Capacity Value Accreditation Concepts in the Reliability Pricing Model (RPM)

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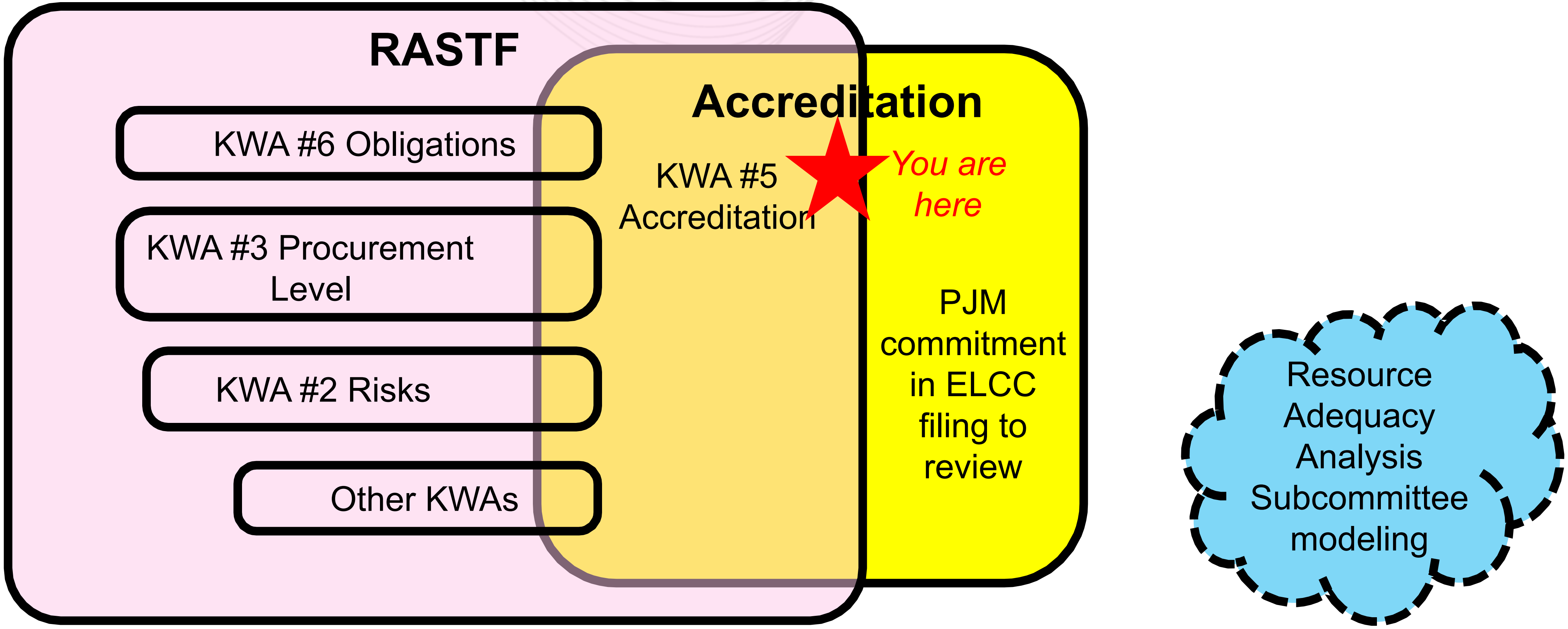
RASTF
KWA #6 Obligations
KWA #3 Procurement Level
KWA #2 Risks
Other KWAs
Accreditation
KWA #5 Accreditation
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PJM commitment in ELCC filing to review
Resource Adequacy Analysis Subcommittee modeling

(For Reference: Explanation of Prior Slide)

- Accreditation discussion taking place at the RASTF as part of Key Work Activity (KWA) #5 will also cover PJM's commitment to review ELCC as part of the final ELCC FERC filing.
- Accreditation discussion also interacts with RASTF KWA #2 (risks), KWA #3 (capacity procurement), KWA #6 (obligations), and other KWAs.
- Accreditation discussion also potentially interacts with the Resource Adequacy Analysis Subcommittee, which manages the capacity market risk models such as PRISM and ELCC.

Why Accredit Capacity Value? Two Potential Views.

Potential View 1: Through the capacity market ("RPM"), PJM commits a physical firm service level to loads.

1. The firm service is necessarily planned/quantified ex ante, which requires ex ante quantitative assessment of suppliers (i.e., capacity accreditation) and demand.
2. Suppliers paid the amount of accredited capacity they contributed to provision of the firm service.
3. **Thus, accreditation is how you count how much product is provided by a supplier (and how much can be offered). Unaccredited capacity <u>does not exist</u>.**

Potential View 2: The penalty/bonus structure of capacity performance makes RPM analogous in some ways to a market for supplier hedges against shortage. Why limit the quantity of hedge that sellers can sell?

A. How do penalties compare with capacity revenues?
B. What would the right collateral be for the credit risk of a pure-financial shortage hedge supplier?
C. How do A & B interact with incentives to sell physical hedges vs. financial-only? How would a non-physical hedge position impact PJM given its role?
D. **Accreditation limits sales only to physical hedges (excluding financial-only).**

Terms for Reference

- Fossil generators = coal, oil, gas. Can be steam turbine, gas turbine, recip, or combined cycle.
- Thermal generators = fossil generators + nuclear.
- Readily deployable, long-run-time generators = thermal generators (except materially run-time limited) + long duration storage (>24 hrs, e.g., some hydro). This group is currently called “Unlimited Resources”.
- Readily deployable generators = thermal generators + limited duration resources (including above and below 24hrs) + Combination Resources.
- Readily deployable resources = readily deployable generators + demand response.
- Variable resources = generators whose availability varies constantly with weather, i.e.: wind, solar, intermittent hydro.
- Limited duration resources = generators with a limited run time that impacts their reliability. (Currently set at < 24 hours). Includes storage. Concept could include run-time limited thermal generators.
- Storage = Limited Duration Resources that must recharge with electric energy.
- Combination Resources = any combination of Unlimited, Variable, and Limited Duration.

Readily deployable, long-run-time generators[†] (aka "Unlimited Resources"):

- **Capacity value = "UCAP" = ICAP*(1-EFORd)** [††]
- ICAP = Installed Capacity = power capability as rated under typical summer peak load conditions.
- EFORd is a measure of unavailability over the last year.

Renewables/storage ("ELCC Resources"):

- **UCAP → EffectiveNameplateMW*ClassRating*PerformanceAdjustment**
  - Actual formula can be a slight variation on this depending on e.g. wind/solar vs. battery vs. hybrid vs. hydro etc.

† E.g., nuclear, coal, oil, gas, etc. Can include long-duration (> 24hrs) storage, e.g. hydro.
†† UCAP is the commodity that is bought and sold in the capacity market. It comes from the term "Unforced Capacity", which is a generator-related term that means "installed capacity that is not on average experiencing a forced outage".

- Status Quo†

  Firm Service Level Customers (FSL)

  - UCAP = (Peak Load Contribution – Firm Service Level)*(1+FPR) ††

  Guaranteed Load Drop Customers (GLD)

  - UCAP = (Guaranteed Load Reduction Amount)*(1+FPR)

- Seasonal considerations
- Potential impact of limited hour windows for interruption capability †††

†Annual capability is determined as the lesser of the summer and winter period capabilities. Excess summer capability may be offered as summer period CP

†† FPR = "Forecast Pool Requirement", it is the excess UCAP that is purchased to cover (mainly) unusually high load, but also overlapping outages, ambient derates, etc. It is on the order of 10%.

†††Must be capable of an unlimited number of interruptions between 10:00AM - 10:00PM ET in summer and 6:00AM - 9:00PM in winter.

Considerations for Accreditation

Capacity addresses loss-of-load risk. Risk is during times of high load and/or low supply.

Capacity accreditation reflects availability during times of risk.

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Thermal: ICAP = unit’s available MW during typical summer peak hours.

- ICAP reflects the hottest day of a typical year, and so (given physics of thermal generators) is generally slightly derated vs. capability on less hot days.
- The reverse is also true: ICAP is slightly too high vs. capability on an exceptionally hot day.
- ICAP is premised on summer peaking characteristic of current and historical PJM system. (Winter capability could be higher than ICAP for many thermal units).
- EFORd derates ICAP→UCAP to account for random average unavailability due to forced outage.
- Ambient derate procedure procures more UCAP on the demand side (via FPR) to account for unavailable ICAP MW during summer peak hours that are hotter than a typical year’s summer peak hour.
- More UCAP procured on the demand side (via FPR) to account for unavailability from other outage effects (maintenance, overlapping outages above average, etc.)

Interpretation of Status Quo

Capacity accreditation reflects availability during times of risk.

- Renewables/storage: ELCC statistically measures available MW during risk periods based on an hourly output profile to produce a class rating factor. Uses historical weather/load/wind/solar/hydro over many years.
  - Analyzes all hours of many simulated years—does not presume when peak risk occurs (both seasonal but also hour of the day).
  - Effective Nameplate Capacity is the size of a unit in megawatts.
  - Performance Adjustment for Variable Resources uses a simplified performance metric related to ELCC, comparing a unit’s metric to the class-average metric.
  - Readily-deployable ELCC Resources like storage are modeled in ELCC without outages, and receive an EFORd-based derate downstream.

Capacity accreditation reflects availability during times of risk.

- Demand Response adjustment for Forecast Pool Requirement:
  - Forecast Pool Requirement procures more UCAP mainly to cover the risk of unusually high load.
  - On unusually high load days, customers are consuming more. They have to therefore curtail more to get to their firm service level.
  - Unusually high load days are the high risk days.
  - Put another way: PJM does not need to procure extra capacity reserves for a customer that promises to reach a given firm service level regardless of the temperature.

Considerations for Accreditation (Outline)

Capacity addresses risk of load shed & shortage. Risk is during times of high load and/or low supply.

Capacity accreditation reflects availability during times of risk.

1. Principle: allocation of supply risk to supply
2. How to model risk
   a) Simulating expected weather dependence of supply and demand risk. Capturing coincidence of weather and outage patterns.
   b) Look back period to capture full expected weather distribution and expected resource performance.
3. How to accredit: differentiating among suppliers
   a) Class-based vs. unit-specific modeling
   b) Look-back periods for class vs. unit models
   c) Marginal ELCC vs. average-total ELCC

Status Quo Quantification and Allocation of Risk

Demand side (VRR curve)

- Unusually high load
- Normal overlapping forced outages
- Other outages (planned etc.)
- Higher outages in winter
- Ambient derate outages

Supply side (capacity value accreditation)

- Unit forced outage risk
- Variable Resource risk (wind/solar etc).
- Limited duration supply capability risk

PRISM model

EFORd method

ELCC model

Supply risk

Demand risk

What if Supply Risk Were Allocated to Suppliers?

Demand side (VRR curve)

- Unusually high load

Supply side (capacity value accreditation)

- Unit forced outage risk
- Variable Resource risk (wind/solar etc).
- Limited duration supply capability risk
- Normal overlapping forced outages
- Other outages (planned etc.)
- Higher outages in winter
- Ambient derate outages

PRISM model

EFORd method

ELCC model

TBD model

Supply risk

Demand risk

Status Quo

Modeling, Data Source, and Look Back of Risk Quantification

Demand side (VRR curve)

Peak load distributions back 10 or 11yrs
Unusually high load

5 years of fleet outage data
Normal overlapping forced outages

5 years of fleet outage data
Other outages (planned etc.)

Back to 2007/08, excl. 2013/14
Higher outages in winter

Single scenario
Ambient derate outages

Supply side (capacity value accreditation)

1-yr unit-specific EFORd
Unit forced outage risk

Fleet modeling back to 2012
Variable Resource risk (wind/solar etc).

Simulated output in conditions back to 2012
Limited duration supply capability risk

PRISM model

EFORd method

ELCC model

Supply risk

Demand risk

Limited Duration Supply Risks Going Forward

Demand side (VRR curve)

Supply side (capacity value accreditation)

Potential for temporary power augmentation at thermal units

Simulated output in conditions back to 2012

Limited duration supply capability risk

Potential growth in environmentally limited fossil units

PRISM model

EFORd method

ELCC model

Supply risk

Demand risk

How to Accredit: Distinguishing Among Suppliers

a) Class-based vs. unit-specific modeling and rating.
b) Availability/performance: historical actual vs. simulated.
c) Look-back periods for class vs. unit models and ratings.
    a) Longer look-backs can include obsolete data, esp. with physical changes to a unit or fleet. Can be undesirable especially for unit-specific rating.
    b) Longer look-backs capture rare weather patterns. Necessary for risk modeling, currently goes back as far as 2007 for winter outages. Better for class modeling?

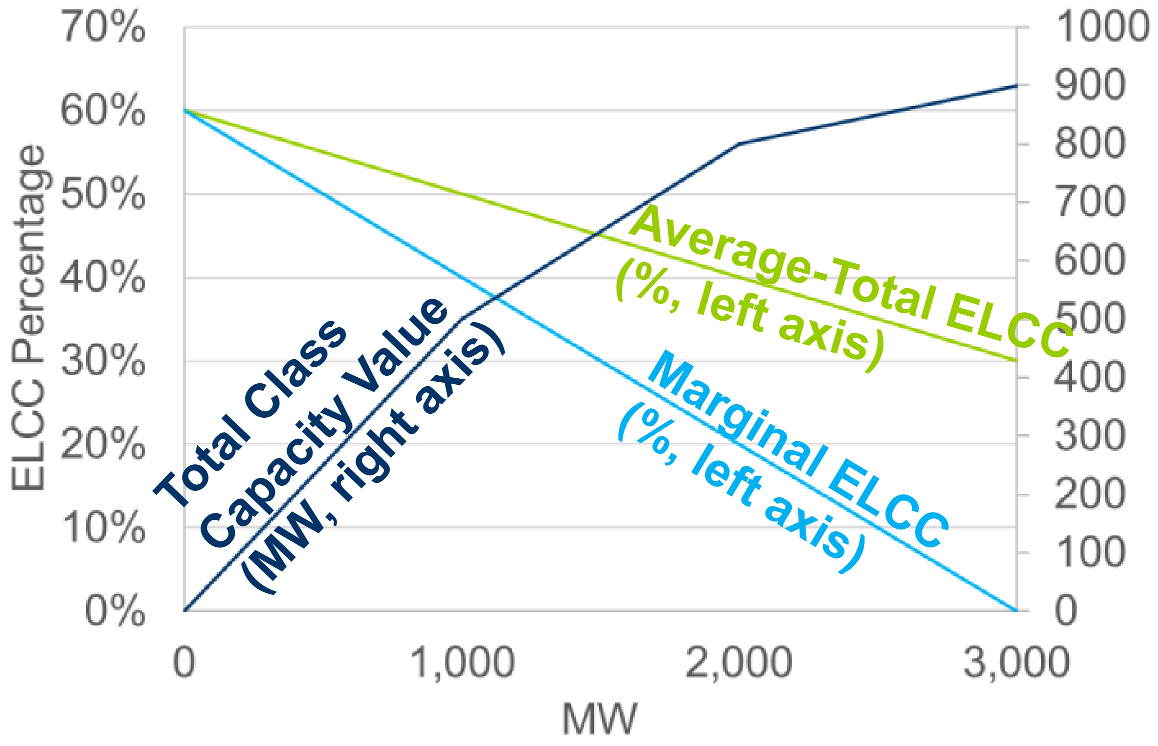
Example of status quo ELCC:

- Hourly profiles by class back to June 1, 2012
- 10 years of unit-specific hourly profile.
- Pros and cons.

Average-Total ELCC vs. Marginal ELCC

- ELCC analysis can identify the equivalent capacity value of all ELCC Resources, or of an entire class, or of a small increment of a class (the latter is the marginal value).
- An average-total approach like PJM's derives class ratings by allocating all of the reliability value of the aggregate of all ELCC Resources using an allocation factor*.
- Marginal sets ratings with the marginal value.

	Total ELCC of Fleet	Avg-Total ELCC Rating	Marginal ELCC Rating
1 MW	0.6 MW	60.00%	60%
1,000 MW	500.0 MW	50.00%	40%
1,001 MW	500.4 MW	49.99%	40%
2,000 MW	800.0 MW	40.00%	20%
2,001 MW	800.2 MW	39.99%	20%
3,000 MW	900.0 MW	30.00%	0%
3,001 MW	900.0 MW	29.99%	0%



*These factors are based on further ELCC analysis.

Marginal vs. Average-total ELCC

- Justification for average-total ELCC (see PJM filing):
  – Correctly identifies the reliability value of the set of all ELCC resource classes.
  – Serves as a “backstop” against suppliers offering more reliability than can be physically provided in the aggregate.
  – Within that backstop, allows suppliers to choose their preferred offer level based on risk tolerance, etc.
- Justification for marginal (see NYISO filing):
  – Cleared quantities above the marginal ELCC quantity are paid more than their value on the margin, yielding poor price signals.
  – This can yield an inefficient resource mix (e.g., too much solar vs. wind or vice versa).
  – Marginal ELCC aligns with expected performance during high risk hours in operations (which is necessarily on the margin).

Implications of Marginal ELCC Accreditation

- Handling of surplus/inframarginal UCAP in excess of aggregate marginal ELCC UCAP values.
- Should procurement of UCAP reflect gross load or marginal risk?
  - View 1: procurement of enough capacity to cover peak load
  - View 2: procurement of enough capacity to meet the risk target
- PAI performance obligation.
  - E.g., if a very large resource class (e.g., 40 GW nameplate) has a marginal reliability value of 0%, but a total reliability value of 25% (10 GW), what is the performance obligation of each unit?

In Conclusion: Opportunities

1. Allocate supply risk to suppliers
2. Adapt to potential future shift in seasonal and hourly risk profile
3. Model supply side risks jointly.
   – E.g. Currently, thermal supply side risk is captured in PRISM while renewable and storage risk in captured in ELCC model.
4. Capture year-by-year coincidence of extreme weather and forced outage risk
   – E.g., PRISM model winter peak week historical outage distribution does not capture correlation with those same week's higher-than-normal load.
5. Comprehensive assessment of lookback periods for risk assessment
6. Comprehensive assessment of ELCC
7. Capture risk of potential growth in limited duration characteristic of fossil fleet

Appendix: How PRISM Works

PRISM together with the peak load forecast **set the demand for UCAP in the capacity market**. PRISM produces the Forecast Pool Requirement.

PRISM accounts for several risks: mainly load above expected, but also overlapping thermal outages (normal, winter, other) and ambient derate of thermals.

All renewables/storage are absent from PRISM (their risks are accounted for on the supply side, not the demand side).

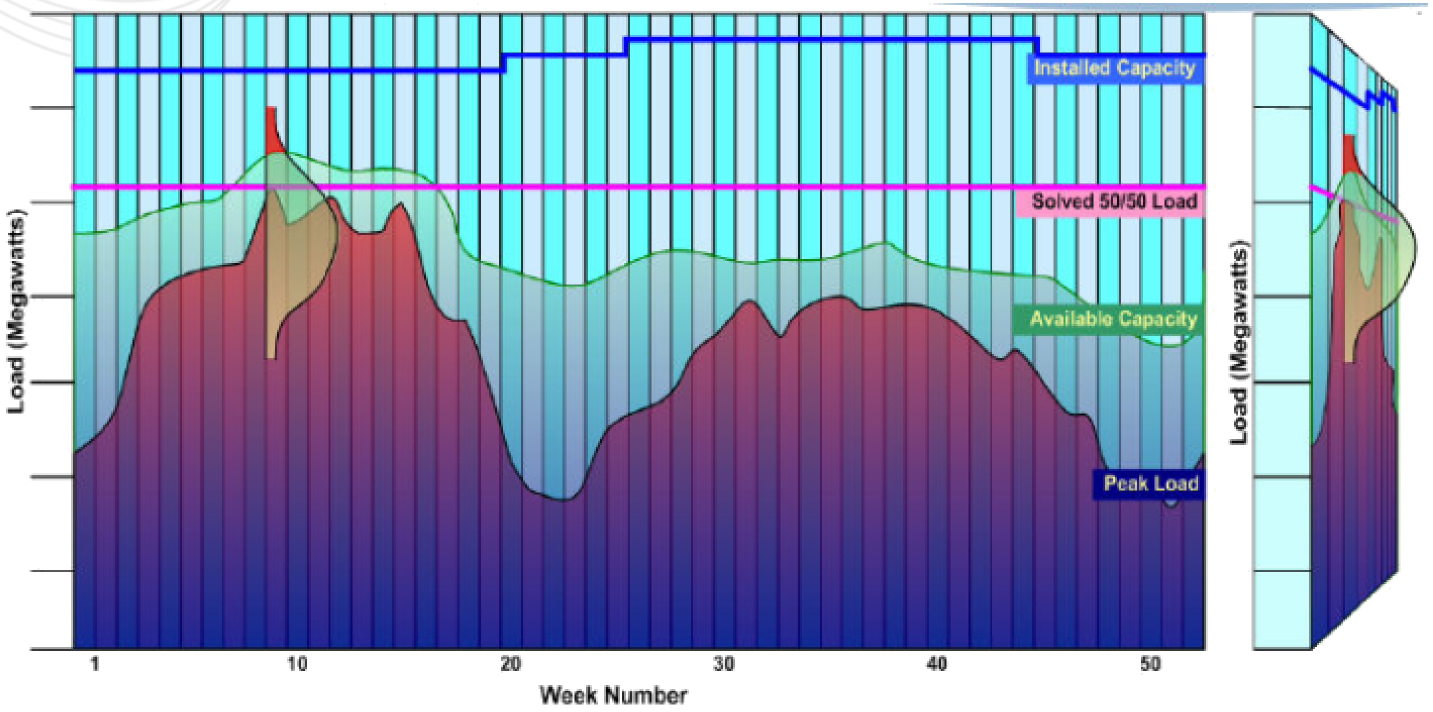
Appendix: How PRISM Works

PRISM is an analytical loss of load probability (LOLP) model that uses distributions of load and outages.

It models peak loads, modeled daily but aggregated weekly, using 52 normal distributions.

Thermal gen outages follow modeled distribution, except one winter week follows the distribution derived from the set of each winter peak week from (all but one) historical winters back to 2007/08.

- *Specifically: except winter peak week, the daily RTO-wide thermal generation availability distribution is derived via convolution using individual unit's 5-year EEFORd and assuming outage independence*



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