Renewable Integration Study Workshop

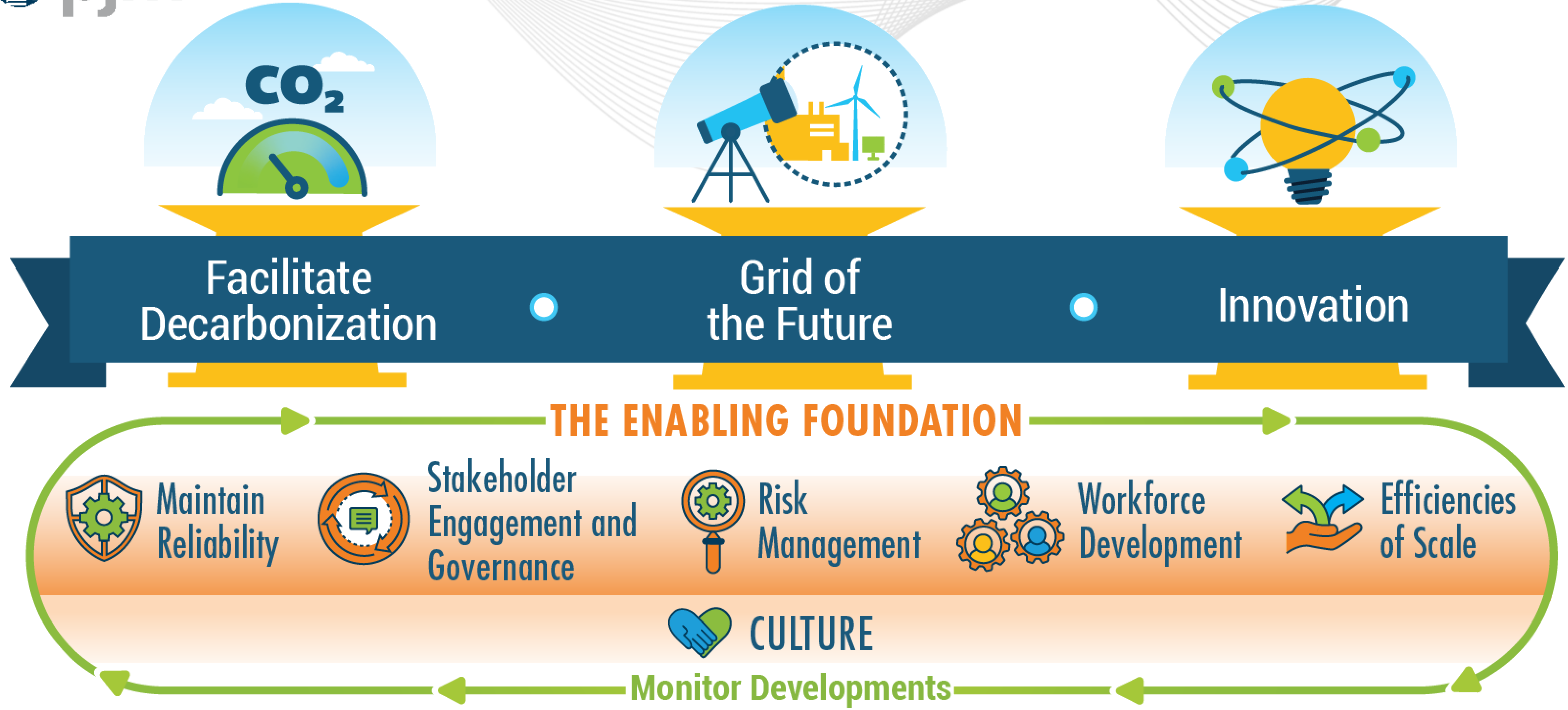
June 27, 2022

Introduction

Agenda

- **Introduction & Objectives**
- **Methodology**
- **Resource Adequacy Analysis**
- **Energy & Ancillary Services Market Analysis**
- **Next Steps (Phase-3)**

Strategic Pillars



Introduction

Industry Research/Outreach

- Leverage PJM's work: RIS 1.0, GE (2014), MOPR, Offshore Wind Study, Carbon Pricing.
- Review industry experience: CAISO, MISO, NERC, ESIG, NREL, SPP, ERCOT.

Analytics Markets/Operations

- Living Study
- Understand the impact of renewables in the context of PJM.
- Identify tipping points.

Takeaways

- We do not propose solutions (it is not a position piece).
- The intent is to inform and initiate discussion on changes that may be required given industry trends.

Methodology & Assumptions

Framework for Analyzing Energy Transition in PJM

Scenario Development
Establishes assumptions for resource portfolios and other analysis inputs. This includes a Base case, a Policy case driven by current state policies, and an Accelerated case factoring additional state and corporate clean energy goals.

Operational Reliability Assessment
Assessment of Reliability Attributes, and impacts Forecasting Tools and Outage Analysis

Energy & Ancillary Services Market Simulations
Uses security-constrained unit commitment and economic dispatch simulations to estimate impacts of each scenario on system generation and prices.

Transmission Planning Impacts
Assesses transmission needs to reliably develop the future grid and inform how PJM's planning processes should evolve to meet these needs.

Resource Adequacy Assessment
Uses the Effective Load Carrying Capability (ELCC) methodology to determine the capacity value of renewables and installed reserve margins in each scenario.

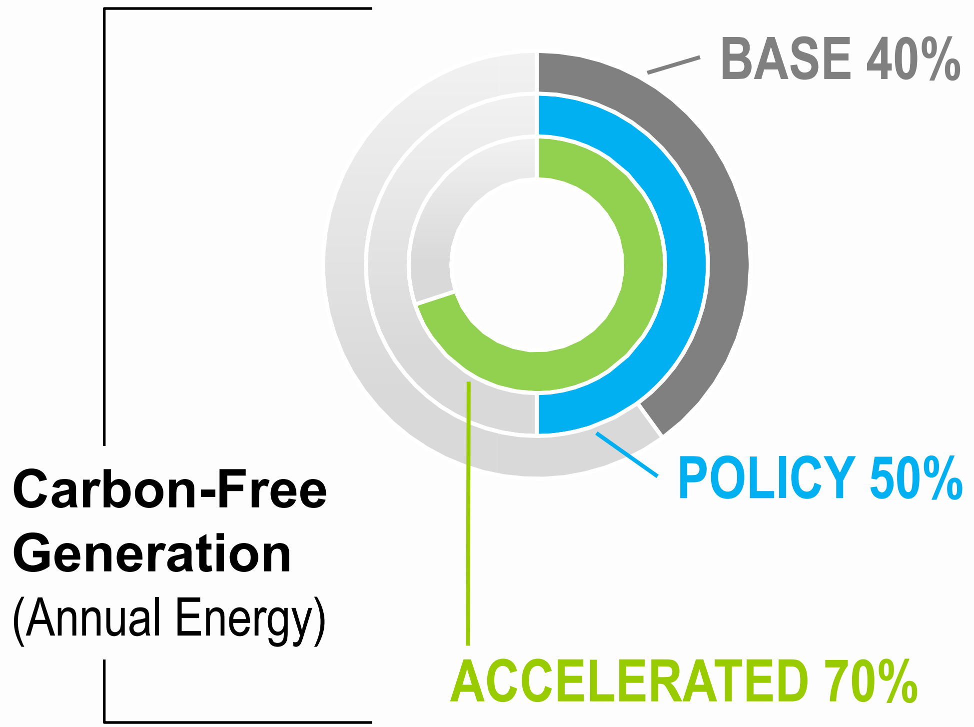
Focus of Phase 2 (2022 publication) & Workshop

Scenario Development

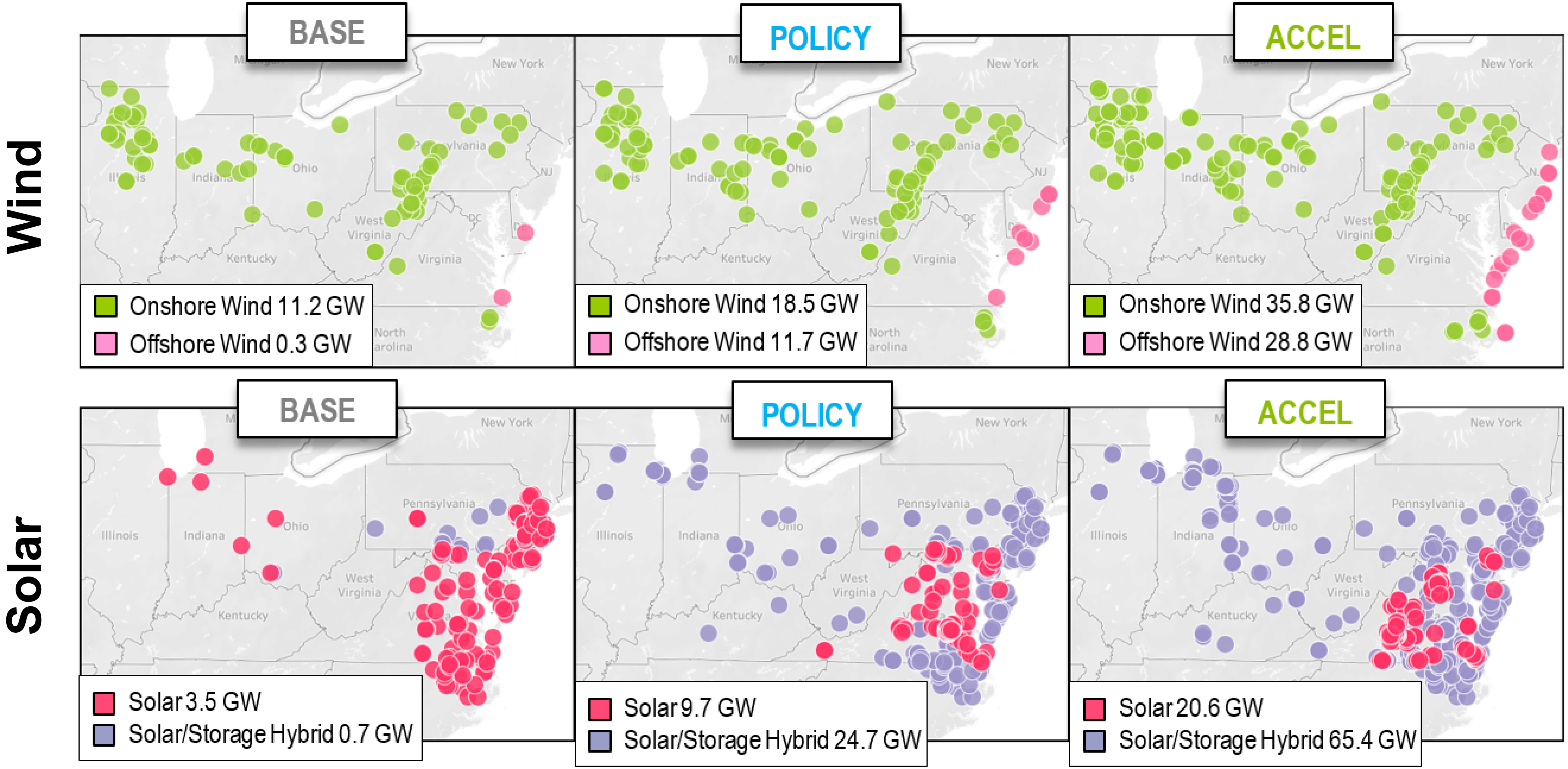
Base: Uses 2023/24 Regional Transmission Expansion Plan case, updated for current retirements.

Policy: References state and corporate clean-energy targets for 2035 to inform buildout and retirements of resources.

Accelerated: References additional state and corporate clean-energy targets extending to 2050, analyzed in context of 2035



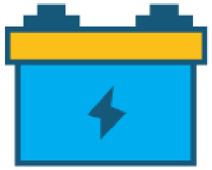
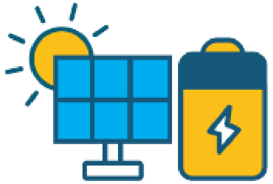
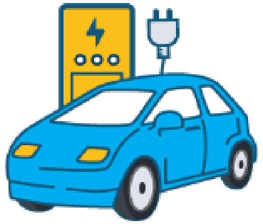
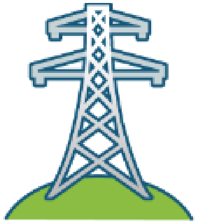
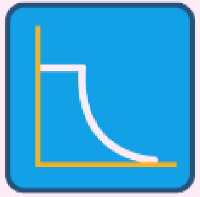
Generation Expansion by Scenario



Refining Study Assumptions (***Phase-2***)

Maintained the same level of Installed Capacity of Renewable Resources

Refined Study Assumptions (Phase-2)

Storage	Solar	Electrification	Interchange	Reserves
6 GW = Stand-Alone **31 GW =** Solar Hybrid 	**21 GW =** Stand-Alone **65 GW =** Solar Hybrid 	**~19 GW =** 17M EVs **14 GW =** Heating 	**Historical Levels of Interchange** 	**Downward-Sloping ORDC** 

Provided only to show ORDC curve impact – not to reflect a PJM intent to refile

Additional Assumption Updates:

- Load Forecasts, Fuel Prices, Emissions Allowance Prices

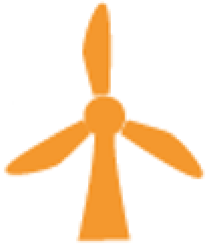
Resource Adequacy Analysis

Effective Load Carrying Capability (ELCC)

1. ELCC uses Loss of Load Expectation analysis (consistent with today's Installed Reserve Margin study) to precisely quantify the resource adequacy contribution of a resource.
2. ELCC uses historical load shapes and weather data to compare future expected load shapes to future expected resource output. Resources that consistently produce during times of expected shortage get a higher ELCC.
3. ELCC is sensitive to a small number (e.g., 200) high-risk hours over 10+ years.
4. ELCC is sensitive to load shapes and the resource mix (e.g., with more solar, risk windows shift.)
5. It was originally developed in the 1960s to quantify the resource adequacy impact of carrying very large plants in a fairly small balancing area.
6. It was later applied to variable resources.

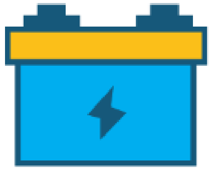
Wind, Solar, and Storage - General Attributes

PJM calculates the unforced capacity (UCAP) value of these resources using ELCC. This value represents the maximum capacity offer they can make in RPM.



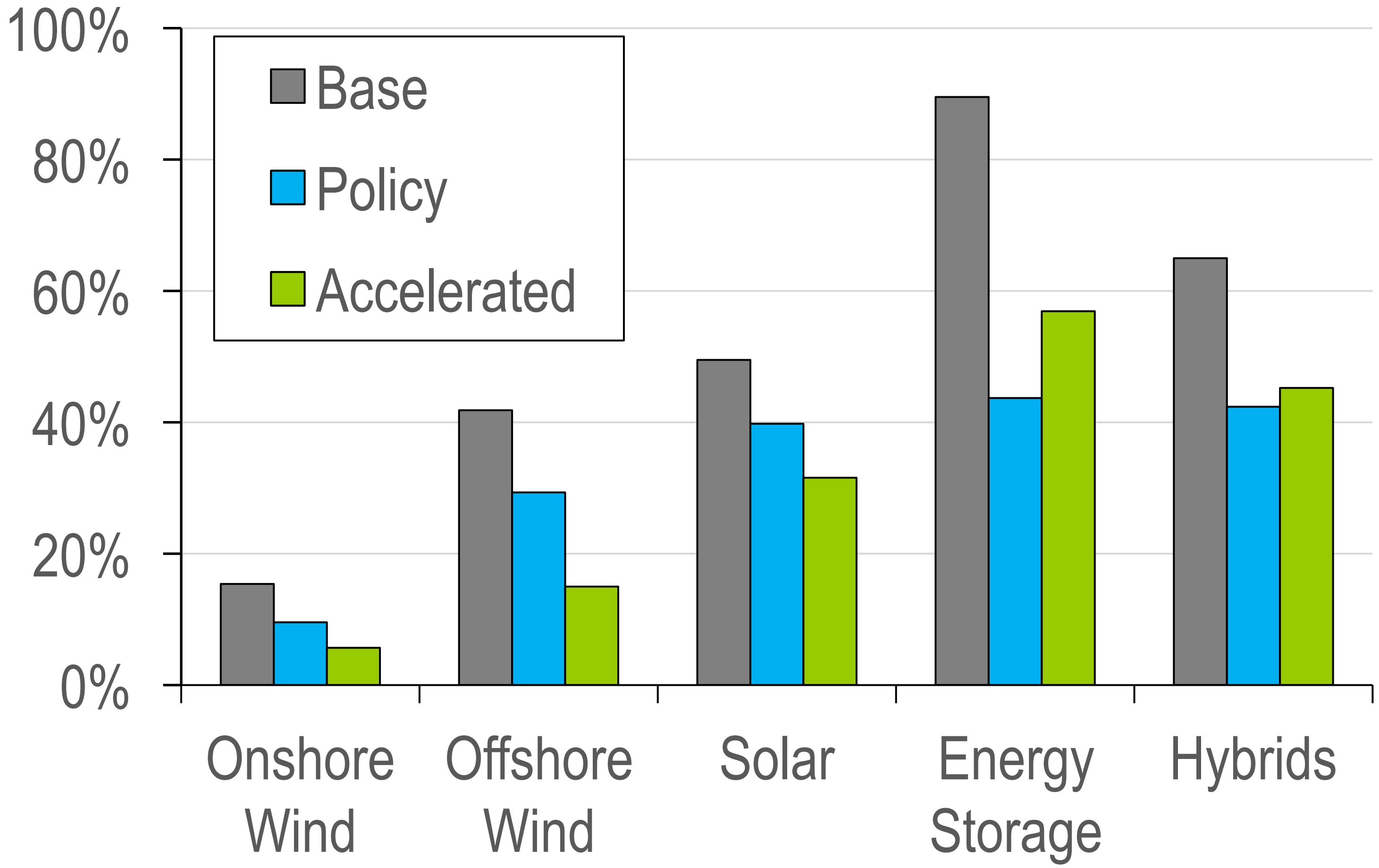
- Variable output
- Performs better in Winter than Summer

- Relatively predictable output
- Cuts off in the evening
- Performs better in Summer than Winter



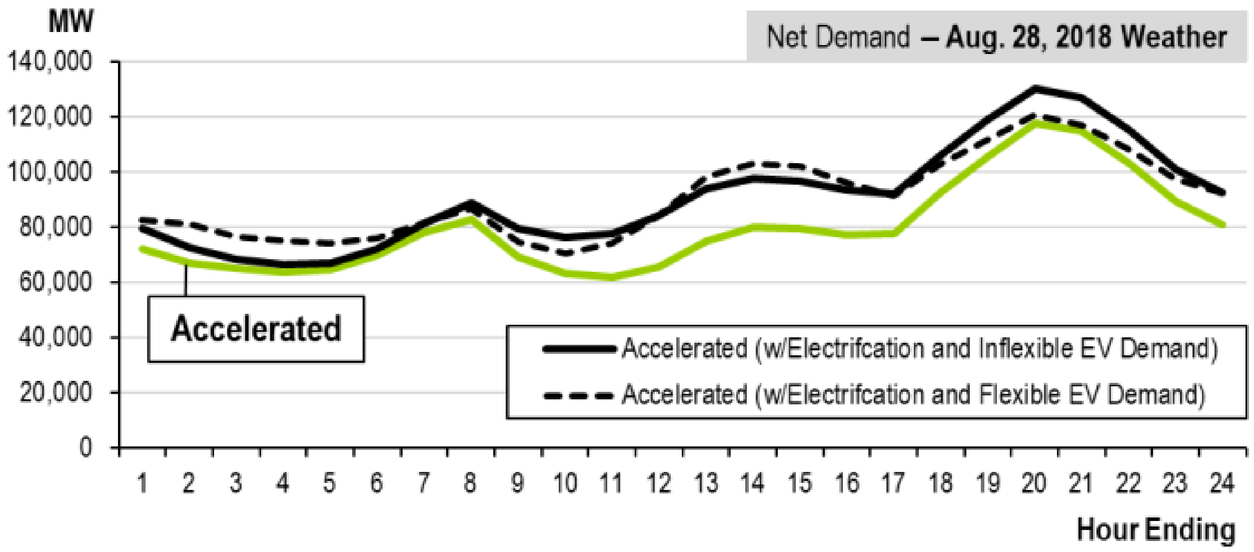
- Limited duration

ELCC Class Values



- Increased penetration drives value down. Solar due to shifting of risk hours to evening, and wind due to increasing supply uncertainty.
- Storage gets a boost in Accelerated due to complementarity with large amounts of solar.

Electrification – Additional EVs and Heat Pumps

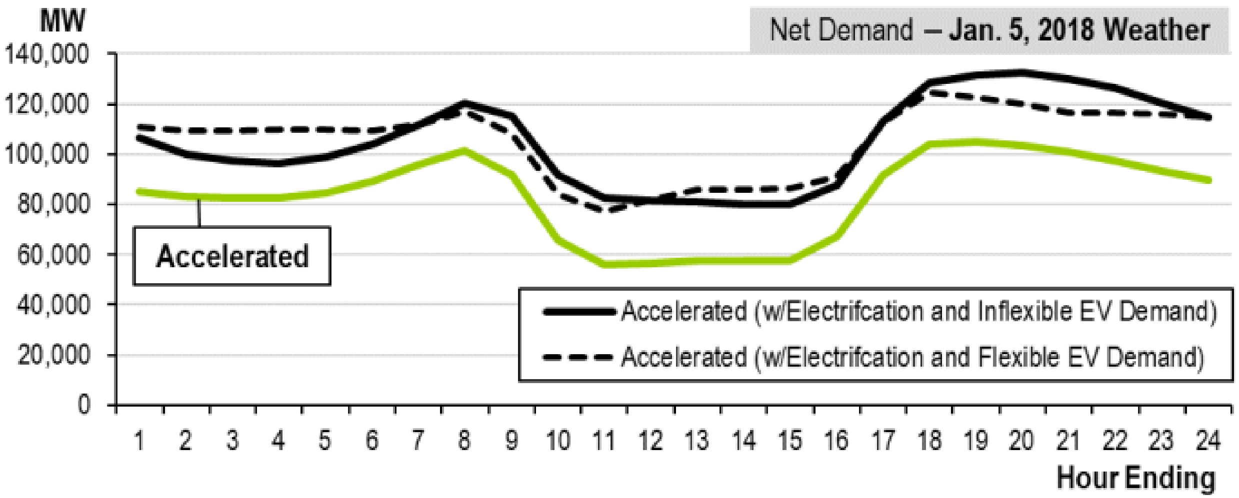


SUMMER

- Summer retains its peaky shape.
- EV charging can be managed such that peak impact is minimal.

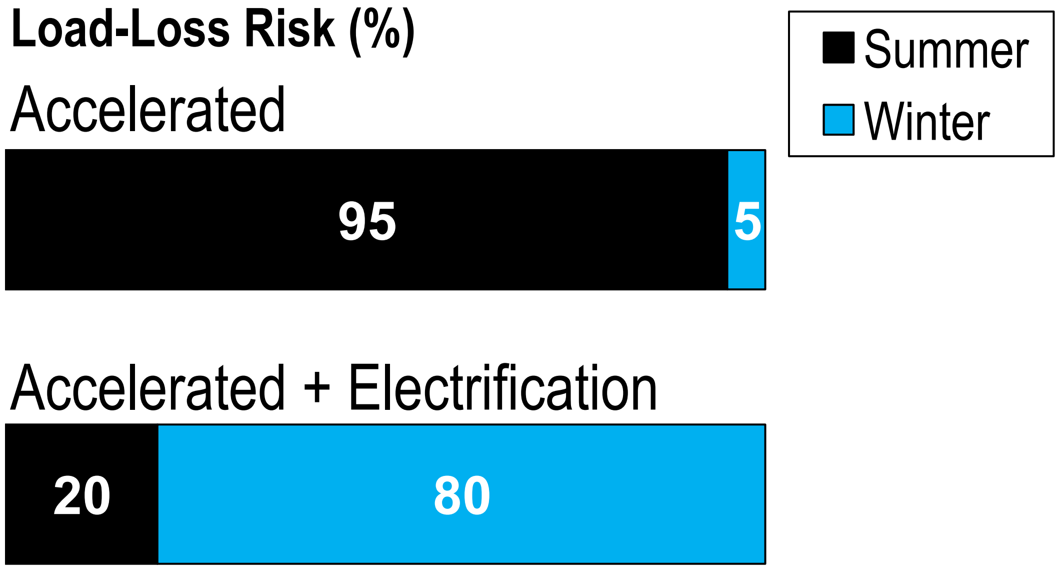
WINTER

- Additional electric heating will raise winter loads.
- Flatter winter shape makes it more difficult to fit in EV charging without also raising peaks.



Focus Area No. 1

Electrification Shifts the Seasonal Resource Adequacy Risk to Winter.

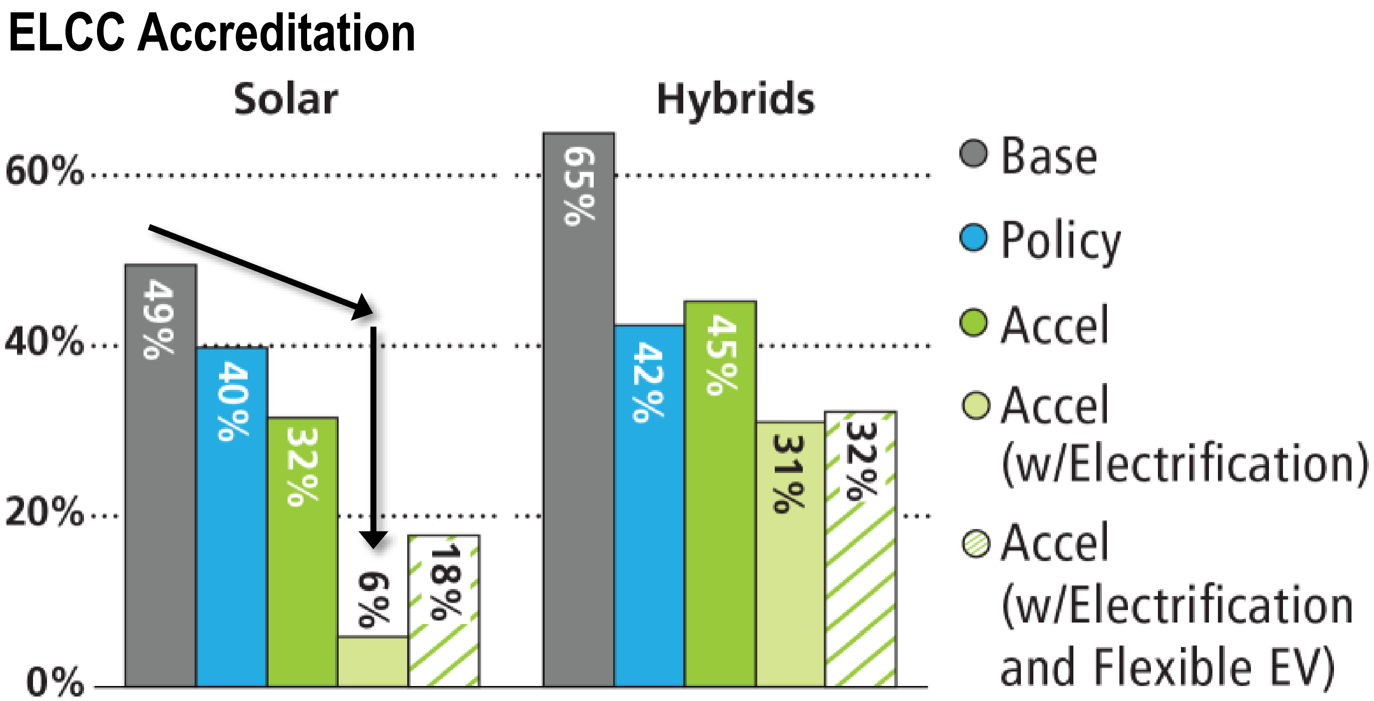


KEY INDICATORS

- Electrification Load Growth: Summer 7%, Winter 15%
- Winter net-load shape is flatter with a substantially wider peak demand
- 60% of the load-loss risk is concentrated during the last 4 hours of the day

Focus Area No. 2

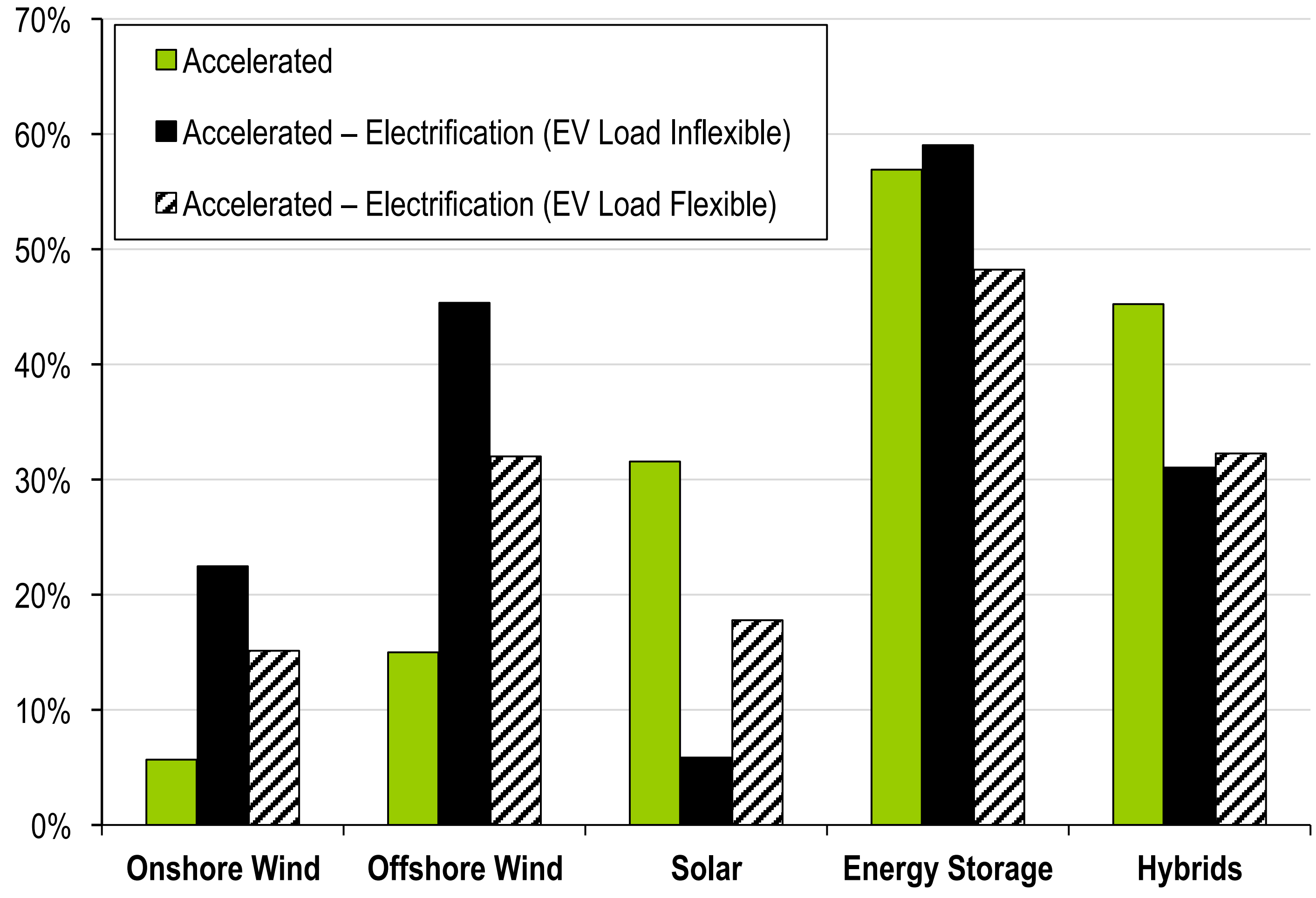
Retail Rate Design & Energy Storage Become Increasingly Important With Electrification.



KEY INDICATORS

- Demand elasticity reduces the amount of capacity procured and triples the value of solar
- Solar-hybrid have a higher capacity value under all scenarios
- Retail rate design and storage do not have a simple additive effect

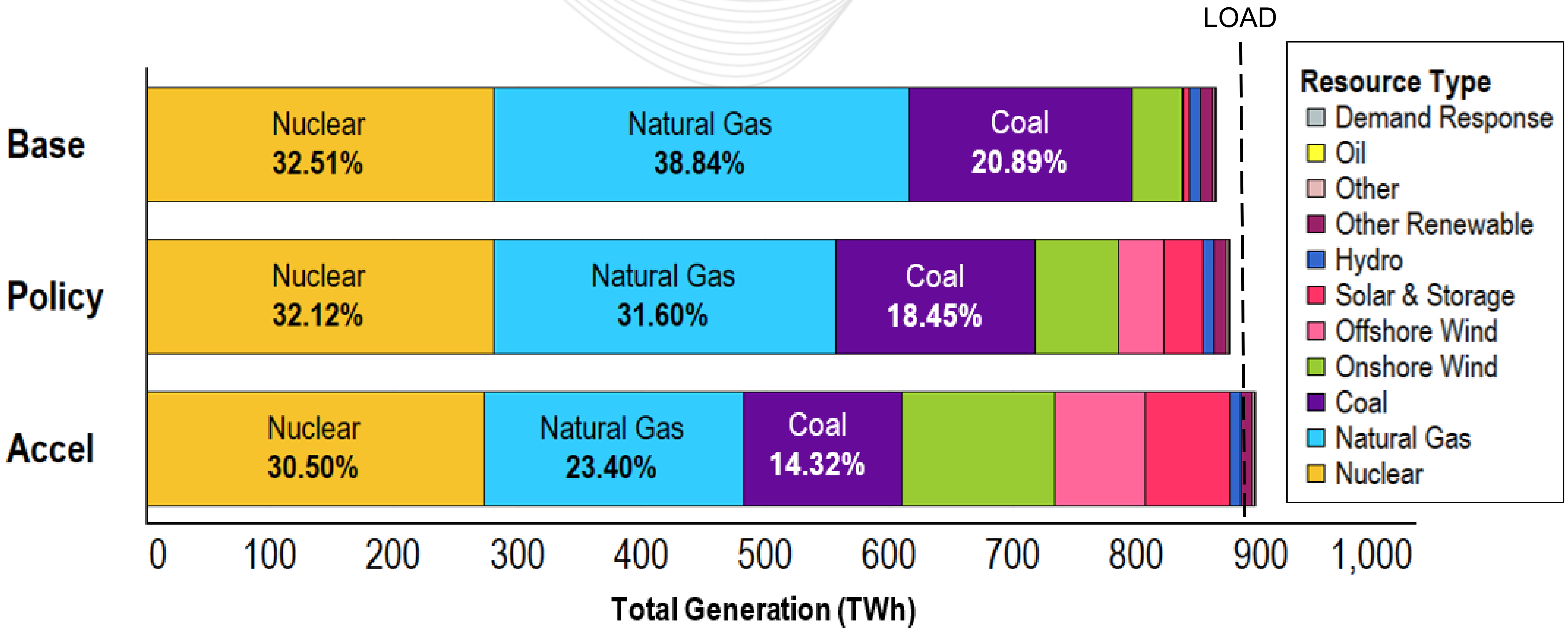
ELCC Class Values – Effect of Electrification



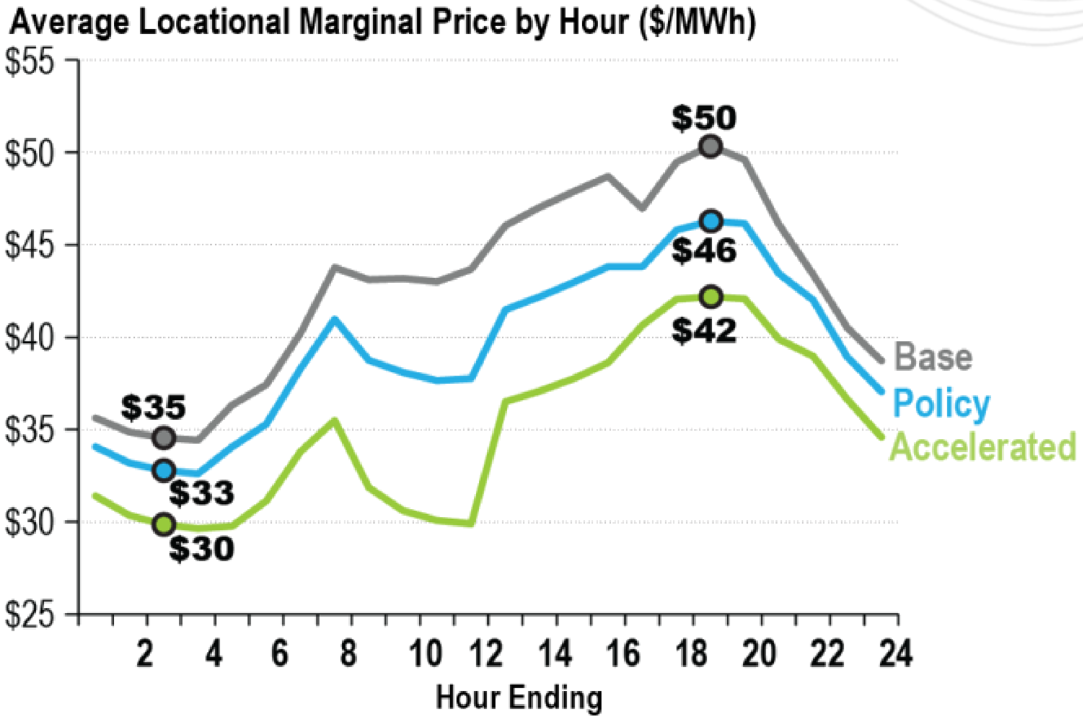
- Shift to Winter risk benefits wind resources and hurts solar resources.
- Flexibility of demand can restore some of solar's value by adding load when they perform comparably well.
- Demand flexibility may spread out the daily risk, which is detrimental to storage.

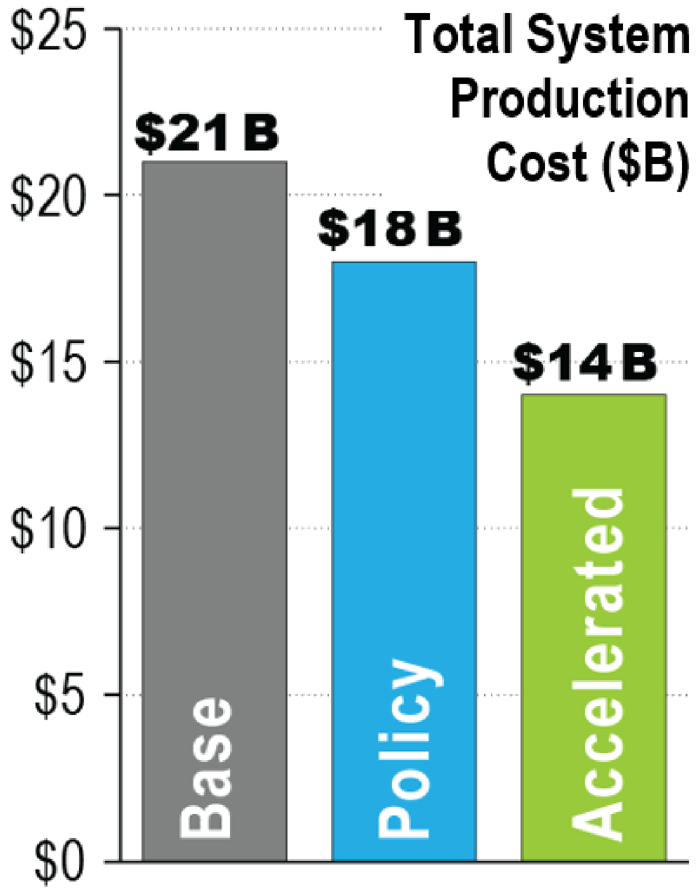
Energy & Ancillary Services Market Analysis

Generation by Fuel Type
Base, Policy & Acceleration 2-Step ORDC Models

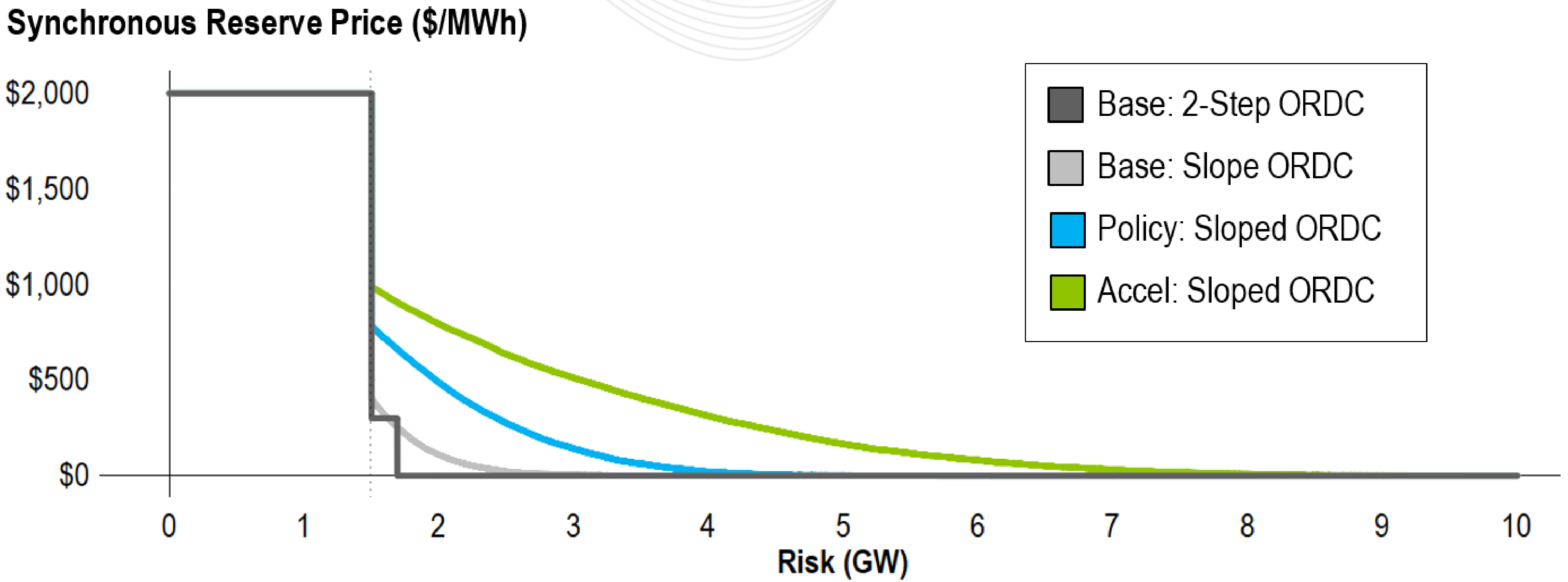


Energy Prices & Production Cost

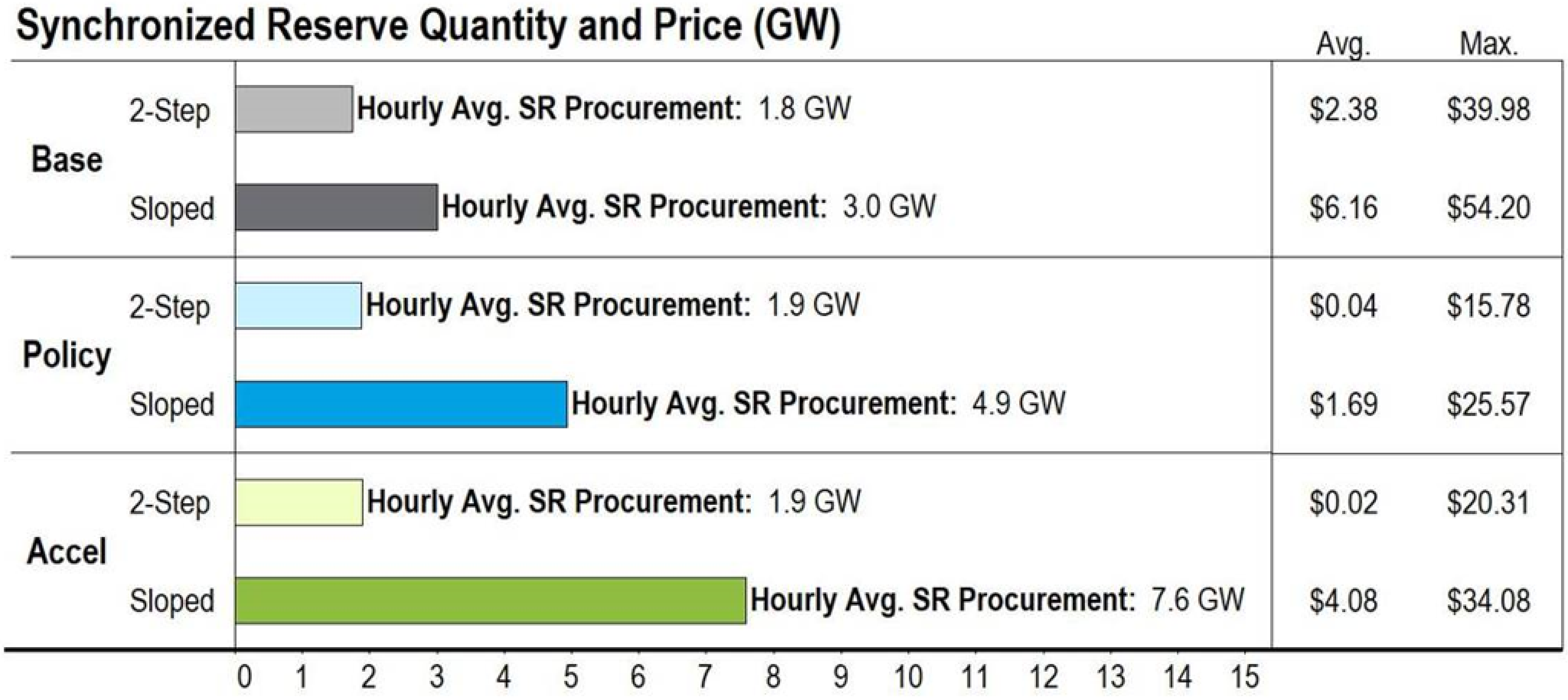




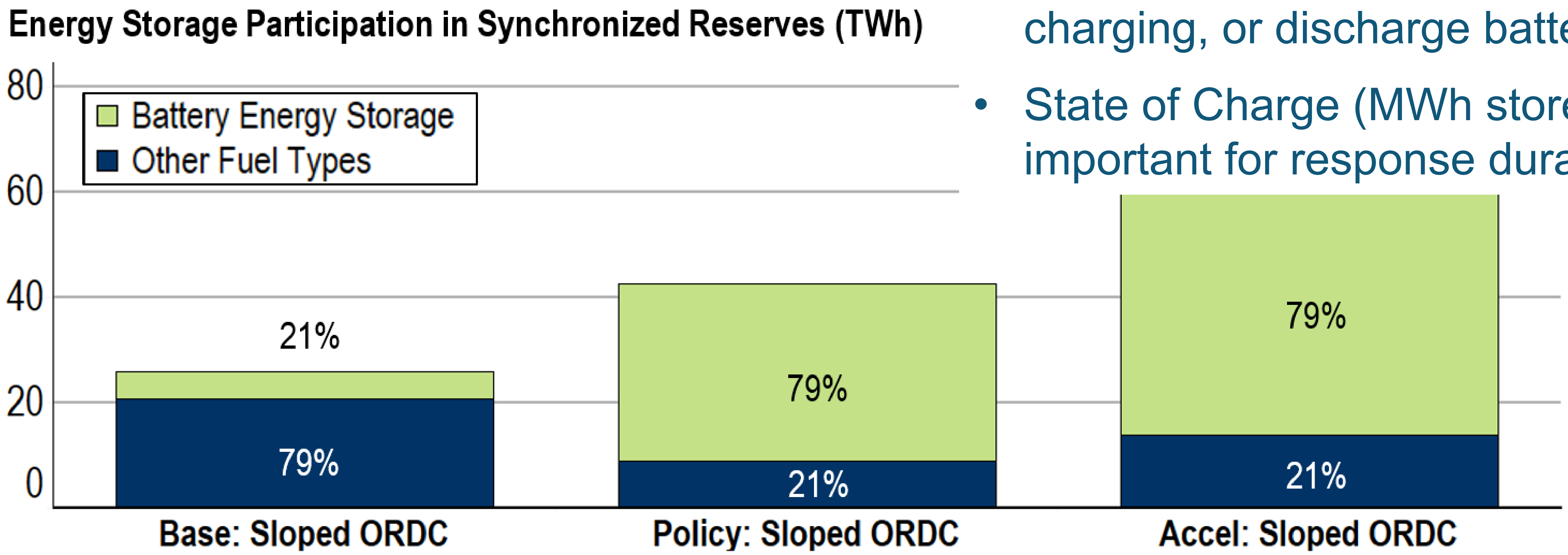
Two-Step and Downward-Sloping ORDC Curves



Reserve Pricing



Energy Storage in Synchronous Reserve

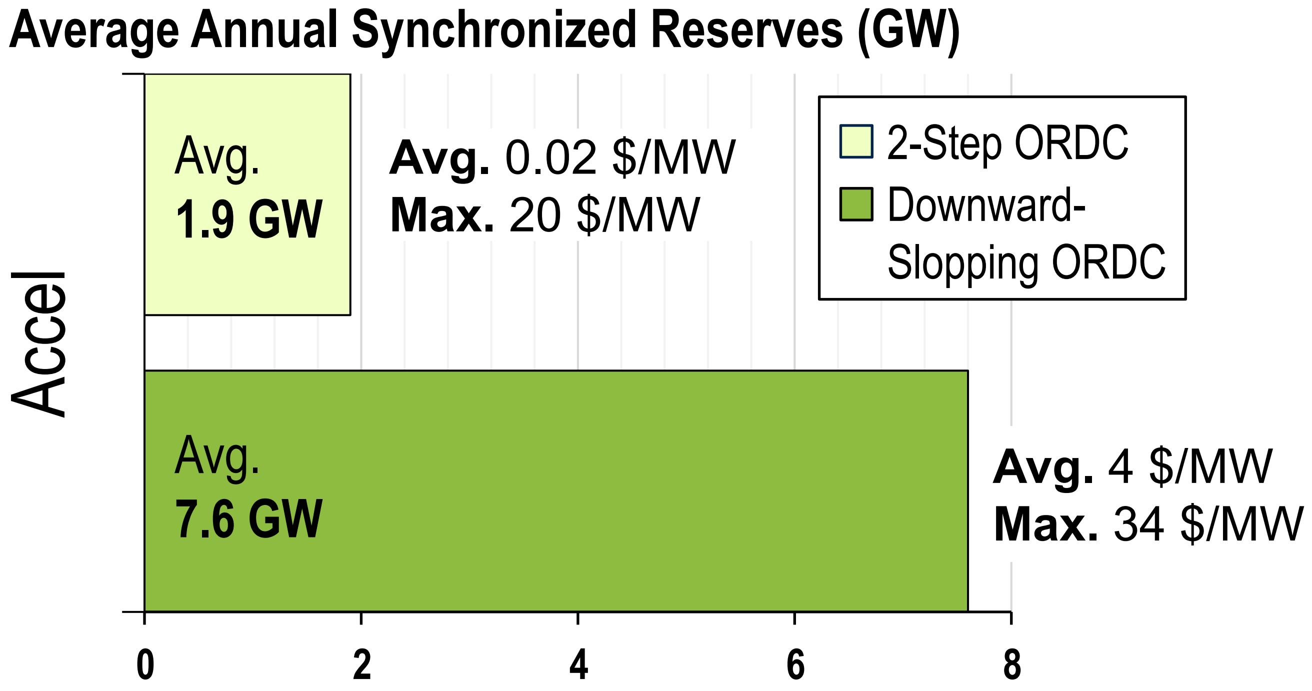


KEY INDICATORS

- Standalone Storage can curtail charging, or discharge battery
- State of Charge (MWh stored) important for response duration

Focus Area No. 3

Market Reforms Are Needed To Mitigate Uncertainty and Incentivize Flexibility

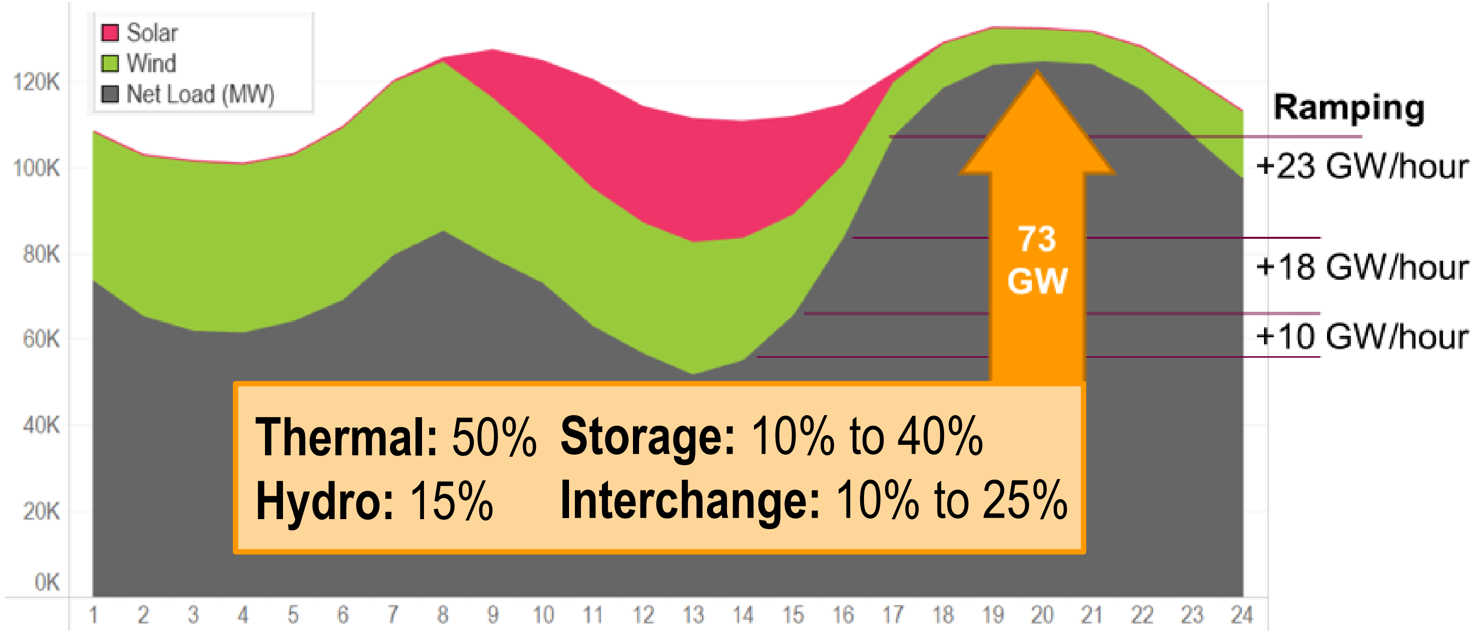


KEY INDICATORS

- 2-step: procured a third of the reserves needed and provided no incentives for flexibility (0.02 $/MW)
- Up to 80% of synch-reserved provided by storage
- PJM does not intend to rehash the ORDC proposal

Focus Area No. 4

The Integration of Renewable Resources Increases the Need for Balancing Resources To Meet Forecasted Ramping Requirements & Increases the Operational Flexibility Needs in Winter.



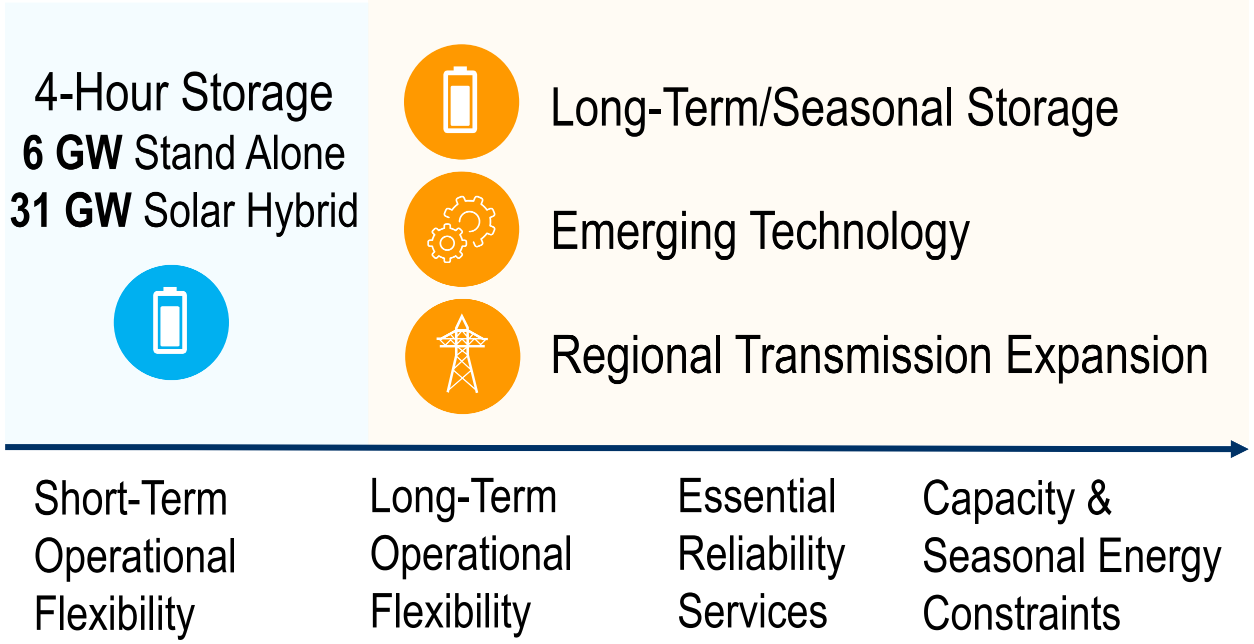
* Peak ramping in Winter

KEY INDICATORS

- Ramping: 50% Load, 50% Renewables
- 90th percentile > 10 GW/hour
- Peak ramping > 20 GW/hour
- Winter season has the highest ramps (adverse alignment with load)

Focus Area No. 5

Energy Storage (4-hours) Enhances Operational Flexibility, but Seasonal Capacity and Energy Constraints Require Transmission Expansion, Long-Term Storage, and other Emerging Technology.



KEY INDICATORS

- Storage provides up to 80% synch-reserves and 30% of ramping requirements
- Congestion increased by 60%
- Renewable curtailment up to 16%

Next Steps

Next Phase of this Living Study (Phase-3)

Refining Study Assumptions (Phase-3)			
Policy Update State/federal policy update of Base, Policy, and Accelerated scenarios	**Retirement Sensitivity** Accelerated retirement of thermal resources	**Interchange** Renewables buildout in the Eastern Interconnection; sensitivity on transfer capability	**100% Carbon-Free Scenario** Resource Adequacy (ELCC) CO_2

Key Findings & Focus Areas (***Phase-1***)

Correctly Calculating Capacity Contribution of Generators Is Essential

Flexibility Becomes Increasingly Important With Growing Uncertainty

Market Reforms Are Needed To Mitigate Uncertainty and Incentivize Flexibility

Regional Markets Facilitate a Reliable and Cost-Effective Energy Transition

Reliability Standards Must Evolve

Key Findings & Focus Areas (***Phase-2***)

Electrification Shifts the Seasonal Resource Adequacy Risk to Winter

Retail Rate Design & Energy Storage Become Increasingly Important With Electrification

Market Reforms Are Needed To Mitigate Uncertainty and Incentivize Flexibility

The Integration of Renewable Resources Increases the Need for Balancing Resources To Meet Forecasted Ramping Requirements & Increases the Operational Flexibility Needs in Winter

Energy Storage (4-hours) Enhances Operational Flexibility, but Seasonal Capacity and Energy Constraints Require Transmission Expansion, Long-Term Storage, and Other Emerging Technology

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