Resource Adequacy Overview

Methods, Metrics and Future Needs

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Aims and Acknowledgments

- Basic overview of adequacy concepts and methods
- Metrics used and how to assess for individual resources
- Where does this need to go in the future?

- Based on work being done by Michael Milligan and Eamonn Lannoye, for upcoming RA guidelines document
  - In turn based on significant experience and studies, particularly Michael
  - Upcoming EPRI deliverable (members only) and maybe website (2020+)
  - Also information from recent work by Bob Entriken and Adam Diamant from EPRI: *Resource Adequacy: History and Catalog of Metrics.* EPRI, Palo Alto, CA: 2016. 3002013734

What does RA do and what tools are used?

Who Are The Decision Makers?

Resource Owners/Developers

- Make decisions related to investments, alterations and retirements of resources
- Economically optimize the operation of their resources

System Planners

- Conduct resource adequacy assessments and planning studies
- Determine necessary interventions to ensure long term reliability

Regulators/Market Design

DEPARTMENT OF ENERGY FEDERAL ENERGY REGULATORY COMMISSION

ACER Agency for the Cooperation of Energy Regulators

- Set the resource adequacy standard
- May specify methods for reliability assessment
- May make determinations related to utility investments and tariffs
- May establish requirements for capacity procurement mechanisms

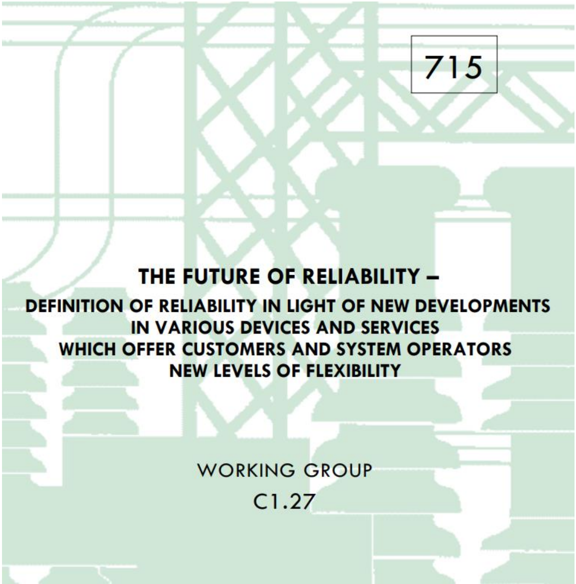
Adequacy – some definitions

- *A measure of the ability of a power system to meet the electric power and energy requirements of its customers within acceptable technical limits, taking into account scheduled and unscheduled outages of system components* (CIGRE: **The Future of Reliability – new definition since 2018)**
  - ***Power system*** *includes all elements of the generation, transmission and distribution systems, and customer facilities that supply or use power and energy, or provide ancillary services;*
  - ***Customers*** *include all parties that supply power and energy or ancillary services, as well as those who consume them;*
  - ***Requirements of customers*** *include their basic power and energy needs, and agreed use of customers' ability to vary power supply, adjust demand and provide ancillary services;*
  - ***Acceptable technical limits*** *and* ***scheduled and unscheduled outages*** *are those specified in the applicable planning criteria and standards; and*
  - ***System components*** *include all elements of the supply, delivery and utilization systems regardless of ownership or control.*

- 'Adequacy' means the ability of in-feeds into an area to meet the load in that area (ENTSO-E)

- The ability of an electric power system to supply the aggregate electric power and energy required by the customers, under steady-state conditions, with system component ratings not exceeded, bus voltages and system frequency maintained within tolerances, taking into account planned and unplanned system component outages "Note – This ability may be measured by one or several appropriate indices (IEC)

- the ability of the electric system to supply the aggregate electrical demand and energy requirements of the customers at all times, taking into account scheduled and reasonably expected unscheduled outages of system elements (IEEE)



Basic Indicators of Adequacy

- Planning Reserve Margin
  - Do you have sufficient resources to meet demand + some margin
  - Margin covers outages, load forecast error and need for reserves
  - Typical values of 11%-16%

- EFORd – Effective Forced Outage Rate
  - Unforced Capacity (UCAP)
    - UCAP = Capacity (1 - EFORd)

More detailed reliability measures

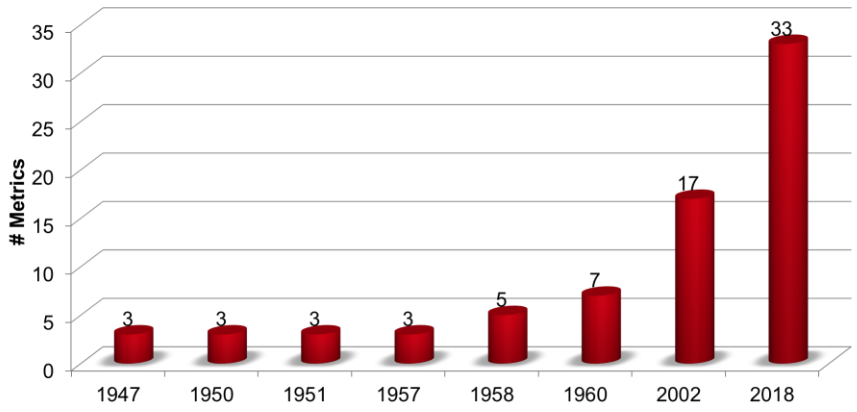
- 1950s → Loss of Load Probability
  - Outages assumed independent
  - Combinations of all plant states calculated
  - Cumulative outage probability table

	MW Out	MW In	Probability	Cumulative Probability (LOLP)
0	0	300	0.60635500	1.00000000
1	50	250	0.31635913	0.39364500
2	100	200	0.06877372	0.07728587
3	150	150	0.00797377	0.00851214
4	200	100	0.00052003	0.00053838
5	250	50	0.00001809	0.00001835
6	300	0	0.00000026	0.00000026

Example Cumulative Outage Probability Table

- To reduce (1950s!) computation burden, peak of each day used

- Probability x time = expectation
  - Loss of Load Expectation



# of RA metrics – from *Resource Adequacy: History and Catalog of Metrics.* EPRI, Palo Alto, CA: 2016. 3002013734

What metrics are used?

- PRM – mostly not used for detailed analysis, but good rule of thumb for certain types of studies/needs
- UCAP – may have more application, particularly for near term
- LOLP – probability load can't be served for particular interval
- LOLE – expectation over time of LOLP (can be daily)
- LOLH (hours) – based on hourly data
- Expected Unserved Energy (EUE) – probabilistic value of energy shortfall
- Unserved energy (USE) – percentage of energy left unserved

- Frequency and duration (F and D) might both need to be considered

Table 1.1: Survey of Reliability Risk Metrics

RRM	Frequency[9]	Duration[10]	Magnitude	Hours Considered	Calculation Method
LOLH	No	Yes	No	All Hours	Monte Carlo or Convolution
LOLEV	Yes	No	No	All Hours	Monte Carlo or Convolution
LOLE	Yes	Yes	No	Peak Hours or All Hours	Monte Carlo
LOLP	Yes	Yes	No	All Hours	Monte Carlo or Convolution
EUE	Yes	Yes	Yes	All Hours	Monte Carlo or Convolution

LOLP
EUE
LOLE
LOLEV
Other

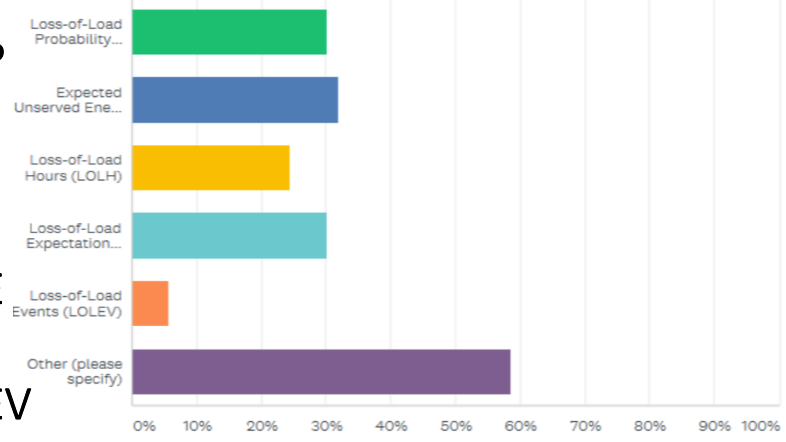


Figure 2.1: Survey-Based Results on the Use of Reliability Risk Metrics

Source: NERC

What models are used?

LOLE model

- Closed form or Monte Carlo sampling model (COPT)
- Estimation of LOLP at each interval and summation to LOLE / EUE
- **Tools:** GE MARS, Many in-house tools
- **Literature:** Billington & Allen, Reliability Evaluation of Power Systems

Production cost model

- 8760 hourly modeling of generator operations
- Level of detail varies (linear vs MIP, transmission, reserves, multi-cycle)
- **Tools:** Plexos, Aurora, Bid3, Promod, PSO, ReSOLVE etc.

Hybrid model

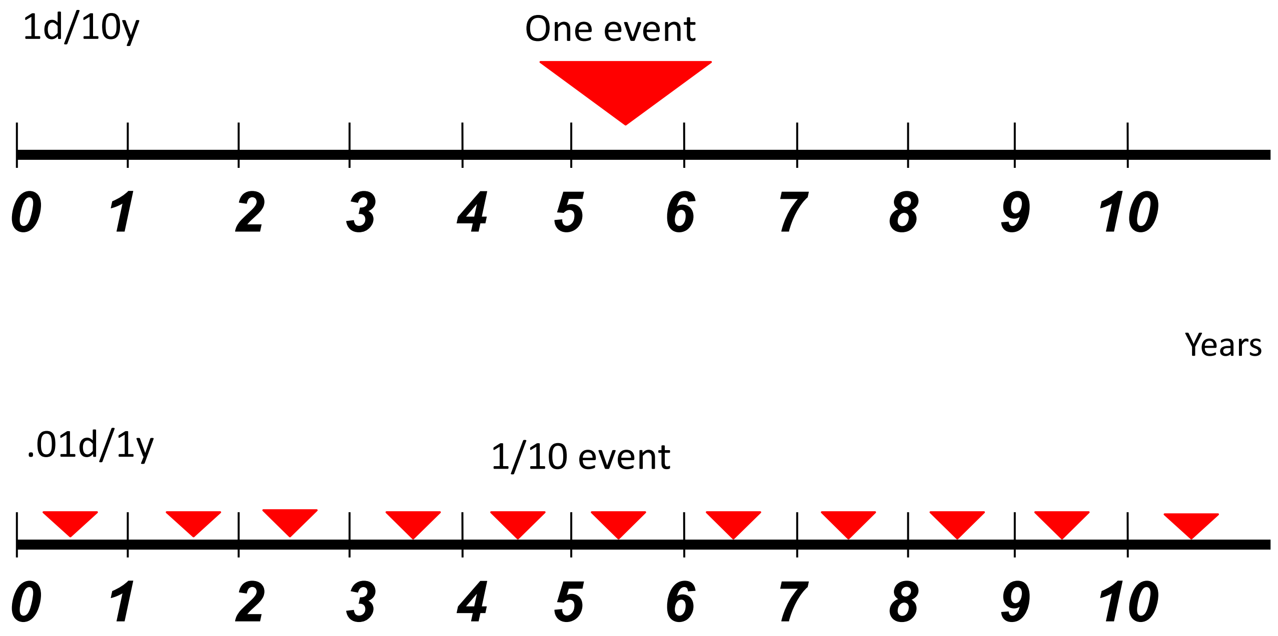
- Heuristic reinforced production cost modeling
- Reduced constraint complexity (limited transmission, MIP constriants) for fast processing of wide range of scenarios (e.g. outage draws)
- **Tools:** Astrape SERVM (https://patents.google.com/patent/US7698233B1/en)

All use load and renewable shapes for different scenarios, and can produce LOLP-family metrics

How is RA calculated for system and resources

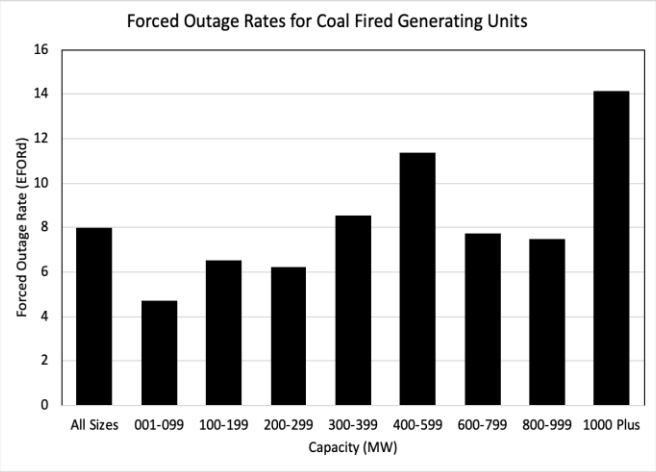
When is there enough RA? Reliability Targets

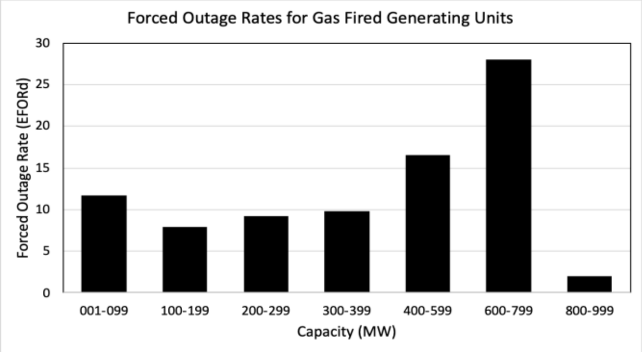
- LOLE measured in days/10 years or day/year
  - 1d/10yrs or 0.1d/1yr often used – but not interchangeable!



Individual resource calculations

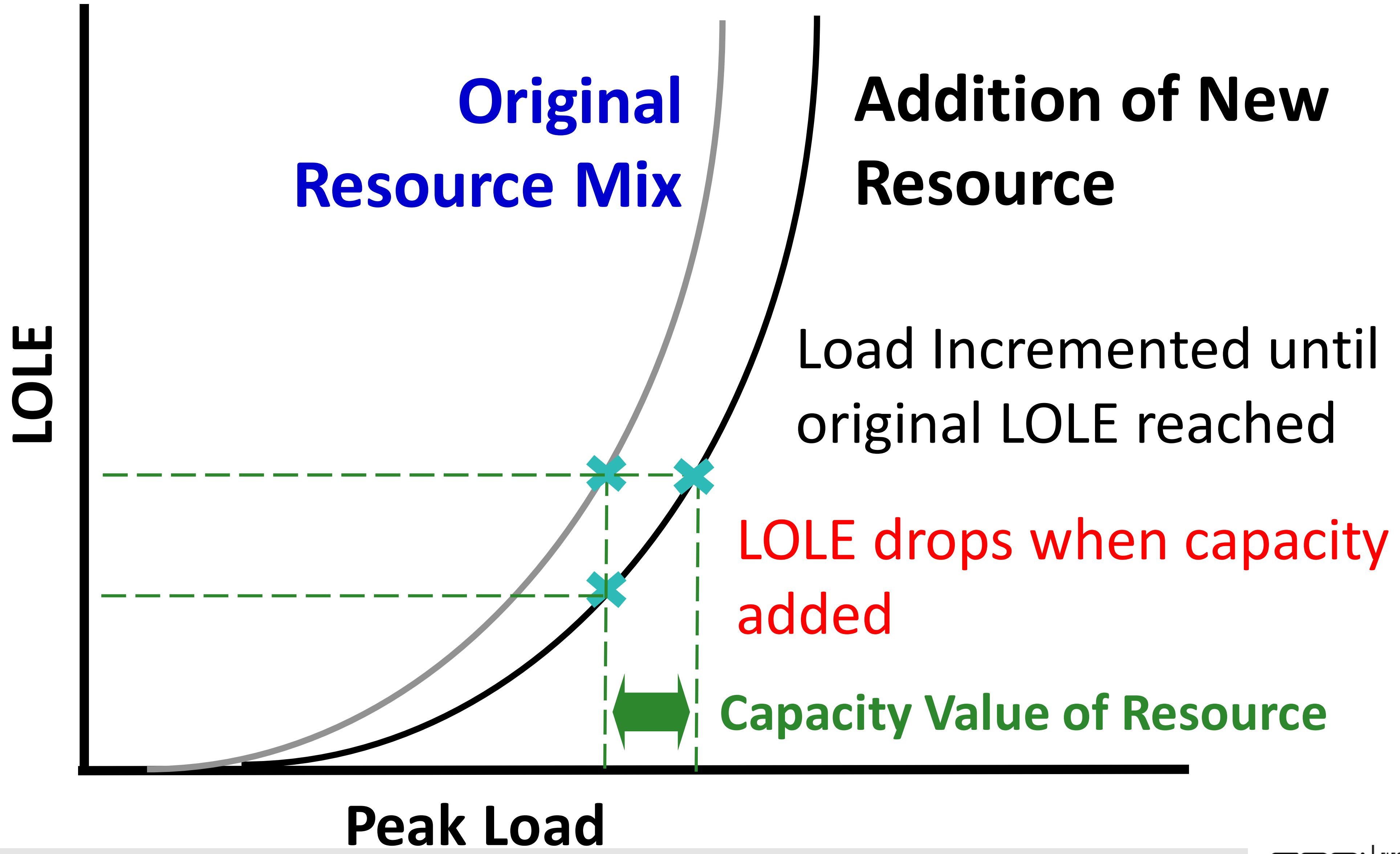
- Equivalent Load Carrying Capability or Equivalent Firm Capacity can be calculated for each resource
- Conventional resources (gas, coal, etc.)
  - Based on EFORd (or other EFOR metric)
  - Doesn't capture common mode type event
- For wind or solar, use time series and adjust load accordingly
  - Initially → estimates of VER based on capacity factor
  - Moving towards more detailed methods
- Storage requires a dispatch assumption (later)





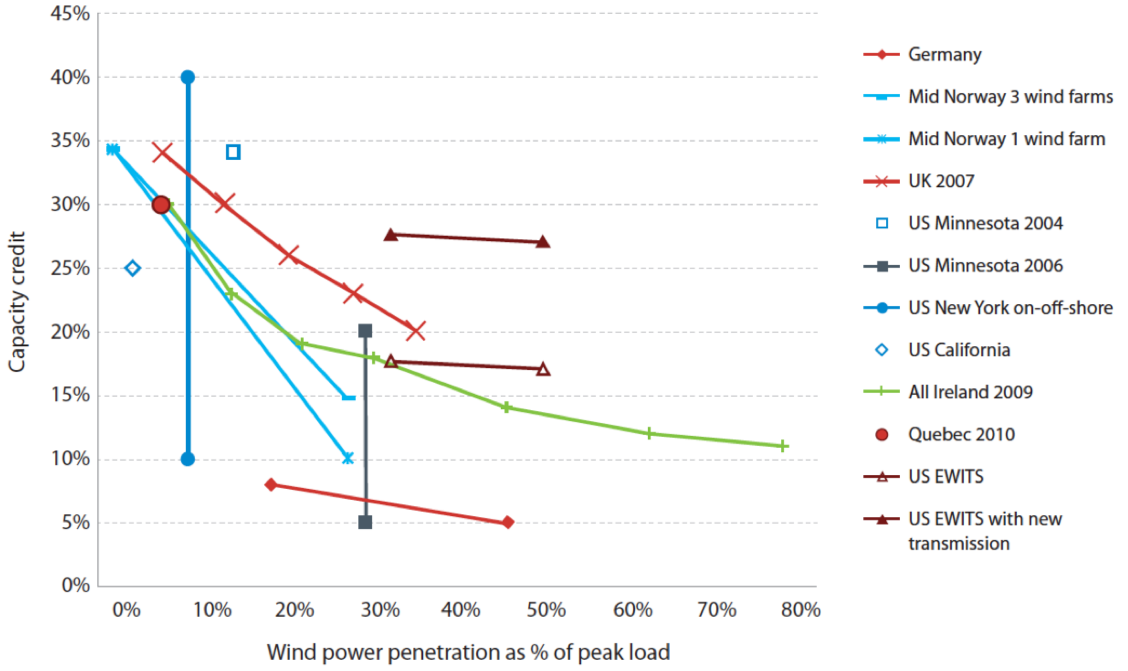
RTO	Season	Months	Time	Default for New Onshore	Default for New Offshore
ISONE	Summer	Jun. 1– Aug. 31	1–6 p.m.	–	–*
	Winter	Oct. 1– May 31	5–7 p.m.	–	–
NYISO	Summer	Jun. 1– Aug. 31	2–6 p.m.	10%	38%
	Winter	Dec. 1– Feb. 28	4–8 p.m.	30%	38%
PJM	Summer	Jun. 1– Aug. 31	2–6 p.m.	13%	13%

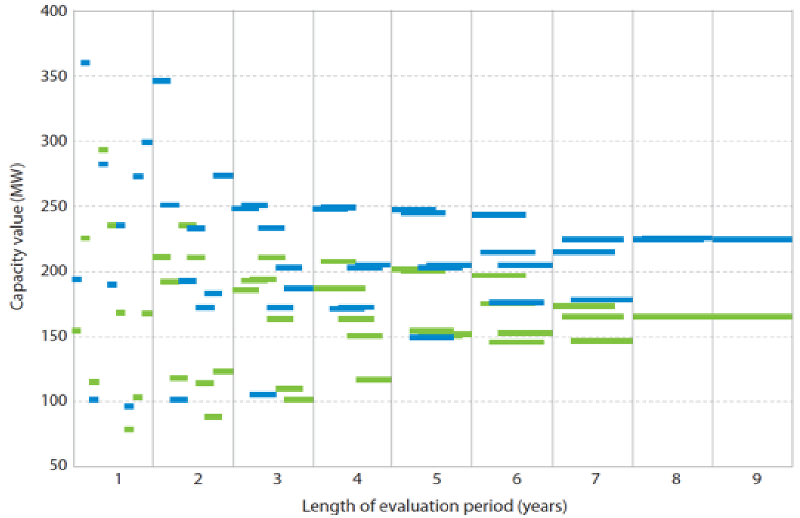
Loss of Load Expectation & Capacity Value



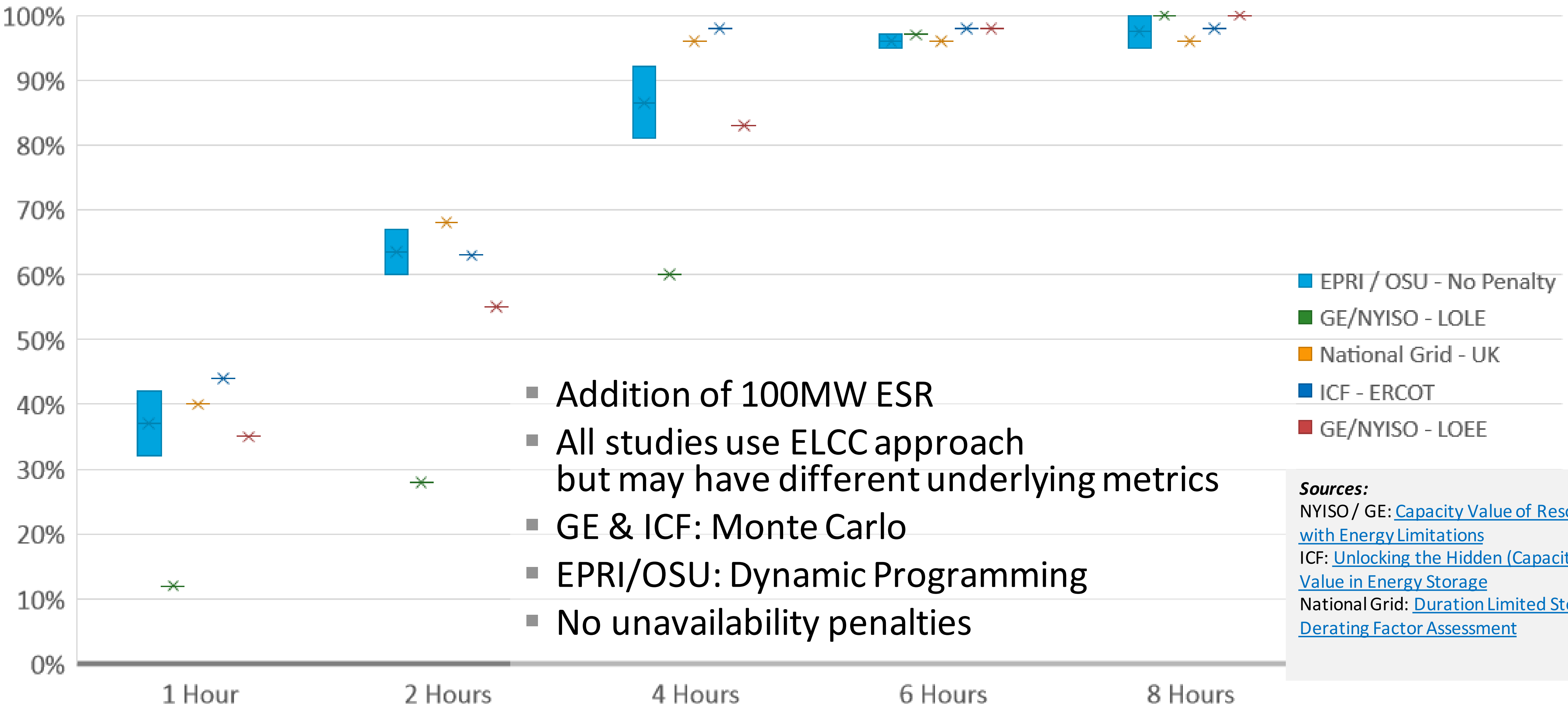
Capacity contribution of VER

- ELCC method widely used and understood
- Still work needed on ensuring data is sufficient (load and VER)
- General incremental decline in ELCC (or other metric)





Comparison of ESR Cap Credit Studies



- Addition of 100MW ESR
- All studies use ELCC approach but may have different underlying metrics
- GE & ICF: Monte Carlo
- EPRI/OSU: Dynamic Programming
- No unavailability penalties

Sources:
NYISO / GE: [Capacity Value of Resources with Energy Limitations]
ICF: [Unlocking the Hidden (Capacity) Value in Energy Storage]
National Grid: [Duration Limited Storage Derating Factor Assessment]

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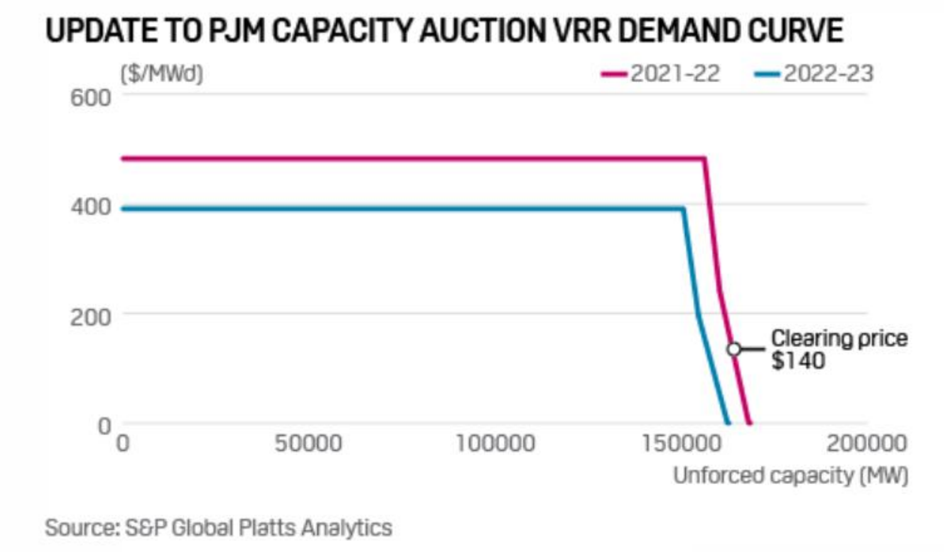
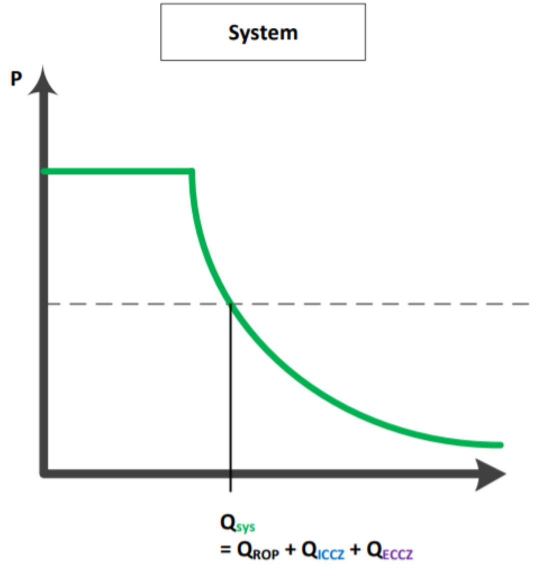
Capacity Markets, Capacity Contribution and Adequacy

- Capacity contribution is a result of RA studies, but also feeds into capacity market constructs
- Used as input to determine capacity requirement to meet the RA standard
  - 1 in 10 LOLE, 0.1 LOLE, etc.
- ISO sets price cap, and may have different methods of valuing excess capacity (including not doing so)
  - Net Cost of New Entry will be important factor (though other caps also considered)
- Resources may clear at Unforced Capacity, though some moves towards using ELCC for wind/solar (recalculated every few years)





From ISO-NE Forward Capacity Market 101 Training Materials

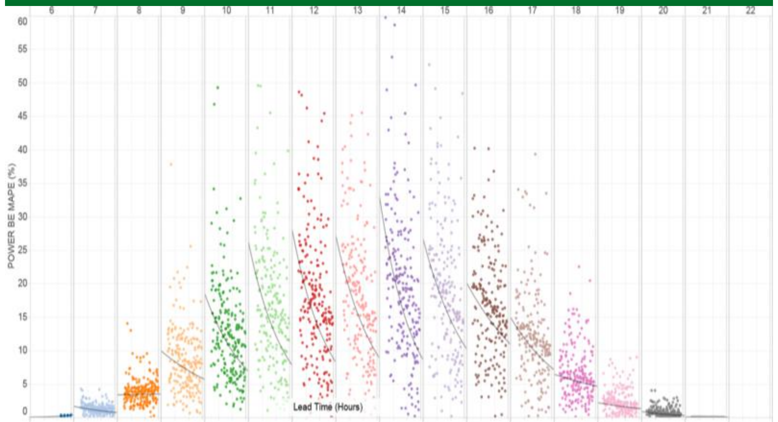
Where does RA need to go in future?

What Is Changing?

Rising Uncertainty

- New generation mix with wind and solar on transmission and distribution networks
- Weather and time dependent drivers for production
- Retirement of synchronous plant
- Increasing interconnectedness
- Increasingly active demand

Increased Variability



- Operational forecast uncertainty increasing due to demand and renewables
- Forecast uncertainty degrades as a function of time horizon
- Need system which can manage both predictable ramps and forecast uncertainty

Reducing Lead Times

- Characteristics of resources needed are different from capacity resources
- Need understanding of requirements in investment planning time frame
- Planning assessments which consider operational reality

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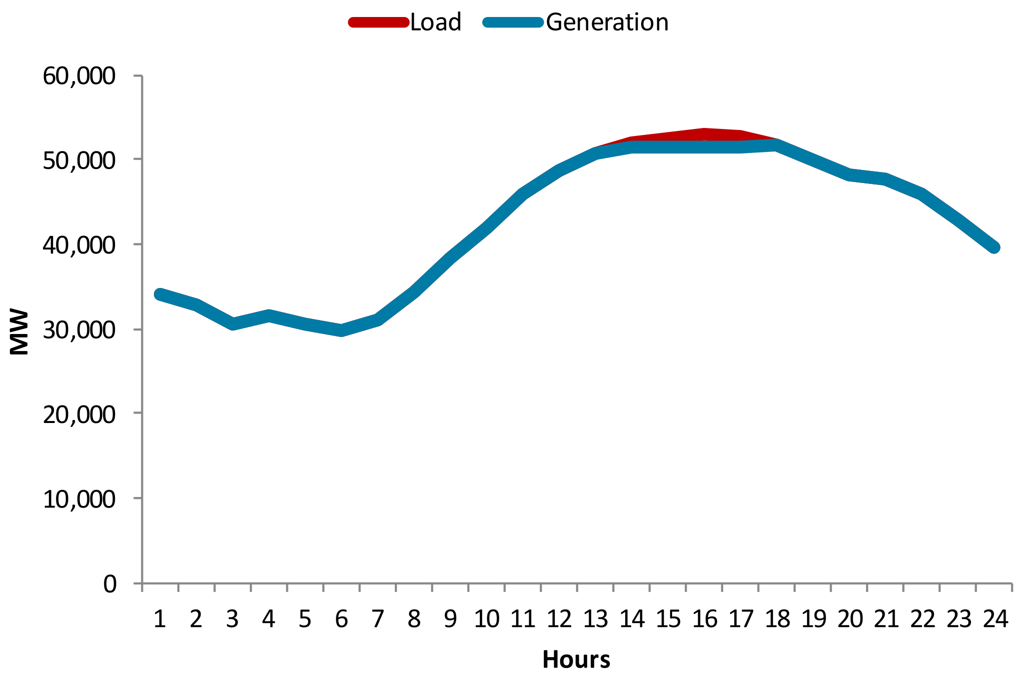
No longer just capacity – need the right mix

Existing Peak Capacity Need

LOLE GENERIC-CAPACITY

Existing metric to capture events that occur due to capacity shortfalls in peak conditions

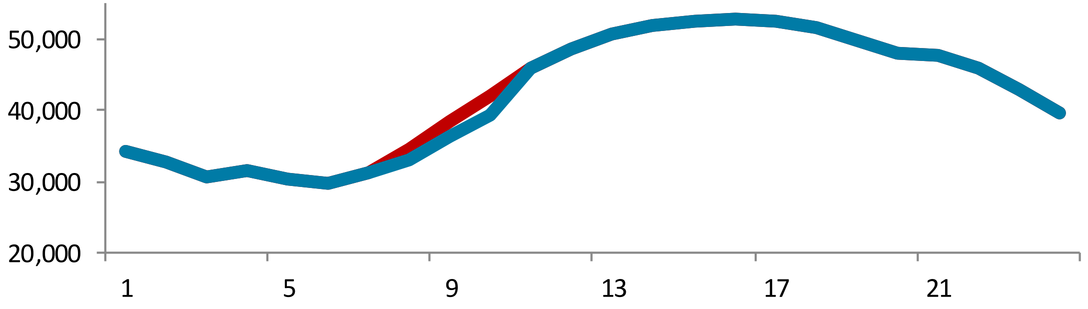


Source: PG&E, SDG&E, Astrape, LLNL and EPRI CES-21 Flexibility Metrics Project

Additional operational flexibility needs

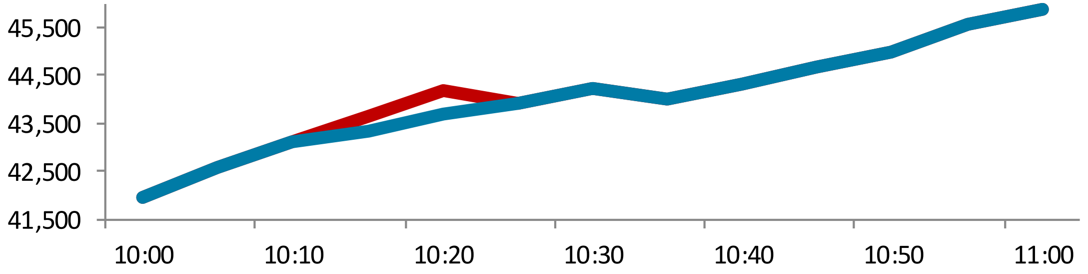
LOLE MULTI-HOUR

Additional metric to capture events due to system ramping deficiencies of longer than one hour in duration

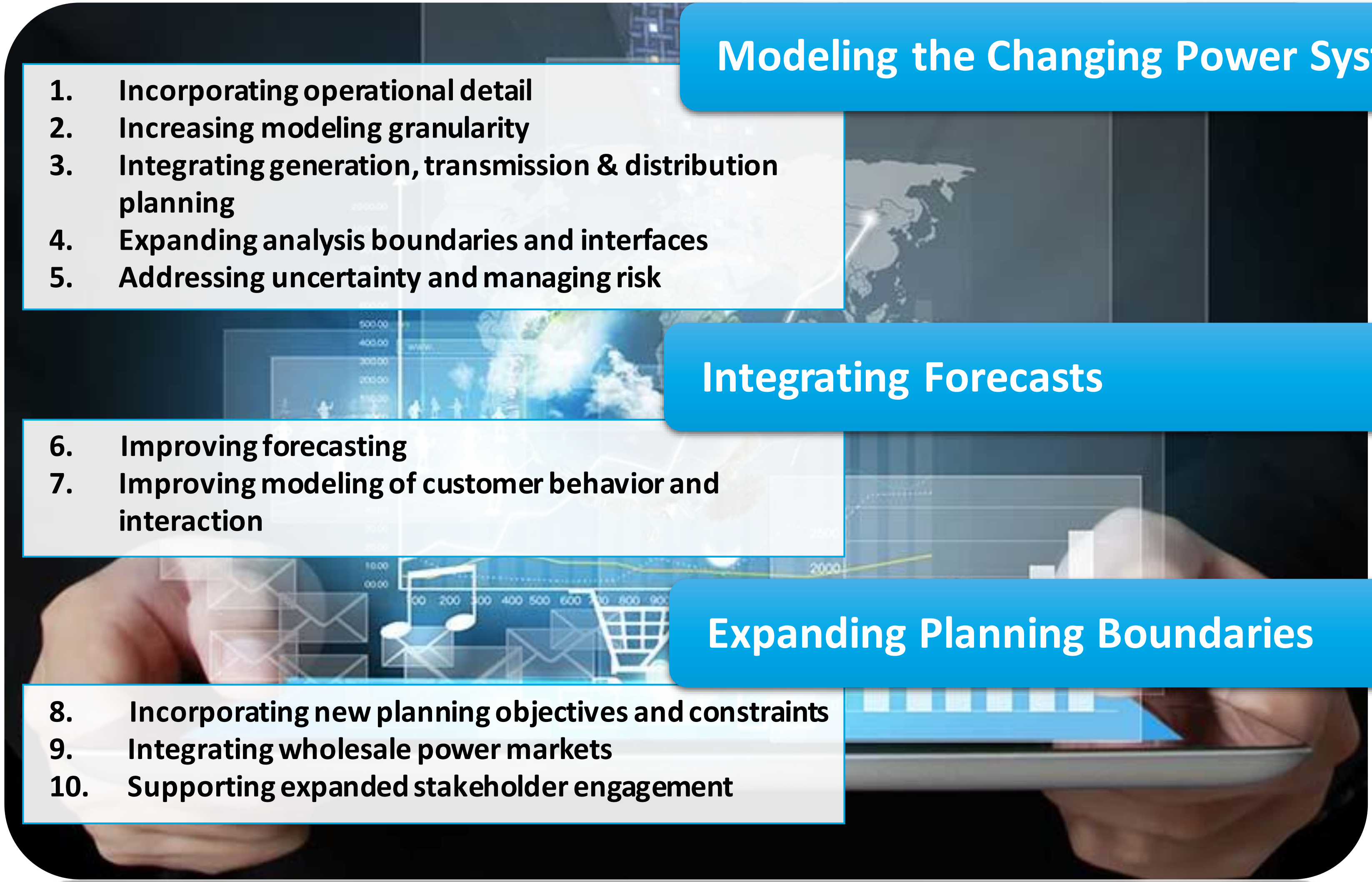


LOLE INTRA-HOUR

Additional metric to capture events due to system ramping deficiencies inside a single hour



The Integrated Energy Network: Resource Planning 10 Critical Challenges



Modeling the Changing Power System

1. Incorporating operational detail
2. Increasing modeling granularity
3. Integrating generation, transmission & distribution planning
4. Expanding analysis boundaries and interfaces
5. Addressing uncertainty and managing risk

Integrating Forecasts

6. Improving forecasting
7. Improving modeling of customer behavior and interaction

Expanding Planning Boundaries

8. Incorporating new planning objectives and constraints
9. Integrating wholesale power markets
10. Supporting expanded stakeholder engagement

More at November ESIG webinar!

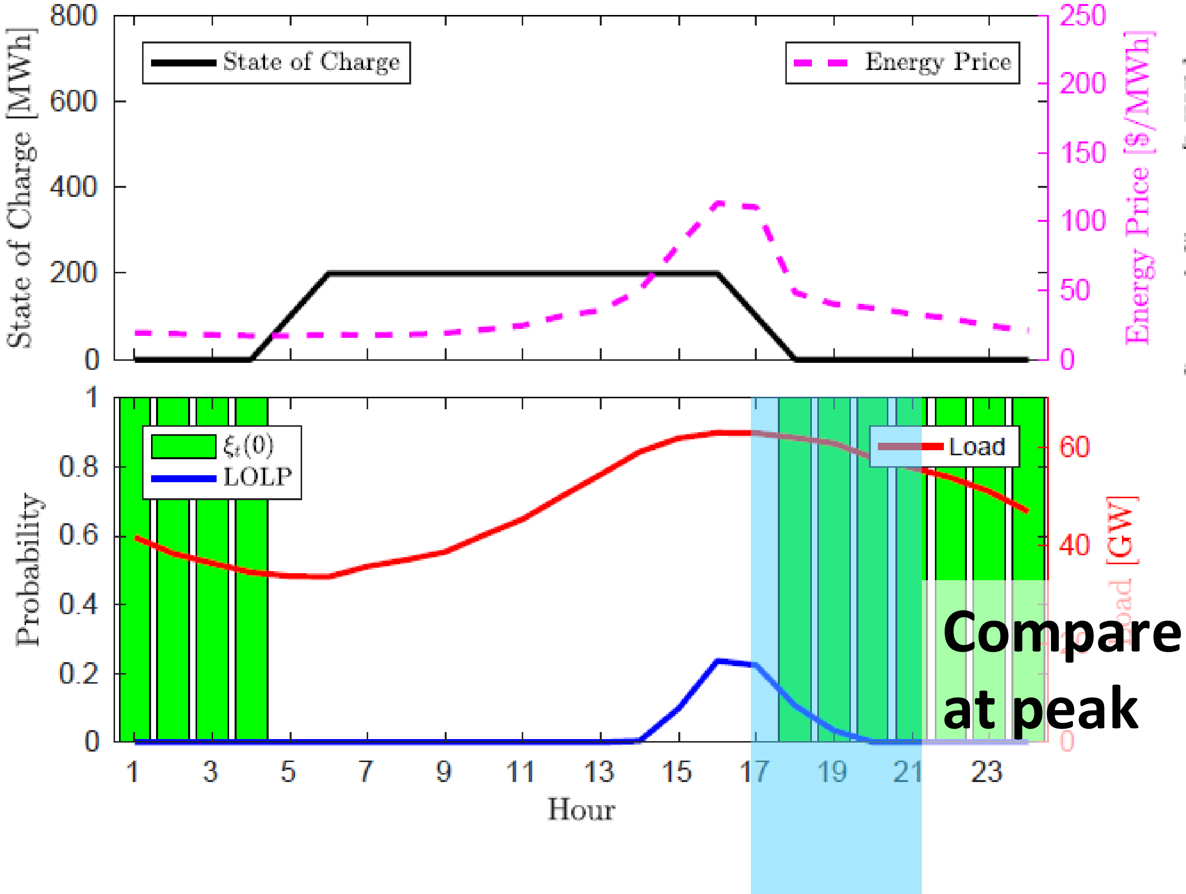
Summary

- Resource Adequacy is an important part of system reliability
  - Methods, tools for traditional RA well understood
  - Can be used for different studies, processes and market products
- Different metrics and methods have strengths and weaknesses
  - Data intensity, complexity, effectiveness in identifying issues, etc. all play into what metrics should be used and when
  - Resource contributions can be calculated, including emerging resources
- New methods might be needed with changes happening to the system

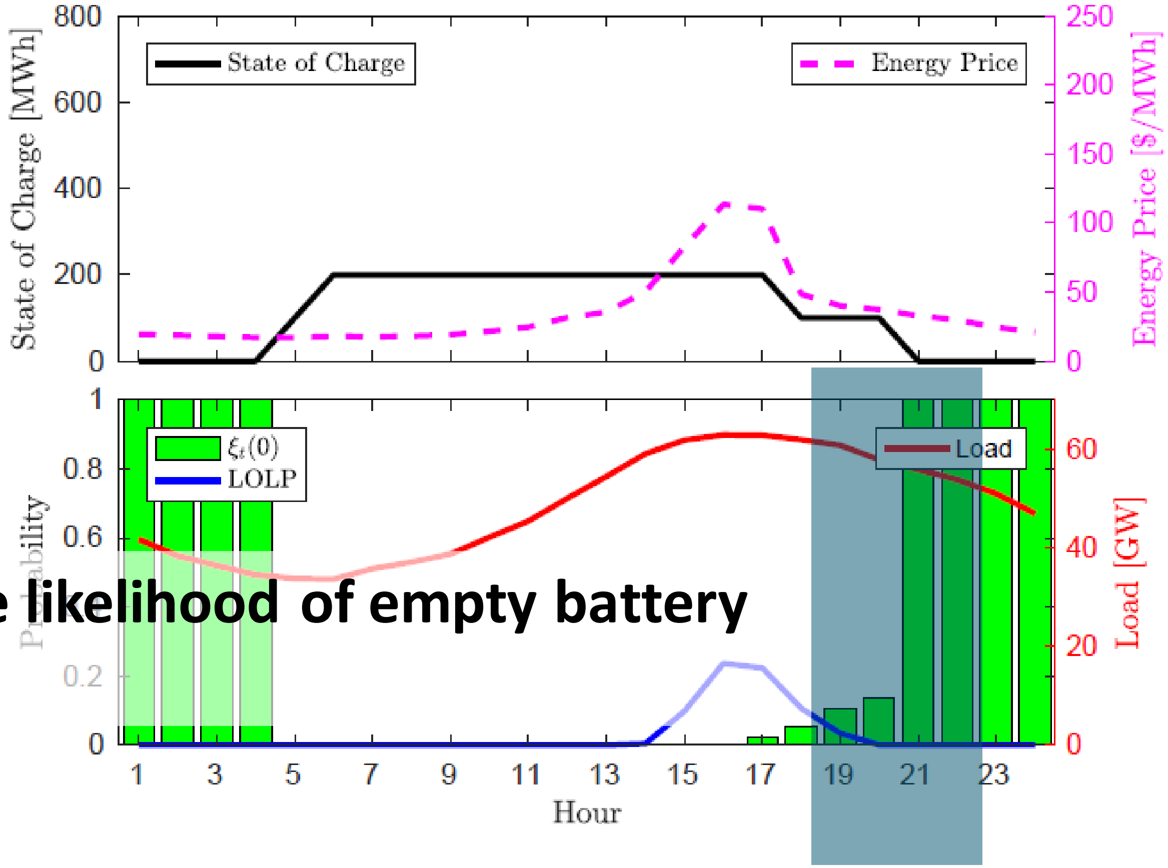
Together...Shaping the Future of Electricity

Storage Behavior Influenced By Incentives

Penalty for Unavailability During Event = $0/MW-h



Penalty for Unavailability During Event = $9,000/MW-h



Compare likelihood of empty battery at peak

Storage Capacity Contribution

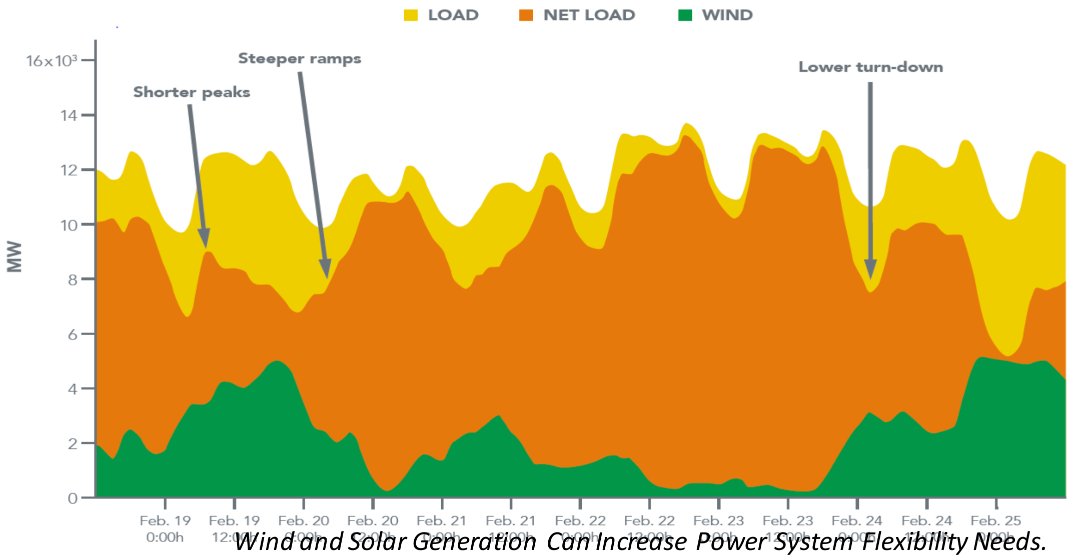
Increasing Penalties for Unavailability

Increasing Duration

Duration	No Penalty	1000 $/ MWh Penalty	$5000 / MWh Penalty	$9000 / MWh Penalty
1 hr	32-42%	81-83%	89-91%	92%
2 hr	60-67%	89-95%	96%	98%
4 hr	81-92%	100%	100%	100%
6 hr	95-97%	100%	100%	100%
8 hr	95-100%	100%	100%	100%

Example: Incorporating Operational Detail

- Evaluate and address potential reliability impacts (e.g., frequency response, voltage stability and short circuit considerations) associated with the changing resource mix.



Wind and Solar Generation Can Increase Power System Flexibility Needs.
Source: Flexibility in 21st Century Power Systems, 21st Century Power Partnership.

- It is becoming more important to incorporate operational reliability capabilities (e.g., ramping rates, minimum generation levels), and adverse interactions (e.g., variability, uncertainty, active and reactive control capabilities) into resource planning.

- Existing resource adequacy metrics (e.g., LOLE) may not be the “best” or only metric to use to measure electric reliability.

How Well Each Model Class Assess Supply Risk Drivers?

Risk	LOLE Models	Production Cost Models	Hybrid PCM / RA models
Peak Demand	Well	Well	Well
Inter-annual variability	Well	Somewhat	Well
Operational variability	Poorly	Well	Well
Operational uncertainty	Absent	Somewhat - Well	Somewhat
Elastic demand	Poorly	Somewhat - Well	Somewhat
Energy Storage / Energy limited resources	Poorly	Somewhat - Well	Somewhat – Well
Generator cycling damage	Poorly	Somewhat - Well	Somewhat
Fuel supply	Somewhat	Poorly – Somewhat	Poorly
Maintenance outages	Somewhat	Somewhat	Somewhat - Well
Deliverability	Absent	Somewhat - Well	Somewhat

Data Intensity	Low	High	V. High
Computational Time	Low	V. High	Med

What are the key issues/challenges you would like to know more about or discuss with the panel?

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