Northwest **Power** and
Conservation Council

April 30, 2019

MEMORANDUM

TO: **Council Members**

FROM: **Steven Simmons**

SUBJECT: **Gauging the Potential Impact of Behind-The-Meter Solar + Battery to Modify Load in the Pacific Northwest**

BACKGROUND:

Presenter: Steven Simmons

Summary: Behind-the-meter solar installations affect the overall system load during the daylight hours while the photovoltaic (PV) systems are generating electricity. As behind-the-meter batteries become available and are paired with PV systems, some of the solar generation could be stored and used later during non-daylight hours. If there were a large build-out of solar + battery systems across the region over the coming decades, the impact on system load, and especially the system load shape and hourly load peaks could be significant.

A study was completed to gauge the potential impact of solar + battery systems on the overall system load and the results were implemented into the long-term load forecast model. The approach was to model the installation of solar + battery systems across the region and aggregate their operations to benefit the grid by flattening the system load and reducing the peak. A function was developed to relate the level of load modification to the level of solar + battery installations.

Relevance: The load forecast that is incorporated into the power plan attempts to capture the factors that might impact the long-term system load. Though

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behind-the- meter solar + battery systems have not yet been installed at a meaningful level, that might change over the next twenty years. The potential effect that a more significant buildout of these systems needs to be reflected in the long-term load forecast.

Workplan: ANLYS 2 – improve the long-term load forecast for emerging markets

Background: The economics of installing behind-the-meter solar + battery systems are improving. The material and installation costs for PV systems have been declining for years. Now, battery costs (such as Lithium-Ion) are also on the decline. Several manufacturers offer battery systems that can be paired with PV systems, including Tesla, LG Chem and Sonnen. Utilities, like Tucson Electric Power, have begun to explore how these systems could be used to reduce peak demands and otherwise benefit the grid.

Gauging the Potential Impact of Behind-The-Meter Solar + Battery to Modify Load in the Pacific Northwest

Steven Simmons
Northwest Power & Conservation Council
May 7, 2019 – Boise Idaho

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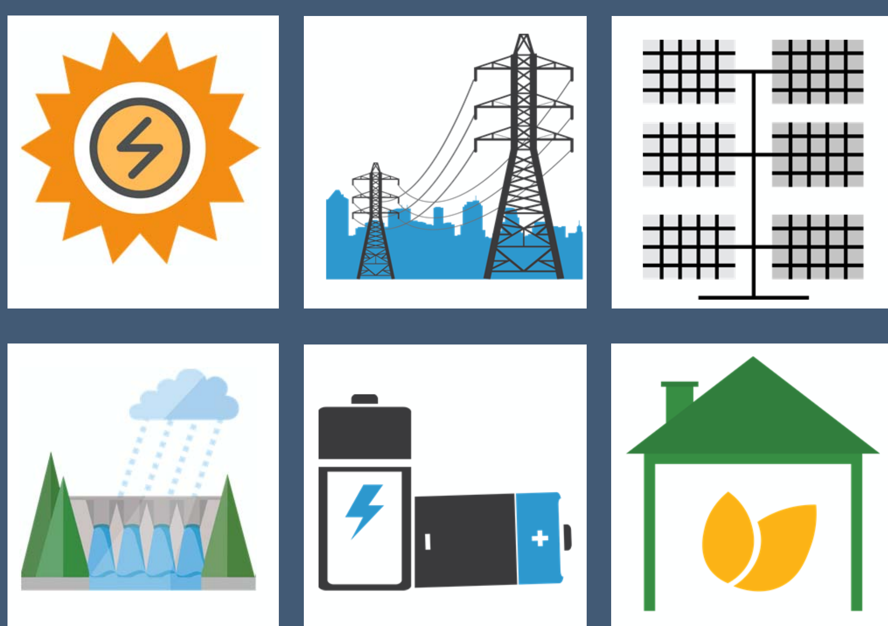

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Today's Discussion

1. Project Background
2. Behind-the-Meter Solar Generation in the Northwest
3. Simulation of Solar + Battery & System Load
4. Results
5. Implementation into our Long Term Load Forecast Model
6. Wrap up

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Project Background

Gauging The Potential Impact of Behind-The-Meter Solar + Battery to Modify the Load in the Pacific Northwest

Background

The economics of **Solar + Battery** systems are improving

- Solar (PV) material and installation costs have been declining for many years
- Now battery costs are also on the decline (such as Li-ion)
- In some areas net metering rates have declined or could be dropped – making storage for self-generation more attractive
- Solar + Battery installation packages are now available

Background

How could the **Solar + Battery** systems be used?

- Provide backup power – for the home or business
- Lower retail electricity bills by modifying time of use (if TOU rates apply)
- Behind-the-meter solar and storage could also potentially be used to enhance grid operations – such as peak load reduction

this is the focus of the project

Background

1. Tucson Electric Power (TEP) has begun an energy storage pilot program to explore how residential solar and battery systems could be used to reduce peak demands and otherwise benefit the grid
2. Home battery systems are still expensive and may need to provide value to the grid to really pay off
3. Home storage products include the Tesla Powerwall, LG Chem RESU, Sonnen ecoLinx – these are all lithium ion based units
4. Example home system

   5.6 kW PV panel coupled with a 6 kWh Lithium Ion battery with inverter

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Our Approach

1. Create an updated library of BTM solar profiles – what does solar look like across our region?
2. Develop a tool to simulate the operation of aggregated levels of **Solar + Battery** installations across the Northwest to flatten the system load, especially peak load
3. From the simulation results, produce a set of functions that relate potential future levels of **Solar + Battery** installations to system load modifications for each month
4. Implement the functions into our long term load forecasting model Energy2020 and test the results

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Behind the Meter Solar Generation in the Northwest

Gauging The Potential Impact of Behind-The-Meter Solar + Battery to Modify the Load in the Pacific Northwest

Solar Profiles

We recently created a library of calculated solar generation profiles

1. For 60 locations - scattered across the 4 Northwest states
2. Used the most recent version of the NREL System Advisory Model (SAM)
3. Single state solar profiles were created using population weights – and brought into Energy2020
4. A region solar profile was created using the state profiles – weighted by a forecast of installed solar capacity by state

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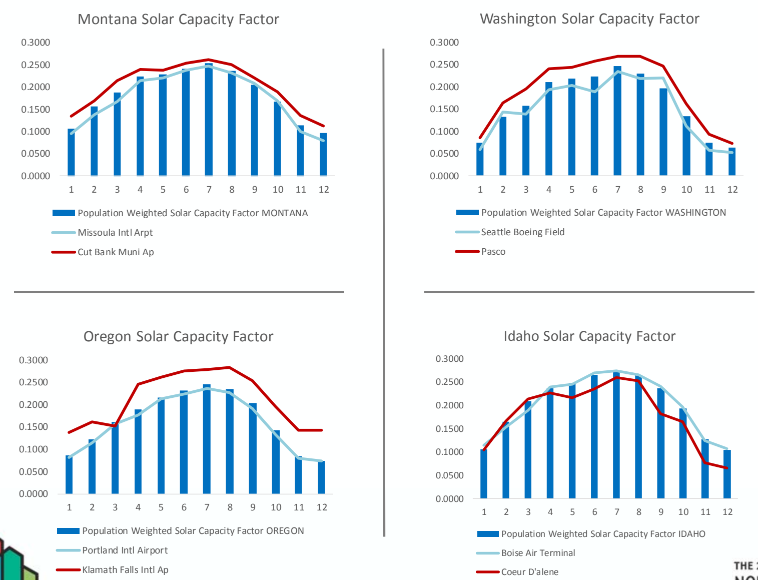

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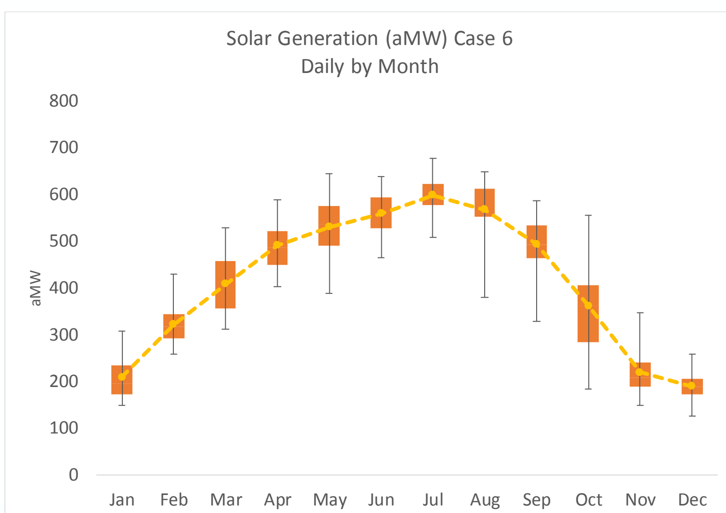
Case 6: 2375 MW Solar Capacity Installed



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Simulation of Solar + Battery & System Load

Gauging The Potential Impact of Behind-The-Meter Solar + Battery to Modify the Load in the Pacific Northwest

Simulation Tool

1. A behind the meter Solar + Battery System could be configured to provide backup power, optimize self-generation for the site, and/or to enhance overall grid performance
2. This project is focusing on a "holistic" perspective – how to produce an overall "flattening" of the system load – in which individual installations of Solar + Battery could be **aggregated** for optimal system results

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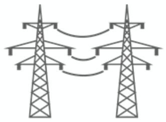
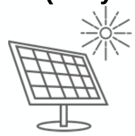
Grid	Solar (PV system)	Battery
		
Can serve load directly	Can serve load directly	Can be charged from the PV system
Can charge the battery for later use	Can be sent to the battery for later use	Can be charge from the grid
		Can discharge to serve load
		The state of charge is kept within operation limits and round trip battery losses are accounted for

Simulation Tool

1. The simulation walks through a single year on a day by day basis
2. Within each day – a "load flattening" algorithm attempts to fit the load for each hour of the day into a defined band using a load "ceiling" and a load "floor"
   a) The algorithm will attempt to reduce any hourly load that is above the load "ceiling" by dispatching solar and/or the battery
   b) Any hourly load that is below the load "floor" will be increased by charging the battery from the grid
3. Multiple load "floor & ceiling" levels are tested and the combination that produces the lowest single-hour maximum load is selected. Note that the minimum hourly load may increase

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Simulation Runs

1. Set up 3 scenarios (configurations) with 10 cases (level of installations)
   a. Solar only
   b. Solar + Battery with no grid charging
   c. Solar + Battery with grid charging
2. For the configurations with batteries, assumed a solar to battery ratio of 1 to 1 – meaning for 1 MW of solar capacity installed, there was 1 MWh Battery energy capacity installed
3. Compared results between the scenarios to gauge the effect of adding batteries to solar
4. Used the results to fit model functions for Energy2020 implementation

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Results

Gauging The Potential Impact of Behind-The-Meter Solar + Battery to Modify the Load in the Pacific Northwest

Single Day Results – for May 4

- The following graphics show results from the
- **Solar + Battery**
- with **Battery- grid charging** allowed
- and 2,375 MW & MWh of solar/battery installed

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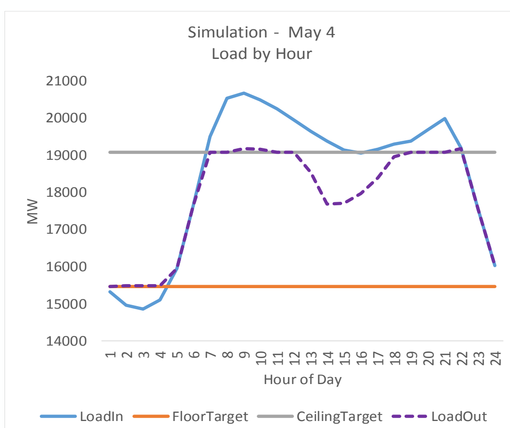

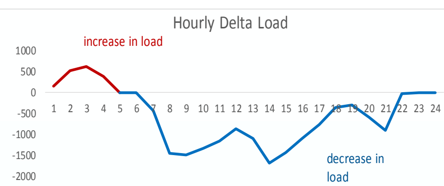

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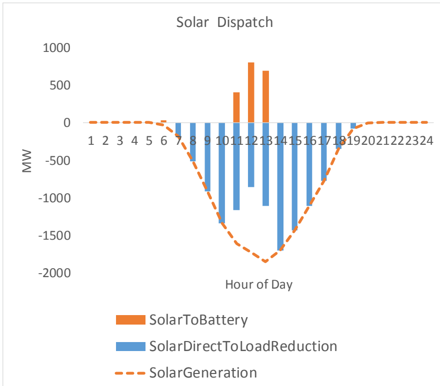
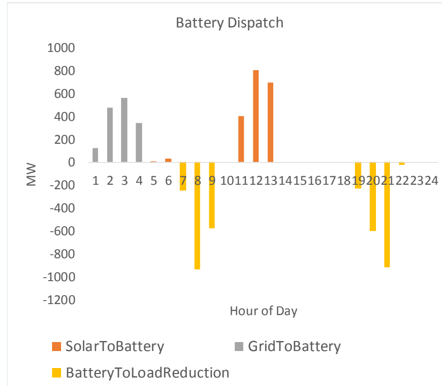
Simulation Results for May 4





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Load Category	Load (MW, *aMW)	Hour of Day
Peak Load - In	20,653	8 - 9 am
Peak Load – Out (after S+B)	19,174	9 – 10 pm
Peak Load Delta	(-) 1,479	
Avg Load In	18,441*	
Avg Load Out	17,883*	
Avg Load Delta	(-) 558*	
Min Load In	14,863	2 – 3 am
Min Load Out	15,468	12 – 1 am
Min Load Delta	(+) 604	

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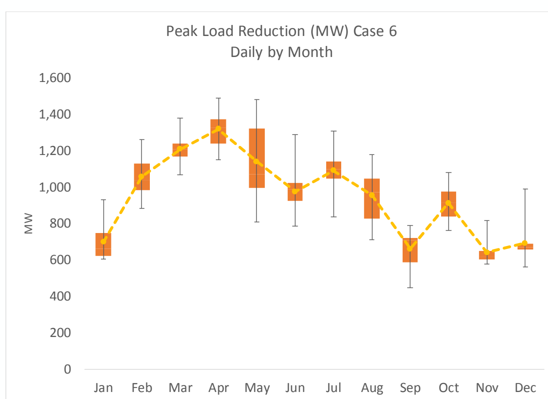
Solar - Energy Dispatch	Battery – Energy Dispatch
85 % - direct to load	47 % - was from solar
14 % - to battery	37 % - was from the grid
1 % - losses	9 % - was energy stored from previous day
	7 % - losses

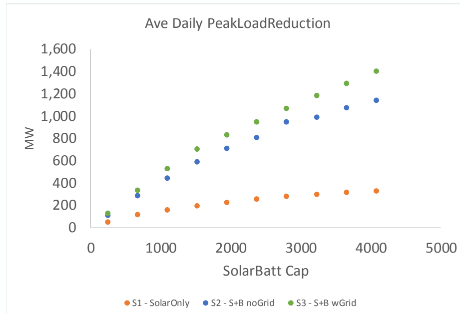
Key Results – Daily Peak Reduction

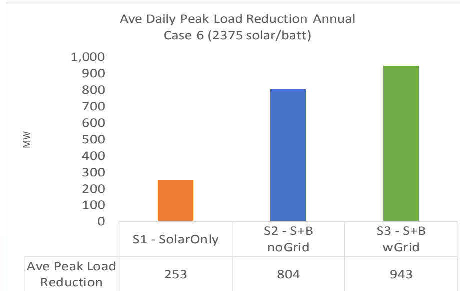
1. Peak reduction can vary from day to day and month to month
2. The shape of the system load & the solar generation are key influencers on peak reduction



Key Results - Overall

1. Solar + Battery with Grid Charging provides the most peak load reduction
2. Adding batteries to solar can provide nearly 4x the amount of peak load reduction
3. Load reduction varies from month to month
4. The greatest improvement from adding batteries to solar with grid charging is in the winter and early spring months





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Energy2020 Forecast Implementation

Gauging The Potential Impact of Behind-The-Meter Solar + Battery to Modify the Load in the Pacific Northwest

1. Using the simulation results, a set of functions were developed to define the relationship between the level of solar+battery installations (MW/MWh), incoming load, and the resulting load reduction
2. Unique load reduction functions for: peak, average, and minimum
3. Parameters were fit for each month
4. The functions have been implemented into Energy2020

$$P_R/B_{IC} = a \cdot \ln\left(B_{IC}/P\right) + b$$

PeakLoadReduction per installed SolarBattery Capacity - as a function of SolarBattery Capacity per incoming PeakLoad

$$A_R/B_{IC} = a \cdot \left(B_{IC}/A\right) + b$$

AveLoadReduction per installed SolarBattery Capacity
- as a function of SolarBattery Capacity per incoming AveLoad

$$M_R/B_{IC} = a \cdot {B_{IC}/M}^2 + b \cdot B_{IC}/M + c$$

MinLoadReduction per installed SolarBattery Capacity
- as a function of SolarBattery Capacity per incoming MinLoad

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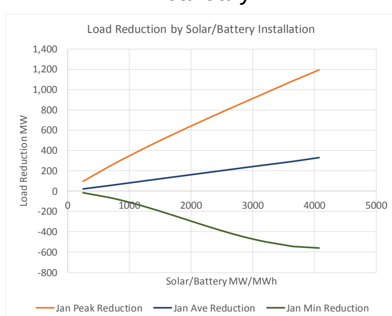
January



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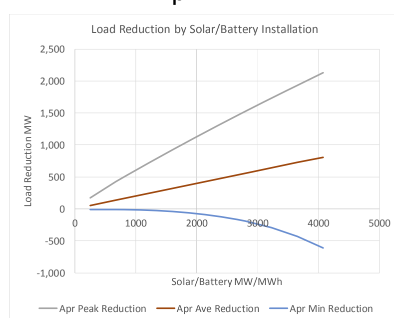

Forecast Implementation: Load reduction as a function of installed Solar + Battery capacity by month

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Wrap Up

Gauging The Potential Impact of Behind-The-Meter Solar + Batteries to Modify the Load in the Pacific Northwest

In Conclusion

1. We now have a library of behind-the meter solar profiles by individual location, state, and the Northwest
2. We have a tool to gauge the impact that aggregated installations of behind-the-meter solar + battery systems could have on system load
3. We have developed functions to relate the level of solar + battery installations to the reduction of peak, average, and minimum system load
4. With the help of SSI, we have implemented new software code into Energy2020 to reflect the potential load impacts in the overall long range forecast of electricity demand

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