QUANTA TECHNOLOGY

Real-Options Approach to Transmission Planning Using Non-Wire Solutions in Support of Net-Zero Futures

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Introductions

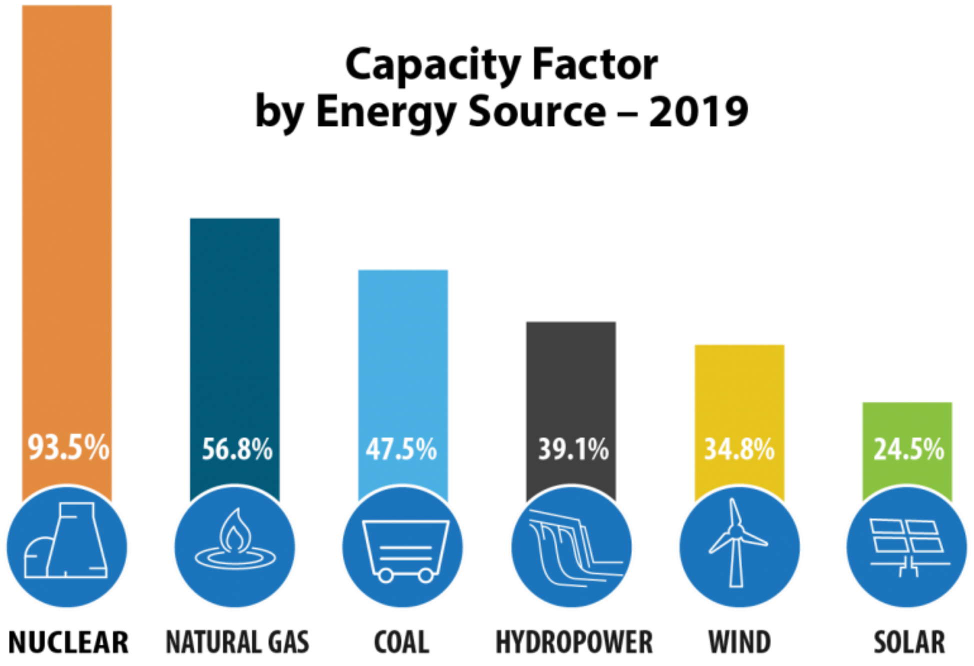
- **Dr. Hisham Othman**
  - *Vice President, Transmission & Regulatory*
  - Areas of expertise include power system dynamics and control, grid integration of renewables and storage, non-wire solutions, reliability of high IBR portfolios, economic analysis, and business strategy.
  - PhD, Electrical Engineering, University of Illinois, Urbana
  - Over 30 years of technical and managerial experience in the electric power industry

Carbon Reduction Plans (NetZero)

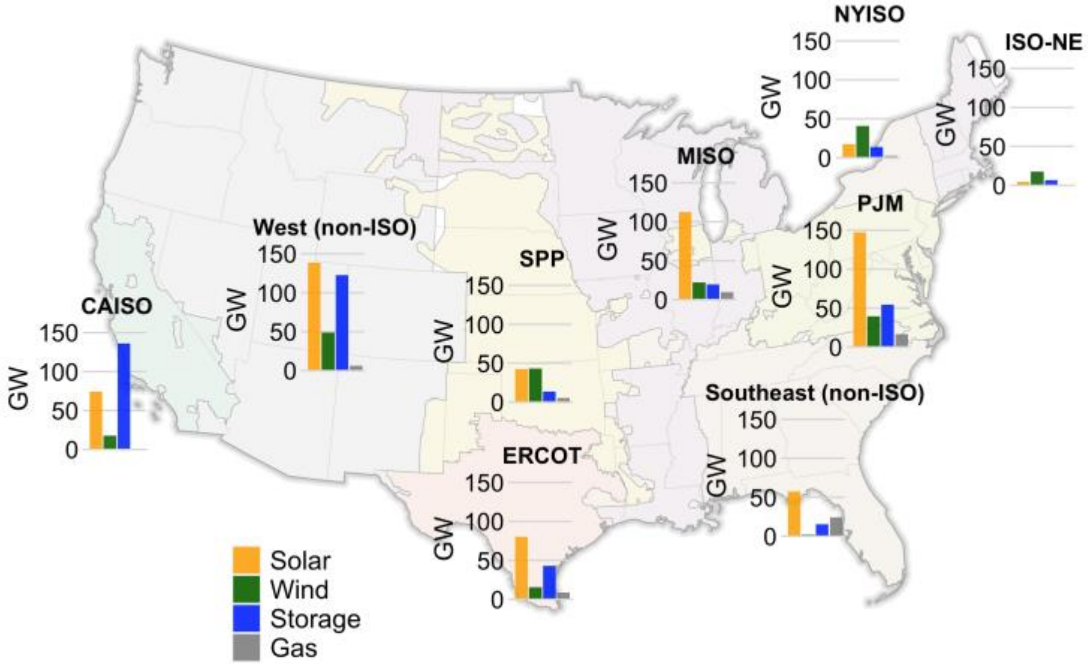
	Dominion	Duke	Southern Co	Xcel	SDGE	WEC	EverSource	PSEG	ConEd	DTE	Entergy	Ameren	SCE	PG&E	CMS	Avangrid	FirstEnergy	AES Corp	Vistra Corp	Pinnacle West	NRG	NationalGrid	Nextera	AEP	Exelon	PPL	Alliant Energy	Atmos Energy	Evergy, Inc.	Center Point	NiSource	PREPA
2025						55										35		50			50		67		15							40
2030		50		80		70	100			50	50	50	40	40			30	70	60	65		20		70			50				90	
2035																100												30		70		
2040									100	80	85	85			100											70						60
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).

The Pressure is Mounting on The Electric Grid to Interconnect Renewables



≈ 1,000 GW in the Interconnection Queues

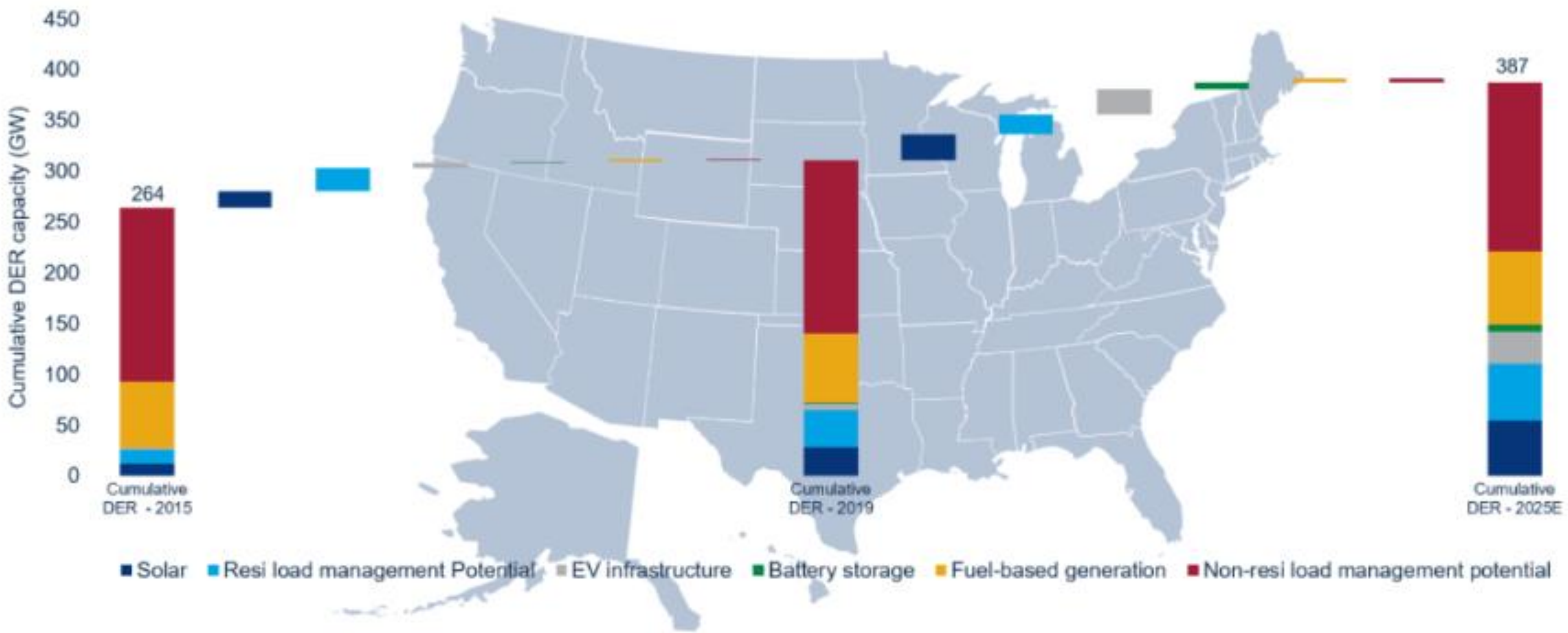


Source: Berkeley Lab

Transmission Security Violations → Rising Grid Upgrade Costs → Queue Withdrawals → Supply Uncertainty (Amount, Timing, Locations, Technology)

Electric Demand is Increasingly Uncertain

Cumulative DER capacity additions by resource and customer type (2016-2025E)



Source: Wood Mackenzie Energy Storage, Grid Edge Service, U.S. Distributed Solar Service; U.S. Department of Energy
Note: Cumulative fuel-based generation capacity figures are the sum of Wood Mackenzie's comprehensive resource database accounting for projects commissioned after 2000 and the Department of Energy's tally of customer-sited CHP sites commissioned between 1980 and 2000.

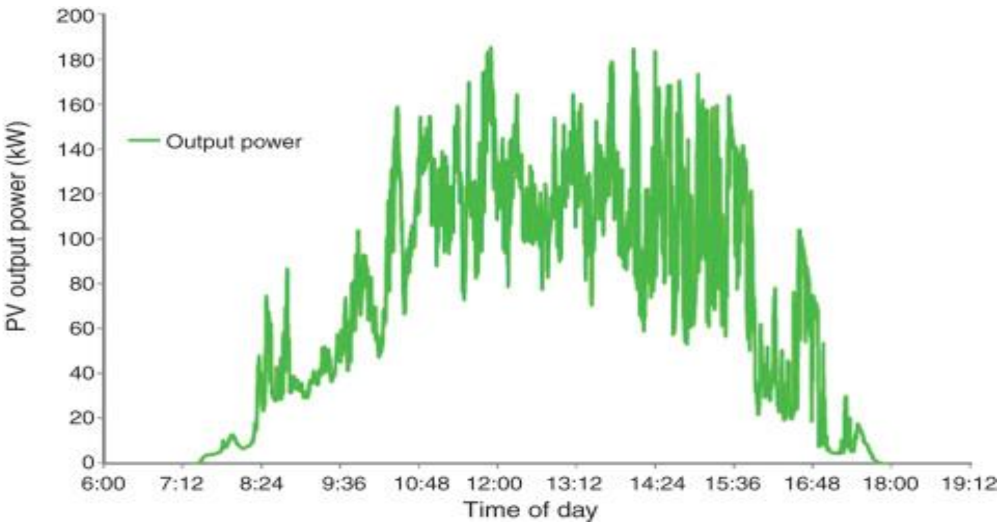
DERs impact the Demand Served by the Grid ..
Uncertainty about Location, Timing, Amounts, and Technology Mix have Profound Implications on Load Forecast and Grid Planning

Transmission Planning Under Uncertainty from Demand and Supply

Integrated Supply and Grid (G&T) Planning to Meet Demand Forecast	Grid Planning To Meet Demand and Supply Forecasts & Passive Grid Controls	Grid Planning with Non-Wire Solutions & Active Grid Controls
1980s	Now	Emerging
• Coordinated Grid and Resource Planning	• Independent Grid Planning	• Participative Grid Planning • Integrated T&D planning
• Limited Demand Uncertainty	• Increasing uncertainty (supply & demand)	• Increasing uncertainty (Electrification)
• Deterministic Grid Planning Criteria • Probabilistic Criteria for generation	• Deterministic Planning Criteria	• Probabilistic & Scenario Planning • Beyond Reliability, Resilience Metrics
• Conventional solutions	• Mainly Conventional Grid Solutions • Emerging Non-Wire Solutions • No reliance on time-limited solutions (e.g., storage) • No active controls (Passive Grid)	• Hybrid Solutions (Wires and Non-Wires) • Acceptance of time-limited solutions • Active inverter controls

Use of Probabilistic Techniques in Grid Planning

- Climate Change and Grid Resilience:
  - Asset fragility curves
  - Weather progression
  - Cascading tree analysis, Value@Risk analysis
  - Probability and consequence of cascading outages
- Renewable Profile Variability:
  - Affects transmission flows and security
  - Requires stochastic models and time-series analysis
- Scenario Analysis:
  - How to assign a probability to a scenario
  - What is an acceptable hedge (e.g., 99% mitigation?)



Grid Solution Types

Long-Life Assets

- 40-100 years

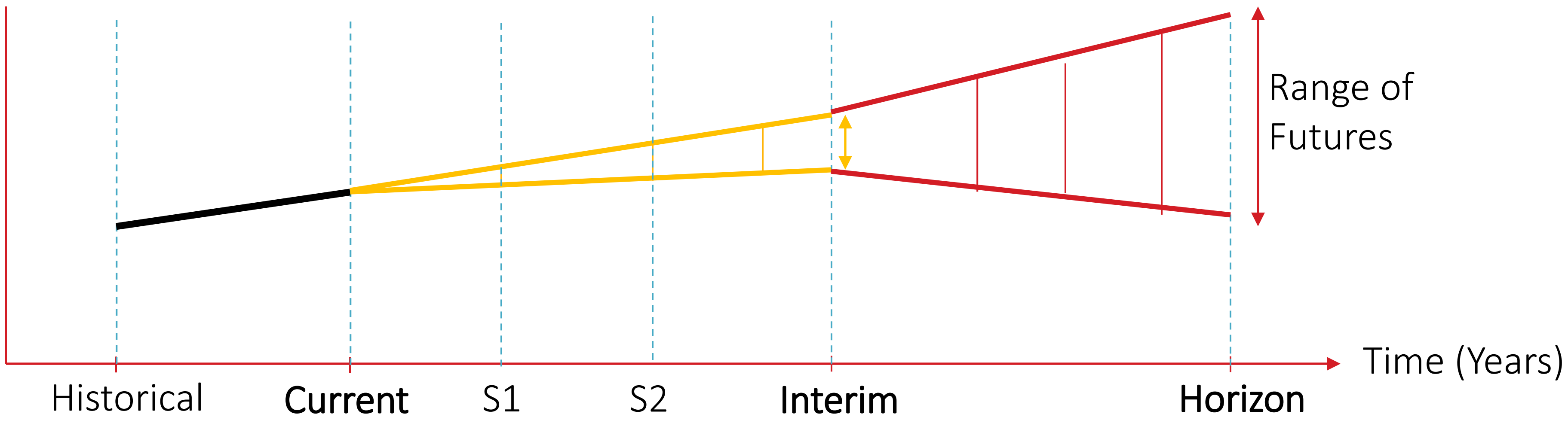
Medium-Life, Expandable Assets

- 10-20 years

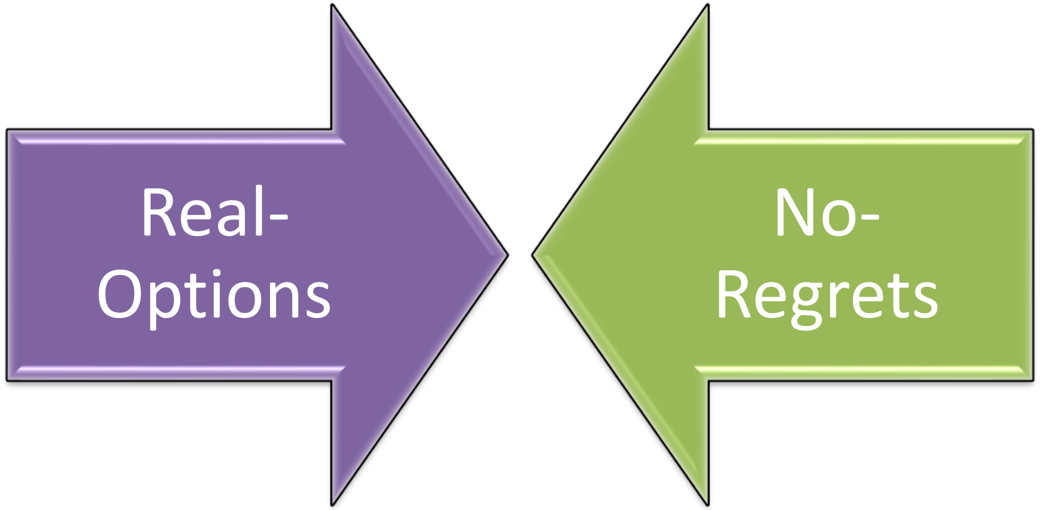
Short-Life Assets

- 1-3 years contract

Approaches to Grid Planning



- Start from the Current year, and design solutions for S1.
- Before reaching S1, re-assess future demands, and expand solution to S2.
- Suitable for short-life assets (e.g., DR), and medium-life expandable assets (e.g., storage)



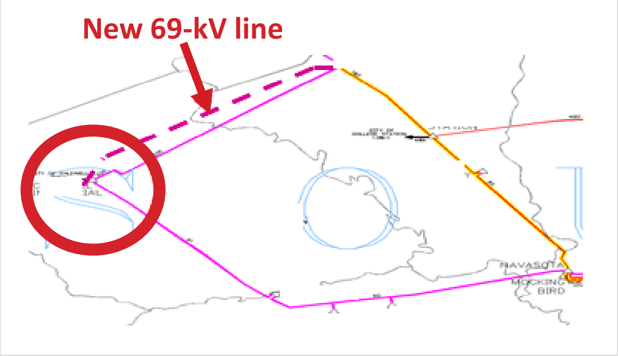
- Start with the Horizon Year to determine the range of grid solutions.
- Walk backward to the Interim planning year and select elements from amongst the horizon year solutions.
- Suitable for long-life assets (e.g., wire solutions)

Case Study 1: Use of Hybrid (Solar plus Storage) for Grid Reliability

- **Motivation**
  - Uncertain load development
  - Long (costly) conventional lines
  - Two Line overloads under P1-3 contingencies

- **Planning Considerations**
  - Peak Load Forecast
  - Allowable grid operating limits, thermal and voltage
  - Hourly load profile (not just a few snap shots)
    - 8760 time-series vs 4 snapshots
  - Charging limits during consecutive daily peaks
  - Battery lifecycle analysis
  - Storage or Hybrid Solutions
  - Solar+Storage requires probabilistic analysis

- **Case Study in MISO Region**
  - 69 kV network serving 25 MW load
  - Thermal and voltage violations during peak summer and winter
  - Conventional solution: $33M
  - Battery: 2.5 MW/24 MWh, $12M
  - Lifetime battery cost is 65% of conventional solution

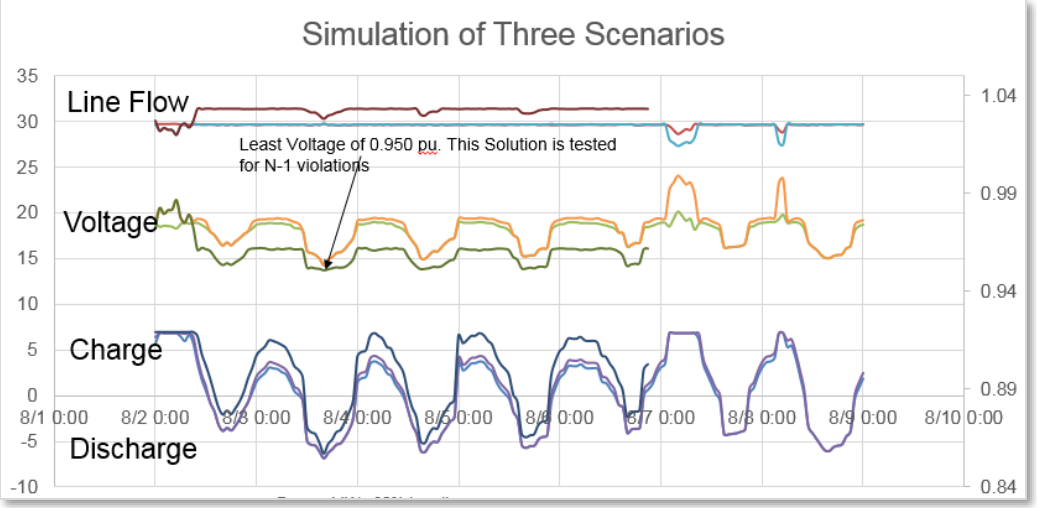


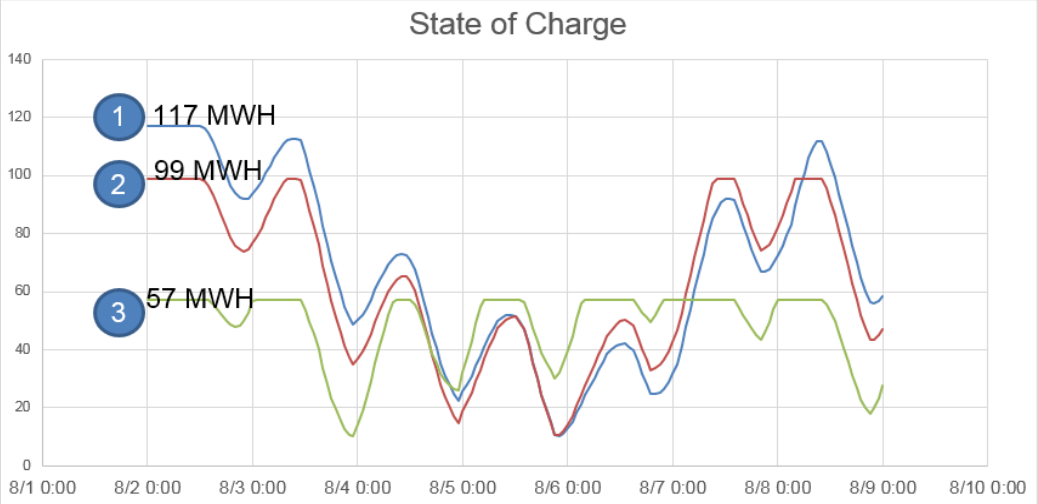
Siting & Sizing Storage to Address Grid Security (Thermal or Voltage Violations)

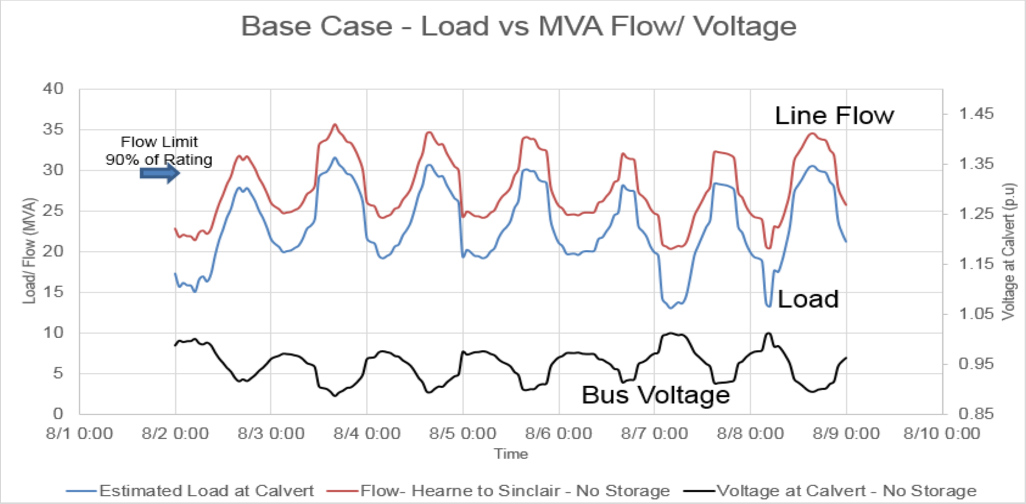
Proper Siting and Sizing of hybrid solutions are critical to Storage Technical and Economic Feasibility

Case Study 1: Time-Series Security Analysis (8760)

- Siting index based on power and outage transfer factors
- Sizing influenced by grid thermal and voltage, in addition to load hourly profile
- Detailed system optimization and simulations under N-0, N-1 conditions are necessary to assure solution efficacy

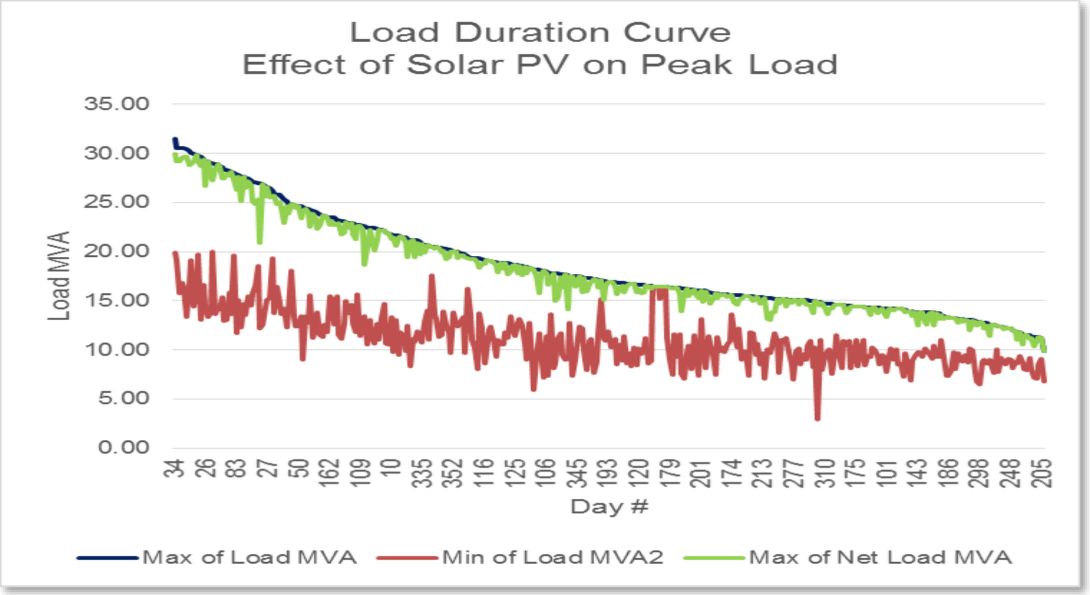


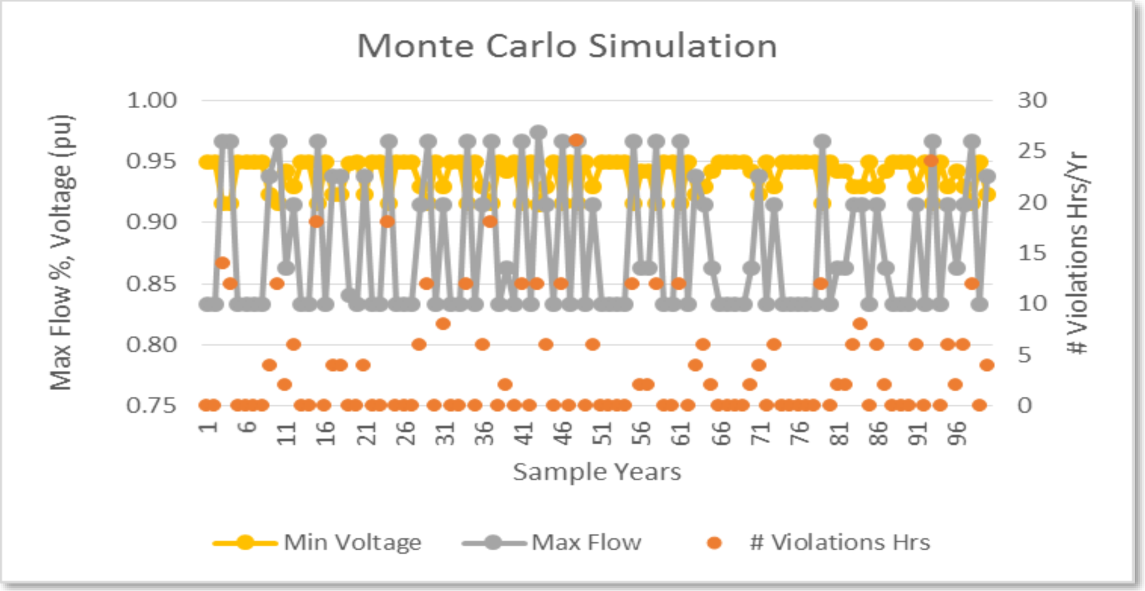




Careful Time-Series Analysis (8760 hours) is required to optimize storage capacity

Case Study 1: Mote-Carlo Analysis





- Using 100 Monte-Carlo Analysis, each representing one-year of 8760 simulations to assess the range and frequency of voltage and line loading violations.

All hours in a Year	# Violations	Max Line Flow	Min Bus Voltage
MEAN	0	83.7%	0.95
Low	0	83.4%	0.92
High	24	96.7%	0.95

Hybrid Solar+Storage solutions can further optimize the solution economics, but require additional probabilistic studies to assure grid security

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Optimizing Transmission Planning Using Energy Storage – A Real Option Approach

- Variables affecting Investment and Operational Decisions:
  - Net Load Growth Rates
  - Equipment Cost Roadmap
  - Technology Breakthroughs
  - Permitting/Interconnection
  - Regulatory Environment
  - Financial Environment
  - Energy and Ancillary Prices

- Managerial Flexibility:
  - When to Install
  - Where to Locate
  - What technology
  - How Much MW/MWh
  - Expand/Replace/Retire
  - Asset Management
  - Revenue Stacking

- Financial Outcome:
  - Rates
  - IRRs
  - NPV
  - Volatility

Monte Carlo Simulation - Option Value and Greeks

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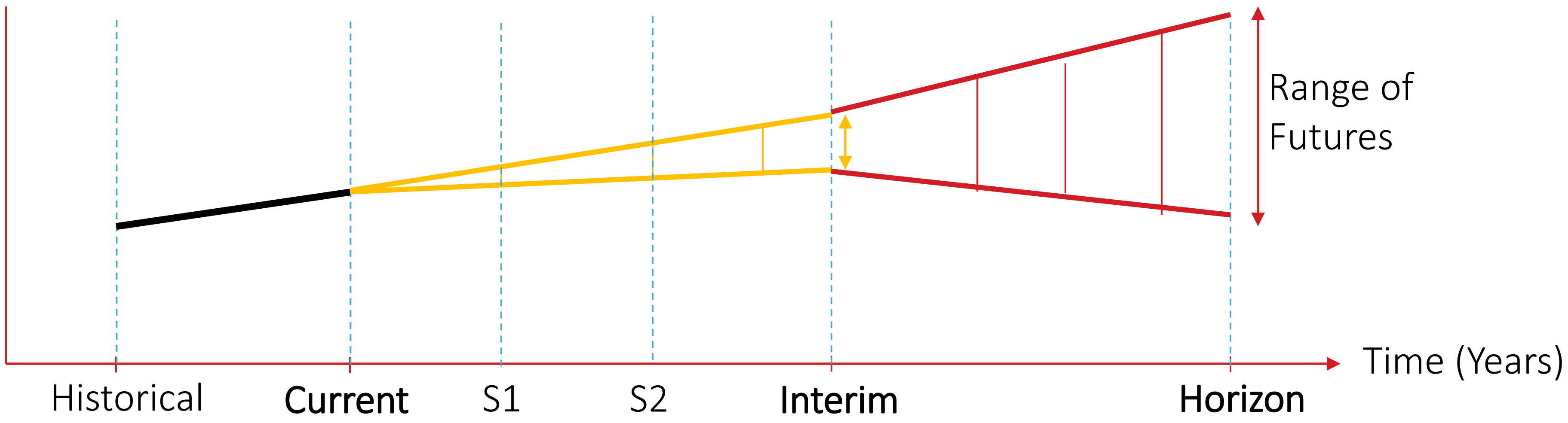
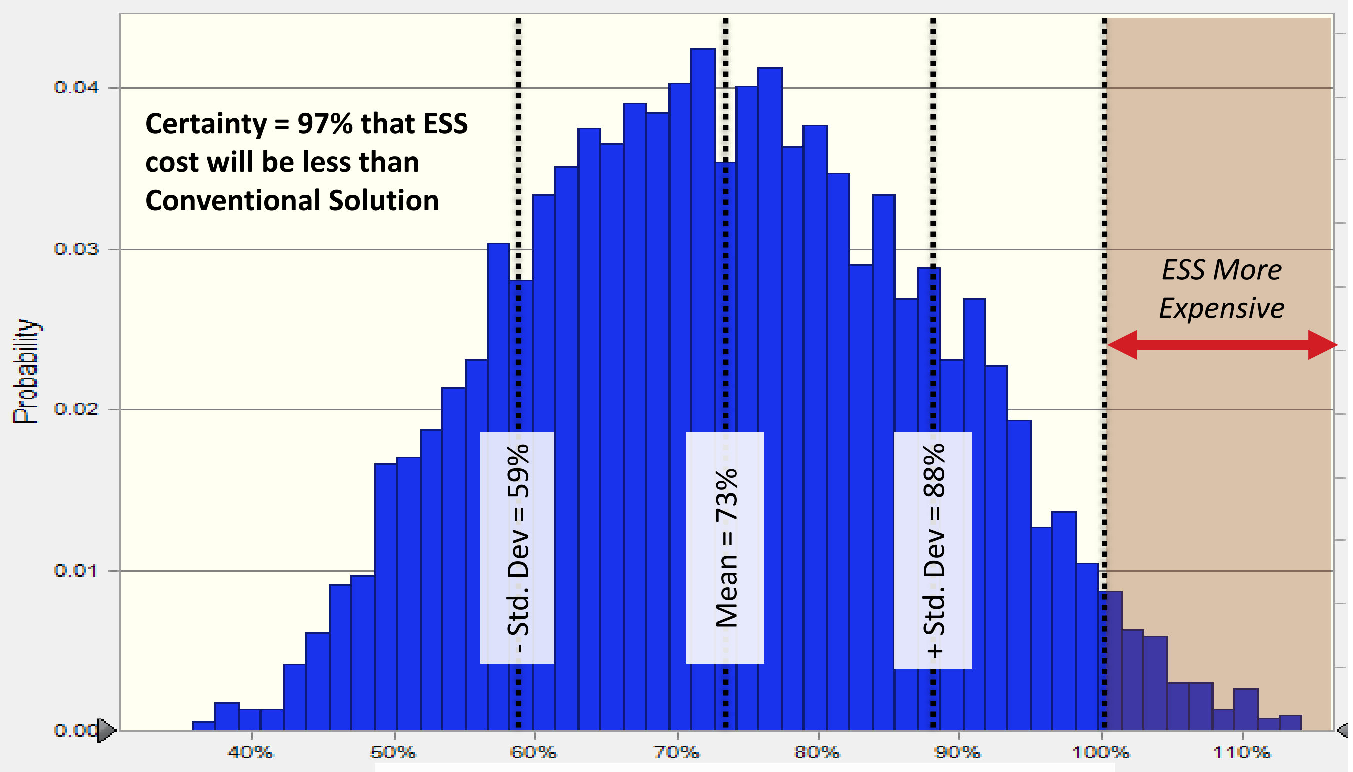
Incremental Planning using Real Options and Flexible Solutions



- Using a flexible and expandable solution set such as energy storage, size the solution to address forecasted system needs at S1 (e.g., 5 years).
- As time approaches S1, Reassess system needs at S2 and expand the flexible solution to address them.
- Compare the present value of the incremental investments versus a solution designed to address the highly uncertain system needs at the Interim year.
- Use Monte-Carlo analysis to assess the envelope of all potential outcomes.

Case Study 2: Real Option Analysis to Optimize 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 and risk

Conclusions

- Uncertainty is growing for grid planners from the supply and the demand sides.
- New supply resources (solar and wind) tend to have low-capacity factors and thus increase the need for grid interconnections and upgrades.
- Deterministic planning methods using conventional wire solutions are increasingly expensive and impede economic clean energy futures.
- Probabilistic analysis is starting to appear in grid planning, especially for climate-change induced resilience solutions, scenario planning driven by planning uncertainty, and the use of non-wire intermittent solutions.
- Industry acceptance and utilization of time-limited solutions (e.g., energy storage) and active grid controls (e.g., renewable inverters) will be paramount to the economic expansion of grid capability to interconnect resources.
- Tools, Processes, and Training are required for grid planning under uncertainty.
- Coordinated G-T-D planning is increasingly required for optimal outcomes.

Thank you!

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