ENERGY STRATEGIES

Avista Variable Energy Resource (VER) Integration Study

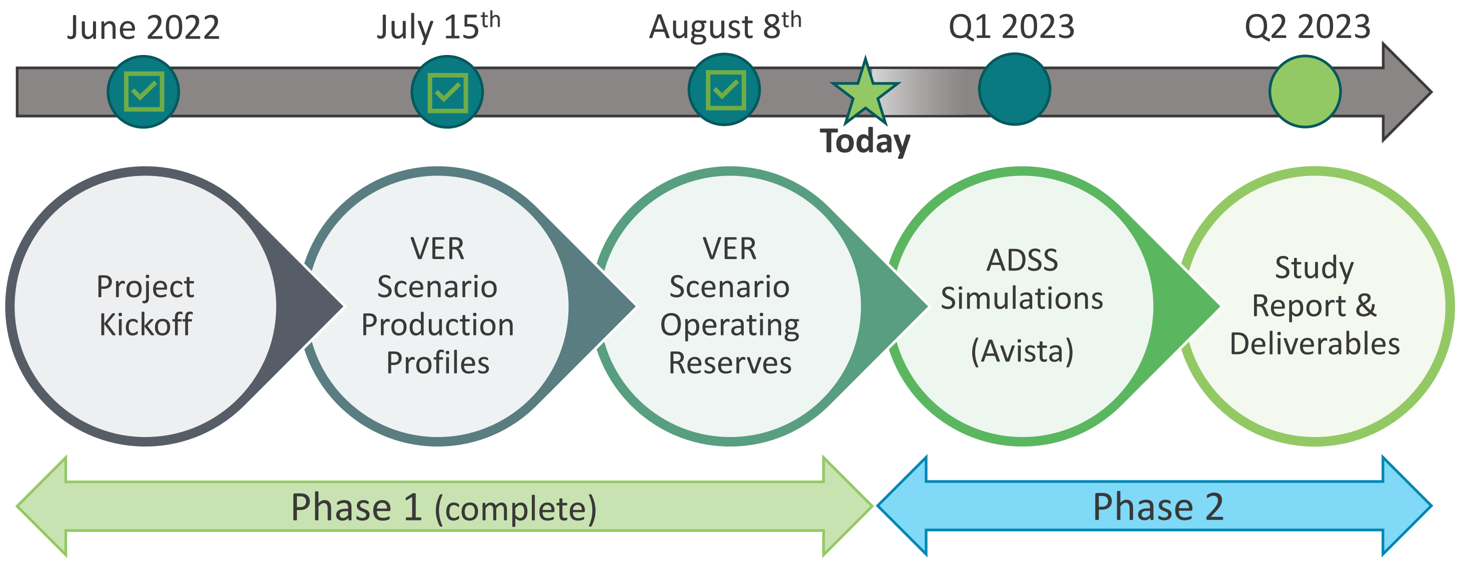
Phase 1 Review

Today's Agenda

- **Review Study Objectives**
  - Study Scope
  - VER Scenarios
  - Methodology
- **VER Production Profiles**
  - NREL Datasets
  - Profile Validation
  - Review of Summer & Winter Profiles
- **Operation Reserves**
  - Reserve Calculation Methodology
  - EIM Implications on Reserves
  - Reserve Calculation Results
  - Phase 1 Deliverables
  - Next Steps
- **Q&A throughout**

Study Background & Timeline

- **In February 2022, Avista released a RFI for the 2022 VER Integration Study**
  - The RFI outlined study scope as the development and implementation of a framework to quantify the incremental integration cost of a range of potential VER penetration levels used to service Avista Load
  - Energy Strategies was selected by Avista to perform the VER Integration Study, and opted to use Avista's in-house production cost modeling platform (ADSS)
- **The VER Integration Study is one of many steps required by Avista to ensure that carbon-neutrality goals can be accomplished in a reliable and cost-effective manner**
  - Avista's last VER Integration Study was completed in 2007
  - Many assumptions have changed since the 2007 VER Integration Study, including resource capital costs, Avista's resource mix, and recently, Avista's participation in the Western EIM
- **Today's materials focus on the efforts completed in Phase 1**



VER Scenarios

- **Energy Strategies developed data inputs for 12 VER scenarios modeled in the Avista Decision Support System (ADSS) production cost model**
  - ❖ Approach includes incremental VER production and operating reserve requirements on top of a 2021 case
- **Operating reserves are latent dispatchable capacity that can be called upon to maintain reliability during sudden, unexpected changes of system load or generation**
  - ❖ Integration cost is primarily driven by the need to hold higher levels of **operating reserves** caused by the variability and uncertainty of VER production

VER Scenarios	Incremental VERs		
	100% Wind	50/50 Wind/Solar	100% Solar
Baseline	No additional VER or VER equivalent energy		
+400 MW VER	400 MW wind	200 MW wind & solar	400 MW solar
+800 MW VER	800 MW wind	400 MW wind & solar	800 MW solar
+1500 MW VER	1500 MW wind	750 MW wind & solar	1500 MW solar
+2500 MW VER	2500 MW wind	1250 MW wind & solar	2500 MW solar

VER Scenarios

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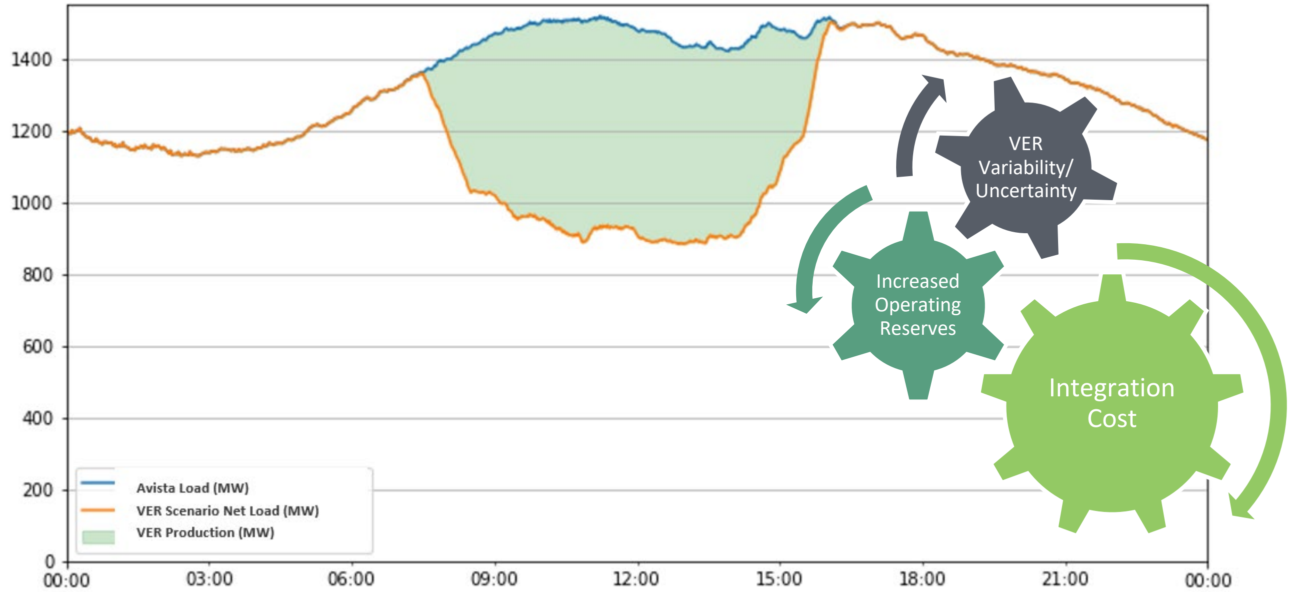
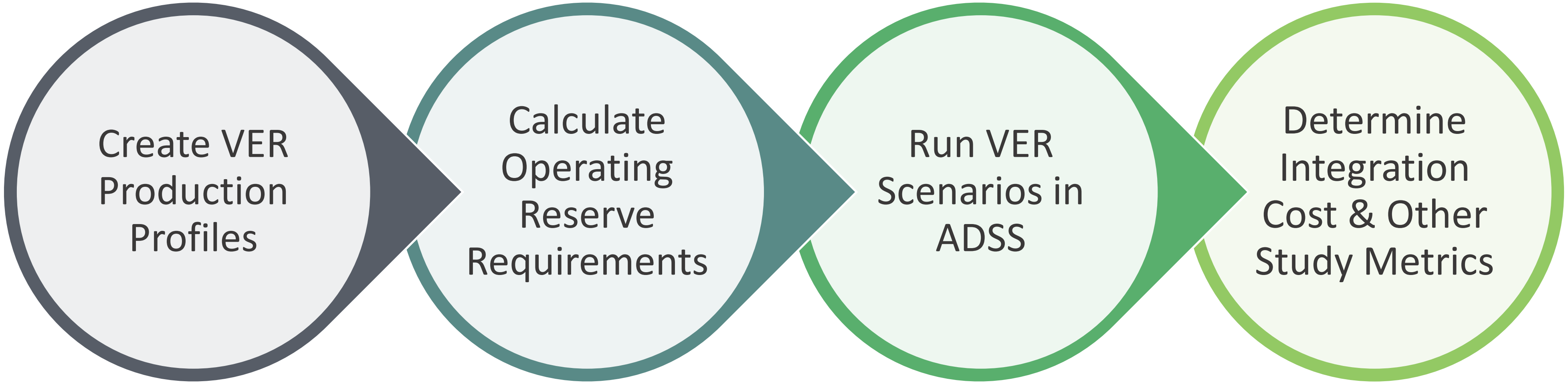
- **Operating reserves are latent dispatchable capacity that can be called upon to maintain reliability during sudden, unexpected changes of system load or generation**
  - ❖ Integration cost is primarily driven by the need to hold higher levels of **operating reserves** caused by the variability and uncertainty of VER production
  - ❖ Held as a constraint in the ADSS model

VER Scenarios	Incremental VERs		
	100% Wind	50/50 Wind/Solar	100% Solar
Baseline	No additional VER or VER equivalent energy		
+400 MW VER	400 MW wind	200 MW wind & solar	400 MW solar
+800 MW VER	800 MW wind	400 MW wind & solar	800 MW solar
+1500 MW VER	1500 MW wind	750 MW wind & solar	1500 MW solar
+2500 MW VER	2500 MW wind	1250 MW wind & solar	2500 MW solar



VER Integration Study Methodology



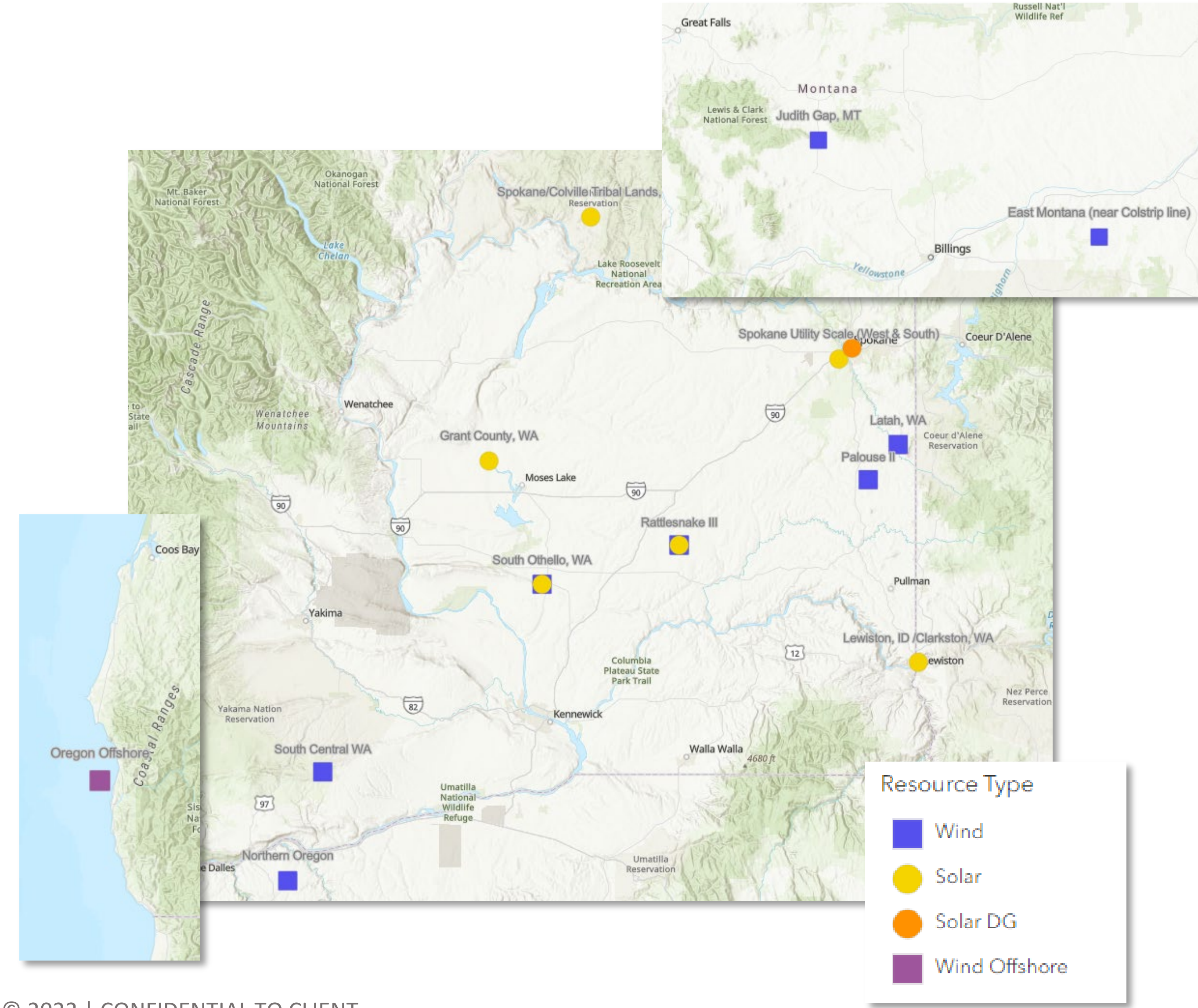
VER Scenario Production & Forecast Profiles

Avista VER Integration Study

VER Locations

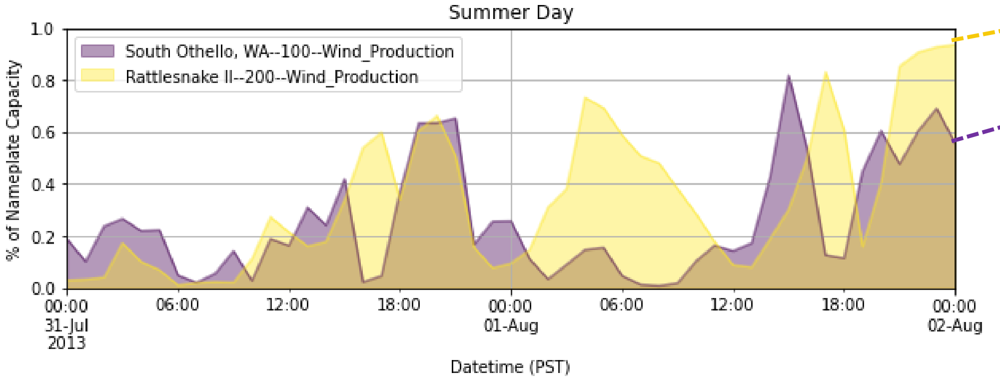
- **Avista identified feasible VER buildouts for each study scenario**
  - ❖ Study locations identified by Avista engineers as likely development locations based on past development proposals

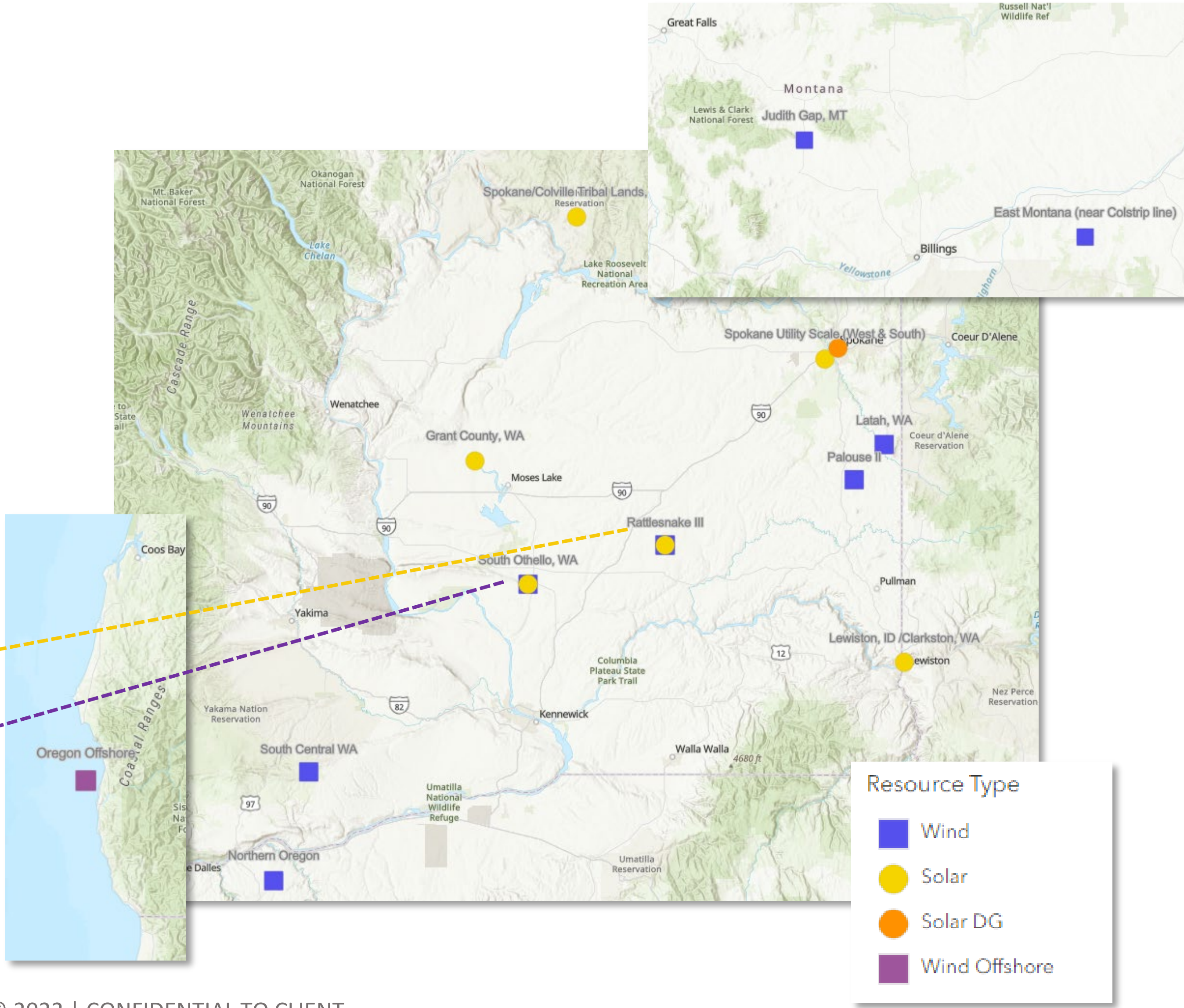
Site Location	Resource Type	+400 MW			+800 MW			+1500 MW			+2500 MW		
		Wind	50/50	Solar	Wind	50/50	Solar	Wind	50/50	Solar	Wind	50/50	Solar
North Colstrip, MT	Wind	100	100		200	200		200	200		400	200	
Judith Gap, MT	Wind	200	100		200	200		300	200		400	300	
South Othello, WA	Wind	100			100			100	100		150	100	
Rattlesnake II	Wind				200			200	200		200	200	
Palouse II	Wind				50			75	50		75	75	
Northern Oregon	Wind				50			200			200		
Latah, WA	Wind							125			125	125	
Oregon Offshore	Wind							200			550	250	
South Central WA	Wind							100			200		
Rattlesnake III	Wind										200		
Lewiston, ID /Clarkston, WA	Solar		200	300		200	300		300	300		300	300
Othello/Lind, WA	Solar			100		200	400		200	400			400
Spokane/CDA DG	Solar						100		150	300		350	500
Grant County, WA	Solar									200		200	200
Spokane/Colville Tribal Lands, WA	Solar								100	100		100	200
Rattlesnake Wind	Solar									200		300	200
Spokane Utility Scale (West & South)	Solar												300
East Montana (near Colstrip line)	Solar												400



VER Profiles

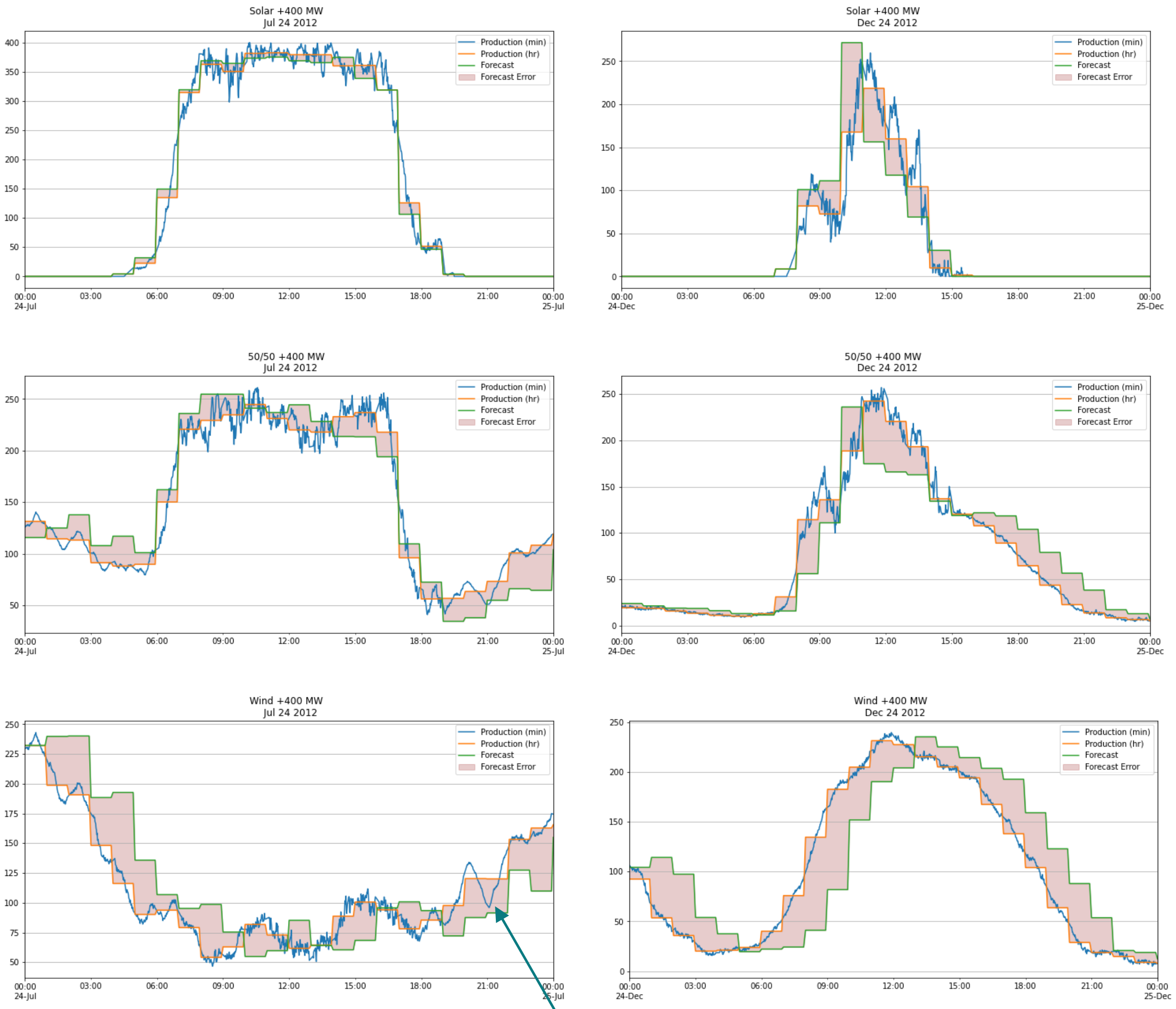
- **Utilized NREL WIND and NSRDB datasets to compile site-specific proxy production & forecast profiles for each VER site**
  - ❖ Data compiled for a timeframe of 2007 – 2013; providing 7 years of data from which to derive reserves
  - ❖ All site production was validated to be within 5% capacity factor of Avista-provided contractor estimates
- **Generic design assumptions were made for VER resources:**
  - ❖ Wind: 100m hub height, standard turbines
  - ❖ PV: 1.4 inverter loading ratio
    - ➢ Utility-Scale PV: Single-axis Tracking (DG Fixed)





VER Profile & Forecasts

- **Forecasts for wind resources utilized the NREL WIND dataset**
  - ❖ Wind forecasts were validated to ensure that hour-ahead forecast errors were consistent with available industry forecast methods available to Avista
- **Forecast for PV resources utilized the NREL SIND dataset**
  - ❖ PV forecasts represented a 2006 weather year, and were adjusted to represent forecast errors consistent with available industry forecast methods available to Avista
- **Site-specific production/forecasts were summed together to represent total VER production/forecast for each VER scenario**



Wind Forecast Error: 27% - 31%
PV Forecast Error: 6% - 8%

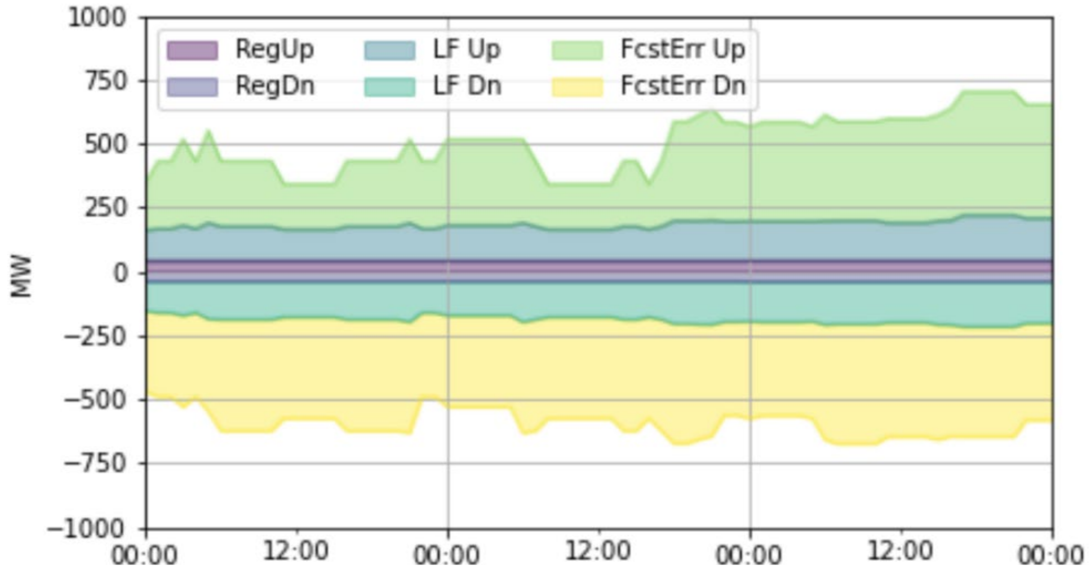
Operating Reserve Calculations

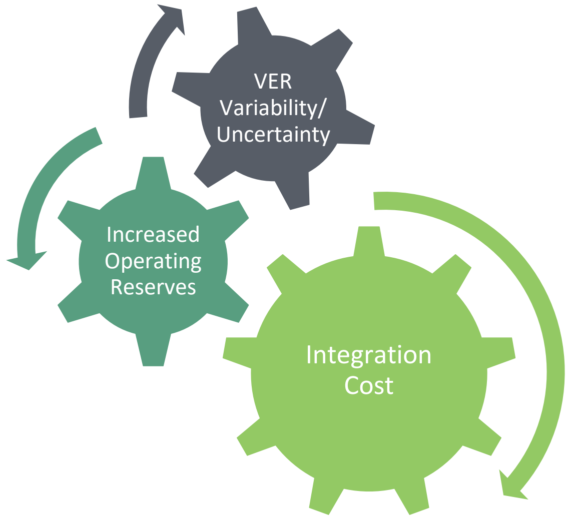
Avista VER Integration Study

Operating Reserves

- **Operating reserves are latent dispatchable capacity that can be called upon to maintain reliability during sudden, unexpected changes of system load or generation**
- **Avista currently holds three unique operating reserves types**
  - **Regulation Reserves** are procured to handle rapid, unexpected variations in net load
  - **Load-Following Reserves** are procured to handle hour-to-hour variations in net load
  - **Forecast Error Reserves** are procured to handle net load uncertainty in the hour-ahead timeframe
- **Reserves are required in both the up and down direction**
  - An "up reserve" is defined as a reserve held to deploy a sudden increase in generation
  - All reserve types are mutually exclusive and held independently

Reserves for a Sample 3-Day Period





Reserve Calculations

- **Reserve levels are determined by taking a statistical confidence interval of "errors" that represent unanticipated variability or uncertainty contributed to the system by VERs**
  - ❖ Reserve calculations identify the MW level of reserves required to 95-99% of variability and uncertainty of VER integration for each scenario.
  - ❖ Each reserve calculation results in an MW value that represents the latent spinning reserve capacity, which should be held by other dispatchable generators in the Avista system, as defined by constraints in the ADSS production cost model.
- **Energy Strategies' calculated reserve confidence intervals via statistical analysis based on 7 historical weather years**

Regulation Reserves

- Procured to handle rapid, unexpected variations in load or generation
- **Regulation Error = 1-min Net Load – 10-minute Net Load Rolling Average**
- Calculated as a 3σ confidence interval of Regulation Errors
- On-Peak and Off-Peak values calculated by month

Load-Following Reserves

- Procured to handle hour-to-hour variations in net load
- **Load-Following Error = 1-min Net Load – Hourly Average Net Load**
- Calculated as 2σ confidence interval of Load-Following Error
- Calculation bins load-following reserves held in operating hour by VER forecast
- Discounted by 25% to represent EIM Diversity Benefit

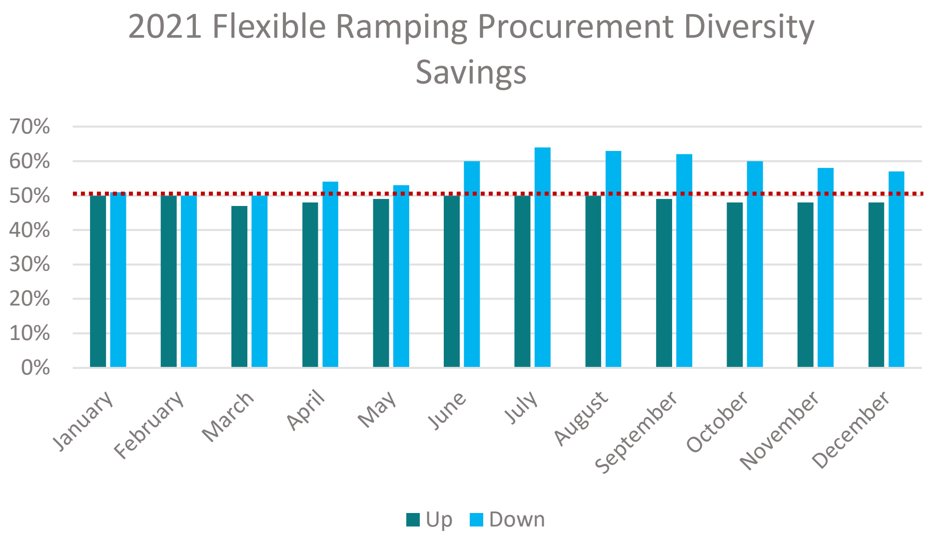
Forecast Error Reserves

- Used to handle net load uncertainty in the hour-ahead timeframe
- **Forecast Error = Net Load – Net Load Hour-Ahead Forecast**
- Calculated as 2σ confidence interval of forecast errors
- Calculation bins forecast reserves held in operating hour based on VER forecast
- Discounted by 25% to represent EIM Diversity Benefit

Net Load = Avista Gross Load – VER Production

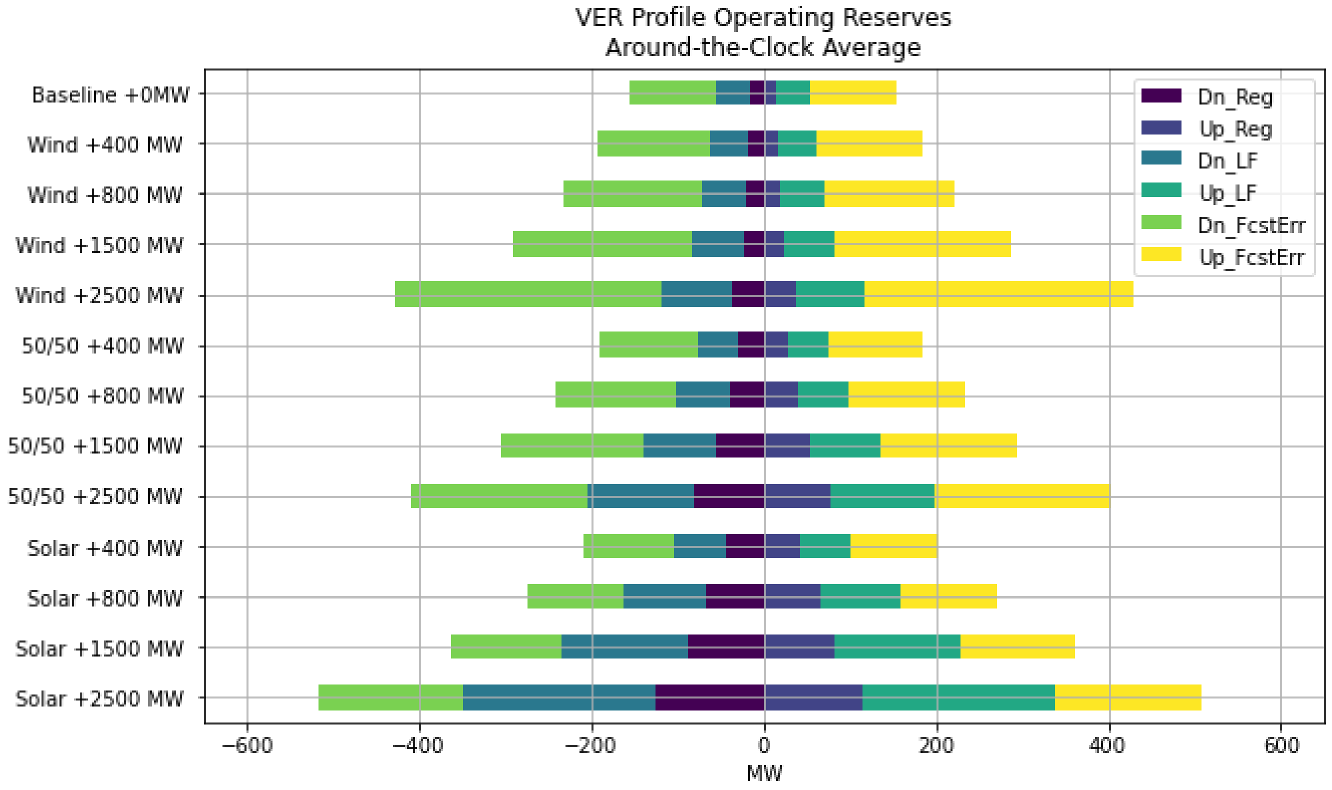
EIM Implications on Reserves

- **The Western EIM facilitates procurement of flexible ramping capacity to address variability that may occur in real-time dispatch**
  - ❖ The application of flexible ramping capacity serves to reduce the level of Load Following and Forecast Error reserves held within the Avista BAA footprint
  - ❖ **In 2021, Western EIM flexible ramping procurement diversity savings averaged to approximately 50%**
- **However flexible ramping capacity likely would not represent a 1:1 reduction in load-following and forecast error reserves due to:**
  - ❖ Flexible capacity may be constrained by EIM import/export limitations and, thus, may not be as dependable as physical capacity, resulting in Avista still carrying some additional level of reserves
  - ❖ Flexible ramping capacity changes hour-to-hour, depending on system conditions, so more reserves may be required in some hours, indicating it may be appropriate to assume some reduction in the average flexible ramping diversity benefit
  - ❖ An EIM participant can be excluded from the flexible ramping diversity benefit if they fail the flexible ramping test, which would also serve to reduce the flexible ramping procurement savings
- **For the VER Integration Study, we conservatively approximate EIM Flexible Ramping Capacity to reduce the Load-Following and Forecast Error reserves held within the Avista footprint by 25%**



Average Reserve Levels: VER Scenarios

- **The graph shows how reserve levels relative to the Avista Reference, and how reserve levels change between VER scenarios**
    - Up- and down reserve levels are similar, in aggregate
    - Solar seems to be driving more reserve increases per MW of installed capacity, primarily due to load following
    - Wind Forecast error is larger than PV forecast error, and drives more of the reserves in the wind-only scenarios



Net Load = Avista Gross Load – VER Production

Reserve Results

- **After all reserves were calculated, we re-applied them to the historical timeseries for implementation into the ADSS simulation**
- **Deliverable formatted as a Microsoft Excel workbook with 8760s for each historical weather-year**
    - ❖ Phase 1 materials have been sent to Avista

Net Load = Avista Gross Load – VER Production

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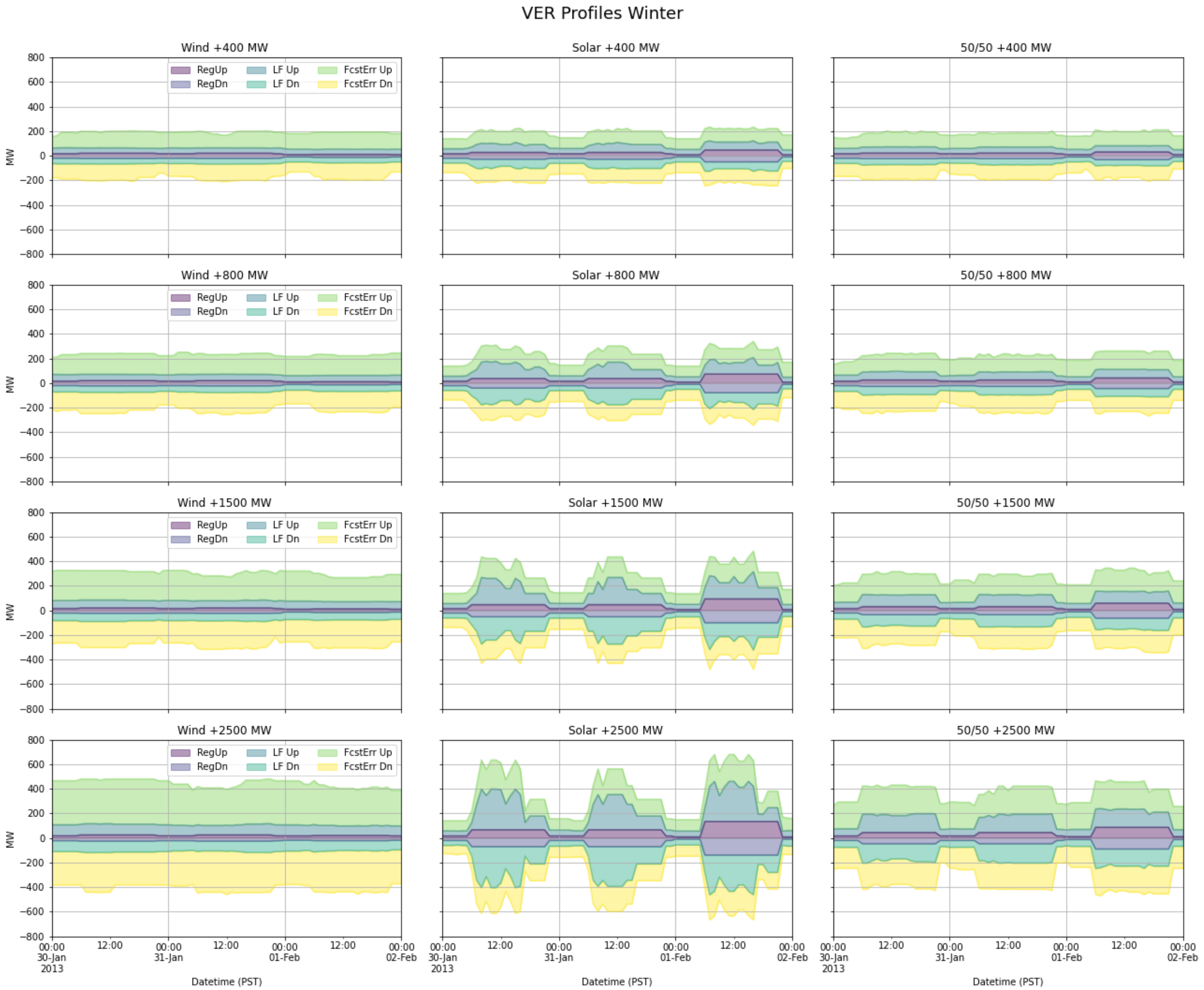
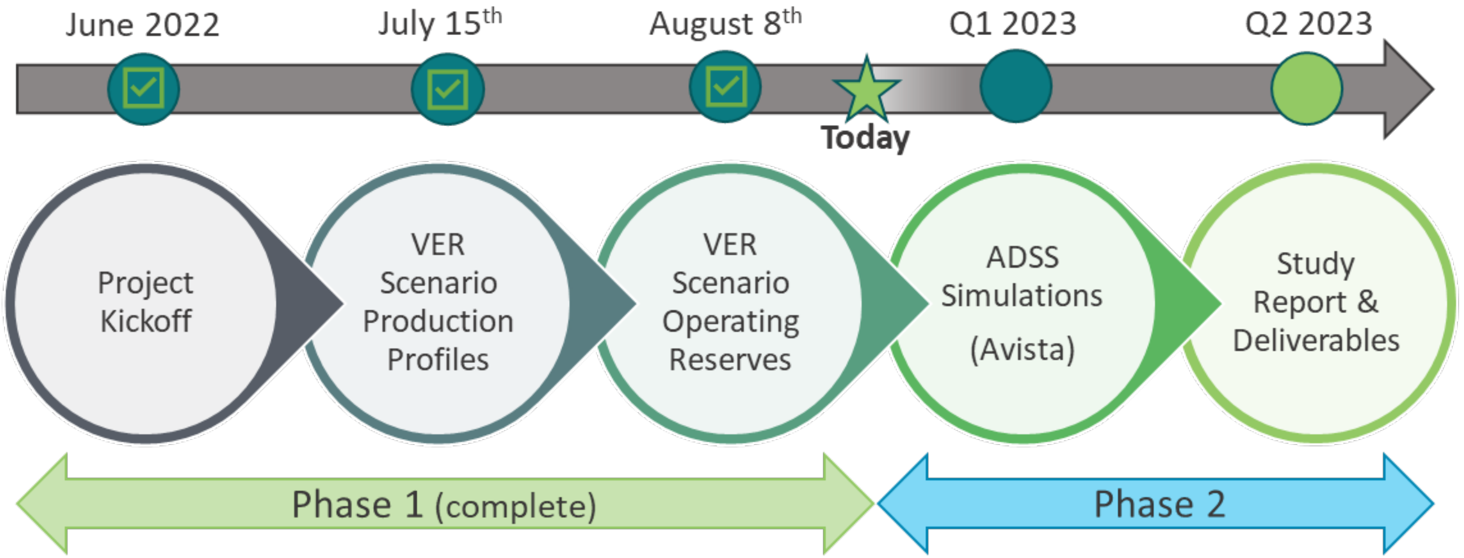


Net Load = Avista Gross Load – VER Production

Next Steps

- **Avista to run VER Scenarios in ADSS**
  - ❖ Production cost model outputs provide the necessary data to calculate integration cost
- **Determine Incremental Integration Cost for each VER Scenario**
- **Begin Phase 2 Deliverables**
  - ❖ Written Report & PowerPoint Presentation containing full analysis and results
  - ❖ Spreadsheet tool allowing Avista to determine/approximate data inputs for other mixes of VERs

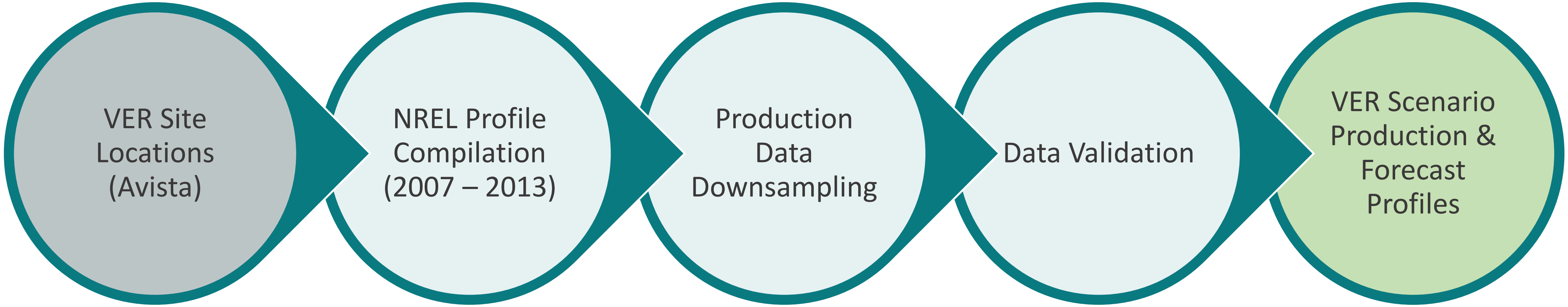


ENERGY STRATEGIES

Thank you.

Extra Slides

Task 2 Overview



- Feasible VER buildouts for each VER scenario identified by Avista Engineers

- Unique production & forecast profile generated for each unique VER location/capacity combination

- Reduced VER production time resolution to 1-min
- Sub-hourly noise introduced based on statistical characterization of VER profiles

- Compare Capacity Factors of ADSS-compatible production profiles to values provided by Avista
- Forecast error validated relative to 2021

- Production & Forecasts aggregated for all sites included in each VER Scenario

Study Data Requirements

- **Study simulations assume a 2021 model year**
  - Avista load and existing VER production actuals will be modeled in the 2021 timeframe
  - For each VER scenario, Energy Strategies will derive VER production and operating reserve requirements using 7 years of historical proxy VER production & forecast data (compared against 2021 actual load & VER production)
- **Avista identified VER buildouts that could reasonably achieve VER penetrations ranging from 400 – 2,500 MW**
  - Using our in-house growing radius methodology, we've compiled proxy production data for each of these sites

Data Requirement	Data Horizon	Data Resolution	Source
Avista Load Actuals	2021	1-minute	Avista
Avista Hour-Ahead Load Forecasts	2021	Hourly	Avista
Avista Existing VER Production	2021	1-minute	Avista
Avista Existing VER Hour-Ahead Forecasts	2021	Hourly	Avista
Avista Existing VER Design Characteristics	-	-	Avista
VER Scenario Resource Location Preferences	VER Scenarios	Lat/Long	Avista
VER Scenario Resource Design Characteristics	-	-	Energy Strategies
VER Scenario Resource Production	2007 – 2013	Differs; aggregated to 1-minute	Energy Strategies (NREL WIND/NSRDB)
VER Scenario Resource Hour-Ahead Forecasts	2007 – 2013	Hourly	Energy Strategies; Derived

Task 2 Data Summary & Progress Table

- **All VER Scenario data has been pulled and compiled onto Energy Strategies servers via Python APIs**
  - ❖ We are currently in the process of post-processing and validating data; the table below summarizes progress and outstanding tasks
- **For validation, Energy Strategies will use provided capacity factors, and forecast errors consistent with T-90 forecast error levels for 2021.**
  - ❖ We plan to ensure all compiled data are within a 5% error of these values.

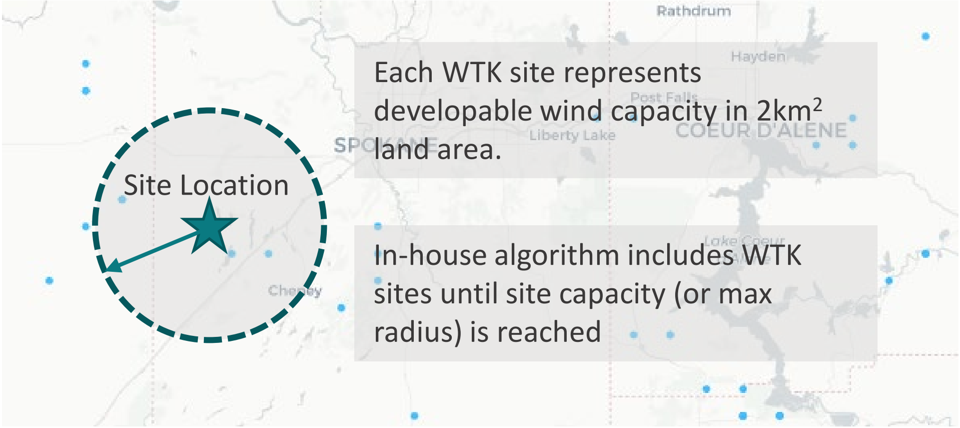
Resource Type	Source	Production Data Compiled for all VER Site/Capacity Combos?	Production Capacity Factor Validated within 5% of target?	Additional down sampling of production data necessary?
Wind Production	NREL WIND WTK	Yes; at 5-min time resolution	Yes	Yes; to 1-min
Wind Forecast	NREL WIND WTK	Yes; at hourly time resolution	No	No
Solar Production	NREL NSRDB & SAM	Yes; at 30 min time resolution	Yes	Yes; to 1-min
Solar Forecast	Derived	No	No	No

VER Site Locations

Site Location	Latitude	Longitude	Resource Type	+400 MW			+800 MW			+1500 MW			+2500 MW		
				Wind	50/50	Solar	Wind	50/50	Solar	Wind	50/50	Solar	Wind	50/50	Solar
North Colstrip, MT	45.9	-106.6	Wind	100	100		200	200		200	200		400	200	
Judith Gap, MT	46.7	-109.7	Wind	200	100		200	200		300	200		400	300	
South Othello, WA	46.7	-119.2	Wind	100			100			100	100		150	100	
Rattlesnake II	46.9	-118.4	Wind				200			200	200		200	200	
Palouse II	47.2	-117.3	Wind				50			75	50		75	75	
Northern Oregon	45.6	-120.6	Wind				50			200			200		
Latah, WA	47.3	-117.1	Wind							125			125	125	
Oregon Offshore	42.5	-124.5	Wind							200			550	250	
South Central WA	46.0	-120.4	Wind							100			200		
Rattlesnake III	46.9	-118.4	Wind										200		
Lewiston, ID /Clarkston, WA	46.4	-117.0	Solar		200	300		200	300		300	300		300	300
Othello/Lind, WA	46.7	-119.2	Solar			100		200	400		200	400			400
Spokane/CDA DG	47.7	-117.4	Solar						100		150	300		350	500
Grant County, WA	47.2	-119.5	Solar									200		200	200
Spokane/Colville Tribal Lands, WA	48.2	-118.9	Solar								100	100		100	200
Rattlesnake Wind	46.9	-118.4	Solar									200		300	200
Spokane Utility Scale (West & South)	47.6	-117.5	Solar												300
East Montana (near Colstrip line)	45.9	-106.6	Solar												400

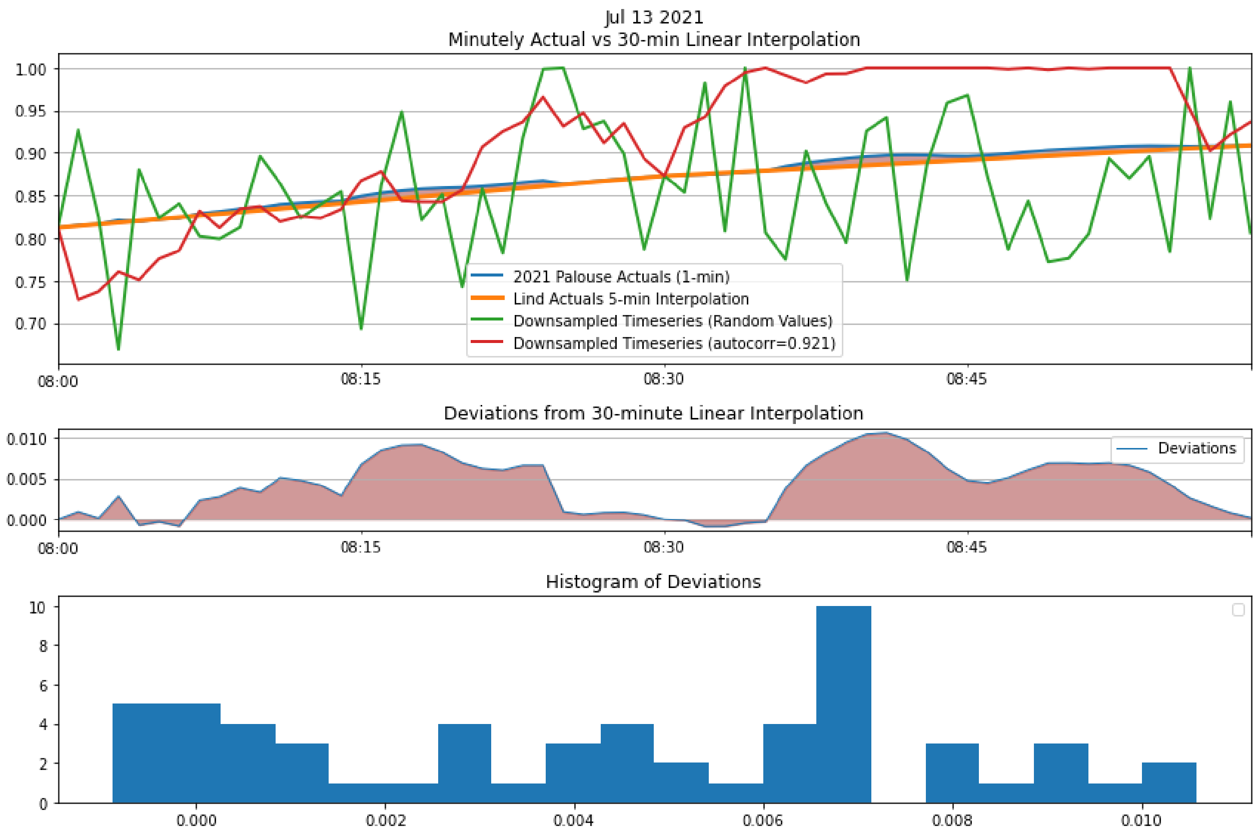
NREL Profile Compilation

- **Energy Strategies used NREL WIND and SAM/NSRDB to compile a proxy production & forecast profile for each VER site & capacity combination**
  - ❖ Data compiled for a timeframe of 2007 – 2013; providing 7 years of data from which to derive reserves
- **Wind sites:**
  - ❖ Used "growing radius" algorithm for geospatial accuracy
  - ❖ Production data at 5-min intervals
  - ❖ Matching forecast data at hourly intervals
- **Solar sites:**
  - ❖ PV profile developed based on historical insolation (NSRDB), and plant design characteristics (SAM)
  - ❖ Production data at 30-min intervals
  - ❖ No matching forecast data provided



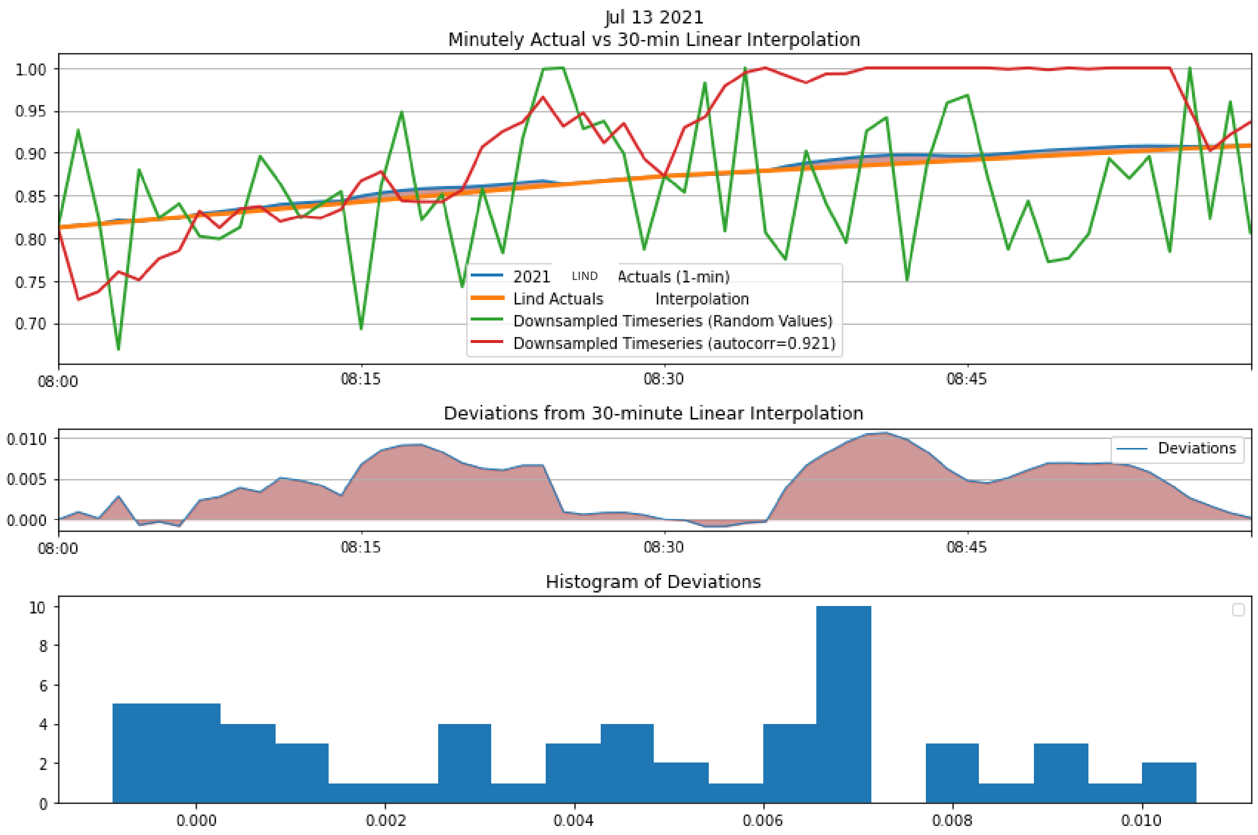
Production Data Downsampling

- **7 years of location-specific production profiles generated from NREL datasets**
- **Detailed statistical process takes native NREL profiles from their respective time resolutions to a 1-minute time resolution**
  - ❖ Calculated from 2021 Avista Actuals (Lind for PV, and Palouse for Wind)
  - ❖ Characterize the minutely deviations from the linearly interpolated values as a normal distribution
  - ❖ Implemented common-sense rules to ensure validity of profiles
    - ➢ No variations before sunrise or after sunset for PV
    - ➢ Do not introduce noise when $P_t = P_{t+1} <= 0$
    - ➢ Noise cannot cause production to go below 0 or above the AC max
- **However, we were not satisfied with the "genuineness" of these profiles**
  (see green profile in figure)



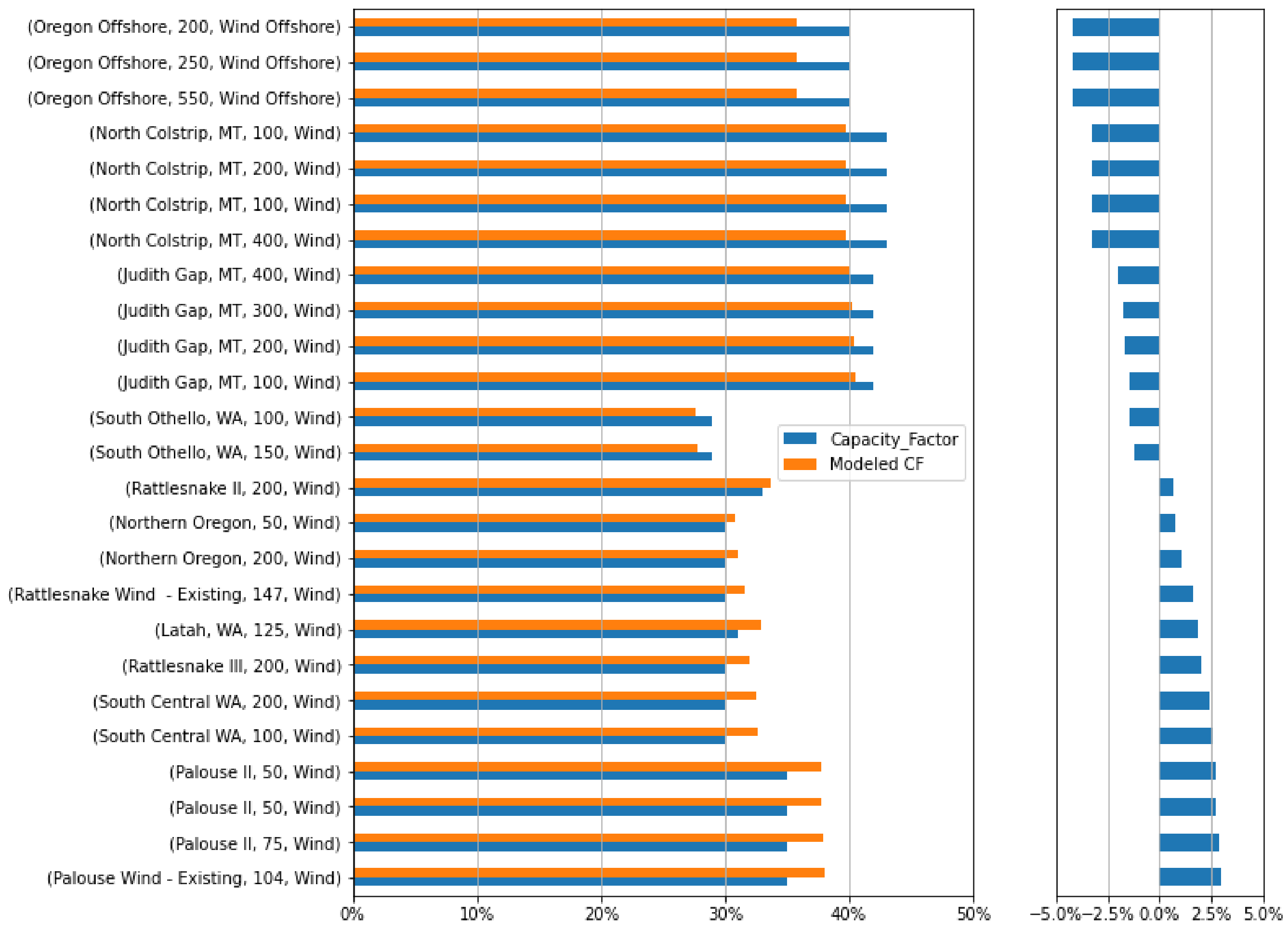
Enhancements to Production Data Downsampling

- **Issue #1:** Downsampled profiles presented in last check-in used random values from a single around-the-clock distribution of "deviations"
  - ❖ **Solution:** Calculation updated to consider the characteristics of deviations for each unique month-hour to capture seasonal & time-of-day differences in variability
- **Issue #2:** Random values were not autocorrelated and thus did not have the "look and feel" of 1-min VER actuals
  - ❖ **Solution:** Introduced a non-zero autocorrelation value for each month-hour which "smoothed" the curves
- **Issue #3:** Since calculation followed 12x24 format, inter-hour seams could result in unrealistic variations
  - ❖ **Solution:** Implemented an algorithm to smooth values within +/- 4 minutes of the top of each hour



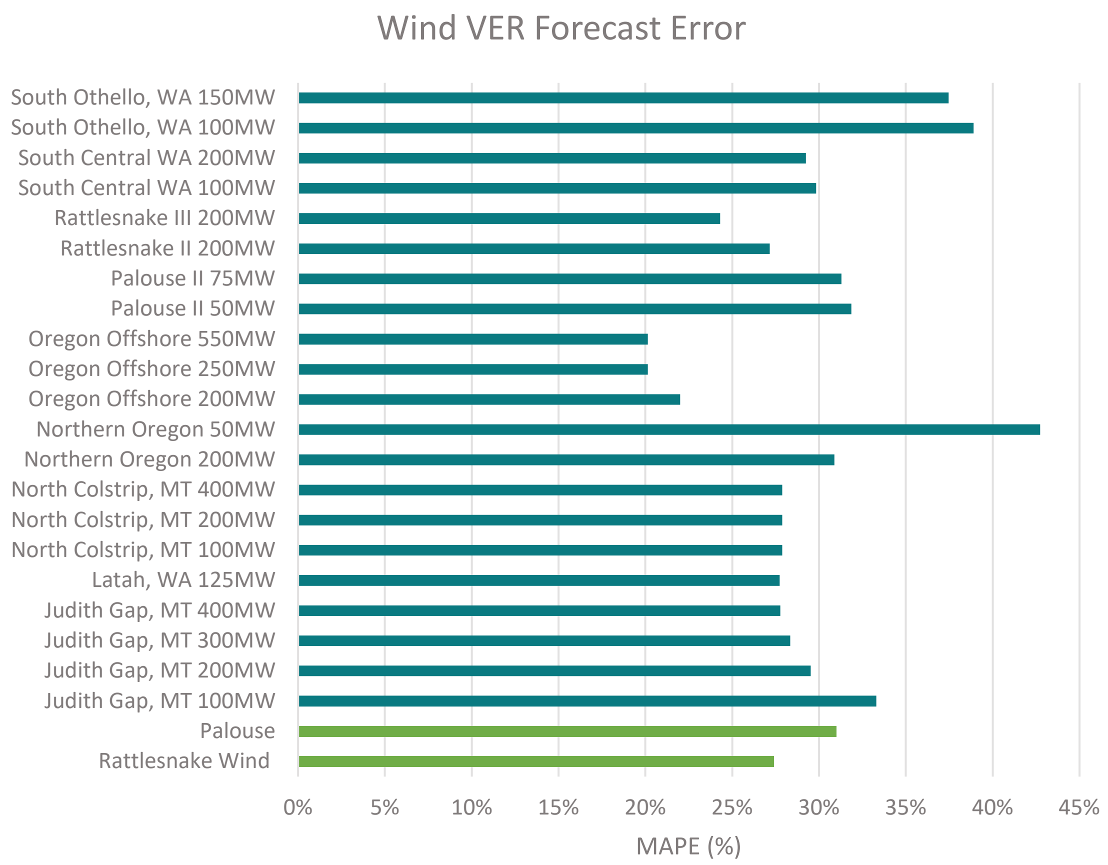
Wind Capacity Factor Validation

- **1-minute production profiles assessed for average capacity factor over 7-year historical period**
  - ❖ Downsampling methods did not significantly alter production capacity factor
- **All modeled capacity factors are within 5% of capacity factor values provided by Avista**
  - ❖ Offshore wind capacity factor 4% lower capacity factor than expected
- **Montana wind profiles show highest onshore capacity factor**



Wind Forecast Error Benchmarking

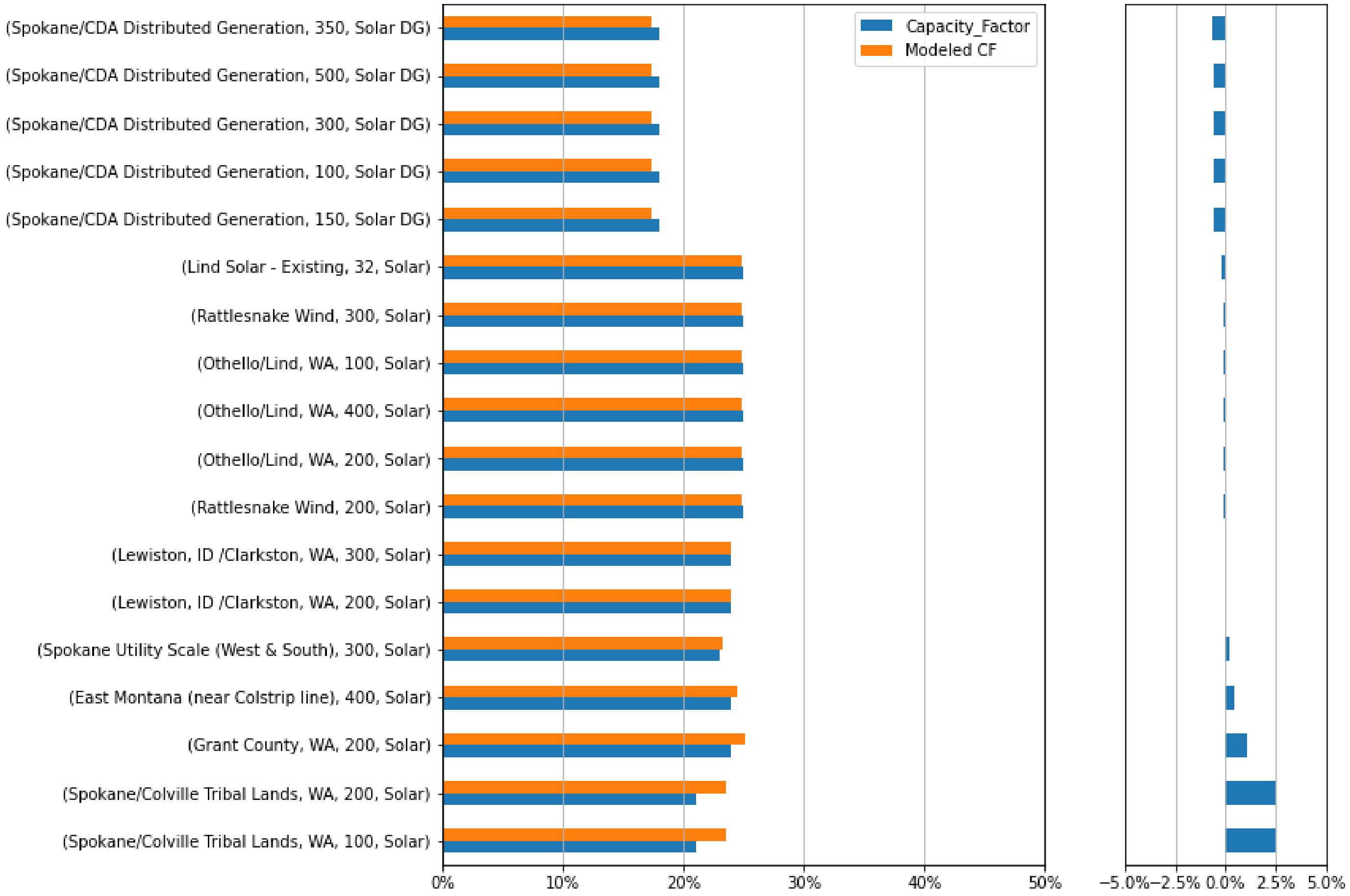
- **Forecast errors were summarized by taking the mean average percent error of hourly forecasts**
  - For 2021, Avista's T-90 forecast error for wind power plants ranged from 28% - 36%
- **NREL provides "industry-standard" hour-ahead production forecasts as part of WIND Toolkit dataset**
  - This data is automatically coupled with production data, and was also assessed with MAPE
  - VER wind forecast errors range in the 20% - 43% range, with offshore units showing noticeably lower forecast error than onshore



	2021 T-90 Forecast MAPE (Avista)	Modeled Forecast MAPE (NREL)
Palouse	28%	31%
Rattlesnake Flat	36%	27%

Solar Capacity Factor Validation

- **Energy Strategies uses a python API from NREL to develop location-specific Solar PV profiles**
- **This approach uses insolation data from the NREL NSRDB, and converts this to production data given a set of PV array design characteristics.**
- **Energy Strategies assumes:**
  - ❖ Single-axis tracking for utility-scale (non-DG) systems; else fixed
  - ❖ An inverter loading ratio of 1.4 for utility-scale systems; else 1.3
  - ❖ Inverter and system losses of ~14% and 4%, respectively
  - ❖ Tilt equal to latitude

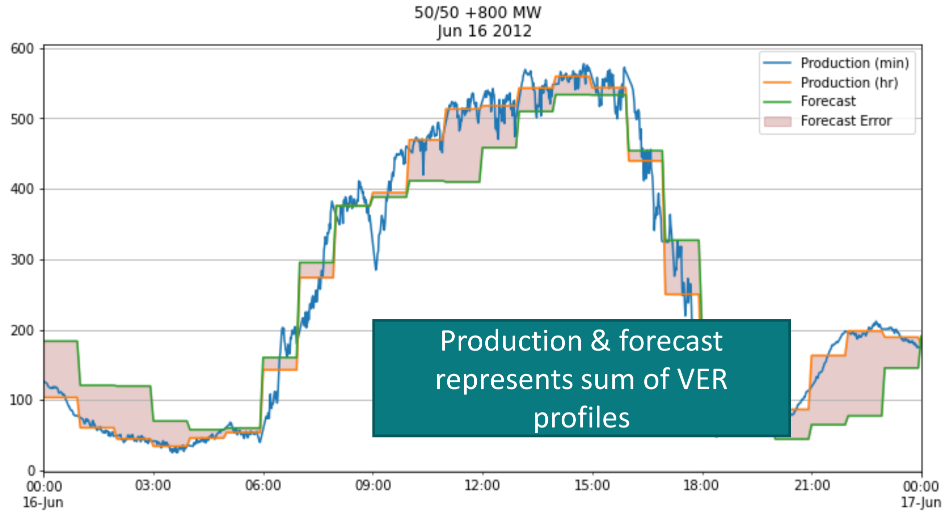


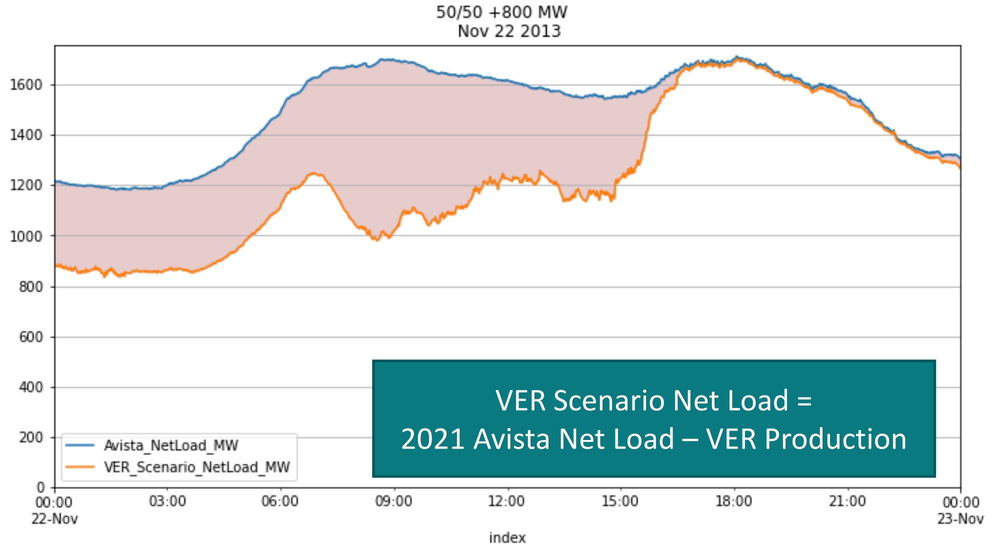
Solar Forecast Error Benchmarking

- **Since no forecast data provided with NREL SAM/NSRDB database, hourly PV forecasts were benchmarked from NREL's SIND dataset**
  - ❖ Production and 4HA production profiles were pulled and assessed for forecast error
  - ❖ Forecast errors for VER locations in the study showed forecast MAPEs in the range of 20% - 29%
- **Used Site-specific forecast errors from SIND database in 8760 format, and applied for all years of historical production data**
  - ❖ Per feedback from Avista forecast vendor, forecast error values were scaled such that the lowest PV MAPE was ~6%

VER Scenario Profiles & Net Load Calculation

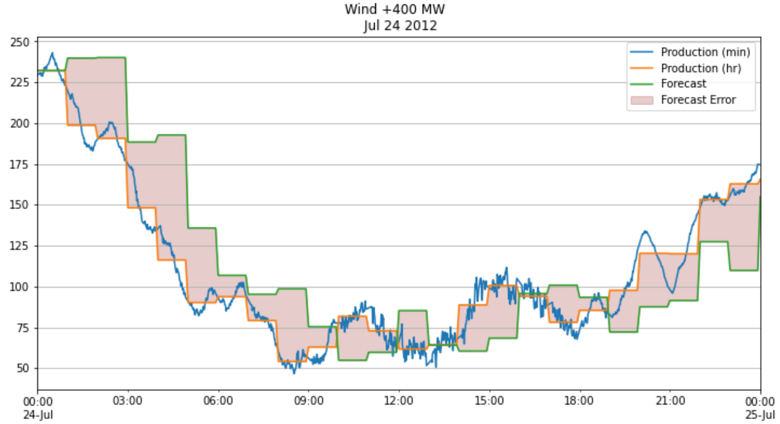
- **All profiles were validated to ensure no significant changes in capacity factor or forecast error.**
- **Validated profiles for each VER scenario aggregated (summed) to determine "incremental" VER production & forecast**
  - ❖ Flat-energy profiles were developed by taking the aMW value of the VER scenario, and are assumed to be perfectly forecastable
- **These incremental values were added onto time-synchronized 2021 Avista net load for use in reserve calculations**
  - ❖ Use of 2021 Avista net load data is repeated for 7 years of VER profiles

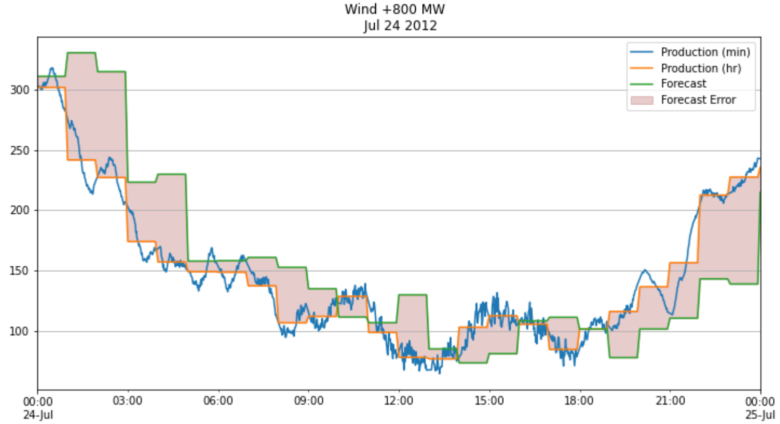




Concern #1: Mid-Day Volatility of Downsampled Wind Profiles

Avista mentioned concern that mid-day volatility is uncharacteristic





12x24 of Palouse Volatility

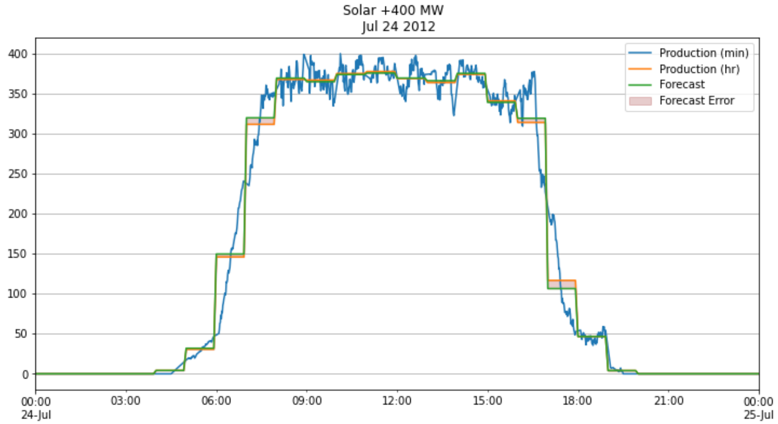
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0.005	0.006	0.004	0.005	0.005	0.007	0.004	0.005	0.005	0.010	0.021	0.006
1	0.004	0.006	0.005	0.005	0.006	0.011	0.006	0.006	0.005	0.006	0.025	0.009
2	0.006	0.006	0.005	0.004	0.012	0.012	0.006	0.005	0.005	0.005	0.006	0.005
3	0.006	0.005	0.006	0.005	0.005	0.016	0.006	0.005	0.005	0.005	0.006	0.005
4	0.006	0.004	0.005	0.006	0.004	0.010	0.007	0.005	0.005	0.006	0.006	0.006
5	0.006	0.005	0.005	0.005	0.006	0.009	0.007	0.005	0.019	0.006	0.006	0.005
6	0.006	0.006	0.006	0.005	0.006	0.007	0.007	0.009	0.006	0.007	0.011	0.005
7	0.007	0.006	0.005	0.005	0.006	0.008	0.009	0.006	0.005	0.007	0.006	0.005
8	0.006	0.006	0.007	0.008	0.009	0.009	0.011	0.007	0.006	0.007	0.007	0.006
9	0.007	0.007	0.008	0.011	0.012	0.009	0.011	0.007	0.008	0.007	0.009	0.007
10	0.009	0.008	0.008	0.017	0.015	0.011	0.013	0.012	0.011	0.007	0.009	0.007
11	0.007	0.008	0.012	0.021	0.018	0.011	0.015	0.016	0.014	0.009	0.009	0.007
12	0.008	0.009	0.015	0.023	0.019	0.014	0.018	0.020	0.016	0.011	0.009	0.007
13	0.006	0.010	0.014	0.022	0.017	0.017	0.017	0.021	0.016	0.013	0.012	0.007
14	0.005	0.008	0.015	0.024	0.020	0.014	0.020	0.021	0.016	0.013	0.009	0.007
15	0.005	0.008	0.014	0.023	0.017	0.013	0.023	0.018	0.017	0.012	0.008	0.006
16	0.005	0.007	0.014	0.021	0.016	0.014	0.021	0.018	0.015	0.010	0.008	0.006
17	0.005	0.006	0.009	0.018	0.011	0.011	0.015	0.014	0.013	0.006	0.007	0.007
18	0.005	0.006	0.008	0.013	0.008	0.008	0.011	0.009	0.008	0.005	0.007	0.007
19	0.004	0.005	0.008	0.008	0.005	0.007	0.006	0.005	0.006	0.004	0.008	0.006
20	0.005	0.006	0.009	0.009	0.004	0.005	0.003	0.005	0.006	0.005	0.007	0.007
21	0.005	0.006	0.006	0.007	0.004	0.005	0.004	0.005	0.005	0.007	0.006	0.007
22	0.004	0.006	0.006	0.005	0.006	0.009	0.006	0.006	0.005	0.006	0.008	0.007
23	0.004	0.006	0.005	0.005	0.005	0.006	0.005	0.007	0.005	0.010	0.005	0.007

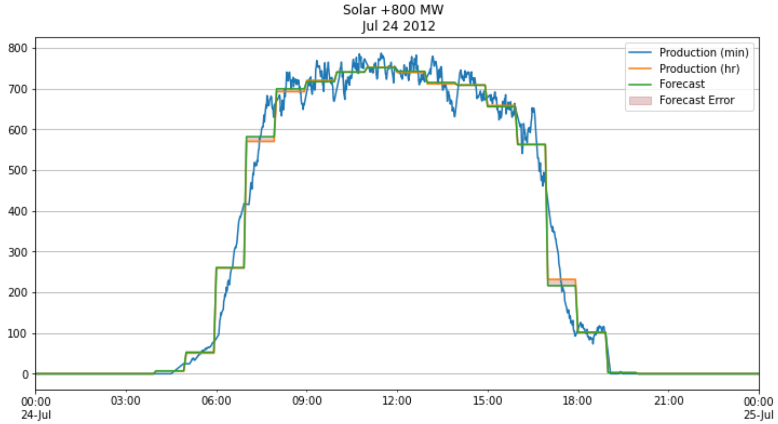
However, data suggests that average standard deviation of minutely Palouse production is more volatile during the mid-day, especially during spring & summer months
(which were displayed in last check-in)

No change was made to wind profiles in the VER study.

Updated Lind Volatility based on a 1.4 Inverter Loading Ratio

We realized that the downsampled volatility for PV was based on Lind Actuals
(implicitly assumes an ILR of 1.15)



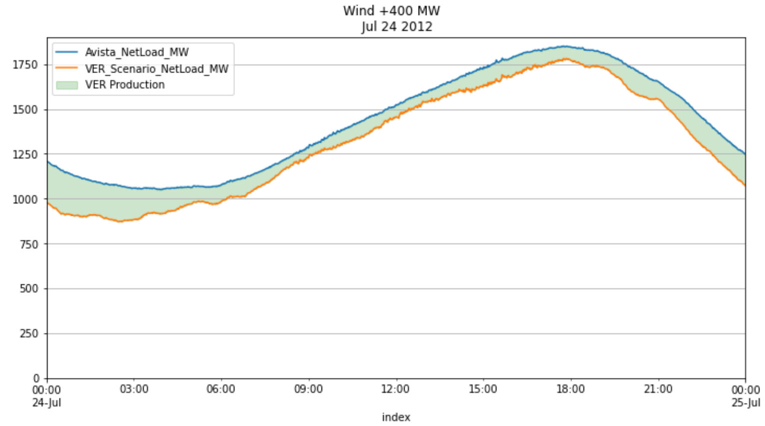


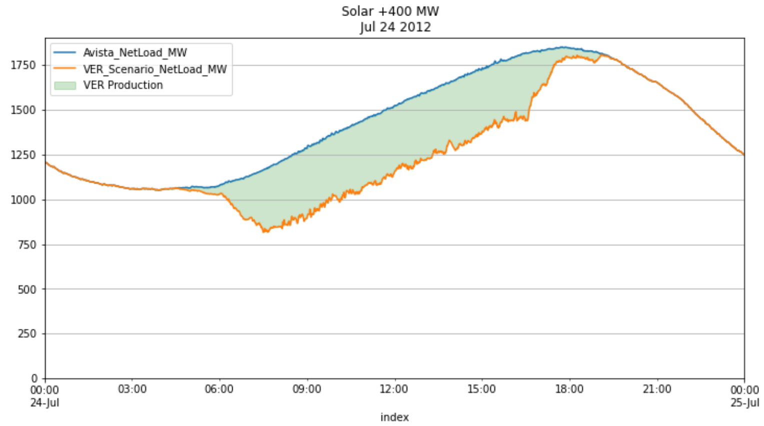
Change in Volatility for PV 1.4 Update

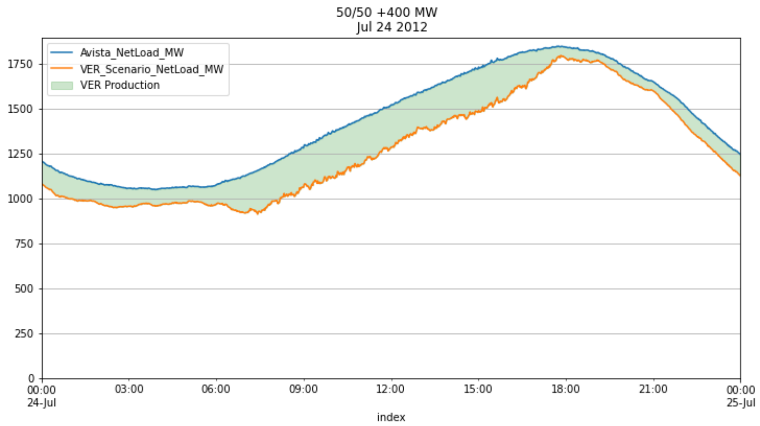
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	4.25E-05	0.004888	0.004911	0.002878	1.47E-05	0.000541	0	0	0
6	0	4.81E-05	0.00217	0.006281	0.013816	0.016356	0.005335	0.004706	0.003256	0	1.07E-05	0
7	0.002163	0.004258	0.007352	0.013605	0.009323	0.007949	0.012287	0.007907	0.012857	0.007073	0.00296	0.000494
8	0.008037	0.015454	0.011228	0.009749	-0.00156	0.001514	0.007919	0.008248	0.019007	0.019792	0.007541	0.01026
9	0.01487	0.01927	0.012103	-0.00026	-0.00693	-0.00493	0.01082	0.001631	0.010821	0.016925	0.012122	0.016484
10	0.011981	0.011708	0.010357	0.00121	-0.01065	-0.01063	0.001094	-0.00076	0.008653	0.014094	0.013696	0.015122
11	0.011924	0.00662	-0.00062	-0.00518	-0.01414	-0.0175	0.002192	-0.00258	0.008226	0.013806	0.012488	0.013614
12	0.009746	0.016433	0.008942	-0.00583	-0.01066	[illegible]	0.006109	-0.00577	0.013684	0.0165	0.015581	0.010322
13	0.013014	0.021332	0.000461	-0.00145	0.003021	-0.00638	0.011435	0.000717	0.00985	0.017337	0.010484	0.013018
14	0.013581	0.010089	0.006037	-0.00155	-0.00894	-0.00617	0.004989	0.003798	0.012058	0.018635	0.017926	0.016882
15	0.007401	0.02023	0.002877	-0.00723	-0.00398	-0.00828	-0.00017	0.004504	0.011142	0.020222	0.011732	0.007181
16	0.0018	0.011612	0.014095	-0.00419	0.00495	0.002397	0.010789	0.006545	0.013056	0.02371	0.010009	1.1E-05
17	0	0.001467	0.01113	0.012918	0.006434	0.005416	0.006554	0.01834	0.018762	0.006832	0.000239	0
18	0	0	0.003254	0.013805	0.024101	0.02008	0.012164	0.014855	0.003274	0.000485	0	0
19	0	0	4.38E-05	0.001507	0.003646	0.011618	0.008242	0.001551	0.000157	0	0	0
20	0	0	0	0	0.000715	0.001051	0.001019	2.58E-05	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0

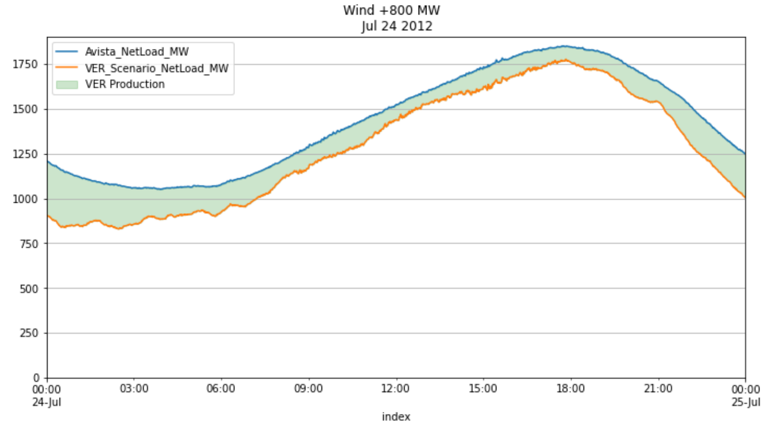
This change slightly increased volatility during the shoulder hours (sunrise & sunset), but decreased volatility during summer mid-day when PV is clipped at full AC output.

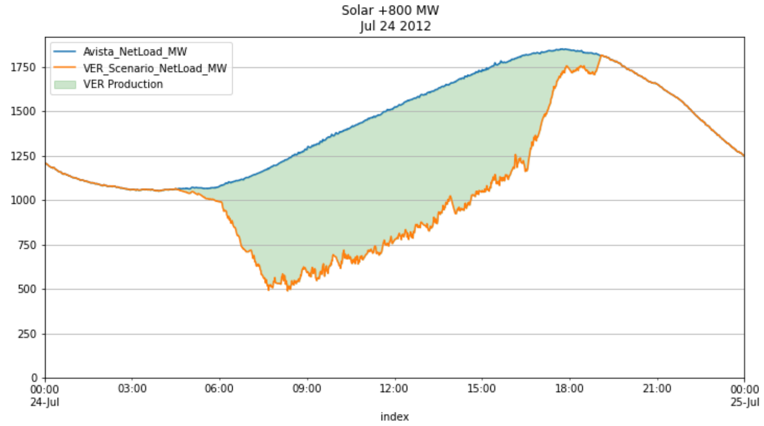
Net Load Profiles (Sample Summer Day)

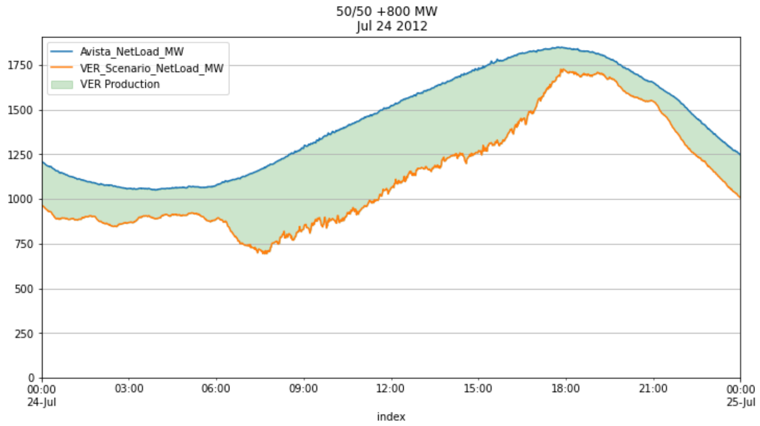




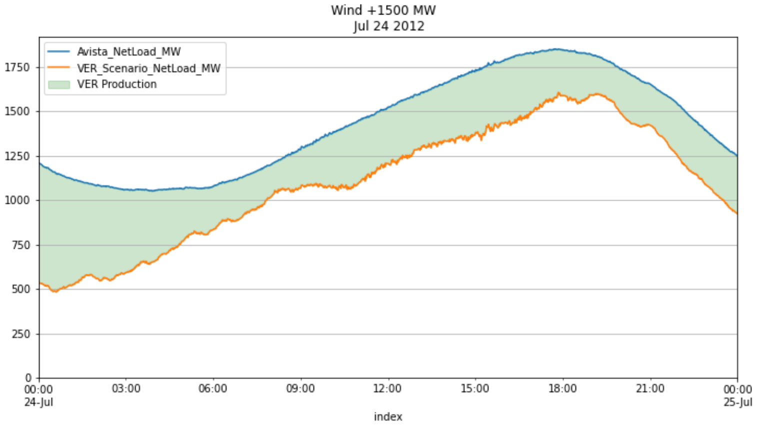


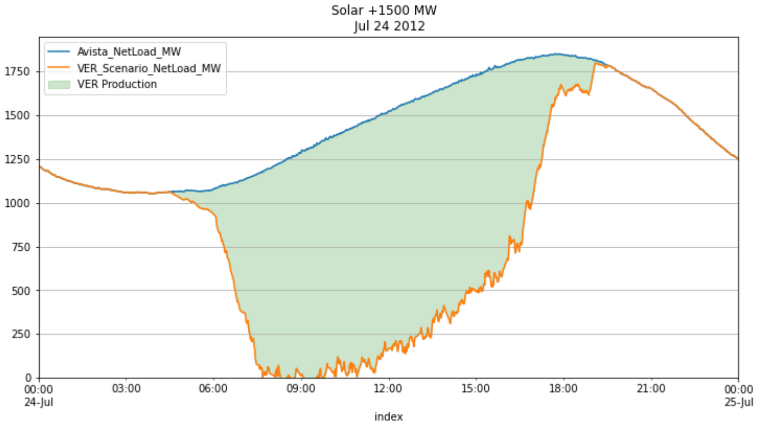


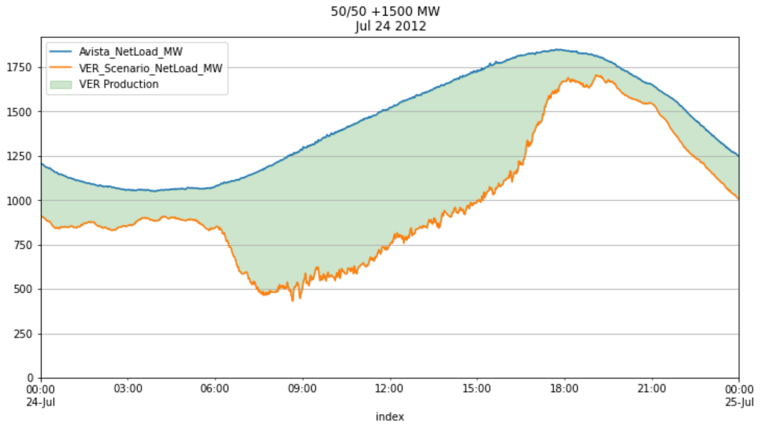


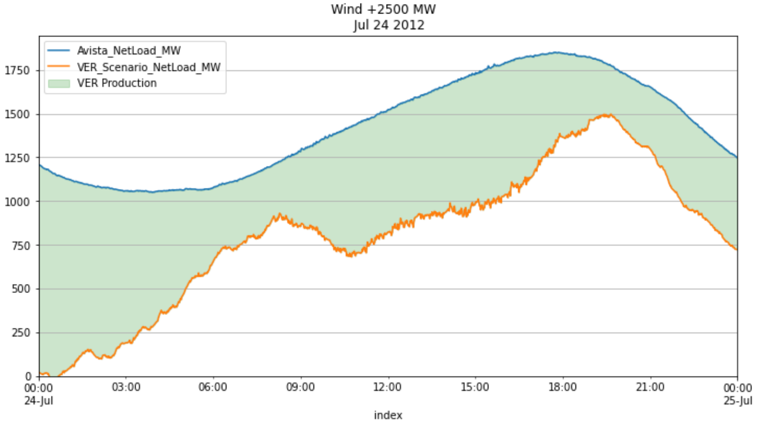


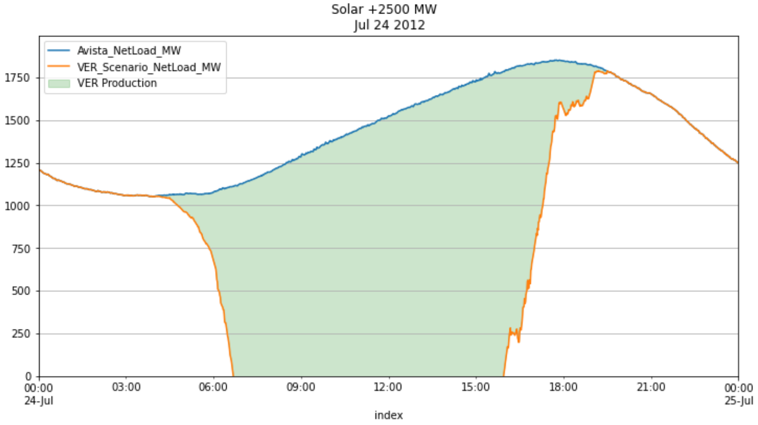
Net Load Profiles (Sample Summer Day)

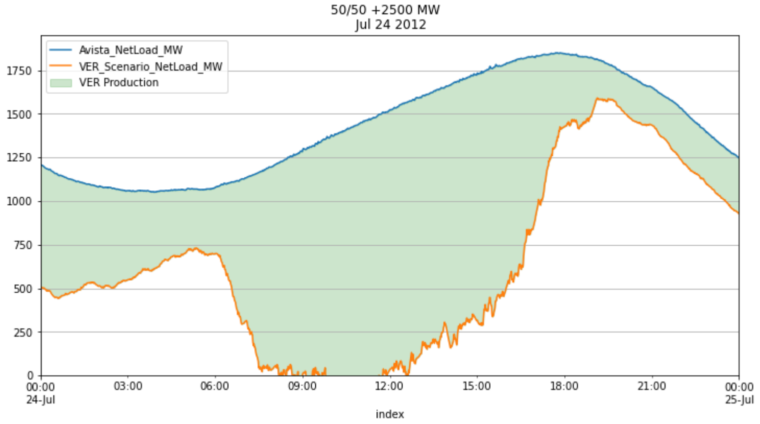




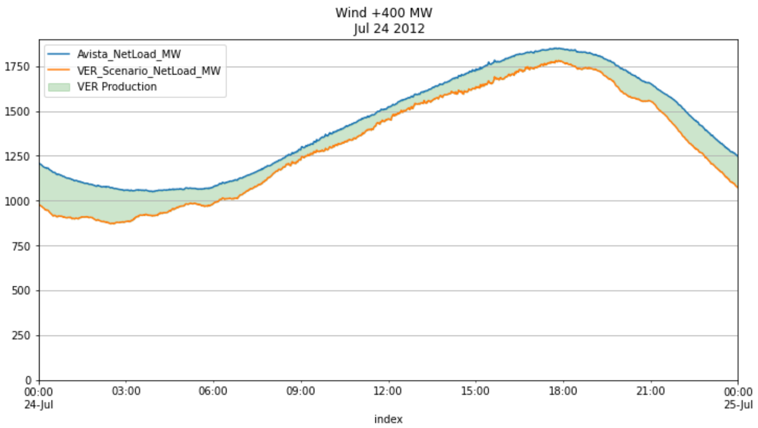


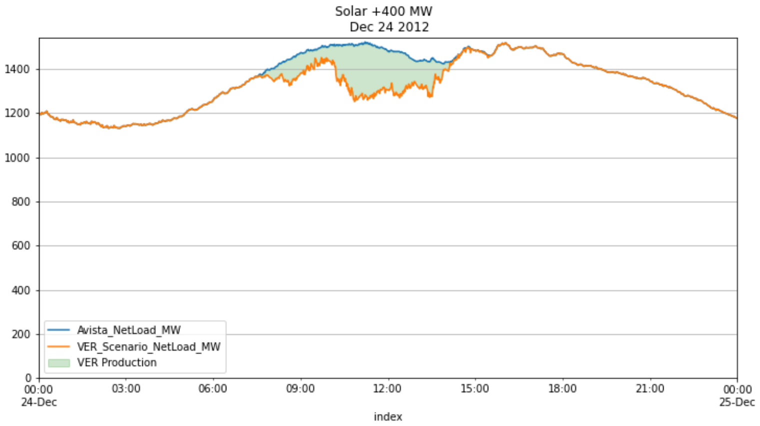


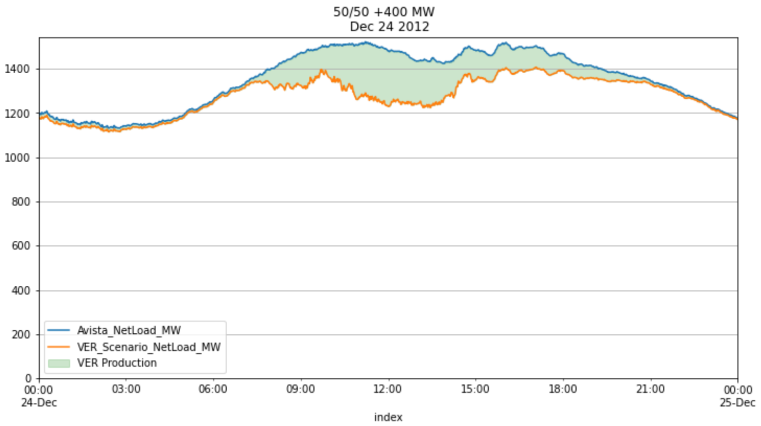


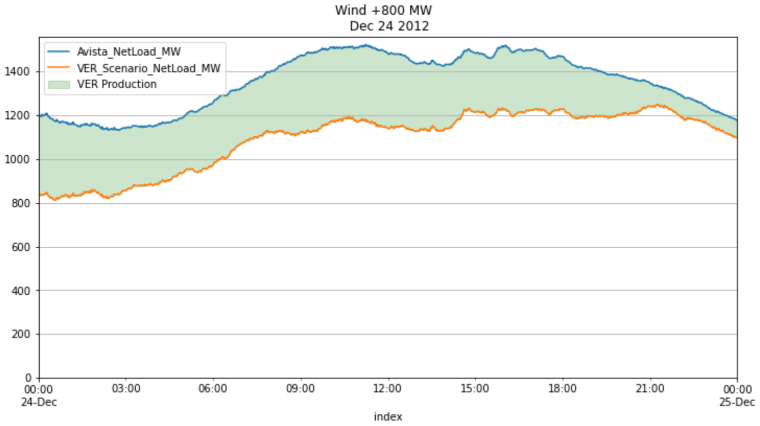


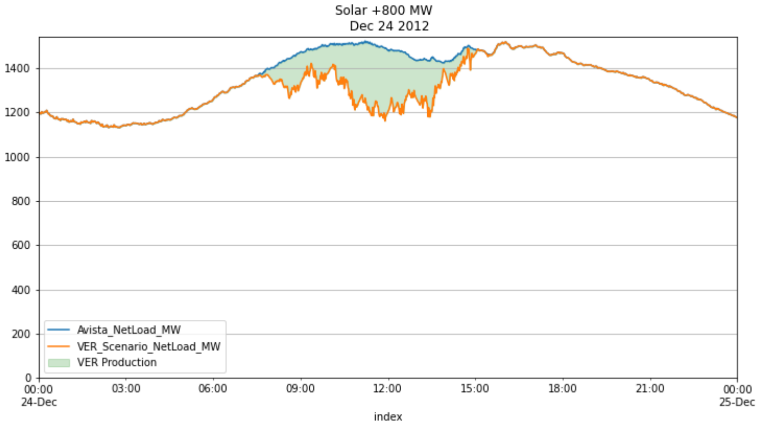
Net Load Profiles (Sample Winter Day)

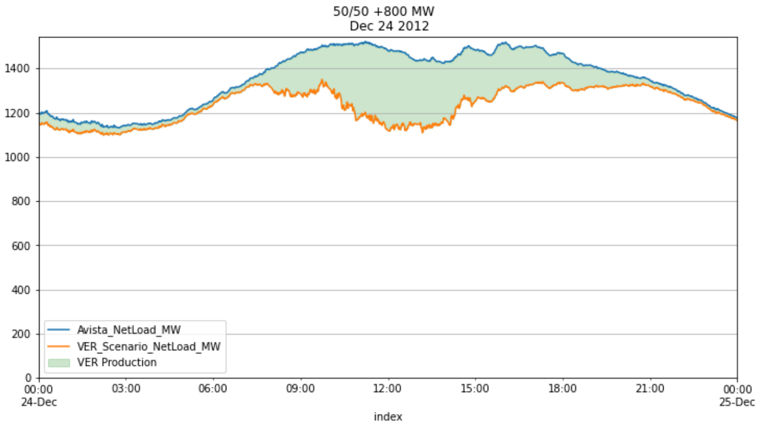




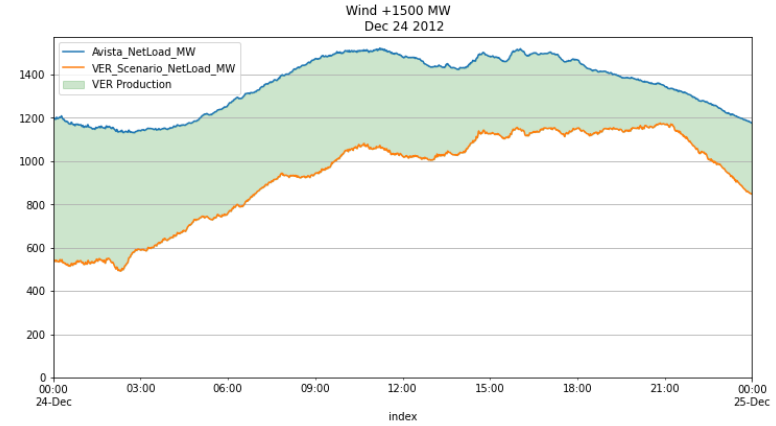


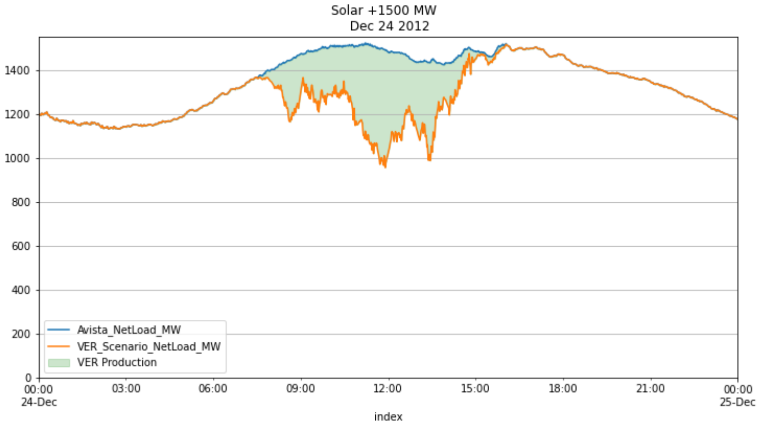


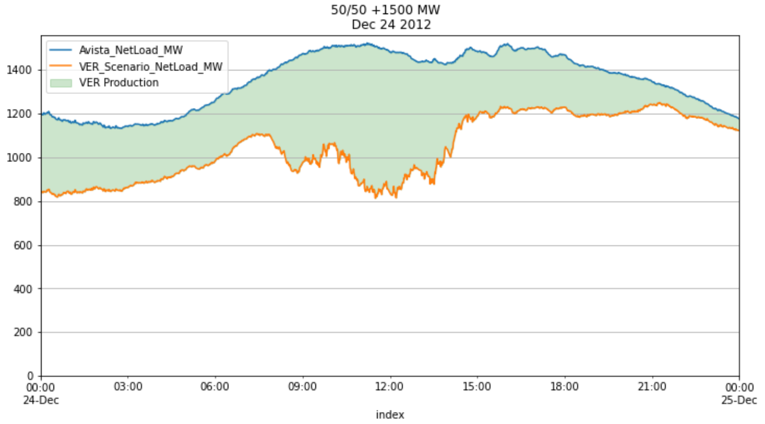


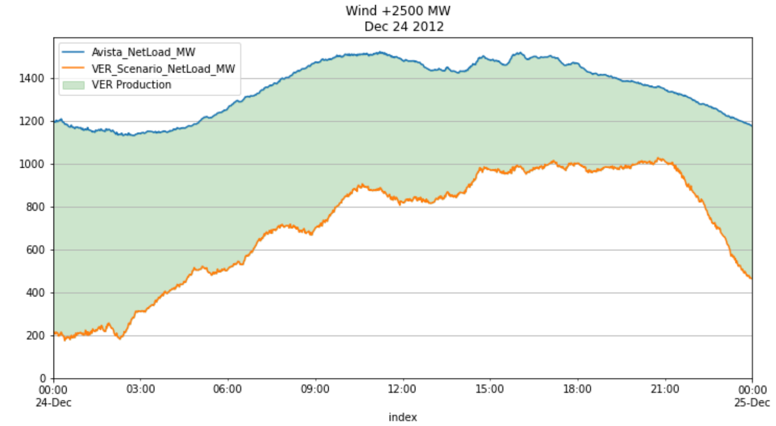


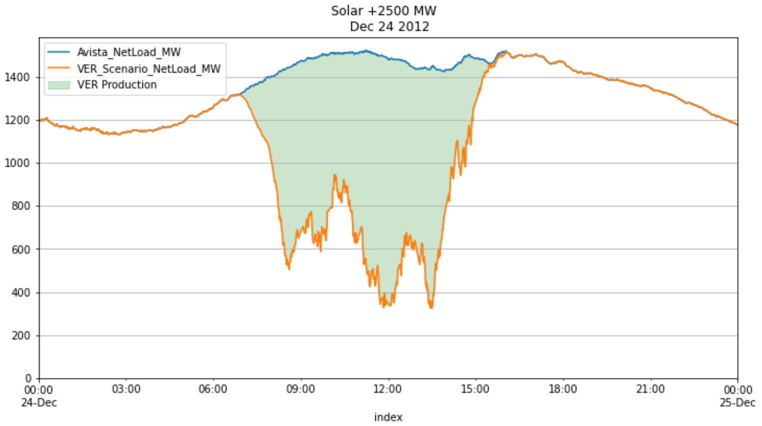
Net Load Profiles (Sample Winter Day)

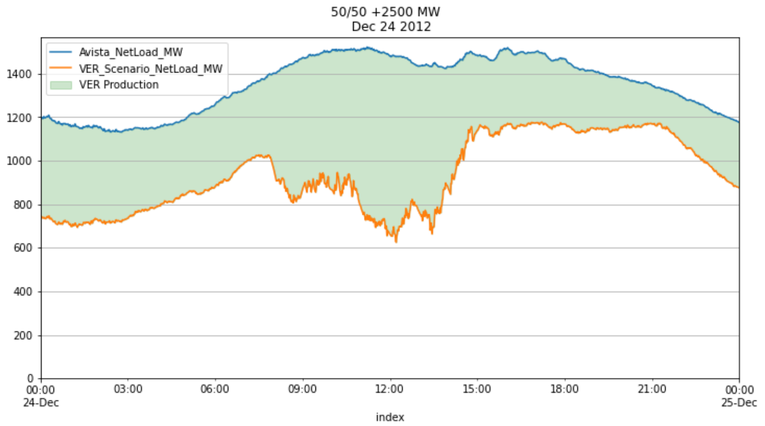












Task 3 Overview

VER Scenario Production & Forecast Profiles

(ADSS Input)

- Production & Forecasts aggregated for all sites included in each VER Scenario
- Incremental VER Production & Forecasts added to 2021 Avista Net Load Actuals

Calculate VER Scenario Reserves

- Calculate Regulation, Load-Following, and Forecast Error Reserves from Net Load & Net Load Forecasts
- Repeat calculation for energy-equivalent scenario

EIM Diversity Benefit Discount

- Estimate that load-following and forecast error reserves could be reduced by 25% as a result of EIM participation

VER Scenario Reserve Values

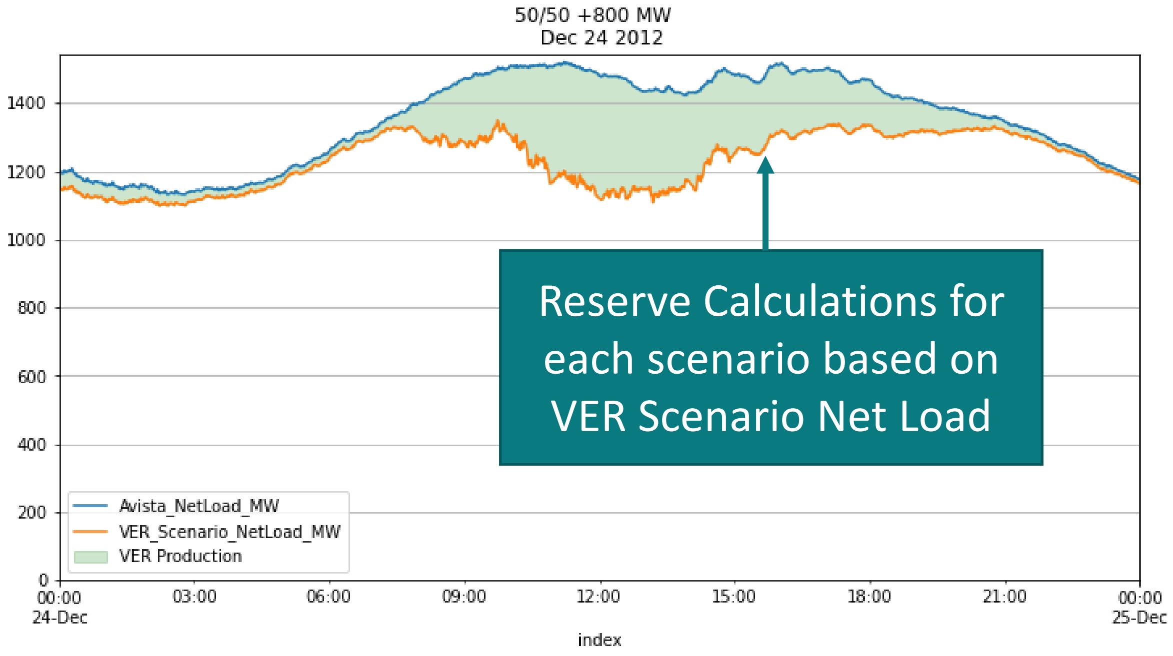
(ADSS Input)

- Reserve profiles based on statistical confidence interval of net load variability and uncertainty for a 7-year historical period

Net Load = Avista Gross Load – VER Production

VER Scenario Profiles & Net Load Calculation

- **Validated profiles for each VER scenario aggregated (summed) to determine "incremental" VER production & forecast**
  - ❖ Flat-energy profiles were developed by taking the aMW value of the VER scenario, and are assumed to be perfectly forecastable
  - ❖ Explored both **flat-energy profiles** and a **12x24 generic shape** per discussions during SOW document scoping
- **These incremental values were added onto time-synchronized 2021 Avista net load for use in reserve calculations**
  - ❖ Use of 2021 Avista net load data is repeated for 7 years of VER profiles
- **Reserves are quantified to handle increased variability and uncertainty of integrating VERs**



Reserve Calculations

- **Reservation calculations use a combination of minutely net load data and hourly net load forecasts to identify the level of reserves required to 95-99% of variability and uncertainty of VER integration for each scenario.**
  - ❖ Each reserve calculation results in an MW value that represents the latent spinning reserve capacity, which should be held by other dispatchable generators in the Avista system, as defined by constraints in the ADSS production cost model.
  - ❖ All reserve types are assumed to be mutually exclusive and held independently
- **Energy Strategies' will provide reserve results backcast for all 7-years of historical data**
  - ❖ If 8760 format is preferred, Energy Strategies and Avista should agree upon which historical year should be represented for ADSS modeling

Regulation Reserves

- Procured to handle rapid, unexpected variations in load or generation
- **Regulation Error = 1-min Net Load – 10-minute Net Load Rolling Average**
- Calculated as a 3σ confidence interval of Regulation Errors
- Calculated monthly, for on-peak and off-peak hours separately

Load-Following Reserves

- Procured to handle hour-to-hour variations in net load
- **Load-Following Error = 1-min Net Load – Hourly Average Net Load**
- Calculated as 2σ confidence interval of Load-Following Error
- Calculation bins load-following reserves held in operating hour by VER forecast; on/off-peak
- Discounted by 25% to represent EIM Diversity Benefit

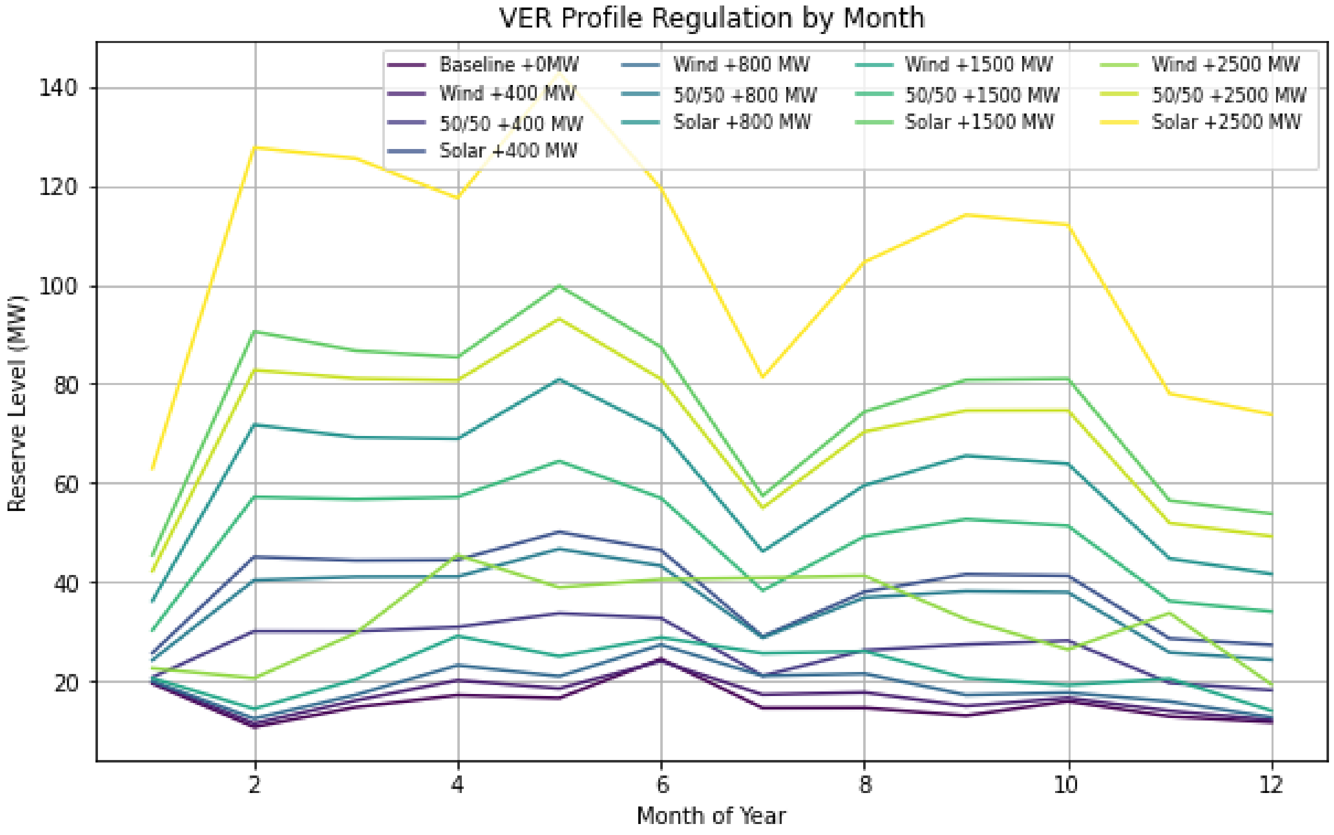
Forecast Error Reserves

- Used to handle net load uncertainty in the hour-ahead timeframe
- **Forecast Error = Net Load – Net Load Hour-Ahead Forecast**
- Calculated as 2σ confidence interval of forecast errors
- Calculation bins forecast reserves held in operating hour based on VER forecast; on/off-peak
- Discounted by 25% to represent EIM Diversity Benefit

Net Load = Avista Gross Load – VER Production

Regulation Results

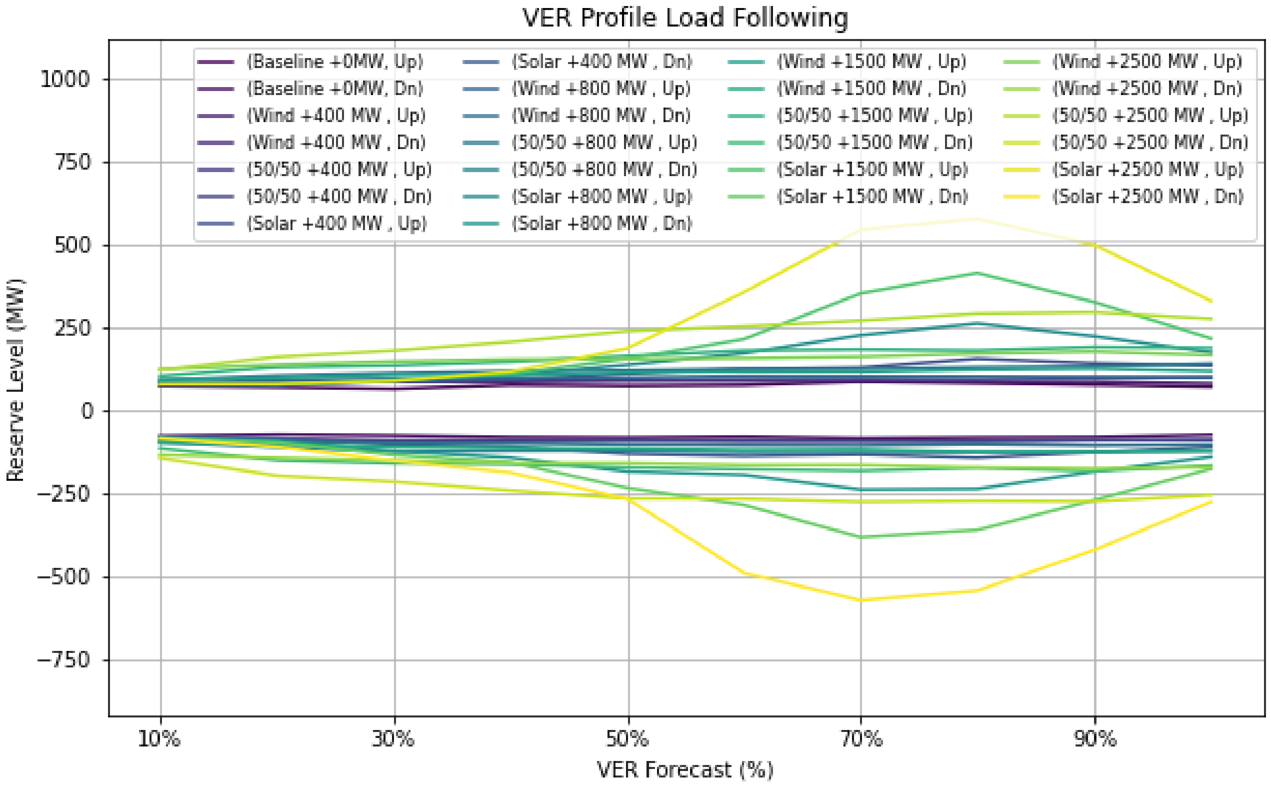
- **In latest correspondence with Avista, Regulation Reserves were proposed to be calculated in a 12x24 format**
  - ❖ However, we noticed an unrealistic change in regulation reserves hour-to-hour, likely exacerbated by the 3-sigma confidence interval requirement for Regulation
  - ❖ We've reverted to a month-specific regulation value
- **Regulation levels tend to be higher in PV scenarios, and generally higher in summer months**



Net Load = Avista Gross Load – VER Production

Load-Following Results

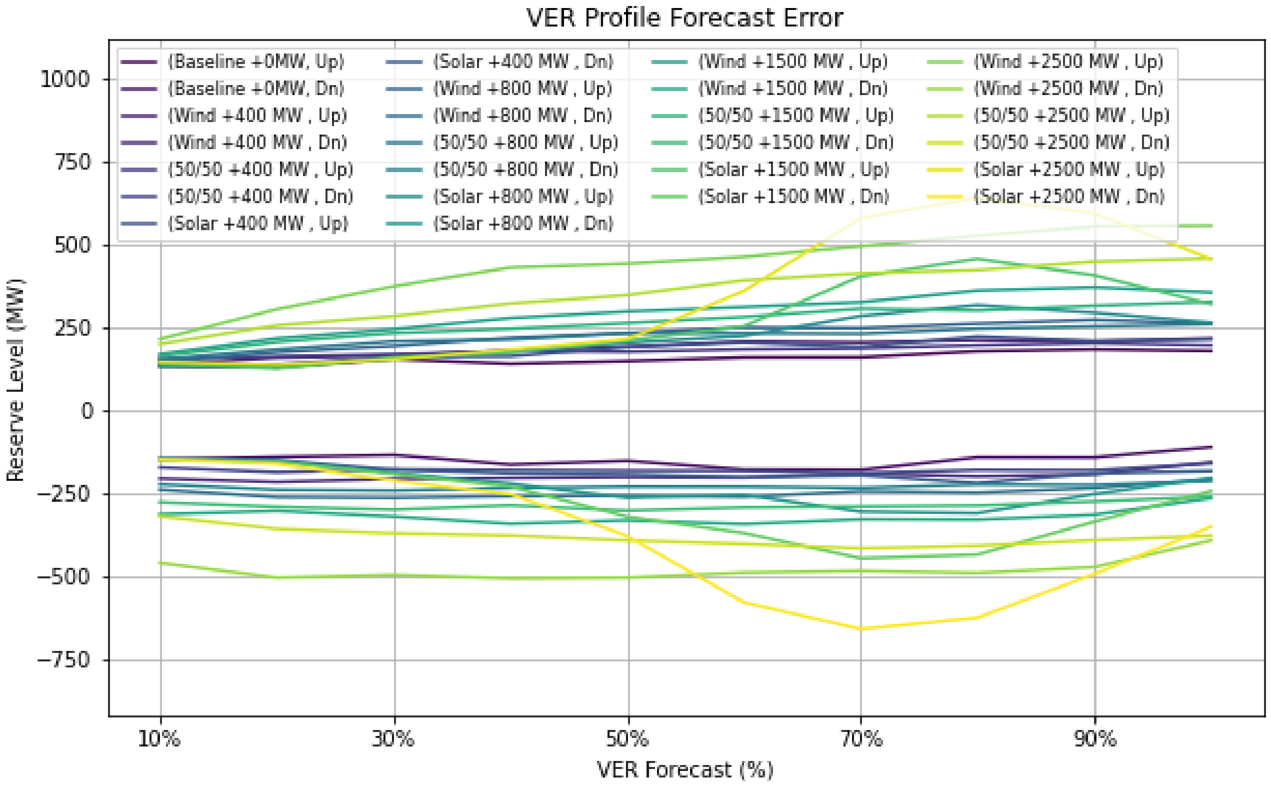
- **Load following reserve levels calculated based on VER Forecast level**
  - ❖ VER forecast levels are separated into "buckets" of 10% increments (0% - 10%, 10% - 20%, etc..)
  - ❖ VER Forecast = Existing VER Forecast + VER Scenario VER Forecast (MW)
  - ❖ This approach used by Avista to:
    - ➢ 1. Select reserve level for next hour based on data available in the operating timeframe
    - ➢ 2. Reflect that less up-reserves may be needed when VER output is at its highest levels, and vice versa
- **We notice that reserves for PV scenarios are significantly higher than 50/50 and wind scenarios**
  - ❖ Max reserves are needed in Solar scenarios with VER forecast levels of ~70% - 80%



Net Load = Avista Gross Load – VER Production

Forecast Error Results

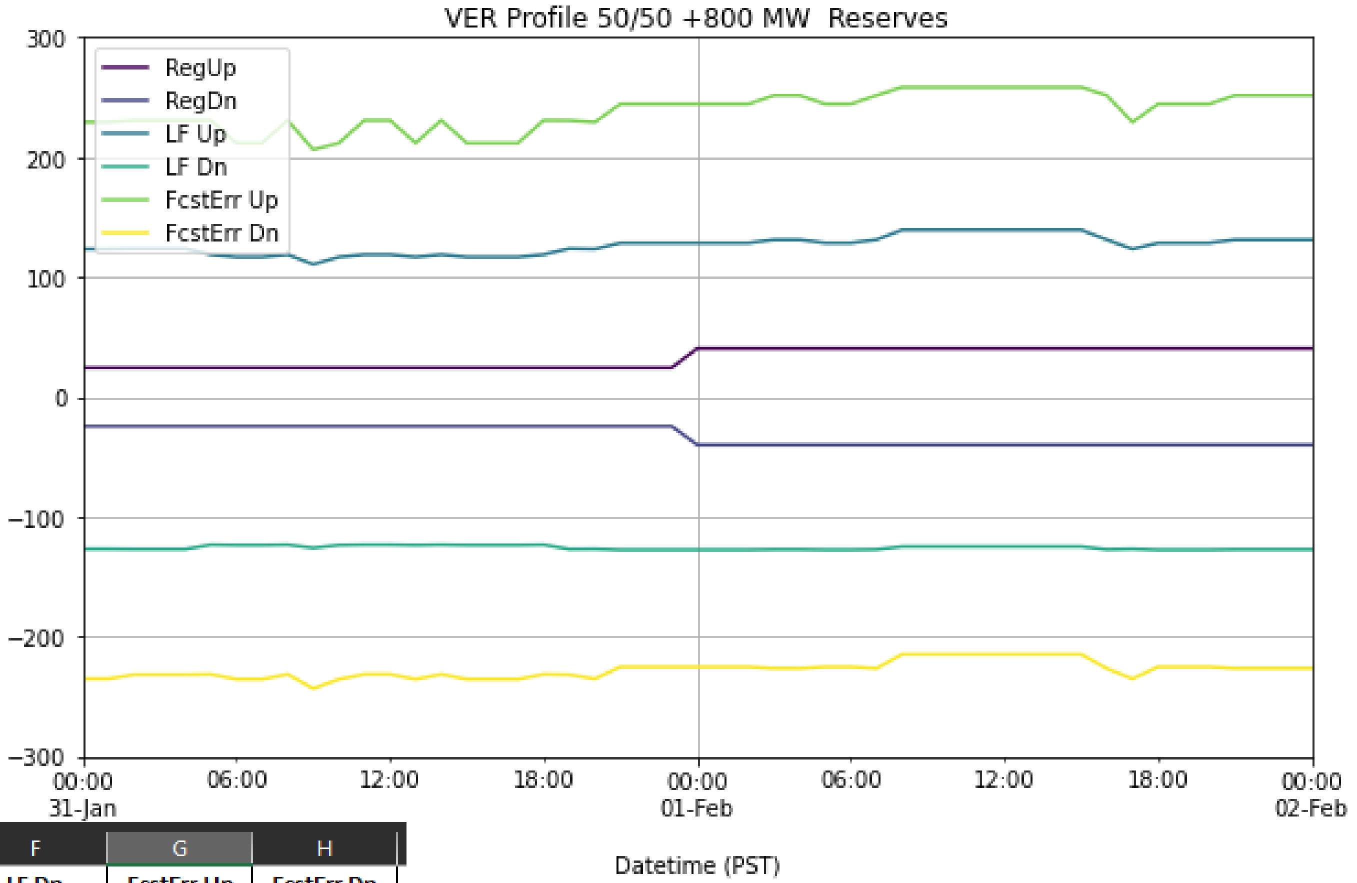
- **Forecast Error is also determined by VER Forecast level**
  - ❖ I.e., how much forecast error are you likely to have given a given VER forecast level
  - ❖ VER forecasts may represent a blend of resources depending on VER scenario
- **We notice that reserves for PV scenarios are significantly higher than 50/50 and wind scenarios**
  - ❖ Max reserves are needed in Solar scenarios with VER forecast levels of ~70% - 80%



Net Load = Avista Gross Load – VER Production

Final Reserve Results

- **After all reserves were calculated, we re-applied them to the historical timeseries for implementation into the ADSS simulation**
- **Deliverable formatted as a Microsoft Excel workbook with 8760s for each historical weather-year**
    - We will send Phase 1 materials following this call, and pending any further questions or comments from Avista
    - Energy Strategies will also need to send updated VER profiles since the ILR assumption



	A	B	C	D	E	F	G	H
1	Hour of Year	Datetime (PST)	RegUp	RegDn	LF Up	LF Dn	FcstErr Up	FcstErr Dn
2	1	2010-01-01 00:00:00-08:00	16.48224323	199.887766	55.28957486	61.15014447	99.82156424	122.1391016
3	2	2010-01-01 01:00:00-08:00	11.59789601	6.428916808	55.28957486	61.15014447	99.82156424	122.1391016
4	3	2010-01-01 02:00:00-08:00	10.22793947	18.27843634	55.28957486	61.15014447	99.82156424	122.1391016
5	4	2010-01-01 03:00:00-08:00	12.26200265	19.61672626	55.28957486	61.15014447	99.82156424	122.1391016
6	5	2010-01-01 04:00:00-08:00	15.51289674	17.84325435	55.28957486	61.15014447	99.82156424	122.1391016

2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013

Net Load = Avista Gross Load – VER Production

Discussion topics from 6/28 check-in meeting

- **In 6/28 meeting, James identified that significant electrification (driving an increase in Avista load) would need to be baked into the 1500MW & 2500 MW VER scenario.**
    - ❖ Avista is exploring the resolutions to this internally, and Energy Strategies will need any updated load assumptions to move forward with reserve calculations
- **Profiles for Oregon offshore wind seem to have a lower capacity factor than anticipated**
    - ❖ Energy Strategies can explore additional offshore locations to increase this number
    - ❖ All CFs are within +/- 5% of values provided by Avista
- **Confusion about max AC output (POI limit) of existing Avista wind/solar assets**
    - ❖ Energy Strategies is developing proxy historical production & forecast curves for these locations as part of the benchmarking process. However, they will not be used in the reserve calculation analysis (2021 production & forecast actuals will be used). As of now, our assumptions are:
        - ➢ Palouse Wind: 106 MW @ 39% Capacity Factor
        - ➢ Rattlesnake Flat Wind: 147 MW @ 32% Capacity Factor
        - ➢ Lind Solar Farm: 20 MW @ 25% Capacity Factor
- **Question regarding the lower capacity factor of site additions due to less favorable land locations**
    - ❖ This question is addressed in the capacity factor analysis results in these materials