QUANTA TECHNOLOGY

Resource Adequacy Discussion

Organization of MISO States

Spring Seminar

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Quanta Technology

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- Global utility experience
- Trusted advisors
- Industry recognized thought leaders
- Ability to address business & technology strategy, as well as the most specialized issues
- End-to-end solution provider, including (EPC) through Quanta Services

Why:

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- Staff extension requiring technical skills
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Our mission is to enable your success with industry-best technical and business expertise, holistic and practical advice and industry thought leadership.

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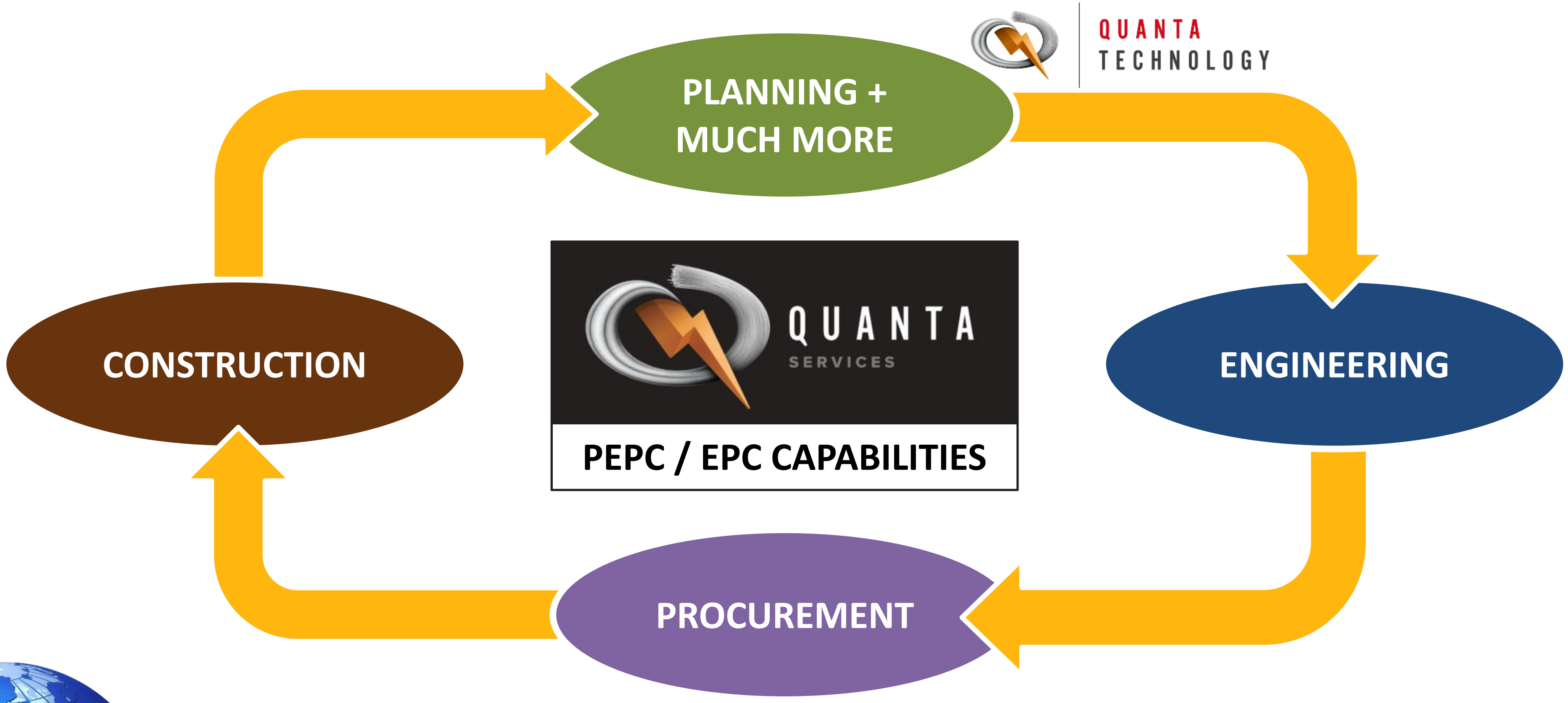
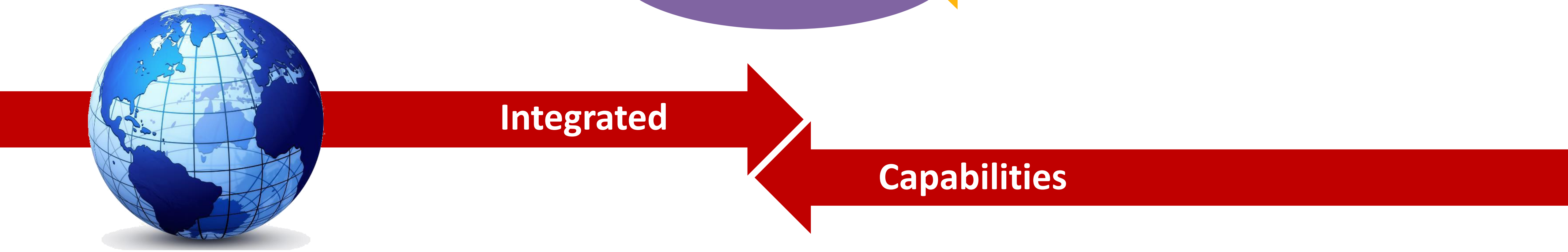




QUANTA TECHNOLOGY

A Likely Scenario of Future Electric Power System

- Compared with the existing grid, the future grid will be clean resources on the power supply side, intelligence on the grid side, and electrification on the demand side:
  - Internal to the power system, the grid will transform from a high-carbon to a low-carbon; from a mechanical electromagnetic coupled system to an electronically coordinated system; from a fuel certain power supply to intermittent; and from a high moment of inertia to a weak moment of inertia system.
  - External to the power system, energy resources will be volatile and uncertain and featured by "extremely hot without wind" and “evening peak without sun". Traditional power plants will co-exist and interact with virtual power plants, distributed energy resources (DERs), while the grid still will be required to maintain reliability.
- As the renewables become the main power source, fully developed DERs would allow the demand side to have dual attributes of generation and consumption, and the boundary between the generation and the consumption becomes blurred. The generation, the grid, and the consumers will intelligently interact.
- Renewables are competing with thermal generation without subsidies. However, high level renewable penetration requires complementary and synergistic interaction mechanism provided by flexible generation to balance the generation and demand, allowing the renewable energy to reach to the consumers.
- Challenges and risks – fast rise in demand and energy shortage during hot summer evenings and cold winter mornings when low availability of wind and solar resources is coincident with high power demand; grid stability, strong non-linearity of the intelligent power equipment yet to be grappled by grid operators, etc.

MISO’s RIIA – Reliability Risks Increase with More Renewables

Resource adequacy – not enough resources around for winter and/or later in the evening peak load

Energy adequacy – unable to flexibly generate enough energy under peak load conditions throughout the year

Operating reliability – remotely clustered renewable resources and unavailable stable resources

Mitigation solutions – more transmission, renewable overbuild, flexible generation, and smart technologies.

Design Criteria for Resource Adequacy and Adequate Transmission

- Adequate resource is measured by the probability of having sufficient resources to meet expected demand and expressed as a loss of load expectation ("LOLE") – typically, 0.1 days per year. This reliability standard defines the design conditions and forms the basis of building adequate resources in electric markets.

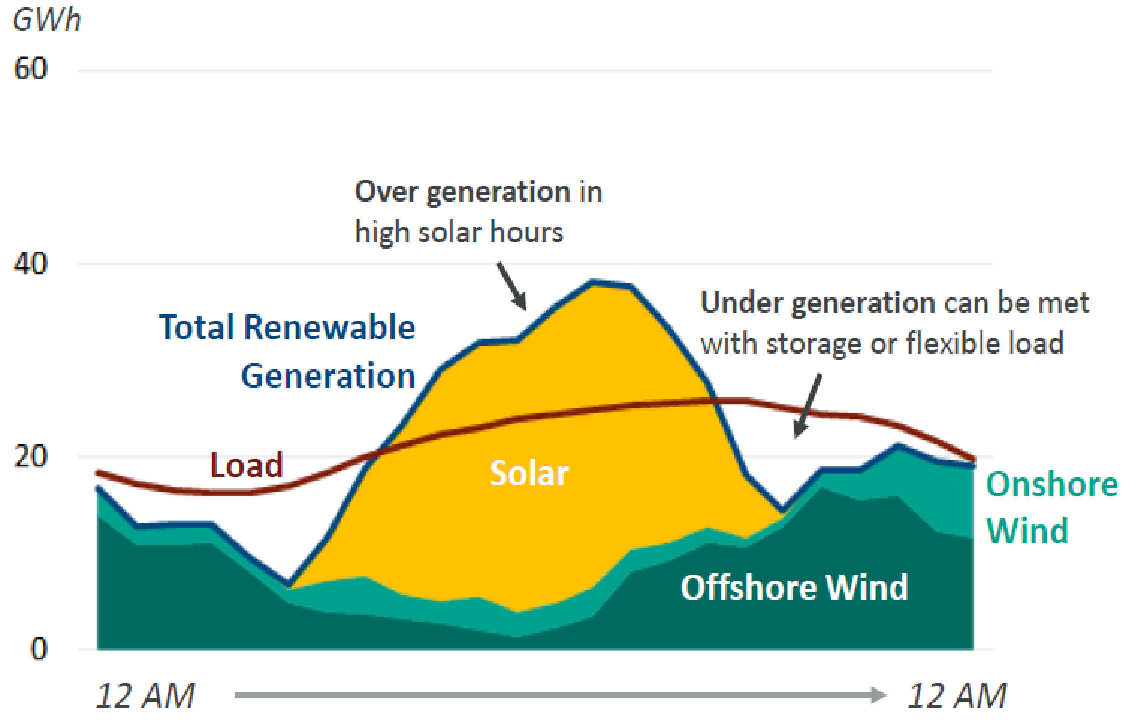
- Adequate transmission is deterministically determined such that all possible N-1 disturbances are identified to ensure continued electricity. An N-1 requirement means that the system can withstand the loss of any one component without affecting service to consumers.

- Three critical elements in Resource Adequacy analysis:

  1) Resource physical performance (failure rate)
  2) Transmission capability and performance
  3) Resource energy production limitations due to fuel availability.

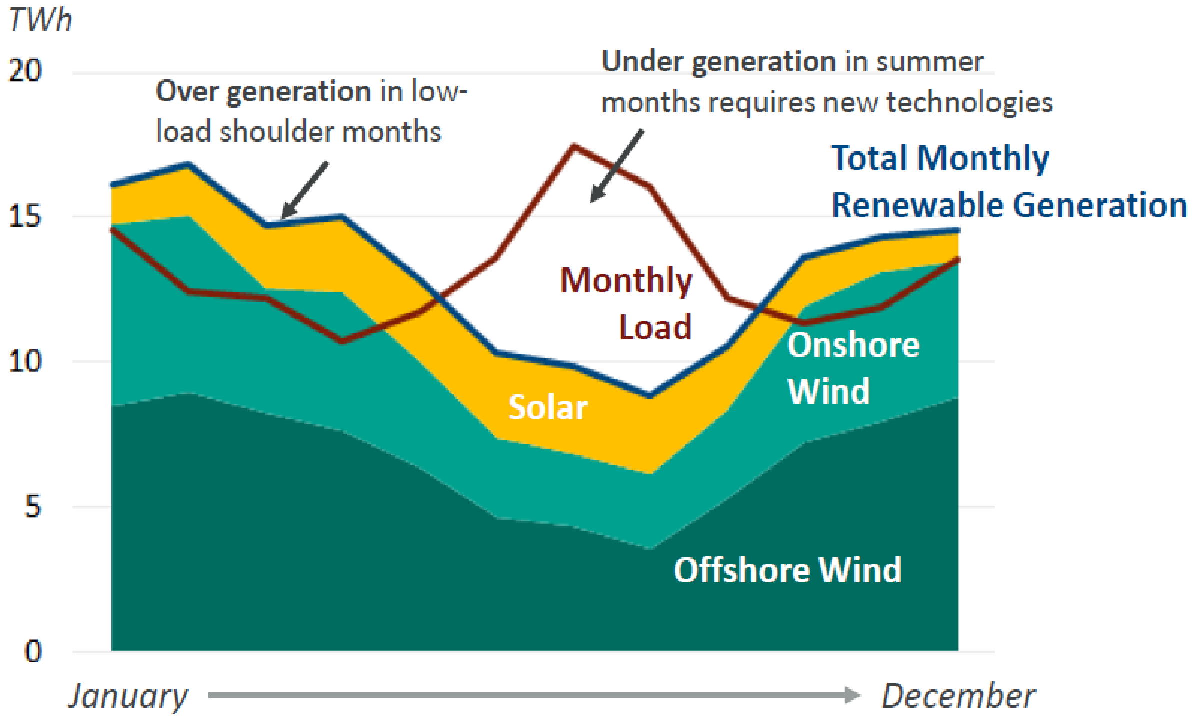
#1 – Planning Reserve Margin with higher levels of renewables

Hourly Balancing Challenge



Batteries and load flexibility can provide short-term balancing.

Seasonal Balancing Challenge

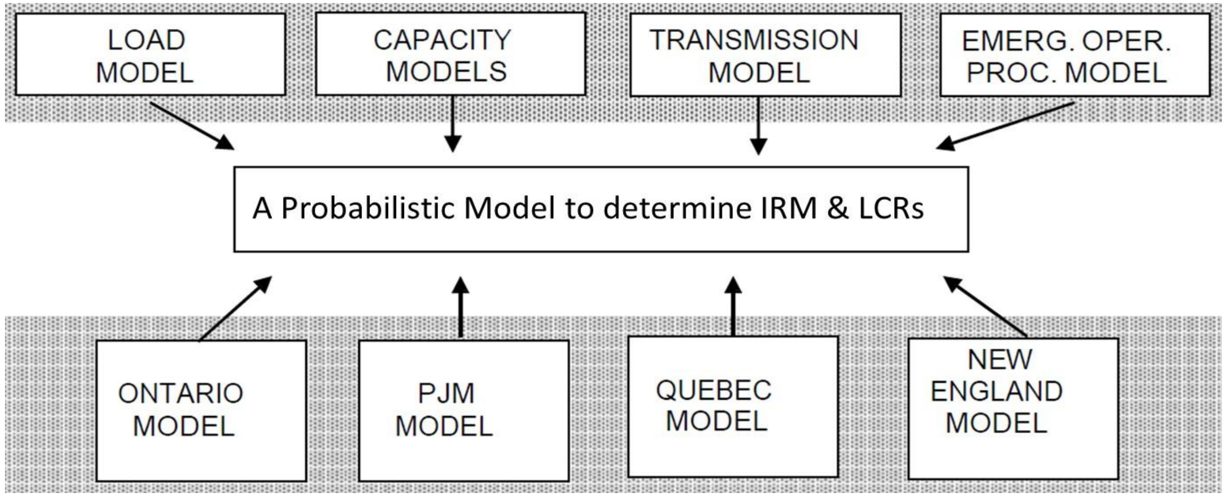


Seasonal balancing is the more difficult challenge, requiring new technologies such as seasonal storage or zero-emission dispatchable generation.

Courtesy of NYISO

Establishing a PRM – An Example

- Rigorous Resource Adequacy Assessment
  - Modeling the probabilities of unavailability of capacity resources (fossil, renewable, demand response, etc.) and transmission, in conjunction with load uncertainties, to determine installed reserve margin (IRM) and Locational Capacity Requirements (LCRs) that satisfy the LOLE criteria:



  - Modeling Parameters:
    - Generation and Transmission Forced Outage Rates (EFORs)
    - Transmission emergency transfer capabilities
    - Load Forecast Uncertainties reflecting extreme weather conditions
    - ELCC for renewables under system peak conditions paired with historical seasonal variability chronologically
    - Energy Limited Resources (e.g., emission constraints annually or seasonally)
    - Emergency Operating Procedures.

- Installed Capacity Markets to satisfy IRM & LCRs
  - Buyer Perspective
    - Supplier Market Power
    - Level & Stability of Prices using the Demand Curve concept
    - Risk of Insufficient Capacity
    - Risk of Over Procurement
    - Interference with Self-Supply
    - Price distortion from Administrative Provisions
  - Supplier Perspective
    - Rationalize Auction Timing with Resource Development Times
    - Price Stability to Support Investment
    - Sufficient Prices to Support Investment
    - Risks of Taking on Capacity Obligation
    - Discrimination between New and Existing Supply
    - Reliance on Out-of-Merit Solutions
    - Buyer Market Power
  - Other Key Attributes
    - Accommodation of Demand Response
    - Recognition of Energy Efficiency
    - Alignment with System Planning Process
    - Alignment with Activities in Neighboring Areas
    - Transition Cost.

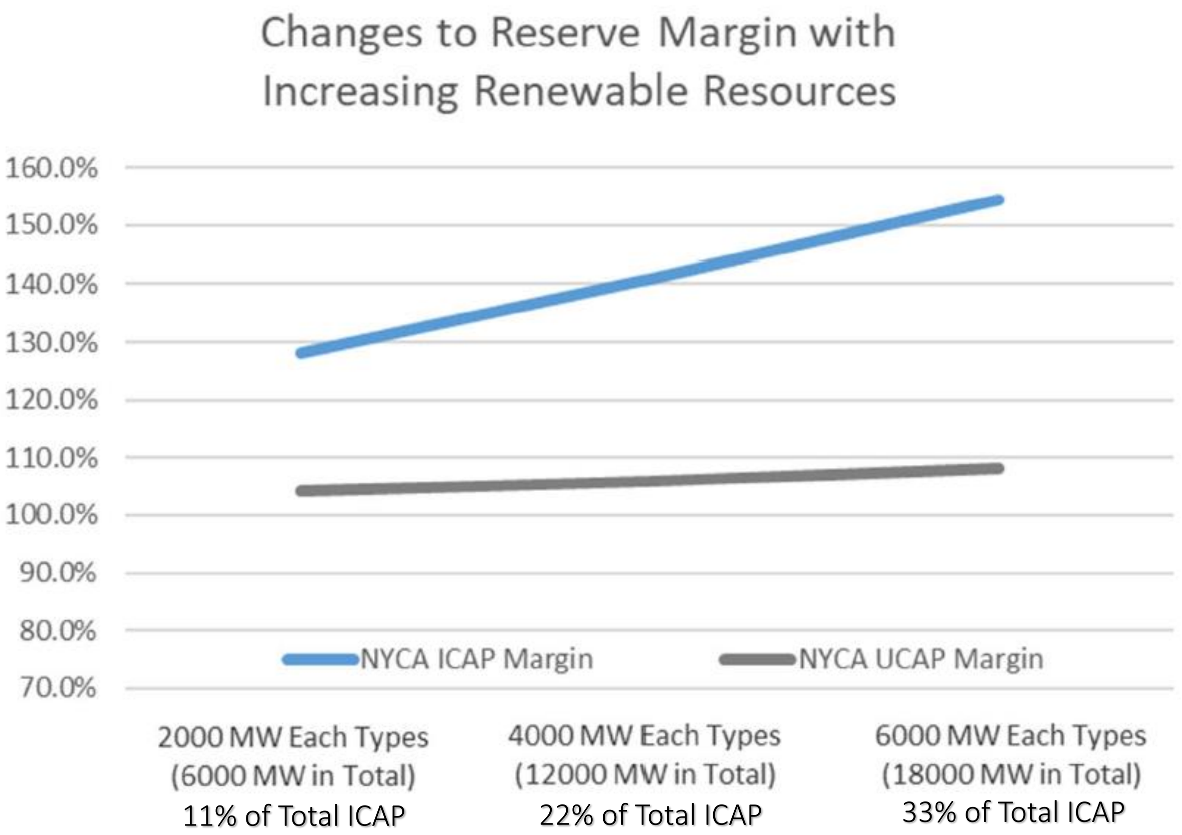
Highlights of the PRM Process

- Use a probabilistic evaluation of resource adequacy to meet the 0.1 day/year LOLE reliability criteria in an annual process with explicit modeling of bulk transmission, all resources at their locations, and historical energy production shapes (all 8,760 hours of the calendar year) for renewable resources that is correlated with other types of renewable resources.
  - Well suited for meeting changing resource adequacy needs occurring for all hours of a day and, importantly, all days of the calendar year.
  - Allowing seasonal variations in intermittent supply and the periods of stressed system conditions of a day.
- Allow for updates to peak load forecasts, generation mix, load forecast uncertainty, transmission system changes, and accommodates improvements to the resource adequacy models as needed through time.
- Recognize the period of a day that capacity resources are required to be available. The defined performance period is expected to change over the time as timeframes change to meet resource adequacy needs as indicated by the RIIA report.
- The location requirements due to inadequate transmission are explicitly set in LCRs, which is optimized/balanced with the overall control area PRM requirement.
- Additionally, some Installed Capacity Markets use a sloped demand curve in support of making additional capacity supply available in excess of established minimum resource adequacy requirements – a useful feature for system resilience for conditions such as out of criteria extreme warm/cold weather.

Changes in Installed Capacity Reserve (ICAP) Margin

▪ Risks with no proper resource mix

- Electric system planning and operations without proper recognition of resource mix has a long-term impact. The challenge has already been witnessed in the marketplace following the recent events — grid owners and operators have had to quickly implement some mitigating transmission upgrades or rely on Reliability Must-Run contracts in order to maintain system reliability.
- Without adequate resources, there is a disconnect between the generation needed to produce energy and the generation needed to support grid operations. Consequently, consumers will likely see price volatility, pay unanticipated transmission and/or generation system upgrades costs, or experience sustained outages.
- As thermal generation retires and is replaced by less fuel secure resources (such as wind and solar), which by nature of their differing operating characteristics and fuel supply security, will affect operations of the electric system in the near term.



Courtesy of NYSRC

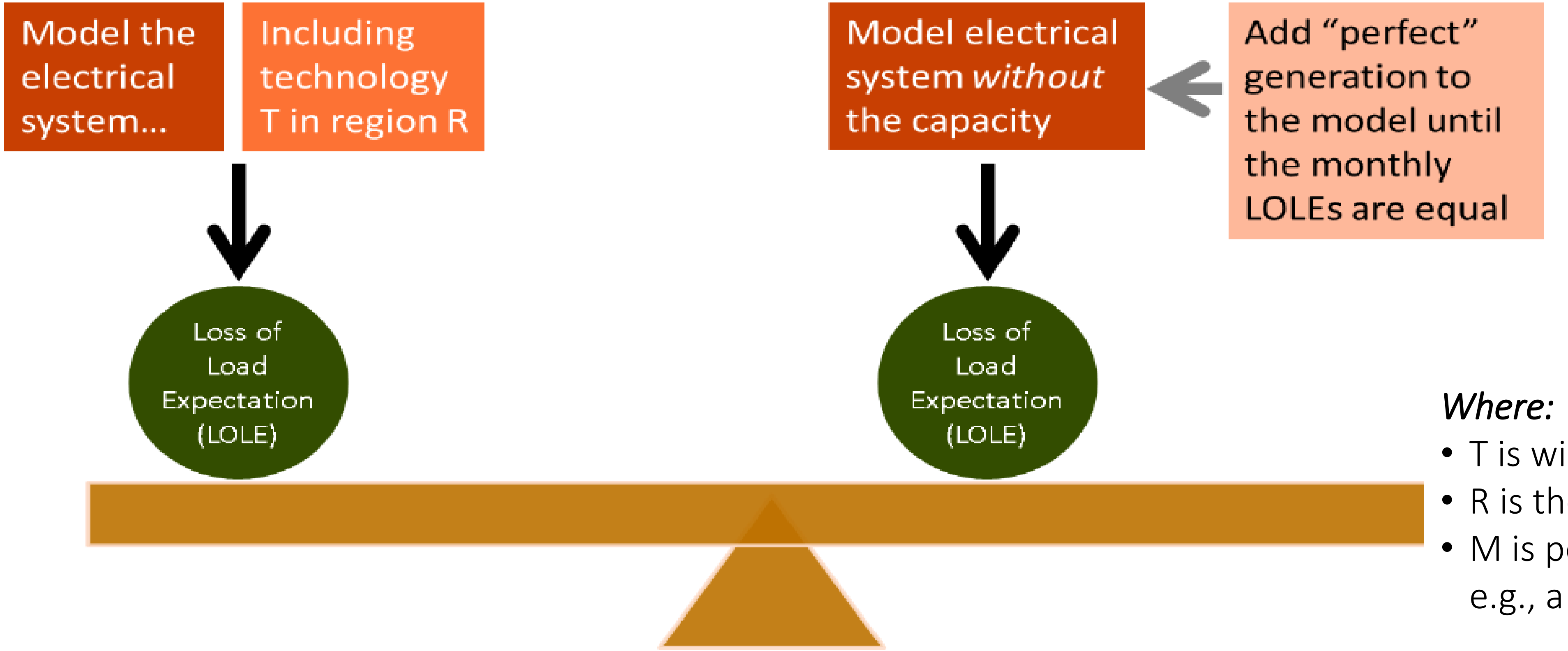
#2 – Transmission Factor in Resource Adequacy

- The Eastern Interconnection is a "one-machine", or many machines connected by transmission to run synchronously. If the transmission is not adequately strong to deliver capacity from place to place, then that capacity should not be counted towards the required PRM.
- The benefit of transmission is apparent – not only can it deliver the renewable energy, but also allow sharing capacity reserves to withstand and recover from unexpected events outside the design conditions discussed above.
- When removing transmission constraints by enforcing transmission, reserve requirement for resources is reduced. For example, for the NYISO control in 2017,
  - the PRM is reduced from 18.1% to 15.2%
  - The PRM would increase from 18.1% to 26.4% if the inter-ties with neighboring control areas are severed.

Case	Description	IRM (%)	% Change from Base Case
0	Final Base Case	18.1	0
1	NYCA isolated	26.4	+8.3
2	No internal NYCA transmission constraints	15.2	-2.9
3	No load forecast uncertainty	10.2	-7.9
4	No wind capacity	14.2	-3.9

Courtesy of NYSRC

#3 – What is Effective Load Carrying Capability (ELCC)



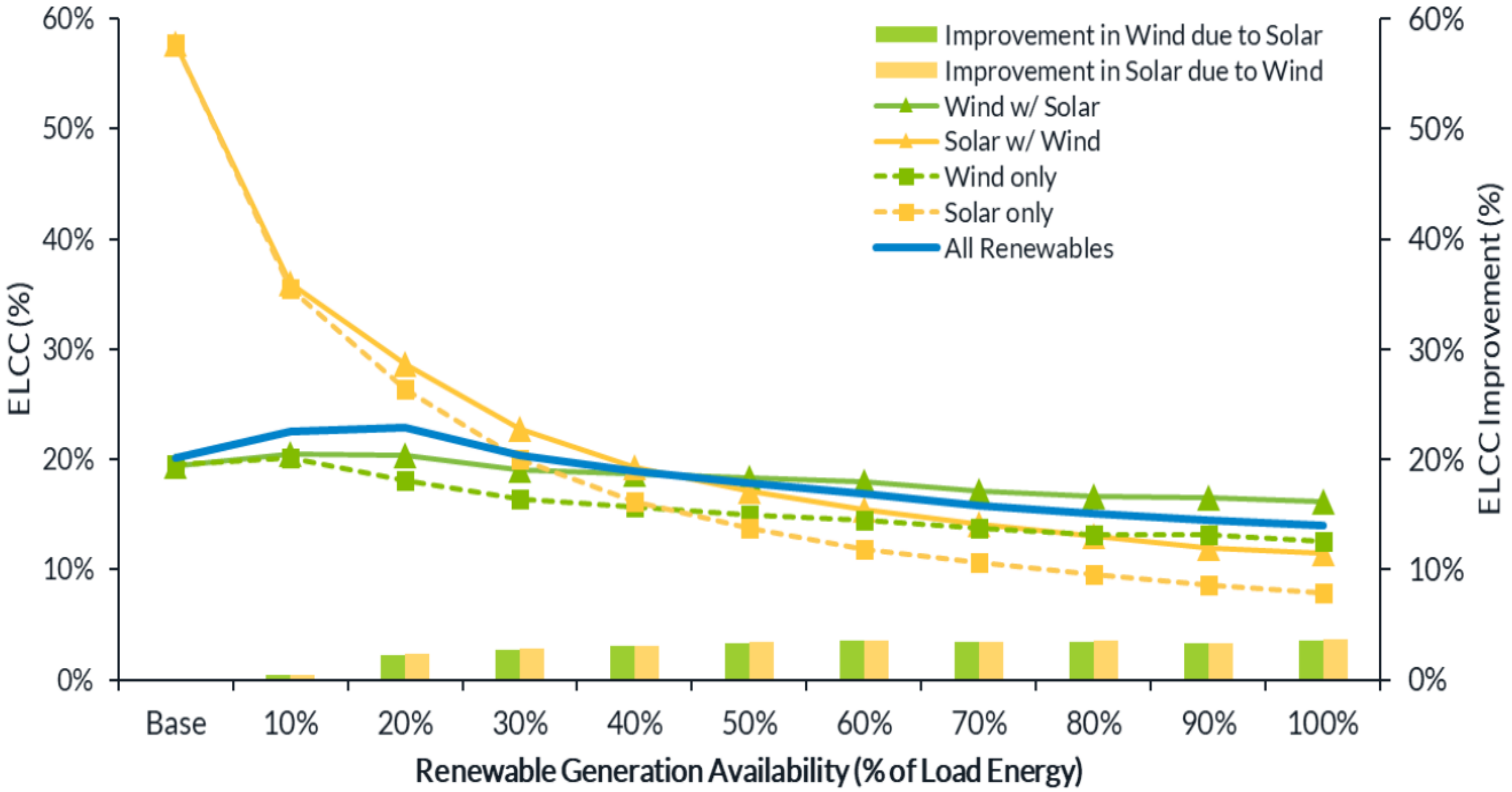
Where:
- T is wind or solar
- R is the region, e.g., NYISO
- M is period for the calculation, e.g., a month

- The ELCC assessment involves simulations where electric load and renewable generation connected via the grid vary randomly, comparing how much “perfect capacity” can be replaced by the renewable technologies.
- The perfect capacity can be a perfect power plant that never is out, can ramp up and down instantly, and can operate around the clock (its ELCC is 100%). If it takes 30 MW of “perfect capacity” to replace a 100 MW solar plant, the ELCC of that solar plant would be 30 MW / 100 MW = 30%.

Modeling Renewable Effective Capacity

- Wind and Solar, without pairing storage, are generally classified as an “intermittent" or "variable generation“ resource with a limited ability to be dispatched. Their effective capacity can be molded using
  - ELCC which is extracted from previously outputs during the summer or winter peak periods; and/or
  - Historical hourly outputs for the previous calendar years, reflecting seasonal variability and geographic location that also affect resource availability
- Data used to model the effective capacity of the renewable generation are calculated statistically:
  - Production hourly wind data and the production profiles are selected randomly during modeling simulations
  - Maintenance cycle and duration
  - EFOR (not related to fuel unavailability)
- For wind, the effective capacity depends primarily on the availability of the wind. Wind farms in New York on average have 14-20% ELCC based on their nameplate ratings. A wind plant’s output can range from close to nameplate under favorable wind conditions to zero when the wind does not blow. On average, a wind plant’s output is higher at night, and has higher output on average in the winter versus the summer.
- For solar, the effective capacity is 32-49% ELCC for the summer; and 2-5% in the winter.

With higher penetration, the ELCC will reduce



Source: MISO's RIIA report

Several factors affect the ELCC for solar and wind in a region:

- Resource mix in a power pool where difference resources interact and back up each other
- Capacity exchange with external control areas
- Transmission system transfer capability
- Electricity usage pattern
- Locations where wind and solar profiles differ
- Penetration level of wind and solar resources.

Point of Views

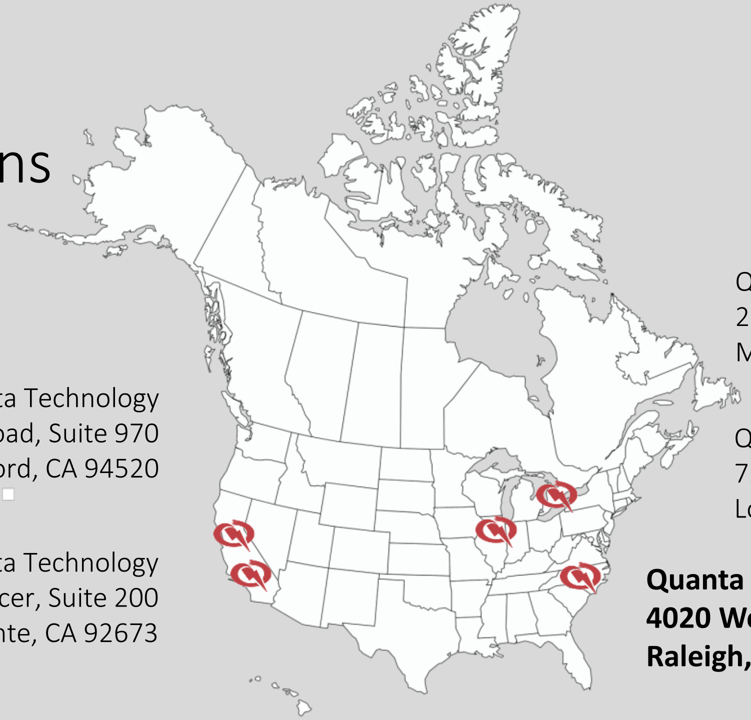
- State legislations have set aggressive climate goals on emission and renewable:
  - For New York, 70% renewables by 2030 and 100% carbon-free by 2040
  - For California, 50% renewable energy by 2026; 60% by 2030, and 100% carbon-free by 2045
  - Renewable activity is bound to increase the pace with the global carbon neutral initiatives in the U.S.
  - Environmentally friendly resource together with complementary technologies at the confluence of resource adequacy and transmission security is facing due and fair recognition and treatment.
- For solar in New York, the ELCC is 38% in the summer today, but is trending down toward 10% with higher penetration of renewables particularly Behind-the-Meter distributed generation
  - Net peak load shifts as New York adds more renewables, therefore Solar's ELCC decreases rapidly as the net peak shifts to the evening when solar production is low.
- It's expected the IRM will increase substantially as the renewable capacity reaches 50% in the overall generation mix, and there will be needs for flexible generation with fuel certainty to support the grid reliability.

Other Thoughts

- While the RIIA evaluated the impacts of increased renewables and the complexities of renewable integration, extreme events such as extreme weather conditions may expose more resilience issues.
- Ongoing interest in DER, behind-the-meter DERs, microgrids, and local disaggregated networks would increase uncertainties in net-load forecast and the availability of load following capacity in grid operations.
- Conventional generation would be useful to smooth net-load variations to ensure that the MISO systems can continue providing reliable, efficient, and sustainable access to renewable energy until alternative technologies are ready.
    - The California and Texas events, either in summer or winter, somehow hinted that we are not ready for the future even though we have thought we were prepared.
    - While striking a better balance between energy services and carbon goals, should we be conscious about the levels of system reliability and resilience that the consumers are used to and that the future will bring?

Thank you!

Office Locations



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