Future Power Markets Forum

Decentralized Market Design

A PROJECT OF

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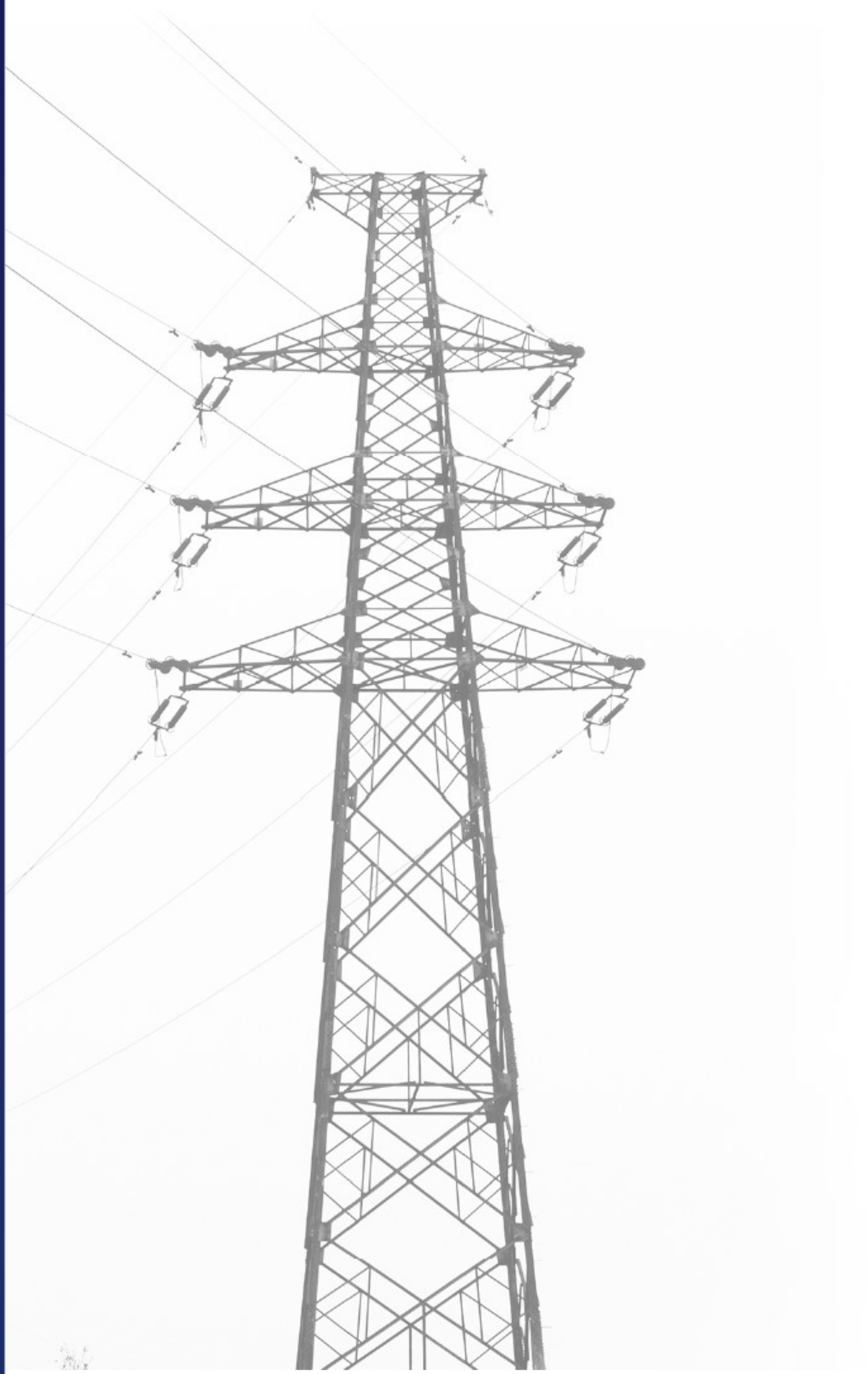
About Future Power Markets Forum



Future Power Markets Forum investigates proposals for market designs that maintain system efficiency and reliability with a high penetration of variable generation.

Future Power Markets Forum began in May 2020 as a joint project of the Columbia University SIPA Center for Global Energy Policy and Johns Hopkins University Whiting School of Engineering.

The Future Power Markets Forum website hosts materials on proposals for electricity market structure and design and a research library of relevant papers.

Forum contributors, representing a balanced group of the sector's practitioners, researchers and regulators, offer commentary on the issues and proposals.

Topic 3: Decentralized Markets

Dr. William Hogan

Harvard Electricity Policy Group

ELECTRICITY MARKET DESIGN:
SUPPORTING VARIABLE GENERATION

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Future Power Markets Forum: Decentralized Market Design

July 22, 2020

The panel charge is to address proposals for market designs that maintain system efficiency and reliability with a high penetration of variable generation.

- **Variable Generation: Zero Variable Cost, Intermittent Availability**
- **"Soup to Nuts" Design**
  - **Broad Policy Requirements**
    - Technology Innovation and Technology Neutrality
    - Pricing Carbon and Other Externalities: For Incentives and to Define How Much is Enough
  - **Electricity Market Design**
    - Real-Time Wholesale Markets
    - Scarcity Pricing
    - Extended Locational Marginal Pricing
    - Multi-Period Pricing
    - Day-Ahead Wholesale
      - Virtual Bidding
      - Energy Trading and Financial Transmission Rights
  - **Long-Term Incentives and Forward Contracting**
  - **Transmission Expansion**
  - **Distributed Energy Resources**

The NAS identified two main barriers and emphasized two "overarching recommendations."
(National Academy of Sciences, *The Power of Change: Innovation for Development and Deployment of Increasingly Clean Electric Power Technologies*, Washington D.C., 2016, pp.3-4.)

Barriers

"The committee concluded that there are two significant barriers to accelerating greater penetration of increasingly clean electricity technologies. First, as noted above, the market prices for electricity do not include "hidden" costs from pollution, stemming mainly from negative impacts on human health, agriculture, and the environment. Levels of criteria pollutants declined over the past three decades, but still cause harms. Harms from GHGs are difficult to estimate, but if accounted for in the market, could be considered by consumers. …

The second barrier is that the scale of the climate change challenge is so large that it necessitates a significant switch to increasingly clean power sources. In most of the United States, however, even with a price on pollution, most increasingly clean technologies would lack cost and performance profiles that would result in the levels of adoption required. In most cases, their levelized costs are higher than those of dirtier technologies, and there are significant challenges and costs entailed in integrating them into the grid at high levels. This means that reducing the harmful effects of emissions due to electricity generation will require a broader range of low-cost, low- and zero-emission energy options than is currently available, as well as significant changes to the technologies and functionality of the electricity grid and the roles of utilities, regulators, and third parties. …

…even if the technological and institutional barriers to greater adoption of increasingly clean power technologies were overcome but their prices were not competitive, an adequate scale of deployment would require tremendous public outlays, and in many parts of the world would be unlikely to occur. While learning by doing can lower some costs, deployment incentives are likely to be insufficient as the primary policy mechanism for achieving timely cost and performance improvements."

The NAS identified two main barriers and emphasized two "overarching recommendations."
(National Academy of Sciences, *The Power of Change: Innovation for Development and Deployment of Increasingly Clean Electric Power Technologies*, Washington D.C., 2016, pp.3-4.)

Recommendations

"The U.S. federal government and state governments should significantly increase their emphasis on supporting innovation in increasingly clean electric power generation technologies.

Simply put, the best way to encourage market uptake is first to have technologies with competitive cost and performance profiles. The need for increased innovation and expanded technology options is especially important given the global picture. In many parts of the world, coal remains the cheapest fuel for electricity generation. China, India, and the nations of Southeast Asia are expected to continue rapidly adding new electricity generation facilities, most of them coal-fired and with minimal pollution controls. Thus there is a need for technological innovations that are affordable outside the United States as well. These improvements in performance and cost will be essential to achieve long-term GHG reductions, such as the reduction called for in the COP21 agreement, without significantly increasing electricity prices. …

Congress should consider an appropriate price on pollution from power production to level the playing field; create consistent market pull; and expand research, development, and commercialization of increasingly clean energy resources and technologies.

Correcting market prices will encourage more deployment of increasingly clean technologies. Where such technologies are already the lowest-price choice, they will become even more so; in other locations, a pollution price will make these technologies the most affordable option or narrow the gap. In addition to providing this market pull for the deployment of mature increasingly clean technologies, pollution pricing can be expected to spur the development of new, even more effective and competitively priced technologies."

A passing reflection on history reinforces the view that there is great uncertainty about energy technology choices for the future. There are many examples of both bad and good surprises.

TVA's nuclear plant auction set for November

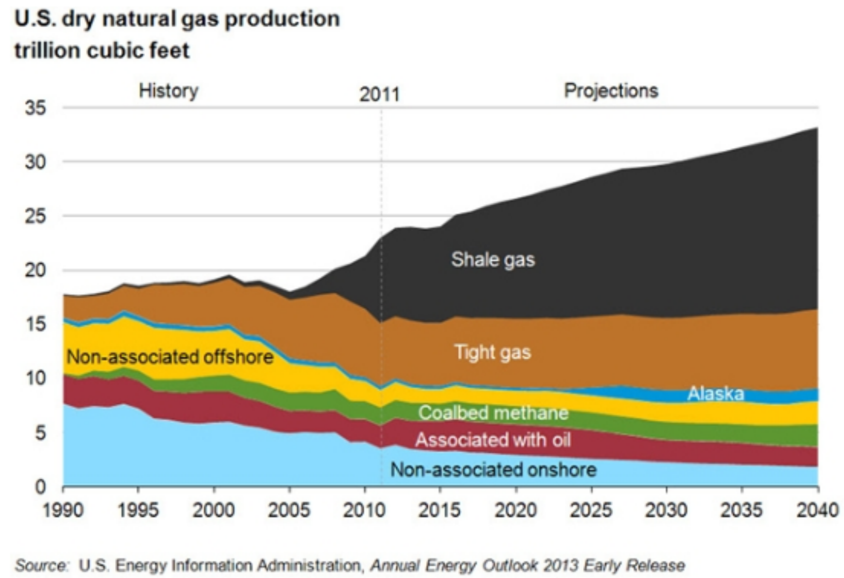
"The Tennessee Valley Authority, in apparently a first in the US power industry, plans to auction its unfinished Bellefonte nuclear plant in Alabama on November 14 in what amounts to a "fire sale" of epic proportions.

Over more than four decades, an estimated $6 billion was pumped into the project imagined at a time of far different economic and electricity projections and expectations. Bellefonte's minimum asking price — $36.4 million."

(Megawatt Daily, October 18, 2016, p. 3)

U.S. Shale Miracle:

Once the technology crossed the market threshold, deployment was both large and rapid.



Good wholesale electricity market design is necessary to provide open access with non-discrimination principles that encourage entry and innovation.

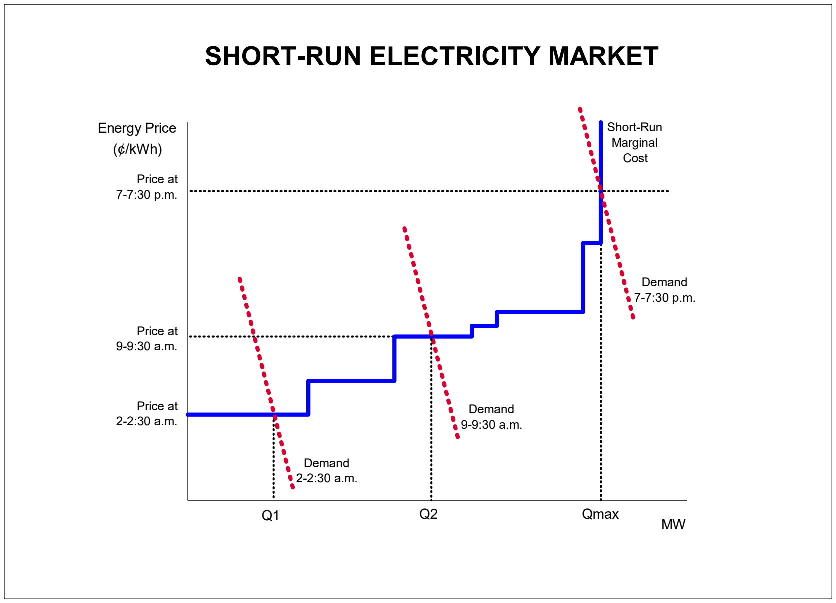
A core challenge for all electricity systems is between monopoly provision and market operations. Electricity market design depends on critical choices. There is no escape from the fundamentals.

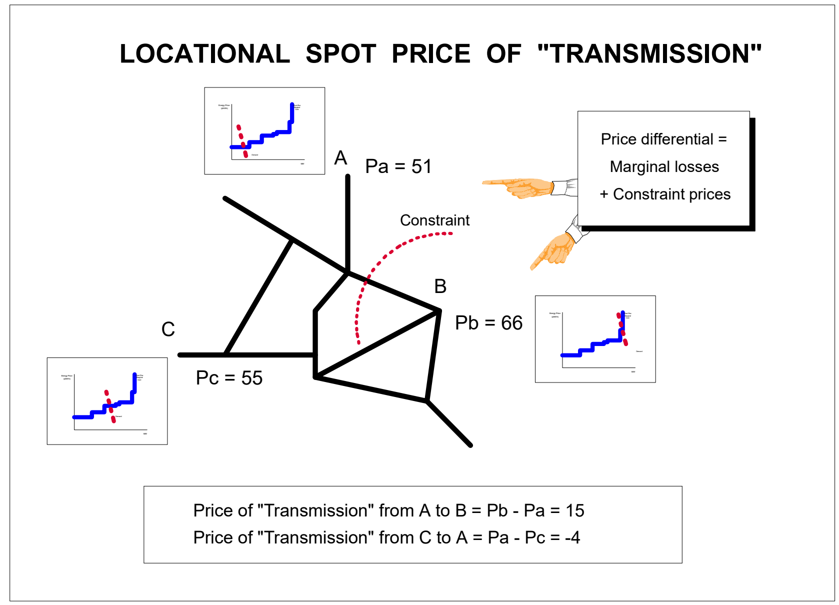
Integrated Monopoly	Competitive Markets
• Mandated	• Voluntary
• Closed Access	• Open Access
• Discrimination	• Non-discrimination
• Central Planning	• Independent Investment
• Few Choices	• Many Choices
• Spending Other People's Money	• Spending Your Own Money
• Average Cost Pricing	• Marginal Cost Pricing

A Key Market Design Objective

Supporting the Solution: Given the prices and settlement payments, individual optimal behavior is consistent with the aggregate optimal solution.

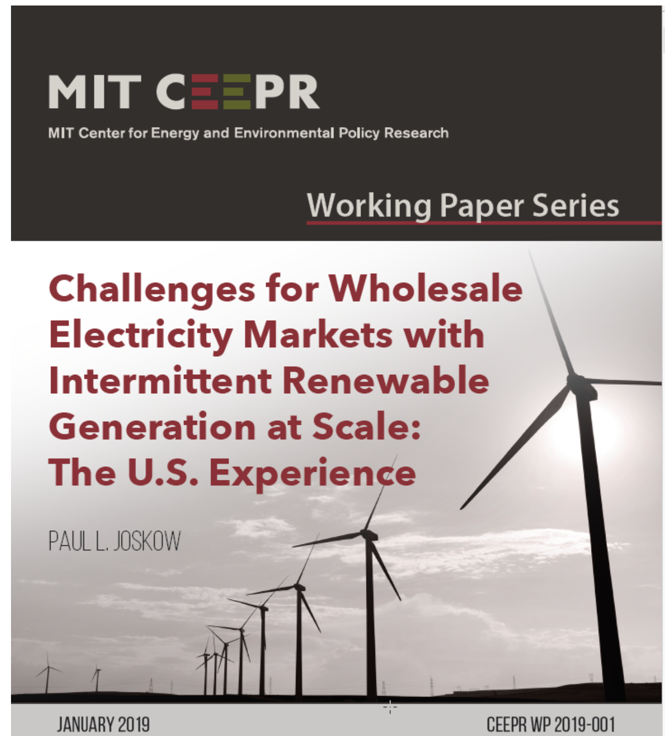
An efficient short-run electricity market determines a market clearing price based on conditions of supply and demand balanced in an economic dispatch. Everyone pays or is paid the same price. The same principles apply in an electric network. (Schweppe, Caramanis, Tabors, & Bohn, 1988)



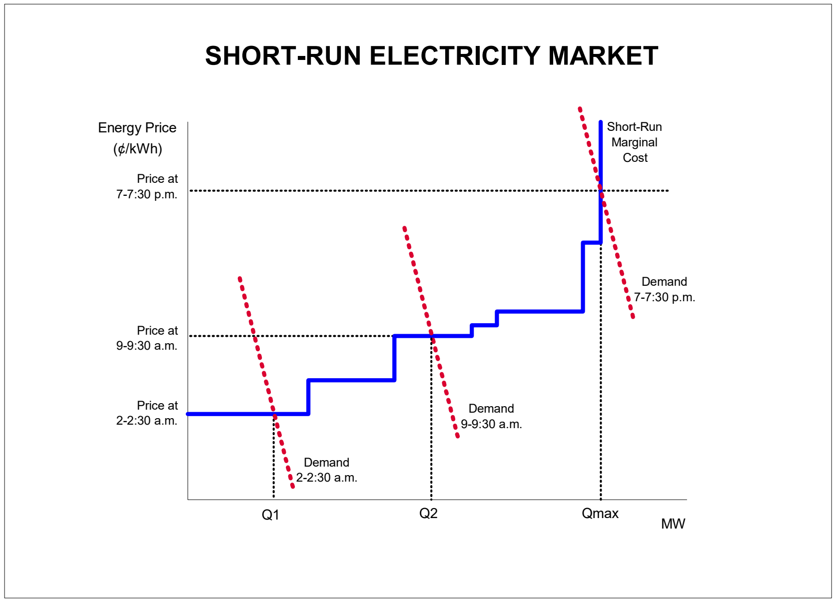


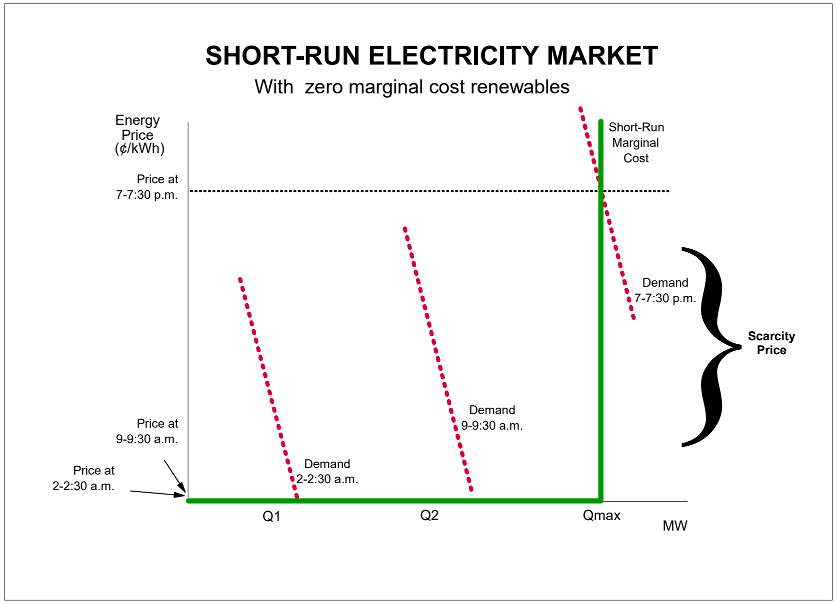
The expansion of intermittent sources and the rise in special subsidies is seen as a threat to efficient electricity market design.

"The supply of intermittent wind and solar generation with zero marginal operating cost is increasingly rapidly in the U.S. These changes are creating challenges for wholesale markets in two dimensions. Short term energy and ancillary services markets, built upon mid-20th century models of optimal pricing and investment, which now work reasonably well, must accommodate the supply variability and energy market price impacts associated with intermittent generation at scale. These developments raise more profound questions about whether the current market designs can be adapted to provide good long-term price signals to support investment in an efficient portfolio of generating capacity and storage consistent with public policy goals. … Reforms in capacity markets and ***scarcity pricing mechanisms*** are needed if policymakers seek to adapt the traditional wholesale market designs to accommodate intermittent generation at scale. However, if the rapid growth of integrated resource planning, subsidies for some technologies but not others, mandated long term contracts, and other expansions of state regulation continues, more fundamental changes are likely to be required in the institutions that determine generator and storage entry and exit decisions." (Joskow, 2019) (emphasis added)



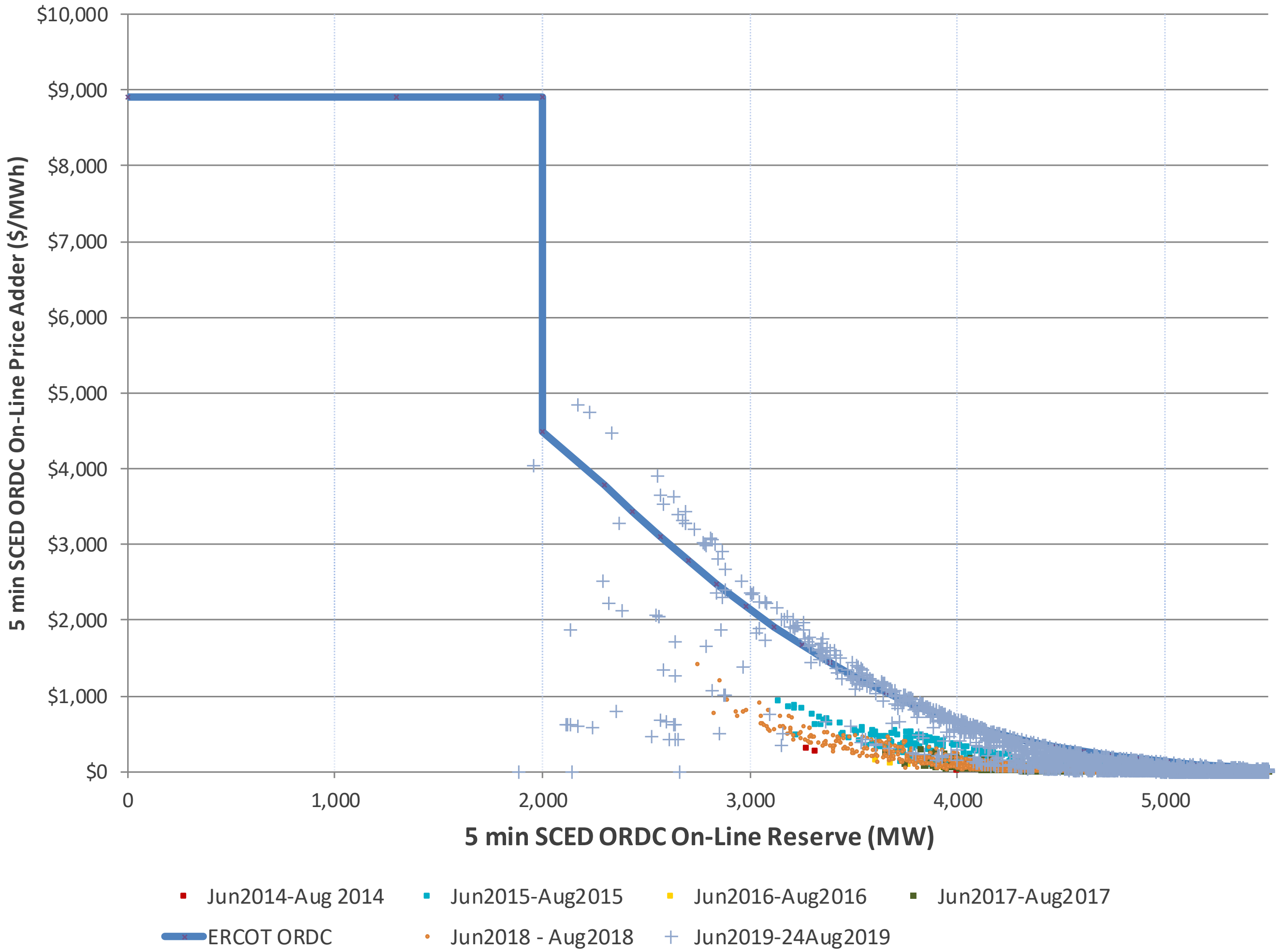
An efficient short-run electricity market determines a market clearing price based on conditions of supply and demand balanced in an economic dispatch. Everyone pays or is paid the same price. The thought experiment of a no-carbon/zero-variable-cost, green energy supply reveals that the basic efficiency principles still apply. The same principles apply in an electric network. (Schweppe et al., 1988) **Storage will be important, but does not change the basic design analysis.** (Korpås & Botterud, 2020)





A key feature would be to increase the importance of scarcity pricing. ERCOT adopted an Operating Reserve Demand Curve in 2014. (Hogan, 2013) **PJM has proposed a series of reforms for energy price formation, motivated in part by the impact of increased penetration of intermittent renewable resources.** (PJM Interconnection, 2017) (PJM Interconnection, 2019)

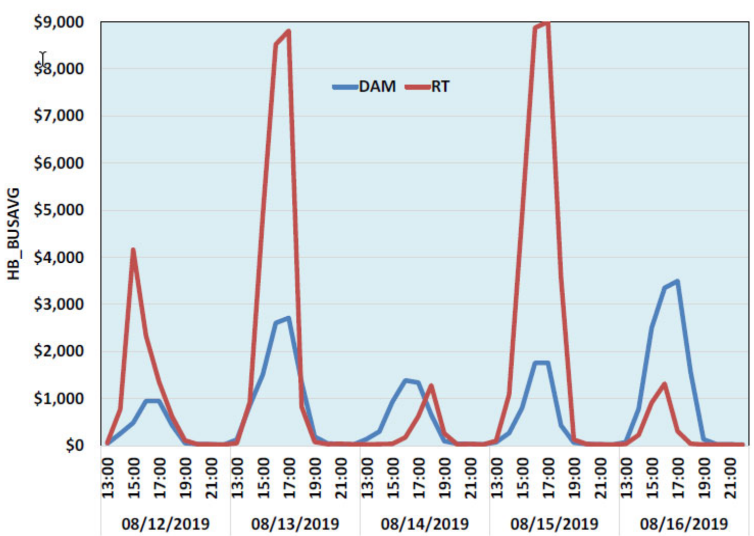
ERCOT launched implementation of the ORDC in in 2014. The summer peak is the most important period. The first five years of results show recent scarcity of reserves and higher reserve prices.



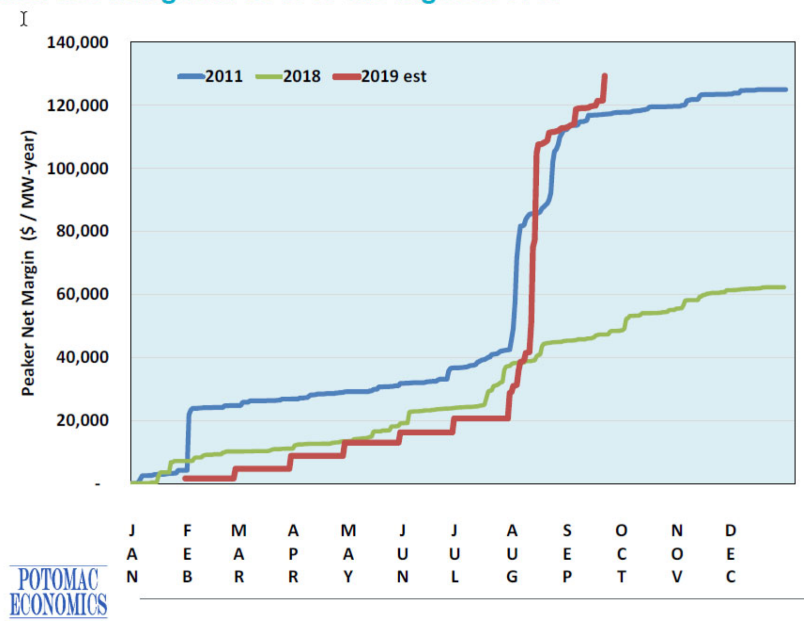
Source: Resmi Surendran, ERCOT, EUCI Presentation, Updated 8/31/2019. The ORDC is illustrative. See also (Hogan & Pope, 2017)

After introduction of the ORDC scarcity prices and the contribution to Peaker Net Margin were low for several years, but this changed in 2019.[1] The PNM target level is $80,000-$95,000/MW-Yr. (Potomac Economics, 2019, p. 112)

Day Ahead vs Real-Time Prices



Peaker net margin in 2019 is the highest ever



[1] Beth Garza, "Independent Market Monitor Report," Potomac Economics, ERCOT Board of Directors Meeting Presentation, October 8, 2019.

An ERCOT review of the Summer of 2019 underscored that scarcity pricing was consistent with performance of the system.[2]

Key Observations for Summer 2019

- Early summer was mild, and August was very hot (September was also above normal).
- There were many days with tight conditions, and an Energy Emergency Alert (EEA) Level 1 was declared twice.
  - Emergency Response Service (ERS) deployments prevented the need for EEA2.
- Peak demand day saw higher Intermittent Renewable Resource (IRR) production.
  - As a result, it was not one of the highest-priced days, and there was no EEA.
- Tightest conditions frequently occurred earlier than time of peak demand.
- Resource performance continues to outpace historical patterns.
- Overall, the market outcomes supported reliability needs.
- Even with significant pricing events, there were no mass transitions.

Notably, high prices occurred at the right time, and were not socialized through capacity market charges spread over all load.

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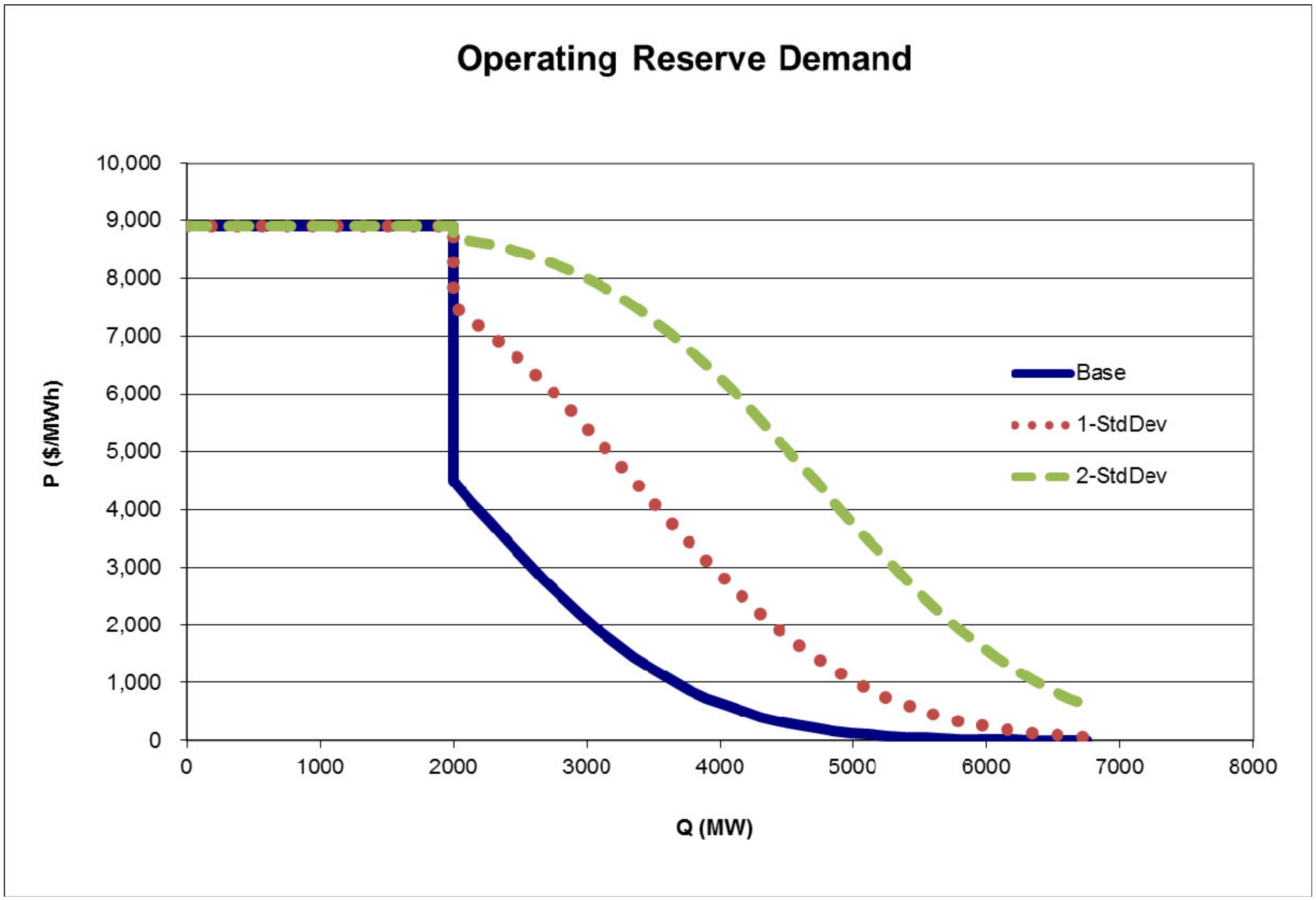
2 Dan Woodfin and Carrie Bivens, "Summer 2019 Operational Review", ERCOT Board of Directors Meeting Presentation, October 8, 2019.

A conservative assumption addressed at reliability would be to increase the estimate of the loss of load probability. A shift of one standard deviation would have a material impact on the estimated scarcity prices. The choice would depend on the margin of safety beyond the economic base. Texas applied this approach in 2019 and 2020 by implementing 0.25 standard deviations shifts.



The basic market design elements include the building blocks for forward energy contracting.

- **Voluntary**
  - **Contracts for Differences.**
  - **Financial Transmission Rights.**
- **Mandatory**
  - **Financial Contracts and Price Hedging.**
    - **New Jersey Basic Generation Services.** Financial contract with no connection to the generation source of the power. The contract is set in terms of the price of full requirements for energy and related services at the customers location. The auction procures one-third of the next three-year requirement. This keeps prices connected to expected spot-market prices, but substantial reduces price volatility. (http://www.bgs-auction.com/)
    - **Australian Retailer Reliability Auction.** "As part of the Retailer Reliability Obligation (RRO), liable entities are required to enter into sufficient qualifying contracts by T-1 to meet their share of AEMO's one-in-two year peak demand forecast during a forecast reliability gap period. Liable entities are required to provide their net contract position, assessed one year before the forecast reliability gap period (at the contract position day), to the AER by reporting day. When reporting to the AER, liable entities must adjust their contract position to reflect how effective they are at limiting exposure to volatility in the wholesale electricity spot price (firmness adjustment)." (Australian Energy Regulator, 2019, p. 6)
  - **Physical Contracts for Delivered Capacity or Energy.** If we knew how to do this, we would not need organized electricity markets.

The extension of market design to distribution systems seems straightforward in principle. (Caramanis, Bohn, & Schweppe, 1982) **But in practice the challenges will be different.**

- **High Voltage Grids (Wholesale Markets)**
  - Small Losses
  - Simpler Voltage Control Challenges
  - Market Design Assumes Sufficient Reactive Power
  - Network Interactions with Thousands of Locations
  - Workable Approximations
    - DC Load Model, at least for local adjustments
    - Nomograms and Interface Constraints
    - Centralized Coordination
    - Long-history with Optimization Models
    - "Dispatch-Based Pricing" Models Accommodate Operator Interventions

- **Low Voltage Grids (Distribution Markets)**
  - Larger Average and Marginal Losses
  - Voltage Control a Central Problem
  - Largely Radial Systems with Millions of Devices
  - Moving from Passive Revelation to Active Participation
  - Less Operating Experience with Optimization Models

Some of the issues (an incomplete list):

- **Coordination**
  - Centralized
  - Decentralized
  - Hybrid Models (Gross Pool versus Net Pool Debate)
  - Operator Interventions

- **Efficiency (Optimization) and Pricing**
  - Dispatch Signals and Settlement Prices
  - Non-Convexities
    - Commitment Decisions
    - Switching Decisions
    - AC Models
  - Uplift (Side Payments and ELMP) (Gribik, Hogan, & Pope, 2007) (Chao, 2019)

- **Intertemporal Optimization and Efficiency**
  - Rolling Update of Dispatch with Look Ahead
  - With Convex Conditions and No Uncertainty: Dispatch Signals = Settlement Prices
  - Non-convexities from Commitment Decisions
    - Dispatch Signals Differ from Settlement Prices (ELMP)
    - Sunk Costs Matter
  - Convexity but with Uncertainty and Intertemporal Updates (Hua, Schiro, Zheng, Baldick, & Litvinov, 2019) (Hogan, 2020)
    - Ramping Constraints
    - Dispatch Signals Differ from Settlement Prices
    - Sunk Costs Matter
  - **Reality**: All of the Above, and More (Aggregators?)

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William W. Hogan is the Raymond Plank Research Professor of Global Energy Policy, John F. Kennedy School of Government, Harvard University. This paper draws on research for the Harvard Electricity Policy Group and for the Harvard-Japan Project on Energy and the Environment. The author is or has been a consultant on electric market reform and transmission issues for Allegheny Electric Global Market, American Electric Power, American National Power, Aquila, AQUIND Limited, Atlantic Wind Connection, Australian Gas Light Company, Avista Corporation, Avista Utilities, Avista Energy, Barclays Bank PLC, Brazil Power Exchange Administrator (ASMAE), British National Grid Company, California Independent Energy Producers Association, California Independent System Operator, California Suppliers Group, Calpine Corporation, CAM Energy, Canadian Imperial Bank of Commerce, Centerpoint Energy, Central Maine Power Company, Chubu Electric Power Company, Citigroup, City Power Marketing LLC, Cobalt Capital Management LLC, Comision Reguladora De Energia (CRE, Mexico), Commonwealth Edison Company, COMPETE Coalition, Conectiv, Constellation Energy, Constellation Energy Commodities Group, Constellation Power Source, Coral Power, Credit First Suisse Boston, DC Energy, Detroit Edison Company, Deutsche Bank, Deutsche Bank Energy Trading LLC, Duquesne Light Company, Dyon LLC, Dynegy, Edison Electric Institute, Edison Mission Energy, Electricity Authority New Zealand, Electricity Corporation of New Zealand, Electric Power Supply Association, El Paso Electric, Energy Endeavors LP, Exelon, Financial Marketers Coalition, FirstEnergy Corporation, FTI Consulting, GenOn Energy, GPU Inc. (and the Supporting Companies of PJM), GPU PowerNet Pty Ltd., GDF SUEZ Energy Resources NA, Great Bay Energy LLC, GWF Energy, Independent Energy Producers Assn, ISO New England, Israel Public Utility Authority-Electricity, Koch Energy Trading, Inc., JP Morgan, LECG LLC, Luz del Sur, Maine Public Advocate, Maine Public Utilities Commission, Merrill Lynch, Midwest ISO, Mirant Corporation, MIT Grid Study, Monterey Enterprises LLC, MPS Merchant Services, Inc. (f/k/a Aquila Power Corporation), JP Morgan Ventures Energy Corp., Morgan Stanley Capital Group, Morrison & Foerster LLP, National Independent Energy Producers, New England Power Company, New York Independent System Operator, New York Power Pool, New York Utilities Collaborative, Niagara Mohawk Corporation, NRG Energy, Inc., Ontario Attorney General, Ontario IMO, Ontario Ministries of Energy and Infrastructure, Pepco, Pinpoint Power, PJM Office of Interconnection, PJM Power Provider (P3) Group, Powerex Corp., Powhatan Energy Fund LLC, PPL Corporation, PPL Montana LLC, PPL EnergyPlus LLC, Public Service Company of Colorado, Public Service Electric & Gas Company, Public Service New Mexico, PSEG Companies, Red Wolf Energy Trading, Reliant Energy, Rhode Island Public Utilities Commission, Round Rock Energy LP, San Diego Gas & Electric Company, Secretaría de Energía (SENER, Mexico), Sempra Energy, SESCO LLC, Shell Energy North America (U.S.) L.P., SPP, Texas Genco, Texas Utilities Co, Tokyo Electric Power Company, Toronto Dominion Bank, Transalta, TransAlta Energy Marketing (California), TransAlta Energy Marketing (U.S.) Inc., Transcanada, TransCanada Energy LTD., TransÉnergie, Transpower of New Zealand, Tucson Electric Power, Twin Cities Power LLC, Vitol Inc., Westbrook Power, Western Power Trading Forum, Williams Energy Group, Wisconsin Electric Power Company, and XO Energy. The views presented here are not necessarily attributable to any of those mentioned, and any remaining errors are solely the responsibility of the author. (Related papers can be found on the web at www.whogan.com).

Topic 3: Decentralized Markets

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Regulatory Assistance Project

RAP®

22 July 2020

Decentralized Market Design for the Energy Transition

Johns Hopkins/Columbia Future Power Markets Forum

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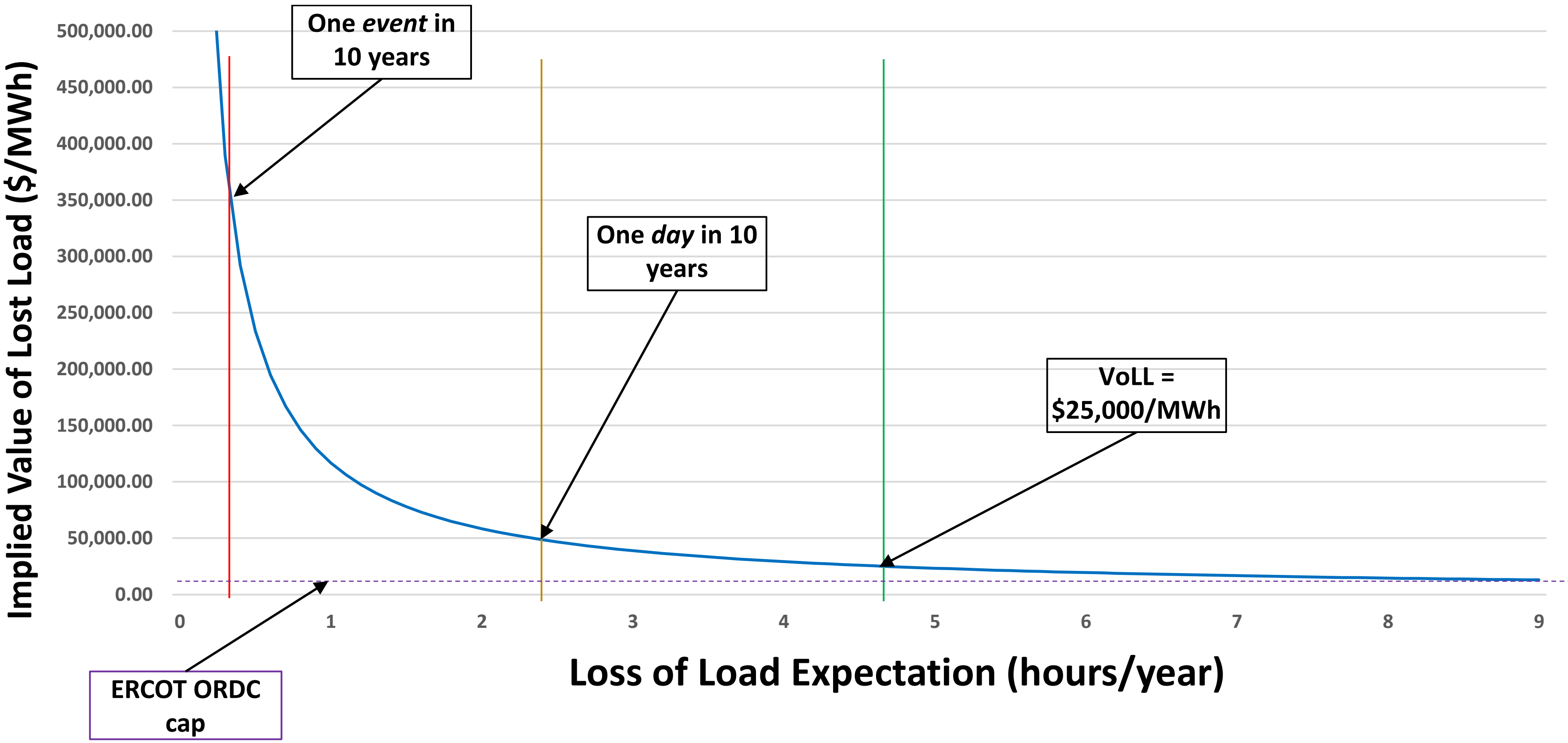
Decentralized market design – focus on the integration challenge:

- Set consistent, economically coherent objectives
- Price energy at true value, temporally and spatially
- Mitigate abuse of market power
- Enforce robust retailer financial standards; ensure both demand and capacity for bilateral contracting
- Let the energy market work; use carbon price, zero carbon energy quotas to drive resource transition
- (Optional) Employ backstop adequacy mechanism based on *minimum acceptable* reserve margins

1 Get the investment objective right…for consumers

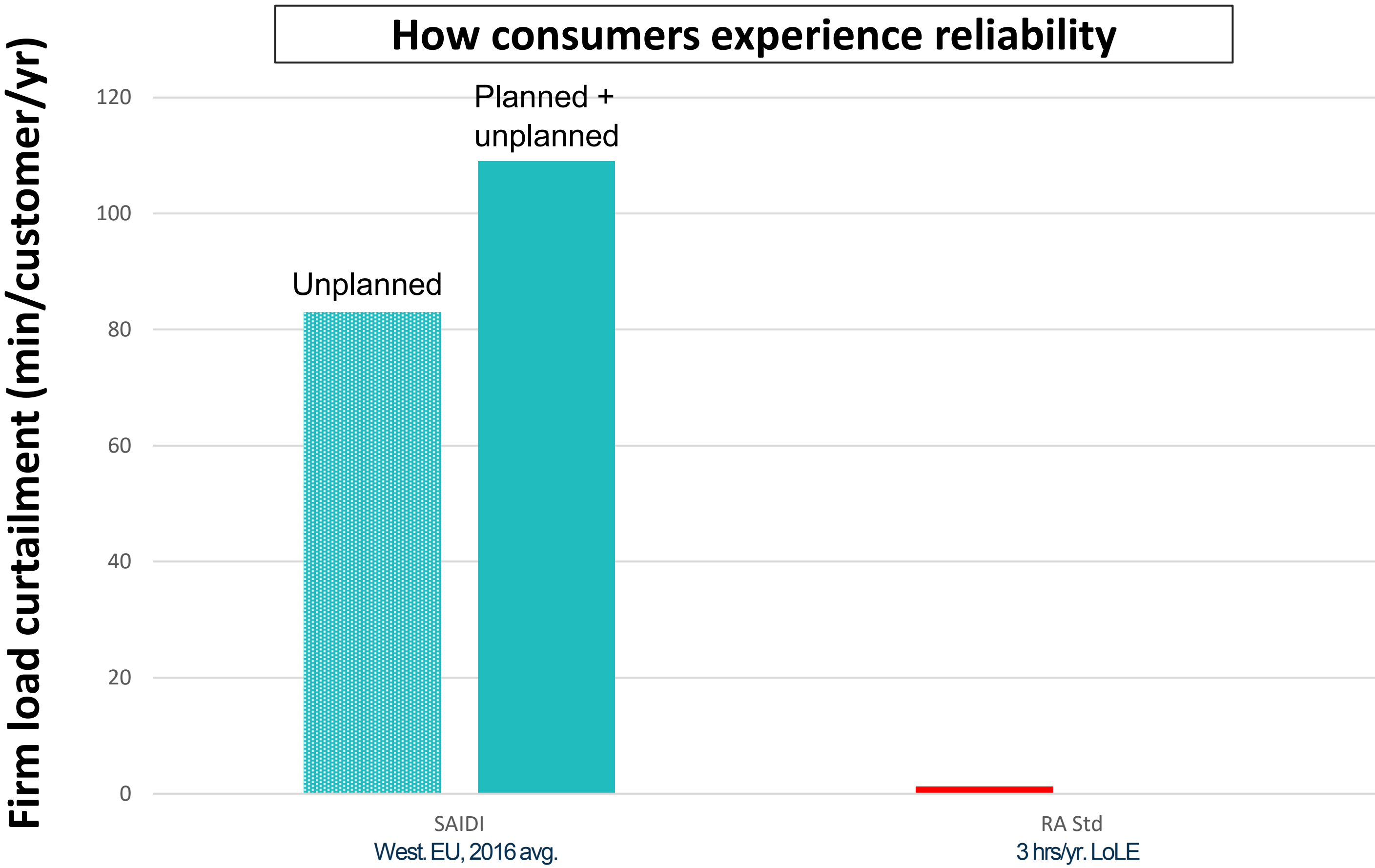
Meeting economically coherent procurement expectations

My favorite Bill Hogan graph (adapted)…



…and then there's what *really* happens!

A consumer's view of reliability

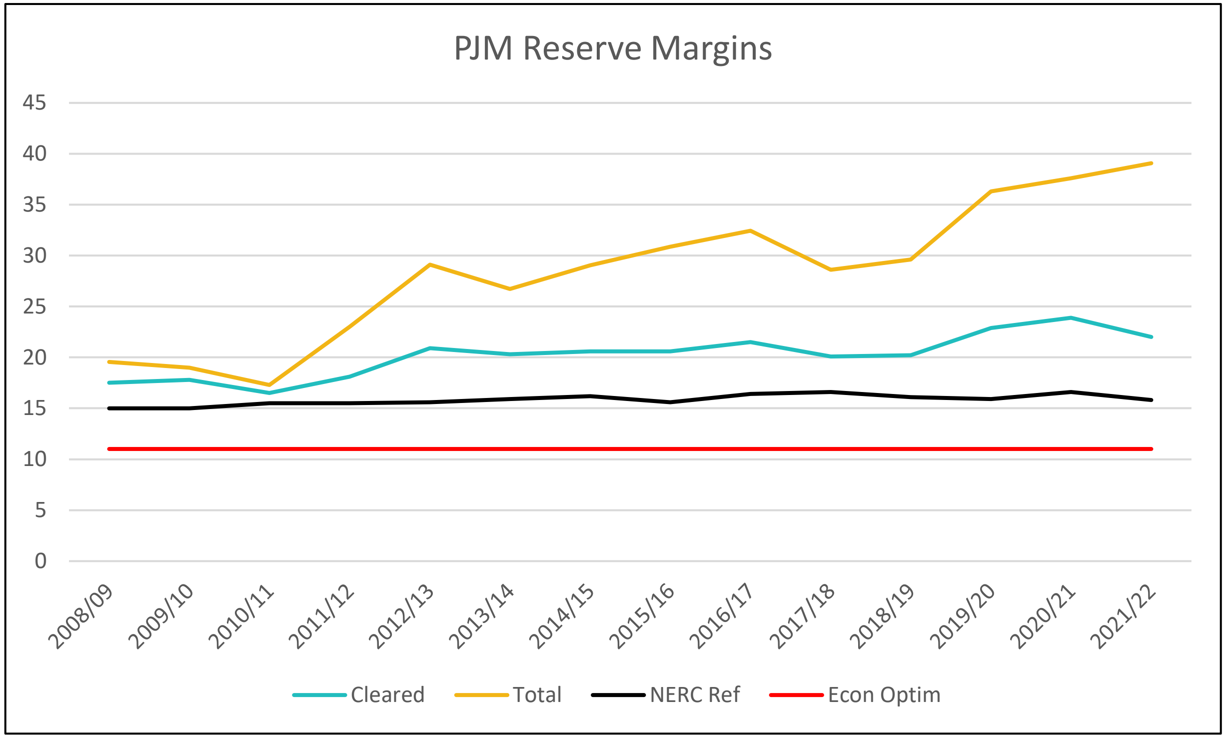


Source (SAIDI data): Council of European Energy Regulators, "Benchmarking Report 6.1 on Continuity of Electric and Gas Supply, Data Update 2015/2016" (26 July 2018)

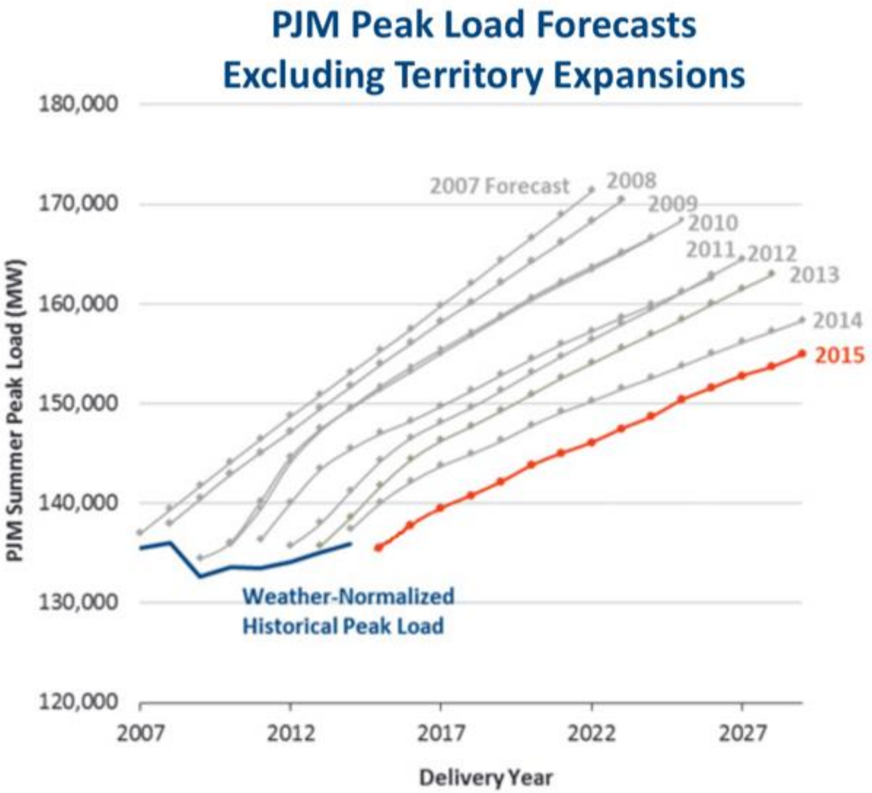
2 Investment under extreme uncertainty

Finding the right balance in driving resource investment

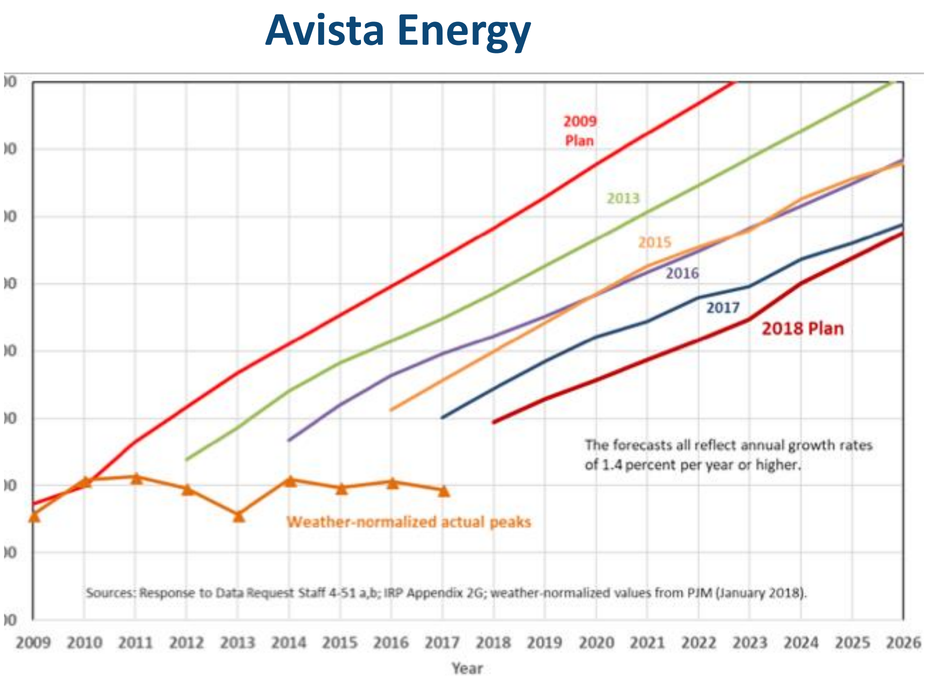
How has centralized forward procurement worked out for PJM customers?



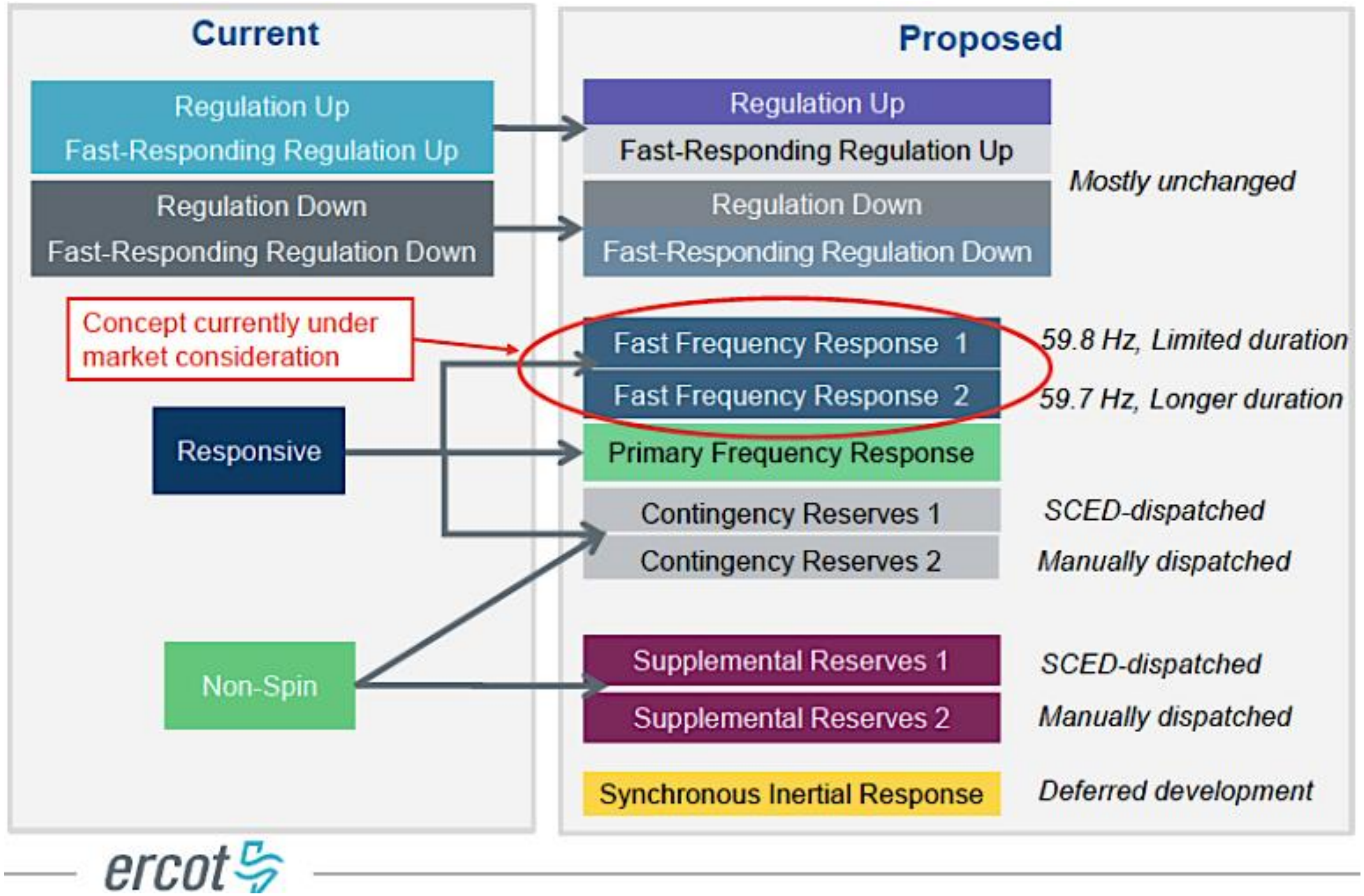
If we can’t even get total capacity right…



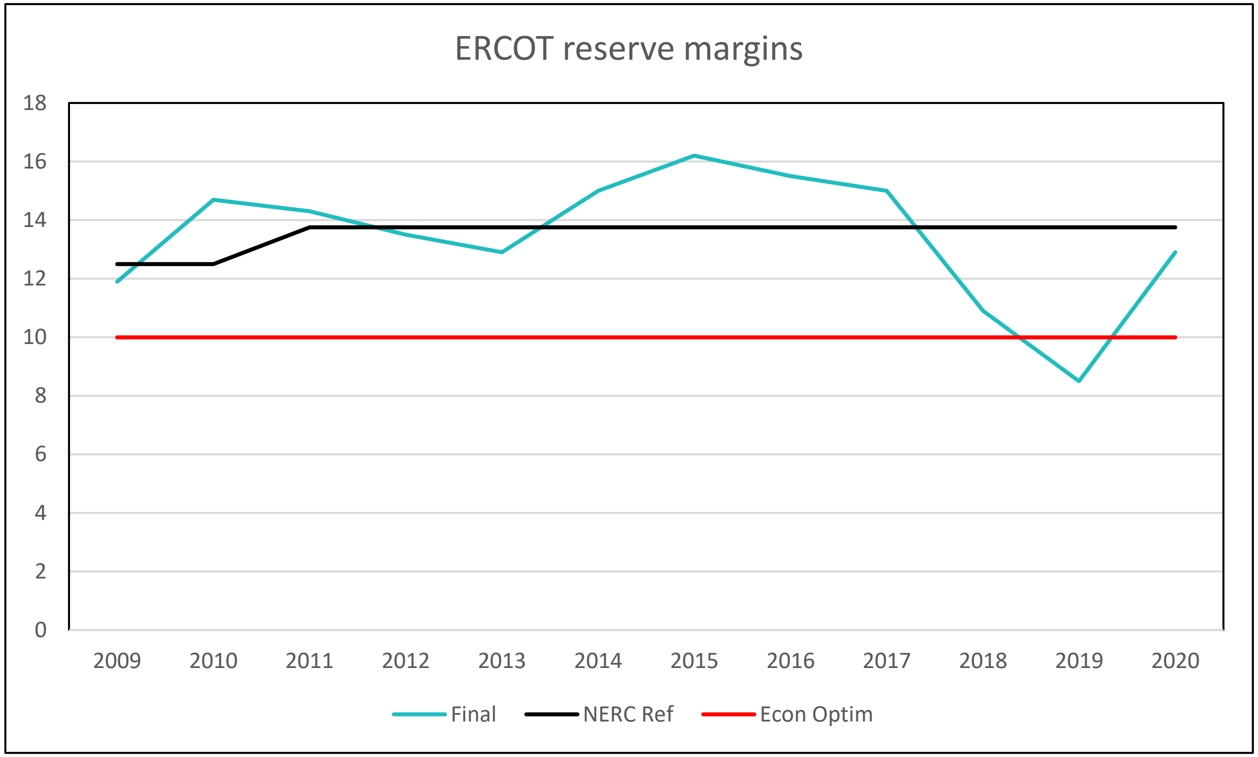
Sources and Notes:
Data from PJM. Forecasts shown here exclude territory expansions in order to enable comparisons across time, thus current load forecast including all current PJM zones are substantially higher.



…what makes us think we'll get this right?

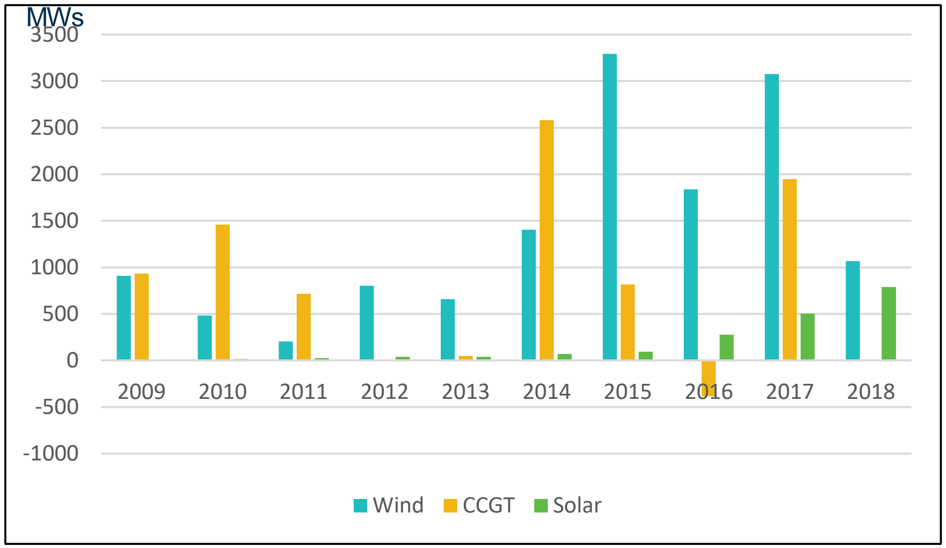


What about letting the energy market work?



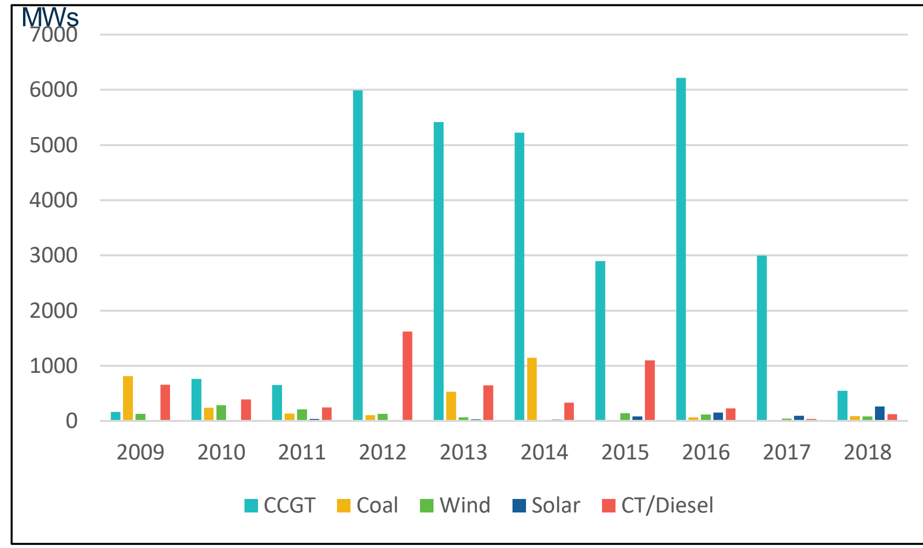
10 years of investment in leading markets

ERCOT



No forward capacity market, but administrative shortage pricing in the energy market, 20% wind share of market in 2018.

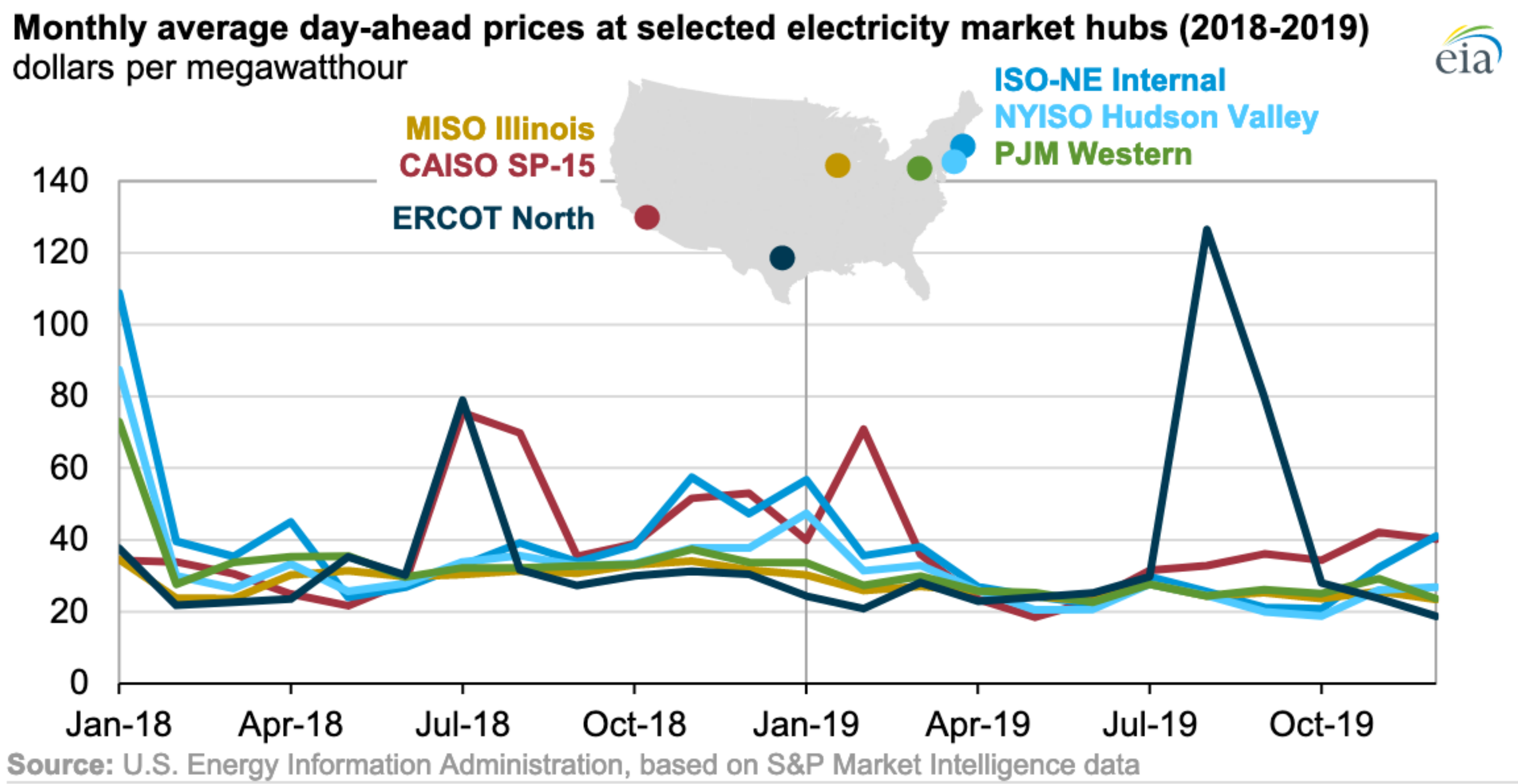
PJM



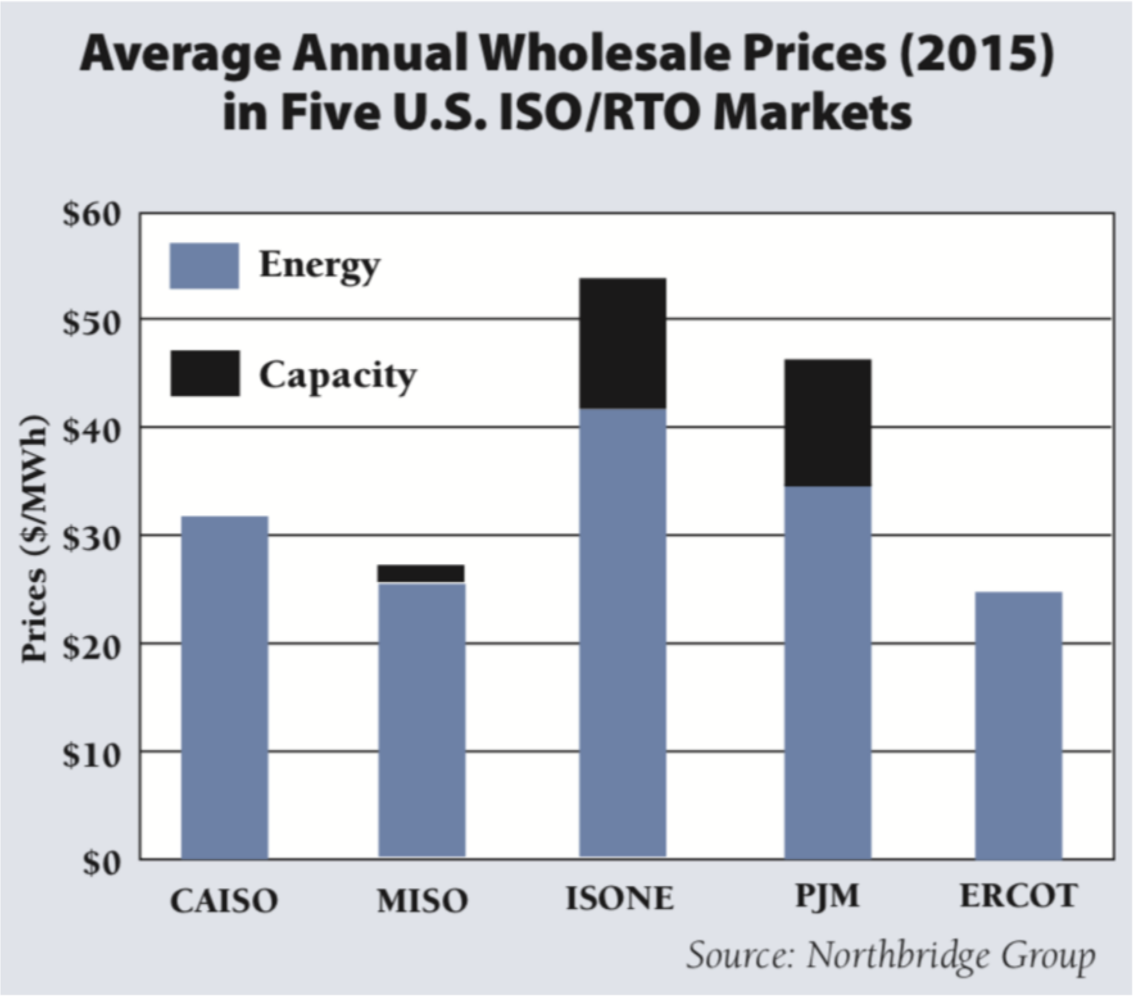
Forward capacity market, but with only 1-year rolling "contracts" for existing & *new* capacity, scarcity pricing, 36% reserve margin in 2018.

- Source: ERCOT and PJM published data.

Wholesale volatility reflects reality



But *volatility & cost* are very different things



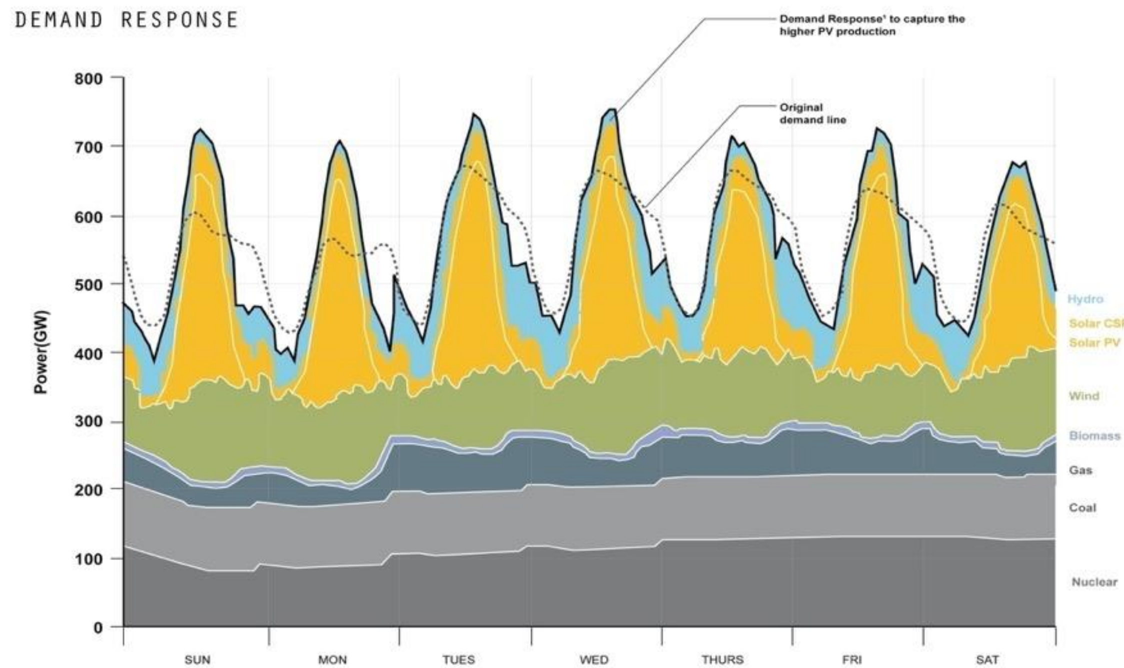
3 Where the rubber really meets the road

The essential role of distributed action in low-cost integration

New role for responsive demand

Moving from a world where we forecast load and schedule generation, to a world where we forecast generation and schedule load

will now need to shape, not just shave, demand



Daily Power Demand In A Week[2]

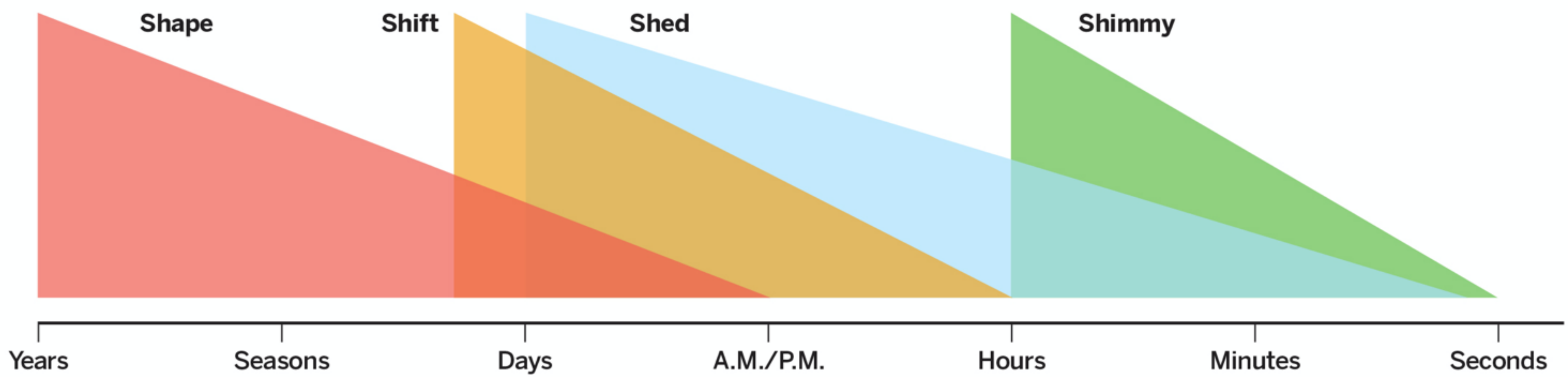
"Demand response as used in this paper refers to changing a customer's electricity demand in response to dispatch instructions or price signals through communications technologies. In the Volume 1 analysis, it is assumed that any such changes retained the total energy consumed within the day, that is, moved or shifted demand rather than reduced total daily consumption"

1) The graph shows how the original demand line (dashed) is shifted to a higher level (black line) by DR to capture the higher PV production
2) 60% RES, 20% DR, Week 32 - Sunny week

SOURCE: Roadmap 2050 Technical Analysis

Wide range of demand flexibility…

Flexibility strategies for the demand side



Incentivize energy efficiency and behavior change

Mitigate ramps and capture surplus renewables

Manage contingency events and coarse net load following

Fast demand response to smooth net load and support frequency

Source: Alstone, P., et al. (2017). *2025 California Demand Response Potential Study — Charting California's Demand Response Future: Final Report on Phase 2 Results*

Limited market access under centralized procurement

	DR Service Product	California Market
Shed	Peak Capacity	System and Local RA Credit
	Economic DR	Economic DR / Proxy Demand Resource
	Contingency Reserve Capacity	AS- spinning
	Contingency Reserve Capacity	AS- non-spin reserves
	Emergency DR	Emergency DR / Reliability DR Resource
	DR for Distribution System	Distribution
Shift	Economic DR	Combination of Energy Market Participation
	Flexible Ramping Capacity	Flexible RA -- energy market participation w/ ramping response availability
Shimmy	Load Following	Flexible Ramping Product (similar)
	Regulating Reserve Capacity	AS- Regulation
Shape	Load modifying DR - Event-based	CPP
	Load Modifying DR - Load shaping	TOU

Key points:

- The case for centralized long-term procurement is based on several false premises
- We are operating under radical uncertainty, and uncertainty is increasing, not decreasing
- Getting system solution wrong will be costly…which is why long-term lock-in is the wrong choice
- We must expand access to markets, not constrain it

Why jump from a perfectly good airplane?

- (Most) current market practice ≠ current market design
- SCED market designed to drive needed investment…
- …yes, even with low/zero production costs
- It won’t drive more than we need. Why would it? Why would we want it to do so?
- Value of investment in flexibility revealed most clearly in varying RT supply/demand for energy & services
- On eve of revolution in electrification & controllable demand, are we really going to gut energy prices?

About RAP

The Regulatory Assistance Project (RAP)® is an independent, non-partisan, non-governmental organization dedicated to accelerating the transition to a clean, reliable, and efficient energy future.

Learn more about our work at raponline.org

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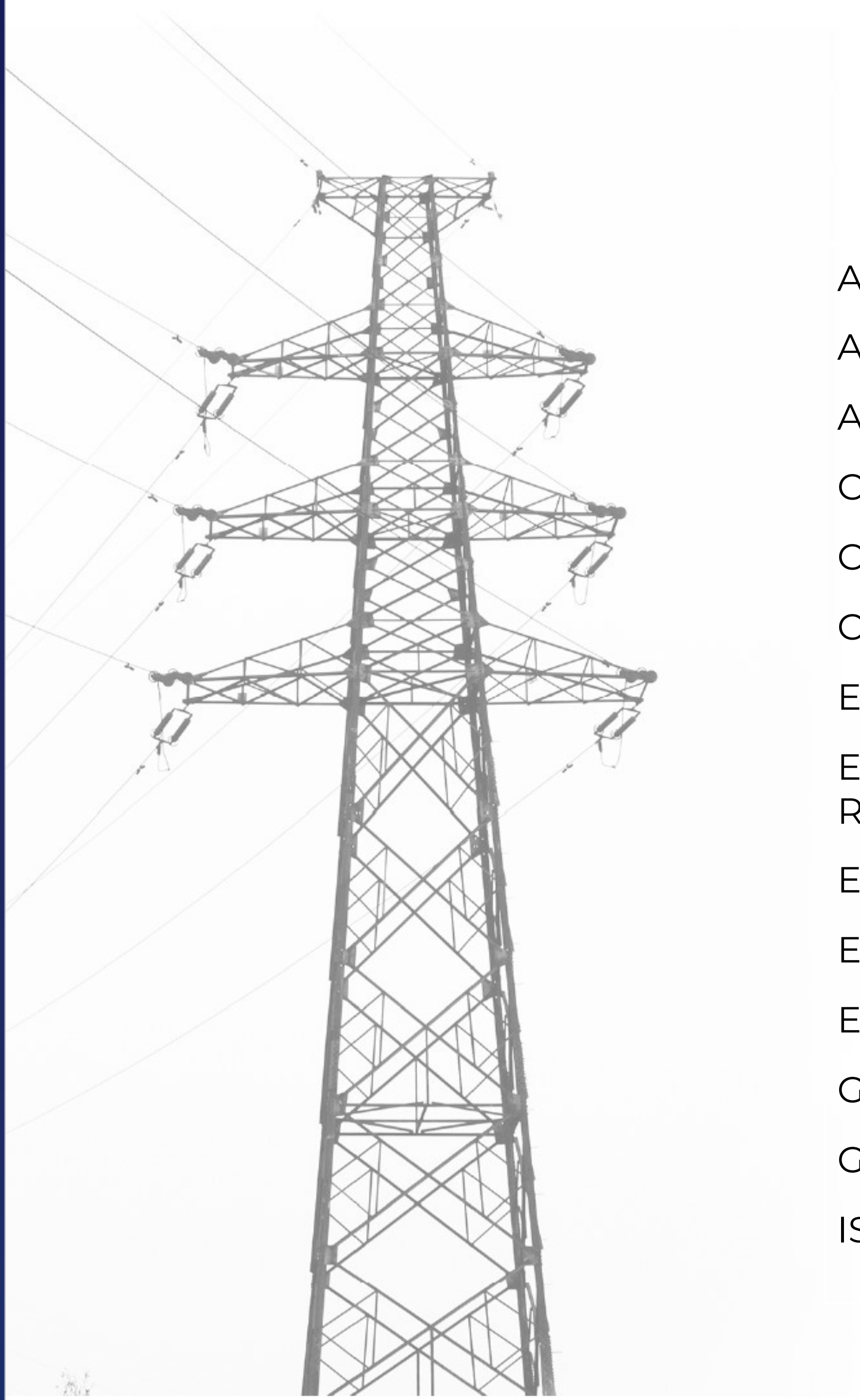

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