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Washington Clean Energy Fund: Use Case Analysis Project

Task 2.1 Preliminary Report Outlining Data Needs for Financial Evaluation

November 2015

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U.S. DEPARTMENT OF ENERGY

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Executive Summary

The Washington State Clean Energy Fund (CEF) is providing $15 million toward the deployment and demonstration of energy storage in an effort to explore the role storage could play in Washington State and the value it could deliver to Washington State's utilities and to its citizens as consumers and workers. The Washington CEF projects are comprised of five battery systems located at three utilities in Washington State. Avista Utilities is deploying a 1 megawatt (MW) / 3.2 megawatt-hour (MWh) UniEnergy Technologies (UET) vanadium-flow battery system in Pullman, Washington. Puget Sound Energy is deploying a 2 MW / 4.4 MWh lithium-ion/phosphate ESS at a substation in Glacier, Washington. Snohomish County Public Utility District (SnoPUD) is deploying two 1 MW / 500 MWh lithium-ion battery systems at a substation in Everett, Washington. At another substation in Everett, SnoPUD is deploying a 2 MW / 6.4 MWh vanadium-flow battery built by UET.

To maximize the value of the CEF, Washington State has worked with Pacific Northwest National Laboratory (PNNL) to design an assessment framework for the demonstration that is based on a consistent set of use cases and measurements during the demonstrations that does not constrain, but rather enhances the diverse scope of applications for energy storage. This framework, and its application for these demonstration projects, will inform and empower other utilities, storage technology developers, and state regulators to prudently and confidently pursue the deployment of energy storage.

This report presents an overview of the use case analysis project (UCAP) data requirements. It represents a significant component in the first of a three-phase project scheduled for completion in 2017. The first phase of this study focuses on the development of data requirements and data systems. The second on the definition of use case testing and financial assessment procedures and on performance monitoring. The third, and final, phase includes evaluation and reporting on the technical and financial performance of the utility ESSs.

To begin the process of developing all of the information required to perform the UCAP analyses, PNNL has outlined preliminary data needs in this report. These input data consist of technical and financial value information required to assess, for instance, the value of deferral of distribution system upgrades, capacity values, outage mitigation and arbitrage. PNNL will work with the utility partners and their contractors to refine this report and transfer the required data using secure systems.

PNNL has already established three SharePoint sites where information can be freely exchanged between PNNL and each utility. Proprietary data will be identified as such and handled per the terms and conditions of signed non-disclosure agreements (NDAs) between PNNL and its subcontractors and each utility. A central data repository has also been established, in compliance with North American Electric Reliability Corporation Critical Infrastructure Protection standards, to provide a location where utility partners are able to upload information from their battery systems.

Acronyms and Abbreviations

BSET	Battery Storage Evaluation Tool
CEF	clean energy fund
ESS	energy storage system(s)
MW	megawatt(s)
MWh	megawatt hour(s)
NDA	non-disclosure agreement
O&M	operations and maintenance
NERC	North American Electric Reliability Corporation
PNNL	Pacific Northwest National Laboratory
PRT	Pattern Recognition Technologies, Inc.
SEL	Schweitzer Energy Laboratories
SnoPUD	Snohomish County Public Utility District
UniEnergy Technologies	UET
UCAP	use case analysis project

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1.0 Introduction

Energy storage systems (ESS) have the potential to improve the operating capabilities of the electricity grid. Their ability to store energy and deliver power can increase the flexibility of grid operations while providing the reliability and robustness that will be necessary in the grid of the future – one that will be able to provide for projected increases in demand and the integration of clean energy sources while being economically viable and environmentally sustainable. Energy storage has received a great deal of attention in recent years. Entrepreneurs are working enthusiastically to commercialize a myriad of promising technologies, and venture capitalists and the U.S. Government are investing in this space. The technologies show promise but it remains difficult to evaluate and measure the benefits that ESS could provide.

The Washington State Clean Energy Fund (CEF) is providing $15 million toward the deployment and demonstration of energy storage in an effort to explore the role storage could play in Washington State and the value storage could deliver to Washington State's utilities and to its citizens as consumers and workers. The Washington CEF projects are comprised of five battery systems located at three utilities in Washington State. Avista Utilities is deploying a 1 megawatt (MW) / 3.2 megawatt-hour (MWh) UniEnergy Technologies (UET) vanadium-flow battery system in Pullman, Washington. Puget Sound Energy is deploying a 2 MW / 4.4 MWh lithium-ion/phosphate ESS at a substation in Glacier, Washington. Snohomish County Public Utility District (SnoPUD) is deploying two 1 MW / 500 MWh lithium-ion battery systems at a substation in Everett, Washington. At another substation in Everett, SnoPUD is deploying a 2 MW / 6.4 MWh vanadium-flow battery built by UET.

To maximize the value of the CEF, Washington State has worked with Pacific Northwest National Laboratory (PNNL) to design an assessment framework for the demonstration that is based on a consistent set of use cases and measurements during the demonstrations that does not constrain, but rather enhances the diverse scope of applications for energy storage. This framework, and its application for these demonstration projects, will inform and empower other utilities, storage technology developers, and state regulators to prudently and confidently pursue the deployment of energy storage.

Figure 1.1. presents an overview of the use cases and applications to be performed and measured/analyzed in coordination with PNNL. "Y" means the service is currently included as part of the use case analysis project (UCAP). The use-cases are grouped according to their intended target benefits within the electric infrastructure topology (e.g., transmission versus distribution). Although an ESS may be located on the low-voltage side of a substation that provides power to a distribution feeder, a use case that addresses bulk power services could still be provided and would be grouped under the transmission system. Use cases for ESS for applications deep into the distribution circuit would be categorized under the distribution system cases.

Use Case and application as described in PNNL Catalog	Avista	PSE	Sno – MESA1	Sno – MESA2	Sno - Controls Integration
UC1: Energy Shifting					
Energy shifting from peak to off-peak on a daily basis	Y	Y	Y	Y	
System capacity to meet adequacy requirements	Y	Y	Y	Y	
UC2: Provide Grid Flexibility					
Regulation services	Y	Y		Y*	
Load following services	Y	Y		Y*	
Real-world flexibility operation	Y	Y		Y*	
UC3: Improving Distribution Systems Efficiency					
Volt/Var control with local and/or remote information	Y		Y	Y	
Load-shaping service	Y	Y	Y	Y	
Deferment of distribution system upgrade	Y	Y			
UC4: Outage Management of Critical Loads		Y			
UC5: Enhanced Voltage Control					
Volt/Var control with local and/or remote information and during enhanced CVR events	Y				
UC6: Grid-connected and islanded micro-grid operations					
Black Start operation	Y				
Micro-grid operation while grid-connected	Y				
Micro-grid operation in islanded mode	Y				
UC7: Optimal Utilization of Energy Storage	Y	Y			Y

Figure 1.1. Washington CEF Use Case Matrix

The models and testing procedures required to perform the technical and financial performance assessments of the ESSs require financial/economic, system and battery-specific data. To begin the process of developing all of the information required to perform the UCAP analyses, PNNL has outlined preliminary data needs in this report. These input data consist of technical and financial value information required to assess, for instance, the value of deferral of distribution system upgrades, capacity values, outage mitigation and arbitrage. PNNL will work with the utility partners and their contractors to refine this report and transfer the required data using secure systems.

PNNL has already established three SharePoint sites where information can be freely exchanged between PNNL and each utility. Proprietary data will be identified as such and handled per the terms and conditions of signed non-disclosure agreements (NDAs) between PNNL and its subcontractors and each utility.

2.0 Data Requirements

This report presents an overview of the UCAP data requirements. It represents a significant component in the first of a three-phase project scheduled for completion in 2017. The three phases of this study cover the following key elements:

- Phase 1 - Data and Data Systems. Working closely with the three participating utilities, PNNL will define the data requirements and systems required to securely transfer data. Testing and validation of the data systems and initiation of large-scale data transfer also falls into this phase.
- Use Cases / Performance Monitoring. This phase includes use case analysis and support / monitoring during performance testing. In this phase, PNNL will also define the approaches used in monetizing the economic benefits associated with ESS services and will document the modeling techniques used to optimize ESS values.
- Evaluate Technical and Financial Performance. PNNL will analyze the test data collected during Phase 2 to assess the technical performance and financial and non-financial benefits associated with energy storage. PNNL will produce a final report that documents the use cases and the individual performance of each ESS in single or bundled use cases.

Phase 1 of the study is nearly complete and PNNL has already transitioned into performing some of the Phase 2 tasks, including the development of ESS test protocols and ESS performance testing at Avista.

2.1 Comprehensive Data Requirements

PNNL models and procedures for evaluating the financial and technical performance of the ESSs at the three utilities participating in the UCAP require financial, system and battery-specific data. Data sharing has already begun at Avista and SnoPUD and the data acquisition process, which will continue throughout the battery testing period, is expected to conclude for the last utility in the Spring of 2017. Data used in this study will be obtained from both public and private sources, much of which will be utility-specific. Data used in this study will encompass competing service providers, utility systems and levels in the electricity grid. Ultimately, data requirements depend on the specific conditions and policies present at each utility. For example, energy price data may differ based on the preferred vendor supplying forecasts at each utility. Data has been stratified within this chapter by utility, as appropriate. PNNL will work closely with each utility in the coming months to identify and acquire data necessary to complete the UCAP.

2.1.1 Price/Financial Data

PNNL will evaluate for each use-case and each utility partner the economics of energy storage using commonly used metrics such as present value benefits, benefit-cost ratios, breakeven capital cost, rates of return and payback periods. This economic analysis will be performed on each use case individually and for a bundled set of co-optimized use cases. Energy storage applications will be monetized using the approaches defined in Phase 2 and data identified in Table 2.1. When identical data requirements apply to multiple utilities, utility columns are joined into one single listed data request. Where existing data sets are unavailable to fully evaluate the financial benefits associated with each use case, PNNL will work with utility partners to develop acceptable alternatives.

Table 2.1. Financial Data Requirements

Item	Avista	PSE	SnoPUD
ESS Capital Cost	Installed cost of each ESS, including site/civil, electrical, installation, communications, information technology, transportation, sales tax and other relevant costs. Please provide in as disaggregated a form as possible.		
ESS operations and maintenance (O&M) costs	Estimated annual fixed and variable O&M costs for each ESS. Long-term O&M cost inflation rates.		
Insurance Premiums	Rate for insurance premiums and other taxes (as fraction of capital investment).		
Cost of Capital	Before-tax weighted cost of capital.		
Property Tax	Property tax rates on the ESS (if applicable for determining rate recovery).		
Income Tax	Marginal income tax built into revenue requirements calculations.		
Other Taxes/Fees	Other taxes or fees required to calculate levelized capital costs as defined by the utility.		
Operating Life	Operating lifetimes for ESSs in terms of number of cycles and years.		
Price Data	Forecast day-ahead hourly price data during testing period and hourly real-time energy price data for 2012-2014. For SnoPUD, high load hour and low load hour average hourly market index prices by month.		
Capacity Value	Capacity value ($/kW-year) in 2015 Integrated Resource Plan.	Cost ($/kW-year) of next best alternative for meeting capacity reserve.	Powerdex super peak hourly market index prices for 2014.
Regulation/Balancing Prices	Historic Mid-C frequency regulation prices and ADSS weekly marginal prices for 2011-2015.	Hourly prices for flexibility operations based on PSE production cost model for 2011-2015.	Identification and discussion of the persistent deviation rates applied in the energy imbalance payment structure.
Distribution Equipment Costs	Cost and life, in terms of number of operations, for each equipment type that might benefit from peak shifting, load shaping and power factor correction.		
Outage Costs	Power reliability/quality benefits to Schweitzer Engineering Laboratories (SEL).	Outage costs by customer type.	None.

2.1.2 System Data

PNNL will use the Battery Storage Evaluation Tool (BSET) to define optimal duty cycles for ESS performance testing and in monetizing the benefits of each ESS. To solve the optimization problem that forms the mathematical foundation of BSET, price/financial, system and battery data are required. For example, the energy requirements associated with a regulation signal are required in order to define an optimal control strategy. Table 2.2 presents an initial list of system data requirements. As the use case reports are further developed and refined for each use case and utility, the data requirements defined below will be modified.

Table 2.2. Electricity System Data Requirements

<table>
<tr><th>Item</th><th>Avista</th><th>PSE</th><th>SnoPUD</th></tr>
<tr><td rowspan="5">Load Data</td><td colspan="3">System-wide hourly load data covering the past five years.</td></tr>
<tr><td colspan="3">For substation and feeder(s) where ESS in installed, load data at the 1-minute frequency over the past three years for the substation and feeder(s) served by the ESS.</td></tr>
<tr><td colspan="2">For equipment on the feeder nearing capacity and a potential candidate for upgrade deferral, equipment-specific 1-minute load data over past three years.</td><td>N/A</td></tr>
<tr><td>For Volt/VAR and/or conservation voltage reduction (CVR), 1-minute reactive power flows for substation and feeder(s) where ESS is installed over past three years.</td><td>N/A</td><td>For Volt/VAR and/or conservation voltage reduction (CVR), 1-minute reactive power flows for substation and feeder(s) where ESS is installed over past three years.</td></tr>
<tr><td>For microgrid operation, cumulative 1-minute load data for the specific load in the microgrid over the past three years.</td><td>N/A</td><td>N/A</td></tr>
<tr><td>Load Forecasts</td><td colspan="3">Long-range (e.g., through 2020) system-wide and local (if available) load forecast. During use case testing, day-head hourly load forecasts.</td></tr>
<tr><td rowspan="4">Substation/Feeder Characteristics</td><td colspan="3">General circuit diagram of the feeder(s) affected by Volt/VAR operations of the ESS, including ESS installation location.</td></tr>
<tr><td colspan="3">1-minute voltage measurements at all available points on the feeder(s) where ESS is installed and substation head voltage (post-regulator, if applicable) for the past three years.</td></tr>
<tr><td colspan="3">Record of voltage regulator and capacitor switching events at substation head and along the length of the feeder(s) where the ESS is installed.</td></tr>
<tr><td colspan="3">Identification of regulators, capacitor banks and other infrastructure that might benefit from load shaping and power factor correction using the ESSs evaluated in this study.</td></tr>
<tr><td>Regulation/Balancing Data</td><td>Historic 4-second regulation signals (frequency and/or AGC) over the past three years.</td><td>Historic 4-second regulation signals (frequency and/or AGC) over the past three years.</td><td>2014 net schedule data.</td></tr>
<tr><td>Outage</td><td>Historic starting time and duration for outages affecting SEL over past five years.</td><td>Historic starting/ending time and number of customers affected by outages on feeder(s) where the ESS is installed over the last three years; transmission outages over past ten years.</td><td>N/A</td></tr>
</table>

2.2 Use Case Analysis Procedures – Arbitrage at Avista

In an effort to better define the data requirements for the UCAP and specific methods used in evaluating the financial and technical performance of each ESS, PNNL is in the process of developing methodology/data reports for each use case at each utility. To help utilities understand how the data collected under this project will be used, this section shares one of the several reports prepared to date. This one is focused on Use Case 1 - Energy shifting from peak to off-peak on a daily basis (arbitrage) as designed for Avista Utilities. Similar reports will be prepared for PSE and SnoPUD as well.

2.2.1 Fundamental Value Proposition

Arbitrage is the practice of taking advantage of differences between peak- and off-peak wholesale energy prices. In the context of electric energy markets, energy storage can be used to charge during low-price periods (i.e., buying electricity) in order to discharge the stored energy during periods of high prices (i.e., selling during high-priced periods). The economic reward is the price differential between buying and selling electrical energy, minus the cost of losses during the full charging/discharging cycle.

2.2.2 Methodology for Evaluating the System and Economic Benefits of Use Case 1 (Arbitrage)

For arbitrage valuation, Avista will supply hourly real-time energy price data for the 2011-2014 time period. The data represents the market prices as annotated in the Avista trading room on an hourly basis. To address the uncertainty associated with fluctuations in the value of energy prices over time, the Monte Carlo method will be adopted. A total of 30 Monte Carlo simulations will be run. The number of Monte Carlo simulations was determined based on past experience in conducting the *National Assessment of Energy Storage for Grid Balancing and Arbitrage* (Kintner-Meyer et al., 2013).

2.2.3 Testing Protocol

Avista obtains forecast hourly energy prices from Pattern Recognition Technologies, Inc. (PRT). Hourly prices are forecast for the next week but are updated hourly throughout the week. Forecast energy price data for the next day will be provided to PNNL through a secure site. The data will be input into BSET. BSET will be used to define an hourly schedule for the battery over the next day. PNNL will define the optimal charging and discharging schedule in order to either maximize value to the system or minimize losses. That is, even if the transactions result in financial losses, the test should be carried out for the purpose of ESS performance testing.

The ESS will be charged at 600 kW to 100 percent SOC. Assuming the initial SOC is 50 percent, the estimated charge time would be six hours. Charging will be done during off peak hours – 11 PM to 5 AM as set by the output of BSET. During peak morning hours, the ESS will be discharged at the power output levels and hours identified by BSET. The BESS will be charged between 10 AM to 4 PM at 600 kW. It will then be discharged during evening peak hours. The ESS will subsequently be charged to 100 percent SOC to calculate the round trip efficiency. One way efficiency will also be calculated as a function of SOC.

The charging and discharging durations will differ because roughly one-third of the energy is lost through efficiency losses. Thus, more energy must flow into the battery to achieve a desired power output. The ESS SOC range during the duty cycle will be between 30% and 90%. If the lower SOC limit is < 50%, the ESS will not provide constant power lasting the entire way to the lower SOC limit. The actual lower SOC limit up to which discharge power is constant at 100 kW will be determined prior to testing.

The duty cycle roundtrip efficiency as a function of discharge power shall be determined by dividing the energy removed from the ESS at a given power by the energy required to recharge the ESS. At the end of the test, the ESS shall be brought to a full state of charge using a procedure as recommended by the manufacturers' specifications and operating instructions.

2.2.4 Data Requirements

The following data are required to evaluate this use case:

1. Real-time energy price data noted by the Avista trading floor for 2011-2014.
2. Hourly energy price data forecast by PRT for the duration of the use case test.

3.0 Conclusions

At this time, PNNL has shared preliminary data requirements for several use cases with Avista and SnoPUD. Both utilities have supplied large volumes of data, which PNNL is beginning to process. PNNL will be working with PSE in the coming weeks to define all data needs and establish the required data systems. PNNL has attempted to exercise some degree of due diligence in preparing this initial data requirements document; however, we recognize the need to be flexible in the coming months as use case methods are further defined and data collected.

PNNL is now successfully receiving, processing, and storing data from our partner utilities. PNNL is exchanging the necessary duty cycles for scheduling of the battery systems and one utility is providing forecast price data and output from battery operations. PNNL is positioned to expand the data repository to include the second and third partner utility data. PNNL continues to make adjustments as necessary to any design criteria needed to support the data and efficiency metrics established for the UCAP.

4.0 References

Kintner-Meyer M, P Balducci, W Colella, M Elizondo, C Jin, T Nguyen, V Viswanathan, and Y Zhang. 2013. National Assessment of Energy Storage for Grid Balancing and Arbitrage: Phase II – WECC, ERCOT, EIC. Volume 1 – Technical Analysis. Richland, WA.

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