ELECTRICITY MARKET DESIGN AND THE GREEN AGENDA

William W. Hogan
Mossavar-Rahmani Center for Business and Government
John F. Kennedy School of Government
Harvard University
Cambridge, Massachusetts 02138

41st IAEE International Conference

Plenary Session: Electricity Market Design

Groningen, the Netherlands

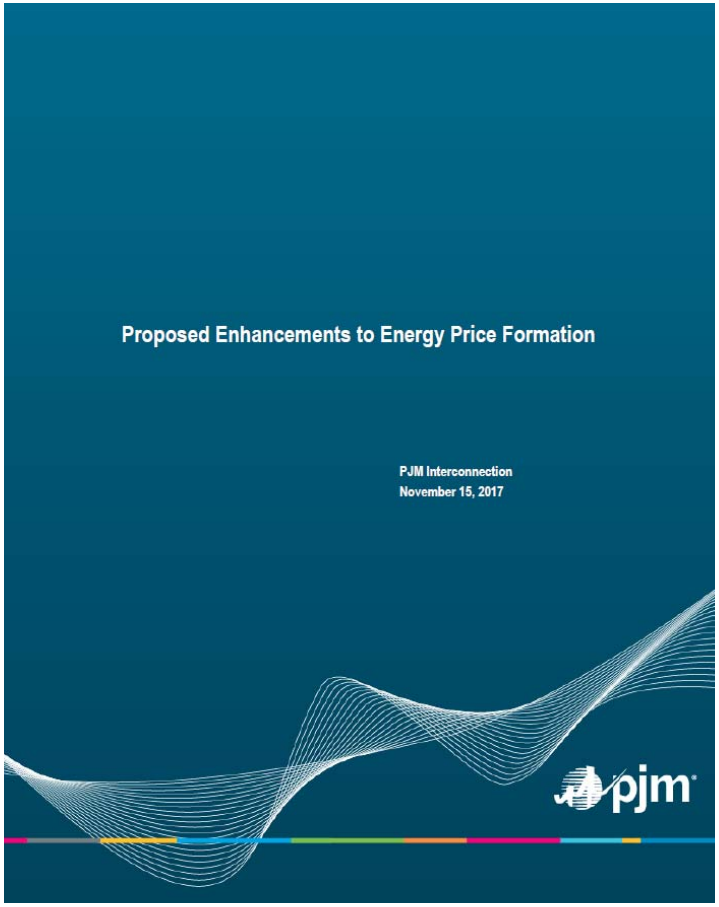
June 12, 2018

Turmoil in electricity market policy is a normal state of affairs.

"Trump-appointed regulators reject plan to rescue coal and nuclear plants."

(Washington Post, 1/8/18)

> "The Federal Energy Regulatory Commission on Monday unanimously rejected a proposal by Energy Secretary Rick Perry that would have propped up nuclear and coal power plants struggling in competitive electricity markets. …
>
> …the language in the current order suggested it would stand by the trend toward free competitive electricity markets."



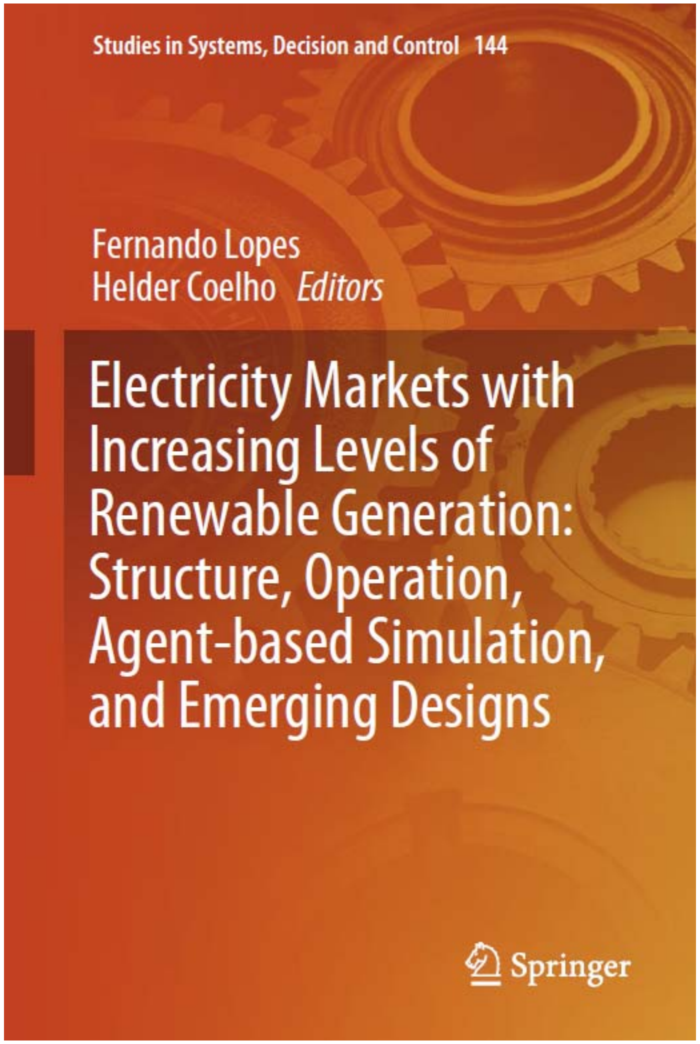
A prominent element of the FERC response included newly focused attention on efforts to improve electricity market design and price formation.

One focus is on proposed enhancements to energy price formation in PJM. (PJM Interconnection, 2017)

"Murky Trump order on coal, nuke plant closures follows mystery memo. .. [Press Secretary] Sanders concluded: 'President Trump has directed Secretary of Energy Perry to stop the loss of these resources, and looks forward to his recommendations.'" (Energy Daily, pp.1-2, Vol. 46, No. 106, 6/4/18)

A major challenge is the integration of increasing levels of renewables. There is a large and growing literature on the subject. (Lopes & Coelho, 2018) (Hogan & Pope, 2017)

- **Are renewables fundamentally different?**
  - Zero marginal cost, which affects the system economics.
  - Intermittency of supply, which affects system operations.
- **Will increasing levels of renewables require a fundamentally new approach to electricity market design?**
  - Clean Power Plan mandates with effects both on investment and operations.
  - Expanded state subsidies (NY, IL), inconsistent carbon markets (CA and EIM), net energy metering (Belmont, MA), and ever present rent seeking.
- **What is wrong with the existing market design fundamentals?**



Subsidies are growing: RPS, RECs, PTCs, ITCs, DR, and now ZECs.

Soon DECs (Dirty Energy Credits)?[1]

> "Subsidies are contagious. Competition in the markets could be replaced by competition to receive subsidies." (Monitoring Analytics, 2017, p. 2)

Regarding the FERC decision on the application of minimum offer price rules in NYISO:

> "The premise of the MOPR appears to be based on an idealized vision of markets free from the influence of public policies. But such a world does not exist, and it is impossible to mitigate our way to its creation. The fact of the matter is that all energy resources receive federal subsidies, and some resources have received subsidies for decades." (Commissioner Norman Bay concurrence) (FERC, 2017, p. 2)

1 Anonymous.

If you are willing to spend enough money, you can make anything look cheap.

"Subsidies pose a more general problem in this context. They attempt to discourage carbon-intensive activities by making other activities more attractive. One difficulty with subsidies is identifying the eligible low-carbon activities. Why subsidize hybrid cars (which we do) and not biking (which we do not)? Is the answer to subsidize all low carbon activities? Of course, that is impossible because there are just too many low-carbon activities, and it would prove astronomically expensive. Another problem is that subsidies are so uneven in their impact. A recent study by the National Academy of Sciences looked at the impact of several subsidies on GHG emissions. It found a vast difference in their effectiveness in terms of CO_2 removed per dollar of subsidy. None of the subsidies were efficient; some were horribly inefficient; and others such as the ethanol subsidy were perverse and actually increased GHG emissions. The net effect of all the subsidies taken together was effectively zero!"

So in the end, it is much more effective to penalize carbon emissions than to subsidize everything else." (Nordhaus, 2013, p. 266)

The expansion of subsidy systems has implications for electricity market design.

"The most market-oriented solution with the greatest transparency, simplicity, and, perhaps, efficiency would be to transition over time to an energy-only market. Assuming the scarcity pricing level is set at the appropriate level (the value of lost load), it addresses the "missing money" problem and eliminates the need for a capacity market. But I recognize that it would be a big step for a wholesale market operator to propose an energy-only market – only ERCOT has adopted this design – and that some may be concerned about the politics of scarcity pricing. The trade-off for critics concerned about costs, however, is that there would not be a capacity market. A decade ago, in the aftermath of the Western Power Crisis, there would have been little appetite for an energy-only market. Now, however, the wholesale market operators, market monitors, and FERC do much better market monitoring, FERC has an anti-manipulation authority, and natural gas is abundant and low priced, so there should be less price volatility in most regions." (Commissioner Norman Bay concurrence) (FERC, 2017, p. 7)

The discussion of the implications of subsidies entails several related issues.

Market conditions are putting pressure on generators, and system operators.

- Subsidized renewables have low variable costs that reinforce low market prices. Intermittency creates more volatility in operations.
- Low natural gas prices have changed the marginal units in the supply and the result is relatively low electricity energy prices.
- Subsidized generation presents challenges for capacity markets.

Important questions include:

- Are these subsidies and related market interventions good public policy?
- Does the Dormant Commerce Clause apply to prevent restraint of interstate trade?
- Does FERC jurisdiction extend over the many and growing state policies?
- Should FERC act to prohibit or reverse the market effects of subsidies and other interventions?
- What should FERC do?
    - Get the prices right.
    - Address market manipulation.

The focus on the electricity sector's role in addressing climate change through improved efficiency, development of renewable energy, and use of low carbon fuels creates expanded demands for and of electricity restructuring.

The transformation envisioned is massive, long term, and affects every aspect of electricity production and use.

- Uncertain conditions require a broad range of activities to integrate new technology and practices.
- Innovation requires promoting technologies and practices not yet identified or imagined. "Silver buckshot rather than silver bullets."
- Smart grids can facilitate smart decisions, but only if the electricity structure provides the right information and incentives.
    - Open access to expand entry and innovation.
    - Smart pricing to support the smart grid technologies and information.
    - Internalizing externalities.
        - Price on carbon emissions.
        - Good market design with efficient prices.
        - Compatible infrastructure expansion rules.

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

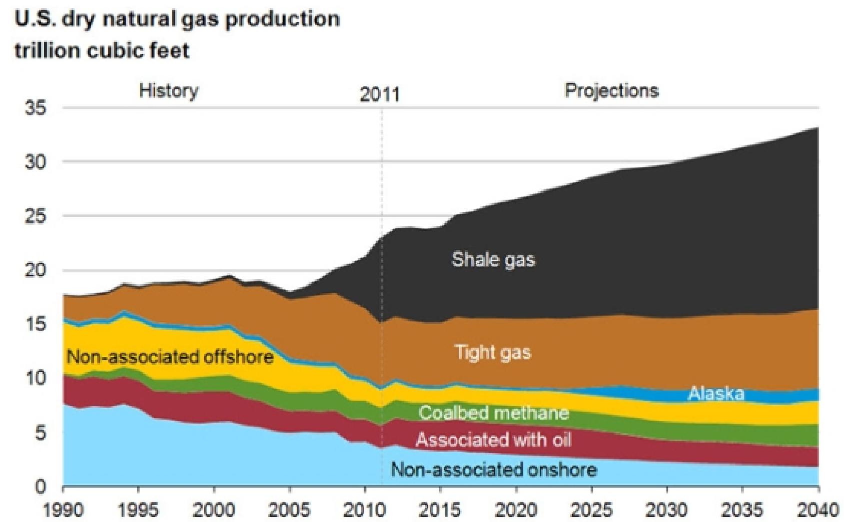
"The Tennessee Valley Authority, in apparently a first in the US power industry, plans to auction its unfinished Bellefonte nuclear plant in Alabama on November 14 in what amounts to a "fire sale" of epic proportions.

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:

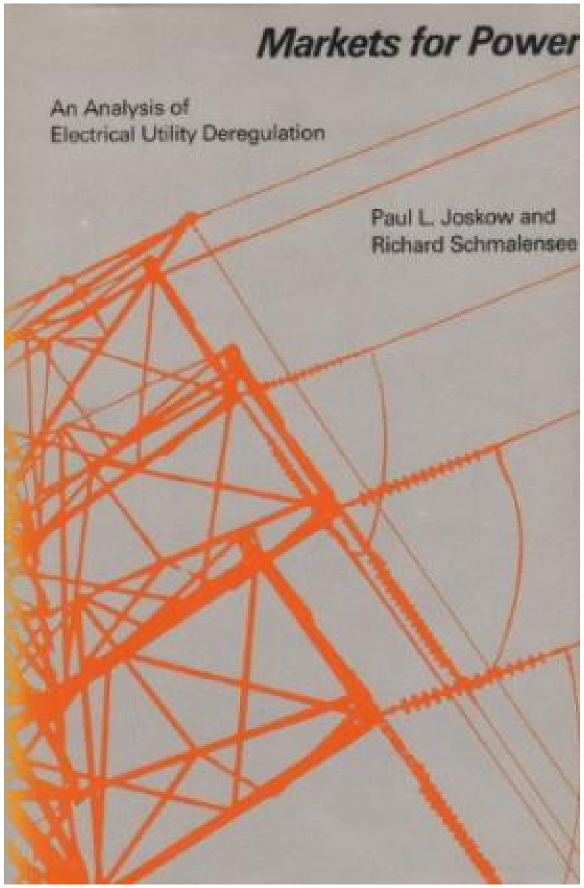
Once the technology crossed the market threshold, deployment was both large and rapid.



Source: U.S. Energy Information Administration, *Annual Energy Outlook 2013 Early Release*

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

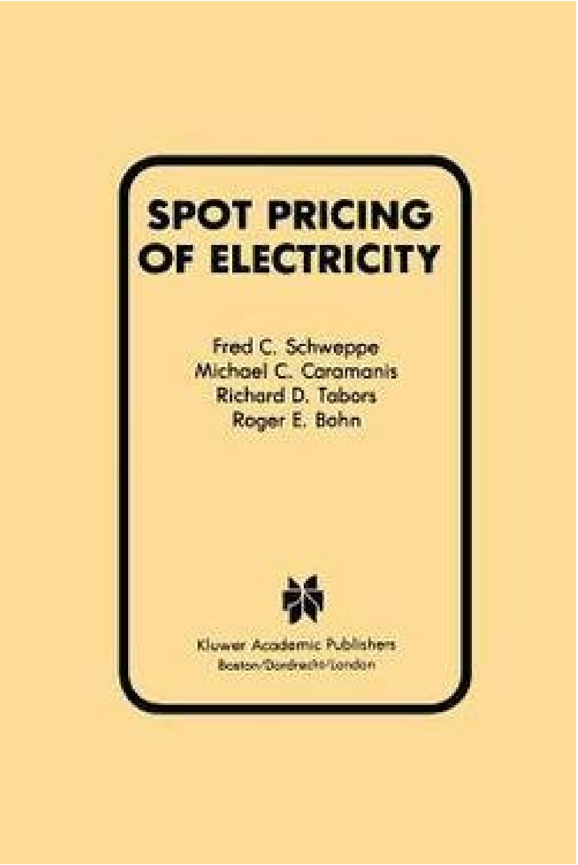
The evolution of electricity restructuring contains a thread of issues related to counterintuitive market design requirements requiring coordination for competition. MIT led the way.



Markets for Power, 1983. Joskow and Schmalensee. Addressed the possibility and problems of introducing competition and markets in the power sector. (Joskow & Schmalensee, 1983)

"*The practice of ignoring the critical functions played by the transmission system in many discussions of deregulation almost certainly leads to incorrect conclusions about the optimal structure of an electric power system.*" (p.63)

Schweppe et al., 1988. Spot Pricing of Electricity, Kluwer. Using prices to direct the dispatch. (Schweppe, Caramanis, Tabors, & Bohn, 1988)



The U.S. experience illustrates successful market design and remaining challenges for both theory and implementation.

- **Design Principle: Integrate Market Design and System Operations**

  Provide good short-run operating incentives.

  Support forward markets and long-run investments.

- **Design Framework: Bid-Based, Security Constrained Economic Dispatch**

  Locational Marginal Prices (LMP) with granularity to match system operations.

  Financial Transmission Rights (FTRs).

- **Design Implementation: Pricing Evolution**

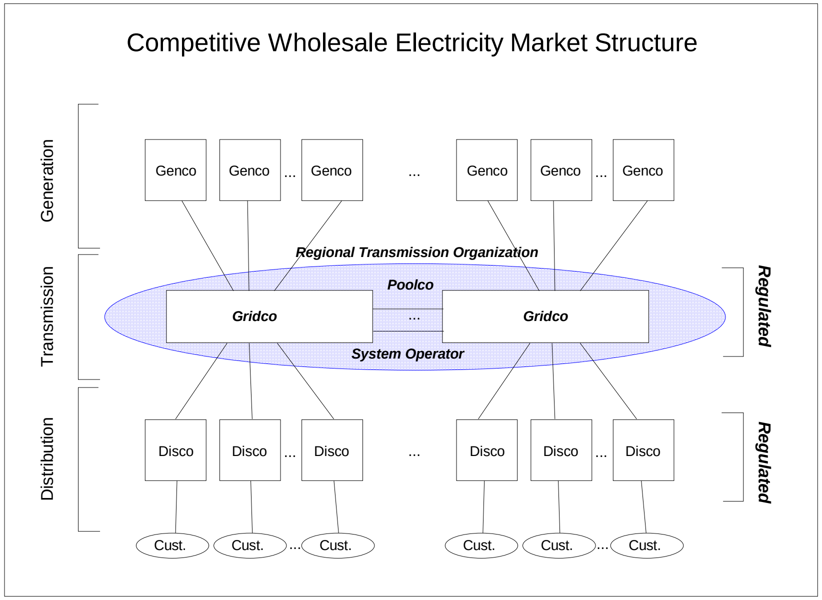
  Better scarcity pricing to support resource adequacy.

  Unit commitment and lumpy decisions with coordination, bid guarantees and uplift payments.

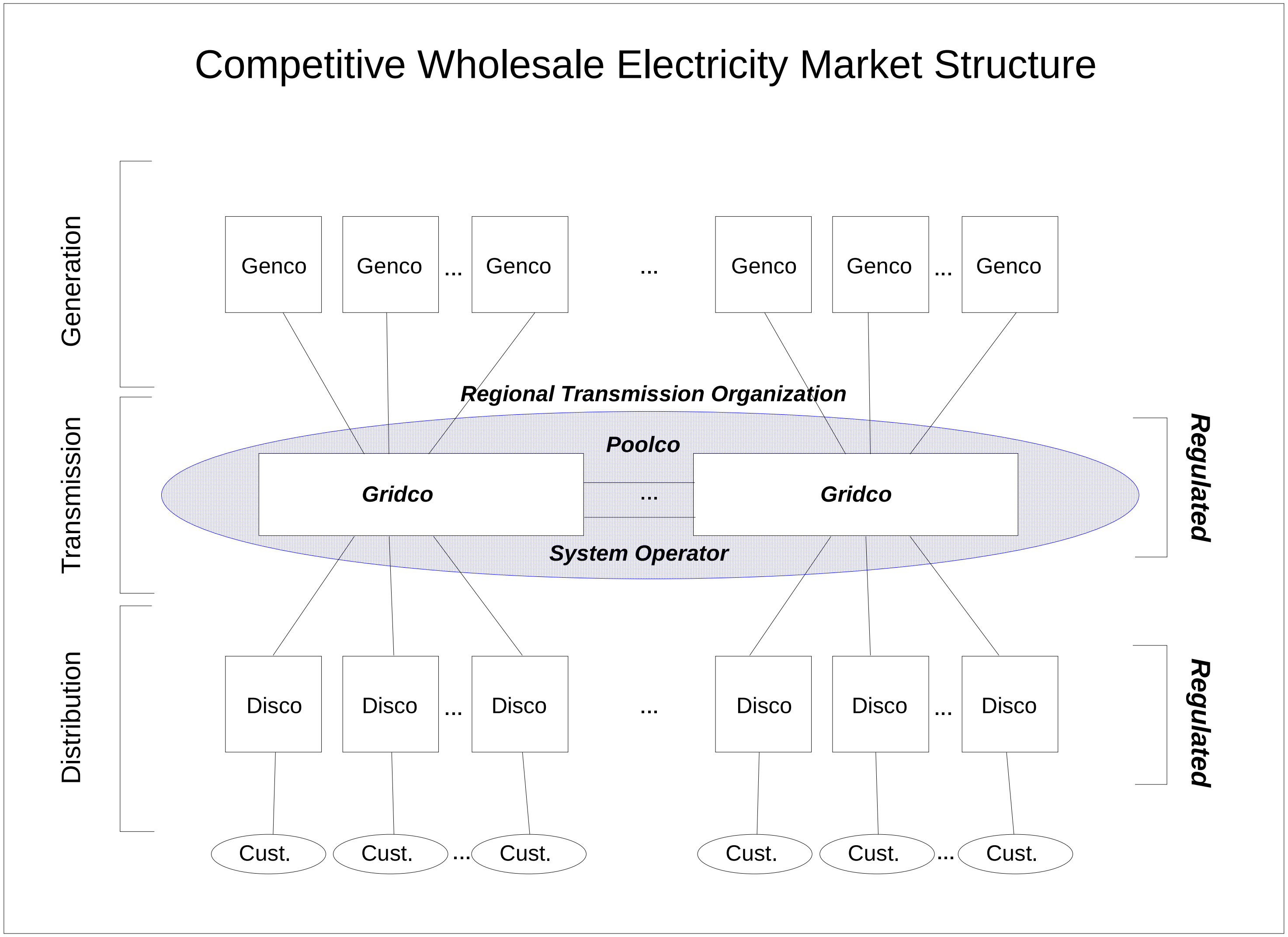
- **Design Challenge: Infrastructure Investment**

  Hybrid models to accommodate both market-based and regulated transmission investments.

  Beneficiary-pays principle to support integration with rest of the market design.



The original arguments for greater reliance on markets emphasized the effects of non-utility generators and the reduction or elimination of the conditions for natural monopoly in generation.



The independent system operator provides a dispatch function. Three questions remain. Just say yes, and the market can decide on the split between bilateral and coordinated exchange.

- **Should the system operator be allowed to offer an economic dispatch service for some plants?**

The alternative would be to define a set of administrative procedures and rules for system balancing that purposely ignore the information about the costs of running particular plants. It seems more natural that the system operator considers customer bids and provides economic dispatch for some plants.

- **Should the system operator apply marginal cost prices for power provided through the dispatch?**

Under an economic dispatch for the flexible plants and loads, it is a straightforward matter to determine the locational marginal costs of additional power. These marginal costs are also the prices that would apply in the case of a perfect competitive market at equilibrium. In addition, these locational marginal cost prices provide the consistent foundation for the design of a comparable transmission tariff.

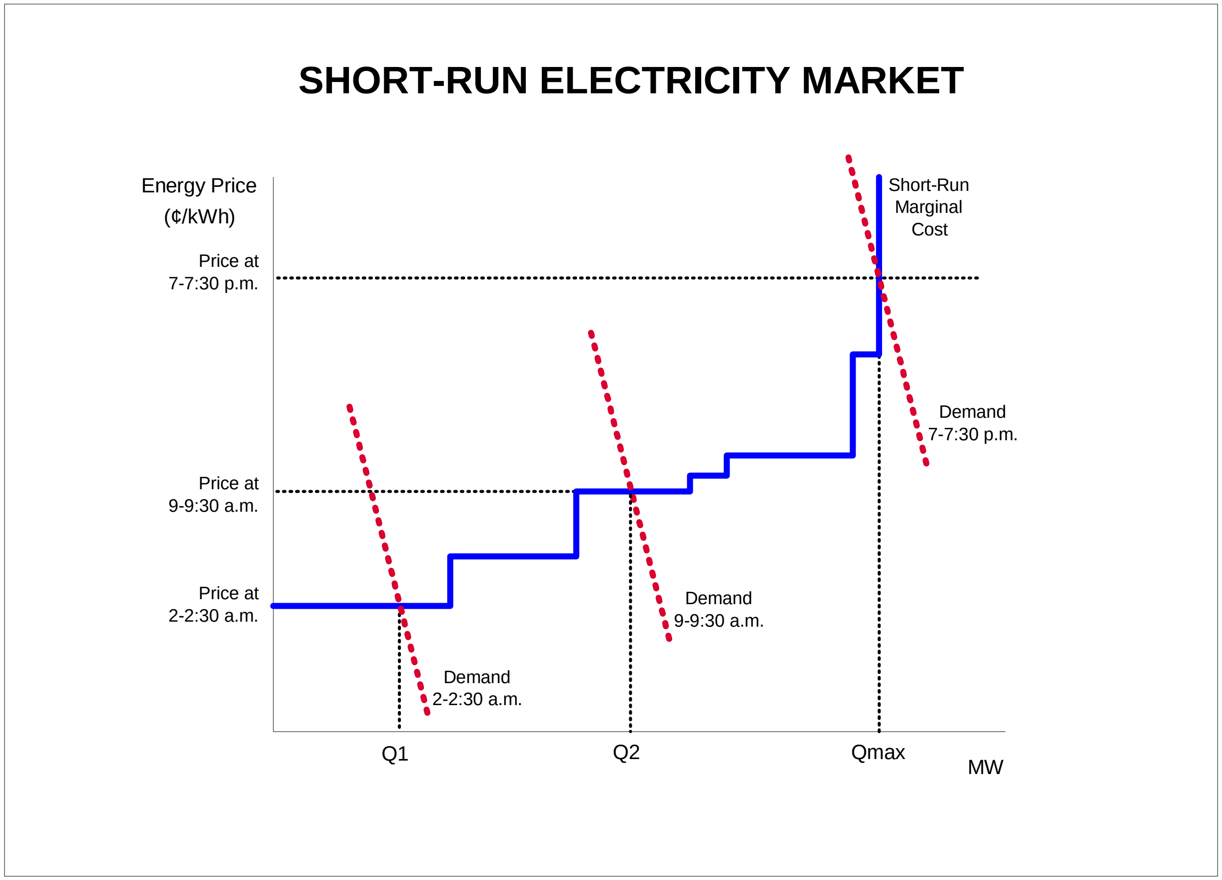
- **Should generators and customers be allowed to participate in the economic dispatch offered by the system operator?**

The natural extension of open access and the principles of choice would suggest that participation should be voluntary. Market participants can evaluate their own economic situation and make their own choice about participating in the operator's economic dispatch or finding similar services elsewhere.

The basic economic dispatch formulation stands at the core of electricity market design and implementation. Under certain conditions, the solution is a market equilibrium.

- **Deterministic**
  - Real-time spot market for physical dispatch and balancing settlements.
  - Day-ahead dispatch and scheduling.
- **Continuous convex economic dispatch**
  - Electric power systems are almost convex, and use convex approximations for dispatch. (Lavaei & Low, 2012),
  - System marginal costs provide locational, market-clearing, linear prices.
  - Linear prices support the economic dispatch.
  - Locational prices provide foundation for financial transmission right (FTRs).
- **Security conditions**
  - Contingency constraints.
  - Operating reserves.
- **Competitive assumption for market design**
  - Price-taking behavior by market participants.
  - Bid-based, security constrained, economic dispatch.
  - Market power mitigation with consistent offer caps.

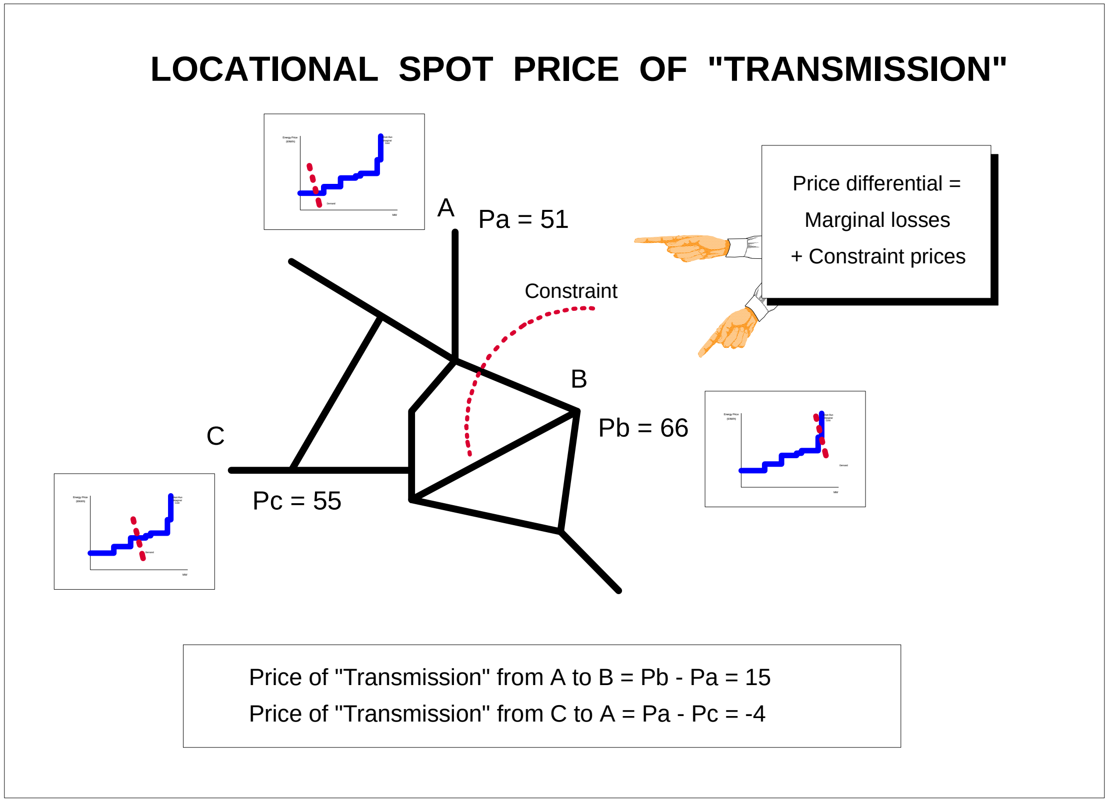
An efficient short-run electricity market determines a market clearing price based on conditions of supply and demand balanced in an economic dispatch. Everyone pays or is paid the same price. The same principles apply in an electric network. (Schweppe et al., 1988) (Hogan, 1992)



The natural extension of a single price electricity market is to operate a market with locational spot prices.

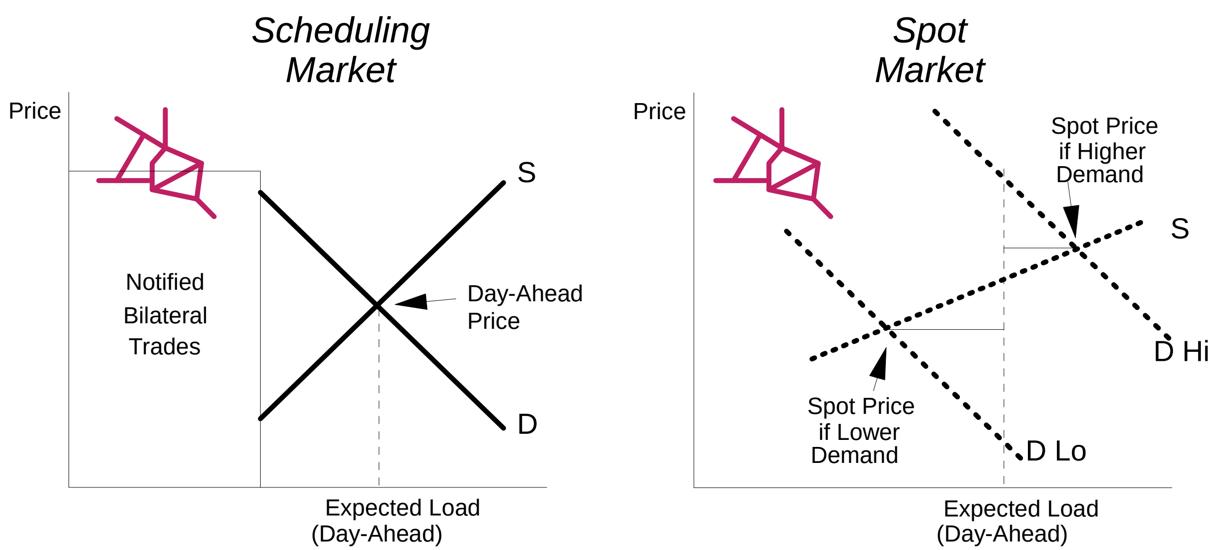
- It is a straightforward matter to compute "Schweppe" spot prices based on marginal costs at each location.

- Transmission spot prices arise as the difference in the locational prices.



The expected value of the real-time dispatch can differ from the day-ahead dispatch.

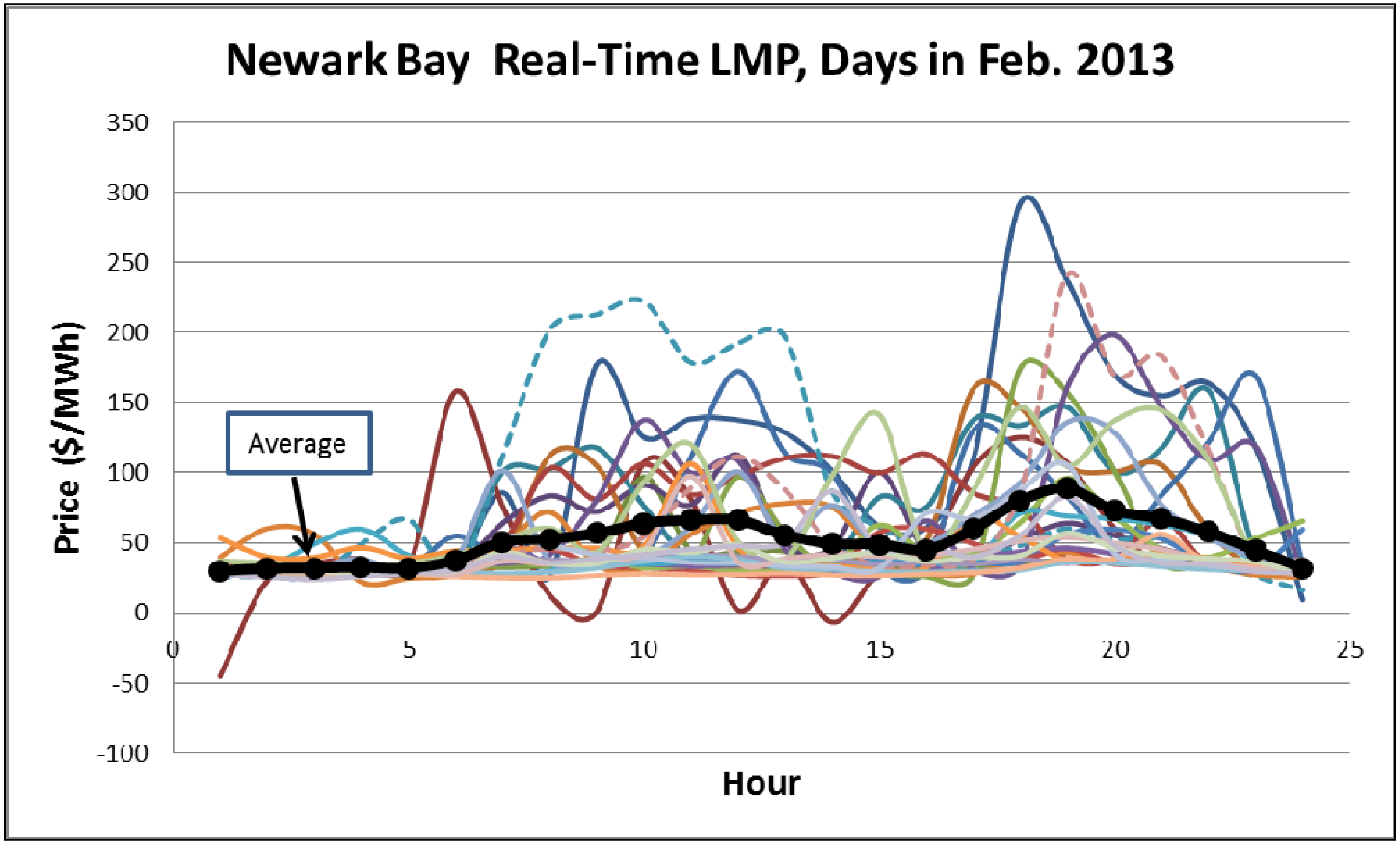
Spot Price Applies to Deviations from Scheduled Quantities



- Notified bilateral trades pay locational transmission charge but are settled outside pool
- Other trades settle at day-ahead price
- Locational congestion rents paid to transmission right holders along with excess congestion costs

- Payments for deviations from day-ahead trades at spot price for all transactions
- Uplift covers ancillary services and other costs
- Excess congestion costs paid to holders of transmission rights

The hourly average prices capture very little of the total real-time price variation.



(Source: www.pjm.com) (W. Hogan, "Time-of-Use Rates and Real-Time Prices," August 23, 2014, www.whogan.com)

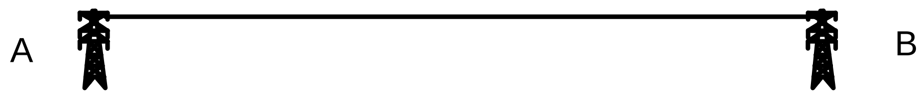
Equilibration of day-ahead prices and expected real-time prices does not mean that expected dispatch in real-time will be the same as the dispatch day-ahead, nor does it imply that the same transmission constraints will be binding or have the same congestion costs. (Hogan, 2016)

Day-Ahead Price Equilibrium

P_A

$-K \le Flow \le K$

$$P_B = \begin{cases} P_B^{Hi} >> P_A, & \pi = 0.5 \\ P_B^{Lo} < P_A, & 1-\pi = 0.5 \end{cases}$$



Expected Values

$$E(P_A) = P_A$$
$$E(\mu_{ab}) = 0.5\left(P_B^{Hi} - P_A\right)$$
$$E(\mu_{ba}) = 0.5\left(P_A - P_B^{Lo}\right)$$
$$E(P_B) = 0.5\left(P_B^{Lo} + P_B^{Hi}\right) > P_A$$
$$E(Flow) = 0.5(K) + 0.5(-K) = 0$$

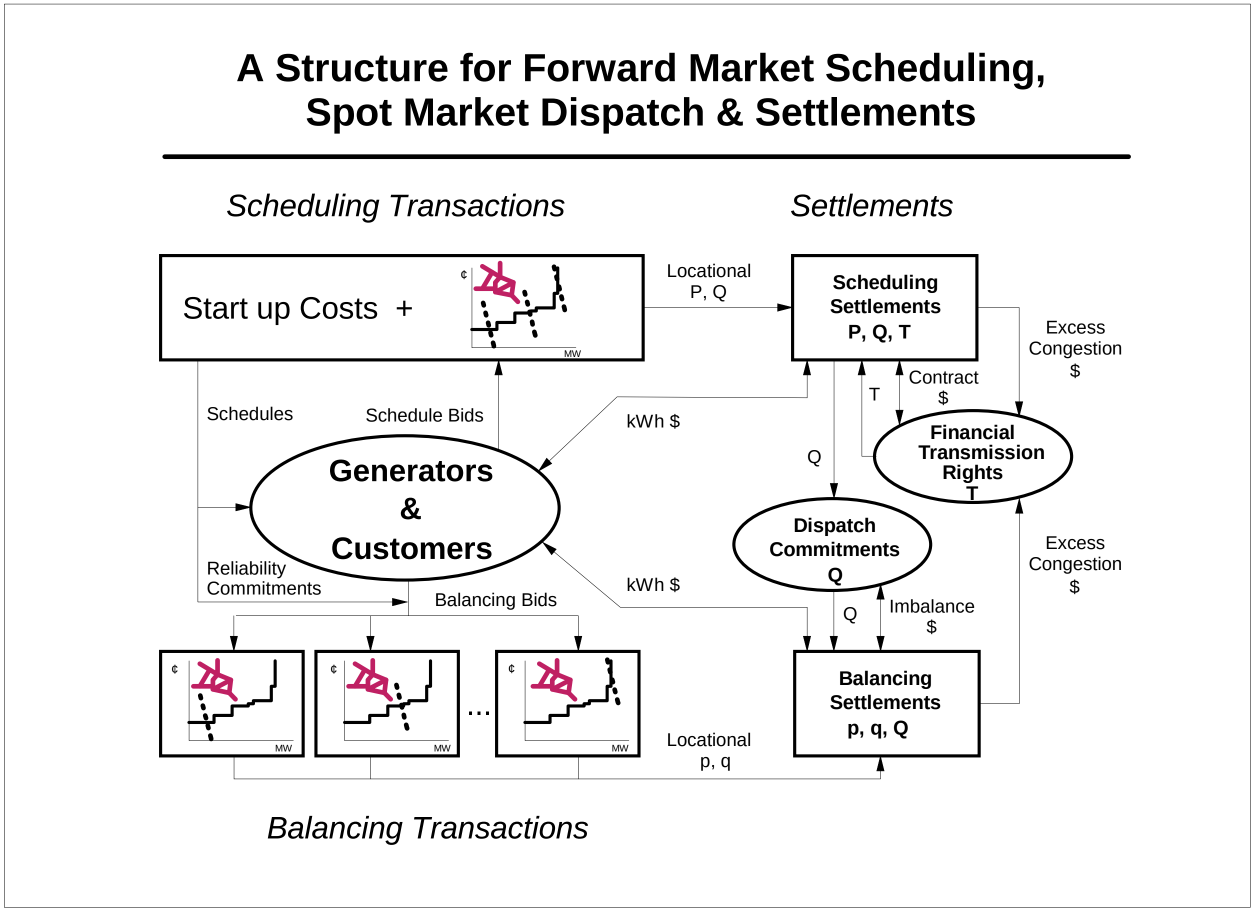
Day-Ahead Dispatch

$$P_A^{DA} = P_A$$
$$P_B^{DA} = E(P_B)$$
$$\mu_{ab}^{DA} = E(P_B) - P_A < E(\mu_{ab})$$
$$\mu_{ba}^{DA} = 0 < E(\mu_{ba})$$
$$Flow^{DA} = K$$

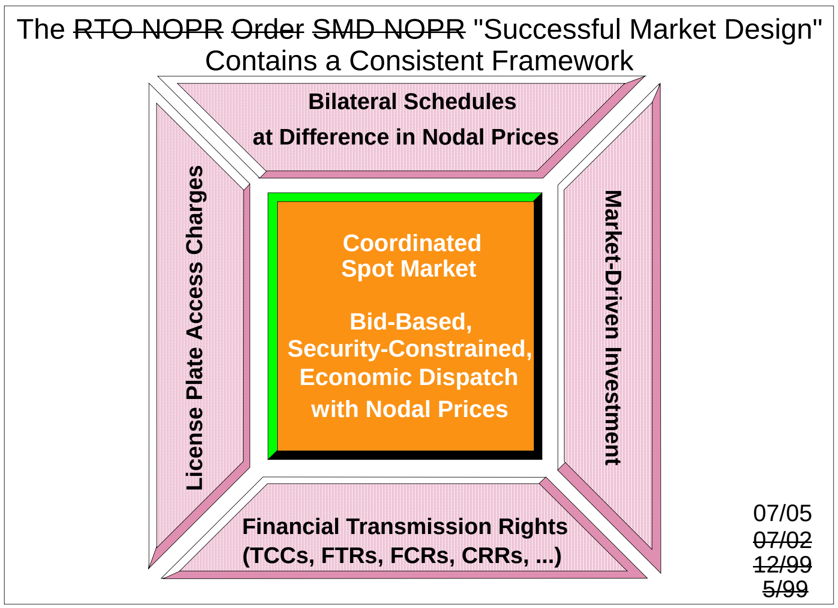
μ: Constraint Shadow Price

π: Scenario Probability

Organized electricity markets utilize day-ahead markets with bid-in loads and generation offers. In addition, day-ahead markets include a reliability commitment to ensure that adequate capacity will be available in real time to meet the actual load.



The example of successful central coordination, ~~CRT, Regional Transmission Organization (RTO) Millennium Order (Order 2000) Standard Market Design (SMD) Notice of Proposed Rulemaking (NOPR),~~ "Successful Market Design" provides a workable market framework that is working in places like New York, PJM in the Mid-Atlantic Region, New England, the Midwest, California, SPP, and Texas. This efficient market design is under (constant) attack.



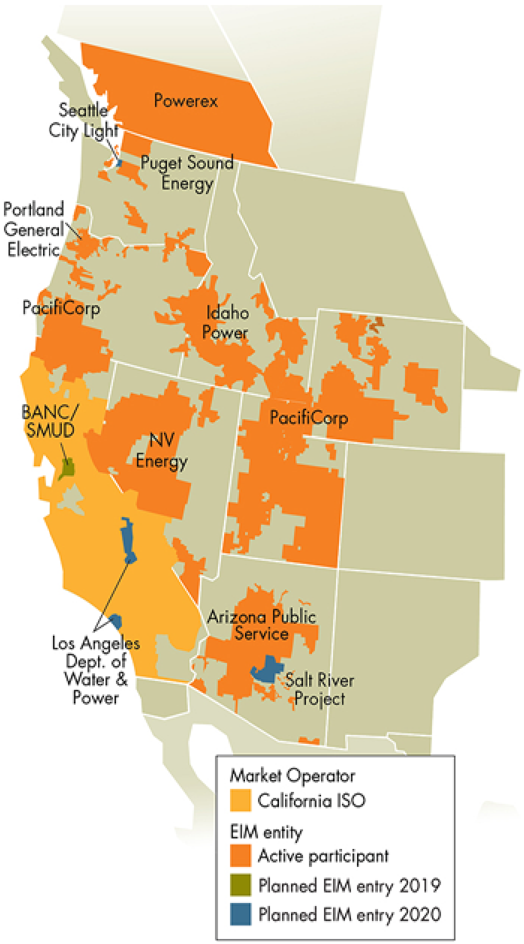
Poolco…OPCO…ISO…IMO…Transco…RTO… ITP…WMP…: "A rose by any other name …"
"Locational marginal pricing (LMP) is the electricity spot pricing model that serves as the benchmark for market design – the textbook ideal that should be the target for policy makers. A trading arrangement based on LMP takes all relevant generation and transmission costs appropriately into account and hence supports optimal investments." (International Energy Agency, 2007)

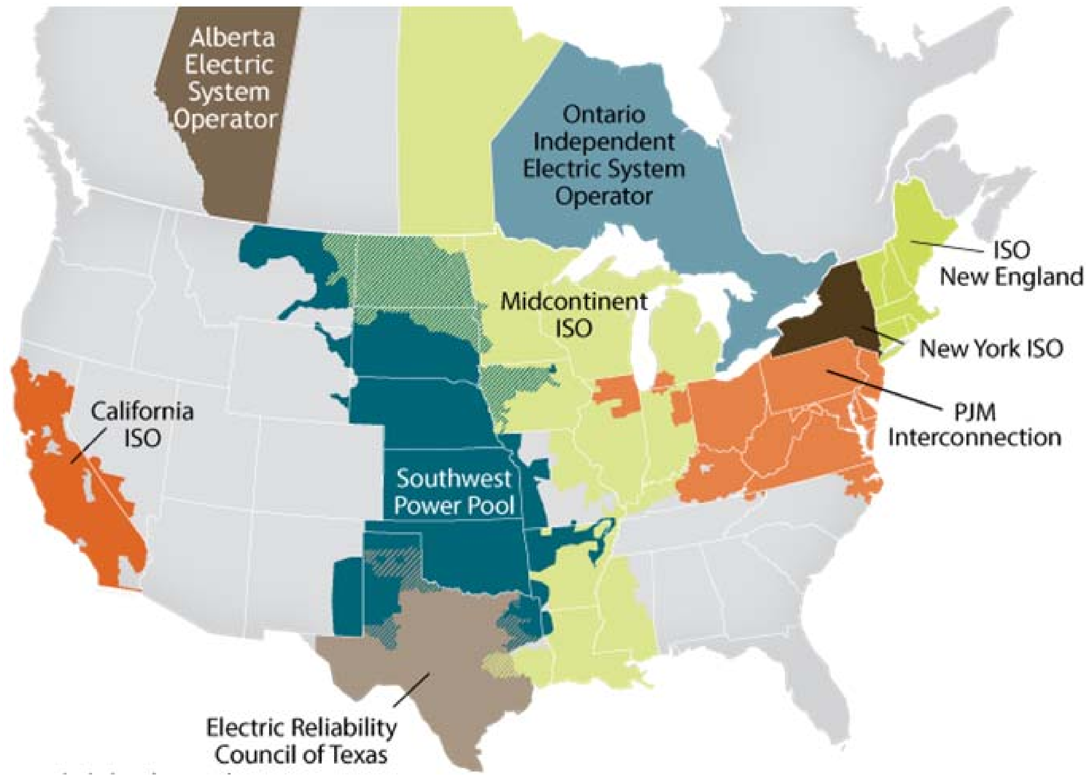
This is the only model that can meet the tests of open access and non-discrimination.

Anything that upsets this design will unravel the wholesale electricity market. The basic economic dispatch model accommodates the green energy agenda, as in the expanding Western Energy Imbalance Market (EIM).

The basic model covers the existing Regional Transmission Organizations and is expanding through the Wester Energy Imbalance Market. (www.westerneim.com)

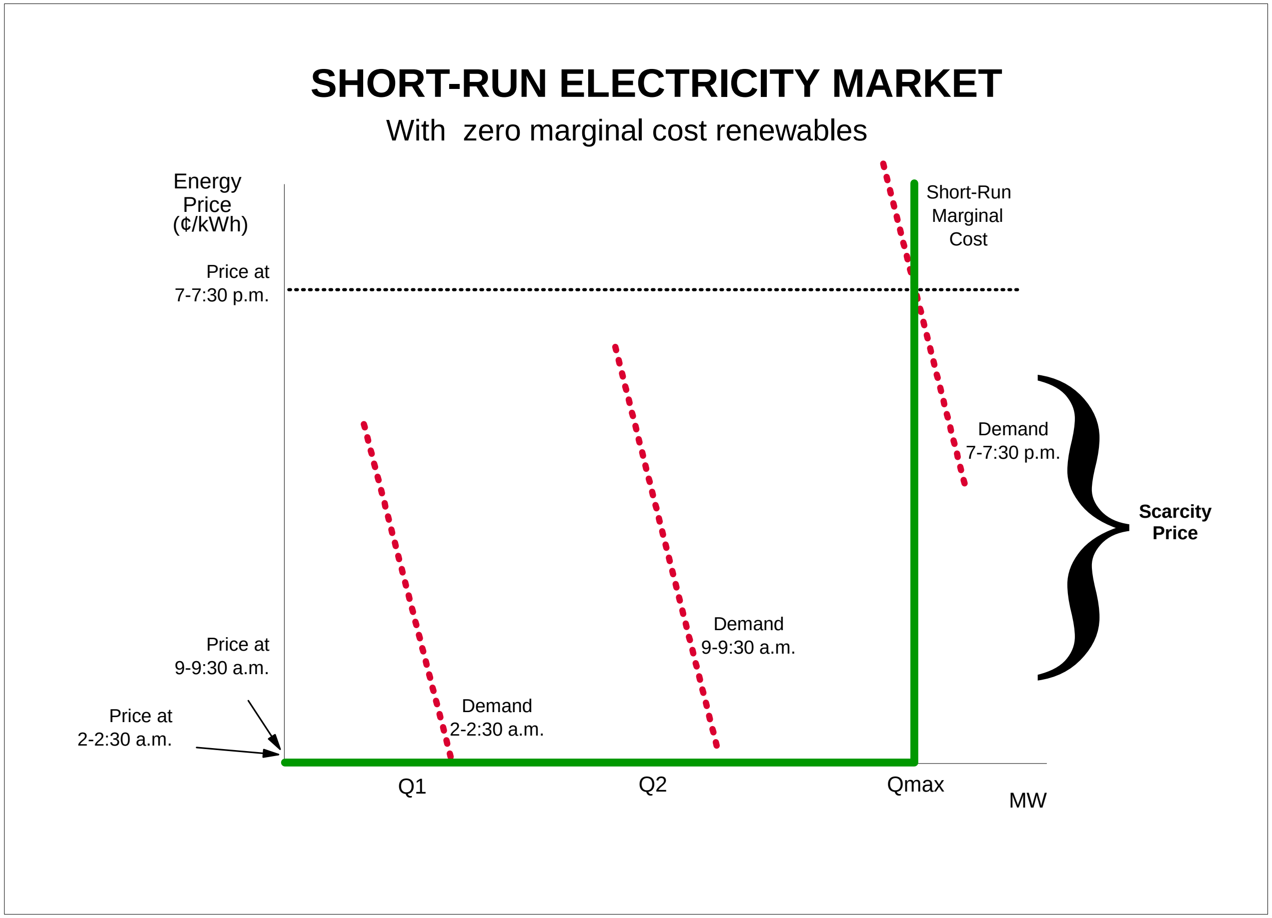
Western EIM active and pending participants





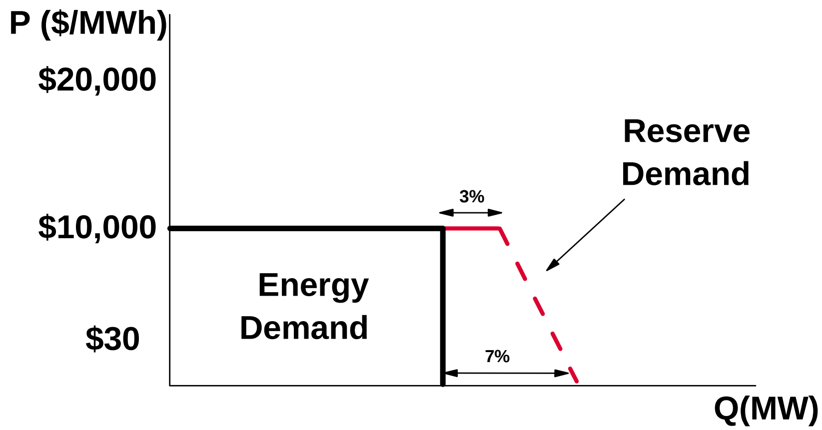
(IRC Council and CAISO maps)

A limiting case illustrates a key issue. Electricity market design with even complete penetration by zero-variable cost renewables would follow the same analysis. But scarcity pricing would be critical to provide efficient incentives.



Operating reserve demand curve would reflect capacity scarcity.

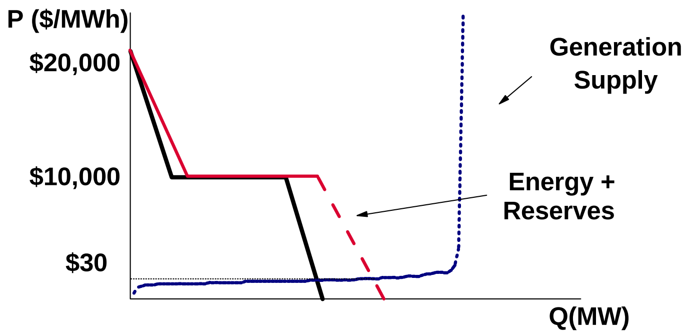
Illustrative Reserve Demand



There is a minimum level of operating reserve (e.g., 3%) to protect against system-wide failure. Above the minimum reserve, reductions below a nominal reserve target (e.g., 7%) are price senstive.

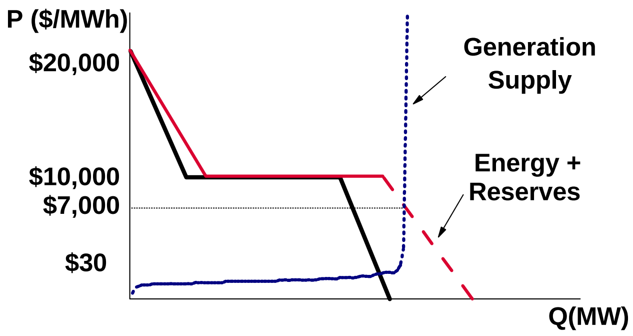
Market clearing addresses the "missing money" that results from inadequate scarcity pricing.

Normal "Energy Only" Market Clearing



When demand is low and capacity available, reserves hit nominal targets at a low price.

Scarcity "Energy Only" Market Clearing



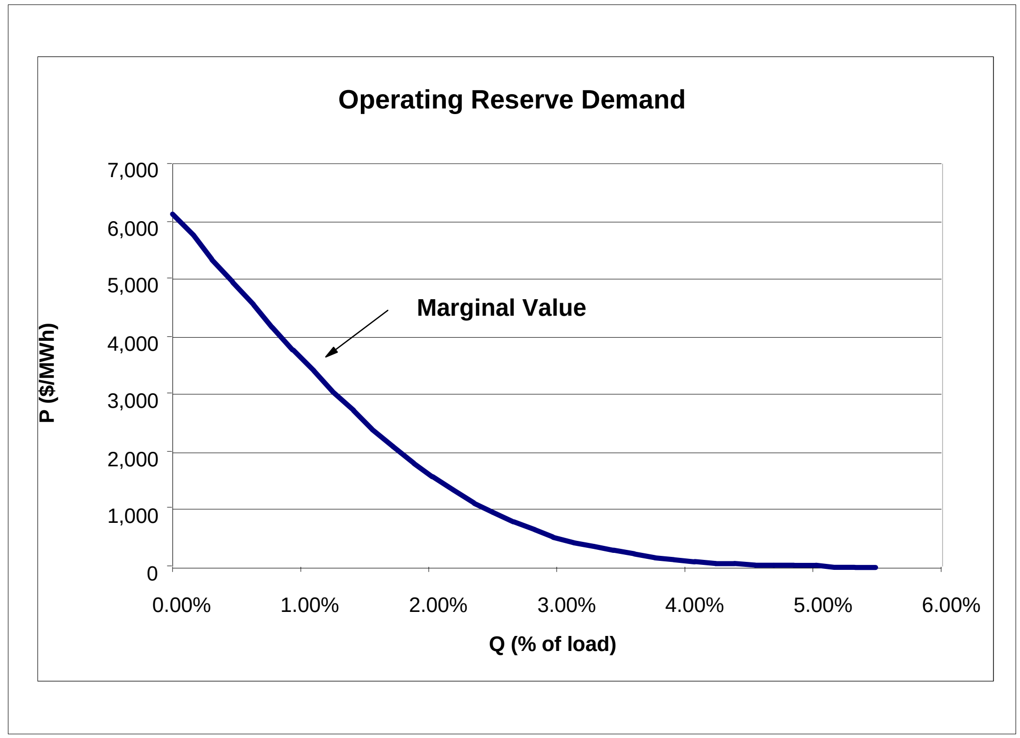
When demand is high and reserve reductions apply, there is a high price.

Operating reserve demand is a complement to energy demand for electricity. The probabilistic demand for operating reserves reflects the cost and probability of lost load.[2]

Example Assumptions

Expected Load (MW)	34000
Std Dev %	1.50%
Expected Outage %	0.45%
Std Dev %	0.45%
Expected Total (MW)	153
Std Dev (MW)	532.46
VOLL ($/MWh)	10000

Under the simplifying assumptions, if the dispersion of the LOLP distribution is proportional to the expected load, the operating reserve demand is proportional to the expected load.



2 "For each cleared Operating Reserve level less than the Market-Wide Operating Reserve Requirement, the Market-Wide Operating Reserve Demand Curve price shall be equal to the product of (i) the Value of Lost Load ("VOLL") and (ii) the estimated conditional probability of a loss of load given that a single forced Resource outage of 100 MW or greater will occur at the cleared Market-Wide Operating Reserve level for which the price is being determined. … The VOLL shall be equal to $3,500 per MWh." MISO, FERC Electric Tariff, Volume No. 1, Schedule 28, January 22, 2009, Sheet 2226.

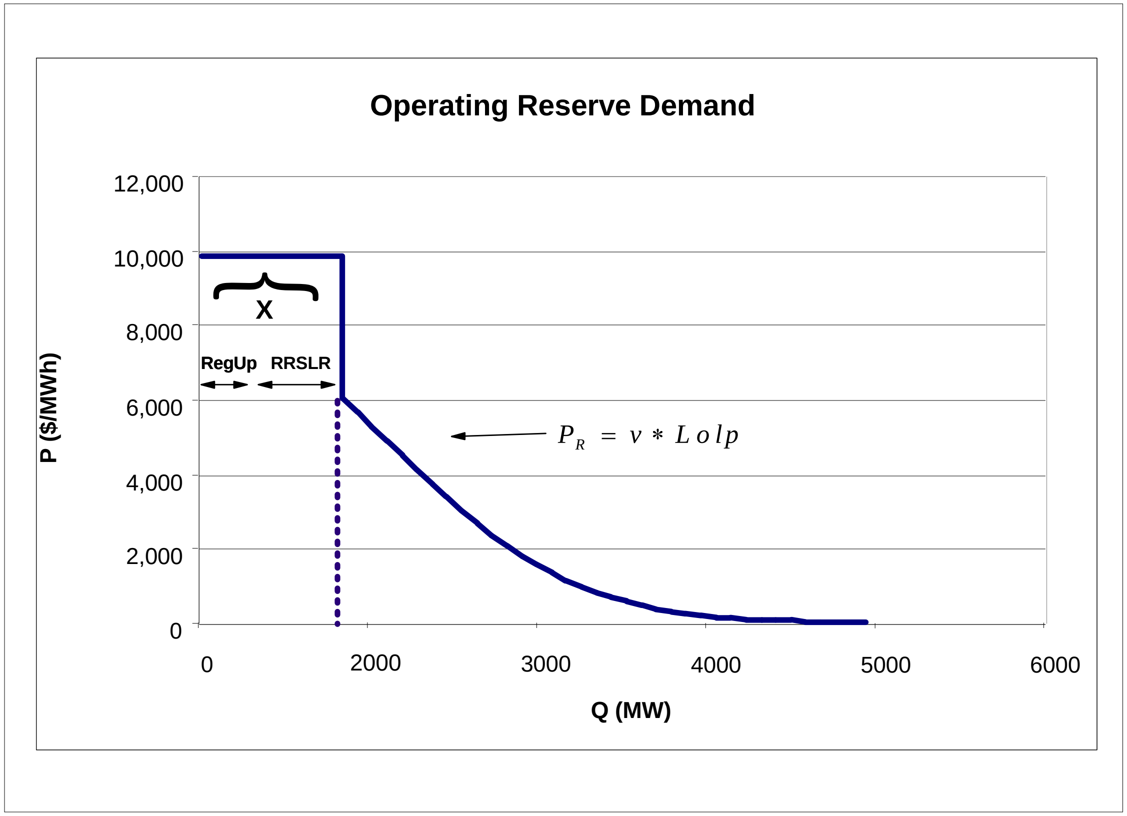
The deterministic approach to security constrained economic dispatch includes lower bounds on the required reserve to ensure that for a set of monitored contingencies (e.g., an n-1 standard) there is sufficient operating reserve to maintain the system for an emergency period.

Suppose that the maximum generation outage contingency quantity is r_{Min}. Then we would have the constraint:

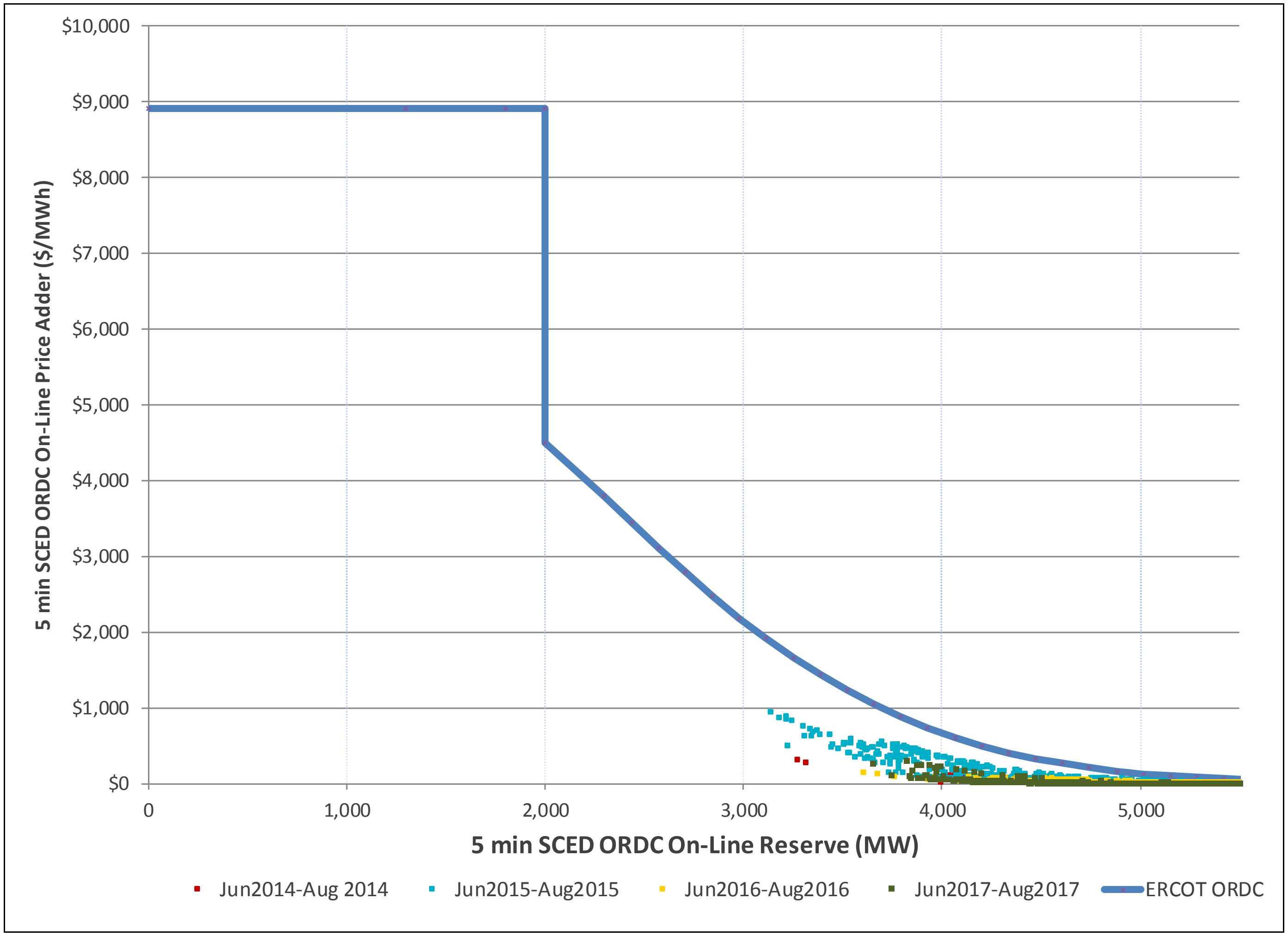
$$r \geq r_{Min}.$$

In effect, the contingency constraint provides a vertical demand curve that adds horizontally to the probabilistic operating reserve demand curve.

If the security minimum will always be maintained over the monitored period, the marginal price at r=0 applies. If the outage shocks allow excursions below the security minimum during the period, the reserve price starts at the security minimum.



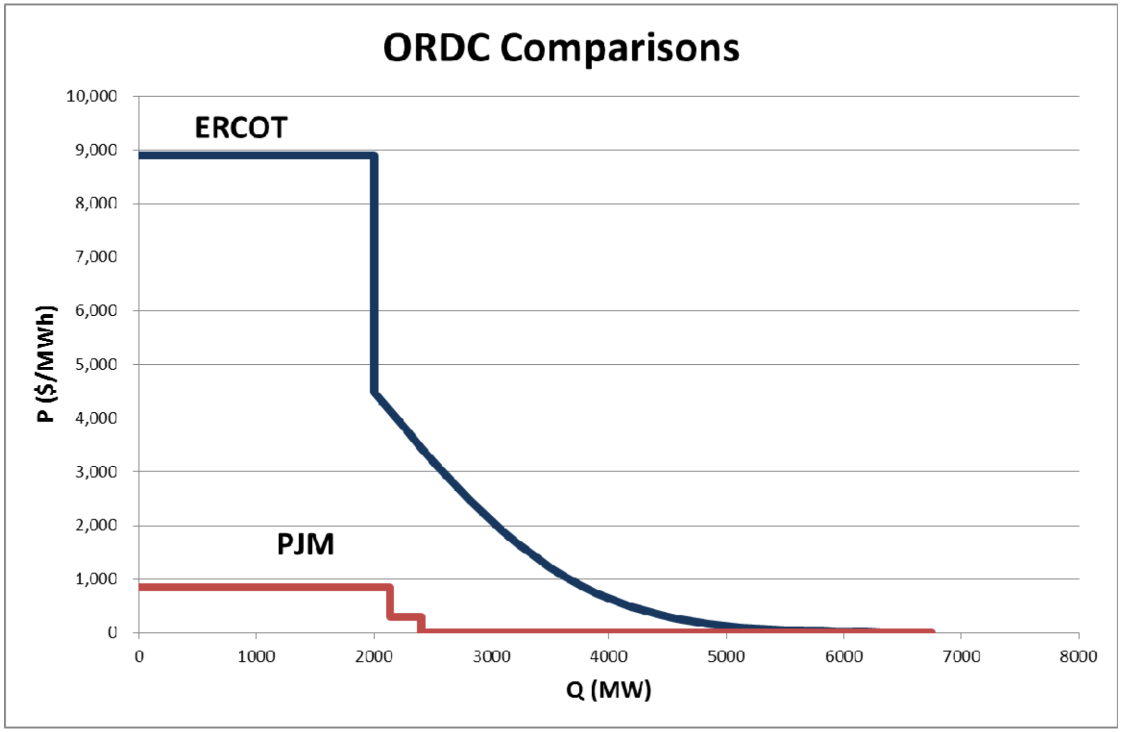
ERCOT launched implementation of the ORDC in in 2014. The summer peak is the most important period. The first four years of results showed high availability of reserves and low reserve prices.



Source: Resmi Surendran, ERCOT, EUCI Presentation, Updated 6/1/2018. The ORDC is illustrative. See also (Hogan & Pope, 2017)

Other RTOs have long used ORDCs, but without building the design on basic principles.

- **Limited to Declared Shortage Conditions.** "The ORDCs PJM currently utilizes were designed under the assumption that shortage pricing would only occur during emergency operating conditions and therefore the curves are a step function." (PJM and SPP, "Joint Comments Of PJM Interconnection, L.L.C And Southwest Power Pool, Inc. Addressing Shortage Pricing," FERC Docket No. RM15-24-000, November 30, 2015.)
- **Based on the Cost of Supply, not the Value of Demand.** "[T]he $300/MWh price is appropriate for reserves on the second step of the proposed ORDC based on an internal analysis of offer data for resources that are likely to be called on to provide reserves in the Operating Day." (PJM, Proposed Tariff Revisions of PJM Interconnection, L.L.C., Docket No. ER15-643-000, December 17, 2014)

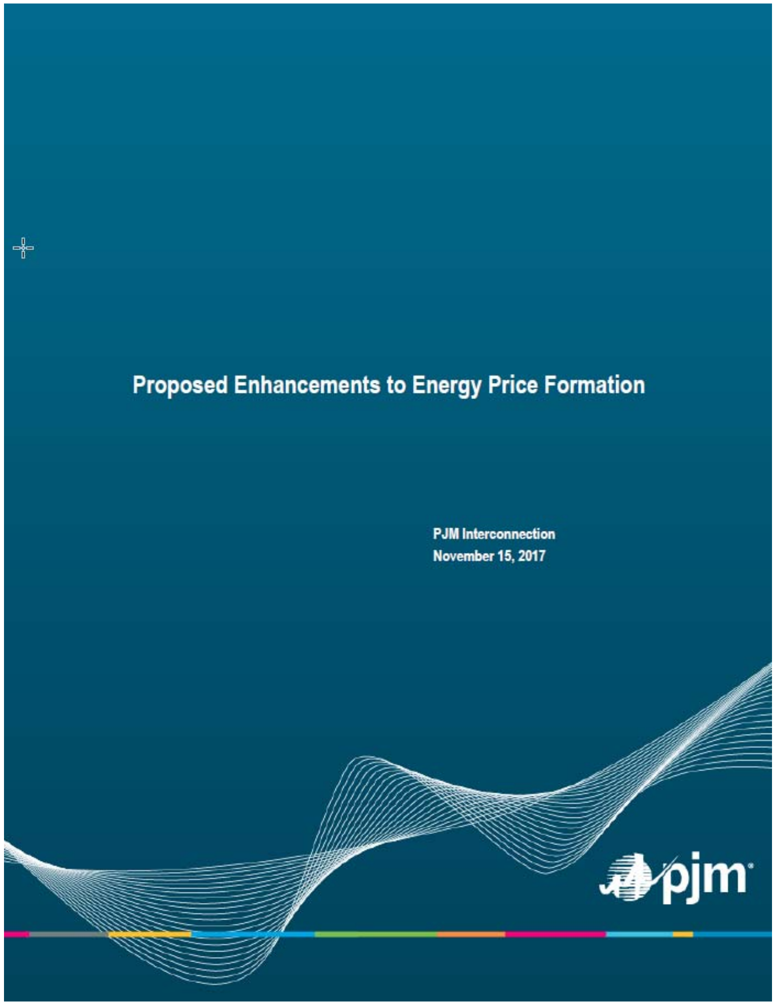


PJM has proposed a series of reforms for energy price formation, motivated in part by the impact of increased penetration of intermittent renewable resources. (PJM Interconnection, 2017)

"…the continuing penetration of zero marginal cost resources, declining natural gas prices, greater generator efficiency and reduced generator margins resulting from low energy prices have resulted in a generation mix that is differentiated less by cost and more by physical operational attributes." (p. 1)

Figure 9. Demand Curve for Operating Reserves with Minimum Reserve Requirement

"Redefining PJM's ORDCs using this methodology would enhance PJM's shortage pricing mechanism by assigning a value to reserves consistent with their reliability benefit to the system. Additionally, this ORDC model allows reserves to be committed in excess of the nominal requirement when it lowers the LOLP but assures that the cost of such reserves will never exceed the reliability benefit." (p.23)



Simulations for ERCOT market illustrate the connection between the missing money and reliability standards. The Texas PUC adopted the economic equilibrium approach. (Anderson, 2017)

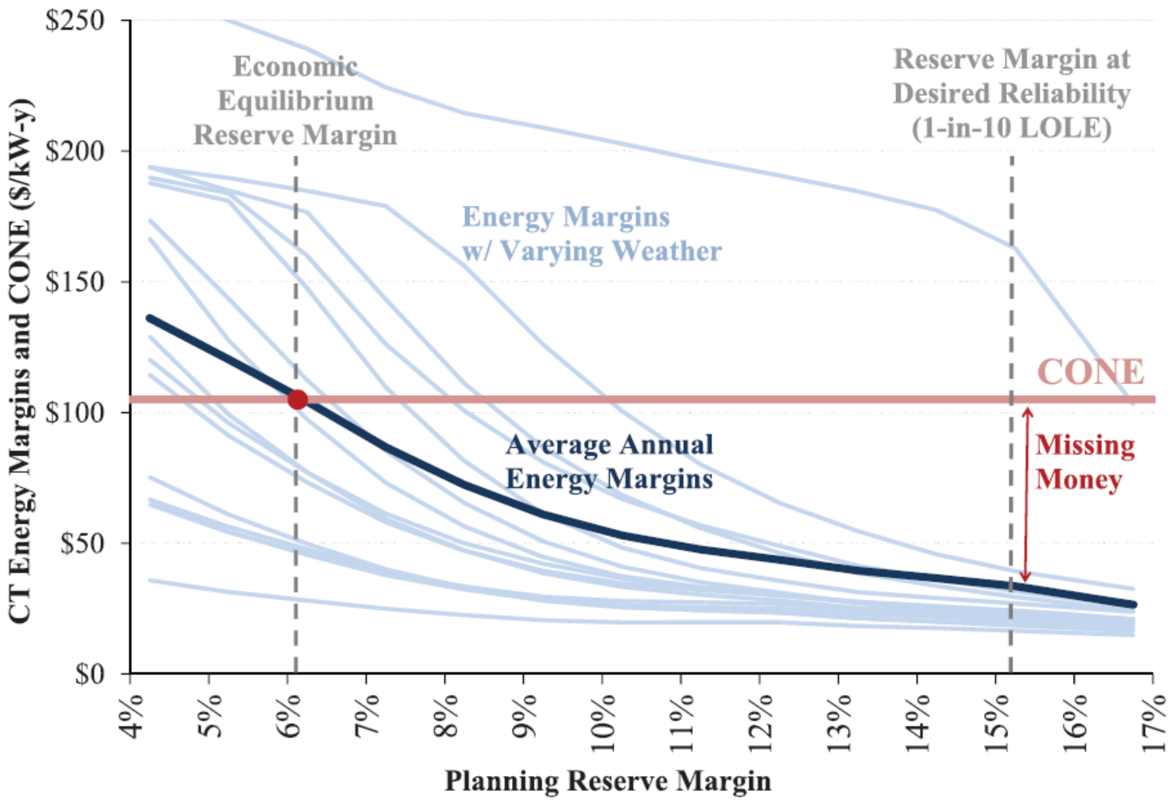


FIGURE 1
Equilibrium Reserve Margin and Missing Money in ERCOT's Energy-Only Market

(Spees, Newell, & Pfeifenberger, 2013, p. 7) See also (Telson, 1973) (Wilson, 2010)

Capacity markets have many problems, such as non-performance when capacity has not been available when needed. The ISONE pay-for-performance reform addresses many of the problems of the forward capacity market, but not all. But the stakeholder process of discussion and final regulatory decision takes a long time, and the capacity market solutions can create new problems.

"In 2010, ISO New England launched a Strategic Planning Initiative to focus the region on developing solutions to five challenges confronting New England's power system and wholesale markets. The first challenge concerns resource performance and flexibility." ISONE, "FCM Performance Incentives October 2012," Strategic Planning Initiative, p. 1.

The pay for performance incentive mechanisms will begin taking effect June 1 2018.

FERC, "Order on ISONE Tariff Filing," Docket ER14-1050, May 30, 2014, p. 4.

PJM called for "pseudo-ties" to ensure real-time capacity delivery: "One of the primary benefits of locational marginal pricing ("LMP") in energy markets is the ability to efficiently and reliably manage network congestion through the commitment and dispatch processes. This is achieved because the RTO can optimize the output of each resource that affects the flow over a transmission constraint positively or negatively. Not only does this reduce costs for an RTO's customers, it also ensures system reliability. Pseudo-ties are fundamentally inconsistent with this foundational principle underlying competitive electricity markets…" (Potomac Economics, 2017)

The capacity performance proposals address some of the problems of market design, but do not fully address the critical issue. For example, consider the ISONE testimony:

> "The motivation for the capacity market is to address a demand-side flaw, the absence of demand response. This causes the energy price to be set too low during periods of scarcity, creating missing money. One could restore the missing money with an "energy only" design by setting a high scarcity price during hours of reserve shortage. The scarcity price would be set in the ISO Tariff to induce the desired level of reliability. The PFP design in the FCM works in the same way as the "energy only" design, but with a forward contracting model that addresses several problems of the "energy only" design. Specifically, the forward contracting coordinates investment at the desired reliability level, reduces payment risk for both consumers and generators, and mitigates market power in the energy market during periods of scarcity."

Peter Campton Testimony, ISO New England Inc. and New England Power Pool, Filings of Performance Incentives Market Rule Changes, Docket ER14-050, January 17, 2014, p. 4.

Is it true?

> "The PFP design in the FCM works in the same way as the "energy only" design."

Not if prices facing the demand-side do not reflect the true scarcity conditions. Forward contracting could hedge the prices on average, but need not hedge prices on the margin. This choice is not available to participants in PJM or ISONE. The "performance prices" are restricted to transfers among generators.

Neither PJM nor ISONE make the logical connection between the analysis of the real-time pricing problem and the prescription of a solution.

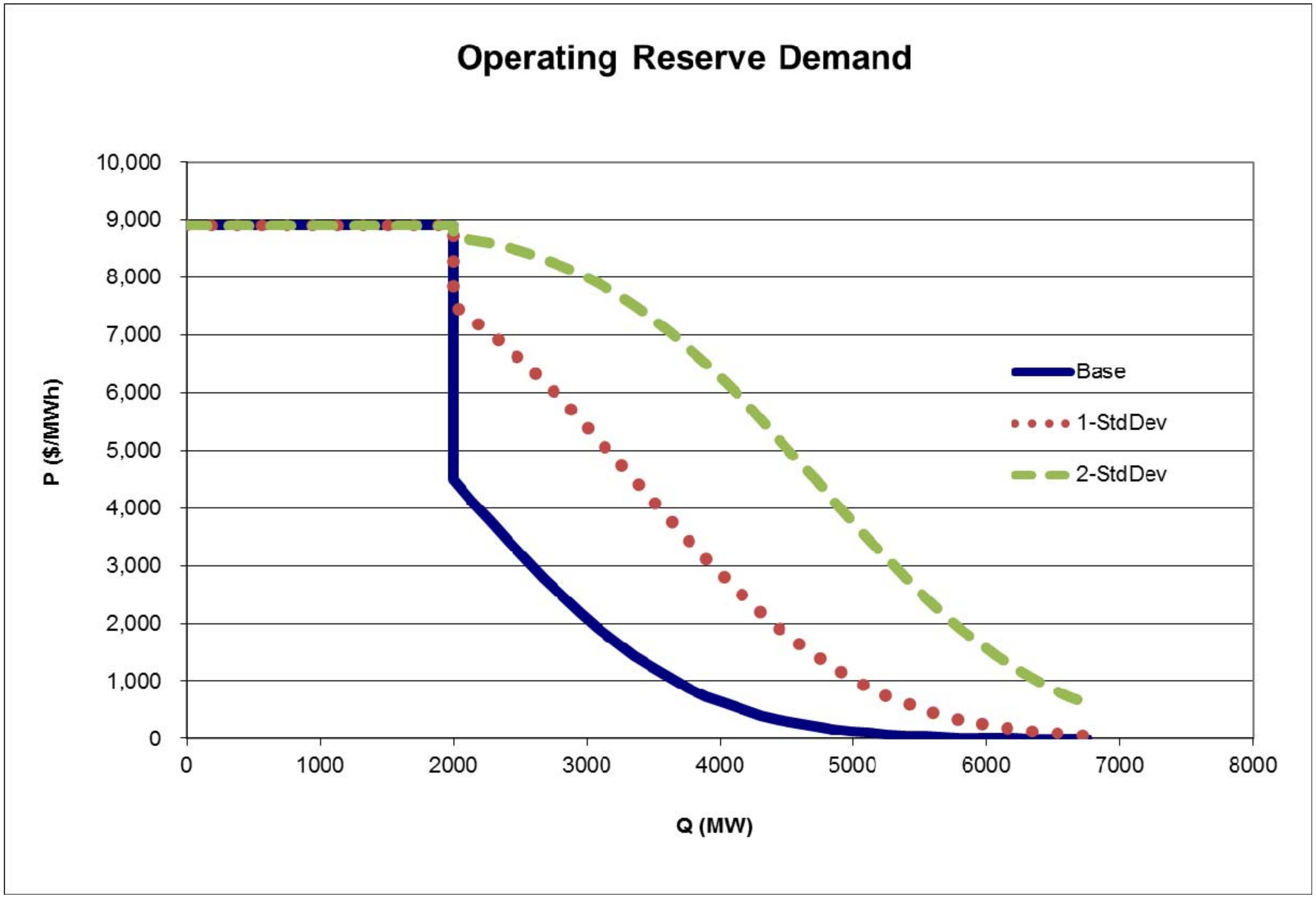
An augmented ORDC would impose conservative assumptions on the basic model. The intent would be to provide both a reliability margin of safety, an associated increase in total operating reserves, and energy payments to address the missing money problem. The three principal parameters of the ORDC are the value of lost load (VOLL), the minimum contingency level (X), and the loss of load probability (LOLP).

- **VOLL.** The VOLL price applies when conditions require involuntary load curtailment. It is important that this price be paid to generation and charged to remaining load. Hence, an upper bound on a conservative VOLL would be the maximum price we were willing to charge in the face of load curtailment. It may be better to err in the direction of a higher VOLL, but this may not be enough to address the reliability goal and provide the missing money.

- **X.** The minimum contingency level is more directly connected to reliability. However, if the minimum contingency threshold is set too high, we would produce periods when VOLL prices were being imposed but no non-market interventions were needed. Regulators would have to defend applying the VOLL when it was not required.

- **LOLP.** The short-term load and generation changes that give rise to the LOLP summarize a complex process. The models applied employ certain assumptions about the accuracy of the system approximations and the ability to avoid problems like human error typically found in events that threaten the stability of the system. A conservative approach to reliability is already part of the motivation for the use of contingency constraints to define secure operations. However, it would be consistent to extend this reliability motivation to a conservative estimation of the LOLP. This would avoid the conflicts that arise with too high a VOLL or too high an X.

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.



No design can be perfect, but the record indicates the high costs of ignoring first principles. When "good enough" is good enough, the costs of the unintended consequences can be high. The examples from scarcity pricing, demand response, transmission expansion and the cleaner energy are illustrative but not exhaustive. Many other areas present similar challenges.

- **Extended Locational Marginal Prices (ELMP).** (Gribik, Hogan, & Pope, 2007)
- **Out-of-Market Transactions and Price Formation.** (Hogan, 2014)
- **Renewable Portfolio Standards.** (Schmalensee, 2012)
- **Net Energy Metering.** (Brown & Bunyan, 2014)
- **Market Manipulation.** (Lo Prete & Hogan, 2014)
- **Reforming the Energy Vision.** (NYS Department of Public Service, 2014) (Caramanis, Ntakou, Hogan, Chakrabortty, & Schoene, 2016)
- **Hidden Values and the Value Stack.** (NYS Department of Public Service, 2016)
- **Virtual Bidding and Financial Trading.** (Hogan, 2016)
- **Clean Power Plan.** (Hogan, 2015)
- **Energy Imbalance Markets.** (Hogan, 2017)
- **Other?**

References

Anderson, K. W. (2017). *Role and Value of Scarcity Pricing and How The Energy Market Addresses Missing Money Problem*. Retrieved from https://www.puc.texas.gov/agency/about/commissioners/anderson/pp/EUCI_Price_Formation_Issues_04132017.pdf

Brown, A., & Bunyan, J. (2014). Valuation of Distributed Solar: A Qualitative View. *Electricity Journal*, *27*(10), 27–48. http://doi.org/10.1016/j.tej.2014.11.005

Caramanis, M. C., Ntakou, E., Hogan, W. W., Chakrabortty, A., & Schoene, J. (2016). Co-Optimization of Power and Reserves in Dynamic T & D Power Markets With Nondispatchable Renewable Generation and Distributed Energy Resources. *Proceedings of the IEEE*, *104*(4), 807–836. Retrieved from http://ieeexplore.ieee.org.ezp-prod1.hul.harvard.edu/stamp/stamp.jsp?arnumber=7429676

FERC. (2017). Order granting complaint in part and denying in part re New York State Public Service Commission et al vs. New York Independent System Operator, Inc. under EL16-92. Federal Energy Regulatory Commission. Retrieved from https://elibrary.ferc.gov/IDMWS/common/opennat.asp?fileID=14483864

Gribik, P. R., Hogan, W. W., & Pope, S. L. (2007). Market-Clearing Electricity Prices and Energy Uplift. Retrieved from http://www.hks.harvard.edu/fs/whogan/Gribik_Hogan_Pope_Price_Uplift_123107.pdf

Hogan, W. W. (1992). Contract networks for electric power transmission. *Journal of Regulatory Economics*, *4*(3), 211–242. Retrieved from http://ezp-prod1.hul.harvard.edu/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=bth&AN=16580807&site=ehost-live&scope=site

Hogan, W. W. (2014). Electricity Market Design and Efficient Pricing: Applications for New England and Beyond. *The Electricity Journal*, *27*(7), 23–49. http://doi.org/10.1016/j.tej.2014.07.009

Hogan, W. W. (2015). Electricity Markets and the Clean Power Plan. *The Electricity Journal*, *28*(9), 9–32. Retrieved from http://www.sciencedirect.com/science/article/pii/S1040619015002006

Hogan, W. W. (2016). Virtual bidding and electricity market design. *The Electricity Journal*, *29*(5), 33–47. http://doi.org/10.1016/j.tej.2016.05.009

Hogan, W. W. (2017). An efficient Western Energy Imbalance Market with conflicting carbon policies. *Electricity Journal*, *30*(10). http://doi.org/10.1016/j.tej.2017.11.001

Hogan, W. W., & Pope, S. L. (2017). *Priorities for the Evolution of an Energy-Only Electricity Market Design in ERCOT*. Retrieved from https://www.hks.harvard.edu/fs/whogan/Hogan_Pope_ERCOT_050917.pdf

International Energy Agency. (2007). *Tackling Investment Challenges in Power Generation in IEA Countries: Energy Market Experience*. Paris. Retrieved from http://www.iea.org/publications/freepublications/publication/tackling_investment.pdf

Joskow, P. L., & Schmalensee, R. (1983). *Markets for power: an analysis of electrical utility deregulation*. *MIT Press Books*. MIT Press Book. Retrieved from http://ideas.repec.org/b/mtp/titles/0262600188.html

Lavaei, J., & Low, S. H. (2012). Zero duality gap in optimal power flow problem. *IEEE Transactions on Power Systems*, *27*(1), 92–107. http://doi.org/10.1109/TPWRS.2011.2160974

Lo Prete, C., & Hogan, W. W. (2014). Manipulation of Day-ahead Electricity Prices through Virtual Bidding in the U. S. *IAEE Energy Forum*, 31–32.

Retrieved from http://www.iaee.org/en/publications/newsletterdl.aspx?id=244

Lopes, F., & Coelho, H. (2018). Electricity Markets with Increasing Levels of Renewable Generation: Structure, Operation, Agent-based Simulation, and Emerging Designs. In F. Lopes & H. Coelho (Eds.), *Studies in Systems, Decision and Control, 144*. Springer International Publishing. http://doi.org/10.1007/978-3-319-74263-2

Monitoring Analytics. (2017). *2016 State of the Market Report for PJM* (Vol. 2). Retrieved from http://www.monitoringanalytics.com/reports/PJM_State_of_the_Market/2016/2016-som-pjm-volume2.pdf

Nordhaus, W. (2013). *The Climate Casino: Risk, Uncertainty, and Economics for a Warming World*. New Haven: Yale University Press. Retrieved from http://books.google.com/books?hl=en&lr=&id=YfzYAQAAQBAJ&oi=fnd&pg=PT7&dq=The+Climate+Casino:+Risk,+Uncertainty,+and+Economics+for+a+Warming+World&ots=g2lR0lTh_s&sig=FMS8QxAOSGvw7pfCZugeOwjoX-E

NYS Department of Public Service. (2014). *Reforming the Energy Vision* (No. CASE 14-M-0101). Retrieved from http://www3.dps.ny.gov/W/PSCWeb.nsf/96f0fec0b45a3c6485257688006a701a/26be8a93967e604785257cc40066b91a/$FILE/ATTK0J3L.pdf/Reforming The Energy Vision (REV) REPORT 4.25. 14.pdf

NYS Department of Public Service. (2016). *Staff Report and Recommendations in the Value of Distributed Energy Resources Proceeding*. Retrieved from http://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId=%7B59B620E6-87C4-4C80-8BEC-E15BB6E0545E%7D

PJM Interconnection. (2017). Proposed Enhancements to Energy Price Formation. Retrieved from http://www.pjm.com/-/media/library/reports-notices/special-reports/20171115-proposed-enhancements-to-energy-price-formation.ashx

Potomac Economics. (2017). Complaint of Potomac Economics. Potomac Economics. Retrieved from https://elibrary.ferc.gov/IDMWS/common/opennat.asp?fileID=14549513

Schmalensee, R. (2012). Evaluating policies to increase electricity generation from renewable energy. *Review of Environmental Economics and Policy*, *6*(1), 45–64. http://doi.org/10.1093/reep/rer020

Schweppe, F. C., Caramanis, M. C., Tabors, R. D., & Bohn, R. E. (1988). *Spot pricing of electricity*. Kluwer Academic Publishers. Retrieved from http://books.google.com/books?id=Sg5zRPWrZ_gC&pg=PA265&lpg=PA265&dq=spot+pricing+of+electricity+schweppe&source=bl&ots=1MIUfKBjBk&sig=FXe_GSyf_V_fcIuTmUtH7mKO_PM&hl=en&ei=Ovg7Tt66DO2x0AH50aGNCg&sa=X&oi=book_result&ct=result&resnum=3&ved=0CDYQ6AEwAg#v=onep

Spees, K., Newell, S., & Pfeifenberger, J. P. (2013). Capacity Markets - Lessons Learned from the First Decade. *Economics of Energy & Environmental Policy*, *2*(2). http://doi.org/10.5547/2160-5890.2.2.1

Telson, M. L. (1973). The economics of reliability for electric generation systems. *MIT Energy Laboratory*, (May). Retrieved from http://dspace.mit.edu/handle/1721.1/27285

Wilson, J. (2010). Reconsidering Resource Adequacy: Part 1. *Public Utilities Fortnightly*, (April), 33–39. Retrieved from https://www.fortnightly.com/fortnightly/2010/04/reconsidering-resource-adequacy-part-1