2020 CAISO Blackouts and Beyond

THE FUTURE OF CALIFORNIA RESOURCE PLANNING

PRESENTED BY

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LSI Electric Power in the West Conference

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Brattle

Agenda

I. CAISO Resource Adequacy Events of August 2020

II. California Wildfire Experience and Broader Resiliency Issues

III. Long-Term Resource Adequacy Challenges

CAISO Resource Adequacy Events of August 2020

Review of August 2020 Events

System Conditions During the August 2020 California Resource Adequacy Events

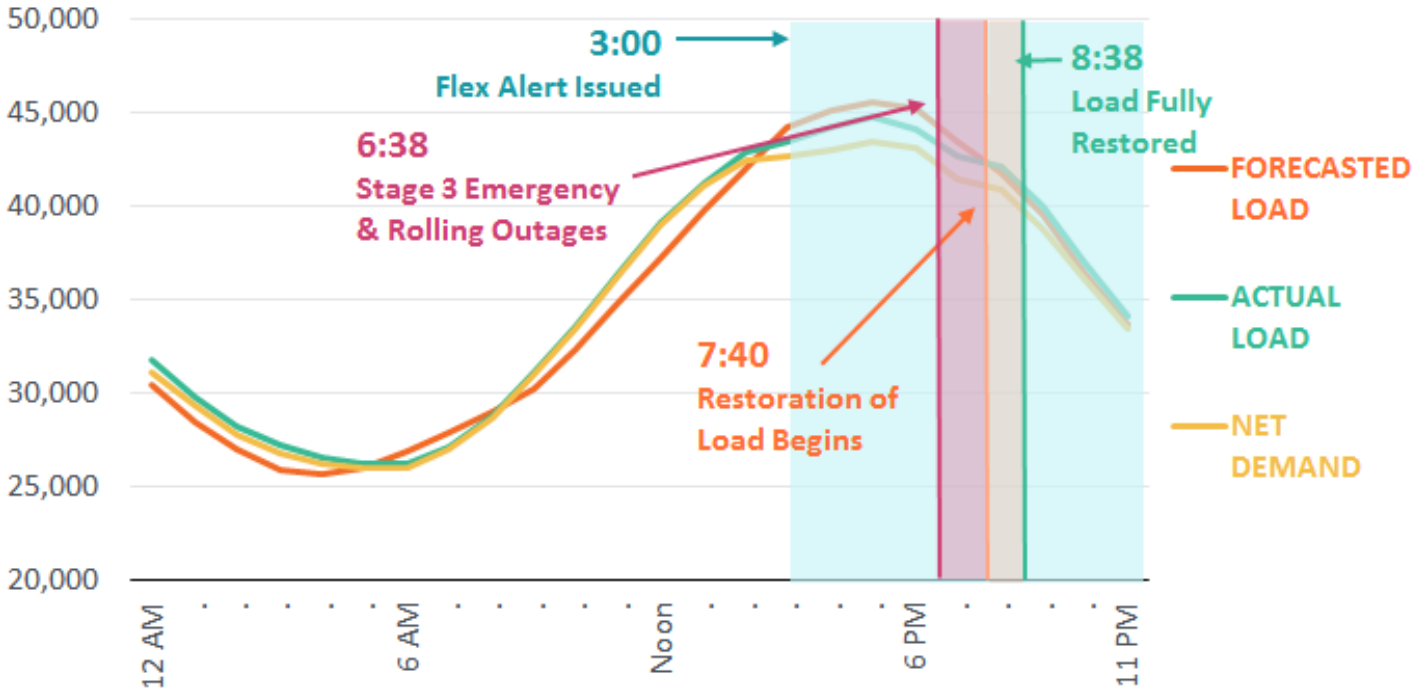
- Two rolling blackout events, first on **August 14th and then August 15th**
- Heat wave throughout the western U.S., constituting a **1-in-30 year weather event**
- Peak load more than **3,000 MW below CAISO's all-time peak** (50,270 MW in 2006) and the highest load in recent years (50,116 MW 2017)
- Rolling outages occurred **after peak load** on each day
- **Solar ramp down of more than 5,000 MW** in 2 hours on each day
- **Wind output lower than expected each evening**, with >1,000 MW unexpected ramp down of wind on August 15th
- On both days, CAISO **called for voluntary load reductions and additional resource bids** several hours prior to load shedding
- CAISO initiated load shedding events **in order to maintain 6% operating reserves** in compliance with WECC standards

Review of August 2020 Events

The first load shedding evening occurred on August 14th at 6:38pm

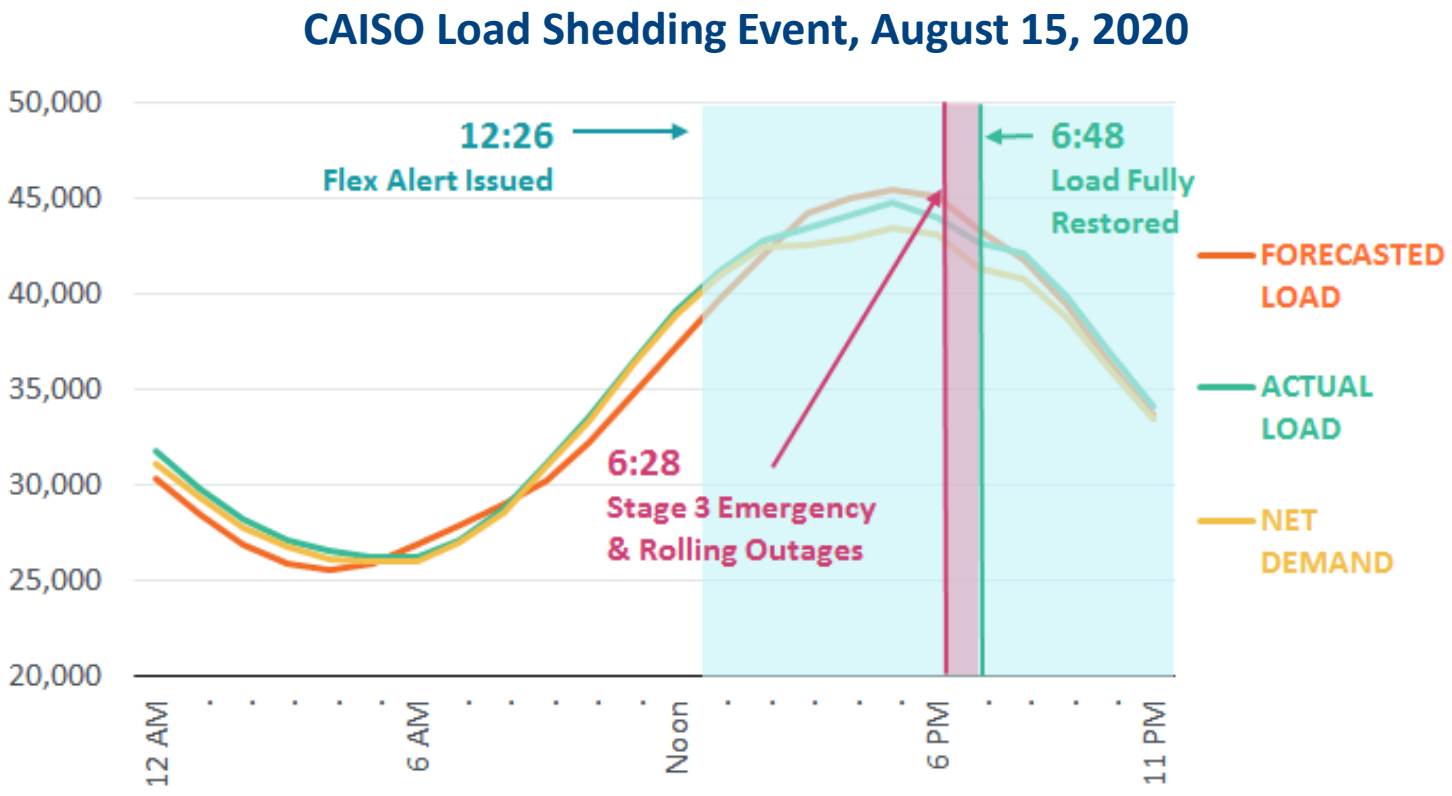
Outage Statistics, *August 14th, 2020*	
Start of Outage	6:38 p.m.
Duration of Outage	2 hours
MW of Outage	1,000
Customers Affected	491,600

CAISO Load Shedding Event, August 14, 2020



Assuming a $1-$2/kWh value of lost load (VOLL), the loss was approximately $2-$4 million

Review of August 2020 Events



The second load shedding event began on August 15th at 6:28pm, lasting about 20 minutes

Outage Statistics, *August 15th, 2020*	
Start of Outage	6:28 p.m.
Duration of Outage	20 minutes
MW of Outage	500
Customers Affected	321,000

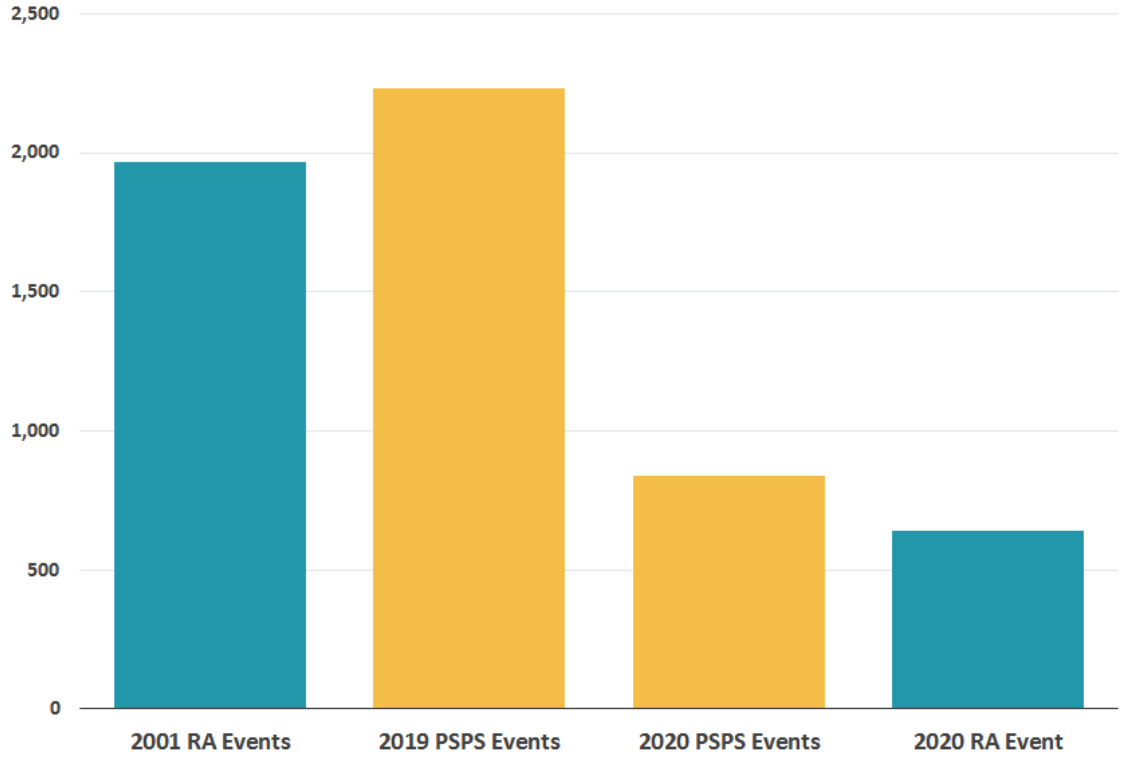
Assuming a $1-$2/kWh VOLL, the loss was < $500,000

Historical Context for August 2020 Events

The August 2020 events were the first RA related load shedding events since 2001

- January and March 2001 events affected about 2 million customers and lasted for weeks
  - Largely the result of improper early market design and supplier manipulations, not resources adequacy
- Public Safety Power Shutoffs (PSPS) outages related to wildfire prevention have affected over 3 million customers in the last two years

Customer's Affected by California Blackouts (2001-2020)



Note: Public Safety Power Shutoff (PSPS) events are implemented by utilities to help prevent wildfires
Estimates for 2001 RA events result from the sum of "several hundreds of thousands of customers" affected January 17-18 (estimated at 300,000), 1.5 million customers affected on March 19-20, and 167,000 customers affected May 7-8, 2001 as reported by CNN, ABC and PBS.

Review of August 2020 Events

CAISO's Root Cause Analysis identified several issues responsible for the load shedding events

Resource Adequacy Planning	• Counting rules based on contribution to serving *gross* peak instead of *net* peak
	• May not account for extreme temperature events caused by climate change
	• Potentially insufficient reserve margin of 15%
Day-Ahead Market Processes	• Ineffective DA load scheduling, DA-RT price convergence due to virtual trading, and RUC commitment process led to higher export volumes than the system could support
RA Resource Performance	• Transmission capacity to Pacific NW de-rated by 650 MW, preventing the import of RA capacity from the region
	• Unplanned NG capacity outages of 475 MW on the 14th and unexpected ramp (due to scheduling error) of 248 MW on the 15th
	• 650 MW of DR resources unavailable on the 14th, 820 MW on the 15th
	• Solar and wind resources performed below procured RA capacity levels

Sources and Notes: CAISO, "Report on System and Market Conditions, Issues and Performance"

CPUC and CAISO Proposed Solutions

Solutions being pursued by CPUC and CAISO focus on the reforming the Resource Adequacy requirements and Day-Ahead market processes and rules

Ongoing Review of Changes to Resource Adequacy Requirements

- CPUC initiated a rule making procedure and directed the IOUs to procure additional resources for this summer
- CAISO recommends Planning Reserve Margin (PRM) apply to gross and net peak, and be increased to 17.5%
  - Consistent with latest SCE IRP finding that 17.5% PRM will be needed by 2026

Review and Update CAISO Market Rules

- Improved load scheduling by LSEs
- Stakeholder processes recommended to discuss: RA resource counting against net load, performance incentives, market design enhancements

Sources and Notes: CAISO, "Report on System and Market Conditions, Issues and Performance"

Key Takeaways from August Resource Adequacy Events

The rolling blackouts of August 14th and 15th in CAISO illustrate *some* of the resource adequacy challenges facing the power system as we transition to clean electricity

- August events are the first resource adequacy events in California since 2001, which frequency (rarity) is consistent with a 1-in-10 planning requirement
  - The last major resource adequacy event in 2001 lasted more than 38 days combined and affecting 2,000,000 customers
  - Wildfire prevention outages have affected over 3,000,000 customers over the last 2 years
- Coupled with recent wildfire-related outages, frustration with the rolling blackouts is understandably high among California customers
- The CAISO has proposed good solutions (though expensive) to shore up RA
- Resource adequacy issues highlighted by August's events are familiar and relatively easy to address compared to emerging long-term issues facing the power system

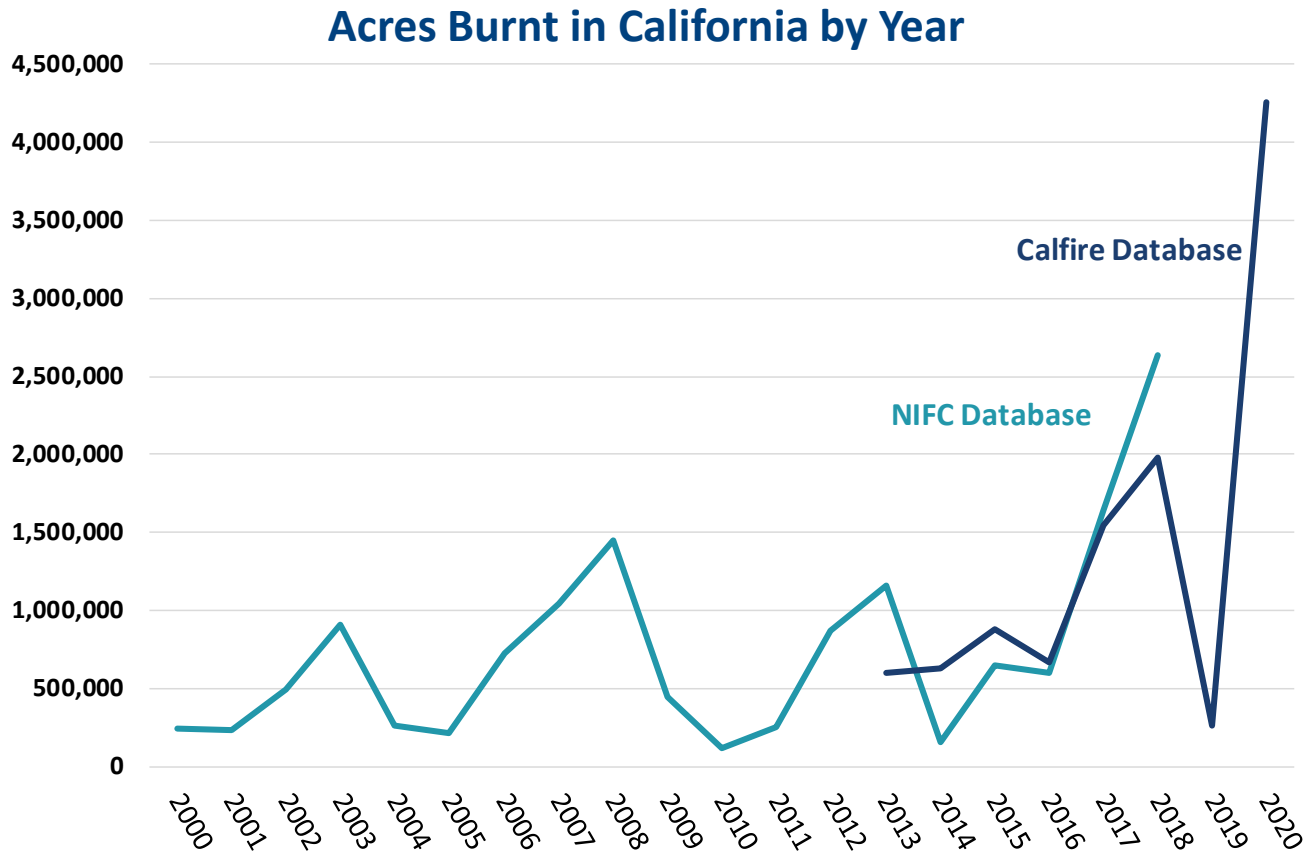
The California Wildfire Experience

Recent Wildfires in California

California's recent experience with wildfires highlights a larger long-term issue for system planners everywhere – ***Resiliency and System Hardening***

California has lost ~2 million acres/year in the last four years

- 4x increase over the prior 15 year history of wildfires in California
- Increase development in Wildland-Urban Interface (WUI), magnifies risks of long transmission lines
- CPUC reports that historically power infrastructure has caused < 10% of fires
  - However, several large fires recently have been from caused by transmission lines



Sources: CalFire Incident Archives, accessed https://www.fire.ca.gov/incidents/2020/ and National Interagency Fire Center (NIFC) Database, accessed https://data-nifc.opendata.arcgis.com/datasets/historic-perimeters-combined-2000-2018

California Public Safety Power Shutoffs

Summary of PSPS Event Outages

Year	Number of Outage Events	Total Hours of Outage	Total Customers Affected
2013	5	35	183
2014	10	158	1,367
2015	0	0	0
2016	0	0	0
2017	66	2,382	20,820
2018	91	3,422	84,565
2019	2,293	105,138	2,230,459
2020	1,112	36,339	836,005

Sources: California Public Utilities Commission (CPUC)
https://www.cpuc.ca.gov/deenergization/

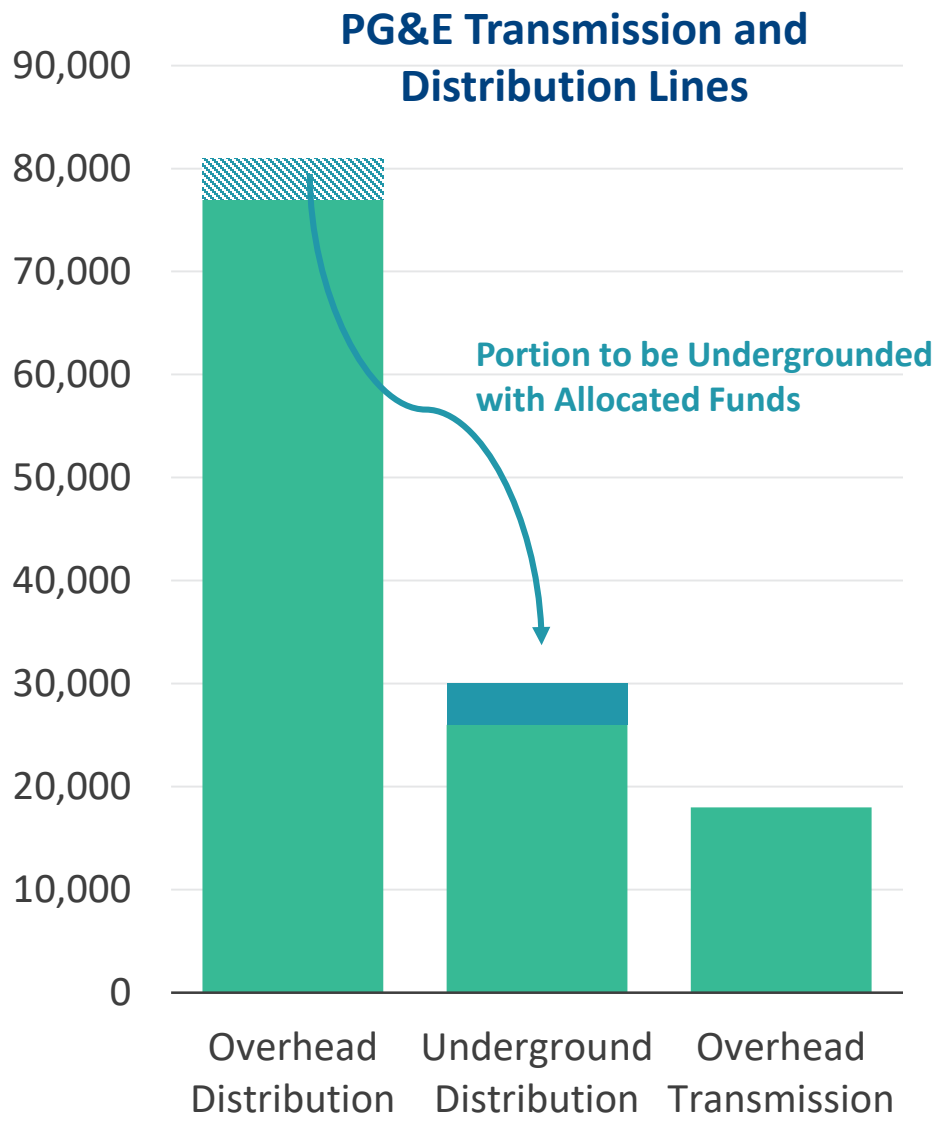
A new disruption to power service is occurring due to Public Safety Power Shutoffs (PSPS), first approved in 2012 by the CPUC

- Guidelines for PSPS amended by new legislation in response to the devastating 2017 wildfire season
- Utilities are responsible for monitoring wind conditions affecting their assets, and other weather conditions that increase or mitigate the risk of fire spread
- Utilities required to notify customers and public safety officials ahead of any likely PSPS events

During and after the historically severe 2017 fire season PSPS events increased dramatically

Response from California Utilities and Policymakers

- PG&E allocated $3 billion to resiliency against wildfires
  - Undergrounding 4,000 miles of distribution lines (at a cost of $800,000/mile*)
  - While significant, the investment will affect ~5% of PG&E distribution lines
- California AB 1054 created $21 billion to insure against future wildfire-related costs (hopefully through 2030)
  - Half funded by SCE, SDG&E, and PG&E, the rest by ratepayers
- New legislation introduced to provide $300 million for the Forest Service and Department of Agriculture to conduct controlled burns on federal, state, and private lands

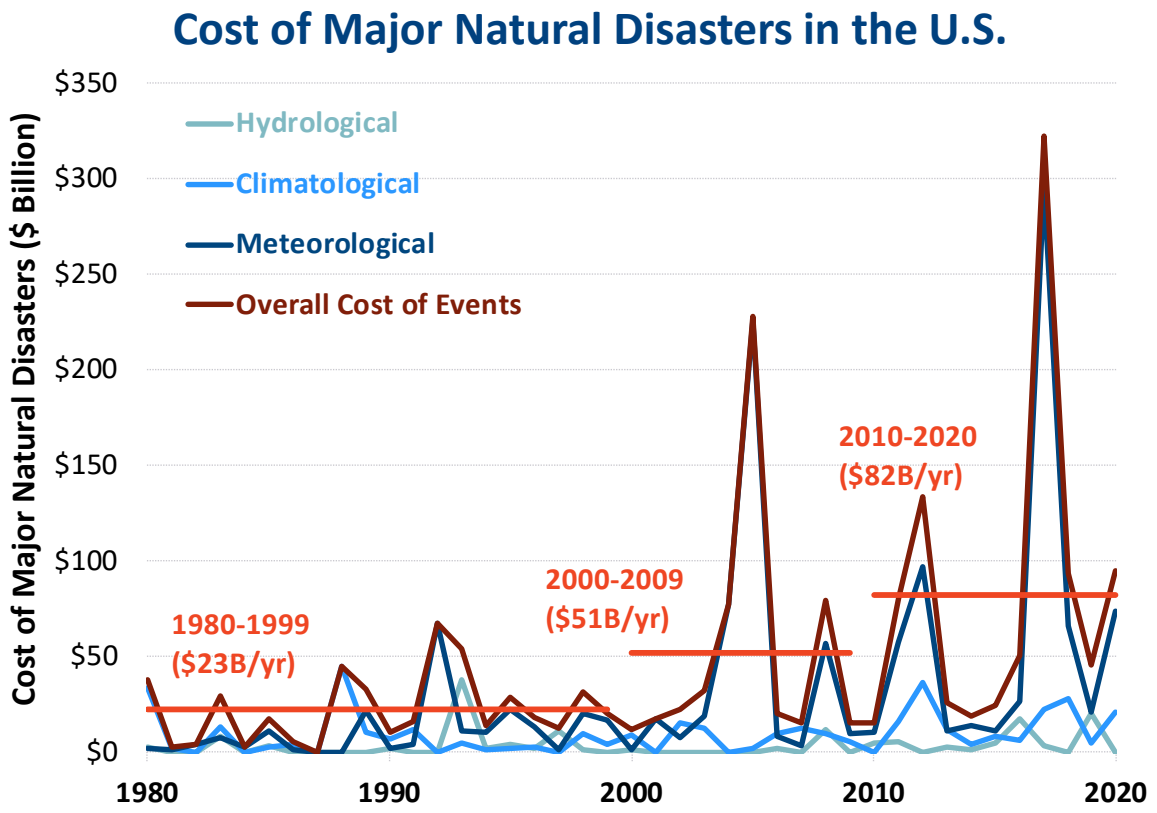


Sources and Notes: In urban areas, Edison Electric Institute estimates this cost at up $1.5 million/mile. Edison Electric Institute, "Out of Sight, Out of Mind, An Updated Study on the Undergrounding of Overhead Power Lines"

Parallel Experiences in other Regions of the U.S.

Resiliency is a growing concern across the U.S., often creating far worse outages than RA problems

- "Once-in-a-century" disasters recently happening every few years:
  - Superstorm Sandy, Hurricanes Harvey, Katrina, Ike, Rita, Laura all in the last 15 years
  - Three "1-in-500-year" floods for Houston since 2005
  - Increasing cold-weather events (blizzards, polar vortex)
  - Wildfires becoming common outside of CA (Alaska, Northwest, Rockies, and Southwest)
- Average annual cost of major natural disasters has increased 4x in 20 years to over $80 billion/year
  - Justifying significant investments in system resiliency



Sources and Notes:

"Billion-Dollar Weather and Climate Disasters," NOAA National Centers for Environmental Information (NCEI), accessed January 2021, https://www.ncdc.noaa.gov/billions/time-series. *See* tab "NOAABillionDisasters".

The increase in losses may be due to a combination of heightened climate risk and increased concentration of property value in at-risk areas. Both factors are also at play in California with regard to wildfires.

Meeting the Challenge of Improving System Resiliency

The power industry does not yet have an agreed planning or regulatory framework to address system resiliency challenges

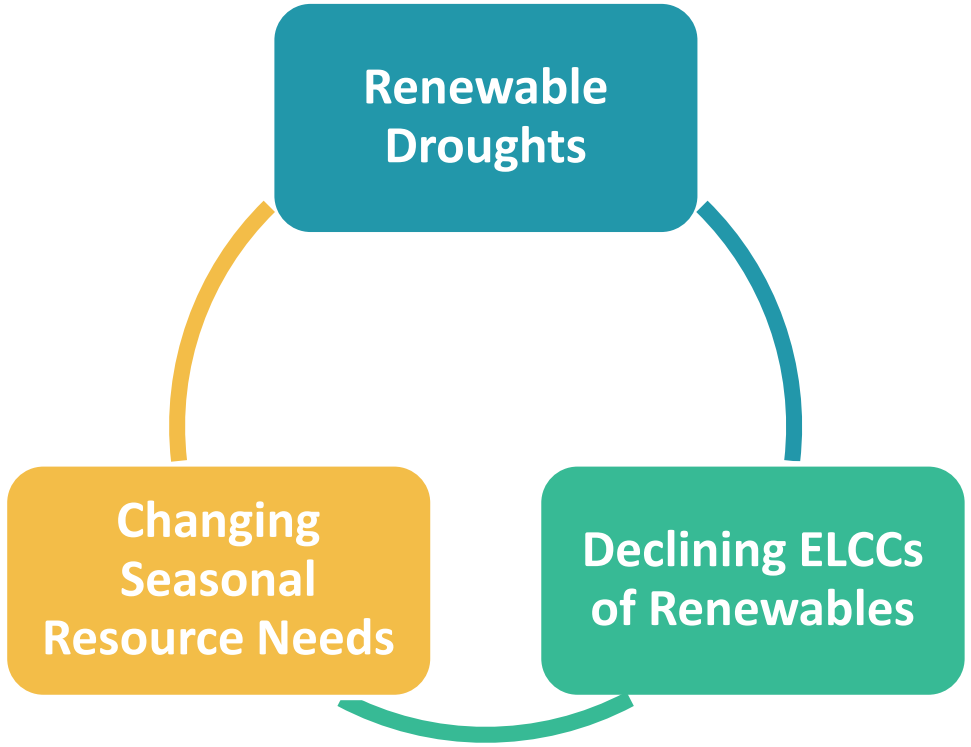
- The problem is statistically very complex: risks are “Black Swan” events not easily measured (unlike resource adequacy); very hard to predict where or how natural disasters will strike, but with severe economic consequences.
- What is the right balance of money spent on system hardening vs. insurance and after-the-fact repairs?
  - System hardening (e.g., undergrounding, redundant infrastructure, micro grids) is expensive.
  - And commercial insurance for damages is increasingly limited and very costly: about $.30/$ for CA wildfires!
- Should just affected ratepayers bear the cost of hardening and repairs, or will taxpayers (or customers in other systems) chip in?
- Who has authority to determine how and where funds are spent (utilities, system planners, regulators, or policymakers)?

Creating an effective framework will require customers, system planners, utilities, policymakers, and regulators to analyze and form consensus on several key challenges and open questions.

Emerging Long-Term Resource Adequacy Challenges

Evolving Resource Adequacy Challenges on a Decarbonized Grid

Economy-wide decarbonization further requires our industry to re-think resource adequacy and system planning



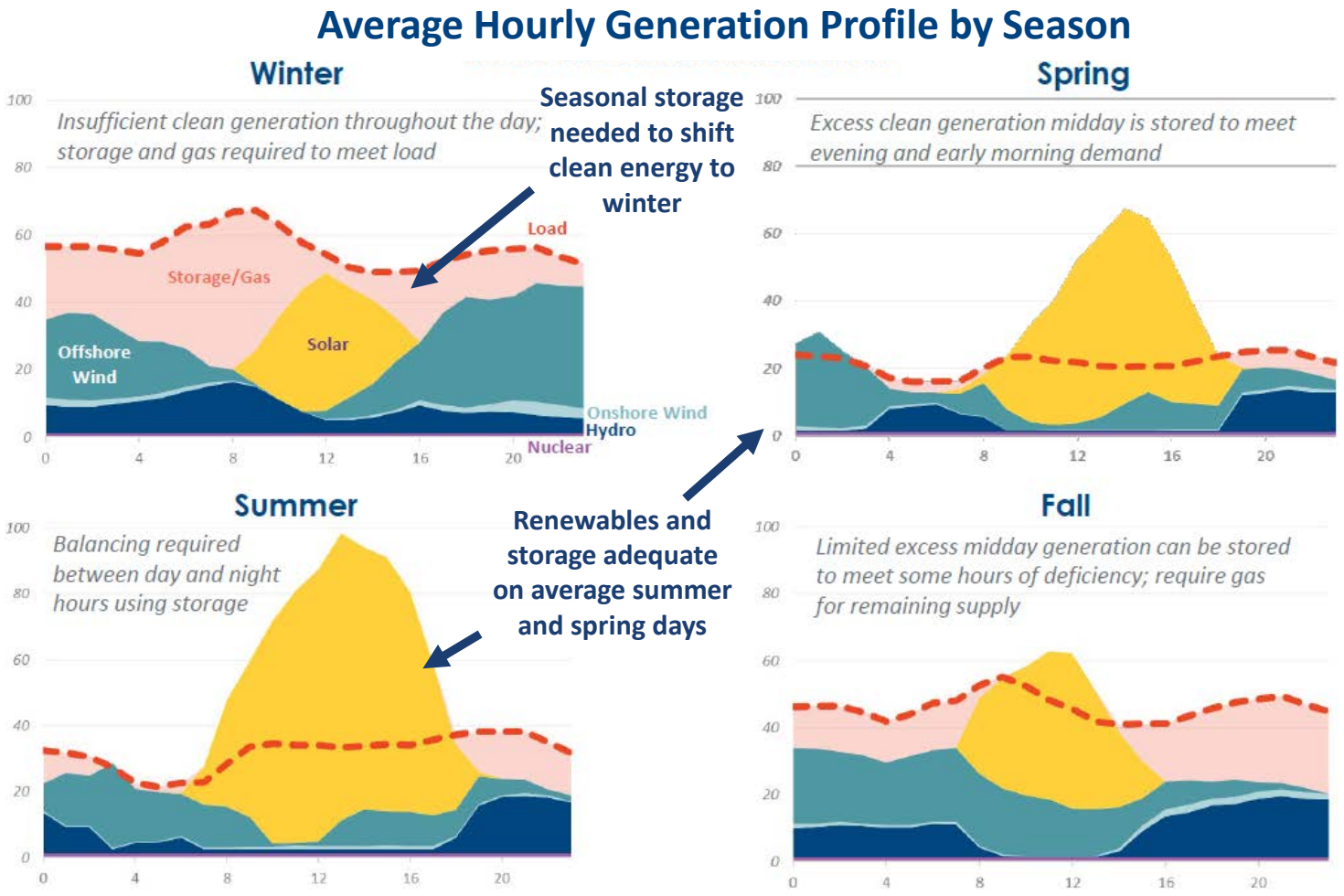
Planning problem is fundamentally different: *getting sufficient clean energy with a viable time pattern* to *match load and intermittency risks.* Many new RA challenges in a high renewables system:

- **Renewable droughts** – multi-day periods without significant wind or solar production
- **Changing Seasonal Resource Needs** – wind and solar production are lower in winter months while electrification is likely to increase winter peak load
- **Declining Effective Load Carrying Capability (ELCC) of Renewables** – higher adoption of wind and solar reduces their ability to provide resource adequacy

Evolving System Design & Management Challenges on a Clean Grid

Brattle analysis of New England's economy-wide decarbonization policies illustrates evolving seasonal resource needs

- ***Huge ramping needs***
- ***RE overbuilds plus storage and curtailments***
- ***New clean dispatchable techs become attractive***

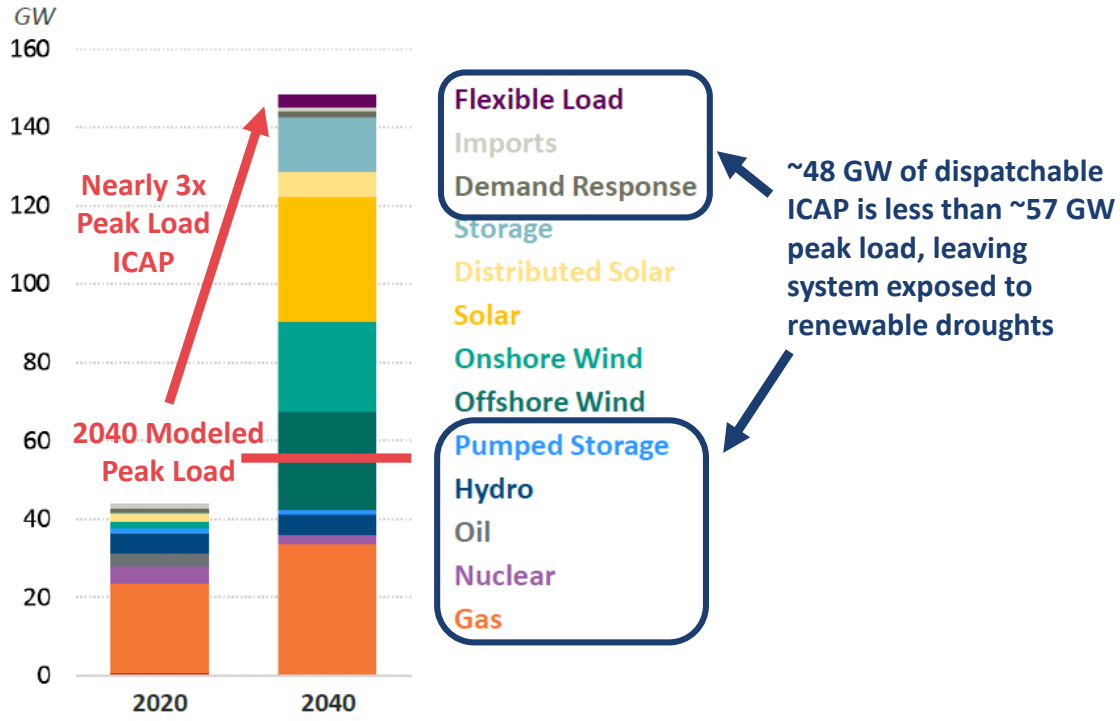


Source: Weiss, et al., "Achieving 80% GHG Reduction in New England by 2050," September 2019, Accessed here.

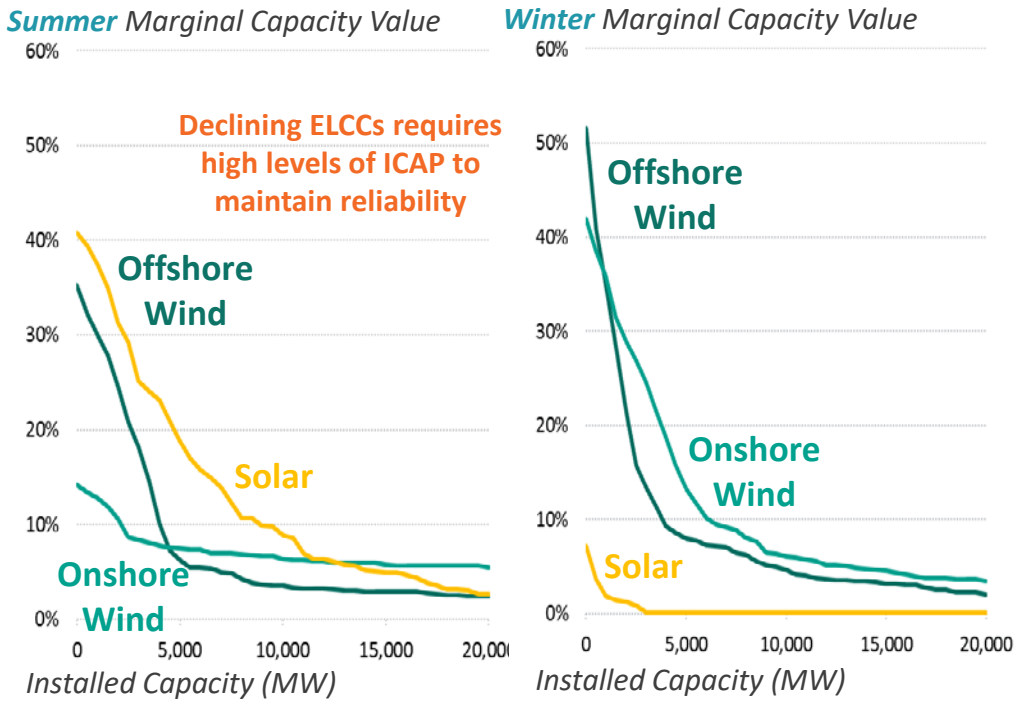
Evolving System Design & Management Challenges on a Clean Grid

Brattle modeling for NYISO illustrates substantially declining RA value of renewables and exposure to renewable droughts on a highly decarbonized system

Simulated NYISO 2040 Installed Capacity to Meet 100% Clean Energy Standard



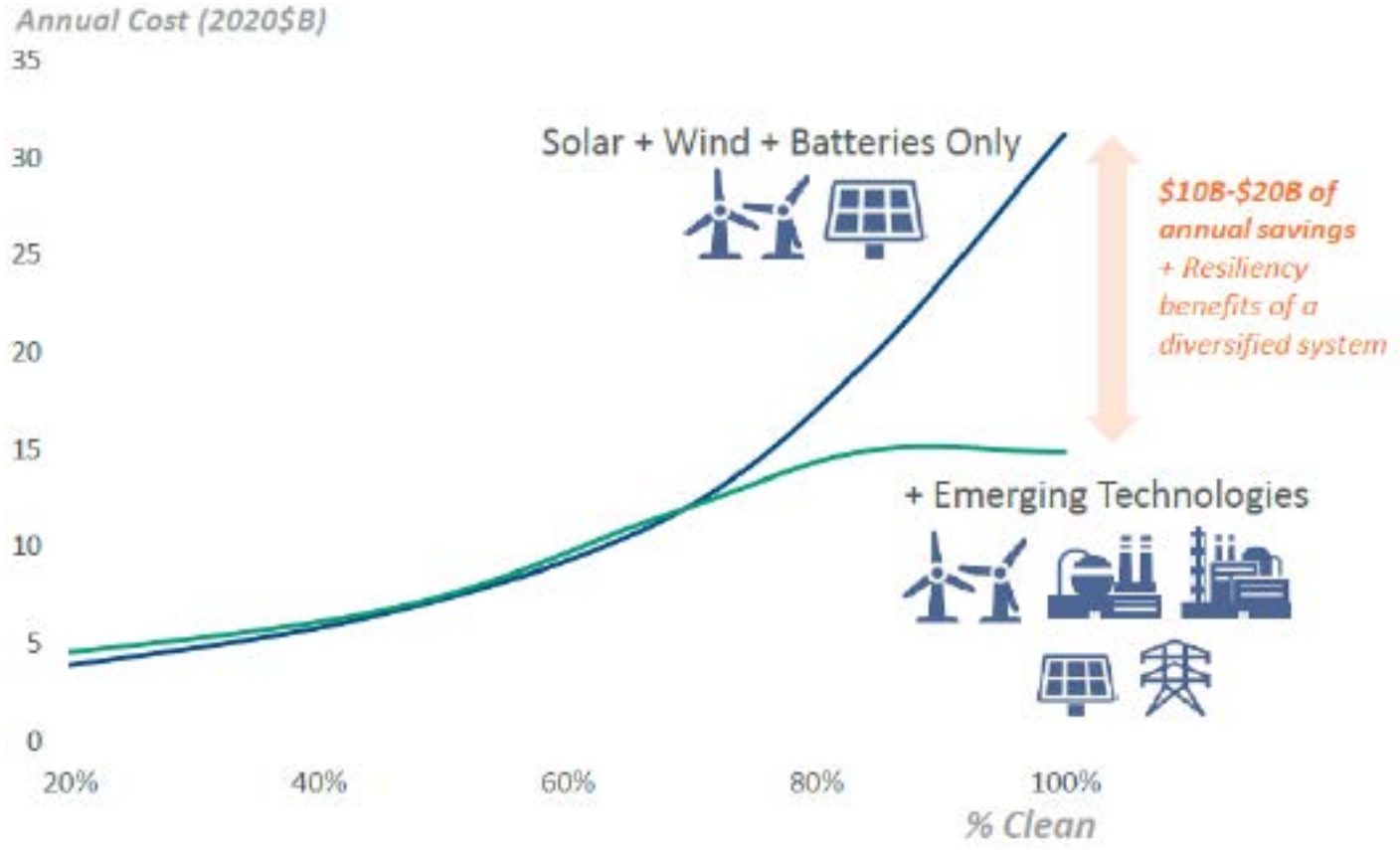
Declining Marginal Capacity Value of Solar and Wind in NYISO



Source: Lueken, et al., "New York's Evolution to a Zero Emission Power System," May 2020, Accessed here.

Increasing Cost of Resource Adequacy under Deep Decarbonization

System Costs for New England at Different Decarbonization Levels



Source: Graves, et al., "Clean Energy and Sustainability Accelerator," January 14, 2021, accessed: https://brattlefiles.blob.core.windows.net/files/20809_clean_energy_and_sustainability_accelerator.pdf

Brattle model of New England illustrates resource adequacy is extremely expensive on the margin at decarbonization levels above about 80%, if relying only on solar, wind, and battery storage

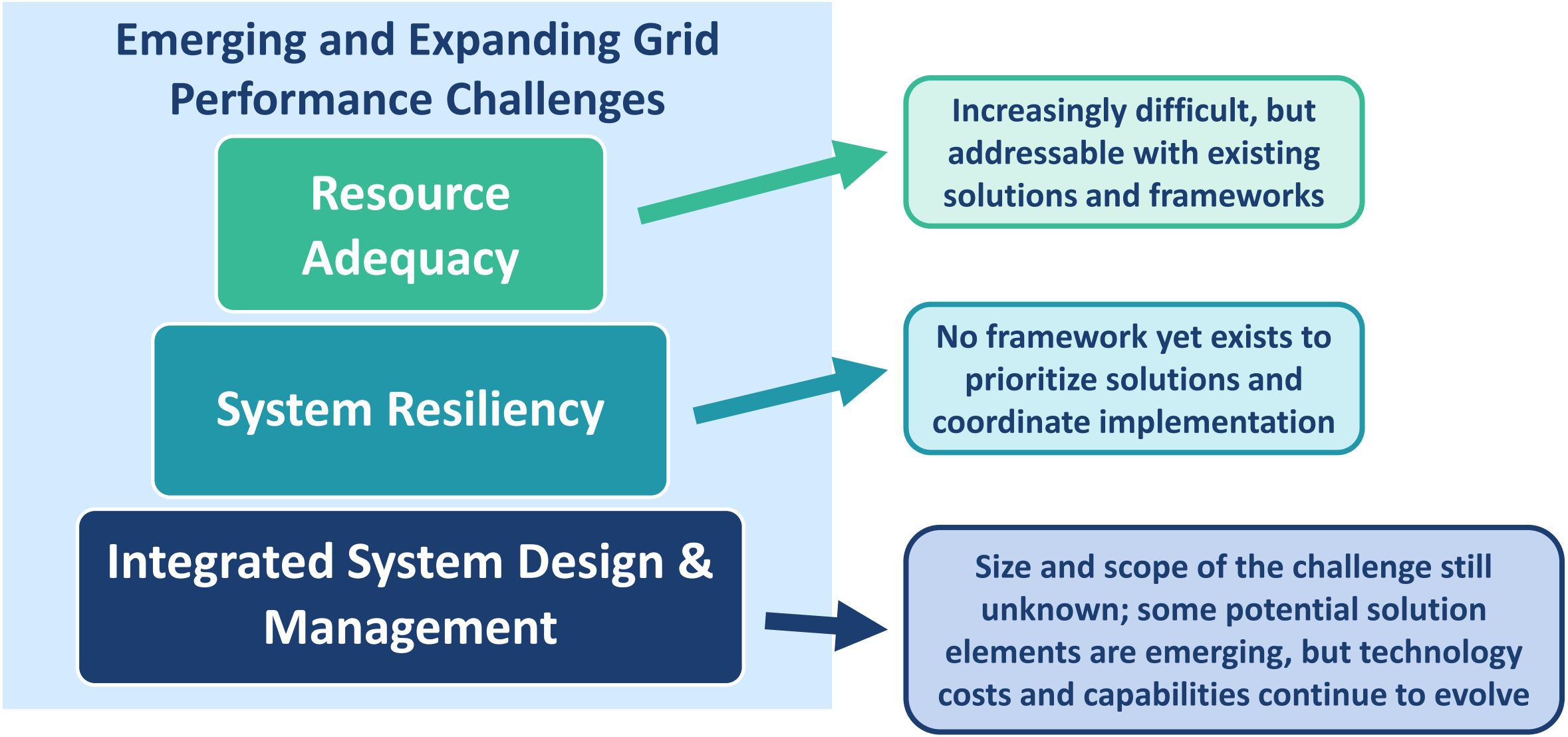
- **Lower-cost solutions likely include other technologies: interregional transmission, carbon capture and storage, renewable natural gas, hydrogen**

Solution Elements to System Design & Management Challenges

Emerging Technologies & Infrastructure	Effective Market Design & Pricing	Retail Pricing & Demand Side Management	Direct & Smart Load Control Measures
• Interregional Transmission • Carbon Capture and Storage • Green Hydrogen • Renewable Natural Gas	• Scarcity Pricing in Shortage Conditions Based on Value of Lost Load • New Ancillary Services to Manage Ramping Needs	• Greater Deployment of Demand Response • Electric Vehicle Managed Charging • Load Shaping • Variable Pricing	• System Control of Water Heating & HVAC • Coordinated EV Charging and Dispatch of Storage

System planners, regulators, utilities, and customers will need to determine the correct balance between deploying emerging technologies, relying on price signals to drive system behavior, and mandating control of load and distributed resources

Final Thoughts and Takeaways



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Frank Graves specializes in regulatory and financial economics, especially for electric and gas utilities, and in litigation matters related to securities litigation and risk management.

He has over 30 years of experience assisting utilities in forecasting, valuation, and risk analysis of many kinds of long-range planning and service design decisions, such as generation and network capacity expansion, supply procurement and cost recovery mechanisms, network flow modeling, renewable asset selection and contracting, and hedging strategies. He has testified before the Federal Energy Regulatory Commission (FERC) and many state regulatory commissions, as well as in state and federal courts.

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John Tsoukalis has broad experience helping clients respond to a range of issues related to wholesale power markets. He is an expert in electric market modeling, analyzing regional market participation, transmission rate design, market design, detection of market manipulation and damages analyses, and strategic planning.

Mr. Tsoukalis has assisted electric utilities, cooperatives, public power authorities, transmission developers, generation owners, and power traders. Mr. Tsoukalis has led numerous efforts in modeling the power system to assess the benefits of participating in wholesale power markets, value generation assets, and analyze the benefits of new transmission. Among his transmission experience, Mr. Tsoukalis has assisted clients in analyzing alternative transmission rate designs and led strategic planning initiatives to help clients plan for the ongoing clean energy transition.

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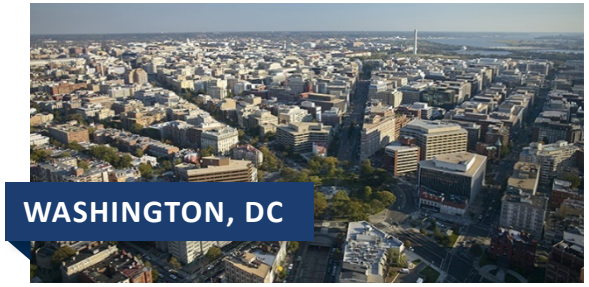
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