



Capacity Markets and Resource Adequacy for a Renewable Rich Future

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- Discuss historic methods of achieving resource adequacy
- The need for capacity markets
- The underlying theory behind capacity markets
- Structure of capacity markets
- The renewable threat to capacity markets
- The need for new resource adequacy concepts and the mechanisms for cost recovery of capital costs

Resource adequacy and central station generation



- At the dawn of electric era – two competing business model
 - Isolated plant – Equipment for customer self supply
 - Central Station – sold service to customer
- Edison - utility concept based on central station
- Samuel Insull – utility concept
 - Economies of scale – increasing generator size led to reduced cost
 - Diversity benefits – customers used power at different times, reducing the overall level of required generation

Dimensions of utility growth



- Through consolidation of multiple systems
 - Individual utility growth
 - Holding companies - multi-state trusts
- Through development of systems that supported interchange between companies
 - PNJ – first power pool in the US – comprised of three utilities to coordinate output of Conowingo Dam on the Susquehanna River.

Growth required generator coordination

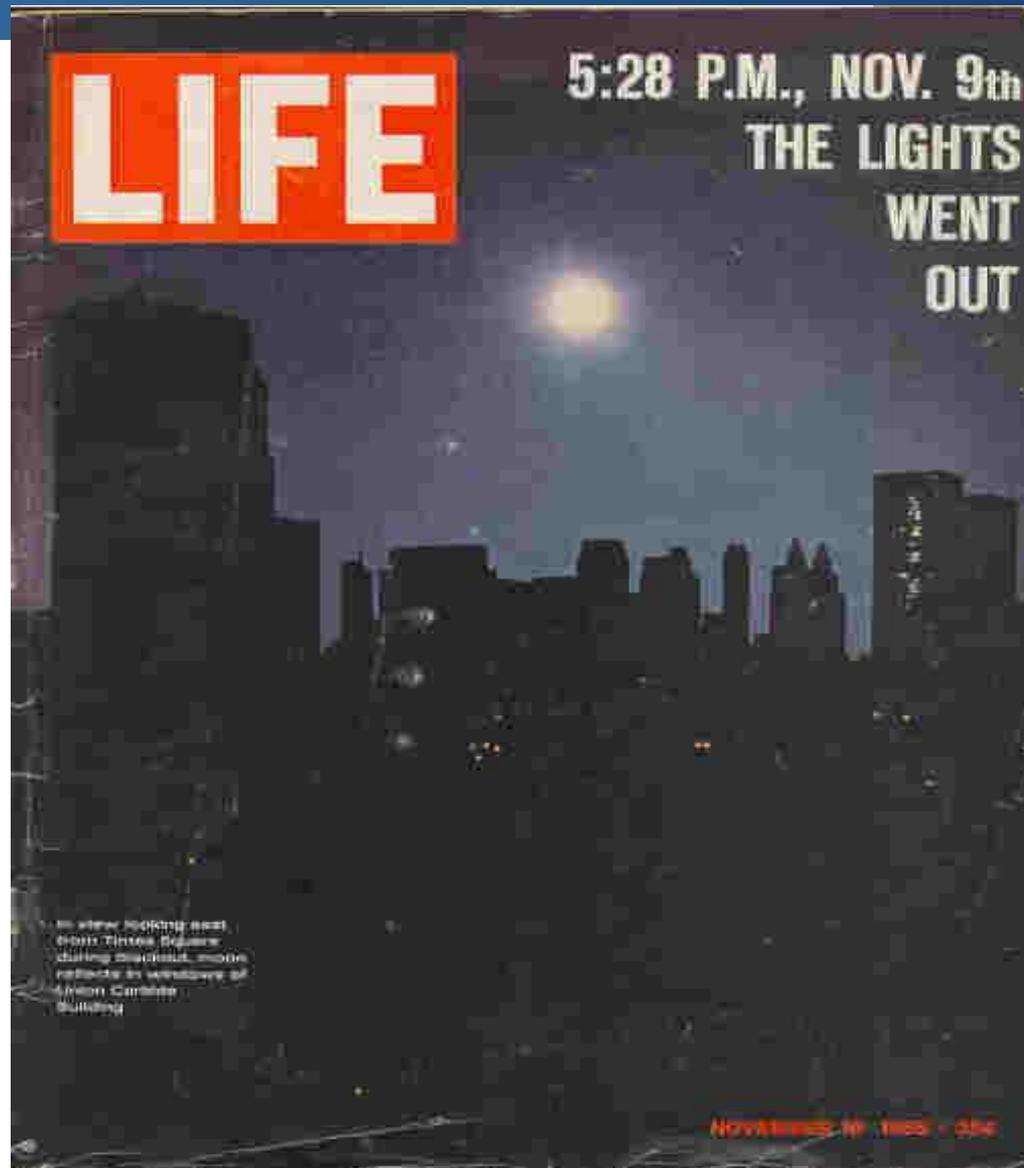
- Multiple generators on system required coordination – dispatch
- In 1930's recognition that costs were minimized when the marginal cost (MC) of all generators equal
- Early analytical tool for supporting dispatch – Incremental Slide Rule



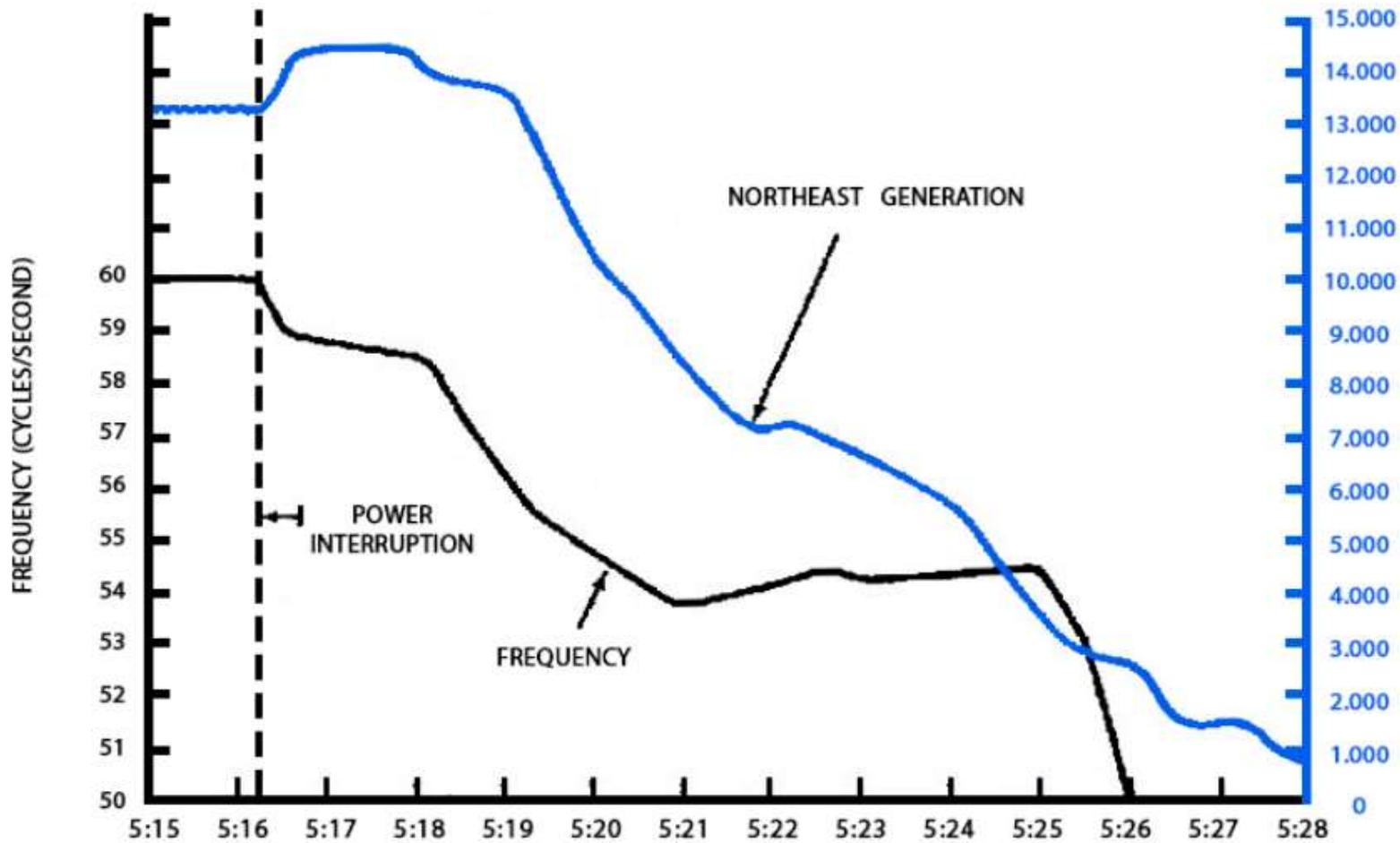
Johnson, H.H., and M. S. Umbenhauer, "An Effective Load Dividing Device," Edison Electric Bulletin 7, No. 8 (1939): 385. Permission granted by EEI.

Integration had unexpected consequences

- Great Northeast Blackout of 1965
- 80,000 sq. miles with 30 million people in 14 minutes
- Highlighted the importance of situation awareness, "difficulty evaluating the extent of the system disturbance"



Minute-by-minute deterioration of NE power system, leading to system generation and frequency drop preceding the 1965 NE Blackout



Response to the blackout – creation of reliability-centric institutions



- NERC – North American Electric Reliability Council
 - Created a forum for reviewing reliability
 - Established metrics and criteria
 - Regional reliability councils – including ERCOT
 - Became the Electric Reliability Organization (ERO)
- Creation of Power Pools
 - Coordinated reliable operation and market for power of multi-utility systems
 - New York Power Pool
 - New England Power Pool
 - Became Independent System Operators

Short-run

- *Security* is the ability of the bulk power electric system to withstand sudden disturbances.”
- *Operating reserves*, to respond to real-time failures of generation and transmission.

Long-run

- *Adequacy* is the ability of the bulk power electric system to supply the aggregate electric power and energy requirements of the consumers at all times.”
- *Installed Reserves*, to guide investment planning to ensure that operating reserves are available when needed

- Traditionally electric utilities vertically integrated
- The cost of generation was an asset incorporated into the utility rate base
- All capacity including installed reserves included in rate base
- Rate base was allocated to different customer classes and recovered through rates

Merchant generation – no rate recovery/now market based



- Cost recovery and profits for merchant generation is based on the level of revenues received through market prices
- First experience with merchant (non-utility generation) was based on the Public Utilities Policy Act of 1978.
- The criteria used was that the price paid would reflect the “avoided cost” to the utility
- Avoided cost was defined in statute as the cost that the utility would have incurred “but for” the purchase of power from the wholesale generator.

- Peaker method is based on the peak load pricing literature
- Problem was first solved by Marcel Boiteux in 1949. See:
 - Boiteux, Marcel P. «La tarification des demandes en pointe: Application de la théorie de la vente au coût marginal», 1949, *Revue générale de l'électricité*
- Simple model further developed, using complex mathematics, into a stochastic model. The basic conclusions and results are not different in the more complex form. See for example:
 - Michael Crew and Paul Kleindorfer, "Peak Load Pricing with a Diverse Technology" *Bell Journal of Economics* 7, No. 1 (Spring 1976) pages 207-231., and
 - Chao Hung Po, "Peak Load Pricing and Capacity Planning with Demand and Supply Uncertainty," *Bell Journal of Economics* Vol 14 (1983), pp. 179-190.

Basic assumption of using Peaker Method for avoided costs



- The marginal cost of electricity is the appropriate measure of avoided costs
- Theory based on peak-load pricing literature
- Literature objective – optimal pricing not cost recovery

Peaker Method's four elements



1. The Process of Economic Dispatch
2. The Need for Reserves
3. Optimal capacity mix.
4. The peaker as a measure of pure reliability

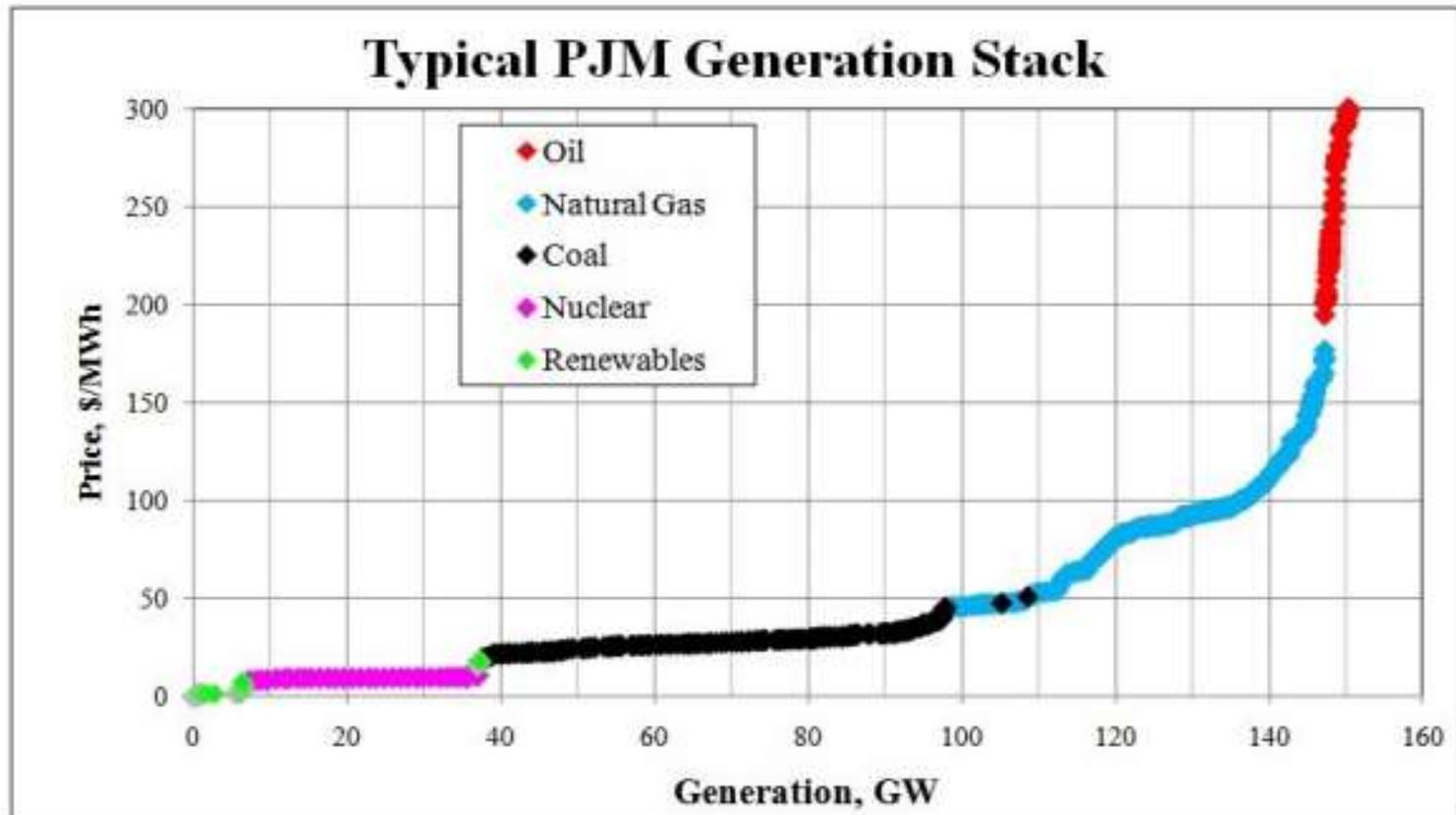
Dispatch has become complex

The PJM control center



Courtesy of PJM.

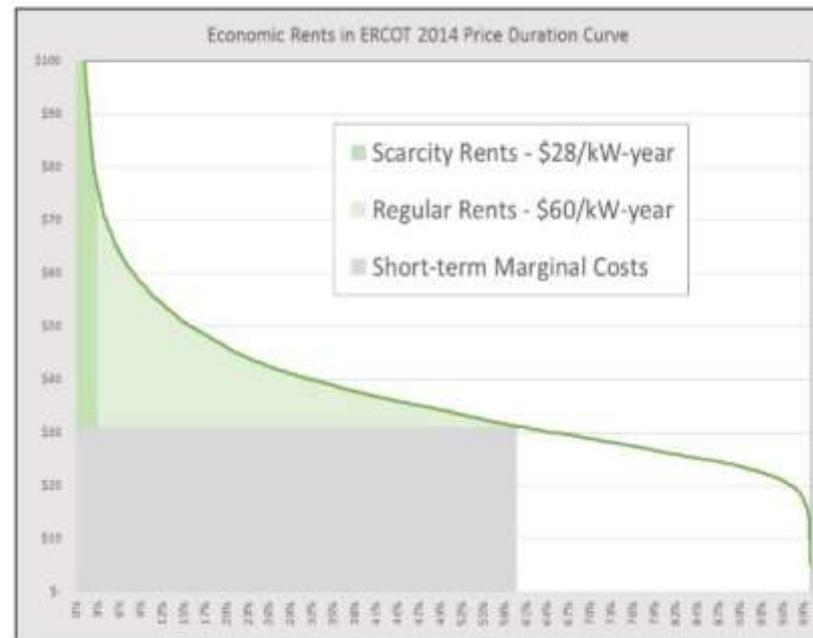
The PJM supply curve



Tayari, F., "Fundamentals of Electric Markets," 2020. Reproduced with permission of the author, <https://www.e-education.psu.edu/ebf200/node/151>.

Earning inframarginal rents

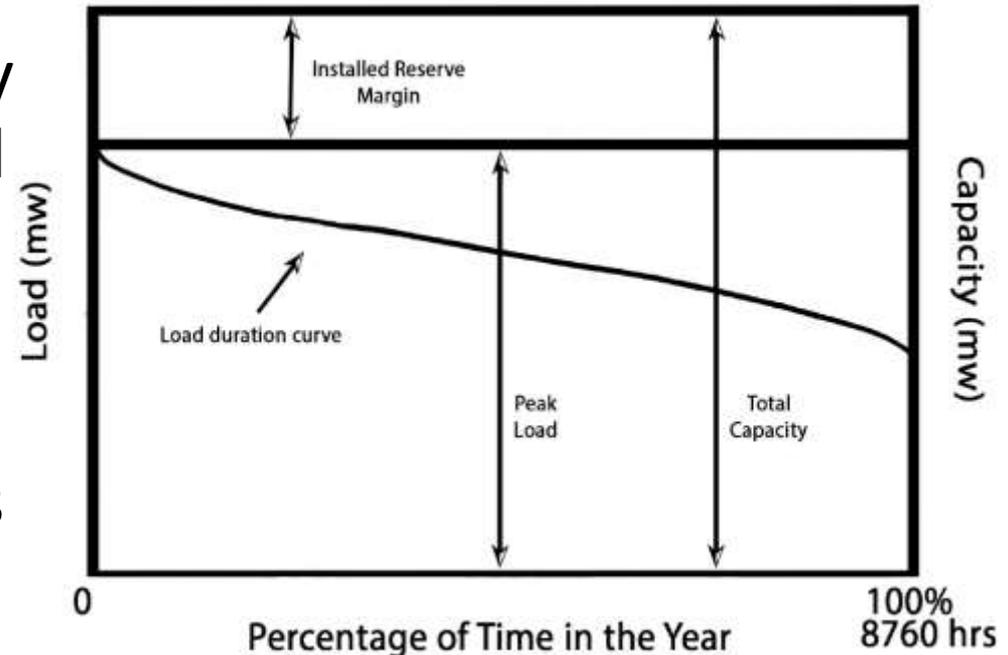
- Inframarginal rents are the difference between a generator's marginal cost and market price
- Inframarginal rents contribute to cost recovery and profits



The installed reserve margins the basis of resource adequacy

- Installed reserves are a planning concept
- The reserve margin is the amount of capacity above what is required to meet peak load
- Reserve margins are based upon models of generator unit outages

Load Duration Curve, the Installed Reserve Margin and Total Capacity



- Optimal capacity mix is the combination of different types of generation that minimize costs of generation
- Traditionally, there is a tradeoff between capital and operating costs.

Generators in the mix

Baseload - nuclear



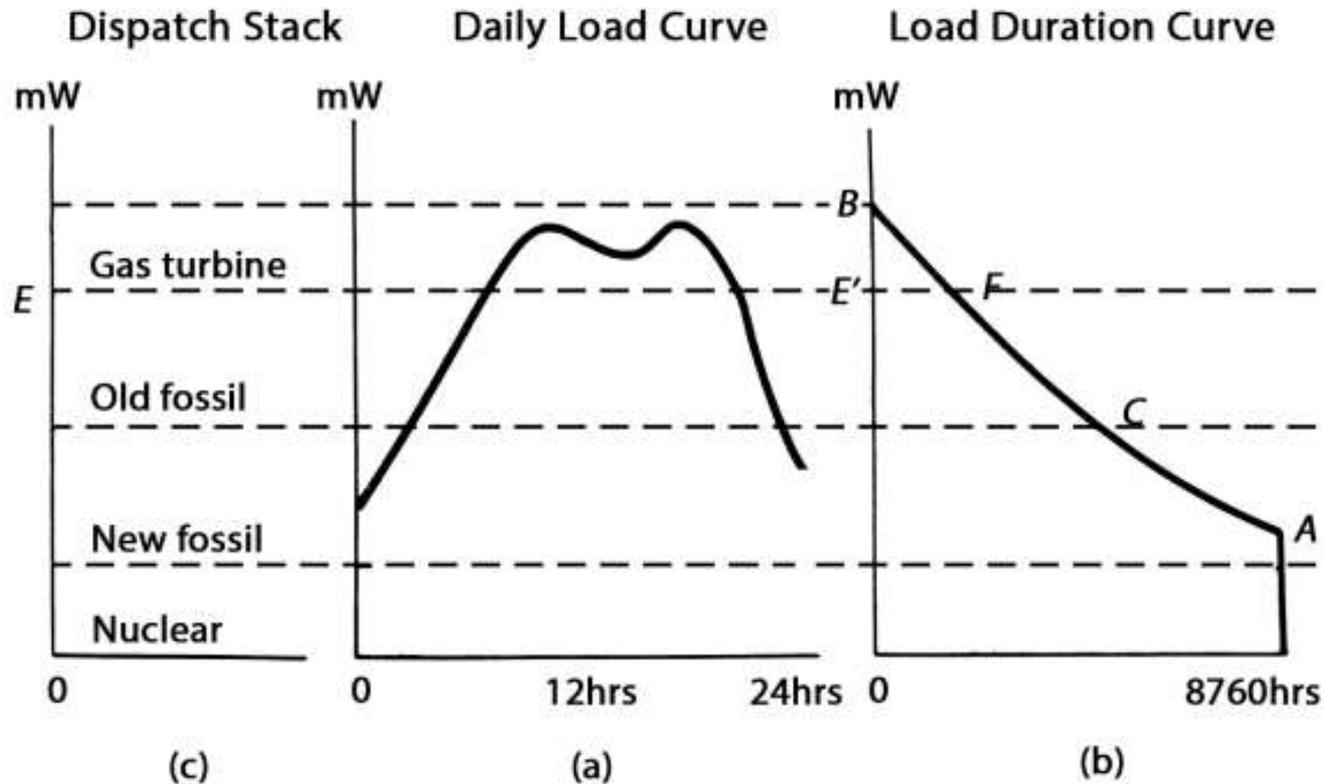
Intermediate – cycling coal plant



Peaker – gas turbine



Relationship of dispatch/bid stack, daily load curve and load duration curve



- Peakers tend to be the least expensive generating unit to build and the most expensive to operate
- Peakers do not earn infra-marginal rents
- The only reason to build a peaker is for reliability
- As a consequence, peaker is thought of as a measure of pure reliability

Putting the pieces together

Given a system with an optimal capacity mix and an installed reserve obligation, with generators paid at a competitive market price (set by the MC of the load following unit) there will be a revenue shortfall equal to the cost of a peaker.

As a consequence,

$$\left\{ \begin{array}{c} \text{Market} \\ \text{price} \end{array} \right\} = \left\{ \begin{array}{c} \text{Marginal} \\ \text{Energy Cost} \end{array} \right\} + \left\{ \begin{array}{c} \text{Marginal Expected} \\ \text{Curtailment Cost} \end{array} \right\}$$

Where the market price is equal to the marginal cost of electricity plus the value of the change in reliability due to a change in load. This change in reliability is called the marginal expected curtailment cost (MECC)

At the optimal reserve margin MECC = Cost of a peaker

Therefore to make generators whole there must be an additional payment – the capacity payment

- In the mid to late 1990's, some electric systems began to restructure from vertically integrated systems to systems with competitive generation
- Independent System Operators (ISO's) were created to coordinate transactions
- The nature of transactions shifted from dispatch based upon generator costs provided by utilities to bids provided by merchant generators
- The focus of the shift to competitive markets was on redesigning energy markets, not cost recovery of generators' capital costs

The relationship of the peaker method to “missing money”



- The underlying theory behind the Peaker Method predicts that there will be a revenue shortfall in a competitive market
- Once competitive markets began to operate, the generators and their representatives began to complain about missing money.
- The rationale behind the missing money claim was that generators were restricted by price caps from recovering the cost of their investments during periods of scarcity (i.e., collect scarcity rents)
- When is a scarcity rent market power?

Early capacity markets relied on deficiency payments

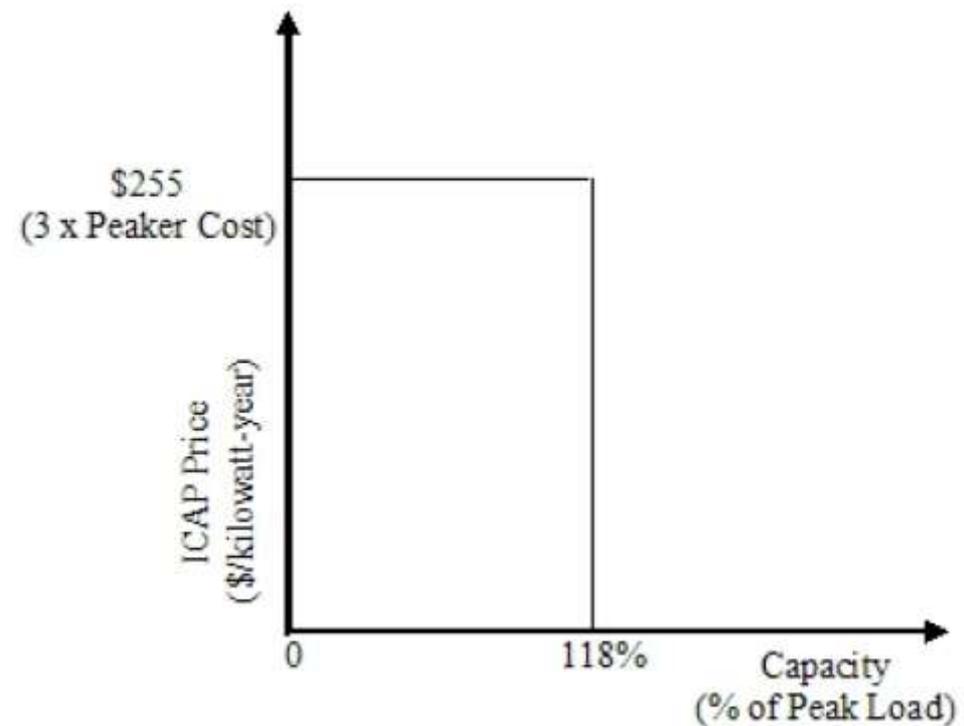


- The three ISO's in the Northeastern evolved from power pools
- Power pools had reserve margin requirements for their member utilities
- To enforce those requirements, power pools had instituted a system of deficiency payments
- Typically, deficiency payments were set at three times the annual cost of a peaker
- Those deficiency payments became the template for the first capacity markets

Markets based on deficiency payments were volatile

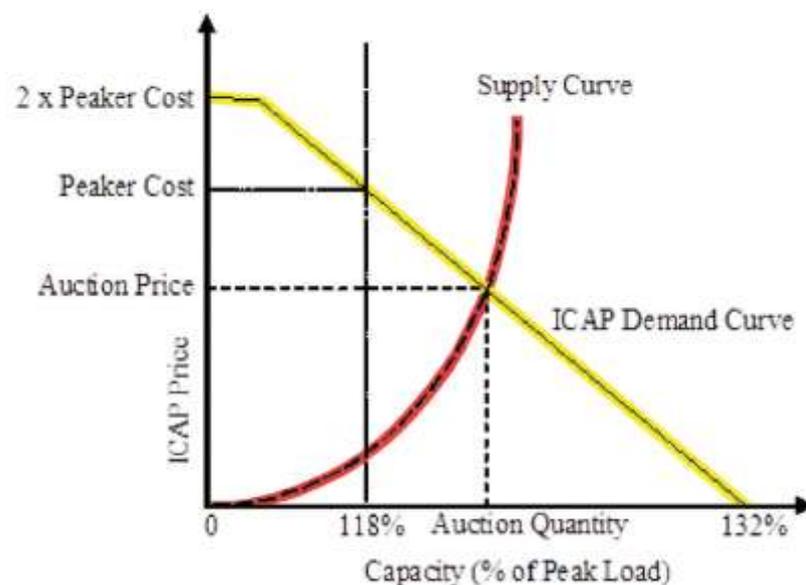
- When there were adequate reserves, prices approached zero
- With inadequate reserves, prices approached deficiency payment
- Led to a call to change the market structure

New York deficiency market price curve



New York developed a capacity market called the “Demand Curve”

- Curve characteristics relying on Peaker Method
the value of capacity at the optimal reserve margin (118 percent of peak load) is equal to cost of a peaker.
- Pivotal points not supported by theory or empirical analysis
 - (1) the maximum allowable price – twice the cost of a peaker
 - (2) the point at which the incremental value of capacity (i.e., its price) is zero.

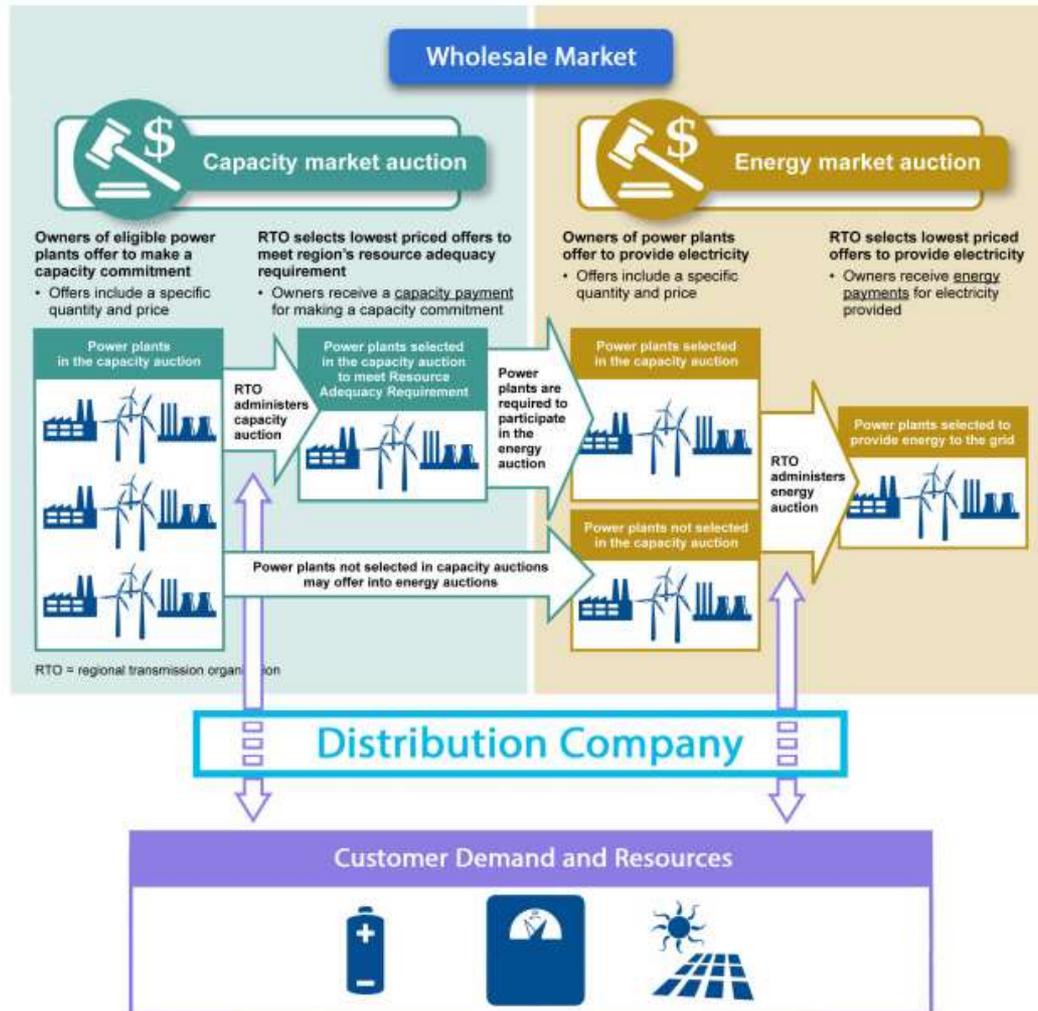


Other ISO's have capacity markets



- PJM – Reliability Pricing Market (RPM)
- ISO-NE – Forward Capacity Market
- Both of these markets have a forward commitment for a number of years
- The idea behind the forward commitment is that it allows generators not yet built to compete against existing generators
- All of these markets have mechanisms to penalize generators receiving capacity payments for non-performance

Summary of capacity market architecture including the growing role of the customer

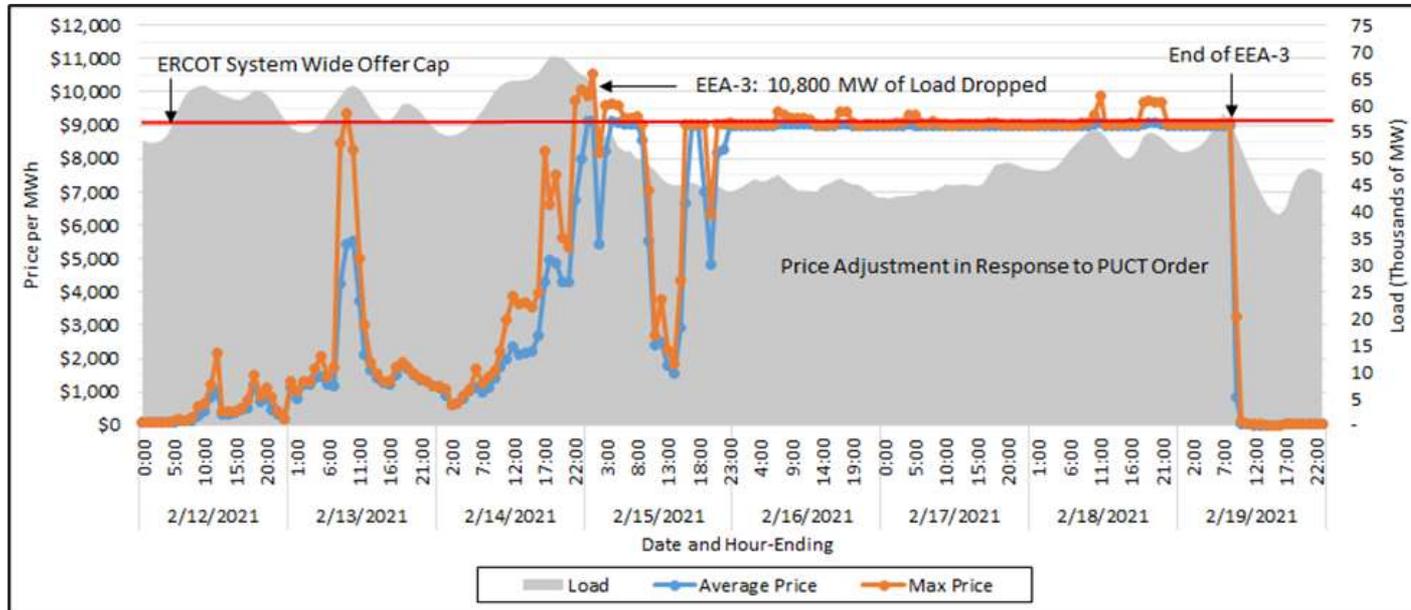


Other capacity acquisition mechanisms



- Vertically integrated utilities participating in organized markets, such as the Midcontinent Independent System Operator, receive cost recovery through rates
- California load serving entities have an obligation to procure forward capacity, which provides a revenue stream for capacity payments
- Texas relies on scarcity pricing

What happened during the Texas freeze?



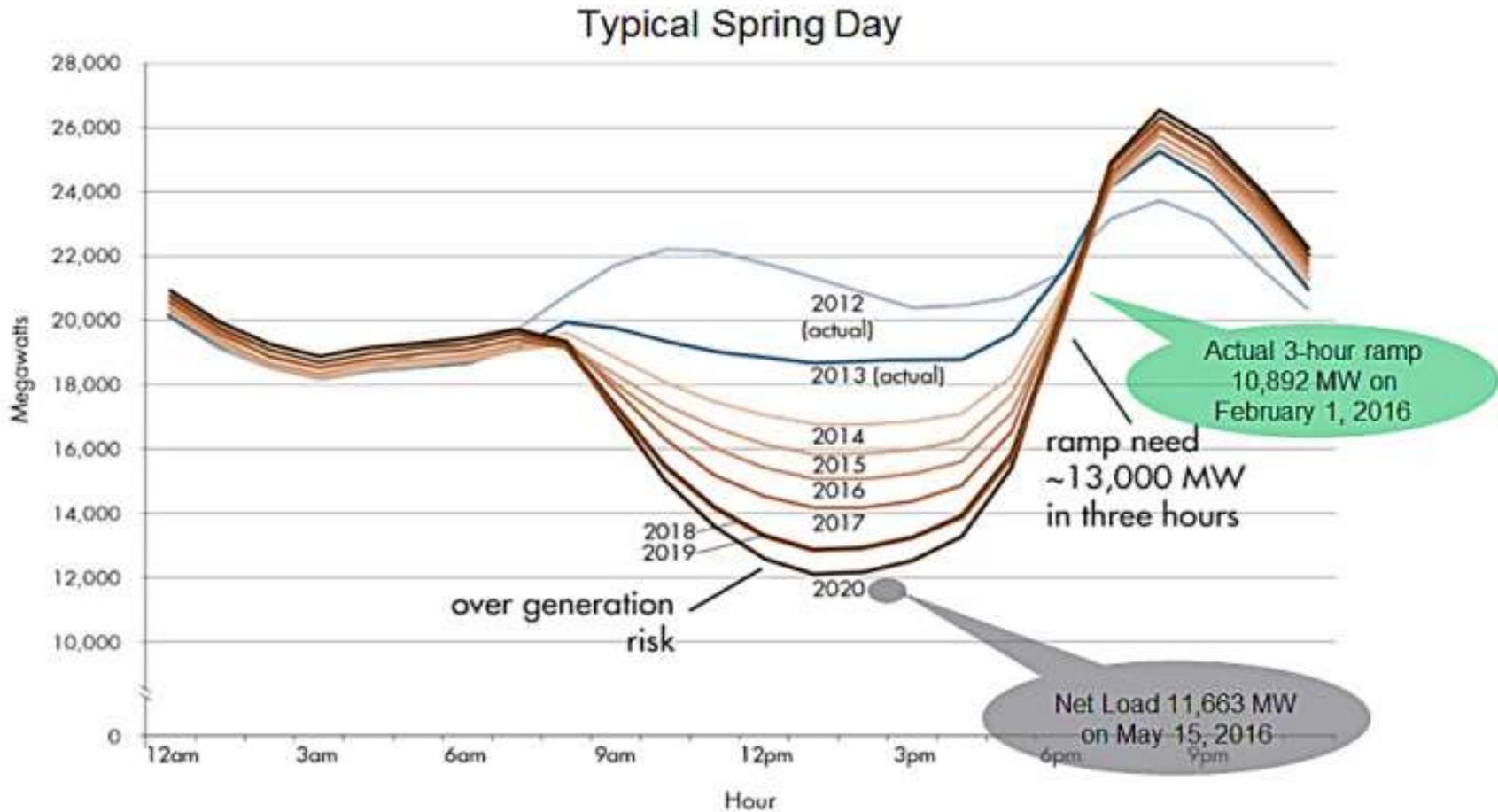
- Texas market based on payment of administratively determined scarcity prices, \$ 9,000/MWh
- Generators had no obligation to perform
- No cap on revenues earned
- No planning or consideration of resilience

Characteristics of renewables that pose an existential threat to capacity markets



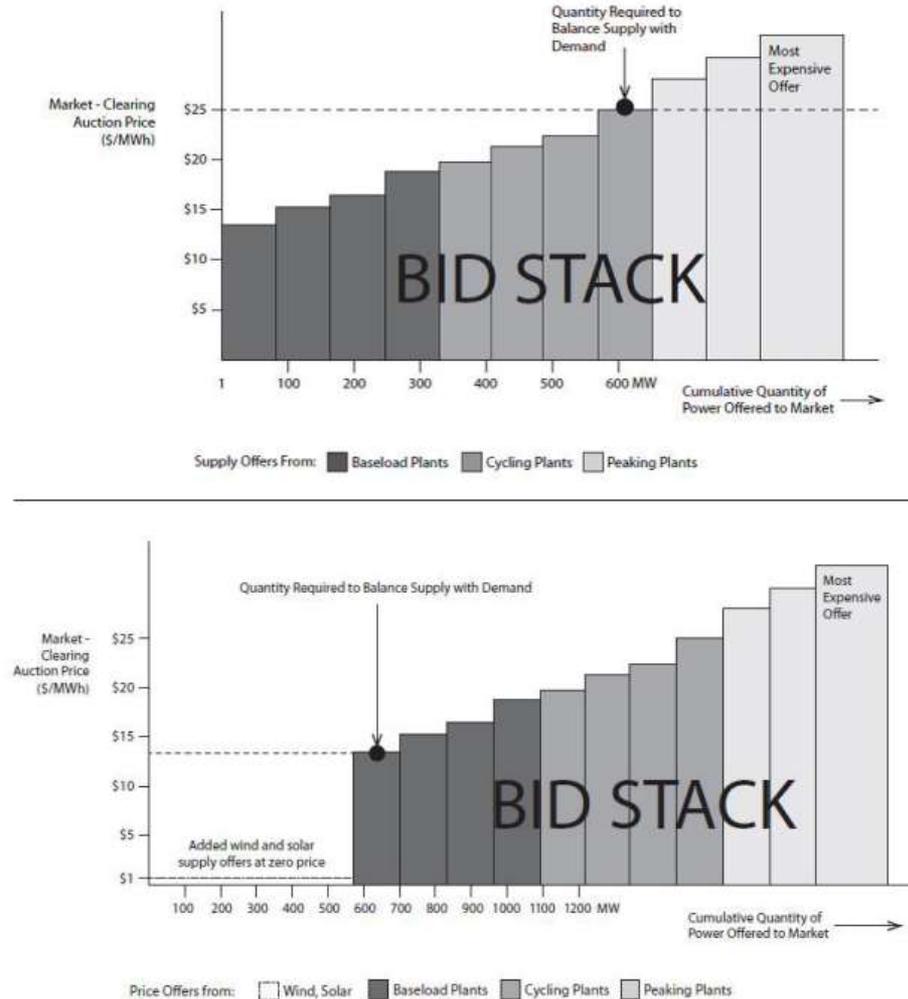
- Renewables have zero marginal cost
- Renewables are intermittent
- Renewables create the need for new types of essential reliability services (such as fast ramping)
- Renewables change the notion of the value of capacity and whether new reserve margin concepts are needed
- Renewables reduce probability of inframarginal rents
- Can there be an optimal capacity mix with renewables?

California Duck Curve demonstrates need for new reliability concepts and products



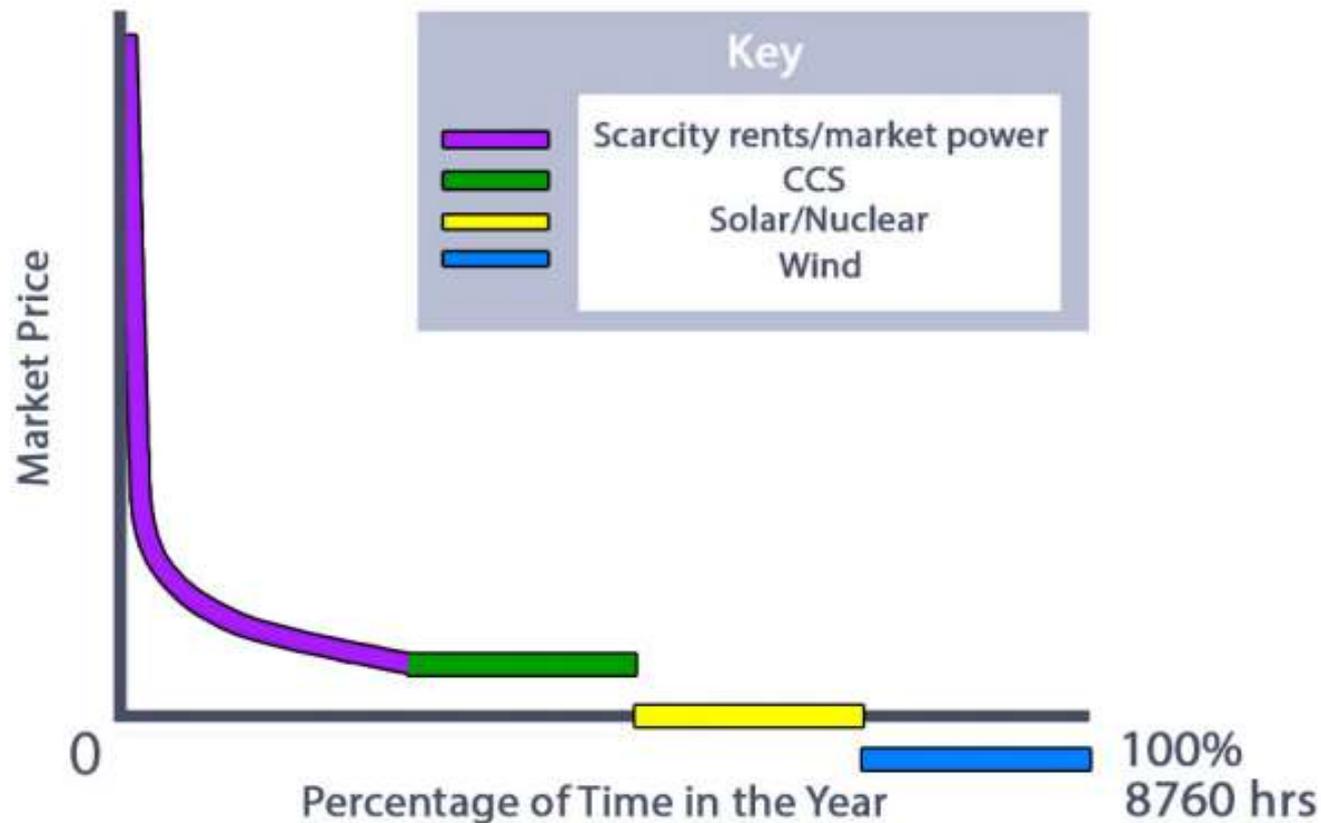
California ISO, "What the duck curve tells us about managing a green grid," Fast Facts Source, p. 3, https://www.caiso.com/Documents/FlexibleResourcesHelpRenewables_FastFacts.pdf. Reproduced with permission.

Renewables shift the market bid stack



Fox-Penner, P., Power After Carbon, Harvard University Press, 2020, pp. 290-291.
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Reduced ability to gain infra-marginal rents from energy markets



- Power markets will operate very differently
 - How would economic dispatch be performed in a 100% renewable, zero marginal cost system?
 - Increased role of the customer (including demand response) and storage
- Concepts of resource adequacy need to be rethought with intermittent generation
- Will planning play a larger role
 - Resources will be more distributed
 - Increasing role of distribution system planning and integration of distribution into operation of bulk system
- New compensation models for capacity are needed
 - Such as World Resources Institute/ Resources for the Future workshop on wholesale market design (<https://www.wri.org/events/2020/12/market-design-clean-energy-transition-advancing-long-term>)



Thank you

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Papers relied on for presentation:

Pechman, C. “Whither the FERC? Overcoming the Existential Threat to Its Magic Pricing Formula through Prudent Regulation.” January, 2021.

<http://bit.ly/whitherferc>

Pechman, C. and Nettercutt, E., “Regulatory Questions Engendered by the Texas Energy Crisis of 2021,” March 2021. <http://bit.ly/TheTexasFreeze>