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TECHNOLOGY

Battery Storage for Generation and Transmission Deferral

Presented at: ICC /DOE/SNL Webinar

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Introductions

- **Dr. Hisham Othman**
  - *Vice President, Transmission & Regulatory*
  - Areas of expertise include power system dynamics and control, hybrid microgrids, grid integration of renewables and storage, economic analysis
  - PhD, Electrical Engineering, University of Illinois, Urbana
  - Over 30 years of technical and managerial experience in the electric power industry

Carbon Reduction Plans (NetZero)

	Dominion	Duke	Southern Co	Xcel	SDGE	WEC	EverSource	PSEG	ConEd	DTE	Entergy	Ameren	SCE	PG&E	CMS	Avangrid	FirstEnergy	AES Corp	Vistra Corp	Pinnacle West	NRG	NationalGrid	Nextera	AEP	Exelon	PPL	Alliant Energy	Atmos Energy	Evergy, Inc.	Center Point	NiSource	PREPA
2025						55										35		50			50		67		15							40
2030		50		80		70	100 ●			50	50	50	40	40			30	70	60	65		20		70			50				90	
2035																100 ●												30		70		
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2045					100 ●			80					100 ●	100 ●																		
2050	100 ●	100 ●	100 ●	100 ●		100 ●		100 ●		100 ●		100 ●					100 ●	100 ●	100 ●	100 ●	100 ●	100 ●		80		80	100 ●		80			100 ●

- NetZero decarbonization goals set at most major utilities and corporations over next 10-30 years
- This is prompting a profound change in the energy resource mix towards inverter-based resources (IBRs) in the form of solar, wind, and energy storage, in addition to clean dispatchable sources (e.g., hydrogen).

Challenge for Incorporating Energy Storage

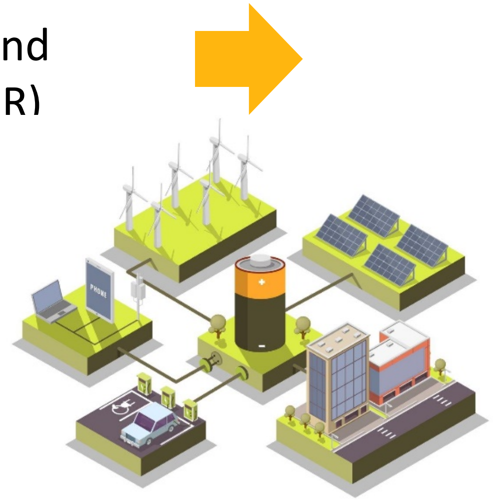
- A robust response from utilities and corporations to climate change culminated in NetZero carbon reduction goals to reach 100% between 2030 and 2050.

- Integrated resource planning (IRP) processes and tools have served the industry well over the past 30 years. However, they are increasingly challenged:
  - Increased uncertainties in load development, electrification, technology, and grid development.
  - Reliability concerns of high penetration of inverter-based resources (IBRs) not modeled.
  - Dependance of resource development on availability of T&D hosting capacities, not co-optimized.
  - Resilience requirements associated with intermittent resources and grid vulnerabilities not modeled.
  - Energy storage capacity (i.e., hours) are pre-selected and not optimized.
  - Energy storage value is often restricted to energy balancing, while the full stack of benefits not exploited.

Role of Energy Storage within an IRP

- Gen Resource:
  - Capacity and Reserves
  - Daily energy balance
  - Firm and shape solar and wind profiles
  - Fast ramping
  - Fast Frequency Response (FFR) and Primary Frequency Response (PFR)
  - Multi-day resilience

- T&D Grid Resource
  - Non-Wire T&D Solution (NWS)



- Model Reliability and Resilience Attributes/Metrics of Resources:
  - Dispatchability
  - Predictability
  - Dependability (e.g., Supply Resilience, firmness)
  - Performance Duration Limits
  - Flexibility (e.g., ramping speed, operating range)
  - Intermittency (e.g., intra-hr and multi-hr ramping)
  - Regulating Power
  - VAR support
  - Energy Profile (e.g., capacity credit / ELCC)
  - Inertial Response
  - Primary Frequency Response
  - Minimum Short Circuit Ratio
  - Locational Characteristics (e.g., deliverability, resilience to grid outages)
  - Black start and system restoration support

Role of Energy Storage within an IRP

Storage Capacity	Challenges	Applications
Sub-hour (Gen)	Intermittency of VERs (e.g., Solar/Wind)	Fast and Flexible Response to control Frequency & Intertie Flows
2-8 hours (T&D)	Address Grid Security Constraints (e.g., NERC TPL Standards)	Non-Wire Alternative (NWA) solutions
4-10 hours (Gen)	Integrated Resource Planning (Capacity, Reserves, Energy)	Peaker Plants Combined Storage+Renewable
hours to Days (Gen)	High Renewable Targets (50%+) using low-capacity factor resources	Balance Supply and Demand Mitigate Supply Risks

VER: Variable Energy Resources
NWA: Non-Wire Alternative Solutions
RE: Renewables

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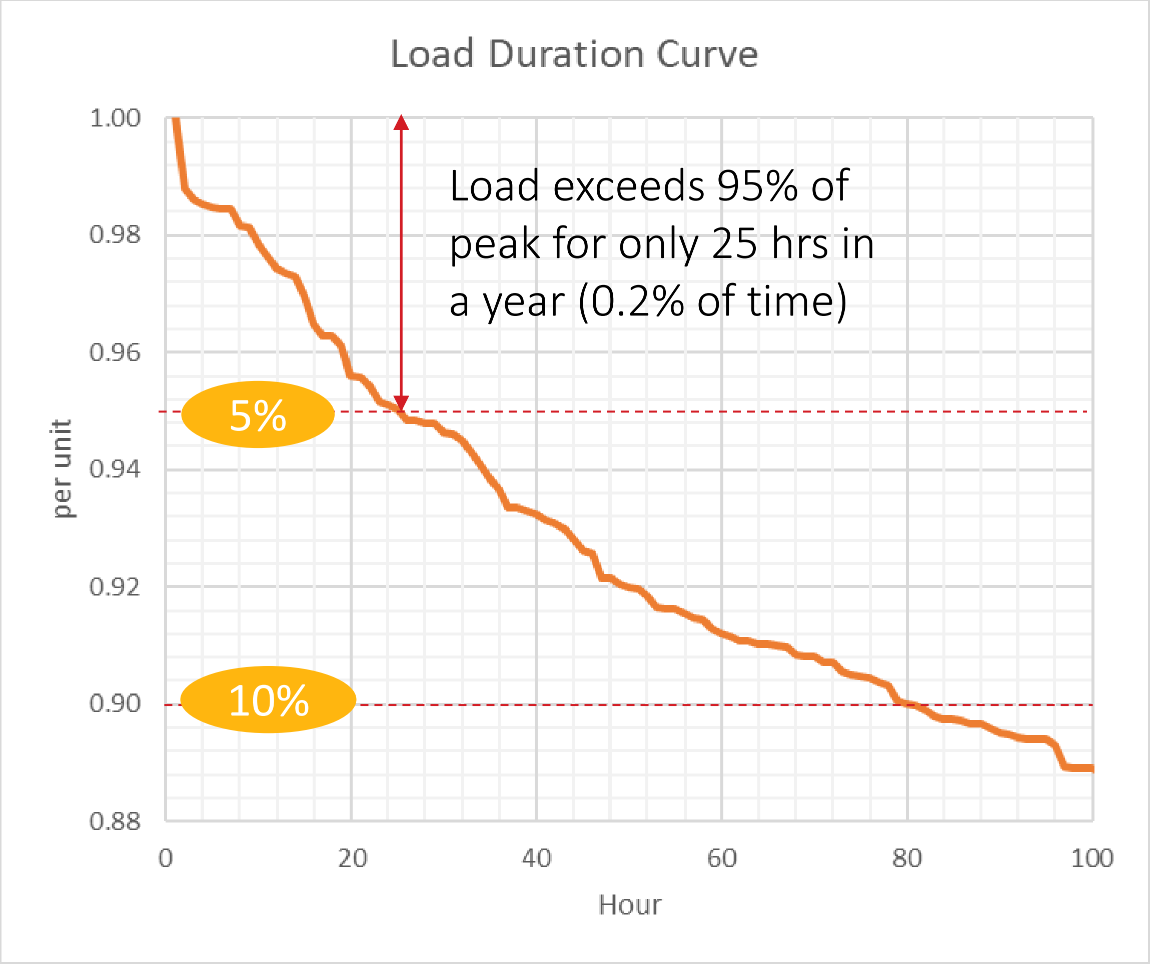
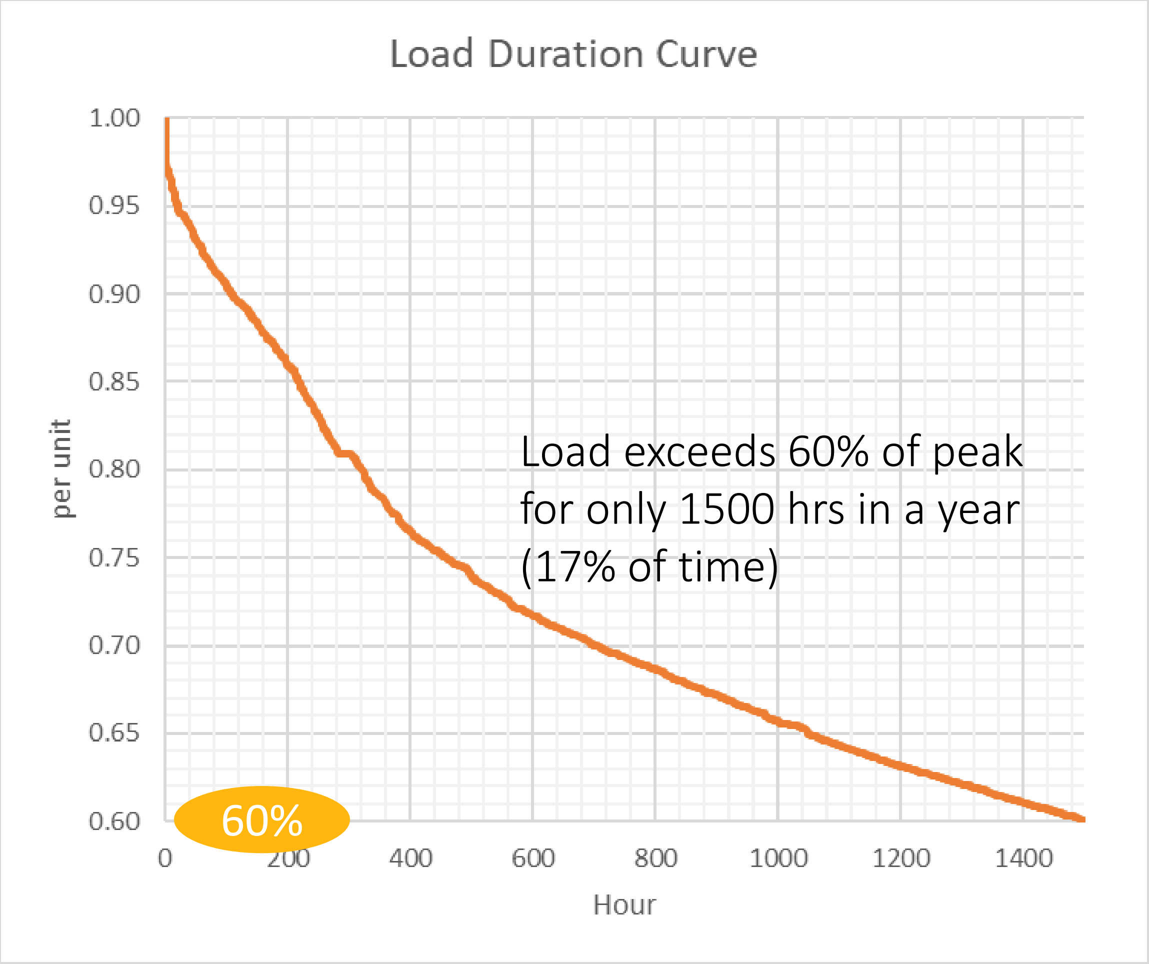
Example 1: Storage as a Peaker

- Load shape is a key driver for Peaker plants.
- Top 5% of peak load lasts for only 25 hours in a year, while Top 10% of peak load lasts for 80 hours.

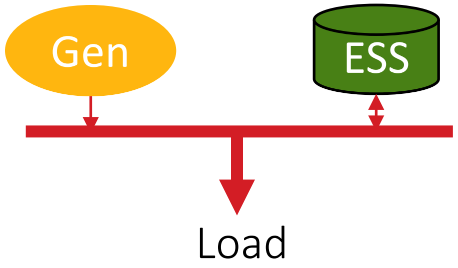


Load exceeds 95% of peak for only 25 hrs in a year (0.2% of time)

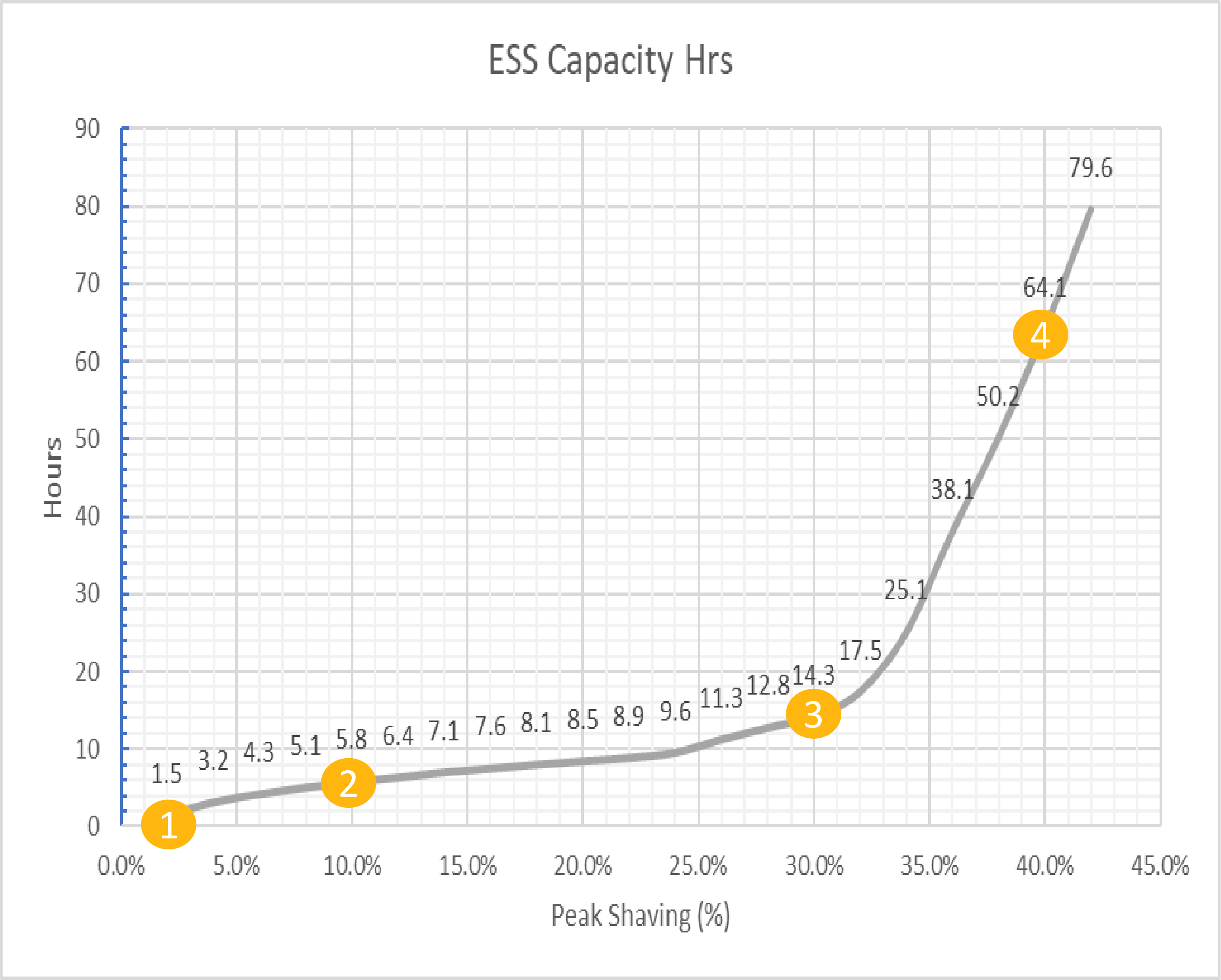


Load exceeds 60% of peak for only 1500 hrs in a year (17% of time)

Example 1: Storage as a Peaker (duration increases with storage MW size)

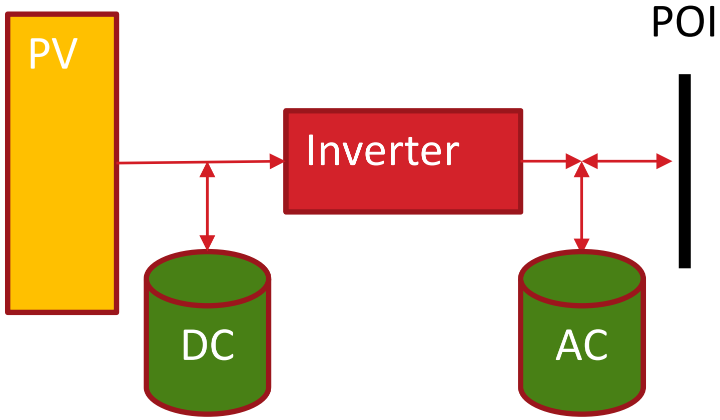


- For a full capacity credit, Peaker's minimum energy capacity is:
  - 1.5hrs when the storage MW size does not exceed 2% of peak load;
  - 6hrs when storage MW size increases to 10% of peak load;
  - 14hrs when the storage MW increases to 30% of peak load; and
  - grows exponentially beyond 30%.
- Ability to recharge the battery on peak load days drives the need to for longer storage duration.



Example 2: Solar + Storage (optimized according to market and grid)

- Optimizing the storage size depends on:
  - Interconnection capacity at POI and upgrade cost.
  - Revenue streams: Energy, Capacity, Ancillary, RECs.
  - Technology Cost: PV, Inverter, ESS (DC or AC connected).
  - Location - Solar Irradiance
  - Investment Tax Credit (ITC)



- Example (Arizona) – POI Capacity 1000 MW:

	Solar PV (MWdc)	ESS-DC connected MW / Hrs	ESS-AC connected MW / Hrs	Net Present Value $M	Plant Capacity Factor%
PV alone	1,370	-	-	$366M	34%
PV + ESS-DC	1,511	1,000 / 3.4	-	$488M	37%
PV + ESS-AC	1,316	-	1,000 / 1.2	$466M	35%
PV + ESS-DC + ESS-AC	**1,363**	**676 / 3.8**	**640 / 1.0**	**$530M**	**34%**
PV + ESS-DC + ESS-AC	2,000	800 / 4.6	377 / 1.0	$483M	46%
PV + ESS-DC + ESS-AC	2,500	883 / 5.8	119 / 1.0	$427M	56%

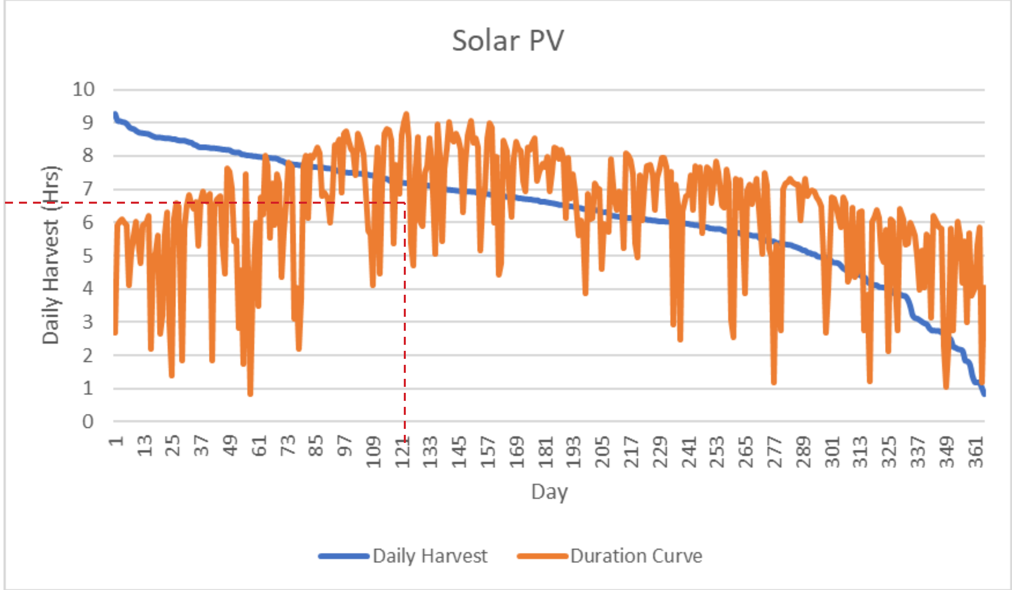
Optimized

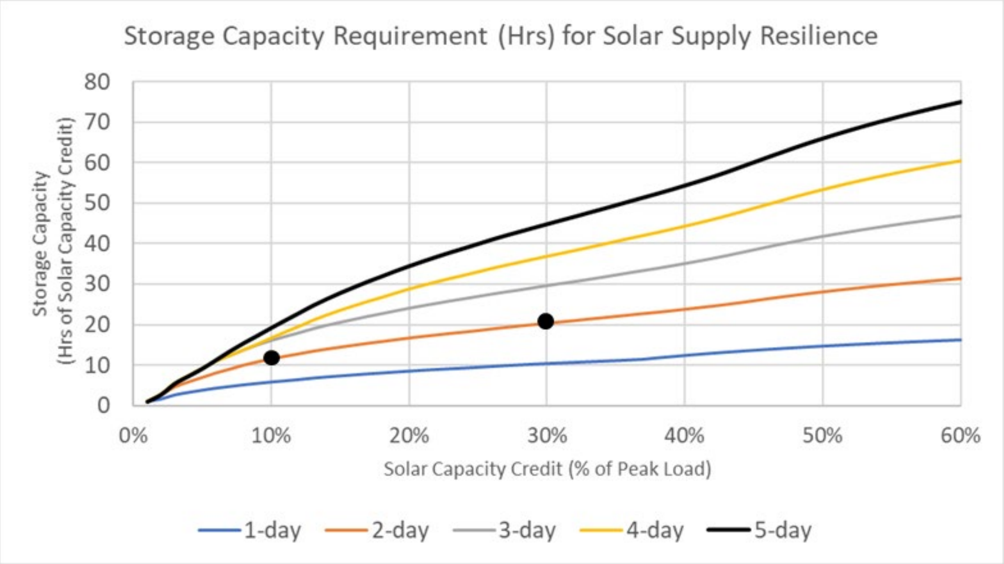
Example 3: Supply Resilience (Requires Long-Duration Storage)

- Solar Daily Energy Harvest:
  - Range 1-9 hrs
  - Median 6.5 hrs

- How much Storage? depends …
  - Installed VER penetration level
  - Load Profile
  - Number of rainy days & Season

- Storage size increases with solar penetration level and number of consecutive rainy days:
  - Peak load of 1000MW,
  - 500MW solar PV with a capacity value of 100MW (10% of peak load)
  - 2 consecutive rainy days
  - Storage size is 1200MWh (or 12 hours of 100MW capacity) or carry a 100MW generator running on renewable fuel.





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Example 4: Transmission NWA - OSW Integration in NY (indicative)

	Sites	Max Dispatch
Zone J	Greenwood	600
	Astoria W	600
	Jamaica	362
	Mott Haven	0
	Gowanus	600
	Hudson River E.	600
	Farragut	0
	Astoria Annex	544
	Rainey	562
	West 49th St	0
Zone K	Riverhead	600
	Holbrook	267
	Shoreham	500
	Sterling	134
	Barrett	209
	Ruland Rd	0

3 GW → 7 Violations

Breakdown
2 – 345kV
5 – 138kV

6 GW → 26 Violations

Breakdown
6 – 345kV
16 – 138kV

9 GW → 44 Violations

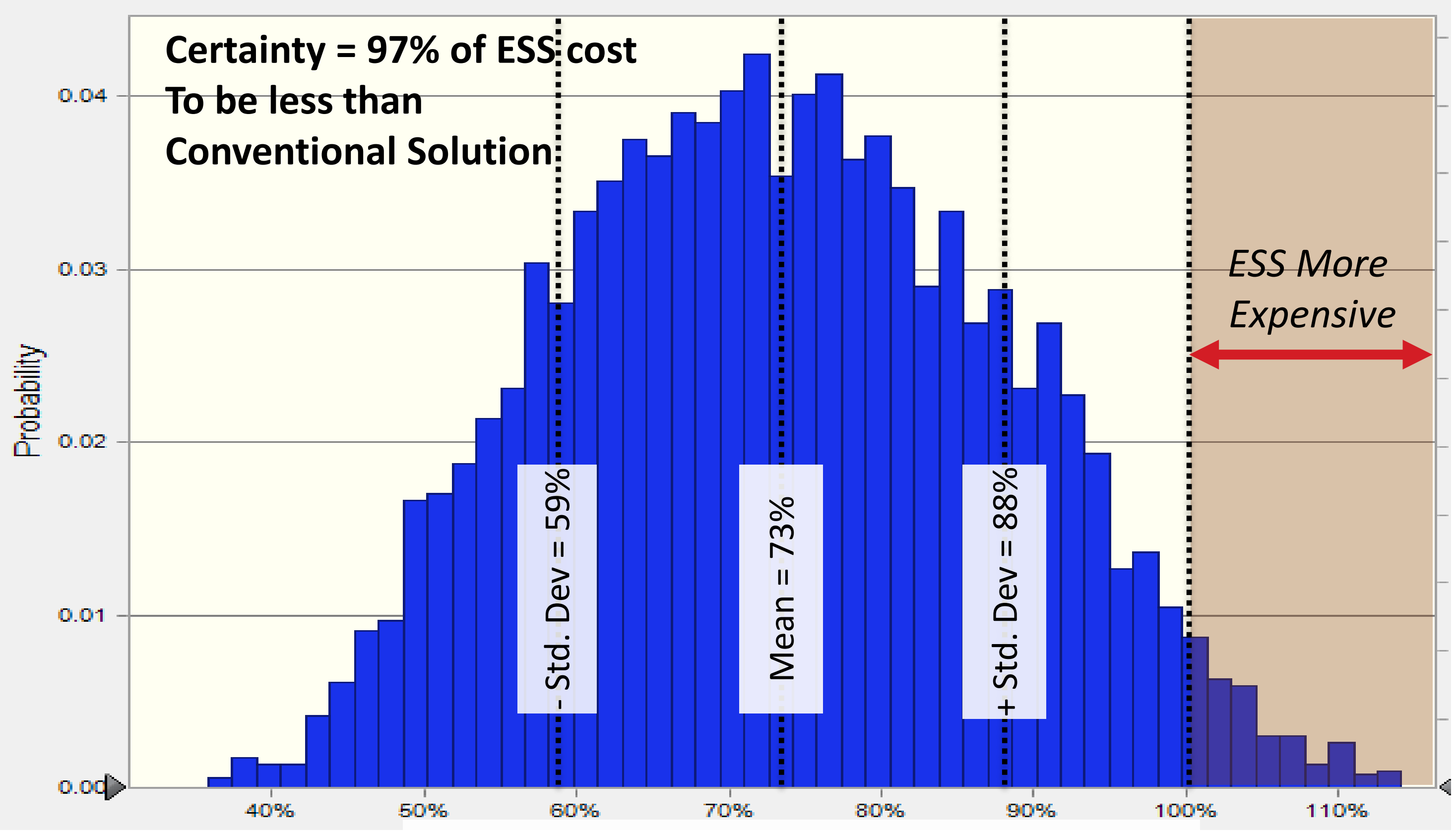
Breakdown
10 – 345kV
33 – 138kV

- This case study is indicative and not actual.
- Grid reliability violations (NERC TPL).
- Conventional Upgrades will cost over $1B to integrate 6GW of OSW.
- Non-Wire storage solution require 2 battery systems totaling 126MVA (8.5 hrs), with an initial cost estimate of $310M.
- Apple-to-Apple lifetime techno-economic analysis shows the NWS cost to be 65% of the conventional solution

Energy Storage as transmission asset should be considered for efficacy and cost effectiveness to address grid reliability

Example 5: NWA Real Option Analysis – Optimizing Transmission Planning Under Uncertainty

- Load Forecast Uncertainty
- LMP and Ancillary Price Uncertainty



ESS to Conventional Solution Cost Ratio

- **Case Study in CAISO**

Conventional Solution	$60M
ESS w/o Markets	$70M
ESS w/ Markets	$50M

- **Option Valuation**
  - ESS cost ranges from 30% to 120%, with a mean value of 70% of conventional solution value
- **Real Option Analysis**
  - Rank Projects Internally
  - Optimize Asset Decisions
  - Balance Customer Risk and Cost

Phased planning in uncertain environments can reduce customer cost & risk

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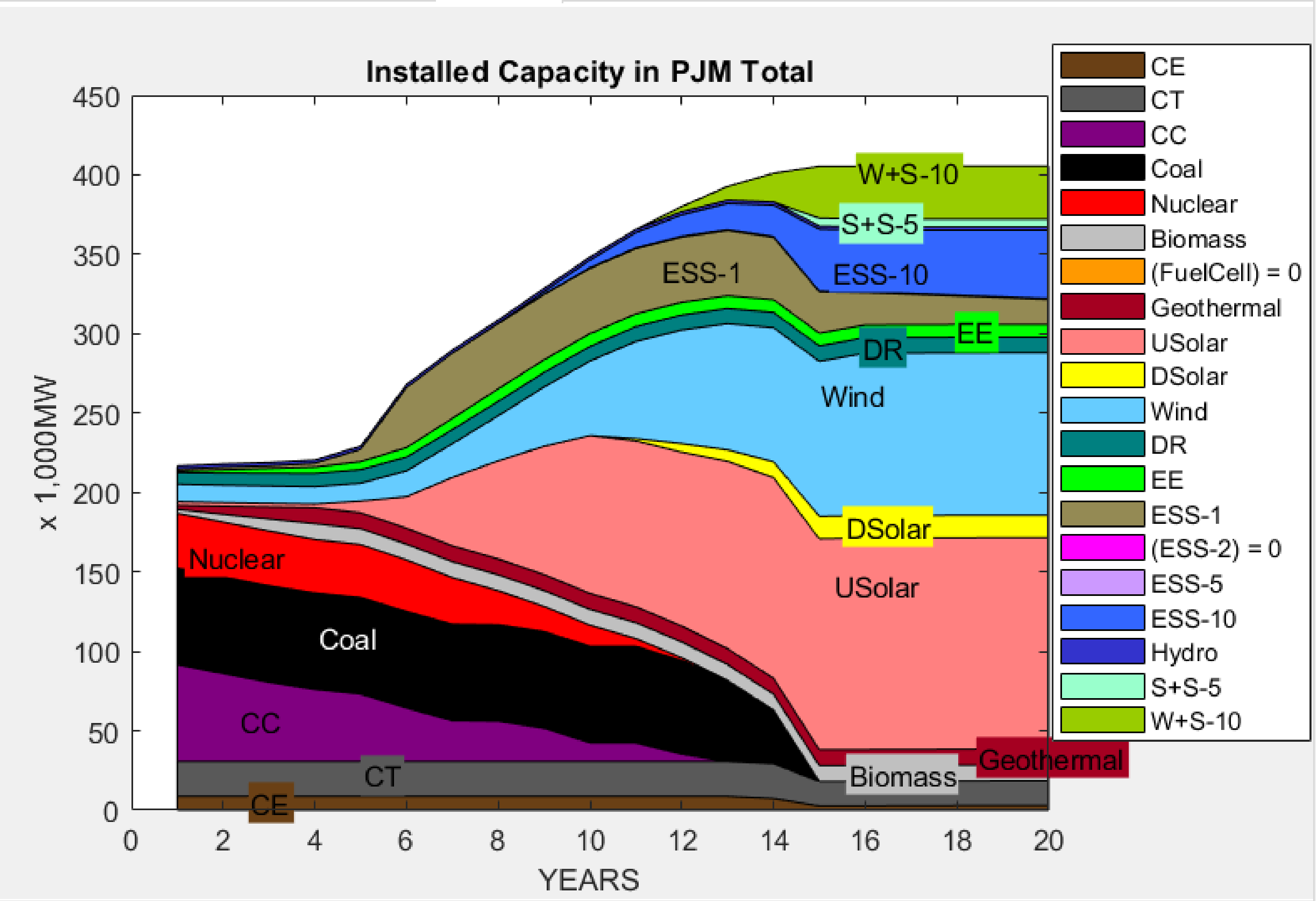
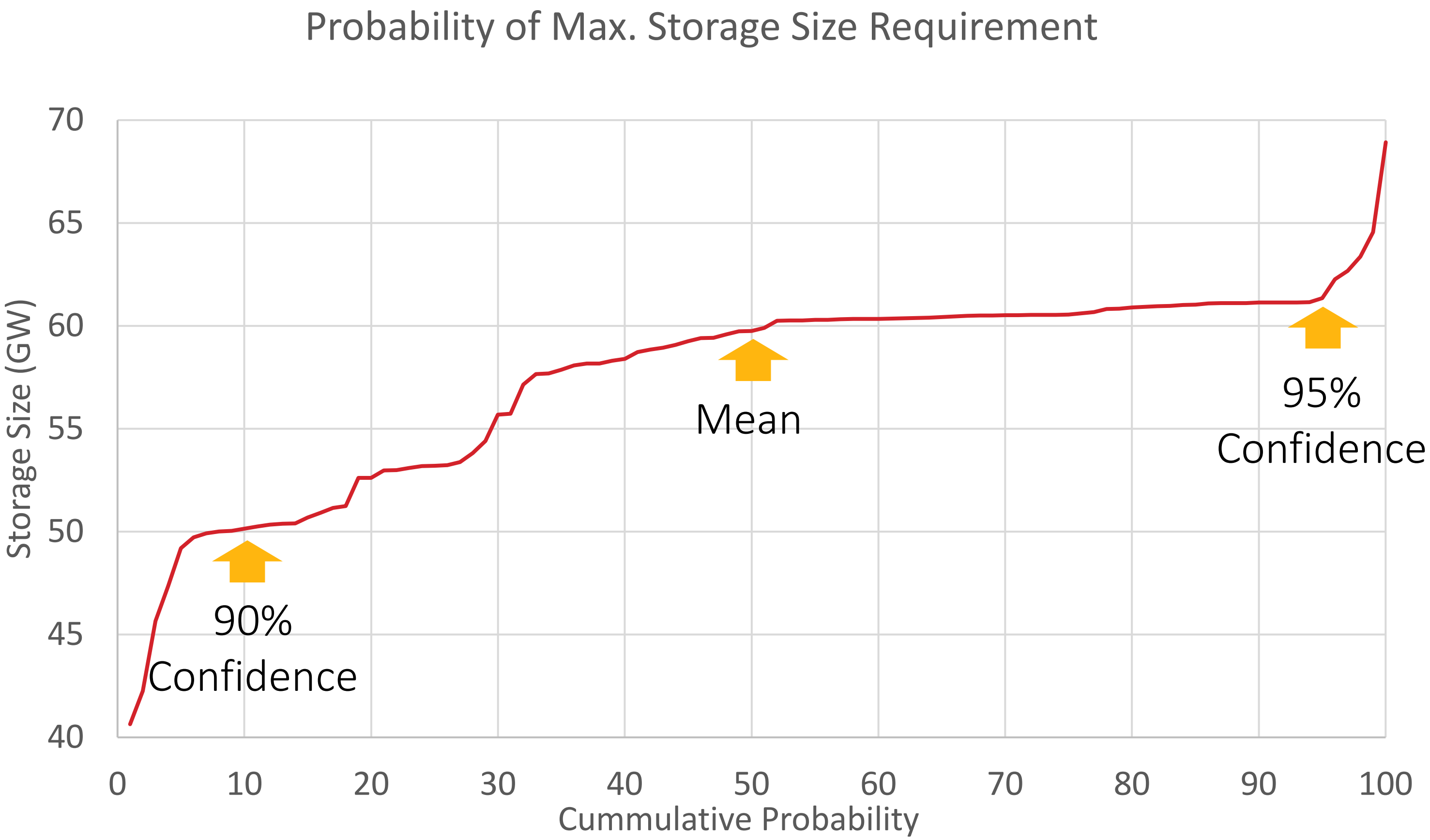
Example 6: 100% Renewable IRP Target

- Storage energy capacity increases with time:
  - Freq Response:
    - ESS-1hr
  - Capacity & Energy Balance:
    - ESS-5hr
    - ESS-10hr
  - Capacity & Energy:
    - S+S-5hr
    - W+S-10hr



Example 6: Energy Storage Requirements at Year 20 (Probabilistic IRP)



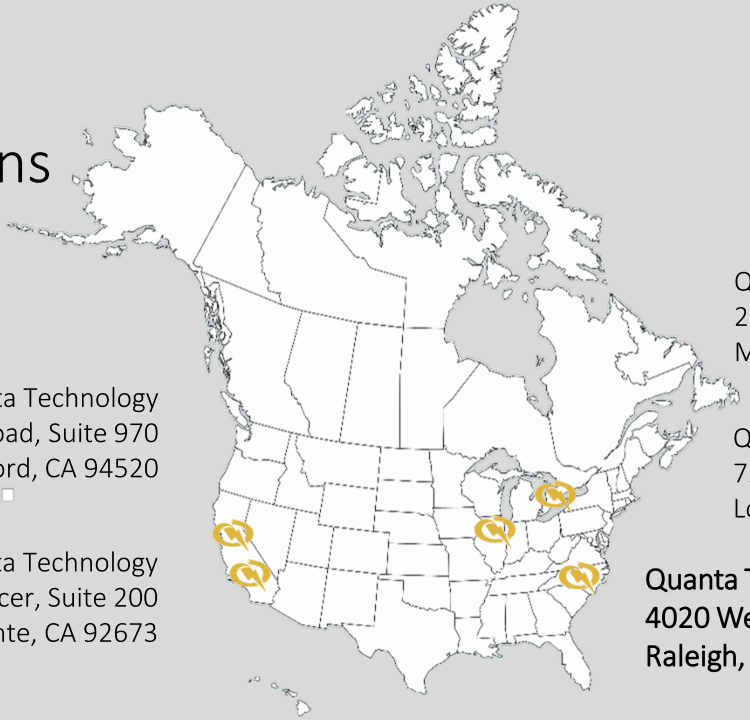
- Storage Requirements range between 41-69GW, with a mean of 60GW.
- 90% probability the storage requirements will exceed 50GW; 95% probability will not exceed 62GW.

Summary

- Energy storage is a versatile tool to help decarbonize the economy.
- Modeling of storage within IRPs needs improvements.
- Many applications require long duration storage.
- Probabilistic analysis and real option valuations provide confidence for investments in uncertain environments.

Thank you!

Office Locations



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