Technical Information Session: Resource Capacity Contributions to Resource Adequacy

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Introductory remarks

Today's discussion is expositional and educational

- We would like to share the ISO's understanding and perspectives regarding resource capacity accreditation, and
- We would like to hear your thoughts and observations on the subject

Resource adequacy assessment

- Broadly speaking, the term ‘reliability’ encompasses many distinct issues, including:
  - Stability (e.g., voltage, VARs, etc.)
  - Operating reserves and contingency response
  - Resource adequacy
- The focus of today’s discussion is resource adequacy *assessment*
  - Resource adequacy *assessment*: How to assess (measure) resource adequacy, prospectively (on a planning horizon)
  - Today’s discussion is intended to be a primer for any subsequent discussions on how to design mechanisms to *achieve* and ensure resource adequacy

Topics to be covered today

- A review of the traditional resource adequacy assessment process
- A primer on capacity accreditation concepts
- Considerations regarding efficient markets and market signals
- Some additional industry materials on this topic

TRADITIONAL RESOURCE ADEQUACY ASSESSMENT PROCESS

This section describes, at a high-level, some of the inherent presumptions within the current resource adequacy process

The traditional resource adequacy assessment

- Generally speaking, the resource adequacy assessment process consists of:
  a) quantifying the contributions of resources (*i.e.*, capacity) to meet,
  b) a specific aggregate target unserved energy ("loss of load") metric, for a specific (future) time period or planning horizon, using
  c) a specified quantitative methodology
- In practice, this requires the use of models and considerable data on many inputs

(a) Quantifying the contributions of resources

- In New England, currently, that measure is a resource's qualified capacity value
  - Conceptually, it is intended to represent the (expected) contribution of a resource toward meeting the system's annual Loss of Load Expectation (LOLE) target

- These values are, currently, empirically determined using different methods, *for example*:
  - Traditional (non-intermittent) resources – based on the resource's demonstrated maximum output capability and (forced) outage rates
  - Variable (intermittent) resources – based on the resource's average historical output during predetermined "reliability" hours (when loss-of-load is anticipated to be a possible risk)

<u>Observations</u> on quantifying the contributions of resources

- Inherent in this approach is **the presumption that all qualified capacity MW are perfectly substitutable**
  - That is, each MW of qualified capacity contributes to resource adequacy *equally*, regardless of which resource provides it
- A key issue is **the existing qualified capacity approach does not depend on the resource *<u>mix</u>***, *i.e.,* what *<u>else</u>* is on the system
  - With evolving technologies, this presumption is (increasingly) questionable
- This approach also **presumes that a resource's contribution to resource adequacy is (fairly) static, year-to-year**
  - That is, provided a resource's capability is not seriously impaired, its qualified capacity will remain (largely) unchanged auction to auction

(b) Specific target loss of load metric

- New England's target metric is the system's Loss of Load Expectation (LOLE) - an NPCC standard
- The target is not, *fundamentally speaking*, a specific amount of (qualified) MW, or a specific planning reserve margin (%)

(c) Specified methodology

- In practice (currently), the target LOLE value is represented as a total (qualified) capacity MW amount (*i.e.*, the Installed Capacity Requirement, ICR)
- <u>Observation</u>: Inherent in this approach is the presumption that all qualified capacity is substitutable (*i.e.*, each MW of qualified capacity has an identical impact on the system's annual LOLE value)
  - That further presumes that as long as the ICR is satisfied with qualified capacity, **the mix of resources comprising that capacity will have no bearing on the system's LOLE (*i.e.*, ICR)**
  - With evolving technologies, this presumption is (increasingly) questionable

Some early takeaways

- Resource qualified capacity values are *intended* to reflect a resource's contribution to the system's resource adequacy objective (the LOLE target)
- Resource qualified capacity values are currently presumed to be independent, relatively static, and (perfectly) substitutable
  - **Static** in the sense capacity values (generally) don't change auction-to-auction
  - **Independent** in the sense capacity values are a function of the resource's capability *alone*, and not dependent on the remaining resource mix on the system

Increasing concerns with the traditional approach

- With the increasing participation of non-traditional resource technologies there are growing concerns within the industry regarding these inherent, historical presumptions
- Concerns revolve around the possible consequences of maintaining the status quo, such as:
  - The possibility of an **energy deficiency** (unserved demand) more frequently than the loss-of-load target stipulates, despite there being enough qualified capacity 'on paper' or 'in the resource adequacy model'
  - **Inefficient market signals;** compensation that fails to reflect resources' *actual* contribution to the system's resource adequacy target

Not all resources have the same stochastic characteristics

- The output profile for conventional generating resources is (currently) represented by the resource's maximum demonstrated capability and equivalent forced outage rate (EFORd)
  - Presumption: These characteristics (*alone*) accurately represent the output profile of *all* conventional generating resources
  - Presumption: A resource's performance is independent of other resources
- The output profile for non-conventional resources is different, and inherently depends on its particular stochastic 'flow' (time-path) of its *input* energy (wind, solar, etc.)
  - Presumption: The output profile for these resources can be approximated by the resource's average output over a predefined set of hours, for example
  - Presumption: A resource's performance is independent of other resources
- Fundamentally, resource output profiles should – are intended to – accurately reflect a resource's contribution to the system's resource adequacy objective (LOLE target)

RESOURCE CAPACITY ACCREDITATION

This section describes, at a high-level, resource accreditation concepts, including factors influencing the accuracy of such approaches

NOTE: The explanations and examples in this section are for illustrative purposes only, and should not be interpreted as proposals or complete methodologies

Three different ways to assess capacity contributions to system resource adequacy

- **Heuristics**. Current accreditation methods in New England (*i.e*., qualified capacity) are based on heuristics
  - For example, the qualified capacity of an intermittent resource is based on historical average output in a predetermined set of hours

- **Effective Load Carrying Capability (ELCC).** A resource's ELCC value measures the equivalent amount of additional load the system could serve ("carry") with the resource (versus without it), while meeting the same LOLE target
  - ELCC is commonly alternatively measured as the amount of 'perfect capacity' needed to serve load *without* the (entire) resource under evaluation
(one MW of 'perfect capacity' produces exactly 1 MWh of energy, with probability 1, in every hour)

- **Marginal Reliability Impact (MRI).** A resource's MRI value measures the <u>incremental</u> impact of its 'last' MW on system LOLE, relative to the incremental impact of 'perfect capacity'

Unlike heuristics, both ELCC and MRI approaches <u>derive</u> capacity values

ELCC and MRI methodologies consider contributions to resource adequacy more holistically

- The objective of ELCC/MRI is to *better* measure the (expected) contribution of a resource class to the system's annual Loss of Load Expectation (LOLE)

- ELCC/MRI methodologies <u>derive</u> capacity value using a probabilistic loss-of-load simulation model
  - They do not rely on heuristics, as does our current practice

Applying ELCC and MRI techniques requires a model

In the next few slides:

- *We first discuss how a model would be used*
  - *Note: Typically, ELCC/MRI techniques are done by resource class (e.g., all wind resources), and the class ELCC/MRI values then applied to each resource within that class*
- *Then we will review a simple illustration of each technique, including:*
  - *The 'effective load' approach to calculate ELCC values*
  - *The 'perfect capacity' approach to calculate ELCC values*
- *We will then discuss factors that influence the accuracy of these approaches*
- *In the next section we discuss the difference between (average) ELCC values and MRI values*

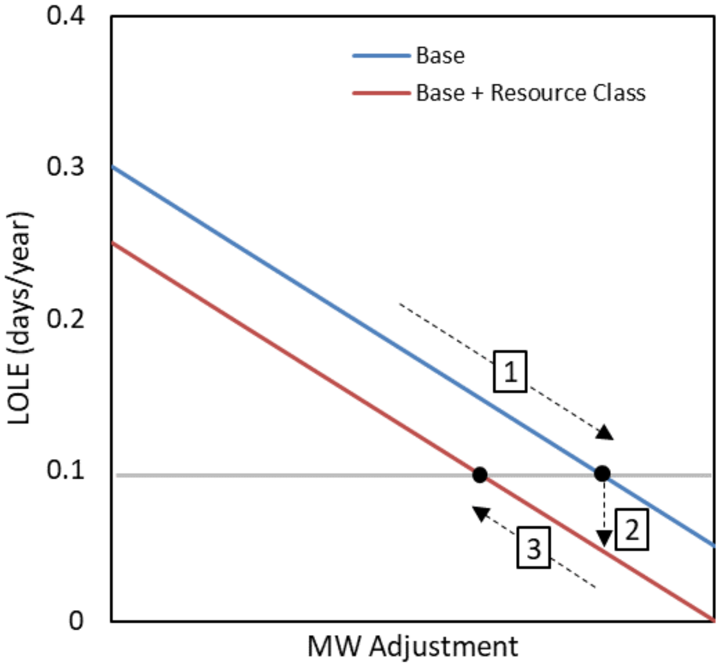
ELCC/MRI approaches rely on a probabilistic modeling tool

- For example, MARS (Multi-Area Reliability Simulation) is a stochastic (a.k.a. Monte Carlo) model that simulates load and resource outage conditions to estimate the likelihood of loss-of-load events
  - MARS, as used currently, simulates outages for conventional generators (*e.g*., CCGT)
- *In principle*, the MARS model could be used to determine ELCC/MRI values for different resource classes
  - For example, wind resources could be modeled *if* the model were (instead) provided relevant wind/weather data and the nameplate capability of (all) wind resources

Using a model to determine ELCC and MRI values

- Both ELCC and MRI approaches add or remove generation (or load) in different runs of the model
- *Continuing the wind class example*: In each case the model is endogenously determining the expected output of wind resources in each hour, and hence the contribution to the system annual LOLE
  - This is in contrast to the current approach, which presumes the output of the wind resources is already known
  - But we can't see the contribution directly; to do that we need to compare model results *with* vs. *without* the resource class *(as we will see on the next few slides)*

Illustrating the 'effective load' approach to calculate ELCC values



ELCC Steps

1. **Find 0.1 LOLE in Base Case**
   - Base case excludes resource class being examined
2. **Add Resource Class**
   - Reliability will improve with the addition of a new resource class
3. **Adjust Load Until Back at 0.1 LOLE**
   - The addition of load will cause reliability to decline

$$ELCC = \frac{Load\ Added\ (MW)}{Resource\ Class\ Nameplate\ Added\ (MW)}$$

Slide updated on 8/20/2021.

Illustrating the 'effective load' approach to calculate ELCC values

1) Begin with a base case reflecting the expected system resource mix, excluding the resource class being examined (*e.g.*, wind)
   - Decrease load so that LOLE = 0.1 days per year

2) Add the resource class to the base case; total nameplate capability along with its stochastic output profiles (*e.g.,* add 1000 MW of wind resources)
   - Because the system now has more supply, the LOLE will be less than 0.1 (better)

3) Add load to the system (step 2) until LOLE returns to 0.1
   - Assume: 300 MW of load was added to bring the system back to LOLE = 0.1

The (average) ELCC of the resource class is the ratio of the load added, relative to total nameplate quantity of the resource class added

- In this example, the ELCC ratio for wind would be 0.3 = 300 MW / 1000 MW

Illustrating the 'perfect capacity' approach to calculate ELCC values

1) Begin with a base case reflecting the expected system resource mix, including the nameplate capability of the resource class being examined along with its stochastic output profiles (*e.g.,* 1000 MW of wind resources)
   – Increase load so that LOLE = 0.1 days per year

2) Remove the resource class from the base case (*i.e.*, remove the 1000 MW of wind resources)
   – Because the system now has less supply, the LOLE will be above 0.1 (worse)

3) Add 'perfect capacity' to the system (step 2) until LOLE returns to 0.1
   – Assume: 300 MW of perfect capacity was needed to bring the system back to LOLE = 0.1

The (average) ELCC of the resource class is the ratio of the perfect capacity added, relative to total nameplate quantity of the resource class removed

– In this example, the ELCC ratio for wind would be 0.3 = 300 MW / 1000 MW

Illustrating the marginal approach (MRI)

1) Begin with a base case reflecting the expected system resource mix, including the nameplate capability of the resource class being examined along with its stochastic output profiles (*e.g.*, wind)
   - Increase load so that LOLE = 0.1 days per year

2) Add to the base case an ***incremental*** amount of nameplate capability for the resource class being examined (*e.g.*, add 10 MW of wind)
   - With more supply, the system LOLE will be less than 0.1 (*e.g.*, new $LOLE_2$ = .095*)

3) Separately, add to the base case the same ***incremental*** amount of 'perfect capacity' (10 MW)
   - With more supply, the system LOLE will also be less than 0.1, but by a different amount than in step 2 (*e.g.*, $LOLE_3$ = .08*)

The MRI of the resource class is the ratio of the change in LOLE in step 2 to the change in LOLE in step 3 [MRI = (0.1 – $LOLE_2$) / (0.1 – $LOLE_3$)]**
   - In this example, the MRI ratio for wind would be 0.25 = 0.005 / 0.02

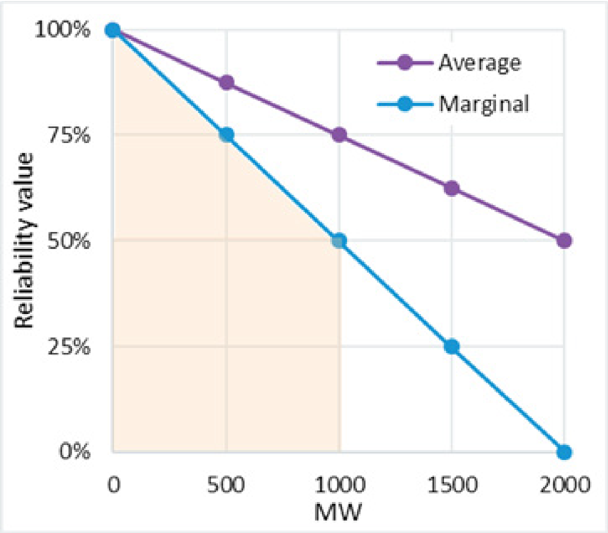
** The LOLE values in this example are for illustrative purposes only*

*** See EMM 2020 Assessment of ISO-NE Markets*

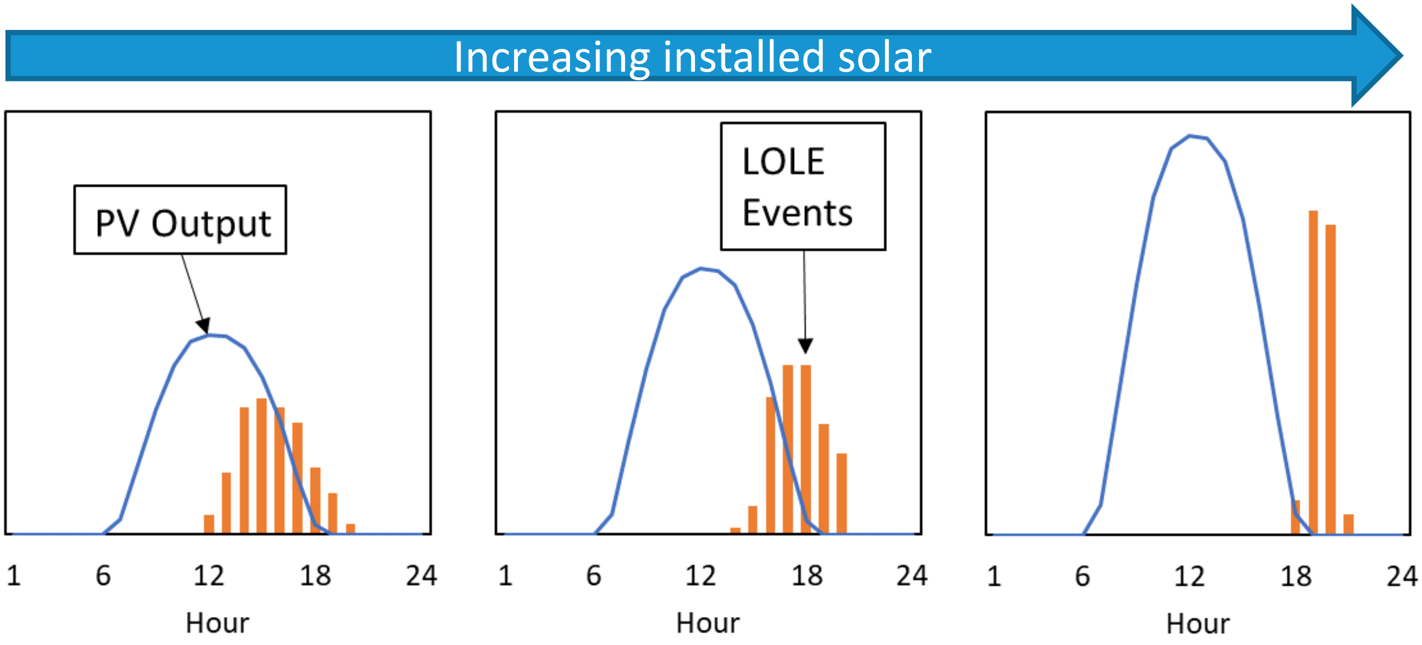
Illustrating the difference between average and marginal value

Assume a class total = 1000 MW (nameplate)

- For simplicity, assume the MRI is linear:
  - The 1st MW MRI ratio is 1.0 (100%)
  - The 1000th MW MRI ratio is 0.5 (50%)
  - The 2000th MW MRI ratio is 0.0 (0%)
- The aggregate class value, the (average) ELCC ratio for all 1000 MW, is 0.75 (750 MW)
  - Illustrated by the shaded area under the *marginal* value curve
- As penetration increases, ELCC/MRI values decrease
  - Aggregate resource class penetration is outside the control of any individual resource



Decreasing contributions to resource adequacy



As more solar is installed, reliability events shift to different hours

Accuracy depends on modeling key factors

To determine either ELCC or MRI values, the model must capture key factors that impact resource contributions to resource adequacy

- Diminishing returns: As the penetration of a given resource class increases (*e.g*., solar), the class contribution to resource adequacy may decrease
- Diversity benefits: Synergies among resource classes may improve the combined contribution to resource adequacy (*e.g*. a combination of solar and batteries may contribute more to resource adequacy than either class alone)
- Correlated effects: Contributions are not independent across all resources (*e.g.,* when it is windy in New England, most wind resources will be generating)
- Common input energy limits: Constraints on the aggregate supply of input energy to a set of resources (*e.g.,* a constrained gas pipeline serving multiple generators)

Accuracy also depends on modeling all resource classes *concurrently*

- To accurately derive ELCC/MRI values for any one class, the model should take into account the expected mix of *<u>all</u>* resource classes
  - All other resource classes should (ideally) be modeled in the same simulation process and in the same fashion (*i.e.,* not assuming fixed qualified capacity values)
  - Including both 'new' and 'existing' resources
- <u>Observation</u>: It is impossible to know with complete precision *before the auction* what resources will be awarded capacity obligations in the auction
  - Thus, the accuracy of ELCC/MRI values determined prior to the auction will likely be impacted by entry/exit in the auction

Takeaways

- A model is used to ***derive*** resource capacity values
  - Consequently, corresponding new model (input) data for each class is needed
- Conceivably, any resource/technology class could be evaluated provided that:
  - The corresponding relevant input data is available, and
  - The simulation model is capable of emulating the class's operational capabilities
- ELCC/MRI values:
  - Are sensitive to the robustness (completeness) of the simulation model
  - Are not strictly analogous to current qualified capacity values; ELCC/MRI ratings can change (*e.g*., due to changes in the class's penetration level)
- Observation: ELCC/MRI values may be different from one auction to the next (*i.e.,* FCA to FCA, FCA thru ARAs)

EFFICIENT MARKETS

In this section we discuss the market implications when interpreting ELCC/MRI values

<u>Observation</u>: Currently, each MW of qualified capacity is *presumed* to be perfectly substitutable

- However, in terms of actual contributions to resource adequacy (*i.e.*, the LOLE target) the marginal impact of one resource's contribution may not be the same as the marginal impact of a different resource's contribution
- The system LOLE is (becoming) a function of <u>both</u> the aggregate capacity level <u>and the particular resource mix</u> (reflecting diminishing returns and diversity benefits)

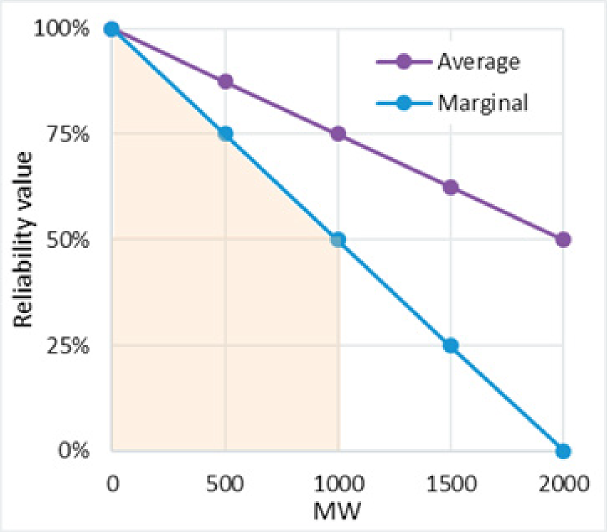
Practical considerations regarding aggregate supply and individual resource accreditation

- **Aggregate reliability contribution**
  - How many total MW of capacity from the class are counted as aggregate supply?
  - Should we take an average or marginal approach?
- **Individual resource accreditation**
  - How should a class adjustment be applied to individual resources?
  - Should we take an average or marginal approach?
- *In the next few slides, using a simple numerical example, we will examine more closely the difference between average and marginal values, and how each influences market efficiency and market signals*

A simple numerical example

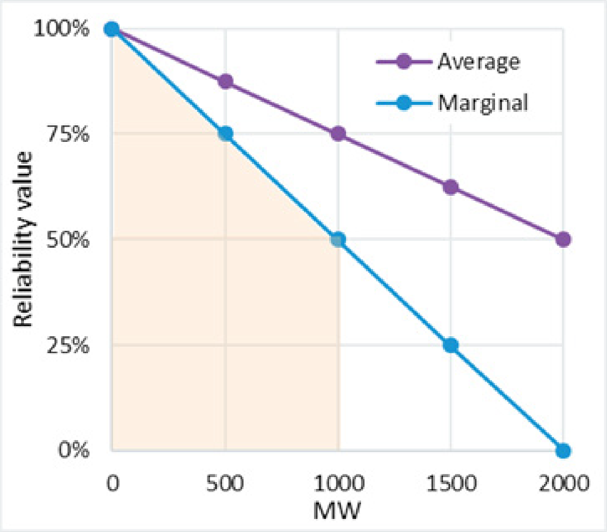
Assume a class total = 1000 MW (nameplate)

- For simplicity, assume the MRI is linear:
  - The 1st MW MRI ratio is 1.0 (100%)
  - The 1000th MW MRI ratio is 0.5 (50%)
  - The 2000th MW MRI ratio is 0.0 (0%)
- The aggregate class value, the (average) ELCC ratio for all 1000 MW, is 0.75 (750 MW)
  - Illustrated by the shaded area under the *marginal* value curve



<u>Observations</u>: Average v. marginal contributions

- <u>On average</u>, the first 1000 MW is equivalent to 750 MW of 'perfect capacity'
- However, the class's contribution <u>at the margin</u> is lower
- The contribution of the marginal (1000th) MW has an MRI ratio of 0.5, equivalent to 0.5 MW



While the average is useful for aggregate resource adequacy assessments, this is not so with respect to individual resource accreditation

Efficient market signals (marginal v. average)

- In the example, basing compensation on average value would create a market signal suggesting that:
  - Adding another MW will provide as much value as 0.75 MW of 'perfect capacity'
  - When adding another MW will only *actually* provide as much value as 0.5 MW of 'perfect capacity'
- That would produce auction results that are not cost-effective (*i.e.*, economically *inefficient*)
  - If we use average contributions, at the auction's solution there would be another way to procure more of the undervalued resource, and less of the overvalued resources, to achieve the same level of reliability, at lower cost

Efficient markets (marginal v. average)

- Using the average rather than the marginal value as a basis for compensation has familiar market problems, here as in other contexts:
  - This would tend to overvalue some resources and undervalue other resources
- This same cost-effectiveness logic and corresponding market signal/compensation rationale is why the demand-side of the annual capacity auction uses the MRI-based framework
  - MRI-based resource capacity contributions would extend the same marginal value concepts to the supply side – same logic, same rationale

INDUSTRY SURVEY

Related materials: Other RTOs

- ELCC Rules at other ISO-RTOs PJM Capacity Capability Senior Task Force, April 7, 2020
- How Effective Load Carrying Capability ("ELCC") Accreditation Works. PJM Planning Committee Special Session, April 20, 2021.
- Effective Load Carrying Capacity and Qualifying Capacity Staff Proposal Resource Adequacy Proceeding R.11-10-023 California Public Utilities Commission – Energy Division January 16, 2014
- Estimation of the Market Equilibrium and Economically Optimal Reserve Margins for the ERCOT Region for 2024 Final report, Astrapé Consulting, January 15, 2021
- MISO Renewable Integration Impact Assessment (RIIA) Summary Report, February 2021
- 2019 State of the Market Report for the New York ISO Markets Potomac Economics, May 2020
- PJM: **FERC Order 175 FERC 61,084**
- **Southwest Power Pool (SPP) ELCC Technical Discussion** Supply Adequacy Working Group

Industry materials

- NERC
  - Methods to Model and Calculate Capacity Contributions of Variable Generation for Resource Adequacy Planning Integration of Variable Generation Task Force, IVGTF; April 2011
  - Probabilistic Adequacy and Measures - Technical Reference Report FINAL NERC Probabilistic Assessment Working Group, July 2018
- IEEE
  - **Effective Load Carrying Capability of Generating Units**, L.L. Garver, IEEE 1966
  - **Adequacy and Responsibility of Locational Generation and Transmission - Optimization Procedures** Narayan S. Rau and Fei Zeng, November 2004

CONCLUSION

Key takeaways

- Currently, resource qualified capacity values are presumed to be independent, relatively static, and (perfectly) substitutable
  - Alternatively, a model could be used to ***derive*** resource capacity values (ELCC/MRI values)
- ELCC/MRI values:
  - Are sensitive to both the size of each class (diminishing returns), and what *other* classes are included in the model (diversity benefits, correlated effects)
  - Are not analogous to the current determination and utilization of qualified capacity values, and can change due to circumstances outside the control of the resource
- Marginal-based capacity contributions:
  - Are more consistent (than average-based approaches) with economic principles and cost-effective outcomes
  - Are consistent with the existing MRI-based framework on the demand side of the capacity market