# 3.0 Conservation and Efficiency Test Cases

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An objective of a smart grid is to conserve energy and improve the grid's overall efficiencies. This section reports on asset systems that were deployed by the Pacific Northwest Smart Grid Demonstration (PNWSGD) project so that less electrical energy would be consumed to perform a given task (i.e., *efficiency*) or less energy would be consumed (i.e., *conservation*). Furthermore, the implementation of some of these asset systems was found to achieve *operational efficiencies* that reduce the costs of operating the system, but do not necessarily accomplish either conservation of energy or energy efficiency.

The project has chosen to employ four organizational headings in this chapter, as described below.

**The power of information − portals, in-home displays, and customer education**. Information itself can motivate consumers to conserve energy. Several participating utilities informed their energy consumers of their historical electricity consumption via Web portals or in-home displays. Energy customers may also become educated during their engagements with their electricity suppliers to make better decisions about their energy consumption. The education may be quite intentional, as occurred when the University of Washington campus created monthly energy reports to educate its campus building managers. On the other hand, energy customers may become better energy consumers after simply receiving smart grid devices and the utilities' accompanying informational fliers.

**Replacing inefficient equipment and tuning existing equipment**. One of the simplest means of conserving energy is to replace existing equipment with more energy efficient alternatives, as Avista Utilities did when it replaced approximately 800 existing distribution transformers with more efficient smart transformers.

**Efficient distribution management**. Still other utilities changed and automated the management of their distribution systems. Examples include the reduction of feeder voltages that reduces the power consumed by some end-use loads, correction of power factor that reduces power line losses, or coordinated volt and volt-ampere reactive control that can both reduce power load and reduce system losses.

Renewable energy. The project has also chosen to report renewable energy generation in this chapter. Numerous solar and wind generator systems were built and monitored during the PNWSGD. These new resources displaced supply energy that would otherwise have been purchased by customers' electricity suppliers. While much of the bulk electric supply in the Pacific Northwest is already environmentally green, the renewable generation may displace dirtier energy resources. The timing of the renewable energy generation also has implications for the generators' owners concerning the time-costs of the displaced energy supply and the renewable generation's potential effect on the customers' demand charges.

## 3.1 The Power of Information − Portals, In-Home Displays, and Customer Education

Advanced customer meters were critical components of many of the PNWSGD's smart grid systems. At many sites, especially those that had already invested in power line carrier communication networks, the meters were important, but not necessarily essential, links to responsive devices, including the switches that controlled water heaters and space conditioning. The project relied heavily on aggregated power data from the premises meters to analyze the performance of the many systems. Table 3.1 summarizes how many meters at each utility provided data for the project and the data intervals that were supported by the meters.

**Table 3.1**. Premises Meter Counts and Data Intervals by Utility

| | Data Interval (h:m) | Premises Meter Count |
|---|---|---|
| Avista Utilities | 0:05 | 14,334 |
| Flathead Electric Cooperative | 1:00 | 349 |
| Idaho Falls Power | 0:15 or 1:00[a] | 17,303 |
| Lower Valley Energy | 1:00 | 548 |
| Milton-Freewater | 0:15 | 1,434 |
| NorthWestern Energy | 0:15 | 196 |
| Portland General Electric | 0:15 | 50 |
| Peninsula Light Company | 24:00 | 2,650 |

(a) Idaho Falls Power was found to have meters that reported at two different data intervals.

The focus of this section is the impact of the energy information that is available from the communicating meters. For example, the power consumption data from these meters may be displayed to the energy consumers via in-home displays or Web portals, and the informed persons may elect to change their energy consumption habits. Even the process of receiving a new meter or display, often accompanied by additional educational fliers from the utility, may change the recipients' energy consumption patterns. Five of the PNWSGD tests looked at this impact.

Avista Utilities finished installing advanced metering information (AMI) throughout Pullman, Washington, early in the project's term Section 7.5). By the project's assessment, the customers given access to an energy Web portal and their historical energy consumption reduced their electricity consumption by about 5 kWh per month, or by about 0.07% of their normal electricity consumption. (The uncertainty in this analysis was large.) By the utility's assessment, it will save $157,000 per year reading the meters remotely, $70,000 per year through reduced in-person customer service, and $8,000 per year upon reducing onsite serviceperson calls. The utility estimated a reduction of 220 truck rolls per month in the project months of 2014. Interestingly, the AMI data may now be compared against data from smart distribution transformers in Pullman to detect and reduce electricity theft.

Idaho Falls Power also tested the impact of AMI and in-home displays on its residents' electricity consumption (Section 11.7). The test was performed with the customers supplied by one of its substations. Those who received only AMI had their premises consumption reduced by 92 ± 56 kWh per month, but those who had received both AMI and in-home displays instead had their consumption increase by a small, insignificant amount. When surveyed at the conclusion of the test, 39% of the test residents reported that they had looked at their in-home displays daily.

Lower Valley Energy conducted a similar test of its cooperative members who had received only AMI and those who had received both AMI meters and in-home displays (Section 12.2). The project's analysis suggested that both sets of premises had experienced rather large reductions in their power consumption—270 +/- 70 W for those who had received only AMI, and 210 +/- 70 W for those who received both AMI and in-home displays. An even larger impact was calculated for those AMI members who had also received demand-response unit switches to control their water heaters. It seems the impact of the in-home displays was very small compared to the impact of receiving the AMI.

The University of Washington campus, while not using conventional premises AMI equipment, individually metered its buildings during the PNWSGD. The information from the meters was conveyed to its building managers in two ways. Section 17.6 describes a real-time Facilities Energy Management System, and Section 17.7 describes a program in which building managers were supplied a building energy report once each month.

## 3.2 Replacing Inefficient Equipment and Tuning Existing Equipment

The asset systems addressed here aim to improve energy efficiency by installing, tuning, or replacing existing infrastructure. The three asset systems specifically address replacement of distribution conductors, the tuning up of a university campus heating and cooling system, and replacement of existing distribution transformers with efficient smart transformers.

When Avista Utilities planned to automate circuit switching in Pullman, Washington, it found it would be constrained unless it upgraded conductors on two of its distribution lines (Section 7.2). The utility estimated that it will save about 24 MWh per year in reduced line losses by making these improvements. The value of this energy is only about $3,000 per year, but the new conductors greatly increased the utility's operational flexibility.

Avista Utilities also replaced about 800 inefficient distribution transformers with efficient, communicating transformers (Section 7.3). The new transformers monitor and report many measurements, including voltage, temperature, current, and power. These newly available measurements were found useful for detecting possible energy theft, verifying acceptable voltage delivery, and monitoring transformer health. By the utility's estimates, savings of 130 kW, or 1,120 MWh annually, were derived from the improved efficiency alone.

The University of Washington replaced many of its stand-alone control systems at campus buildings with direct digital building controls, which it expects will glean additional efficiencies from the improved operation of its commercial-scale buildings (Section 17.4).

## 3.3 Efficient Distribution Management

This subsection includes distribution-scale asset systems that strive to conserve distribution system energy by better managing circuit voltages, by reducing reactive power, or by simultaneously managing both system voltage and reactive power.

Voltage management or conservation voltage reduction was featured at Idaho Falls Power (Section 11.1), the City of Milton-Freewater (Section 13.5), Peninsula Light Company (Section 15.2), and at the two NorthWestern Energy sites (Section 14.1). The project calculated that the Idaho Fall, Idaho test feeder used about 137 kW less power while its voltage was actively reduced, thus potentially avoiding about $5,420 supply energy costs if the system were active throughout the year. Another estimated $6,770 might be avoided if the asset were consistently used to reduce the utility's demand charges.

In the City of Milton-Freewater, four feeders were estimated to reduce their consumption by about 26 kW, on average (about 0.8% of the average load), while the feeders' voltages were reduced by about 1.5%.

The project made no conclusion about the conservation voltage reduction impacts of tests conducted by Peninsula Light Company. The measured voltages were not found to have been altered at the times the utility said it had reduced the voltage, and the changes in system power, too, were insignificant.

The first NorthWestern site in Helena, Montana, consumed 16.6 ± 1.5 kW less when the IVVC system was "Engaged" than it did while it was "Not Engaged." That is about 0.9% of the average power on the circuit during 2014 and about 0.4% of the peak power during 2014. The second site, on the east side of Helena, produced inconclusive results.

Reactive power was managed at Idaho Falls (Section 11.2) and Lower Valley Energy (Section 12.6), where a static volt-ampere reactive compensator was installed. The power factors on two Idaho Falls test feeders were improved to better than 0.99, which suggests that feeder line losses were likely reduced by 7.5 and 22% at the two feeders. At Lower Valley Energy, line losses were likely reduced by between 7.5 and 33%.

A more complex integrated control of both voltage and reactive power was installed and tested by Avista Utilities. The system attempted to optimize both. Because of the tradeoffs in this optimization, one of the feeders was observed to have actually increased its voltage at the times the system was active. The installation was preceded by a careful correction of static power factors in the April 2013 time frame. Much effort was also expended to make the remote end-of-line voltage metering sufficiently accurate to safely support the system's automated distribution control. The project estimated that the system could conserve 2.1% of Pullman's energy consumption—similar to the utility's estimate of 1.85%. The power factors of the controlled feeders were noticeably improved while the system was active. Perhaps four of the feeders reduced their line losses by more than 1%, and the biggest feeder impact might have resulted in about a 4.6% reduction in its line losses. Avista Utilities estimated that the distribution automation will save about $500,000 per year in Pullman.

## 3.4 Renewable Energy

This subsection reports on solar photovoltaic and wind renewable energy generation assets at scales typically installed by customers or communities. At these scales, the monetary value of generated renewable energy lies primarily in the displacement of electrical energy, avoided power kWh purchases as well as mitigating system peaks (kW) and avoiding demand charges, that must otherwise be supplied to the electrical distribution system.

The total energy production of each renewable generator system was evaluated by season and by year. For utilities supplied by the Bonneville Power Administration, production may be evaluated separately for heavy-load and for light-load hours, during which a utility's energy supply charges may differ. The yearly energy production may be compared quite directly against the annualized cost of constructing and operating the renewable generator system.

The average rate of renewable energy generation—power—is evaluated for hourly or even shorter intervals. Once the typical hourly generation profile of a renewable resource is known by month and hour, the impact of the renewable generation on demand charges (where these exist) may be estimated.

Many of the project's renewable energy generators were at the Ellensburg Community Renewable Park in Ellensburg, Washington. Residents of Ellensburg could purchase shares in the energy production of the generators at this community park. The municipality installed, maintained, and completed distribution connectivity of these generators for the residents. It thereby consolidated renewable resources that might otherwise be installed piecemeal throughout the city. The experiment with wind turbines encountered a number of challenges, and when one of the turbine towers failed, the City of Ellensburg committed to quickly remove all of its towers.

Two subsections below address the two types of renewable energy being demonstrated—solar and wind renewable generator systems.

### 3.4.1 Solar Renewable Energy Systems

The PNWSGD included five solar energy generator installations. These installations are listed in Table 3.2 along with their nameplate power capacity, demonstrated seasonal energy production, and calculated seasonal capacity factors. A *capacity factor* is the system's average power production divided by the system's nameplate power rating. The table also lists the report sections where additional details about the project's analysis may be found in this report. Two of the four systems were installed at the City of Ellensburg Renewable Energy Park, one was installed at the Lower Valley Energy Hoback Substation in Bondurant, Wyoming, and two were installed on the University of Washington Campus in Seattle, Washington. The reporting of capacity factors and actual seasonal energy production for these arrays should help others in the Pacific Northwest decide whether to pursue similar installations.

The seasons here are defined as sequential 3-month groupings of months December through February (winter), March through May (spring), and so on.

Unlike the wind turbine systems reported in Section 3.4.2, energy production from solar generators was relatively reliable and predictable. For each system, in seasons having the greatest energy production, production was about 2 to 4 times as much as in the seasons having the worst energy production. Capacity factors ranged from about 9 to 40%.

**Table 3.2**. Seasonal Nameplate Capacity, Energy Production, and Capacity Factor for the Demonstrated Solar Generation Systems

| Site/Technology | Nameplate Capacity (kW) | Report Section | Season[a] | Energy Production (MWh) | Capacity Factor (%) |
|---|---|---|---|---|---|
| City of Ellensburg – Polycrystalline | 56 | 9.2 | **Project** | **165** | **33.8** |
| | | | Summer 2012[b] | 9.45 | 41.9 |
| | | | Fall 2012 | 16.5 | 31.4 |
| | | | Winter 2012 | 10.7 | 24.6 |
| | | | Spring 2013 | 23.7 | 35.9 |
| | | | Summer 2013 | 26.8 | 36.4 |
| | | | Fall 2013 | 19.3 | 33.4 |
| | | | Winter 2013 | 10.7 | 25.2 |
| | | | Spring 2014 | 20.3 | 35.1 |
| | | | Summer 2014 | 28.0 | 37.9 |
| City of Ellensburg – Thin-Film | 54 | 9.3 | **Project** | **173** | **34.5** |
| | | | Summer 2012[b] | 17.6 | 35.5 |
| | | | Fall 2012 | 15.9 | 31.4 |
| | | | Winter 2012 | 10.3 | 24.6 |
| | | | Spring 2013 | 23.8 | 37.4 |
| | | | Summer 2013 | 27.5 | 38.7 |
| | | | Fall 2013 | 18.9 | 33.9 |
| | | | Winter 2013 | 10.1 | 24.6 |
| | | | Spring 2014 | 20.1 | 36.2 |
| | | | Summer 2014 | 28.4 | 39.9 |
| Lower Valley Energy | 20 | 12.8 | **Project** | **39.8** | **34.4** |
| | | | Fall 2012[b] | 1.97 | 29.4 |
| | | | Winter 2012 | 4.56 | 28.0 |
| | | | Spring 2013 | 9.58 | 39.5 |
| | | | Summer 2013 | 9.58 | 36.8 |
| | | | Fall 2013 | 5.87 | 33.9 |
| | | | Winter 2013 | 4.02 | 28.2 |
| | | | Spring 2014 | 3.94 | 40.0 |
| | | | Summer 2014[b] | .208 | 25.4 |

**Table 3.2**. (cont.)

| Site/Technology | Nameplate Capacity (kW) | Report Section | Season[(a)] | Energy Production (MWh) | Capacity Factor (%) |
|---|---|---|---|---|---|
| University of Washington – Small − Mix of Thin-Film, Mono- and Polycrystalline Technologies | 6.2 | 17.3 | **Project** | **13.7** | **30.5** |
| | | | Summer 2012[(b)] | 0.289 | 34.8 |
| | | | Fall 2012 | 1.26 | 24.3 |
| | | | Winter 2012 | 0.423 | 11.2 |
| | | | Spring 2013 | 2.19 | 33.7 |
| | | | Summer 2013 | 3.31 | 45.6 |
| | | | Fall 2013 | 1.12 | 22.2 |
| | | | Winter 2013 | 0.490 | 12.8 |
| | | | Spring 2014 | 1.57 | 32.0 |
| | | | Summer 2014 | 3.06 | 39.9 |
| University of Washington − Large | 67.2 | 17.3 | **Project** | **76.8** | **19.4** |
| | | | Summer 2013[(b)] | 18.6 | 25.9 |
| | | | Fall 2013 | 11.6 | 14.5 |
| | | | Winter 2013 | 6.38 | 9.13 |
| | | | Spring 2014 | 14.2 | 20.8 |
| | | | Summer 2014 | 26.1 | 24.5 |

(a) Seasons have been defined as winter (Dec. – Feb.), spring (Mar. – May), summer (Jun. – Aug.), and fall (Sep. – Nov.)
(b) Data was incomplete for this period.

For most of the demonstrated solar power generation installations, the project was able to further estimate the monthly energy production by light- and heavy-load hours. This then allowed the project to estimate the value of the supply energy that might be displaced by the solar power generation each calendar month. For the two utilities supplied energy by Bonneville Power Administration, the project also estimated the impact the generation would have on the demand charges that are incurred by the utilities.

### 3.4.2 Wind Renewable Energy Systems

The PNWSGD included 10 small- and medium-scale wind turbine installations. Nine of the 10 were installed at the City of Ellensburg Renewable Energy Park. The capacities and energy production from these nine systems are summarized in Table 3.3. The table further lists the report sections where more details about the project's analysis of these wind turbines may be found. Columns of the table also report the nameplate power generation capacities and installed tower hub heights of these installations. Total energy generation is listed for each project season for which data was available and is summed for the entire project. The last column states the capacity factor, which is the average power generation divided by the system's nameplate generation capacity.

The referenced report sections contain additional details about monthly generation from these systems during light- and heavy-load hours. For some of the systems, the project could estimate the value of the supply energy that might be displaced by the wind turbine generators each month. For many of the systems, the project was further able to estimate the likely impact they would have each calendar month on the demand charges that are incurred by the utility.

**Table 3.3.** Seasonal Nameplate Capacity, Energy Production, and Capacity Factor for City of Ellensburg Wind Turbine Systems

| Make/Model | Report Section | Capacity (kW) | Height (ft) | Season | Energy Production (kWh) | Capacity Factor (%) |
|---|---|---|---|---|---|---|
| Honeywell WindTronics® WT6500[c] | 9.4 | 1.5 | 37 | **Project** | **10** | **0.24** |
| | | | | Fall 2012[a] | 0.155 | 0.03 |
| | | | | Winter 2012 | 8.60 | 0.27 |
| | | | | Spring 2013[a,b] | 1.46 | 0.30 |
| Windspire® v1.2[c] | 9.5 | 1.2 | 35 | **Project** | **38** | **0.68** |
| | | | | Summer 2012[a] | 17.9 | 2.46 |
| | | | | Fall 2012 | 9.93 | 0.38 |
| | | | | Winter 2012[a,b] | 9.83 | 0.84 |
| Home Energy International Energy Ball® V200 | 9.6 | 2.5 | 50 | **Project** | **160** | **0.67** |
| | | | | Fall 2012[a] | 13.1 | 0.31 |
| | | | | Winter 2012 | 18.8 | 0.35 |
| | | | | Spring 2013 | 54.2 | 0.99 |
| | | | | Summer 2013 | 66.3 | 1.21 |
| | | | | Fall 2013[a,b] | 7.12 | 0.21 |
| Southwest Windpower Skystream® 3.7 | 9.7 | 2.4 | 51 | **Project** | **1,782** | **7.11** |
| | | | | Summer 2012[a] | 30.7 | 1.72 |
| | | | | Fall 2012 | 49.9 | 0.97 |
| | | | | Winter 2012 | 243 | 4.68 |
| | | | | Spring 2013 | 612 | 11.7 |
| | | | | Summer 2013 | 726 | 13.9 |
| | | | | Fall 2013[a,b] | 121 | 4.91 |
| Bergey WindPower Excel 10 | 9.8 | 10 | 95 | **Project** | **6,945** | **8.39** |
| | | | | Fall 2012[a] | 46.5 | 1.36 |
| | | | | Winter 2012 | 1,001 | 4.63 |
| | | | | Spring 2013 | 2,480 | 11.4 |
| | | | | Summer 2013 | 2,887 | 13.2 |
| | | | | Fall 2013[a,b] | 531 | 3.78 |

**Table 3.3**. (cont.)

| Make/Model | Report Section | Capacity (kW) | Height (ft) | Season | Energy Production (kWh) | Capacity Factor (%) |
|---|---|---|---|---|---|---|
| Tangarie Gale®[c] | 9.9 | 10 | 97 | **Project** | **431** | **3.05** |
| | | | | Summer 2012[a,b] | 431 | 3.05 |
| Urban Green Energy[c] | 9.10 | 4 | 115 | **Project** | **664** | **2.87** |
| | | | | Summer 2012[a] | 389 | 6.55 |
| | | | | Fall 2012 | 194 | 2.63 |
| | | | | Winter 2012 | 71 | 0.82 |
| | | | | Spring 2013[a,b] | 11 | 0.91 |
| Ventera VT10 | 9.11 | 10 | - | **Project** | **5,824** | **8.30** |
| | | | | Winter 2012[b] | 662 | 5.47 |
| | | | | Spring 2013 | 2,131 | 9.76 |
| | | | | Summer 2013 | 2,524 | 11.6 |
| | | | | Fall 2013[a,b] | 506 | 3.51 |
| Wing Power Energy[c] | 9.12 | 2 | - | **Project** | **338** | **1.63** |
| | | | | Summer 2012[a] | 69 | 4.67 |
| | | | | Fall 2012 | 75 | 1.77 |
| | | | | Winter 2012 | 28 | 0.64 |
| | | | | Spring 2013 | 73 | 1.27 |
| | | | | Summer 2013 | 81 | 1.86 |
| | | | | Fall 2013[a,b] | 11 | 0.59 |

(a) Data is incomplete for this season.
(b) Asset was taken out of service during this season.
(c) These systems were not functioning by the time they were dismantled in fall 2013.

Five of the nine demonstrated City of Ellensburg wind turbine systems had failed by the time the city removed them in fall 2013. This accounts for the different numbers of seasons for which data were reported for the nine systems. After a turbine tower collapsed, the city resolved that wind systems should not operate so close to residential foot traffic in the Renewable Energy Park. The PNWSGD collected data as long as it remained available.

The tenth wind turbine system was installed by Lower Valley Energy at its Hoback substation—four 2.5 kW WindTronics Energy Solutions wind turbines. Power data from all four turbines was received from October 26, 2012 until September 1, 2014. A total of 16,046 hourly records were received in this period but 13,398 of the records were zero. Of the remaining records, 335 showed a total of 52.37 kWh being produced, mostly in 0.13 kWh increments (285 of them), and 313 showed 74.35 kWh as being *consumed*, again mostly in 0.13 kWh increments (310 of them). Project analysts could not determine whether the badly discretized production and consumption values were meaningful. The product's vendor closed on January 14, 2013. Some additional analysis details may be found in Section 12.9 of this report.

According to Table 3.3, the turbine systems' seasonal capacity factors were quite low, ranging from 0.3 to almost 14%. The systems having greater nameplate capacities typically achieved significantly better capacity factors than did the smaller, residential-scale turbine systems.