Capacity Markets

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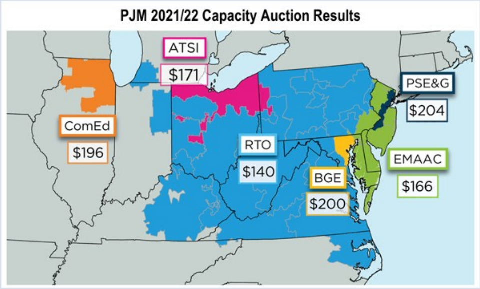

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Presentation Outline

1. Capacity Markets Basics
2. In Practice
3. Market Equilibrium
4. Market Design
5. The Texas Alternative
6. Conclusion

The Electricity Trilemma

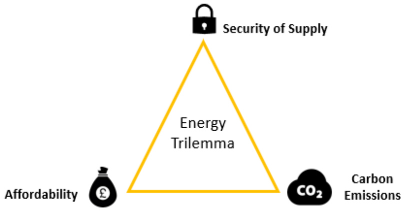

Figure 1: Why are there so many trilemmas?

Grid Reliability

- **Definition:**
  - The ability of the power grid to deliver electricity continuously and at the desired quality, even during peak demand or unexpected events.
- **Key Components:**
  - **Adequacy:**
    - Sufficient generation and transmission capacity to meet demand.
  - **Security:**
    - The grid's ability to withstand sudden disturbances (e.g., outages, equipment failures).
- **Factors Affecting Grid Reliability:**
  - **Resource Availability:**
    - Dependence on weather-sensitive resources like wind and solar.
  - **Demand Growth:**
    - Rising electrification (e.g., EVs, heat pumps) increases demand.
  - **Aging Infrastructure:**
    - Legacy systems struggle to meet modern reliability standards.
  - **Extreme Weather Events:**
    - Climate change leads to more frequent and severe grid stress.

Overview of Capacity Markets

- **Definition:**
  - A capacity market is a mechanism designed to ensure sufficient electricity generation capacity to meet peak demand and maintain grid reliability.
- **Purpose:**
  - Address the “missing money” problem in energy-only markets, where energy prices alone may not provide enough revenue for generators to cover fixed costs and incentivize new investment.
  - Provide long-term revenue stability for generators.
  - Ensure reliability by maintaining reserve margins above expected demand.

Overview of Capacity Markets

- **Key Features:**
  - **Centralized Auctions:**
    - Market operators procure capacity commitments from generators and other resources (e.g., demand response, storage).
  - **Forward Procurements:**
    - Capacity is typically procured several years in advance of the delivery period to encourage new investments.
  - **Obligations and Penalties:**
    - Resources commit to being available during critical periods and face penalties for non-performance.
- **Types of Resources in Capacity Markets:**
  - Traditional generation (e.g., gas, coal, nuclear).
  - Renewable resources (e.g., wind, solar).
  - Demand response and energy storage.
- **Examples of Capacity Markets:**
  - **PJM:** Reliability Pricing Model (RPM).
  - **ISO-NE:** Forward Capacity Market (FCM).
  - **NYISO:** Installed Capacity (ICAP) Market.

The Missing Money Problem

The **Missing Money Problem** refers to a situation in electricity markets where, despite being crucial for reliability, certain resources (such as certain generation types or capacity) fail to earn sufficient revenue in the market to cover their fixed costs. This can occur when:

Causes of Missing Money Problem

- **Energy-only markets**: In these markets, prices are determined solely by the supply and demand for electricity at a given time. However, when there is a supply-demand imbalance (e.g., low demand or excess generation), prices may fall too low, leaving resources unable to recover their fixed costs.
- **High fixed costs**: Some types of generation, particularly those with high upfront capital costs or long operating lifespans (e.g., nuclear plants, renewable energy installations), require long-term financial viability which energy-only prices may not provide.
- **Lack of capacity markets**: In markets without specific capacity mechanisms (where resources are paid for being available, not just for producing energy), providers of flexible or reliability-oriented resources may not be compensated adequately for their availability, resulting in missing money.

Example of the Missing Money Problem

Consider a **base-load generation unit**, such as a nuclear plant, with high fixed costs (e.g., infrastructure, operation). In an energy-only market, the price of electricity is determined by short-run marginal cost, meaning the price fluctuates depending on supply and demand.

- During periods of low demand, the price may fall to the marginal cost of the cheapest generation source (e.g., wind or solar), which is often close to zero.
- The nuclear plant, with a high fixed cost but low marginal cost, may not be able to earn sufficient revenue in these low-price periods to cover its fixed costs.
- If the nuclear plant is unable to recover these costs over time, it may be forced to retire, even though it provides essential reliability services to the grid.

Inelastic Demand and the Case for Capacity Markets

- **Inelasticity of Electricity Demand:**
  - **Definition:**
    - Electricity demand does not respond significantly to price changes in the short term.
  - **Causes:**
    - Essential nature of electricity for households and businesses.
    - Lack of real-time price signals reaching most consumers.
    - Limited deployment of advanced demand-response technologies.
- **Challenges Created by Demand Inelasticity:**
  - **Volatile Prices:**
    - During scarcity events, prices spike dramatically due to inelastic demand.
  - **Insufficient Investment Signals:**
    - Without capacity mechanisms, price volatility alone may not provide sufficient incentives for new generation investment.

Criticism of Capacity markets

- **Over-Procurement:**
  - May result in more capacity than needed, raising costs for consumers.
- **Distorted Signals:**
  - Capacity markets can reduce the role of energy market prices in driving efficient behavior.

Reliability as a Public Good

- **Definition of a Public Good:**
  - A good that is non-excludable and non-rivalrous:
    - **Non-Excludable:** No one can be excluded from benefiting.
    - **Non-Rivalrous:** One person's use does not diminish its availability to others.
- **Reliability as a Public Good:**
  - Grid reliability ensures continuous electricity supply for all users.
  - No individual consumer can be excluded from the benefits of a stable grid.
  - High reliability benefits all users without reducing its value to others.
- **Challenges of Treating Reliability as a Public Good:**
  - **Free-Rider Problem:**
    - Consumers benefit without directly contributing to investments in reliability.
  - **Under-Investment:**
    - Market mechanisms alone may fail to ensure adequate reliability.
  - **Equity Issues:**
    - Disparities in grid reliability across regions or customer classes.

Offer Caps and Price Signal Distortions

- **Definition of Offer Caps:**
  - Maximum price that generators can bid into electricity markets.
  - Intended to prevent price spikes and protect consumers from excessive costs.
- **Purpose of Offer Caps:**
  - Mitigate the exercise of market power by large suppliers.
  - Maintain market stability during scarcity or emergencies.
- **How Offer Caps Distort Price Signals:**
  - **Reduced Scarcity Pricing:**
    - Caps suppress prices during scarcity, failing to reflect the true value of reliability.
  - **Investment Disincentives:**
    - Lower price signals reduce incentives for new generation and grid investment.
  - **Demand-Side Effects:**
    - Diminished price volatility discourages demand response participation.
  - **Operational Distortions:**
    - Generators may operate inefficiently to avoid losses from capped prices.

Offer Cap Price Distortions

- **Examples of Price Distortions:**
  - Scarcity events in ERCOT highlight tensions between high offer caps and price stability.
  - Prolonged low prices in capacity markets lead to underinvestment in flexible resources.
- **Potential Solutions:**
  - Allow scarcity pricing during critical conditions to reflect the value of lost load (VOLL).
  - Implement demand-side management programs to reduce reliance on price caps.
  - Use locational pricing to address regional supply-demand imbalances.
- **Conclusion:**
  - While offer caps stabilize markets in the short term, they risk undermining long-term reliability and investment incentives.

Engineering-Based Reliability Standards

- **Definition of Engineering-Based Reliability Standards:**
  - Technical criteria ensuring the grid operates reliably under normal and emergency conditions.
  - Focus on grid stability, security, and adequacy, such as the N-1 contingency rule.
- **Interaction with Traditional Economic Theory:**
  - **Market Efficiency vs. Reliability:**
    - Engineering standards prioritize reliability, which may conflict with cost-minimization objectives.
    - Imposing stringent reliability requirements can lead to over-investment in infrastructure.
  - **Public Good Characteristics:**
    - Reliability is a non-excludable, non-rivalrous good.
    - Markets alone may fail to provide optimal reliability due to the free-rider problem.
  - **Scarcity Pricing and Standards:**
    - Economic theory supports scarcity pricing to signal the value of reliability.

Engineering-Based Reliability Standards

- **Tensions Between Theory and Practice:**
  - Economic models assume rational responses to price signals, but real-world markets may lack sufficient liquidity or information.
  - Standards may override market mechanisms to prevent catastrophic failures, even at higher costs.
- **Balancing Standards and Economics:**
  - Design markets to complement engineering standards (e.g., scarcity pricing reflecting Loss of Load Probability).
  - Use cost-benefit analysis to evaluate the trade-offs between reliability investments and economic efficiency.
- **Conclusion:**
  - Engineering-based reliability standards address market failures but must be harmonized with economic incentives for long-term efficiency.

Cost of New Entry (CONE)

The **Cost of New Entry (CONE)** refers to the minimum cost that a new generation resource must recover in order to cover its fixed and variable costs while providing a competitive return on investment. This cost is critical for determining the viability of new generation technologies in electricity markets.

CONE typically includes:

- **Capital costs**: The cost to build a new generation plant, including land, construction, and equipment.
- **Fixed operation and maintenance (OM) costs**: The ongoing costs of maintaining and operating the plant, which do not vary with production levels.
- **Return on investment (ROI)**: The return required by investors for financing the plant's construction.
- **Financing costs**: The costs associated with borrowing capital to fund the construction of the plant.

Calculation of Cost of New Entry (CONE)

The Cost of New Entry is calculated by summing the following components:

- **Capital Cost**: This includes the construction and equipment costs required to build the plant. It is typically expressed on a per-megawatt ($\$/MW$) or per-megawatt-hour ($\$/MWh$) basis, depending on the plant's expected output.
- **Fixed OM Costs**: These are the costs for operating and maintaining the plant regardless of its generation level, typically calculated on a per-year or per-MW basis.

Calculation of Cost of New Entry (CONE)

- **Return on Investment (ROI)**: This is the required return on the capital invested in the project, typically expressed as a percentage. It is calculated by multiplying the capital investment by the required return rate.
- **Financing Costs**: These costs account for the interest on debt used to finance the plant construction. This is typically calculated using the weighted average cost of capital (WACC).

The overall CONE can be represented as:

$$CONE = \frac{\text{Capital Cost} + \text{Fixed O\&M Costs} + \text{Financing Costs}}{\text{Capacity Factor} \times \text{Plant Lifetime}}$$

Where:

- **Capacity Factor**: The ratio of actual output to potential output (i.e., how often the plant is running).
- **Plant Lifetime**: The expected operational life of the plant (often in years).

Example of Cost of New Entry (CONE)

Let's calculate the Cost of New Entry (CONE) for a new natural gas plant. Given the following parameters:

- **Capital Cost**: \$1,000,000 per MW.
- **Fixed OM Cost**: \$50,000 per MW per year.
- **Required ROI**: 10% per year.
- **Financing Costs**: \$25,000 per MW per year (calculated based on WACC).
- **Capacity Factor**: 85% (0.85).
- **Plant Lifetime**: 25 years.

First, calculate the annual fixed costs:

$$\text{Annual Capital Recovery} = \text{Capital Cost} \times \text{ROI} = 1,000,000 \times 0.10 = 100,000$$

Example of Cost of New Entry (CONE)

Next, calculate the total annual cost:

Total Annual Cost = Annual Capital Recovery+Fixed O&M Costs+Financing

Total Annual Cost $= 100,000 + 50,000 + 25,000 = 175,000$ per MW per year

Finally, calculate the Cost of New Entry (CONE):

$$CONE = \frac{\text{Total Annual Cost}}{\text{Capacity Factor} \times \text{Plant Lifetime}} = \frac{175,000}{0.85 \times 25} = \frac{175,000}{21.25} = 8,235$$

Thus, the CONE for this natural gas plant is $8,235.29 per MWh.

Elasticity of the Cost of New Entry (CONE)

- **Definition:**
  - The elasticity of CONE refers to the responsiveness of the Cost of New Entry to changes in key market or regulatory factors.
  - Reflects how supply-side investment reacts to changes in costs or market incentives.
- **Determinants of CONE Elasticity:**
  - **Capital Costs:**
    - Variability in equipment, construction, and financing costs impacts CONE.
  - **Market Dynamics:**
    - High market prices reduce the effective CONE by increasing expected revenue from energy markets.
  - **Policy and Regulation:**
    - Renewable subsidies or carbon pricing can alter relative costs, affecting CONE elasticity.
  - **Technology Evolution:**
    - Innovations in generation or storage technologies can lower CONE over time.

Elasticity of the Cost of New Entry (CONE)

- **Implications of Elasticity:**
  - **Low Elasticity:**
    - Supply is less responsive to changes in market conditions, potentially leading to capacity shortages.
    - Indicates high barriers to entry (e.g., regulatory, technical, or financial).
  - **High Elasticity:**
    - Supply adjusts more readily, stabilizing capacity markets.
    - Promotes competitive market outcomes and efficient investment.
- **Economic Insights:**
  - Elasticity of CONE helps determine the sensitivity of capacity prices to demand changes.
  - Higher elasticity leads to smoother adjustments in capacity markets, reducing price volatility.
- **Challenges:**
  - Accurately estimating elasticity requires reliable data on costs, market conditions, and regulatory impacts.
  - Long lead times for capacity development can reduce apparent short-term elasticity.

Impacts of Renewable Energy Resources on Reliability

- **Positive Impacts:**
  - **Diverse Resource Mix:**
    - Integration of wind, solar, and other renewables enhances resource diversity.
  - **Reduced Dependence on Fossil Fuels:**
    - Mitigates risks of fuel supply disruptions and price volatility.
  - **Decentralized Generation:**
    - Distributed renewables improve resilience by reducing reliance on centralized generation.

Impacts of Renewable Energy Resources on Reliability

- **Challenges to Reliability:**
  - **Intermittency:**
    - Variability in wind and solar generation creates mismatches between supply and demand.
  - **Predictability Issues:**
    - Difficult to accurately forecast renewable output, increasing reliance on backup resources.
  - **Grid Stability:**
    - Lack of inertia from non-synchronous generators (e.g., solar PV) challenges frequency regulation.
  - **Transmission Constraints:**
    - Renewable resources are often located far from load centers, requiring significant transmission investment.

Impacts of Renewable Energy Resources on Reliability

- **Mitigation Strategies:**
  - **Energy Storage:**
    - Batteries and other storage solutions can buffer renewable intermittency.
  - **Demand Response:**
    - Aligning consumption with renewable output to balance the grid.
  - **Enhanced Grid Flexibility:**
    - Upgrading infrastructure and adopting smart grid technologies.
  - **Complementary Resources:**
    - Using flexible generation sources (e.g., natural gas peakers) to stabilize the grid.
- **Conclusion:**
  - Renewable energy resources offer significant environmental and economic benefits but require careful integration to ensure reliability.

How Capacity Markets Work in Practice

- **Step 1: Determine Capacity Requirements**
  - The market operator (e.g., PJM, ISO-NE) forecasts peak electricity demand plus reserve margins for a future delivery period.
  - Reserve margins ensure sufficient capacity to handle unexpected outages or demand surges.
- **Step 2: Conduct Centralized Auctions**
  - Auctions are held to procure the required capacity several years ahead of the delivery period (e.g., 3 years).
  - Generators, demand response providers, and storage facilities submit offers to provide capacity.
  - The market clears at the intersection of supply offers and the capacity requirement.
- **Step 3: Capacity Commitments**
  - Winning resources commit to being available during critical system periods.
  - Capacity payments are provided to ensure resource availability.

How Capacity Markets Work in Practice

- **Step 4: Performance Monitoring**
  - During scarcity events or emergencies, the market operator evaluates whether resources meet their commitments.
  - Resources failing to meet obligations face financial penalties, while over-performers may receive additional payments.
- **Step 5: Short-Term Adjustments**
  - Incremental auctions or bilateral trades allow market participants to adjust commitments closer to the delivery period.

How Capacity Markets Work in Practice

- **Step 6: Settlement and Payment**
  - Capacity providers receive payments based on their cleared offers.
  - Payments are typically funded through charges to load-serving entities (LSEs), passed on to consumers.
- **Example: PJM Reliability Pricing Model (RPM)**
  - **Three-Year Forward Auction:** Primary procurement of capacity.
  - **Incremental Auctions:** Adjustments to commitments before the delivery year.
  - **Locational Pricing:** Reflects transmission constraints and regional needs.
- **Conclusion:**
  - Capacity markets ensure long-term reliability by incentivizing resource availability and providing a stable revenue stream for generators.

First-Generation Capacity Markets

- **Definition:**
  - Early capacity markets designed to ensure adequate resource investment and reliability.
  - Focused on meeting forecasted peak demand plus reserve margins.
- **Key Features:**
  - **Capacity Obligations:** Utilities and load-serving entities (LSEs) required to secure capacity.
  - **Bilateral Contracts:** Capacity often procured through long-term bilateral agreements.
  - **Lack of Market Dynamics:** Minimal price competition; capacity prices set administratively or through limited mechanisms.

First-Generation Capacity Markets

- **Challenges:**
  - **Inefficiency:** Over-procurement due to conservative planning assumptions.
  - **Static Design:** Poor adaptation to changing supply-demand conditions.
  - **Limited Innovation:** Focused on conventional generators, excluding demand response and emerging technologies.
- **Transition to Modern Capacity Markets:**
  - Shift toward centralized auctions with competitive bidding.
  - Greater integration of market-based price signals to drive resource investment.

Comparison of Capacity Markets

Aspect	PJM: Capacity Credit Market	NYISO: ICAP Market	ISO-NE: Forward Capacity Market
Auction Type	Three-year forward auctions	Monthly auctions	Three-year forward auctions
Market Design	Reliability Pricing Model (RPM)	Installed Capacity (ICAP) market	Forward Capacity Auction (FCA)
Capacity Obligations	Long-term	Short-term	Long-term
Pricing Mechanism	Locational	Locational	Locational
Resource Inclusion	Broad	Limited demand response	Broad, including imports
Performance Incentives	Strong penalties	Limited	Pay-for-Performance

Table 1: Key Features of Capacity Markets

Comparison of Capacity Markets

- **PJM:**
  - Uses the Reliability Pricing Model to incentivize resource availability.
  - Three-year forward auctions with locational pricing.
- **NYISO:**
  - Focuses on monthly ICAP auctions for near-term capacity needs.
  - Limited integration of demand response compared to other ISOs.
- **ISO-NE:**
  - Operates a Forward Capacity Market with strong performance incentives.
  - Pay-for-Performance mechanism aligns payments with reliability goals.

Second-Generation Capacity Markets

- **Definition:**
  - Evolved capacity markets that incorporate competitive auctions, improved price signals, and enhanced participation by diverse resources.
  - Focused on addressing inefficiencies and limitations of first-generation markets.
- **Key Features:**
  - **Centralized Auctions:**
    - Competitive, transparent auctions to procure capacity.
    - Long-term (e.g., 3 years ahead) and short-term adjustments.
  - **Locational Pricing:**
    - Accounts for transmission constraints and regional supply-demand differences.
  - **Resource Neutrality:**
    - Includes traditional generation, demand response, energy storage, and renewable resources.
  - **Performance Incentives:**
    - Penalties for underperformance during scarcity events.
    - Rewards for exceeding performance expectations.

Frame Title

- **Advantages:**
  - Better alignment of capacity procurement with system reliability needs.
  - Encourages participation of diverse resource types.
  - Provides long-term investment signals to market participants.
- **Challenges:**
  - Complex market design increases administrative costs.
  - May conflict with state-level energy policies (e.g., renewable mandates).
  - Risks of market power and over-procurement persist.
- **Examples:**
  - PJM's Reliability Pricing Model (RPM).
  - ISO-NE's Forward Capacity Market (FCM).

Criticisms of Traditional Capacity Markets

- **Over-Procurement:**
  - Capacity markets often procure more capacity than needed to meet reliability standards.
  - Results in increased costs for consumers without commensurate reliability benefits.
- **Inefficient Price Signals:**
  - Capacity payments may dampen energy market price signals.
  - Reduces incentives for investment in flexible, fast-ramping resources.
- **Barrier to Innovation:**
  - Traditional capacity markets favor large, centralized generators.
  - Limited opportunities for demand response, storage, and distributed energy resources to compete effectively.
- **Misalignment with Policy Goals:**
  - Capacity markets may conflict with state-level clean energy policies.
  - Subsidized renewable resources face challenges under rules like the Minimum Offer Price Rule (MOPR).

Criticisms of Traditional Capacity Markets

- **Market Power Concerns:**
  - Large suppliers can exert significant influence over clearing prices.
  - Requires complex monitoring and mitigation mechanisms.
- **High Administrative Costs:**
  - Design, operation, and enforcement of capacity markets require substantial administrative effort.
  - Costs are ultimately borne by market participants and consumers.
- **Static Nature:**
  - Capacity markets are less responsive to rapid changes in technology and grid needs.
  - May not adequately address the challenges posed by variable renewable generation.

Determining Capacity Market Demand through Forecasting

- **Purpose:**
  - Ensure sufficient capacity is procured to meet peak demand plus a reserve margin.
- **Key Steps in Forecasting:**
  - **Load Forecasting:**
    - Project peak demand for the delivery period using historical data, weather patterns, and economic factors.
    - Includes expected growth in electricity consumption (e.g., due to electrification).
  - **Reserve Margin Calculation:**
    - Add a safety buffer to ensure reliability during unexpected demand spikes or generator outages.
    - Typical reserve margins range from 10
  - **Resource Adequacy Analysis:**
    - Assess the available supply to meet forecasted demand, accounting for outages and resource retirements.

Determining Capacity Market Demand through Forecasting

- **Data Inputs:**
  - Historical demand patterns and weather data.
  - Economic indicators affecting electricity consumption (e.g., population growth, industrial output).
  - Known generator additions, retirements, and maintenance schedules.
- **Uncertainty Factors:**
  - Weather variability and extreme events.
  - Economic conditions and energy policy changes.
  - Integration of renewable and distributed energy resources.
- **Conclusion:**
  - Accurate demand forecasting is critical for determining capacity requirements and ensuring grid reliability.

Shape and Slope of the Capacity Market Demand Curve

- **Purpose of the Demand Curve:**
  - Reflect the relationship between capacity procurement and price.
  - Ensure sufficient capacity is procured without significant price volatility.
- **Shape of the Demand Curve:**
  - Typically downward-sloping, indicating a higher willingness to pay for capacity near critical levels.
  - Includes:
    - **Vertical Portion:** Represents the minimum required capacity (e.g., peak demand plus reserve margin).
    - **Downward-Sloping Portion:** Reflects reduced willingness to pay for excess capacity.
- **Slope of the Demand Curve:**
  - Steeper slopes near required capacity levels ensure reliability by signaling scarcity.
  - Shallower slopes for excess capacity reduce the cost impact of over-procurement.

Shape and Slope of the Capacity Market Demand Curve

- **Factors Influencing Shape and Slope:**
  - **Reserve Margins:** Higher margins flatten the curve by reducing the risk of scarcity.
  - **Scarcity Pricing:** More aggressive scarcity pricing steepens the curve near critical levels.
  - **Policy Objectives:** Curves may be adjusted to reflect renewable integration or specific reliability goals.
- **Example: PJM and ISO-NE Demand Curves:**
  - Locational demand curves reflect regional constraints and supply-demand imbalances.
  - Adjusted for resource adequacy and economic efficiency.
- **Conclusion:**
  - The demand curve's shape and slope play a critical role in balancing reliability and cost-efficiency in capacity markets.

Demand Curve Visualized

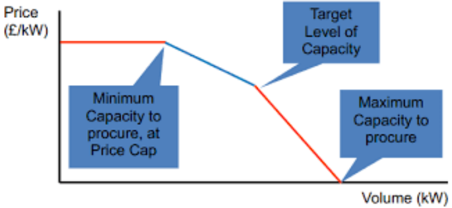

Figure 2: When do you stop paying for more capacity?

Demand Curve by ISO

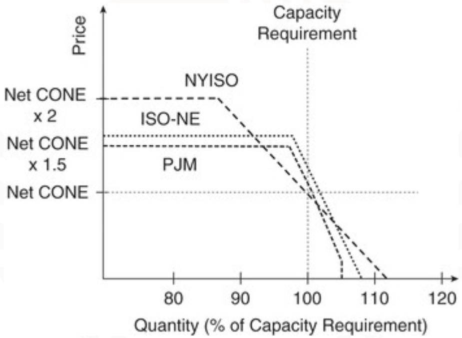

Figure 3: Net CONE

Consistent Overestimation of Net CONE by Northeast RTOs

- **Net CONE Overview:**
    - Represents the cost of building a new resource, net of expected revenues from energy and ancillary services markets.
    - A critical input in setting capacity market demand curves and offer caps.
- **Observations in Northeast RTOs (e.g., ISO-NE, NYISO):**
    - Net CONE values consistently exceed realized costs and market conditions.
    - Leads to:
        - Higher capacity market clearing prices.
        - Over-procurement of capacity.
        - Increased costs passed on to consumers.

Consistent Overestimation of Net CONE by Northeast RTOs

- **Impacts of Overestimation:**
  - **Inefficient Market Signals:**
    - Inflated Net CONE values reduce the accuracy of market signals for resource investment.
  - **Higher Consumer Costs:**
    - Overestimated Net CONE leads to unnecessarily high capacity payments.
  - **Barriers to Entry for New Resources:**
    - Inaccurate benchmarks discourage investment in innovative or low-cost technologies.
- **Regional Examples:**
  - ISO-NE's Forward Capacity Market (FCM) and NYISO's ICAP market have faced criticism for using overly conservative Net CONE estimates.

Potential Flaws in Net CONE Calculation Methodology

- **Key Methodological Issues:**
  - **Overly Conservative Assumptions:**
    - Capital cost estimates often reflect outdated or overly pessimistic assumptions.
    - Ignore recent declines in technology costs (e.g., solar, wind, storage).
  - **Static Energy Revenue Estimates:**
    - Expected market revenues from energy and ancillary services are underestimated due to reliance on historical averages.
    - Fails to account for dynamic market conditions or price volatility.
  - **Misaligned Risk Premiums:**
    - Assumes high financing costs or risk premiums that may not reflect actual investor expectations.
  - **Limited Consideration of Resource Diversity:**
    - Focus on traditional generation (e.g., gas peakers) excludes cheaper or more flexible resources like renewables and demand response.

Potential Flaws in Net CONE Calculation Methodology

- **Structural and Analytical Issues:**
  - **One-Size-Fits-All Approach:**
    - Uniform Net CONE estimates may not reflect locational differences in costs or market dynamics.
  - **Insufficient Stakeholder Engagement:**
    - Lack of input from diverse market participants can lead to biased or incomplete estimates.
- **Implications of Methodological Flaws:**
  - **Inflated Capacity Market Prices:**
    - Overestimation drives higher capacity costs, burdening consumers.
  - **Market Inefficiencies:**
    - Suboptimal investment signals distort market outcomes and delay the integration of cost-effective resources.
- **Recommendations for Improvement:**
  - Use updated and technology-specific cost data.
  - Incorporate forward-looking energy revenue projections.
  - Engage stakeholders to refine assumptions and methodologies.

Defining the Capacity Product

- **What is the Capacity Product?**
  - The capacity product represents a commitment by resources to be available to generate electricity or reduce demand during peak periods or reliability events.
- **Purpose:**
  - Ensure sufficient resources are available to maintain system reliability.
  - Provide long-term investment signals for resource adequacy.
- **Characteristics:**
  - **Availability:** Resources must be ready to perform during specific system conditions.
  - **Firmness:** Capacity must be reliable and deliverable when needed.
  - **Diversity:** Includes traditional generation, renewables, demand response, and storage.
- **Performance Metrics:**
  - Tested during peak demand periods or scarcity events.
  - Failure to perform can result in penalties, while exceeding commitments may yield bonuses.

Capacity Market Bidding Behavior

- **Factors Influencing Bids:**
  - **Net CONE:** Bids are often based on the expected Net Cost of New Entry.
  - **Opportunity Costs:** Reflect potential earnings in energy and ancillary service markets.
  - **Risk Tolerance:** Generators with higher risk tolerance may bid more aggressively.
- **Types of Bidding Strategies:**
  - **Cost-Based Bidding:** Reflects actual fixed and variable costs of providing capacity.
  - **Strategic Bidding:** Generators adjust bids to maximize profits while complying with market rules.
  - **Pivotal Supplier Behavior:** Large suppliers with significant market share may bid higher, knowing their capacity is essential.
- **Market Power Mitigation:**
  - Offer caps based on Net CONE or marginal costs.
  - Pivotal supplier tests to identify and mitigate anti-competitive behavior.

Counting Capacity: Non-Dispatchable Resources, Demand Response, and Storage

- **Non-Dispatchable Resources (e.g., Wind, Solar):**
  - **Capacity Credit:** Based on historical performance during peak periods or probabilistic modeling.
  - **Challenges:**
    - Variability and intermittency.
    - Dependence on weather and time of day.
- **Demand Response:**
  - **Definition:** Reductions in electricity consumption by consumers during peak demand.
  - **Capacity Counting:**
    - Verified through testing or historical performance.
    - Requires clear baselines to measure reductions accurately.
  - **Advantages:** Low cost and fast response to grid needs.

Counting Capacity: Non-Dispatchable Resources, Demand Response, and Storage

- **Energy Storage:**
  - **Capacity Contribution:** Determined by storage duration and discharge rate.
  - **Integration Challenges:**
    - Accounting for energy limitations during extended scarcity events.
    - Ensuring alignment with market signals for charging and discharging.
- **Methods for Capacity Counting:**
  - Effective Load Carrying Capability (ELCC) used for renewables and storage.
  - Historical or test-based performance metrics for demand response.
- **Conclusion:**
  - Accurate capacity counting is critical to integrating diverse resources while maintaining reliability.

Timing and Capacity Market Supply

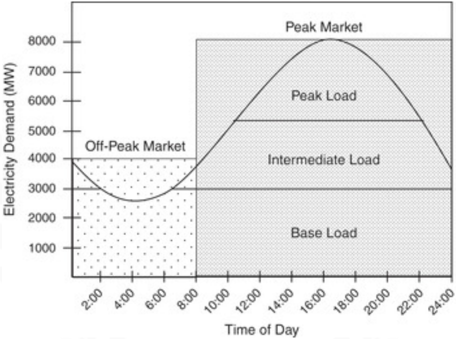

Figure 4: Load that can be available for peaks should demand a premium

Location and Capacity Market Supply

- RTOs now differentiate capacity markets by location
- RTOs set boundaries of capacity markets so reliability takes into account real grid constraints
- Tradeoff between high capacity costs by segmenting markets and advantaging supply in zone and reflecting reality of transmission
- Capacity zones encourage transmission build out in the long term

NYISO Capacity Zones

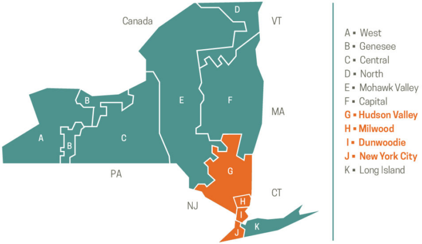

Figure 5: New York is an oddly big state

Capacity Market Equilibrium

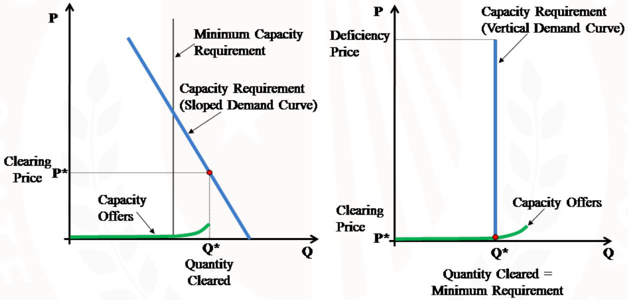

Figure 6: Supply meets demand.

What is Market Design?

- **Market Design:** The process of creating rules and frameworks that define how a market operates, ensuring efficiency, transparency, and alignment with policy objectives.
- Key elements include:
  - **Market Structure:** Types of participants, products, and market platforms.
  - **Market Rules:** Pricing mechanisms, trading protocols, and settlement procedures.
  - **Market Performance:** Ensuring competition, reliability, and innovation.
- Effective market design balances economic efficiency with regulatory and societal goals.

Impact of Market Design on Capacity Markets

- **Capacity Market:** A mechanism to ensure that sufficient generation capacity is available to meet future demand, enhancing grid reliability.
- **Market Design Impacts:**
  - **Pricing Signals:** Design choices determine how generators are incentivized to invest in new capacity.
  - **Reliability Standards:** Rules affect how capacity requirements are calculated and enforced.
  - **Market Participation:** Inclusion of different resource types (e.g., renewables, storage, demand response) depends on the market framework.
- Challenges include:
  - Avoiding over-procurement or under-procurement of capacity.
  - Integrating intermittent resources while maintaining reliability.

Auction Design Considerations

- **Objectives of the Auction:**
  - Ensure efficiency in resource allocation.
  - Promote transparency and competition.
  - Align with policy goals (e.g., reliability, decarbonization).
- **Key Design Features:**
  - **Pricing Mechanism:** Pay-as-bid vs. uniform pricing.
  - **Bid Structure:** Single round vs. multi-round auctions.
  - **Eligibility Rules:** Which participants and resources qualify.
- **Market Dynamics:**
  - Avoid market power and ensure competitive behavior.
  - Manage uncertainty and risk for participants.
- **Regulatory and Policy Considerations:**
  - Compliance with legal frameworks.
  - Alignment with environmental and reliability standards.

Auction Design in Capacity Markets: NYISO, PJM, ISO-NE

Feature	NYISO	PJM	ISO-NE
Auction Type	Seasonal	Annual	Forward
Time Horizon	6 months ahead	3 years ahead	3 years ahead
Pricing Mechanism	Uniform price	Uniform price	Uniform price
Demand Curve	Installed Capacity	Reliability Requirement	Reliability Requirement
Resource Inclusion	Limited DERs	DERs, Storage	Broad (incl. DERs, Imports)
Locational Signals	Strong	Moderate	Strong

Table 2: Key Features of Auction Designs in Capacity Markets

- Differences reflect regional policy priorities and market conditions.
- Locational signals in NYISO and ISO-NE ensure reliability in constrained zones.

Incremental Auctions: Overview

- **Definition:**
  - Incremental auctions are held after the primary capacity auction to adjust the amount of procured capacity.
- **Purpose:**
  - Address changes in demand forecasts or resource availability.
  - Allow market participants to buy or sell capacity commitments closer to the delivery period.
- **Benefits:**
  - Enhances flexibility in capacity markets.
  - Provides a mechanism to optimize resource allocation as conditions change.
- **Key Characteristics:**
  - Shorter lead time compared to primary auctions.
  - Focus on incremental adjustments rather than full capacity procurement.

How Incremental Auctions Work in PJM

- **Role in the Capacity Market:**
  - Held three times between the Base Residual Auction (BRA) and the delivery year.
  - Adjust capacity commitments to reflect changes in demand or supply.
- **Key Functions:**
  - Allow capacity resources to offer additional commitments if available.
  - Enable load-serving entities to procure additional capacity if needed.
- **Mechanism:**
  - Participants submit bids and offers based on updated forecasts and resource conditions.
  - Pricing is determined by market clearing, similar to the BRA.
- **Impact:**
  - Facilitates a more accurate match between capacity supply and demand.
  - Reduces the risk of over- or under-procurement of capacity.

How Incremental Auctions Work in ISO-NE

- **Purpose:**
  - Adjust Forward Capacity Market (FCM) commitments as conditions evolve closer to the delivery year.
  - Address changes in system needs due to updated forecasts or unexpected resource additions/withdrawals.
- **Key Features:**
  - Known as **Reconfiguration Auctions**, held annually and monthly before the commitment period.
  - Includes both demand- and supply-side adjustments:
    - Load-serving entities (LSEs) can adjust capacity obligations.
    - Resources can modify commitments by buying back obligations or offering additional capacity.
- **Mechanism:**
  - Participants bid to buy or sell capacity commitments.
  - Clearing prices are based on the intersection of supply and demand curves.
  - Results in incremental trades that align capacity resources with updated system needs.

Transmission Constraints and Capacity Markets

- **Transmission Constraints:**
  - Limit the ability to transfer power between regions.
  - Create locational differences in supply and demand dynamics.
- **Impact on Capacity Markets:**
  - **Locational Capacity Requirements:**
    - Capacity is procured based on regional needs to ensure reliability in constrained areas.
  - **Price Separation:**
    - Transmission limits can lead to different capacity clearing prices across zones.
  - **Incentives for Investment:**
    - Higher prices in constrained zones encourage investment in local generation or transmission upgrades.
- **Challenges:**
  - Balancing capacity procurement across zones without over- or under-supplying.
  - Accounting for changing grid topology and future demand growth.

Transmission Constraints and Capacity Markets

- **Examples of Interaction:**
  - ISO-NE, NYISO, and PJM use zonal capacity markets to reflect transmission constraints.
  - Locational requirements ensure reliability in load pockets and reduce dependence on long-distance transmission.

Opting Out of Capacity Markets

- **Definition:**
  - Certain entities can choose to meet their resource adequacy obligations outside of centralized capacity markets.
- **Reasons for Opting Out:**
  - Greater control over resource planning and procurement.
  - Desire to avoid exposure to capacity market clearing prices.
  - Support for self-sufficiency or local resource preferences.
- **Mechanisms for Opting Out:**
  - Alternative compliance frameworks, such as bilateral contracts or self-supply arrangements.
  - Local regulatory policies allowing resource adequacy outside market mechanisms.
- **Challenges:**
  - Ensuring long-term reliability without centralized market signals.
  - Balancing local resource adequacy with broader system needs.

PJM's Fixed Resource Requirement (FRR) Option

- **Definition:**
  - The FRR option allows load-serving entities (LSEs) to meet their capacity obligations outside of PJM's Reliability Pricing Model (RPM).
- **Eligibility:**
  - LSEs must demonstrate that they can provide adequate capacity resources to meet their load plus reserve requirements.
  - Must commit to the FRR option for a minimum of five years.
- **Key Features:**
  - Resources can include owned generation, bilateral contracts, or demand response.
  - No participation in centralized capacity auctions.
- **Advantages:**
  - Greater autonomy over capacity procurement.
  - Ability to align resource choices with local policy objectives (e.g., renewable energy targets).

ISO-NE and NYISO: Opt-Out by Self-Supplied Capacity Resources

- **Self-Supplied Capacity Resources:**
  - Allows load-serving entities (LSEs) to meet capacity obligations using owned or contracted resources instead of participating fully in capacity auctions.
  - **ISO-NE:**
    - LSEs can declare resources as self-supply in the Forward Capacity Market (FCM).
    - Self-supplied resources must meet equivalent reliability requirements.
  - **NYISO:**
    - Entities can fulfill obligations through self-supply while still being subject to locational capacity requirements.
    - Helps avoid over-procurement while meeting local reliability needs.

ISO-NE and NYISO: Opt-Out by Self-Supplied Capacity Resources

- **Procurement via Bilateral Transactions:**
  - Enables LSEs to procure capacity directly from generators through negotiated agreements.
  - **ISO-NE:**
    - Bilateral transactions can offset auction obligations, provided they meet the required standards.
  - **NYISO:**
    - Bilateral transactions allow flexibility in meeting locational and system-wide capacity needs.
- **Advantages:**
  - Greater control over resource planning.
  - Avoidance of auction price volatility.
- **Challenges:**
  - Requires detailed planning and coordination to ensure reliability.
  - Potential reduction in market liquidity.

Expanded Minimum Offer Price Rule (MOPR)

- **Definition:**
  - MOPR sets a floor price for capacity market offers to prevent uneconomic resources from distorting market outcomes.
  - Expanded MOPR applies to a broader set of resources, including those receiving out-of-market subsidies (e.g., renewable incentives or state support).
- **Purpose:**
  - Maintain competitive market outcomes by ensuring all offers reflect true economic costs.
- **Scope of Expansion:**
  - Applies to state-supported clean energy resources, including wind, solar, and nuclear.
  - Includes exemptions for certain self-supplied and demand response resources.
- **Controversy:**
  - Critics argue it undermines state policies promoting clean energy.
  - Supporters claim it preserves market integrity and reliability.

Effects of Expanded MOPR on PJM's Capacity Market

- **Impacts on Market Dynamics:**
  - **Increased Costs:** Floor prices can raise clearing prices, increasing costs for load-serving entities (LSEs).
  - **Over-Procurement:** May lead to over-procurement of capacity as subsidized resources are excluded.
- **Effects on Resources:**
  - **Subsidized Clean Energy:** Limited ability to clear in capacity auctions, creating financial uncertainty.
  - **Conventional Generators:** Gain competitive advantage, potentially delaying retirement of older plants.
- **Challenges for State Policies:**
  - Conflict with state-level renewable portfolio standards (RPS) and clean energy mandates.
  - States may consider alternative mechanisms, such as opting out of PJM's capacity market.

ISO-NE Performance Incentives in Capacity Markets

- **Objective:**
  - Align capacity market payments with actual resource performance during critical system events.
- **Key Features:**
  - **Pay-for-Performance (PFP):**
    - Incentivizes resources to perform during scarcity conditions.
    - Penalizes underperformance and rewards overperformance relative to obligations.
  - **Capacity Payments:**
    - Base payments are adjusted by performance incentives during scarcity events.
- **Benefits:**
  - Encourages resource reliability and flexibility.
  - Reduces reliance on penalties by creating strong performance-based incentives.

Capacity Performance Payments and CONE

- **Capacity Performance Payment Equation:**

$$\text{Performance Payment} = (\text{Actual Performance} - \text{Capacity Obligation}) \times \text{Pe}$$

  - **Actual Performance:** The electricity produced during a scarcity event.
  - **Capacity Obligation:** The amount of capacity the resource committed to providing.
  - **Performance Payment Rate:** A monetary value ($MWh) tied to system reliability needs.

- **Relation to CONE:**

$$\text{Net CONE} = \text{Gross CONE} - \text{Energy Market Revenues}$$

  - **CONE (Cost of New Entry):** The cost of building a new resource to meet capacity needs.
  - **Net CONE:** Reflects market revenues offsetting new resource costs.

Market Power in Capacity Markets

- **Definition:**
  - Market power arises when a participant can manipulate market outcomes to their advantage, such as inflating prices or restricting supply.
- **Sources of Market Power:**
  - **Concentration of Supply:** A few suppliers control a significant share of capacity.
  - **Transmission Constraints:** Limit competition by restricting access to markets.
  - **Limited Substitution:** Few alternatives to meet reliability requirements.
- **Effects:**
  - Higher costs for consumers due to inflated capacity prices.
  - Reduced market efficiency and fairness.
  - Potential underinvestment in new capacity if manipulated prices signal an unstable market.

Pivotal Supplier Test and Offer Mitigation

- **Pivotal Supplier Test:**
  - Used to identify suppliers with market power in capacity auctions.
  - A supplier is **pivotal** if their capacity is required to meet demand in the market.
  - Formula:

    $$\text{Residual Supply} = \text{Total Capacity} - \text{Supplier's Capacity} - \text{Demand Requiren}$$

  - If Residual Supply ¡ 0, the supplier is pivotal.
- **Offer Mitigation:**
  - Pivotal suppliers are subject to restrictions to prevent excessive bidding.
  - **Mitigation Mechanisms:**
    - Imposing bid caps based on reference prices or cost-based benchmarks.
    - Adjusting offers to reflect competitive levels.
  - Applied by market monitors to ensure fairness and efficiency.
- **Examples:**
  - In PJM, the Market Monitoring Unit (MMU) applies the test to assess market power.
  - Offer caps align with Net CONE or other cost-based metrics.

Market Power Mitigation: PJM, ISO-NE, and NYISO

- **PJM:**
  - Employs an independent MMU to monitor and mitigate market power.
  - Uses the Three-Pivotal Supplier Test to identify suppliers with market power.
  - Mitigates offers exceeding competitive levels based on Net CONE or ACR.
- **ISO-NE:**
  - Internal MMU conducts market monitoring and mitigation.
  - Applies a Pivotal Supplier Test in capacity auctions.
  - Mitigates offers to competitive levels determined by reference prices.
- **NYISO:**
  - Internal MMU oversees market power issues.
  - Utilizes supplier-specific market share tests.
  - Implements offer floors or caps based on default or unit-specific benchmarks.

Renewable Energy Certificates (RECs)

- **Definition:**
  - A Renewable Energy Certificate (REC) represents the environmental attributes of one megawatt-hour (MWh) of electricity generated from renewable resources.
- **Purpose:**
  - Encourage the development and use of renewable energy.
  - Provide a market-based mechanism to support clean energy goals.
- **Key Features:**
  - RECs are tradable, allowing entities to meet renewable portfolio standards (RPS) or voluntary sustainability goals.
  - Separation of environmental attributes from the physical delivery of energy.
- **Types of RECs:**
  - **Compliance RECs:** Used to meet regulatory requirements.
  - **Voluntary RECs:** Purchased by organizations to meet self-imposed clean energy goals.

Renewable Energy Certificates

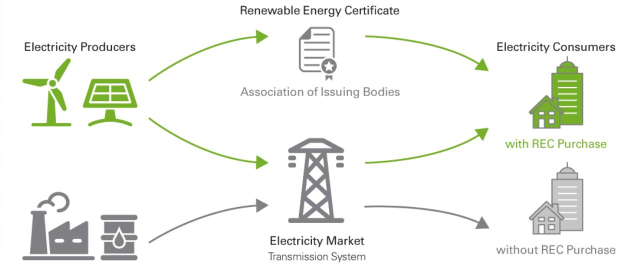

Figure 7: Get Rec'd!

Interaction of RECs with Transmission Constraints

- **Impact of Transmission Constraints on RECs:**
  - Renewable generation may be curtailed if transmission capacity is insufficient.
  - Limited transmission can restrict the delivery of renewable energy to REC-eligible markets.
- **Market Implications:**
  - **Locational Differences:** REC prices may vary significantly across regions due to transmission bottlenecks.
  - **Curtailment Risk:** Increases uncertainty for renewable generators, affecting REC availability.
- **Policy Responses:**
  - Investment in transmission infrastructure to support renewable integration.
  - Regional trading mechanisms to reduce the impact of localized constraints.

ERCOT

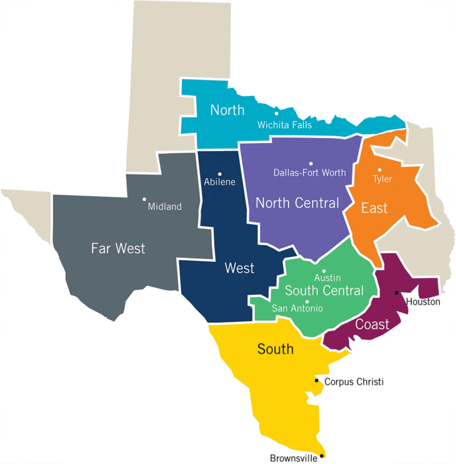

Figure 8: Don't mess with Texas!

History of ERCOT

- **Formation:**
  - Established in 1970 as the Electric Reliability Council of Texas.
  - Created to coordinate power flow and ensure grid reliability within Texas.
- **Unique Features:**
  - Operates as a single-state grid, largely independent of other U.S. interconnections.
  - Avoids federal jurisdiction under the Federal Energy Regulatory Commission (FERC) by operating solely within Texas.
- **Deregulation:**
  - Texas restructured its electricity market in 1999 under Senate Bill 7.
  - Introduced retail competition and separated power generation, transmission, and retail services.
- **Current Role:**
  - Manages 90% of Texas's electric load and over 50,000 miles of transmission lines.
  - Operates the competitive wholesale and retail electricity markets.

Why Texas Chose the "Energy-Only" Market Approach

- **Definition of Energy-Only Market:**
  - Generators are paid only for the electricity they produce, without separate capacity payments.
- **Rationale for Adoption:**
  - **Philosophy of Market Efficiency:**
    - Emphasis on free-market principles to drive investment and innovation.
    - Avoids administratively determined capacity requirements.
  - **Regulatory Independence:**
    - Desire to maintain state jurisdiction and minimize federal oversight.
  - **Cost Minimization:**
    - Avoids capacity payments, which can increase costs to consumers.
- **Design Features:**
  - **Scarcity Pricing:** High prices during tight supply incentivize investment in new capacity.
  - **Demand Response:** Encourages consumers to adjust usage during peak times.

Offer Caps and Value of Lost Load in ERCOT

- **Offer Caps:**
  - Maximum price that generators can bid into the ERCOT wholesale electricity market.
  - Intended to prevent price manipulation and ensure market stability.
  - Current Structure in ERCOT:
    - **System-Wide Offer Cap (SWOC):**
    - Initially set at 9, 000/*MWhbutreducedto*5,000/MWh after Winter Storm Uri (2021).
    - **Peaker Net Margin (PNM):**
    - Offer cap is lowered when generators' cumulative net revenue exceeds a defined threshold ($315,000/MW per year).

Offer Caps and Value of Lost Load in ERCOT

- **Value of Lost Load (VOLL):**
- Represents the estimated economic cost of an unserved megawatt-hour (MWh) of electricity to consumers.
- Used to:
  - Set offer caps that align with the cost of electricity interruptions.
  - Guide scarcity pricing mechanisms to incentivize reliability.
- ERCOT's VOLL is implicitly reflected in the high SWOC, which incentivizes generation during scarcity.
- **Interaction Between Offer Caps and VOLL:**
- High offer caps signal generators to increase supply during scarcity, reducing blackout risks.
- Aligning offer caps with VOLL ensures that scarcity pricing reflects the true economic value of reliability.

Operating Reserve Demand Curve (ORDC) in ERCOT

- **Definition:**
- The ORDC is a scarcity pricing mechanism used to value reserves based on the probability of grid reliability events.
- **Purpose:**
- Provide real-time price signals to incentivize resource availability during scarcity conditions.
- Reflect the economic value of maintaining operating reserves to avoid loss of load.

2021 ERCOT Outages: Causes and Price Effects

- **Key Features:**
- **Price Adder:** Adds a reserve scarcity price to energy prices when reserves fall below a threshold.
- **Value Based on Loss of Load Probability (LOLP):**

$$\text{ORDC Price} = \text{LOLP} \times \text{VOLL}$$

- Prices increase non-linearly as reserves approach critical levels.

2021 ERCOT Outages: Causes and Price Effects

- **Implementation in ERCOT:**
- Calculated in real-time for reserves below 6,500 MW.
- Linked to the $5,000/MWh offer cap to ensure high scarcity pricing.
- **Impact:**
- Encourages generation availability during tight supply conditions.
- Provides price signals to support investments in flexible resources, such as demand response and storage.
- **Challenges:**
- Volatile pricing can create financial uncertainty for market participants.
- High scarcity prices may raise consumer costs during extreme conditions.

2021 ERCOT Outages: Causes and Price Effects

- **Event Overview:**
- Occurred during Winter Storm Uri in February 2021.
- Widespread power outages affected over 4.5 million homes and businesses in Texas.
- **Causes:**
- **Weather-Related Failures:**
    - Power plants (natural gas, coal, nuclear, and wind) were not adequately winterized.
    - Frozen equipment and fuel supply disruptions caused significant generation outages.
- **Gas Supply Issues:**
    - Natural gas pipelines and production facilities froze, reducing fuel availability for generators.

2021 ERCOT Outages: Causes and Price Effects

- **Demand Surge:**
- Extreme cold weather led to record electricity demand, surpassing ERCOT's capacity.

Effects on Prices:

- Prices reached the $9,000/MWh offer cap during peak scarcity conditions.
- **Extended Scarcity Pricing:**
- ERCOT maintained high prices for several days, leading to billions of dollars in market costs.
- **Market Disruptions:**
- Financial strain on electricity providers, with some declaring bankruptcy.
- Significant impacts on retail electricity customers with variable-rate plans.

Aftermath and Reforms

- Reduction of the System-Wide Offer Cap (SWOC) from \$9,000/MWh to \$5,000/MWh.
- Increased focus on weatherization requirements for power plants and gas facilities.
- Renewed discussions on grid resilience and capacity market designs.

ERCOT be like:

Figure 9: The price is the price...

Thank You So Much!

List of References