ENERGY STRATEGIES

Avista Variable Energy Resource (VER) Integration Study

Phase 2 Deliverable

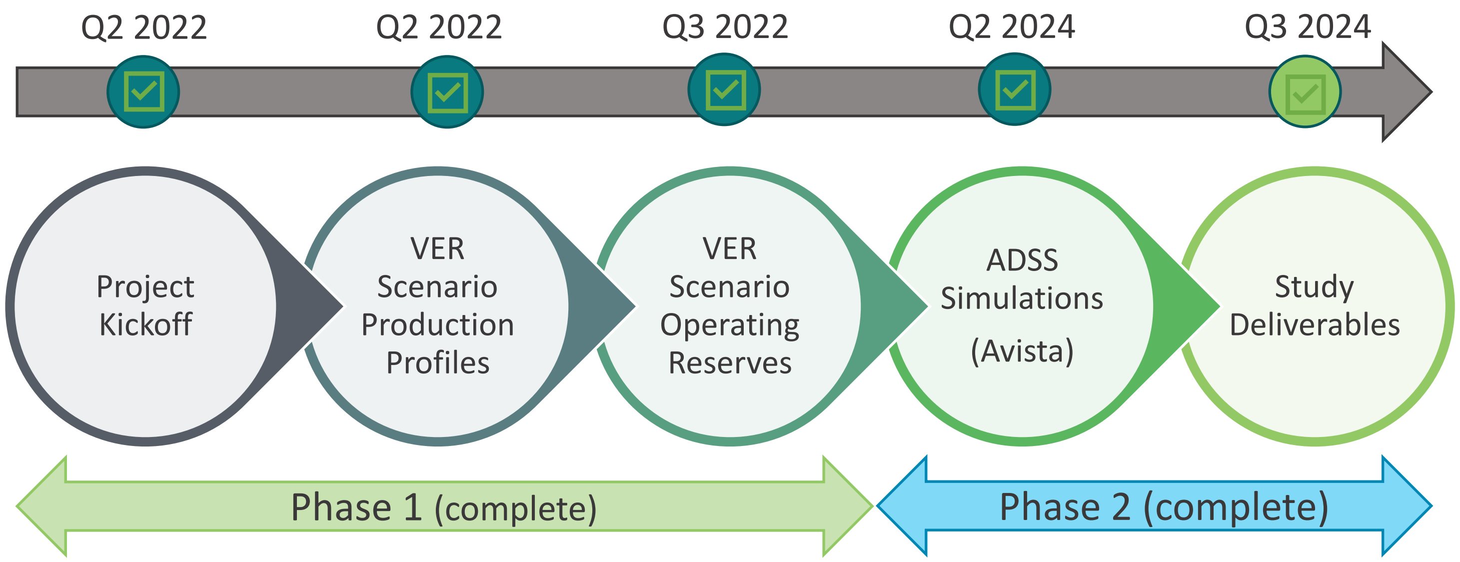
September 2024 | Avista VER Workgroup

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
- **Phase 2 Overview**
  - ADSS Simulations
  - Integration Cost Results
  - Integration Cost Calculator

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 Phases 1 and 2**



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

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  - ❖ Held as a constraint in the ADSS model

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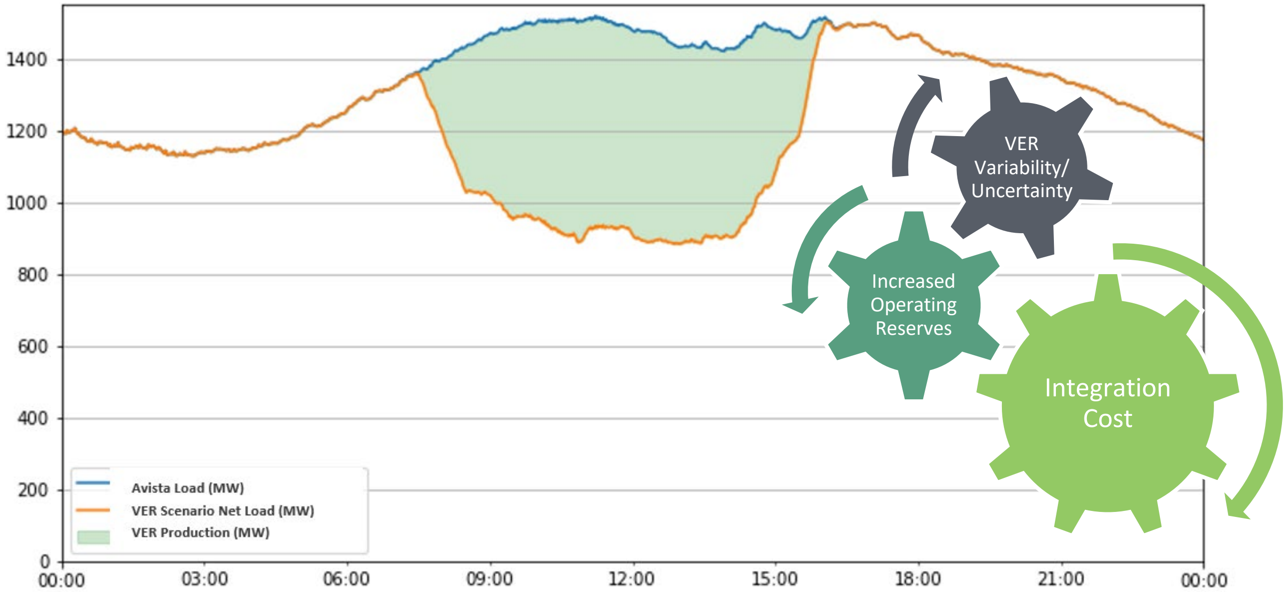
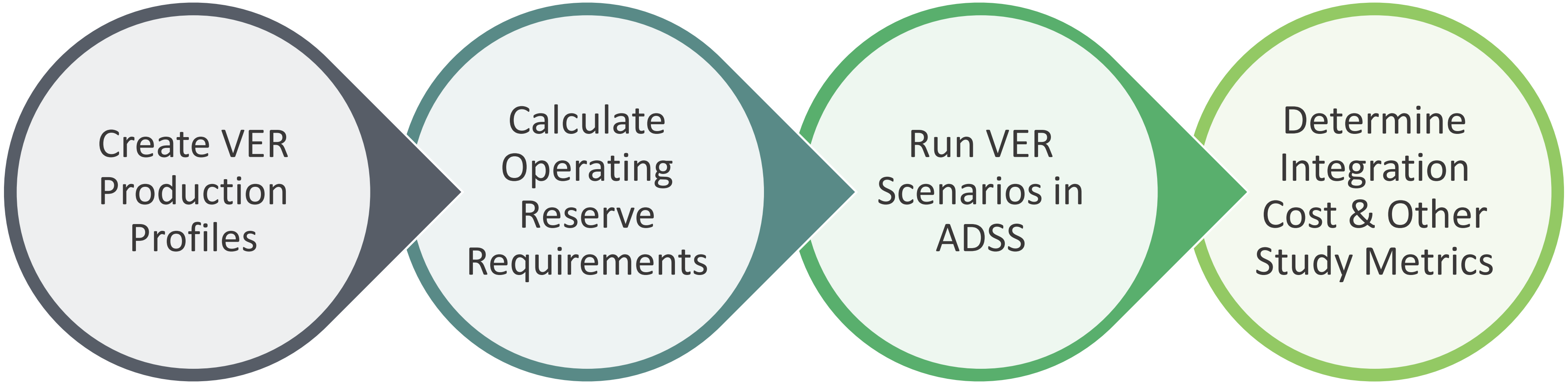
+2500 MW VER	2500 MW wind	1250 MW wind & solar	2500 MW solar



VER Integration Study Methodology



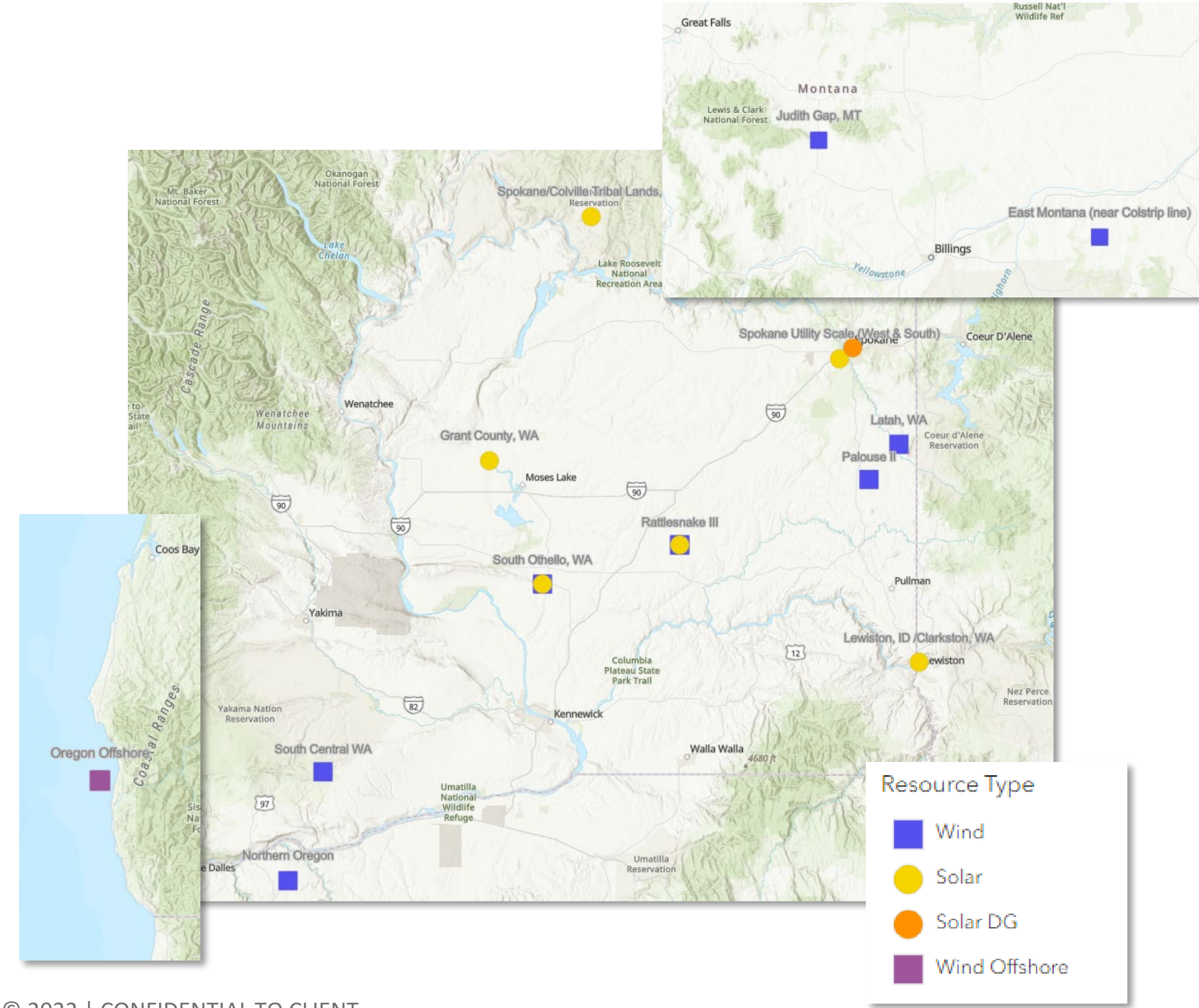
VER Scenario Production & Forecast Profiles

Avista VER Integration Study

VER Locations

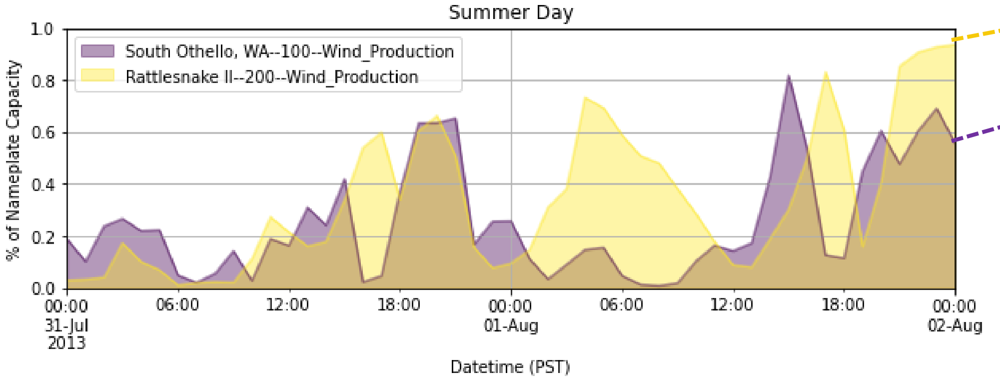
- **Avista identified feasible VER buildouts for each study scenario**
  - ❖ Study locations identified by Avista engineers as likely development locations based on past development proposals

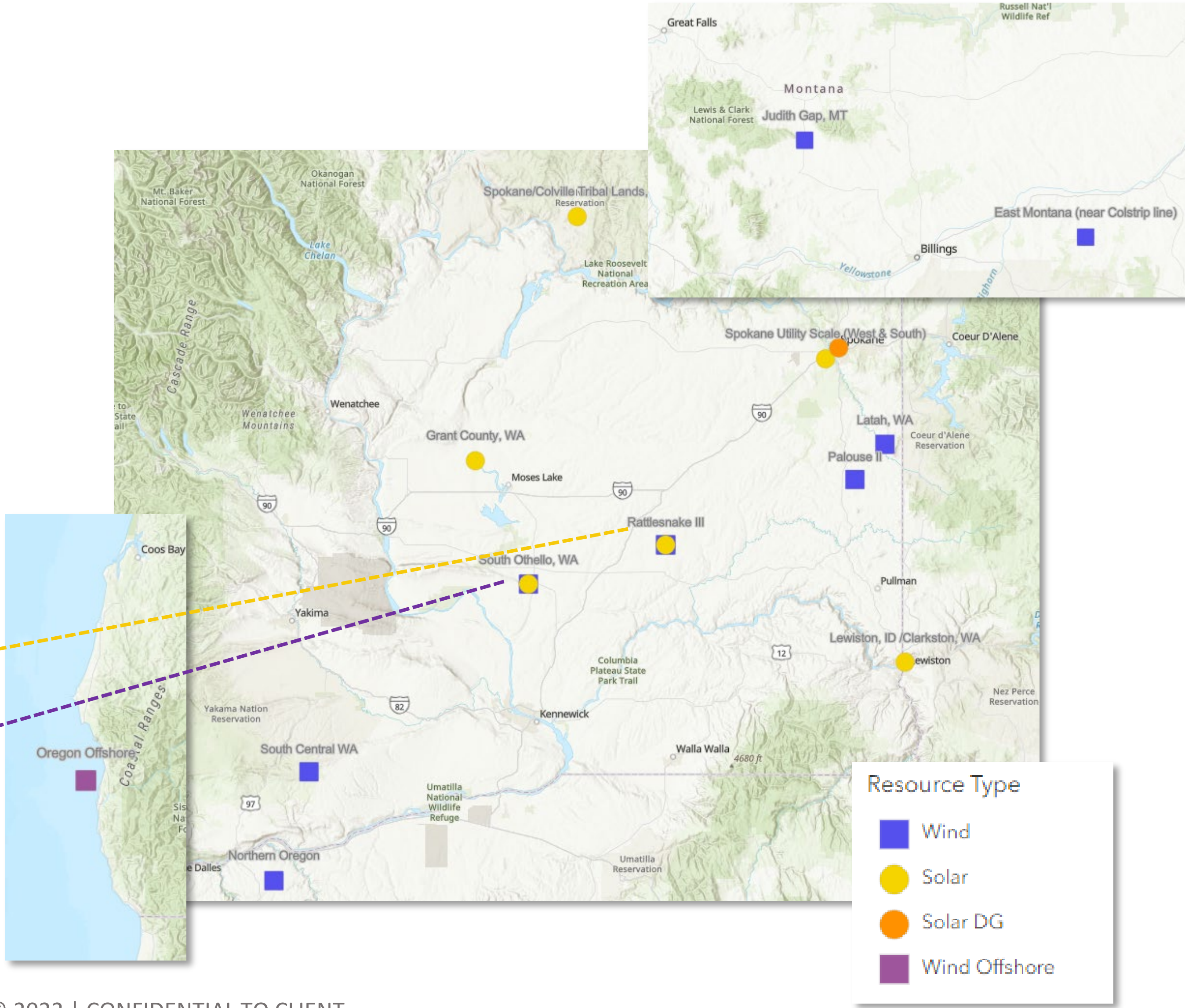
Site Location	Resource Type	+400 MW			+800 MW			+1500 MW			+2500 MW		
		Wind	50/50	Solar	Wind	50/50	Solar	Wind	50/50	Solar	Wind	50/50	Solar
North Colstrip, MT	Wind	100	100		200	200		200	200		400	200	
Judith Gap, MT	Wind	200	100		200	200		300	200		400	300	
South Othello, WA	Wind	100			100			100	100		150	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

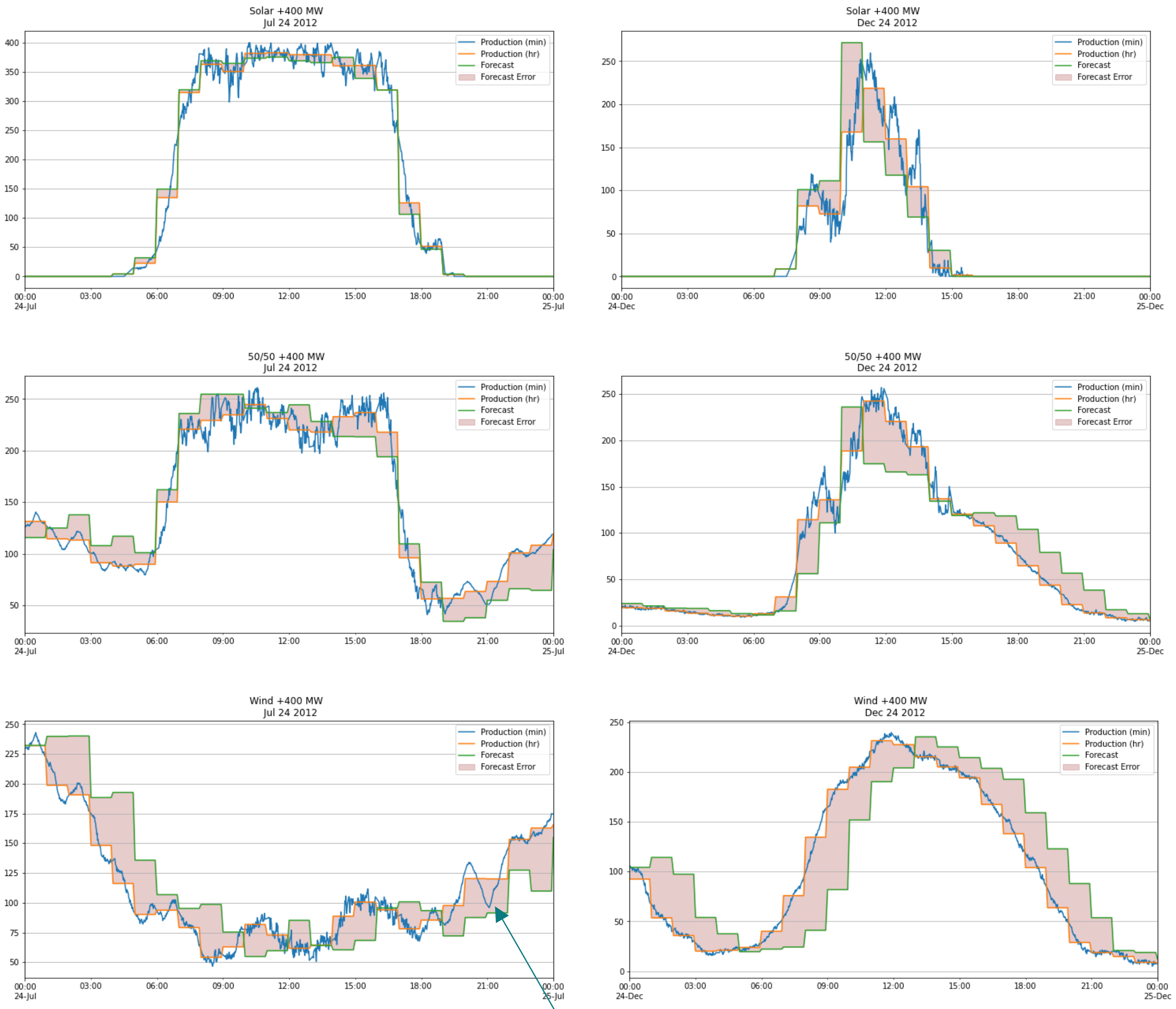
- **Utilized NREL WIND and NSRDB datasets to compile site-specific proxy production & forecast profiles for each VER site**
  - Data compiled for a timeframe of 2007 – 2013; providing 7 years of data from which to derive reserves
  - All site production was validated to be within 5% capacity factor of 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%

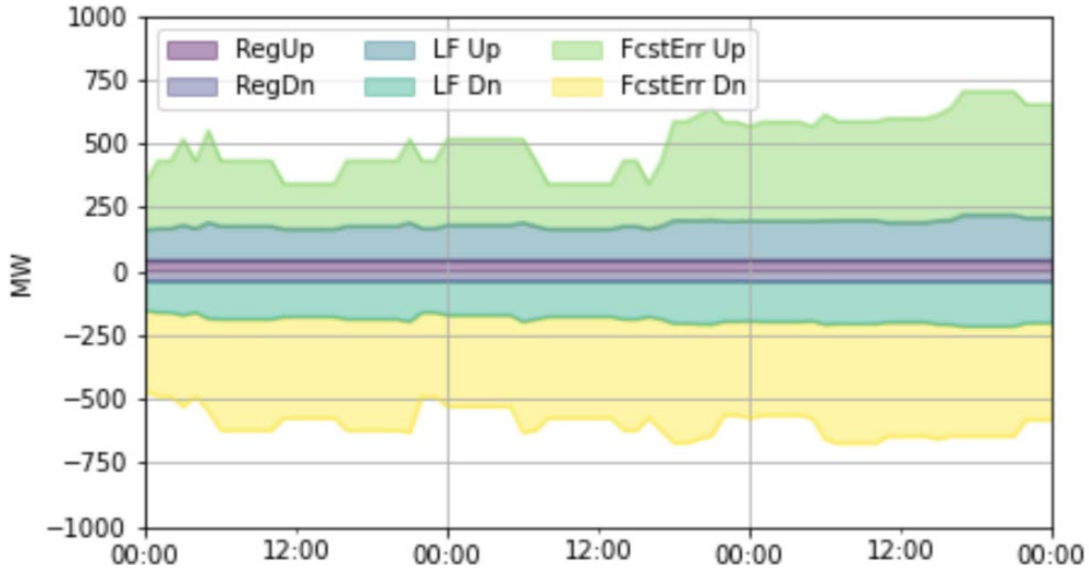
Operating Reserve Calculations

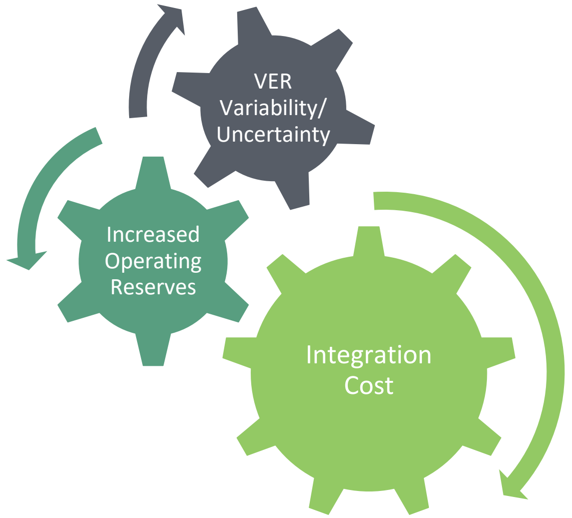
Avista VER Integration Study

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

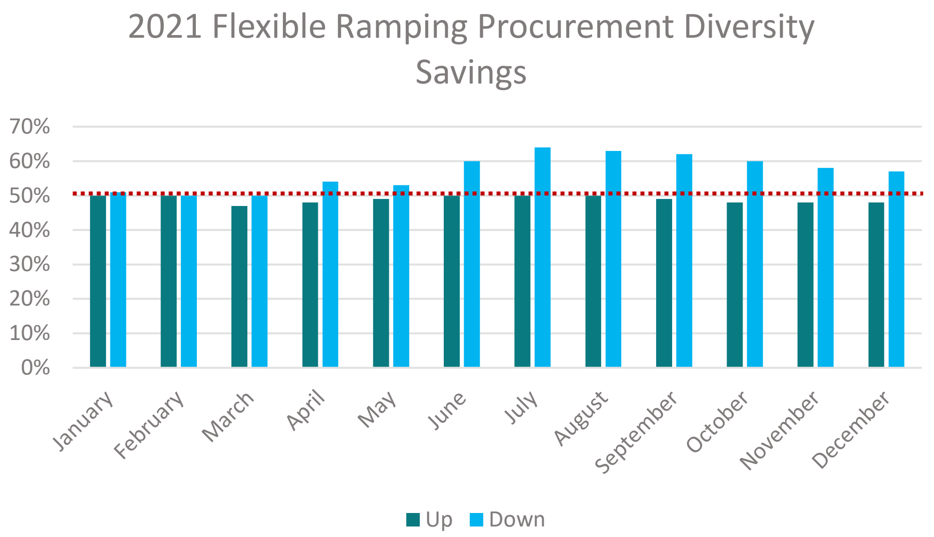
- Procured to handle hour-to-hour variations in net load
- **Load-Following Error = 1-min Net Load – Hourly Average Net Load**
- Calculated as 2σ confidence interval of Load-Following Error
- Calculation bins load-following reserves held in operating hour by VER forecast
- <u>Discounted by 50% to represent EIM Diversity Benefit</u>

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
- <u>Discounted by 50% to represent EIM Diversity Benefit</u>

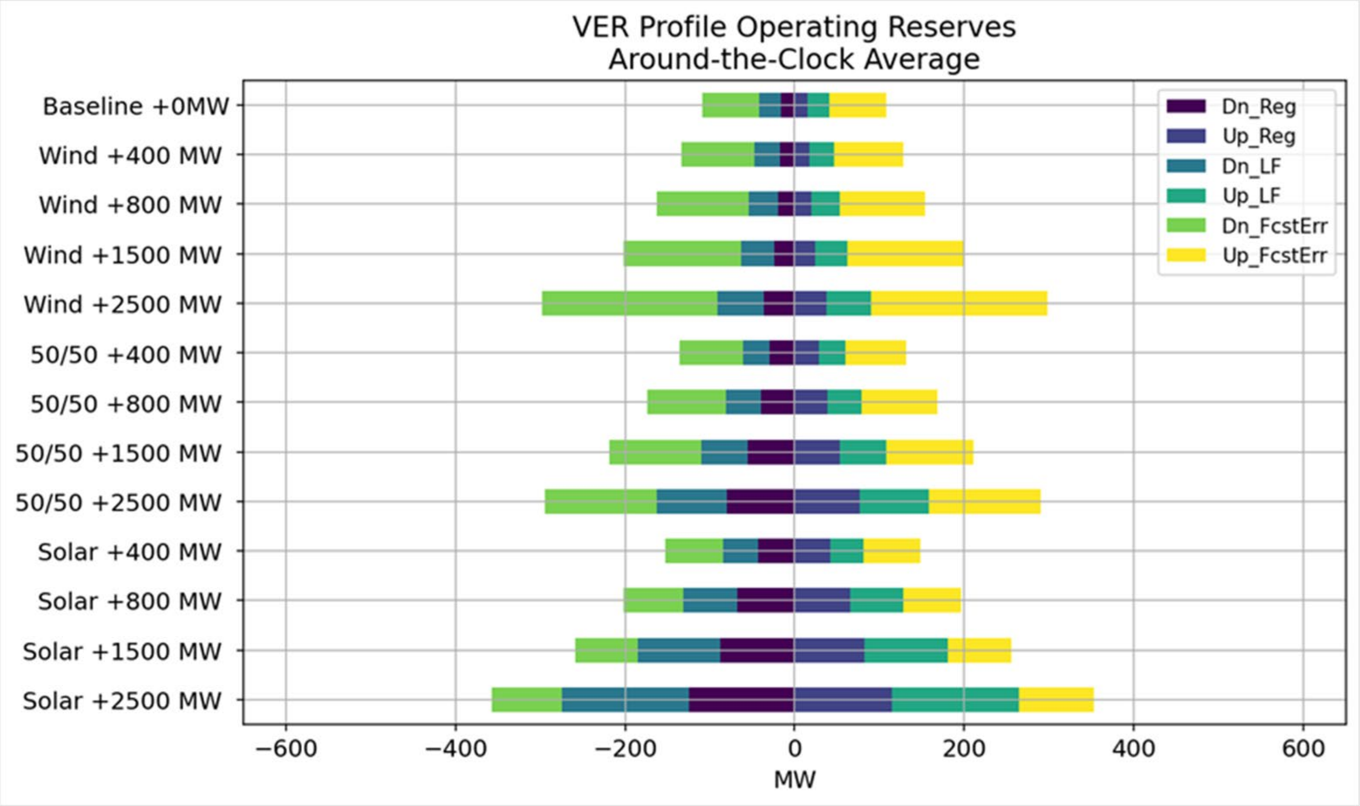
EIM Implications on Reserves

- **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 approximate EIM Flexible Ramping Capacity to reduce the Load-Following and Forecast Error reserves held within the Avista footprint by 50%**



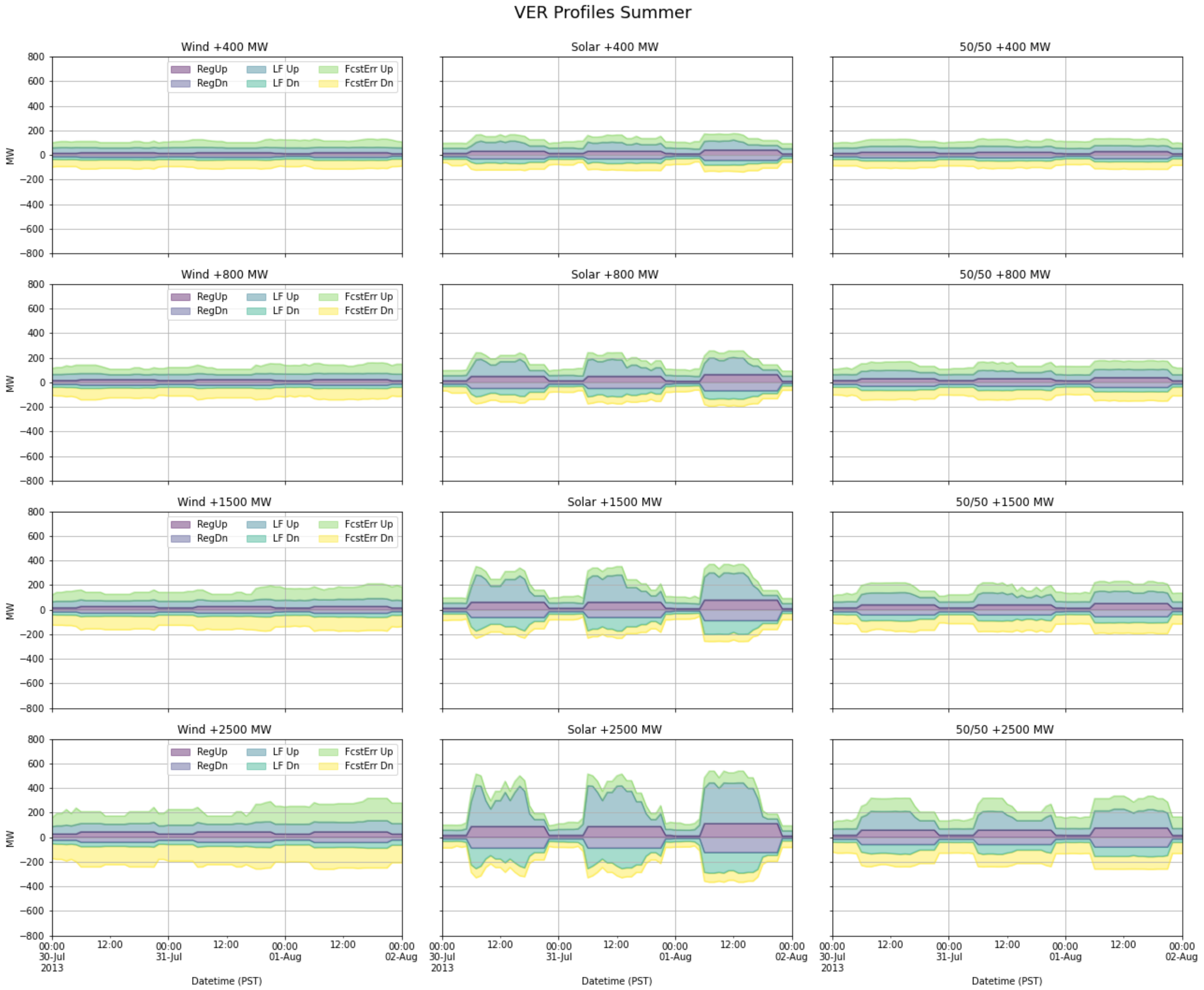
Average Reserve Levels: VER Scenarios

- **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



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 were sent to Avista for use in ADSS simulations



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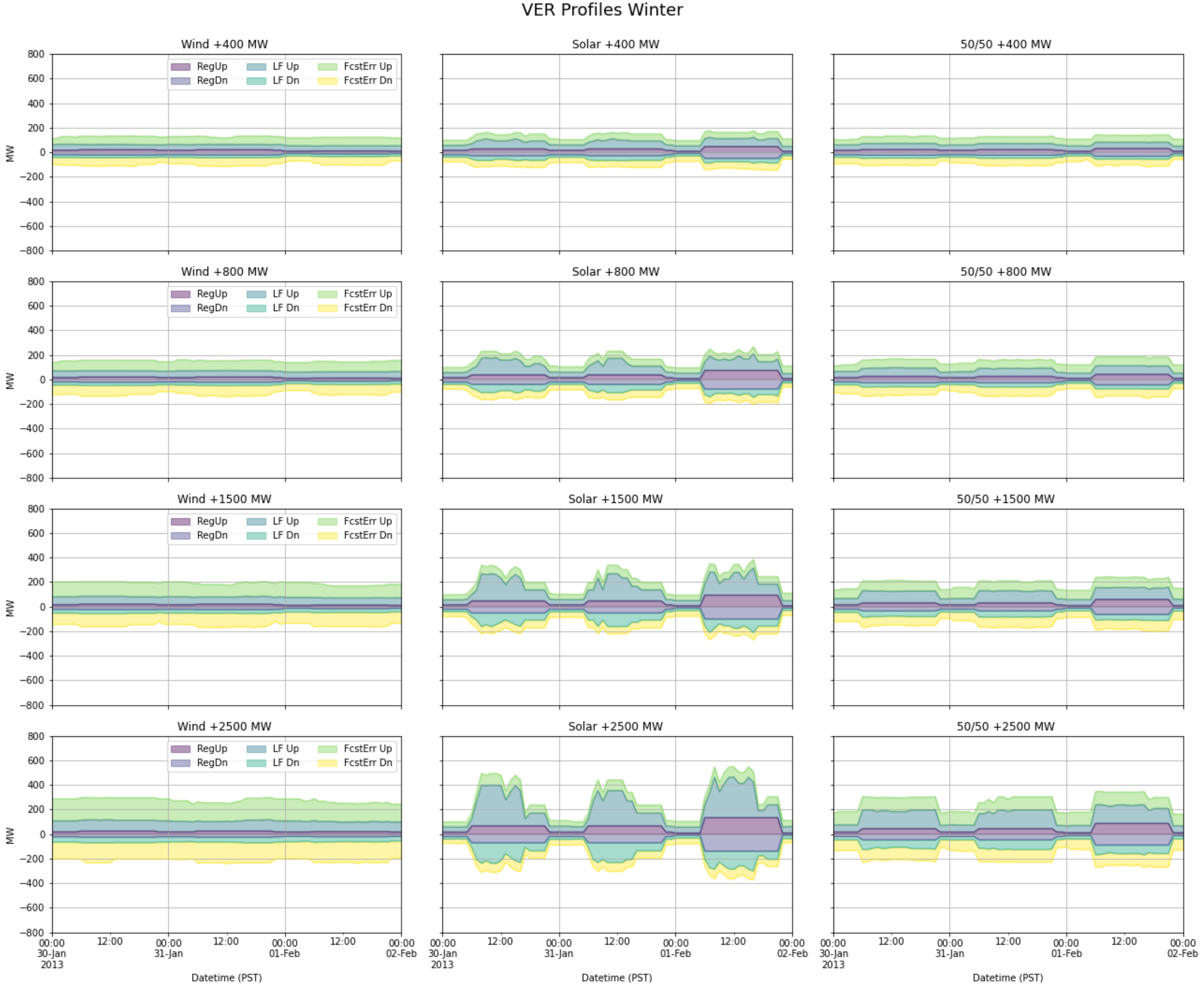
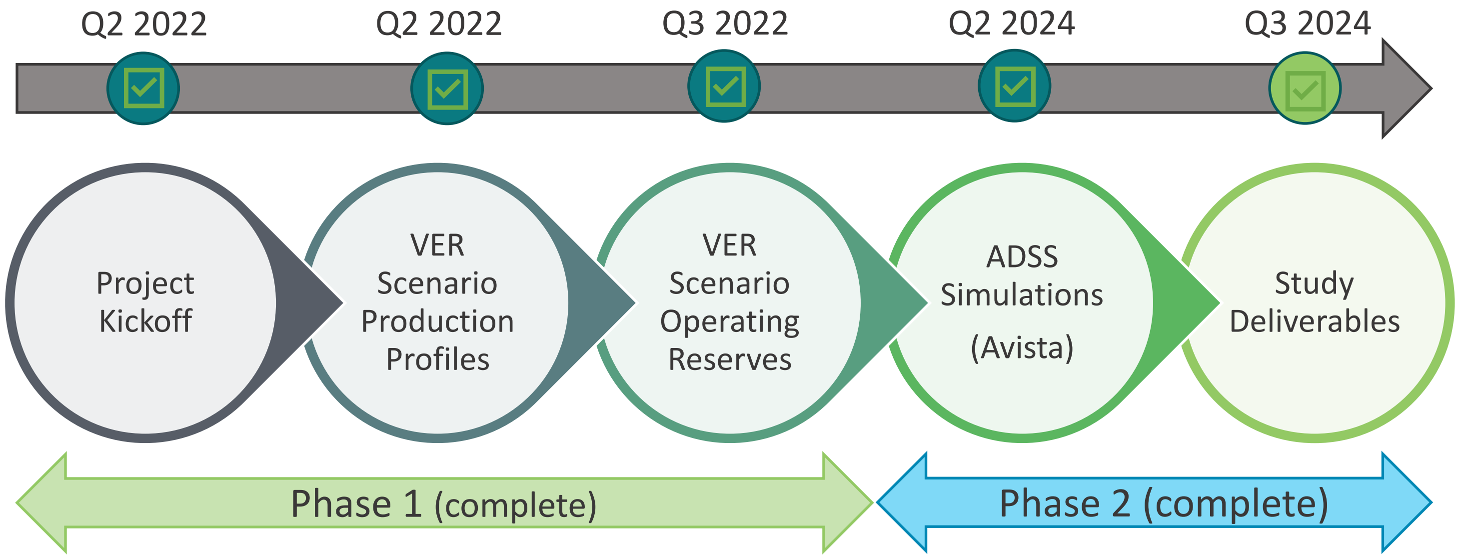


Integration Study Results

Avista VER Integration Study Phase 2

VER Integration Study Phase 2

- **Energy Strategies delivered Phase 1 deliverables to Avista in Q3 2022**
- **Avista ran ADSS simulations with these inputs and delivered integration cost results to Energy Strategies in Q2 2024**
- **Phase 2 deliverables include this slide deck and an excel-based integration cost calculator to be used by Avista in subsequent integration studies or study sensitivities**



Avista Decision Support System (ADSS) Model

- **ADSS is Avista's in-house commitment & dispatch optimization model**
  - Used for several applications within Avista including for long-term planning, maintenance planning, and trading
  - Includes high-quality of chronological system needs & constraints, especially for thermal and hydro generation units
  - ADSS was used in this study to assess the production costs of VER portfolios and holding their associated incremental reserves
  - VERs assumed to be curtailable to support system operations

- **As part of Phase 2 of the VER Integration Study, Avista staff performed ADSS simulations for each of the studied futures**
  - Each scenario was run with and without the incremental reserves Energy Strategies calculated in Phase 1
  - The difference in production cost between these two production cost models represents the integration cost
  - Each of these scenarios was assessed with a low, base, and high value of power in external wholesale markets
  - Model assumes sufficient non-firm transmission and liquidity in external markets to accommodate simulated purchases and sales

Mid-C price assumed in ADSS simulations

	Mid-C Price ($/MWh)
Low	22.15
Base	44.31
High	88.64

Integration Cost Results

- **Base Integration Costs range from $0.40/MWh (Solar 400) to $4.92/MWh (Wind 2500)**
  - ❖ Wind scenarios represent highest integration cost at all penetration levels
  - ❖ Solar exhibits the lowest integration costs at all penetration levels
  - ❖ Solar integration cost is lower than the integration cost of existing VERs through a 1,500MW penetration level
  - ❖ For penetrations 1,500 – 2,500 MW and greater, mixed wind/solar portfolios may be desirable from an integration cost perspective, especially in the low-market price scenario
  - ❖ Integration costs for wind resources increase dramatically after 1,500 MW of penetration
- **Integration costs are sensitive to the assumption of wholesale market prices in ADSS simulations**

Integration Cost

	Base ($/kW-mo)	High ($/kW-mo)	Low ($/kW-mo)	Base ($/MWh)	High ($/MWh)	Low ($/MWh)
Existing VERs	0.19	0.40	0.15	0.54	1.12	0.44
50/50 400	0.16	0.34	0.09	0.56	1.19	0.32
Wind 400	0.22	0.48	0.13	0.89	1.90	0.50
Solar 400	0.12	0.26	0.07	0.40	0.85	0.23
50/50 800	0.19	0.39	0.11	0.69	1.43	0.40
Wind 800	0.27	0.56	0.16	1.21	2.50	0.70
Solar 800	0.12	0.25	0.07	0.43	0.90	0.25
50/50 1500	0.17	0.33	0.10	0.70	1.41	0.43
Wind 1500	0.25	0.48	0.19	1.25	2.44	0.94
Solar 1500	0.11	0.23	0.07	0.43	0.87	0.27
50/50 2500	0.22	0.39	0.20	0.98	1.74	0.90
Wind 2500	0.85	1.21	0.79	4.92	7.05	4.56
Solar 2500	0.21	0.33	0.22	0.84	1.33	0.90

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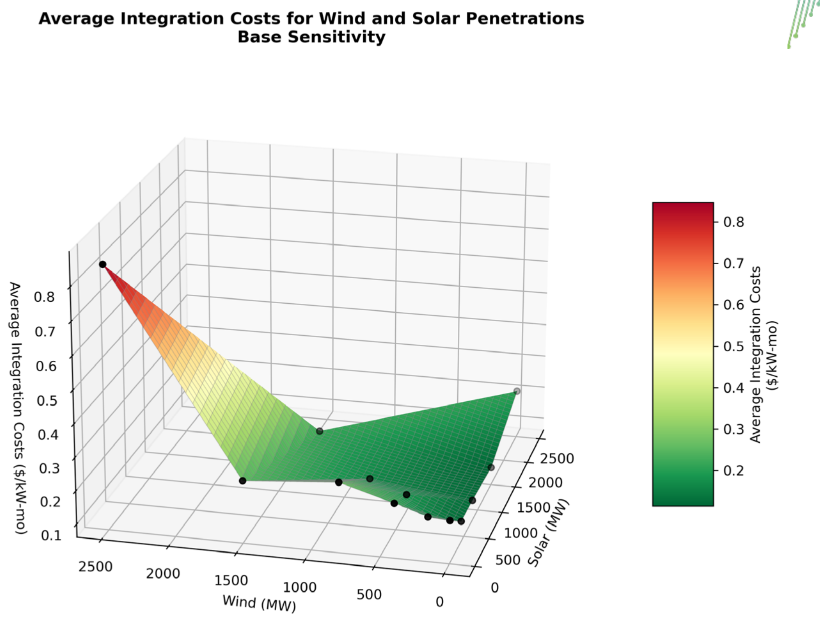
Integration Cost

(Incremental Relative to Existing VERs)

Integration Scenario	Base ($/kW-mo)	High ($/kW-mo)	Low ($/kW-mo)	Base ($/MWh)	High ($/MWh)	Low ($/MWh)
50/50 400	-0.03	-0.06	-0.06	0.02	0.07	-0.12
Wind 400	0.03	0.08	-0.02	0.35	0.78	0.06
Solar 400	-0.07	-0.14	-0.08	-0.14	-0.27	-0.21
50/50 800	0	-0.01	-0.04	0.15	0.31	-0.04
Wind 800	0.08	0.16	0.01	0.67	1.38	0.26
Solar 800	-0.07	-0.15	-0.08	-0.11	-0.22	-0.19
50/50 1500	-0.02	-0.07	-0.05	0.16	0.29	-0.01
Wind 1500	0.06	0.08	0.04	0.71	1.32	0.5
Solar 1500	-0.08	-0.17	-0.08	-0.11	-0.25	-0.17
50/50 2500	0.03	-0.01	0.05	0.44	0.62	0.46
Wind 2500	0.66	0.81	0.64	4.38	5.93	4.12
Solar 2500	0.02	-0.07	0.07	0.3	0.21	0.46

Integration Cost Calculator

- **Energy Strategies developed an excel-based Integration Cost Calculator for Avista**
  - ❖ Calculator takes results from studied integration scenarios and uses linear interpolation to find a solution for wind/solar integration costs within a 2,500 MW penetration level
  - ❖ To use the calculator:
    - ➢ Select the desired Scenario
    - ➢ Input wind and solar capacities
      - *Total = 0-2500 MW*
  - ❖ Energy Strategies delivered a zip file containing the Excel calculator, a supporting python file, and written instructions so that the Avista team can update the calculator internally for future integration cost sensitivities



Scenario:	**Base ($/kW-mo)**	
Solar:	**2500**	**MW**
Wind:	**0**	**MW**
Cost:	**0.21**	**($/kW-mo)**

	Integration Cost ($/kW-mo)			Integration Cost ($/MWh)		
Changeset	**Base ($/kW-mo)**	**High ($/kW-mo)**	**Low ($/kW-mo)**	**Base ($/MWh)**	**High ($/MWh)**	**Low ($/MWh)**
Existing	0.19	0.40	0.15	0.54	1.12	0.44
5050 400	0.16	0.34	0.09	0.56	1.19	0.32
Wind 400	0.22	0.48	0.13	0.89	1.90	0.50
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Solar 1500	0.11	0.23	0.07	0.43	0.87	0.27
5050 2500	0.22	0.39	0.20	0.98	1.74	0.90
Wind 2500	0.85	1.21	0.79	4.92	7.05	4.56
Solar 2500	0.21	0.33	0.22	0.84	1.33	0.90

ENERGY STRATEGIES

Thank you.

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