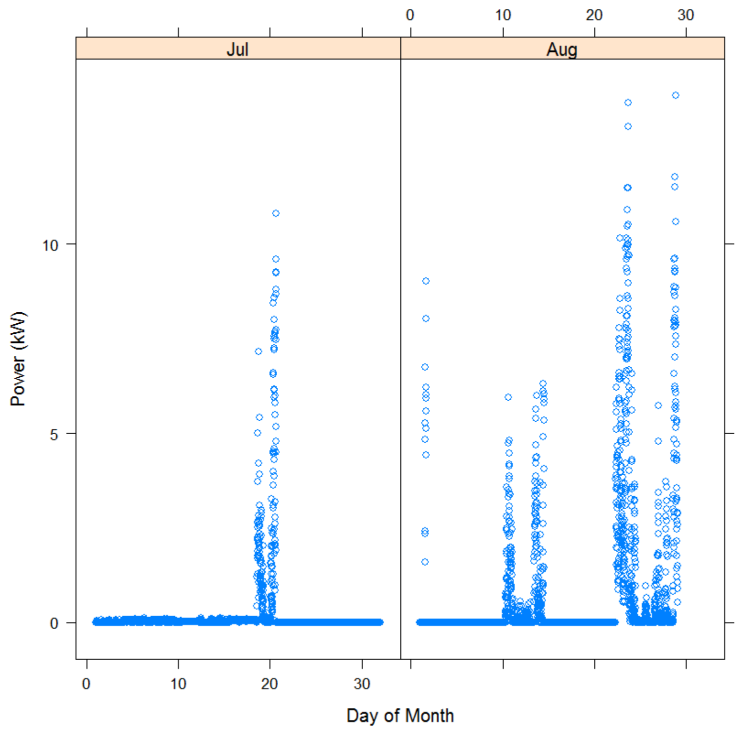


Figure 9.37. Tangarie Wind System Power Generation for the Two Months of 2012 that Data was Available

9.9.2 Performance of the Tangarie System

Figure 9.38 shows the average hourly power production from the two summer months that the wind turbine was operational.

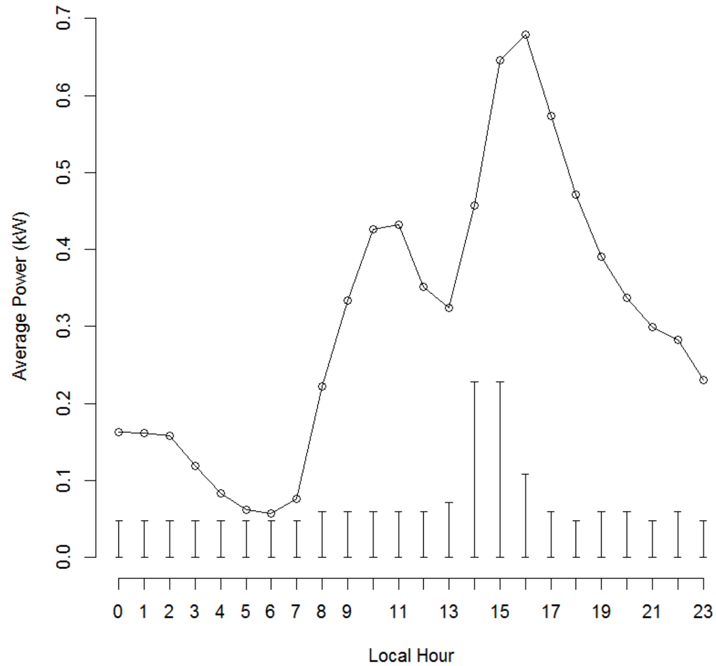


Figure 9.38. Average Diurnal Power Generation for July and August 2012 while the Tangarie Wind Turbine was Operational

Referring to Table 9.21, the wind system could have generated 474 kWh during July and August, and the value of this energy, based on the value of load-shaping supply energy that the city would otherwise purchase, would be $15.23. Given that the generator functioned for only two months before its tower toppled, the project will not estimate the total energy that might have been generated or the total value of the yearly energy it might have displaced.

Table 9.21. Quantities of HLH and LLH Energy Generated During the Two Months of Operation for the Tangarie System

	HLH		LLH		Total	
	(kWh)	($)	(kWh)	($)	(kWh)	($)
Jul	75	2.28	18	0.43	92	2.71
Aug	314	10.66	69	1.86	382	12.52

Referring to Table 9.22, the wind system could have reduced the city’s demand charges somewhat, but the project will not estimate a yearly impact based on its limited operational data.

Table 9.22. Impact on Peak Demand for the Two Months of Operation of the Tangarie System

	Δ Demand (kW)	Δ aHLH (kWh/h)	Δ Expense ($)
Jul	0.2	0.2	0.2
Aug	1.2	0.7	−4.84

9.10 Urban Green Energy 4 kW Wind Turbine

The City of Ellensburg further complemented its power and energy requirements with the power generated by a 4 kW Urban Green Energy (Urban Green Energy 2015) wind generator located at its renewable park. This is one of the four commercial-class wind systems tested by the city. The turbine is shown installed in Figure 9.39.

Figure 9.39. 4 kW Urban Green Energy Wind System at the Ellensburg Renewable Energy Park (City of Ellensburg 2013a)

The Urban Green Energy generator failed. The unit had a bearing failure causing a grinding noise while operating. The city's attempts to get it serviced failed. The unit ceased to generate electricity and was shut down.

The annualized costs of the system and its components are listed in Table 9.23. The total system cost $26.8K per year on an annualized basis. The greatest cost was for the turbine generator, followed by the costs of communication upgrades, consultancy, electrical hardware upgrades, and other site upgrades.

Table 9.23. City of Ellensburg Costs of 4 kW Urban Green Energy Wind Turbine System

	Shared Usage of Component (%)	Annualized Component Cost ($K)	Allocated Annual Component Cost ($K)
4 kW Urban Green Energy Wind Turbine	100	12.5	12.5
SCADA and Monitoring	11	33.2	3.7
Consultants	11	18.5	2.0
Fiber Optic Communication	11	16.4	1.8
Outreach and Education	11	15.9	1.7
High-Voltage Equipment Installation	11	13.1	1.4
Low-Voltage Equipment Installation	11	7.8	0.9
Project Signs	11	7.4	0.8
Climate Data Equipment	11	6.7	0.7
Administrative	11	5.1	0.6
Fencing	11	4.6	0.5
Customer Service	11	1.0	0.1
Total Annualized Asset Cost			**$26.8K**

9.10.1 Data for the Urban Green Energy System

All the power generation data observed for the Urban Green Energy wind turbine system is shown in Figure 9.40. Usable data was gathered and delivered for a period from mid-July 2012 until mid-March 2013, a period of about eight months. The source of this data was site metering point “MP-10.” Spring is poorly represented, with less than one month’s data.

The generated power magnitudes in 2012 were greater than those in 2013. While this variability could potentially be caused by natural wind variability, it is more likely that the performance of the wind generator degraded over the months that it was monitored by the project. The reduction in wind power was not similarly observed for other of the Ellensburg wind turbines. The initial 2012 power had at times approached the turbine’s nameplate capacity, but it never did so in 2013.

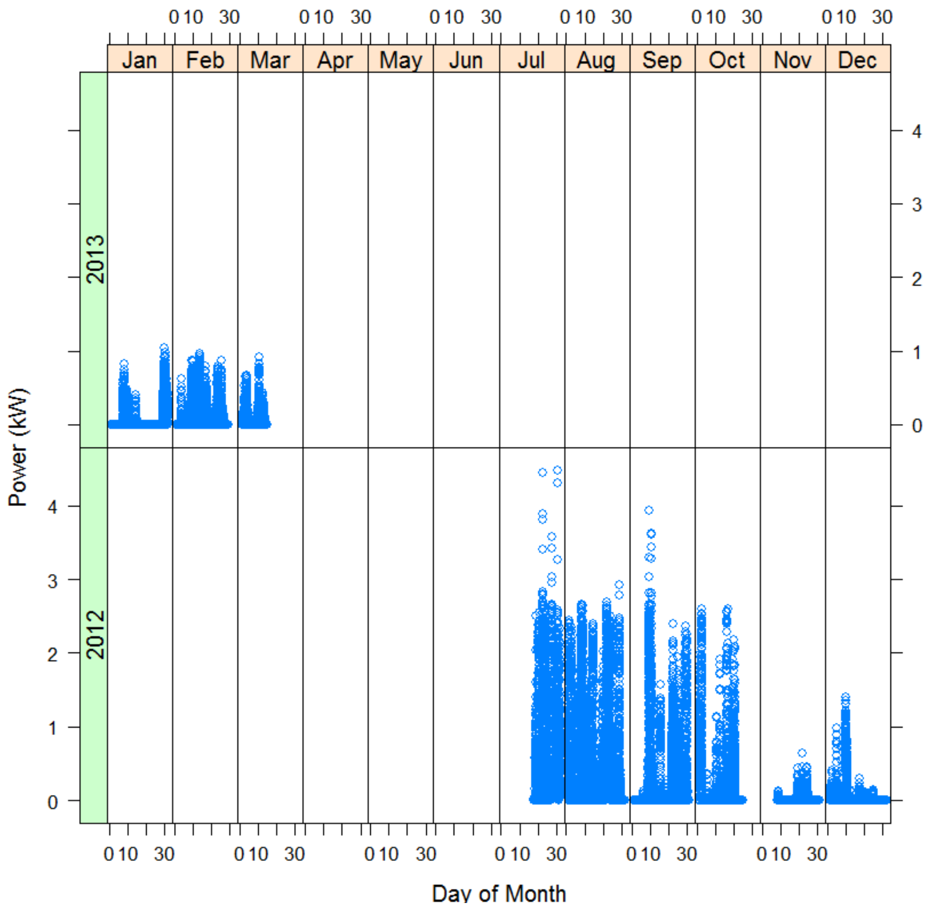
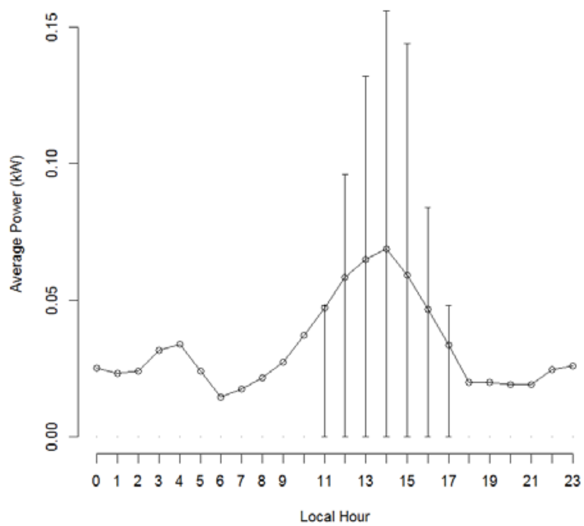


Figure 9.40. Power Generation for the Urban Green Energy Wind Turbine System

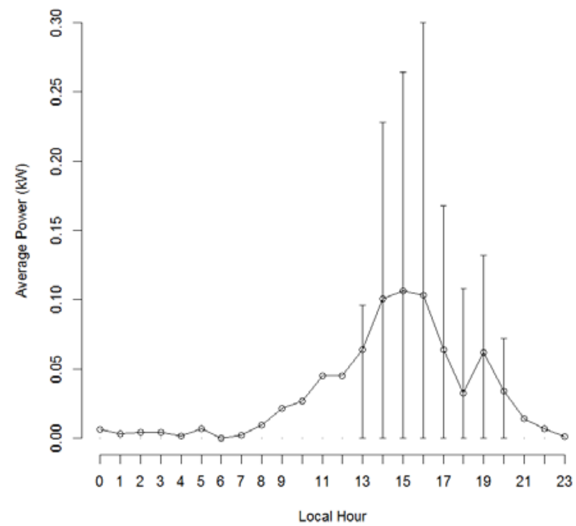
9.10.2 Performance of the Urban Green Energy System

Given the apparent change in the Urban Green Energy generator output after October 2012, analysts determined that a plot of the system's characteristic wind generation as a function of wind speed would likely be inaccurate, thus misleading. The project elected not to publish such a characteristic curve for this wind system.

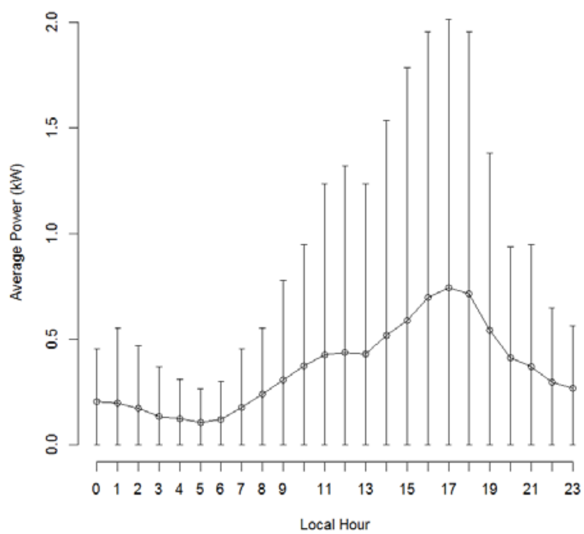
The average seasonal diurnal power generation has been plotted in Figure 9.41. The hour 0 refers to the hour that begins at midnight local Pacific Time. The error bars span the range of data from the 16th to the 84th percentiles. The summer plot includes only the available late July and August 2012 data. The spring plot includes only the data that was available from early March 2013. Analysts suspect that the system's performance degraded significantly after October 2012, so the generated diurnal power levels reported for fall, winter, and spring are probably inaccurate due to the degradation of the system's performance.



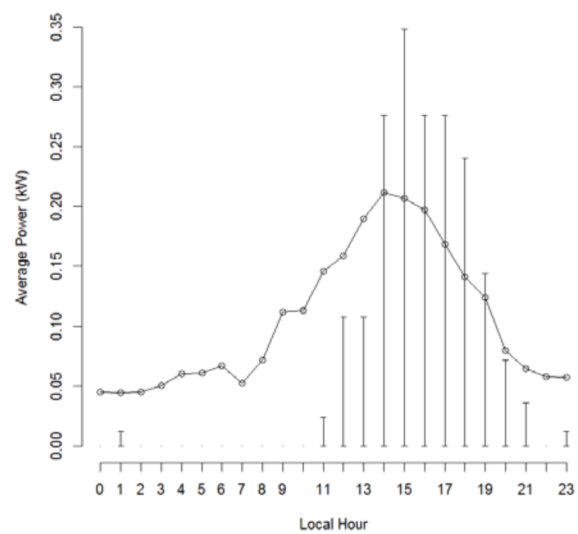
(a) Winter



(b) Spring



(c) Summer



(d) Fall

Figure 9.41. Average Diurnal Power Generation by Season for the Urban Green Energy System

The impacts of the diurnal generation patterns affected the average monthly HLH and LLH energy generation as is shown in Figure 9.42. Data was available for only eight of the 12 calendar months.

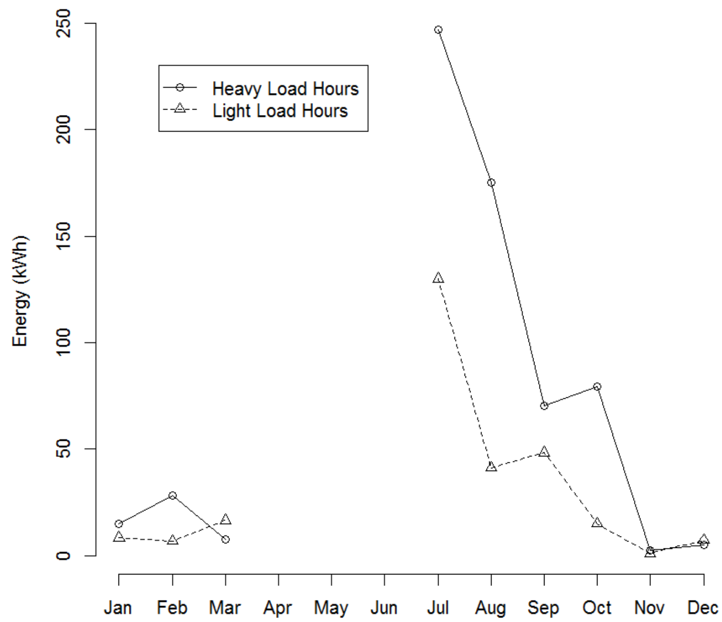


Figure 9.42. HLH and LLH Energy Production for the Urban Green Energy System, for Months that Data was Available

Annual generation would be 1.2 MWh, presuming the generator had operated throughout the year and the months of data collection were typical. The total annual value of displaced energy supply would be $26.93 if the generator had produced throughout the year and presuming the months of data collection can be used to represent the entire year. Table 9.24 lists the HLH, LLH, total energy, and the monetary values of these amounts of energy by calendar month. No estimate can be made for the variability in these calculations because data was collected for less than one year.

Table 9.24. Energy and Monetary Value of Displaced Energy Supply by Calendar Month for the Urban Green Energy System

	HLH		LLH		Total	
	(kWh)	($)	(kWh)	($)	(kWh)	($)
Jan	15	0.57	8	0.26	23	0.82
Feb	28	1.04	7	0.21	35	1.25
Mar	8	0.23	17	0.42	24	0.65
…	-	-	-	-	-	-
Jul	247	7.55	130	3.19	378	10.73
Aug	175	5.94	41	1.12	216	7.05
Sep	70	2.37	48	1.35	119	3.72
Oct	79	2.50	15	0.41	94	2.92
Nov	2	0.09	1	0.03	4	0.12
Dec	5	0.20	7	0.24	12	0.44

The monthly impacts of this wind generation on peak demand and demand charges have been listed in Table 9.25. The total impact of this renewable generation on peak demand might be a reduction of only about $2, based on the impacts during the nine calendar months that data was available to the project.

Table 9.25. Impact of Generation on Peak Demand for the Urban Green Energy System

	Δ Demand (kW)	Δ aHLH (kWh/h)	Δ Expense ($)
Jan	0.0 ± 0.2	0.0	0.01
Feb	0.1 ± 0.2	0.1	0.20
Mar	0.0 ± 0.0	0.0	0.08
…	-	-	-
Jul	0.6 ± 1.2	0.6	0.10
Aug	0.6 ± 1.2	0.4	−1.96
Sep	0.2 ± 0.8	0.2	−0.61
Oct	0.1 ± 0.4	0.2	0.64
Nov	0.0 ± 0.0	0.0	0.05
Dec	0.0 ± 0.0	0.0	0.09

9.11 Ventera Wind 10 kW VT10 Wind Turbine

The City of Ellensburg installed and operated a 10 kW Ventera Wind VT10 wind generator (Ventera Wind 2015) at its renewable park. This is one of four commercial-class wind systems that were tested by the city. Again, the city was investigating how its need for energy supply and demand might be impacted by renewable energy generation. The turbine is shown installed in Figure 9.43.

Figure 9.43. 10 kW Ventera Wind System at the Ellensburg Renewable Energy Park (City of Ellensburg 2013a)

The annualized costs of the system and its components are listed in Table 9.26. The total system costs $27.8K per year on an annualized basis. The greatest cost was for the turbine generator, followed by the costs of communication upgrades, consultancy, electrical hardware upgrades, and other site upgrades.

Table 9.26. City of Ellensburg Costs of 10 kW Ventera Wind Turbine System

	Shared Usage of Component (%)	Annualized Component Cost ($K)	Allocated Annual Component Cost ($K)
10 kW Ventera Wind Turbine	100	13.6	13.6
SCADA and Monitoring	11	33.2	3.7
Consultants	11	18.5	2.0
Fiber Optic Communication	11	16.4	1.8
Outreach and Education	11	15.9	1.7
High-Voltage Equipment Installation	11	13.1	1.4
Low-Voltage Equipment Installation	11	7.8	0.9
Project Signs	11	7.4	0.8
Climate Data Equipment	11	6.7	0.7
Administrative	11	5.1	0.6
Fencing	11	4.6	0.5
Customer Service	11	1.0	0.1
Total Annualized Asset Cost			**$27.8K**

In a report to its city council, the one-time installed cost of the Ventera Wind system was stated as $110,660 (City of Ellensburg 2013b).

9.11.1 Data for the Ventera Wind System

Referring now to Figure 9.44, the City of Ellensburg supplied a data stream of the energy generated every 5 minutes for the period from the beginning of January until late October 2013. The source of this data was the city's site metering point "MP-11." The system never generated its 10 kW nameplate capacity, but it occasionally exceeded an 8 kW power output.

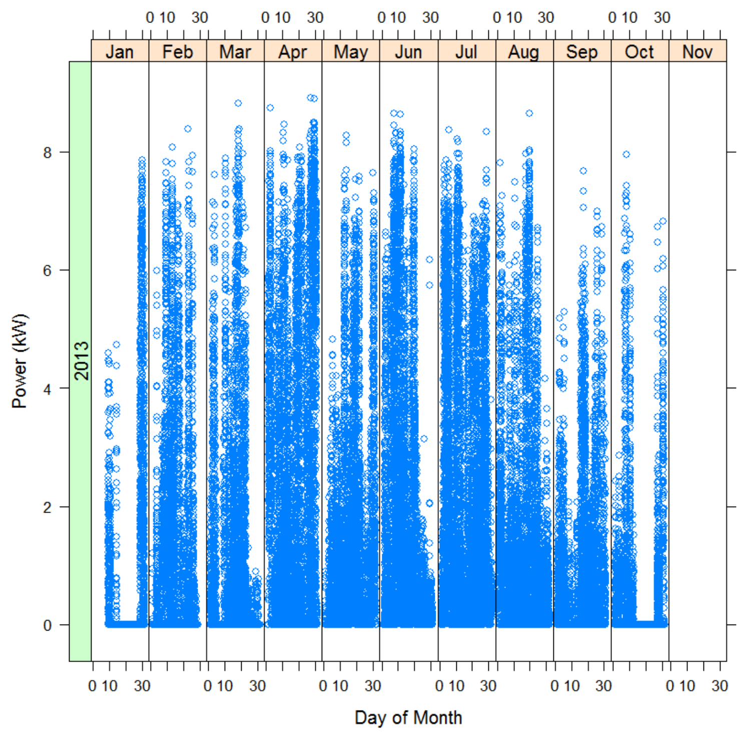


Figure 9.44. Available Power Generation Data from January through October 2013 for the Ventera Wind System

9.11.2 Performance of the Ventera Wind System

According to the Ventera Wind website, the generator is rated to start at winds of 2.7 m/s (6 mph) and generate 10 kW at wind speeds of 13 m/s (29 mph). It is advertised to withstand winds at 58 m/s (130 mph).

The characteristic power generation of the Ventera Wind system was checked by plotting power generation as a function of wind speed that was measured 36 feet above ground at the renewable energy park site. The results are shown in Figure 9.45. All of the available 5-minute power and wind-speed data were used for this figure. The markers represent average generated power at the given wind speed, and the error bars represent a span of data from the 16th to the 84th percentiles. Substantial power was generated at high winds, but the results fall short of the claims in the preceding paragraph.

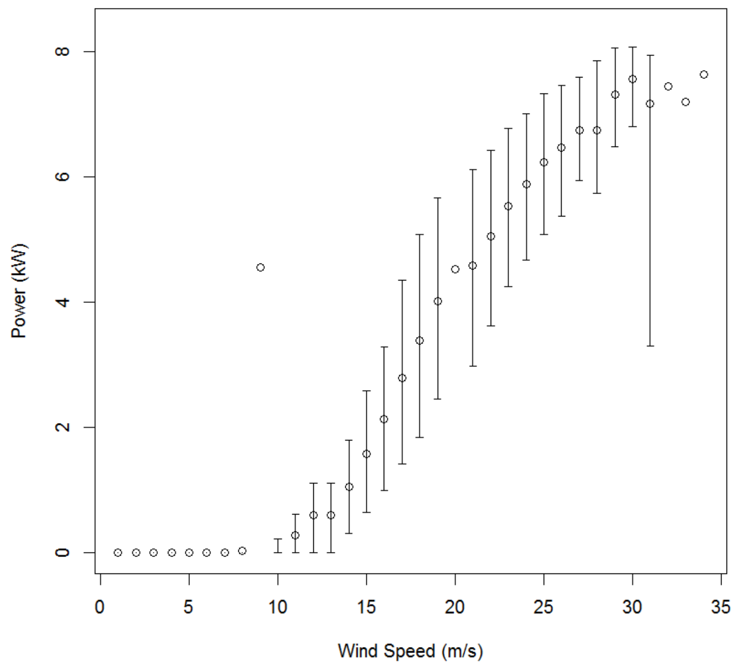
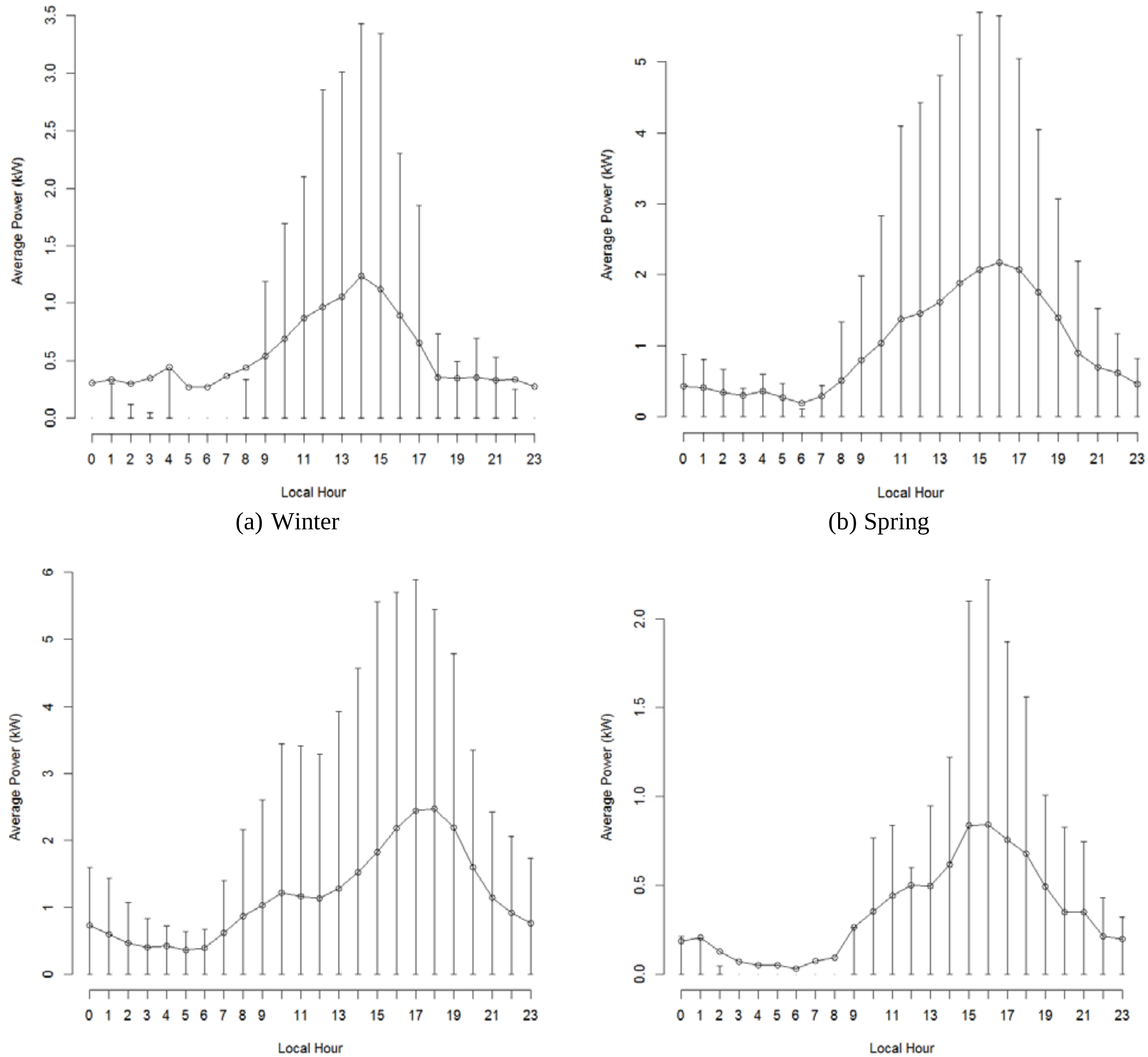


Figure 9.45. Characteristic Power Generation as a Function of Wind Speed at 36 Feet for the Ventera Wind System

The average hourly power generation each season is shown in Figure 9.46 for the Ventera Wind system. Unlike what has been found for other of the wind systems, the average power generation in these figures often lies within the 16th to 84th percentile data range. It would appear that the generator does indeed activate and generate power at relatively low wind speeds as was claimed.



(a) Winter (b) Spring

(c) Summer (d) Fall

Figure 9.46. Hourly Power Generation Patterns by Season for the Ventera Wind System

The impact of these diurnal power generation patterns on the monthly energy production has been summarized in Figure 9.47. The amounts of energy production during HLH and LLH hours have been shown separately.

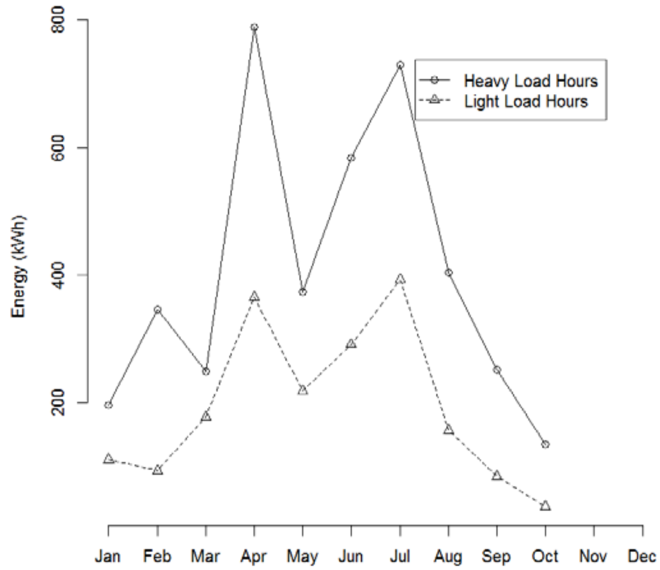


Figure 9.47. HLH and LLH Energy Generated as a Function of Calendar Month for the Ventera Wind System. No data was available for the months of November or December.

Table 9.27 lists the HLH and LLH energy that was generated each calendar month by the Ventera Wind generator system. If the 10 monitored months of generation can be meaningfully extrapolated, then the wind system might generate about 7.2 MWh per year. For comparison, the Ventera Wind website (Ventera Wind 2015) projected that this system would generate 24 MWh per year given a 6.5 m/s (14.5 mph) wind speed at its hub.

Extrapolating from the 10 calendar months for which data was available, the value of annual displaced energy supply would be about $192, based on recent BPA load-shaping rates. The variability in this projection will not be estimated because less than one year of data was available.

Table 9.27. Monthly HLH and LLH Energy Production and the Monetary Value of Displaced Supply Energy for the Ventera Wind System

	HLH		LLH		Total	
	(kWh)	($)	(kWh)	($)	(kWh)	($)
Jan	196	7.42	110	3.38	307	10.80
Feb	346	12.75	93	2.86	439	15.61
Mar	248	7.50	177	4.44	425	11.94
Apr	789	20.33	365	7.34	1,150	27.67
May	374	7.85	218	2.85	592	10.70
Jun	584	13.26	291	4.24	874	17.50
Jul	729	22.22	393	9.62	1,120	31.83
Aug	404	13.71	156	4.22	559	17.93
Sep	251	8.45	84	2.35	335	10.80
Oct	134	4.24	37	1.01	171	5.25
…	-	-	-	-	-	-

If we can extrapolate the estimated monthly change in demand charges from the 10 months that data is available (see Table 9.28), the result would be a reduction in these charges of only $2.65 for the year. In fact, the missing months were winter months, so it is likely that the impact would be even less. Wind generation does not significantly affect calculated BPA demand charges at this location.

Table 9.28. Impact of Generation on Peak Demand for the Ventera Wind System

	Demand (kW)	aHLH (kWh/h)	Expense ($)
Jan	0.5 ± 1.9	0.5	−0.15
Feb	0.7 ± 1.9	0.9	2.00
Mar	0.5 ± 1.5	0.6	1.20
Apr	0.9 ± 2.1	1.9	7.69
May	1.2 ± 2.7	0.9	−1.94
Jun	2.0 ± 3.6	1.5	−3.95
Jul	1.8 ± 3.5	1.8	−0.86
Aug	1.3 ± 3.0	0.9	−3.53
Sep	1.1 ± 2.2	0.7	−3.92
Oct	0.2 ± 0.8	0.3	1.25
…	-	-	-

9.12 Wing Power 1.4 kW Wind Turbine

The City of Ellensburg hoped to still further supplement its power and energy requirements with the power generated by a 1.4 kW Wing Power wind generator (Wing Power Energy 2012). This is among a set of five residential-class wind systems that were installed and tested by the City of Ellensburg. The turbine is shown installed at the renewable energy park site in Figure 9.48.

Figure 9.48. 1.4 kW Wing Power Wind System at the Ellensburg Renewable Energy Park (City of Ellensburg 2013a)

The city apparently needed to replace the Wing Power wind system several times during the project. In a November 1, 2013, report to the city council, two wing failures had occurred, and failed bolts were recurring issues. A third unit was installed by the city (City of Ellensburg 2013c). The city chose to remove all the wind turbine systems, including this one, in late 2013.

The annualized costs of the wind system and its components are listed in Table 9.29. The greatest costs were to update site SCADA and fiber optic communications. Technical consultants, too, were more expensive than the wind system itself.

Table 9.29. City of Ellensburg Costs of 1.4 kW Wing Power Wind Turbine System

	Shared Usage of Component (%)	Annualized Component Cost ($K)	Allocated Annual Component Cost ($K)
SCADA and Monitoring	8	33.2	2.7
Consultants	8	18.5	1.5
Fiber Optic Communication	8	16.4	1.3
Outreach and Education	8	15.9	1.3
1.4 kW Wing Power Wind Turbine	100	1.3	1.3
High-Voltage Equipment Installation	8	13.1	1.0
Climate Data Equipment	8	6.7	0.5
Low-Voltage Equipment Installation	8	7.8	0.6
Project Signs	8	7.4	0.6
Fencing	8	4.6	0.4
Administrative	8	5.1	0.4
Customer Service	8	1.0	0.1
Total Annualized Asset Cost			**$11.7K**

9.12.1 Data for the Wing Power System

Power generation data from this wind turbine system was received from August 2012 through November 2013. The raw data was the energy generated every 5 minutes at the site's "MP-7" metering point. Data after December 10, 2013, remained zero and was removed from analysis. Figure 9.49 displays all the available data. Generation data greater than 5 kW—twice the nameplate generation—was discarded. Power generated in early in the test period during 2012 attained values greater than those in 2013. That the power generation became smaller over time might be a sign of generator fatigue. Generator output approached the 1.4 kW nameplate capacity into fall 2012, but never again through the remaining data collection period.

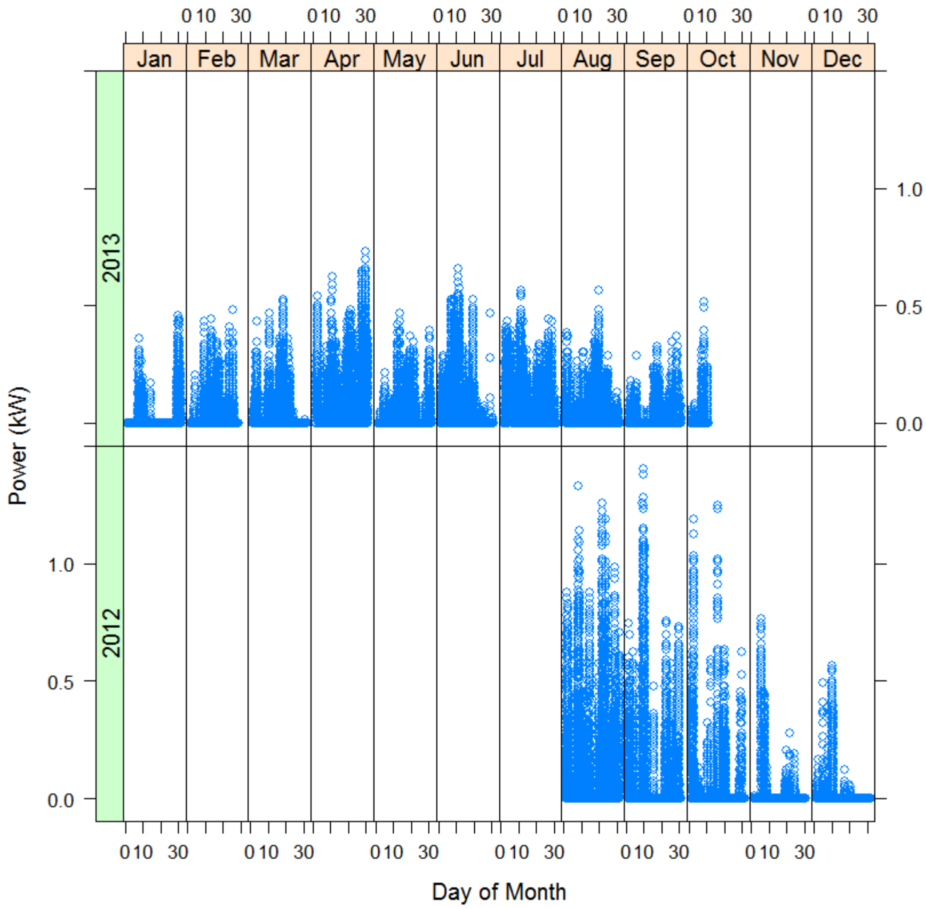
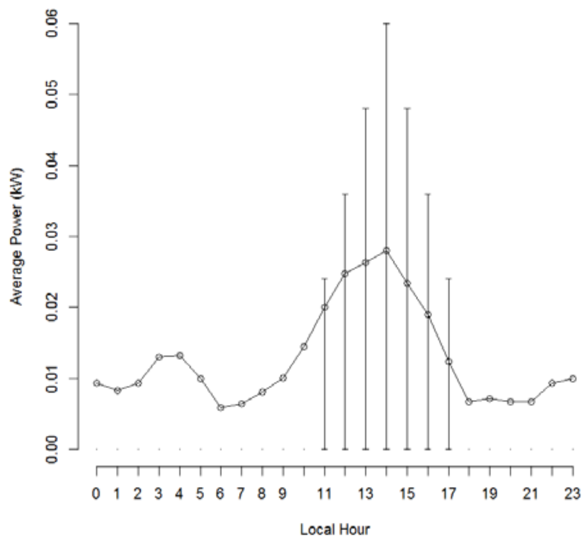


Figure 9.49. Wind Power Generation Data Received by the Project for the Wing Power System

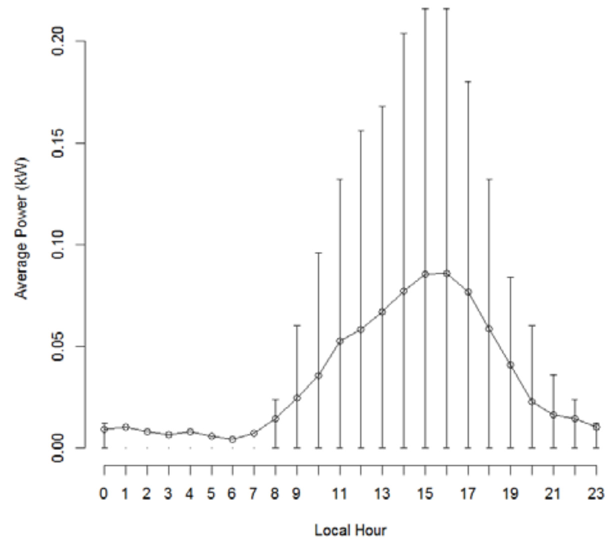
9.12.2 Performance of the Wing Power Turbine System

Given the apparent reduction in power generation over time by this system, the project chose not to present a characteristic power curve as a function of wind speed. That characteristic curve would likely be inaccurate or misleading.

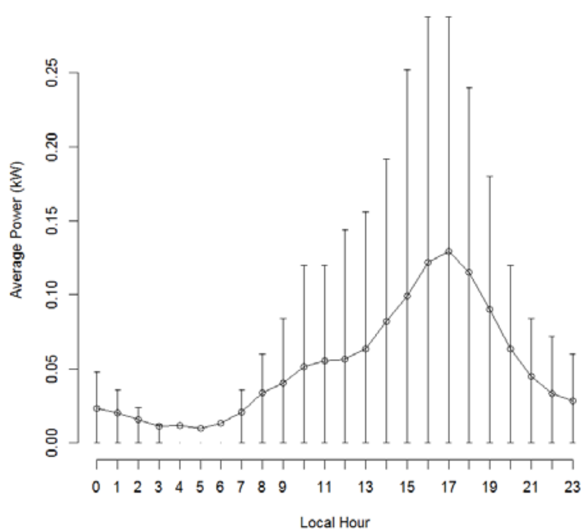
Refer to the average diurnal power generation for the four seasons in Figure 9.50. Hour 0 in these figures is the hour that begins midnight local Pacific Time. The greatest average generation occurred during the summer. About 125 W was generated, on average, during summer early afternoons. Wind generation is most productive and reliable in the early afternoon, regardless of season. The apparent generator fatigue discussed in Section 9.12.1 and evident in Figure 9.49 affected (reduced) the calculated seasonal power generation every season.



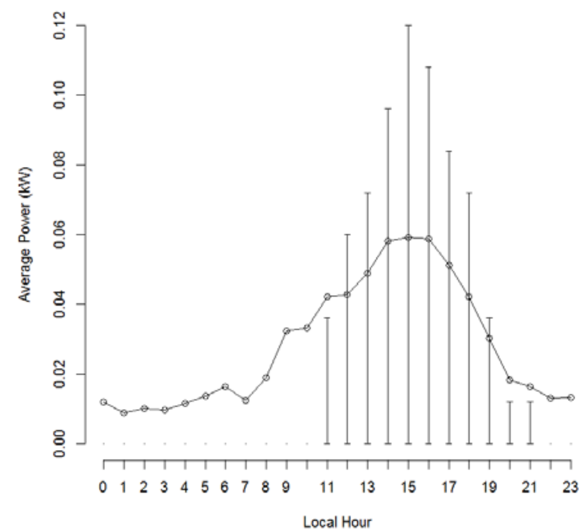
(a) Winter



(b) Spring



(c) Summer



(d) Fall

Figure 9.50. Hourly Generation Patterns by Season for the Wing Power System

The HLH, LLH, and combined energy production for each calendar month are provided in Table 9.30. The variabilities of the averaged energy and monetary values in Table 9.30 are quite large for those months that data was collected in both 2012 and 2013. This is probably caused again by the degradation in system performance that occurred between 2012 and 2013. Energy production in 2013 was nearly halved compared to that in 2012. Therefore, the ranges of variability have magnitudes similar to those of the energy production and monetized values themselves. Regardless, the system might be projected to generate 270 ± 80 kWh in a typical year. The total value of annual generated energy is projected to be only about $7.50 ± 2.40.

Table 9.30. Generated Energy and the Value of the Supply that it Displaced for the Wing Power System

	HLH		LLH		Total	
	(kWh)	($)	(kWh)	($)	(kWh)	($)
Jan	6	0.22	3	0.10	9	0.32
Feb	11	0.42	2	0.08	14	0.5
Mar	8	0.25	6	0.14	14	0.39
Apr	31	0.79	12	0.25	43	1.04
May	11	0.24	6	0.08	17	0.31
Jun	22	0.50	9	0.13	31	0.63
Jul	25	0.76	11	0.27	36	1.03
Aug	35 ± 33	1.19 ± 1.11	7 ± 5	0.20 ± 0.15	43 ± 33	1.39 ± 1.12
Sep	15 ± 12	0.52 ± 0.41	11± 14	0.31 ± 0.38	27 ± 18	0.83 ± 0.56
Oct	17 ± 9	0.54 ± 0.3	3 ± 3	0.08 ± 0.08	20 ± 10	0.62 ± 0.31
Nov	7	0.23	2	0.05	8	0.28
Dec	2	0.07	3	0.10	5	0.17

The impact of the wind generation on peak demand was found to be trivial—less than $1.

9.13 Conclusions and Lessons Learned

The City of Ellensburg tested altogether two solar panel technologies and nine wind turbine generators during the PNWSGD project. The two solar technologies—polycrystalline and thin-film—produce significant, predictable quantities of energy and continue to operate today.

The wind generators were not as reliable and produced relatively small amounts of energy for the city. Altogether, four of the nine wind generators failed. Two of the five residential-class wind generators—the 1.2 kW Windspire and 1.5 kW Honeywell WindTronics turbines—failed to operate throughout the short demonstration period. Two of the four commercial-class wind generator systems—the 4.0 kW Urban Green Energy and 10 kW Tangarie Alternative Power turbines—also failed during the demonstration period. In the case of the Tangarie Alternative Power system, its tower toppled, after which the City of Ellensburg committed to quickly remove all its wind and metrology towers.

The projected annual energy generation and its monetary values, according to BPA load-shaping rates, have been summarized in Table 9.31. The solar arrays each generate about 80 MWh per year that is worth thousands of dollars, even using the modest value of the displaced wholesale electricity supply, as was done here. The commercial wind generators and the 2.4 kW Southwest Windpower Skystream 3.7, too, produced thousands of kWh of energy per year that was worth from $45 to under $200 each year, based on the value of displaced wholesale electricity that the city would otherwise buy. Excepting the 2.4 kW Southwest Windpower Skystream 3.7, the residential-class wind generators produced very little energy, which was worth less than $10 per year. This evaluation was conducted from the perspective of the utility. The generated energy might be valued more from the perspectives of customers, who pay a higher retail rate.

Table 9.31. Projected Annual Energy Generation and Monetized Value of the Energy for each Technology

Tested Renewable Generator Technologies	Cost ($/year)[a]	Generation (kWh/year)	Capacity Factor (%)	Energy Value ($/year)
Solar Technologies				
56 kW polycrystalline	8,600	81,900 ± 3,300	16.7	2,377 ± 104
54 kW thin-film	39,400	80,700 ± 3,000	17.1	2,335 ± 94
Residential-Class Wind Turbine Technologies				
1.5 kW Honeywell WindTronics WT6500[b]	16,000	29	0.2	~1
1.2 kW Windspire[b]	15,400	76	0.7	~2
2.25 kW Home Energy International Energy Ball	15,300	153 ± 10	0.8	4
2.4 kW Southwest Windpower Skystream 3.7	14,900	1,700 ± 200	8.1	45 ± 6
1.4 kW Wing Power	11,700	270 ± 80	2.2	8 ± 2
Commercial-Class Wind Turbine Technologies				
10 kW Bergey WindPower Excel 10	29,900	7,100	8.1	191
10 kW Tangarie Alternative Power Gale[b]	34,200	-[c]	-[c]	-[c]
4 kW Urban Green Energy[b]	26,800	1,200	3.4	27
10 kW Ventera Wind VT10	27,800	7,200	8.2	192

(a) This cost may include the costs of the installed generator, plus many system costs for metering, administration, signage, outreach, maintenance, system communications, etc. Refer to the individual sections to view a more complete listing of cost components.

(b) This wind generation system failed during the demonstration period.

(c) Annual production is not being estimated. Data was generated for only two project months.

Table 9.31 also includes the calculated capacity factor, which is the average generation over all hours stated as a percentage of the systems' declared nameplate capacity. The solar arrays were found to generate, on average, about 17% of their nameplate rating. The wind generators' capacity factors were lower: 4–8% for the Southwest Windpower and commercial-class generators, and less than 1 for the other residential-class wind systems.

The project analyzed the impact that these renewable generators would have on demand and the demand charges that are incurred by the City of Ellensburg. The impacts were small to negligible. The solar generator systems tended to reduce the utility's peak demand in the summers, when the monthly peak hour was likely to occur while the generators were producing power. But those gains were offset in winter when the coincidence was poor. The generators appear to increase demand charges in the winter. The net impacts were small increases of less than $25 in yearly demand charges for each of the two solar arrays.

Because wind generation produced less energy and is fairly randomly distributed over time, the impacts of the wind generators on peak and incurred demand charges were even less than calculated for the solar arrays.

Annualized costs of the polycrystalline system were 3.6 times greater than the annual value of the displaced BPA energy supply for the City of Ellensburg even though the solar panels of this system were preexisting and were not included in the system costs.

The City of Ellensburg received benefit from the visibility of the renewable technologies at its renewable energy park site. These benefits are indirectly realized, and the project did not attempt to monetize them.

The way that the project elected to report annualized system costs creates a pessimistic view of the return on investment for these technologies. The costs, summarized above in Table 9.31, generally included not only the costs of the installed generator technologies, but also many costs that the utility incurred to meter the performance of these technologies and communicate the performance and status back to the utility and to the project. Some of these expenditures and activities had been requested by the project and its clients for the purposes of the demonstration and might not have been necessary otherwise. The project had elected to account for benefits from the utility's perspective, which devalued the impacts on transmission, generation, and customers, which impacts do not directly accrue for the utility.

Following is a summary of the lessons learned as the City of Ellensburg implemented its renewables park as a utility site participant in the PNWSGD project.

Even having signed contracts with prepayments to vendors did not mean the products would be delivered. There are many vendors who only exist on the Web. Small wind turbines are finicky, and maintenance issues are frequent on some units. Local suppliers come and go and cannot be depended upon to provide ongoing maintenance. Our project site was originally intended to use two types of flat-panel solar panels, one concentrating-solar system, and eight small wind systems. The city had hoped to make real-world comparisons of reliability, efficiency and cost-effectiveness of a variety of small renewable systems. The city also hoped to demonstrate the viability of using the aggregated power from small renewable systems as a means to help alleviate some of the overgeneration issues the region faces at times.

The city wanted to test many diverse renewable generation technologies. It went through four concentrating-solar vendors, including signing contracts and paying a deposit with one of the vendors. The vendor went out of business, taking a large deposit with them. The city ultimately could not find a vendor who could provide a concentrating-solar product. For the eight small wind systems the city had originally identified, only half of them were still available in the marketplace by the time the project moved into its construction phase. The city finally found replacement vendors and installed nine small wind systems (one was experimental and was provided to the project at no charge), but it took over a year and review of more than a half-dozen additional vendors before the city could obtain the four replacement systems for the wind technologies that had become unavailable.

The city contracted with two electrical contractors who sell and install renewable products. The electrical contractors procured all of the small wind systems, so the city did not have a lot of direct contact with vendors. Most of the vendors were selected based on their internet presence, and this process was very frustrating. Many vendors did not actually have a product to sell or were so undercapitalized that they could not manage public procurement processes.

The city marketed only the output of the community solar portion of the project to its customers. They could contribute as little as $250 and could receive a credit on their utility bill commensurate with their contribution as compared with all customer contributions. The city had planned to also market the wind portion of the project, but the small wind generators proved to be unreliable, subject to repeated failures, and were ultimately taken down for safety reasons.

Few contractors or support firms are available to supply maintenance to equipment. Contractors only service a few product types, and because the city had difficulty finding vendors to sell products, it ended up with vendors from all over the country. Few of the renewable systems have local factory authorized dealers, so the city had difficulty finding qualified contractors to work on many of the systems.

In summary, the City of Ellensburg spent almost two years just finding products to be part of the project. This was very frustrating and caused significant delays in meeting project milestone dates. The small renewables industry is very much fledging. Vendors, suppliers and contractors come and go very quickly. There were great differences in reliability and efficiency of the various systems. Solar panels, while more expensive per nameplate kW than the wind systems, were more reliable and required little maintenance. Even so, solar panel glass broke and an inverter failed. The broken panels were left in place with crystallized glass and are still generating. The inverter was able to be replaced. There seems to be little correlation between an economically good product and its chances of surviving in the marketplace. SCADA software also proved to be problematic as it was continually evolving.

With the relatively short life span of many products, local or even regional contractors and suppliers hesitate to invest in parts supply or staff training unless the product has a long track record of successful installations. This scarcity of support, combined with the large variety of technologies involved, means that there are few, if any, qualified contractors to maintain many of the products that are on the market.

Table 9.32. The City of Ellensburg's Assessment of Generated Renewable Energy and the Effective Unit Cost of the Renewable Energy

Component	Projected Annual Generation (kWh)	Actual Annual Generation (kWh)	Cost ($K)	Average Unit Cost[(a)] ($/kWh)
Phase-4 PV	52,600	52,740	291.8	0.28
Bergey	-	5,362	96.4	0.90
Ventera Wind	-	5,285	85.0	0.80
Skystream	-	1,337	24.8	0.90
Wind Turbines	50,100	12,155	525.8	2.16
PNWSGD Project	1,020,700	64,895	1,481.0[(b)]	1.14
BPA Wholesale Power Cost – Tier-1				0.035
BPA Wholesale Power Cost – Tier-2				0.049
City Retail Residential Rate				0.065
Statistics on the other six wind turbines are not presented due to lack of performance.				

(a) Assumes 20-year financing, 0% interest rate, no operation and maintenance or other continuing costs.

(b) This is a sum cost for the city's participation. It includes the above asset costs and other operational and administrative costs.