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Power Market Design for an Era of Rapid Decarbonization

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The electricity industry is in the midst of a transition to clean energy. The success of that transition depends, in large part, on the ability of electricity markets to support needed investment and to continue to facilitate reliable delivery of low-cost electricity to customers while increasing reliance on renewables. The electricity grid is decarbonizing through a combination of state policy, customer demands, and changing economics. Recent trends in clean energy investment will need to accelerate so that the states may meet their ambitious clean energy goals. The Biden Administration has set the goal of decarbonizing the electricity sector by 2035. This goal will require a substantial increase in clean energy investment, as well as new and updated market designs.

As the industry transitions, interest in exploring new market designs has grown, as shown by the launch of the Johns Hopkins and Columbia University's Future Power Markets Forum in 2020; discussion of market designs in a recent National Academies of Science, Engineering, and Medicine report on accelerating decarbonization in the United States; and a series of papers devoted to the topic published recently in IEEE Power and Energy.[1] The Texas Energy Crisis of 2021 has also spurred more interest in determining how best to ensure resilience, reliability, and performance in the context of rapid and deep decarbonization of the grid.

A number of experts agree that today's wholesale market designs adequately manage system operations and help maintain resource adequacy for systems that are still largely fossil-based.[2] However, a growing body of research suggests that these designs face challenges in terms of rationalizing the mix of new technologies and supporting efficient investments, at the same time that new technologies, policies, and consumer preferences drive deep emissions reductions in the power sector, and as demand for electricity expands to support the decarbonization of other sectors of the economy.[3]

The market designs of Regional Transmission Organizations and Independent System Operators (RTO/ISOs) in the United States share one fundamental feature: a short run energy market that uses generator bids to supply energy and system constraints to find the least cost way to deliver both the energy that consumers want and the ancillary services that are needed to operate the system and keep demand and supply in balance at all times. This market design determines hourly energy prices by location, known as locational marginal prices (LMP). The LMP-based energy market operates in

1 For information on the Future Power Market Forum, see powermarkets.org. Other referenced work includes "Accelerating Decarbonization of the U.S. Energy System," *National Academies of Sciences, Engineering, and Medicine* (2021), https://www.nap.edu/catalog/25932; "Choices in Tools and Design: Zero-Marginal-Cost Electricity Market," *IEEE Power and Energy* (January/February 2021), https://magazine.ieee-pes.org/back-issues/.

2 See: Peter Fox-Penner, *Power after Carbon: Building a Clean, Resilient Grid,* Harvard University Press: 2020. William Hogan, "Electricity Market Design and Efficient Pricing: Applications for New England and Beyond," *The Electricity Journal,* 27:7 (August–September 2014), https://www.sciencedirect.com/science/article/abs/pii/S1040619014001705?via%3Dihub; William Hogan, "Electricity Market Design Interactions of Multiple Markets," presentation at RFF's Workshop on the Future of Power Markets in a Low Marginal Cost, September 14, 2017, at https://media.rff.org/documents/170914_PowerMarkets_WilliamHogan.pdf; and Paul Joskow and Richard Schmalensee, "Electricity Markets," [podcast] *MIT Energy Initiative,* Episode #14 (2020), http://energy.mit.edu/podcast/electricity-markets/.

3 See, for example: "Whole Electricity Market Design for Rapid Decarbonization," *Energy Innovation Policy & Technology LLC.* (June 25, 2019), https://energyinnovation.org/publication/wholesale-electricity-market-design-for-rapid-decarbonization and Bielen, Burtraw, Palmer and Steinberg, "The Future of Power Markets in a Low Marginal Cost World," *Resources for the Future Working Paper* (December 18, 2017), https://www.rff.org/publications/working-papers/the-future-of-power-markets-in-a-low-marginal-cost-world/.

two time frames. Day-ahead markets secure financially binding schedules of electricity supply and purchasing by retailers who sell electricity to customers by the hour for the next day. Real-time markets balance the differences between day-ahead schedules and real-time, actual loads.[4]

Where RTO/ISO markets differ is in the approach taken either by the RTO or by the state (or some combination of the two) to ensure resource adequacy. Three different approaches are used:[5]

1. "Energy-only" market: The Electric Reliability Council of Texas (ERCOT) uses scarcity pricing, including an operating reserve demand curve (ORDC)[6] adder to energy market payments when operating reserves are low to ensure resource adequacy.[7] The size of the ORDC adder on price varies by time of day and the extent to which reserves fall short of minimum levels. It reflects an administrative estimate of the cost to customers of losing power, also known as the value of lost load (VOLL).

2. "Energy and capacity" markets: Three RTOs — New York Independent System Operator (NYISO), New England's Independent System Operator (ISO-NE), and PJM (a multi-state RTO covering a wide swath of the mid-Atlantic and the Midwest) — use a separate market for capacity (MW) that looks out up to three years into the future and secures capacity commitments from generators to be available to be called on to serve load in exchange for payments to do so.

3. Energy market plus state-level cost-of-service regulation of generation assets that support sufficient capacity to meet resource adequacy requirements for regulated utilities, perhaps with a residual centralized capacity market. This is the approach used by the California Independent System Operator (CAISO), the Midwest Independent System Operator (MISO), and the Southwest Power Pool (SPP).

A growing concern has emerged regarding how well-suited each of these three approaches to encouraging capacity availability will be for supporting least cost investment and new project financing in a deeply decarbonized electric grid that relies heavily on generation resources with variable and intermittent output and very low to zero operating costs.[8]

In response to concerns about the efficacy of current market designs to support deep decarbonization, the World Resources Institute (WRI) and Resources for the Future (RFF) explored new ideas for the design and implementation of long-term markets in a workshop held on December 16-17, 2020.[9] Each proposed market design includes long-term features not present in current market designs that could identify and support the financing and development of efficient, reliable mixes of clean (i.e., zero- and very low-carbon) resources.

This essay describes the rationale for exploring long-term market designs presented by MIT Professors Paul Joskow and Richard Schmalensee. It then reviews the designs presented by four experts: Steven Corneli, Susan Tierney, Eric Gimon, and Brendan Pierpont.[10]

4 *Energy Primer: A Handbook for Energy Market Basics.* FERC, 2020, https://www.ferc.gov/media/energy-primer-updated-6320.

5 These three types, along with variations among RTOs and ISOs, are described in more detail in J. Brewer, S. Lin, M. Prica, R. Wallace, P. Shirley, C. E. Logan, "Power Market Primers, Rev. 01." National Energy Technology Laboratory, Pittsburgh, February 28, 2019, https://www.netl.doe.gov/projects/files/Power%20Market%20Primers%20Rev%2001.pdf.

6 Some consider this a form of capacity payment.

7 For more information see: William Hogan, "Electricity Scarcity Pricing Through Operating Reserves: An ERCOT Window of Opportunity," November 1, 2012, https://scholar.harvard.edu/whogan/files/hogan_ordc_110112r.pdf.

8 See: Carl Pechman, *Whither the FERC: Overcoming the Existential Threat to its Magic Pricing Formula through Prudent Regulation,* National Regulatory Research Institute, January 2021.

9 All papers, presentations, videos, are available from the December 2020 workshop at: https://www.rff.org/events/workshops/market-design-for-the-clean-energy-transition-advancing-long-term-approaches/.

10 Background on these four authors is available at: https://rmi.org/people/steven-corneli/; https://www.analysisgroup.com/experts-and-consultants/senior-advisors/susan-f--tierney/; https://energyinnovation.org/team-member/eric-gimon-2/; and https://www.linkedin.com/in/brendanpierpont/.

Why Long-Term Markets?

Exploring options for an organized long-term market to augment or complement an energy-only market may help to determine how best to ensure decarbonization of the energy sector without sacrificing reliability.

One longstanding school of thought holds fast to approaches to market design that yield the most efficient outcome according to economic theory.[11] This economically ideal market design suggests that an energy-only market with very high or no price caps, scarcity pricing, and price-responsive electricity demand with time varying prices, paired with a policy that prices carbon at its social cost, is the most efficient approach and that deviations from this approach would raise the cost of electricity to society unnecessarily.[12] This school of thought suggests that market designs and associated environmental policies should evolve toward this ideal and that market operations and the resulting prices take into account the full cost of electricity production, including the social costs imposed by carbon emissions. Incentives for investment in such a market would stem from high prices during periods of shortage providing high revenues to generators available to generate or offer operating reserve services at those times. The prices emerging from these markets could form the basis for decentralized forward-looking contracts that generators and electricity buyers might use to hedge their risks.[13]

Professor Joskow has expressed skepticism about creating such a market, given the distance between this idea and the way policies and markets work in the real world. Examples that illustrate this gap between current practice and the economists' ideal approach include state approaches to encouraging clean energy through incentives or procurement, difficulties with implementing carbon pricing at the levels necessary to meet society's clean energy goals, concerns about electricity price volatility, and regulatory reluctance to eliminate price caps. Instead, he suggests a different approach, a "hybrid market," that would combine two distinct phases of competition—competition **for** the market resulting in long-term contracts that enable investment, and competition **in** the market, referring to the current day-ahead and real-time energy markets that facilitate the production of electricity from existing assets.[14]

A rudimentary form of such a hybrid market can be seen in states like New York or utilities like Public Service of Colorado that issue competitive procurements for wind and solar power, as well as for complementary resources such as storage.[15] These acquisitions seek to meet clean energy and greenhouse gas emissions reduction goals using resources that are dispatched and operated competitively in the near-term energy markets.

Businesses and some large consumers are following a similar pattern by using long-term contracts to drive major investments in wind and solar power. These investments are motivated largely by the need to meet voluntary targets for renewable purchasing, often without regard to the broader need to support the integration of those variable resources into the electric grid. Professor Joskow has argued that an effective, efficient hybrid market should replace today's somewhat *ad hoc* approach to the selection of clean energy resource types with a rationally derived "indicative plan" designed to work in conjunction with short-term markets. Such a hybrid market would then guide vigorous competition **for** the market and for the long-term contracts

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11 See for example, Peter Cramton, "Electricity Market Design," *Oxford Review of Economic Policy,* Volume 33, Issue 4, Winter 2017, https://academic.oup.com/oxrep/article/33/4/589/4587939.

12 Roy Devjani, "William Hogan on Electricity Markets, Solutions for Climate Change and Carbon Tax Policy," *GrowthPolicy.org,* December 2019, https://www.hks.harvard.edu/centers/mrcbg/programs/growthpolicy/william-hogan-electricity-markets-solutions-climate-change-and.

13 Peter Cramton, "Electricity Market Design," *Oxford Review of Economic Policy,* Volume 33, Issue 4, Winter 2017: 589–612, https://doi.org/10.1093/oxrep/grx041.

14 See also: Paul Joskow, "Challenges for wholesale electricity markets with intermittent renewable generation at scale: the US experience," *Oxford Review of Economic Policy,* Volume 35, Number 2, 2019: 291–331.

15 For a description of competitive procurements, see Kathryne Cleary and Heidi Bishop Ratz, "Experience with Competitive Procurements and Centralized Resource Planning to Advance Clean Energy," *Resources for the Future,* Working Paper 21-01, (January 2021) https://media.rff.org/documents/RFF_WP_21-01.pdf; and Fredrich Kahrl, "All Source Competitive Solicitations: State and Electric Utility Practices," *Lawrence Berkeley Lab,* Grid Modernization Laboratory Consortium (March 2021), https://emp.lbl.gov/publications/all-source-competitive-solicitations.

that would help ensure financing for these projects.[16]

This school of thought embraces the economic ideal and suggests that prices arising from energy-only markets that reflect underlying carbon pricing at the social cost of carbon may be sufficient to ensure efficient investment. This outcome depends on the cyclical appearance of reserve shortages and associated scarcity pricing in energy markets. To be effective, these prices would need to be high enough and occur frequently enough to provide adequate returns on investment in existing and new plants over time. At the same time, Joskow has also noted that with variable renewable energy (VRE) sources with near-zero marginal cost making up larger portions of the generation mix and the growing uncertainty over the frequency and timing of their availability, relying on scarcity prices will create greater and increasingly harder-to-manage risks for investors and could limit their access to low-cost debt financing. Given this scenario, hybrid markets could offer more stable revenues under long-term contracts and better support the volume and mix of clean energy investment required to meet aggressive decarbonization goals.

Professor Richard Schmalensee makes a similar point about the risks and impacts of price volatility on future energy markets.[17] MIT modeling results for high VRE scenarios forecast extraordinarily high energy prices (over $1000/MWh up to nearly $50,000/MWh) in just a handful of hours and very low (or zero) prices for the remaining hours, depending on the scenario. He has pointed out that market regulators are unlikely to allow the extremely high scarcity prices required by energy-only markets to guide investment and ration demand. For example, during the recent Texas power crisis, caused by scarcity conditions associated with extreme cold weather, unprecedented levels of demand and failures in various parts of the electricity supply system quickly drove prices up to the $9000/MWh offer cap, resulting in unanticipated high monthly bills of several thousand dollars for many customers and some company bankruptcies.[18] Bloomberg estimates that ERCOT overcharged its customers by $16 billion due to the high offer cap.[19]

In a world where the highly variable prices associated predominantly with the energy-only markets solution are likely to be unacceptable to market regulators, there is a need for a more predictable supplement to energy-only market revenues. Traditional capacity markets focus on ensuring sufficient supply during hours of peak demand, but this approach, in conjunction with a climate policy that either directly limits emissions or rewards clean energy generation, would not generate the investment needed to decarbonize the grid and ensure reliability, given the low correlation of wind and solar availability with peak load.

The real world thus requires a market design that would address both short- and long-run efficiency. In the short run, such a design should allow retail rates to vary with real-time wholesale energy prices to improve the efficiency of the grid overall. Time-varying retail electricity prices are particularly important as a mechanism to encourage electrification of other energy end uses and therefore to encourage decarbonization beyond the electricity sector. For example, time-varying prices would encourage efficient charging of variable electric loads during periods of low prices and abundant renewable supply.

Four Designs for Organized Long-Term Markets

As described earlier, at the WRI/RFF workshop, four experts offered conceptual designs for an organized long-term market (OLTM) aimed at guiding investment in zero- and low-carbon resources. Other experts have offered various ideas for an OLTM or other policy mech-

16 Paul Joskow, "Hybrid Electricity Markets to Support Deep Decarbonization Goals," December 16, 2020, https://files.wri.org/s3fs-public/joskow_rff_presentation-12-16.pdf?cheKLe66OWrgB1cPtOZxCjxYXVEmzUoK.

17 See also: Paul Joskow and Richard Schmalensee, "Electricity Markets," [podcast] *MIT Energy Initiative,* Episode #14 (2020), http://energy.mit.edu/podcast/electricity-markets/.

18 See: Shannon Najmabadi, "Texans blindsided by massive electric bills await details of Gov. Greg Abbot's promised relief," *The Texas Tribune,* February 22, 2021, https://www.texastribune.org/2021/02/22/texas-pauses-electric-bills/.

19 "Texas Watchdog Says Grid Operator Made $16 Billion Error," *Bloomberg News,* March 4, 2021, https://www.bloomberg.com/news/articles/2021-03-04/texas-watchdog-says-power-grid-operator-made-16-billion-error?sref=Os5mORbE.

Table 1: Key Features of OLTM Designs

Author	Goals	Product
Pierpont	Promote readily financed clean energy investments	MWh – forward energy schedules (hourly) Swap contracts: as-bid hourly schedule prices for energy prices
Gimon	Promote readily financed, efficient clean energy portfolios with liquid, tradable long-term contracts	MWh – Swap contracts: forward energy schedules for energy prices
Tierney	Resource Adequacy Climate/energy goals Least-cost system	Capacity (MW) + must-offer available energy Adds new "RA" products: "Local RA" and "Flexible RA"
Corneli	System balance (match load & generation in all hours, even under extreme conditions) Decarbonization constraint Least-cost system optimization	"Capability" + must-offer available energy Swap contracts: as-bid project costs for energy revenues

Source: Author's construct

anism with similar aims.[20] This section summarizes some of the common elements of the four designs.[21]

Each OLTM would operate in parallel with the existing short-run energy markets. These short-run markets should also further evolve to better integrate storage and demand response options. The authors are generally flexible on who should operate the OLTM—it could be the existing RTO/ISO or a multistate collaborative of some sort. The OLTM designs would allow load-serving entities (LSEs) to self-supply, either partially or fully, and would operate in a manner that resulted in gradual, incremental changes in the generation mix. Finally, the OLTMs would accommodate federal and state climate and clean energy goals and associated policies to achieve those goals.

Table 1 depicts how the four OLTM designs compare with respect to two important features: the design's goal and the products offered. The designs suggested by Pierpont and Gimon, have a relatively narrow set of goals focused on promoting investment and increasing liquid, tradeable, long-term contracts. Tierney and Corneli suggest designs with a broader set of goals that include resource adequacy, reliability, specific climate/energy goals, and least-cost systems.

Brendan Pierpont

The Pierpont OLTM has three components:

- Long-term, fixed price contracts for energy based on a specified production profile, structured to preserve short-term market signals and incentives for efficient operations.
- A market clearing mechanism that selects those resources that have the highest value to the electricity system or to buyers in the long-term market relative to contract costs.

20 For examples, see: Frank Wolak, "Market Design in a Zero Marginal Cost Intermittent Renewable Future," *Stanford University,* October 15 2020, https://web.stanford.edu/group/fwolak/cgi-bin/sites/default/files/wolak_ieee_v6.pdf; Arne Olson et al., "Scalable Markets for the Energy Transition: A Blueprint for Wholesale Electricity Market Reform," *Energy and Environmental Economics, Inc., May 2021,* https://www.ethree.com/wp-content/uploads/2021/05/E3-Scalable-Clean-Energy-Market-Design-2021.05.25.pdf*; Kathleen Spees and Sam Newell, "Forward Clean Energy Markets: A new solution to state-RTO conflicts," Utility Dive, January 27, 2020,* www.utilitydive.com/news/forward-clean-energy-markets-a-new-solution-to-state-rto-conflicts/571151/.

21 The workshop webpage provides the four papers and a matrix that summarizes key features across the four market designs, along with plenary presentations and videos (https://www.wri.org/events/2020/12/market-design-clean-energy-transition-advancing-long-term).

- Allocation of contract costs and benefits to buyers by pooling contracts together and selling them as a bundle, diversifying the counterparty and credit risk for any one buyer or seller.

There are two potential mechanisms for selecting winning bids and clearing the OLTM:

- In the first, LSEs submit the quantities of MWh they seek to purchase, and total demand is aggregated. Bids are evaluated against an agreed-upon forward price projection with hourly price profiles. Bids are ranked from highest to lowest net value (forecast price per MWH minus fixed-price bid per MWH, levelized over contract years of project). Winning bids are pooled, and payments allocated proportionately to LSEs.

- In the second mechanism, LSEs submit an hourly willingness to pay and quantity profile. An optimization routine selects those bids that have the highest value to LSEs, given each bidding resource's hourly production profile and fixed price.

Under these contracts, the seller would be paid a fixed as-bid price for all contracted forward energy production. The seller would then pay the buyer the real-time energy price as determined by the short-term security constrained economic dispatch (SCED) market for the contract's contracted production profile. For this reason, the long-term contract can be viewed as a financial swap (or contract for differences) applied to a specific hourly and seasonal production profile.

Eric Gimon

Eric Gimon proposes an OLTM that assembles a portfolio of easily re-traded, long-term energy contracts that can adapt over time. The Gimon OLTM:

- Solicits bids from sellers with heterogenous technology characteristics and production profiles.

- Assembles selected bids in portfolios optimized around buyer criteria (least-cost, production shape, emissions).

- Creates standardized long-term energy contracts that buyers can buy and trade.

The OLTM selects winning bids using a highly granular capacity expansion/production-cost model (for example, WIS:DOM)[22] and optimizes for least-cost for the collective demand. Winning bidders are offered contracts at as-bid prices for scheduled delivery of energy contingent on the portfolio selling in the long-term energy contract market. Voluntary buyers then subscribe to shares of the energy deliveries promised by winning bidders in portfolios sold on the market. Fully subscribed project contracts are finalized, and when the project begins commercial operations, buyers pay as-bid prices as a financial derivative (e.g., a swap) of DA/RT prices.

These contracts would be tradeable to allow providers of storage and flexible load to adapt and take on changing market positions. Such a process would match actual production and consumption to scheduled deliveries efficiently.

Sue Tierney

The Tierney OLTM concept builds on the existing designs of RTO capacity markets. Current market designs define Resource Adequacy (RA) in terms of meeting a system peak load. Tierney's OLTM would define and procure three elements of RA:

- System RA – reflecting the amounts of capability necessary to meet peak load (with varying capacity value by technology type) and state emission targets, support for emerging technologies, etc.

- Flexible RA – reflecting the amounts of capability needed to provide ramping and other flexibility/balancing services.

- Local RA – reflecting amounts of capabilities needed for reliability in load pockets.

The RTO would conduct long-term resource planning to identify state and LSE requirements, transmission needs (including non-wires alternatives), and expected distributed resources. The plan would determine the amounts and types of capacities the RTO would procure and the cost to be allocated to LSEs.

22 See: Vibrant Clean Energy [products] www.vibrantcleanenergy.com/products/.

The RTO would conduct annual procurements for the three types of RA capabilities, soliciting bids sequentially for local, flexible, and system RA. Bidders would make $/MW offers for long-term contracts based on their expected future revenues in the energy and ancillary services markets. Start dates would be flexible (up to 9 years ahead) to allow for varying lead times. A sophisticated system planning model would evaluate combinations of bids. The RTO would select winners based on a best-fit/cost-minimized portfolio. LSEs would have the option of using bilateral contracts for some or all of their system RA obligations.

Steve Corneli

The Corneli OLTM would identify and procure new tranches of clean energy resources on a regular basis to incent the deep decarbonization of the power sector while ensuring continued electric system reliability at the lowest possible cost. The OLTM would evaluate bids from a wide variety of clean energy projects and would identify and select combinations of projects that minimize the cost of meeting both the power grid's balancing requirement and a science-based declining carbon budget.

Bid evaluation would be provided by new types of power system capacity expansion models. These new models, called precise renewable inputs system expansion models (PRISM), would use wind and solar irradiance data with very small spatial and temporal granularity. These inputs would allow the OLTM to produce an efficient configuration of resource types and quantities.

This "configuration market" would operate every three years. In each pricing round, the market would procure an incremental tranche of new clean energy projects that when aggregated with existing resources would ensure that both the electric system's balancing requirement and the declining carbon budget are met at the lowest cost under a wide variety of possible weather and demand conditions.

The OLTM would offer each winning project a long-term hedging contract structured as a swap with load. The contract would ensure that the project receives a performance adjusted stream of fixed revenue based on its as-bid levelized cost and load, as well as a revenue stream from the project's spot market revenues.

Net payments to resources would be settled against load similar to the way that capacity and transmission costs are settled in today's RTO markets.[23]

Conclusion

The decarbonization imperative creates new demands on power markets. Commenters have expressed a concern that current market designs are inadequate to meet those demands. As a consequence, increased attention has been focused on new designs for long-term markets. There is no consensus today on the need for organized long-term markets, but rigorous analysis, modeling, and debate are needed to determine when and whether such market designs will be required. Policy groups, system operators, and various consortia devoted to helping shape the future of the power sector will continue to review these market design issues in concert with state and federal policy makers and other stakeholders to evaluate the inherent tradeoffs in various design choices and to identify the most efficient options for the future.

23 These revenues are typically allocated on the basis of peak load by customer class.

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