LET'S GET ORGANIZED! LONG-TERM MARKET DESIGN FOR A HIGH PENETRATION GRID

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SUMMARY

This paper describes how to support continued rapid investment in new clean energy resources and retirement of dirty energy resources even as the raw output from variable energy resources gets more and more out of sync with customer demand profiles. It lays out principles for an "electricity markets cascade" that efficiently recruits capital for electric sector investment to deliver on investor expectations of risk and return while meeting customer and policymaker expectations for a least-cost, clean, and reliable grid. It also proposes a new feature, Organized Long-Term Markets, as part of the standard design for restructured wholesale electricity markets.[i,ii]

[ii] The author thanks Mark Ahlstrom, Elise Caplan, Eric Ela, Cliff Hamal, Andy Kleit, Jacob Mays, Richard O'Neil, Cynthia Wilson, and an anonymous reviewer for their many helpful comments and suggestions on an earlier version of this paper. Thanks also to Michael O'Boyle, Silvio Marcacci, and Sarah Spengeman for crucial editing help. Any errors in substance or presentation in this version are entirely the author's responsibility.

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INTRODUCTION

The world is in the midst of a climate crisis. Avoiding the most dangerous climate future requires a concerted society-wide effort, with many small but necessary contributions from all of us. This paper endeavors to contribute to climate mitigation by conceptualizing the desired end state for a clean economy and developing tools to help bring about and sustain this clean energy transition. In particular, it proposes a new concept, the Organized Long-Term Market (OLTM), which empowers organized markets to recruit and optimize clean energy resource portfolios and combines them into easily traded and understood long-term energy delivery contracts. This instrument will help create more efficient and functional electricity markets to better support rapid, economical, and reliable electricity sector decarbonization.

A clear narrative connects the dots between the OLTM concept and the overall goal of climate mitigation. Energy is one of the primary sources of anthropogenic emissions driving climate change, accounting for 72 percent of global emissions.[3] Broad consensus exists that a successful mitigation strategy for the energy sector proceeds as follows: clean up the electricity sector, electrify as many energy end uses as possible, develop a clean secondary energy storage and transport medium (e.g., green hydrogen) for the remaining energy applications, and capture and store or reuse any residual emissions. The OLTM belongs to the first part of this mitigation strategy, although it also connects to the others.

Diverse opinions exist about how to clean up the electricity sector, but given rapidly diminishing solar and wind generation costs, along with fast-falling battery energy storage costs in recent years, these variable renewable energy (VRE) resources typically play a starring role. Each U.S. state will respond to the climate crisis differently, alongside new support from the federal government through the Inflation Reduction Act. A growing handful of U.S. states have already required their utilities to reach 100 percent clean electricity by midcentury, and many utilities are voluntarily adopting these goals. The context for this paper is reaching for and achieving a system mix with a large fraction of energy generation (more than 70 percent) from VREs, although many of the ideas presented here may apply more broadly. Within this context, even at 90 percent or 100 percent clean, the questions are similar enough. This paper does not advocate for a particular immediate clean energy target, but rather explores some of the implications of a grid with a large fraction of energy from VREs.

Broadly speaking, cleaning up the electricity sector in a timely manner faces three principal barriers:

- Creating the broad local, regional, and inter-regional platform (transmission and other infrastructure assets) capable of sustaining the rapid power grid transformation

[3] For the latest data, see the World Resources Institute's Climate Analysis Indicators Tool, https://www.climatewatchdata.org/?source=cait.

- Creating a techno-economic system satisfying policy demands to rapidly recruit and deploy a least-cost and reliable clean (or cleaner) portfolio of resources (generation, storage, and demand-side)
- Creating a set of technical standards to maintain grid stability, security, and resilience—especially with the rise of inverter-based and decentralized generation resources

These three problems are related, but each is separate enough to be discussed independently. OLTMs mostly factor into the middle problem, specifically in regions with restructured wholesale power markets (currently about two-thirds of U.S. electricity consumption).

Advocates working to clean up the restructured wholesale power market generation mix by adding large amounts of wind and solar immediately face two big challenges: How can these resources be built out fast enough to address the climate challenge, and will this accelerated build-out be able to continuously balance supply and demand? Decades of practical experience and modeling efforts[4] have shown that high fractions (at least 70 percent) of VREs are perfectly manageable from a technical balancing point of view, with the right arsenal of complementary resources like inter-regional transmission, dispatchable low- or zero-carbon resources, energy storage, and dynamic price-responsive demand.

The studies, however, provide few policy solutions for how to build a greater share of clean energy resources faster. Moreover, many policymakers have unresolved questions about how wholesale markets, built around short-term marginal cost pricing, will work when a large fraction of the electricity is generated at zero-marginal cost.

"Working" from a technical balancing point of view is not enough for a fully functioning economic market to sustain clean energy growth. We also need to know how these resources, and others, recover their capital expenditures with a sustainable profit if prices are always zero. Another way of asking this is: How can we expect rapid investment in new clean energy resources and continued retirement of dirty energy resources if prices paid to these new resources keep decreasing, even with the most supportive policy? The answers to these questions have a lot to do with market design and the role of complementary resources in price formation.

This paper aims to develop an important part of the economics answer to the questions above so as to provide policymakers with confidence that today's restructured market constructs can be improved to deliver on their clean energy goals. It examines a key missing element in today's instances of restructured wholesale markets: An electricity markets cascade that efficiently recruits capital for electric sector investment to meet investor expectations of risk and return, while also meeting customer and policymaker expectations for a least-cost, clean, and reliable grid. Rather

[4] See, for example, Amol Phadke et al., "2035 The Report: Plummeting Solar, Wind, and Battery Costs Can Accelerate Our Clean Electricity Future," (Goldman School of Public Policy, 2020), https://www.2035report.com/.

than tweaking dysfunctional capacity markets[1] and hybrid monopoly-competitive markets, this paper proposes policymakers focus instead on creating OLTMs as part of the standard design for restructured wholesale electricity markets.

The metrics for evaluating market design take many forms. Proper energy market design goals include public policy objectives like: minimizing the cost and risks of investing in the electric grid, facilitating a higher-performance portfolio of resources and platform investments, addressing policymaker concerns about resource adequacy, minimizing the potential for market manipulation, and providing a productive avenue for implementing public policy in resource procurement. Given rapid technological change in the field and the varied public policy and geographic context for each market, it is helpful to approach the market design challenge with a principles-based approach. Principles provide a North Star to guide policy development without rigidly precluding practical implementation.

The next section offers three principles for addressing long-term procurement and resource adequacy challenges. We look at how current restructured market designs, loosely designated as energy-only, monopoly-competitive hybrids, and energy-plus capacity market, fail to honor these principles and we touch on some of the consequences of these deficiencies. Next, we sketch out the broad outlines of OLTM design. In the last section, we identify practical uses for OLTM today and explain how OLTMs can help resolve current policy challenges for policymakers while providing a foundation for rapid power sector decarbonization.

PRINCIPLES FOR LONG-TERM PROCUREMENT AND RESOURCE ADEQUACY IN ELECTRICITY MARKETS

Real-time market prices provide the foundation for existing electricity market design. The clean energy transition's challenge is designing markets capable of fostering and maintaining investment in capital-intensive heavy equipment and infrastructure with low to zero short-term marginal cost. Spurring such investment requires connecting the dots between a five-minute market and capital investment in a storage project, wind farm, or electric vehicle charger built to last for multiple decades. A sequence of markets connects the multi-year revenue streams required to justify large capital investment in renewables with the real-time market through intermediary yearly, seasonal, monthly, and daily timescales, all the way down to the foundational real-time market.

This "energy markets cascade" reflects the interconnectedness of these markets and the way transactions and settlement flow from long term to short term.

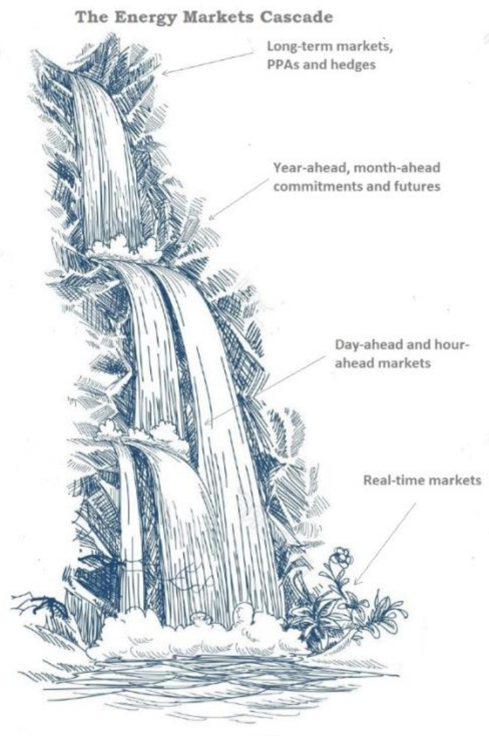
Three principles make up a healthy energy markets cascade. Current practices fail to realize all three, creating the need for OLTMs.

Three Principles for an Energy Markets Cascade

The following three design principles should shape the structure of the energy markets cascade:

Principle one: The cascade should trade in only one underlying commodity, the delivered megawatt-hours of electricity, so all markets except the real-time market should be derivative markets.

Like the pictured cascade featuring a single material—water—flowing from pool to pool, the markets in our cascade best align if they trade in the same underlying commodity. Participants in any given market will face changing conditions and forecast errors, but if the underlying commodity is the same across markets, then the next market down can account for the new situation through trade and adjustment of any given commitment. For example, a wind developer may have a long-term contract in place to secure financing, but as they approach delivery of their electricity output, they will often anticipate an excess or shortfall from what was promised in the real-time market. They can use a market with the most appropriate time frame (monthly futures if they expect a deviation a month ahead, day-ahead if they get a clearer picture in the preceding day, and so on) to cover their positions and minimize differences between their financial commitments and physical delivery as they move toward real time, always keeping risk at acceptable levels. Another market participant might be a load-serving entity (LSE) faced with losing or gaining customer load in ways they did not anticipate. LSEs can use the markets to sell off or take on new obligations for the underlying product they sell, megawatt-hours (MWh).



Principle two: Participation in the derivative longer-duration markets should be voluntary.

If participation in a longer-duration market is compulsory, then its price formation mechanism decouples from the real-time market. Participants can no longer act on just their volume and price expectations. Instead, a central authority enforcing the mandate must provide targets, thereby obscuring market information available from price discovery. Voluntary markets, on the other hand, can balance a diversity of future outlooks. For example, if an electricity customer sees current long-term prices as too high compared to what they expect in a time frame closer to delivery, they might not commit to buy what they need until closer to that delivery window. This will lower prices upstream and raise them downstream, bringing prices across markets back into alignment. Conversely, if current price forwards look cheaper relative to forecasts, more demand will materialize and raise prices. These factors produce an equilibrium that reflects market sentiment—valuable pricing information.

One exception to this rule is a partial mandate, for example a mandate (or credit-requirement-linked incentive) that, at time of delivery, hedges some fraction of each LSE's consumption years, months, or days ahead for the sake of prudence. These entities would still have some choice to adjust extent of participation in each market in the cascade. Since price formation happens mostly on the margin, market prices in the cascade would still be usefully connected.

Principle three: Markets in the cascade should be non-discriminatory, transparent, and liquid.

Equal, or "non-discriminatory access" is a loaded term. Presumably, all resources have equal access to the market under Federal Energy Regulatory Commission (FERC) jurisdiction, but this is often not the case in practice. However, non-discriminatory access is not just about fairness; it plays an important functional role in the market. Ideally, broad market access should lead to more diverse and independent participation in the market. More participation and greater competition facilitate liquidity because of more potential buyers and sellers. The law of large numbers also implies some reversion to the mean around forecast error. Instead of just a few large buyers or sellers that can skew the market by under- or over-procuring, these kinds of mistakes will average out in markets with many participants. Current markets are especially skewed to minimal active participation on the demand side. Improved access requires better participation models and rules minimizing barriers to entry for all resources whose interests align with participation at any point in the energy markets cascade.

Transparency and liquidity are aspirational aspects of principle three since they must always be balanced against implementation costs and competitive concerns. However, market arbiters can still set desired thresholds for transparency and liquidity. In economics, a market is transparent if much is known by many about what products and services or capital assets are available, market depth (quantity available), at what price, and where. Transparency is one of the commonly held theoretical conditions required for a free market to be efficient. In the context of energy markets cascades, transparency at a minimum includes a clearing price or most recent price and information about trading volumes, which also addresses liquidity. Transparency does not always need to include public visibility of individual bids, although some later disclosure might be desirable within the realm of commercial viability.

Liquidity along the whole energy markets cascade requires a standard set of products diverse enough to address different stakeholder needs yet limited in number so that sufficient trading volume exists to value products on common terms. Product standardization makes it easier to optain credit to buy and sell by, for example, making it easier to formulate credit default provisions—in general standardization reduces friction in markets. On the longer-term end of the cascade, liquidity for partial contracts is also important. Common secondary sales enable pricing of partial contracts for risk management purposes (e.g., credit assurance and liquidation terms), and make it easier to assemble and maintain portfolios with diverse vintages and settlement dates aligned to the needs of each market participant.

These three principles would not surprise any student of economics, and of commodity, equity, and bond markets in particular.[5] Non-discriminatory access, transparency, and liquidity are important not just for future VRE heavy markets, but in today's context as well. Current electricity markets fail to satisfy the energy markets cascade principles, with further decarbonization likely to aggravate the situation.

Current market designs fail to honor principles

Roughly speaking, three kinds of electricity markets operate today in the U.S.: energy-only markets, energy markets with mandatory capacity markets, and monopoly-competitive hybrids and state-regulated monopolies with captive consumers and owning generators. The sole energy-only market in the U.S. is the Electric Reliability Council of Texas (ERCOT), although many other examples of energy-only markets exist overseas. The energy-only market design includes day-ahead trading, liquid futures markets, hedging arrangements, and bilateral arrangements. It comes closest to satisfying the three principles and features of OLTMs.

Energy markets with mandatory capacity markets include PJM, New York Independent System Operator (NYISO), and ISO New England (ISO-NE). The details of the constructs differ, but generally all require participating LSEs to acquire access to future resources at a level centrally determined by the system operator through a forward capacity auction. These markets also prohibit distribution utilities and retail competitors from owning generation, with a few exceptions.

For many years these markets did a decent job satisfying our third principle: equal access, transparency, and liquidity. Both large and small LSEs, as well as other buyers, paid the same price to meet their future resource requirements, and generation participated on an equal footing. Today, these markets are open to accusations of bias toward legacy resources. Capacity market participation rules favor some resources over others, and struggle to be compatible with state public policy goals.

Furthermore, energy markets with mandatory capacity markets are weak on the other two design principles. Capacity is not a derivative product for energy, as it is not settled in the energy market. A capacity contract is an agreement to participate in the market, with no specified amount of

[5] Some argue that electricity is an exception compared to other commodities because of lack of storage and low substitutability, and because supply and demand must constantly be balanced to prevent system breakdown. These factors have become less applicable today; more and more, they are mitigated with the advent of complementary resources.

energy sales required. For this reason, existing capacity markets fail the first principle, having just one underlying commodity.[6] They also fail the second principle since they are mandatory and not voluntary.[7] The net effect disrupts the energy markets cascade because it drains revenue from energy markets in ways that interfere with price formation as a proxy for real-time value. In a changing technology and policy landscape, this makes mandatory capacity markets particularly ill adapted to equitably serving market stakeholder interests going forward.

Hybrid markets are real-time electricity markets with long-term procurement still firmly under the sway of vertically integrated utilities or state regulators. These include Midcontinent Independent System Operator (MISO), Southwest Power Pool (SPP), and California ISO (CAISO). In the first two, the energy markets cascade is effectively truncated, as all long-term energy provision is negotiated between the utilities and their regulators, with little room for merchant generators or other third-party market participants. There is effectively only one buyer for long-term energy contracts (monopsony), which in both markets may also own and operate generation. CAISO is a partially deregulated market, where the three main investor-owned utilities (IOUs) do not own most of their generation and are meant to mostly contract with third parties for their future energy needs (with some notable exceptions).

The rise of community-choice aggregators (CCAs), local entities that aggregate electricity contracts within a specific jurisdiction to procure electricity as a group rather than as individuals,[2] is challenging this design in a narrow way by introducing a limited form of retail competition. Still, the state's public utilities commission keeps a firm hand over the resource mix and requires purchase of resource adequacy forward commitments under rules and targets mandated by the commission.

Given that the upper part of the energy markets cascade is either non-existent or heavily regulated in hybrid markets, it should not come as a surprise that they fail on all three principles. States have good reasons to choose to keep their hybrid markets, even more so given state versus system operator tensions appearing in the Northeast and Mid-Atlantic regions. Keeping a tighter grip on long-term procurement allows states to optimize their generation fleet transition during a period of massive change and more readily manifest their policy preferences. But they may also face a price for this neither-fish-nor-fowl approach to energy markets.

The hybrid nature of MISO, SPP, and CAISO opens them up to certain pathologies. States in the first two are at the mercy of utility planning and procurement processes. Supposedly, these structures ensure their regulated utilities procure the most desirable resource mix and look at exiting costly legacy resources. However, utilities hold the upper hand on information about what the market can offer and confidently assert their primacy over what should go into their integrated resource

[6] ISO-NE's Forward Capacity Market comes closest to satisfying the "energy derivative" requirement because its penalty scheme is tied to energy sales during times of stress, with laggards compensating high performers—a kind of negative image of scarcity pricing—but this not an exact substitute for a true derivative.

[7] MISO has a voluntary market, but we classify it with hybrid markets.

plan (IRP). This often means ignoring potential savings from retirements that are inconvenient for the utility, inertia in looking at new technology solutions (e.g., batteries over peakers), and persistent bias against demand-side resource participation or competition from distributed energy resources. On top of that, utilities in SPP and MISO indulge in energy market self-dispatch, forcing their captive customers to buy more expensive power from their regulated assets instead of cheaper power available on the open market.[3]

CAISO is a special case all on its own: Like unhappy families in the opening lines of *Anna Karenina,*[8] it truncates the energy cascade in its own unique way. Long-term procurement has broken down as customers flow from the three big IOUs to CCAs and the state implements its ambitious clean energy goals. The utilities are understandably loath to enter new long-term contracts given uncertainty in how many customers they will need to serve. Bitter fights have occurred over exit fees that CCAs must pay,[9] which speaks to, among other things, market illiquidity for long-term obligations. Furthermore, resource adequacy requirements (system RA, local RA, flex RA), are becoming even more complicated and less consistent with the energy cascade principles outlined above. They are neither derivative products nor voluntary, and arguably do not generate market transparency or liquidity. Meanwhile, demand-side participation is not progressing and has been almost wholly excluded from the IRP process.[4] The CAISO market has a difficult path to reform: It must balance competing priorities and historical contingencies while navigating the largest state electricity regulatory apparatus in the U.S.

Why an energy-only market might not be enough

Given hybrid and capacity market issues, some observers understandably view energy-only markets like ERCOT as the basis for a market design that can best accommodate rapid decarbonization.[10] However, an improved market design that incorporates equal access, transparency, and liquidity is possible, and better suited to high clean energy penetrations.

Energy-only markets may work fine with a high penetration of zero-marginal-cost VRE resources, and another paper in this series will articulate why a combination of an energy markets cascade and the presence of complementary resources can lead to a perfectly reasonable distribution of

[8] The first sentence of Leo Tolstoy's novel *Anna Karenina* is: "Happy families are all alike; every unhappy family is unhappy in its own way."

[9] These center on the infamous Power Charge Indifference Adjustment. California Public Utilities Commission, "California Public Utilities Commission Fact Sheet: Power Charge Indifference Adjustment," January 2017, https://www.cpuc.ca.gov/uploadedfiles/cpuc_public_website/content/news_room/fact_sheets/english/pciafactsheet010917.pdf.

[10] This is exactly what was proposed by Rob Gramlich and Mike Hogan. Rob Gramlich and Michael Hogan, "Wholesale Electricity Market Design for Rapid Decarbonization: A Decentralized Markets Approach" (Energy Innovation: Policy and Technology LLC, June 2019), https://energyinnovation.org/wp-content/uploads/2019/06/Wholesale-Electricity-Market-Design-For-Rapid-Decarbonization-A-Decentralized-Markets-Approach.pdf.

prices, with no skyscraper price distribution curves or major periods of zero prices. But all markets can fail, and policymakers must ensure these failures do not impact reliability and the orderly transition to a cleaner grid. They can do this by choosing a design that minimizes the chance of failure and by taking active measures without unduly disrupting the energy markets cascade supporting long-term investment in variable renewables and their complementary resources.

For example, the simplest step in ERCOT's energy markets cascade is between the real-time market and the day-ahead market. While the day-ahead is a voluntary market, ERCOT also operates a Reliability Unit Commitment in parallel to ensure enough capacity is committed to serve forecast load, and that committed capacity will be available at the right locations. This small violation of our energy markets cascade principles raises questions. Policymakers with a long view share market operators' concern that sufficient resources will meet demand in real time. They may believe that resource adequacy assurances such as capacity markets are analogous to Reliability Unit Commitments—but slow start-up times are not analogous constraints to slow construction times. This type of thinking leads to trouble by mixing up operational and investment decisions—forcing the market operator into making centralized investment decisions in areas outside their expertise.

In fact, market participants can take many actions if energy markets cascade price signals hint of shortages ahead, and participants are much better suited to evaluate and take on these risks than central regulators or market administrators. Generators can adjust maintenance schedules to ensure they are available for more lucrative prices,[11] many new resources can be built faster than the five to seven years required to permit and build a combined cycle gas generator, and consumer outreach can yield savings from reduced consumption all along the cascade. The ISO also has options like Reliability-Must-Run contracts.

Still, it helps to have a clear picture of potential future resource shortages as early as possible. Unfortunately, beyond the futures markets run by Intercontinental Exchange, the long-term market in ERCOT is an opaque arrangement of bilateral arrangements, power purchase agreements (PPAs), and hedges with little liquidity or transparency to the broader market. ERCOT does publish regular analysis of future supply and demand, but this survey work can only do so much. In 2016 Panda Power famously sued ERCOT, alleging it had committed negligent misrepresentation, fraud, and breach of duty by sponsoring false and misleading market reports concerning future capacity needs that led Panda Power to invest nearly $2.2 billion in new electricity-generating facilities.[12] Waves of on-and-off coal plant retirements are among the factors that have created large swings in the planning reserve margin. As an energy-only market, ERCOT could do better achieving

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[11] Potomac Economics, "2019 State of the Market Report for the ERCOT Electricity Markets," May 2020, https://www.potomaceconomics.com/wp-content/uploads/2020/06/2019-State-of-the-Market-Report.pdf, 88 (Figure 44).

[12] *Panda Power Generation Infrastructure Fund, LLC D/B/A Panda Power Funds v. ERCOT*, No. CV-16-0401 (Tex. App. Feb. 23, 2022).

principle three: open access, transparency, and liquidity. If investors could get a sense of who else had intentions to invest, and loads could contract with portfolios of resources, ERCOT could expect more stability and higher reliability, with less temptation for policymakers to interfere with markets in the name of resource adequacy.[13]

The Texas Competitive Renewable Energy Zone (CREZ) effort, which built out transmission to areas with high wind potential, provides a clear example of the dividends that a thoughtful focus on long-term planning can have in a market-driven system.[5] Although this was purely a transmission, infrastructure, and platform investment, if ERCOT heads to high penetration of wind and solar it may be useful to repeat the exercise alongside some specific project proposals and portfolio optimization of the VRE fleet. It is possible to better coordinate long-term resource investment without a heavy regulatory hand by using market principles. This approach can take many forms, depending on the local context, but OLTM provides an overarching set of characteristics and design principles.

THE DESIGN AND IMPLEMENTATION OF AN ORGANIZED LONG-TERM MARKET

An OLTM is a structure for financing the steady delivery of energy in pre-determined timeframes over a long-term horizon (multiple years to decades). It is a derivative market in that the ultimate pricing of electricity is still determined in the spot market. An OLTM aims to standardize long-term energy delivery, but is otherwise quite flexible and evolutionary, and could be realized in many ways—this paper summarizes only some of the possible choices.

[13] For example, it is hard to see how the recent shifts in the loss-of-load probability distribution used to calculate the Operating Reserve Demand Curve adder have any more rationale than generators stating they need more money to invest in resource adequacy, despite the lucid testimony put forward by NRG and Calpine. See Maria Faconti, "Texas Public Utility Commission Contemplates Market Changes to Plan for the Future of Texas Reliability and Infrastructure," *Husch Blackwell Emerging Energy Insights (Blog)*, January 2019, https://www.emergingenergyinsights.com/2019/01/texas-public-utility-commission-contemplates-market-changes/

This section is organized along classic journalistic lines: who, what, when, where, and how. Two figures also illustrate the possible maturation path for OLTMs, and a table synthesizes some of the benefits of adding an OLTM. Many details will still be missing from this description, but the goal is to provoke dialogue and further research among policy influencers, especially as to *how* to implement an OLTM in practice. The next section provides examples to show how an OLTM could manage challenges in today's markets.

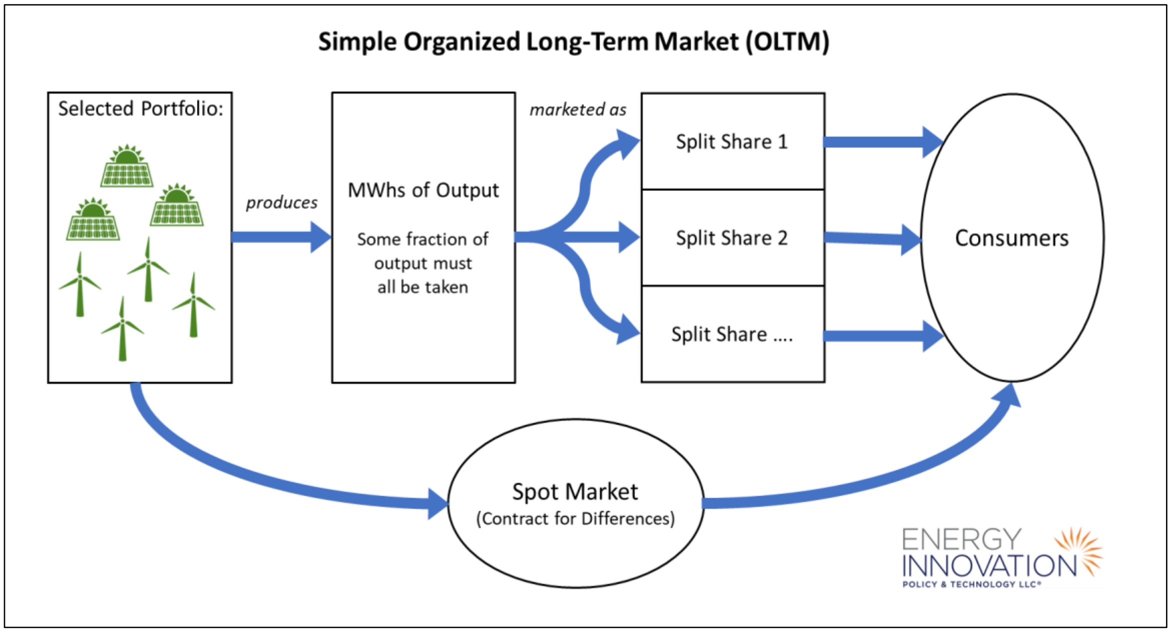

Figure 1. Simple OLTM, similar to syndicated PPA deals today.

Who: Participants in organized long-term markets

OLTM participants fall into three broad categories: producers, consumers, and facilitators. Producers generate electricity,[14] consumers use it, and facilitators help balance and shape supply and demand across time intervals and locations; these categories can overlap. Although they are not strictly speaking market participants (although they are not excluded), policymakers, market administrators, and regulators are also important stakeholders for OLTMs, as representatives of the public interest and protectors against market manipulation.

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[14] It is sometimes helpful to consider straight-up energy-efficiency programs as a source of supply and add to the producer side of the ledger as "nega-watts." Amory B. Lovins, "Negawatts: Twelve Transitions, Eight Improvements and One Distraction," *Energy Policy* 24, no. 4 (1996): 331–343.

As an OLTM is designed for a high-VRE penetration grid, utility-scale VREs figure prominently as **producers** in the future. VREs are the anchor "base-cost" producers[6] in a portfolio of resources that is then subdivided into discrete energy sales with the OLTM acting as aggregator, optimizer, and clearinghouse for long-term contracts. Distributed energy resources can also play a role, either as aggregated sources of energy (e.g., distributed solar or certain kinds of energy-efficiency upgrades) or as facilitators (e.g., distributed storage or load management). Similarly, more firm supplies of clean energy like geothermal, hydropower, and nuclear, as well as traditional fossil power, could also participate as producers (providers of raw MWhs) and facilitators (shaping their output). If a clean source of energy is required—or if an emissions standard is applied—some form of well-audited carbon mitigation (e.g., on-site capture or air capture of greenhouse gases with sequestration or use) will need to be included in the portfolio and an accounting of emissions will be attached to output shares.

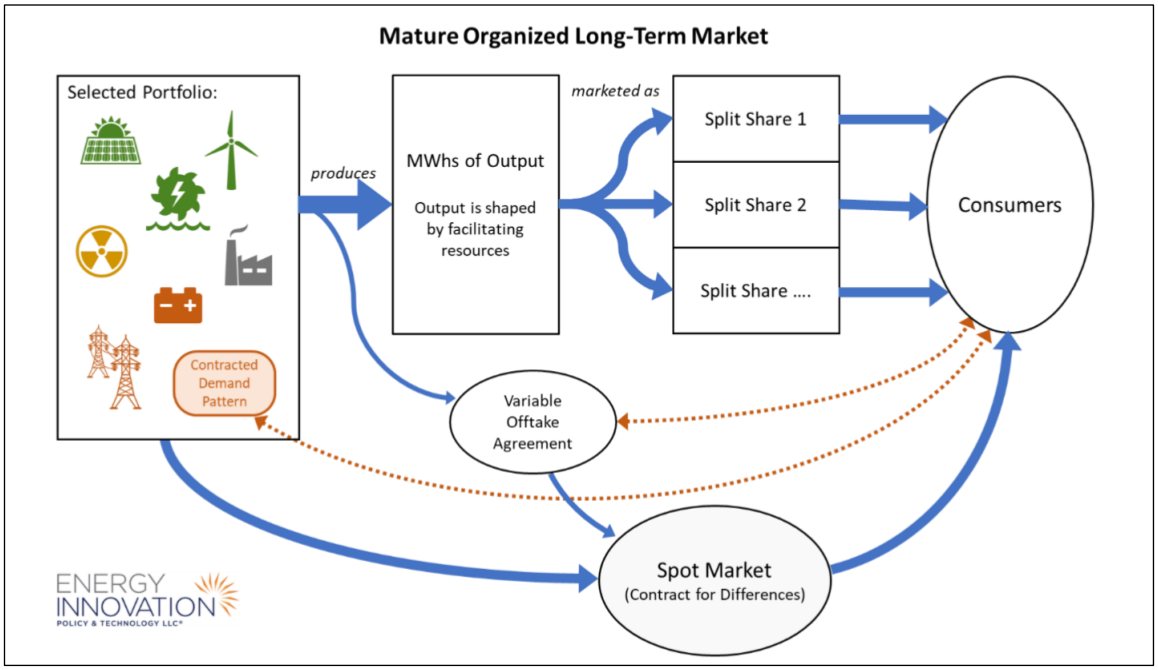

Figure 2. Mature instance of an OLTM with facilitators included.

Consumers include any LSE or electric power reseller. In the sense used by hedge arrangements, OLTMs can produce strictly financial hedges or contracts for physical delivery. These are essentially the same but differ in the contractual arrangements. This satisfies the first principle: Any market in the cascade must be derivative of the real-time market. Consumers do not get electricity from a specific source, but rather power at a settlement hub, and are buying a form of insurance or hedge to manage their exposure to buying power in the spot markets. One choice that needs to be made in structuring the types of products an OLTM sells to consumers is between fixed or floating volume. With a high fraction of VREs in the production mix, some output variability is predictable. Consumers may well purchase energy at fixed quantities in regular intervals at a given price (real or nominal) or at some fixed percentage-share of the output level. If fixed quantities are the main traded product, some consumers might participate in the market as buffers (see "Variable Offtake Agreement" in Figure 2), buying the variable residual output of the portfolio at a discounted price and taking a facilitator function.[15]

To create an aggregate demand curve for the optimizer, consumers indicate how much they are interested in buying, at what price, and under what constraints. They choose whether to buy or not once the optimizer sets a price. Of course, once they buy a fraction contract they are on the hook for the duration of the contract unless they participate in a secondary sale. Ideally, the portfolio optimizer can create a range of prices adjusting for the number of final buyers, and even create a supply curve. The process can allow for some iteration on final price and quantity, but unlike in the downstream markets, it is not crucial for a transaction to happen in each OLTM run. Although large gaps in contract vintages are undesirable, room usually exists to try again in the next quarter, year, or other interval.

Consumers or producers may also be virtual bidders[7] who play an important role in price convergence by arbitraging differences in the day-ahead and real-time prices.[8] In the OLTM, virtual demand might come from a trader who anticipates an increasing value of the energy produced by the portfolio with time, or wants the option to buy power at later date. Since we anticipate and desire that the underlying energy delivery obligation potentially be bought and sold multiple times, it seems reasonable to allow this (with possible caps). A power glut and reduced prices in markets further down the cascade is the biggest risk, but this situation should correct itself in time. From a policymaker's point of view, virtual supply where a market actor offers to sell long-term contracts without an actual portfolio in hand to deliver, perhaps anticipating future surplus, seems more problematic if it does not lead to the commitment of capital in time for physical delivery.[16] In any case, virtual demand or virtual supply will have to be subject to strong collateral or credit assurance standards in case of default to avoid the equivalent of PJM's GreenHat fiasco.[9]

Facilitators help balance and shape supply and demand along with hedging financial risks of consumers and producers. Facilitators are an important, although not strictly necessary (especially initially), OLTM participant. Examples of facilitators in markets today include utility-scale or distributed storage, transmission assets, flexible demand, virtual bidders, fast flexible generation, and wholesale electricity traders. They can play a physical role in the portfolios being assembled

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[15] This is reminiscent of the two-sided market discussed in Malcolm Keay, "Electricity Markets Are Broken–Can They Be Fixed?" 2016, but strictly at the wholesale level and within the OLTM.
[16] Hedges in today's market are contingent on an underlying physical unit capable of delivery of electricity and creating the underlying financial flows. In a healthy energy markets cascade, though, the hope is that the only effect of virtual supply would be to raise prices further down the cascade, providing an incentive for more investment in supply.

by enabling greater efficiency, access, and diversity in producers (e.g., transmission, energy storage as "virtual transmission"[10] and other contracted flexibility resources). Facilitators can also play an important role smoothing production or hedging physical delivery risk by filling in deficits or absorbing excess in the electricity production of the main producers of the portfolio (e.g., hydro reservoirs, flexible demand, battery storage, hybrid VREs, variable delivery contracts). Producer portfolios can also financially shape the end product sold to consumers through an insurance provider, which takes on some of the risks: basis risks, volume risk, production risk, weather risk, and so on.

The level to which grid resource adequacy is managed by scarcity pricing[17] is a key determinant of the role of financial facilitators, as they can only hedge financial risk. Energy flow adjustments will have to come from outside physical resources trading in the spot markets—market participants and policymakers need to feel confident this can happen. On the other hand, finance can also play an important internal role for portfolios participating in the market by helping manage counter-party risk (much like in a futures market). Finally, facilitators can also play an important external role in an OLTM: Rating agencies rate the basic product performance, and traders create liquidity by buying and reselling full or partially fulfilled contracts, much like in any other market.

Market administrators have many possibilities to facilitate aggregation, optimization, and exchange. This role could be a natural evolution of private clearinghouses, businesses, or current trade organizations such as the Australian Futures Exchange, European Energy Exchange, LevelTen Energy, or WSPP Inc. The market administrator (also referred to as the optimizer) would likely be a purpose-built organization separate from the ISO. Another possible further split would be between the entities soliciting, optimizing, and packaging portfolios, and the entity marketing and trading shares in the output of these portfolios. In any case, ISO coordination would be desirable, especially to improve transparency.

Regulators also have a role representing the public interest in market design and oversight. Because the OLTM is essentially a futures or swaps market, absent coordination with FERC it might be regulated by the Commodity Futures Trading Commission (CFTC). Many regulatory bodies are potentially involved in an OLTM design: state commissions and energy offices will have to have their say through regulatory proceedings, any inter-state trade will also implicate FERC, and the financial arrangements may require CFTC involvement. These regulators should have implementation of the three market design principles above as their guiding charge, which will help

[17] The other papers in this series will define the term "fiscalization" and explore the concept in more detail. The ideas are along the lines that Shmuel S. Oren outlined in 2005. Shmuel S. Oren, "Ensuring Generation Adequacy in Competitive Electricity Markets," *Electricity Deregulation: Choices and Challenges*, 2005, 388–414; Shmuel S. Oren, "Generation Adequacy via Call Options Obligations: Safe Passage to the Promised Land," *The Electricity Journal* 18, no. 9 (2005): 28–42.

ensure the grid meets appropriate standards for reliability, affordability, and pollution. The markets will also be audited and may have independent monitors.

What: Basic features of an organized long-term market

An OLTM extends the organized energy markets cascade to a much longer time horizon than exists today. It improves upon ad hoc long-term bilateral contracts by increasing liquidity and transparency and by facilitating effective risk sharing. One key feature is that it is a voluntary market without an administratively determined mandate to buy or sell energy, in line with the second principle. As such, it is still a derivative market and the fundamental foundation of pricing still happens through the spot markets, in line with the first principle. One measure of the health of an organized market is convergence between average spot market prices and average long-term prices.[18]

	Additional Benefits from an Organized Long Term Market
Commitment & Planning	*• Portfolio construction takes advantage of geographic diversity in VER deviations from forecast.* *• Integrate state environmental goals as constraints to portfolio construction.* *• The portfolio can include a balanced mix of resource types (different generation types, various facilitating resources, flexible contracts with demand, etc.).* *• Long-term contracts available for new capital-intensive resources and for loads with long-term outlook on their demand. Economies of scale in contracting and procurement.*
Risk Management	*• More predictable forecast of avaiable energy for system operators.* *• New hedging tool for market participants.* *• Liquidity allows vintage diversity and load serving entities to resell/buy contracts to adjust for their nearer-term forecasts. Incentivizes competition and reduces gaming.*
Alignment	*• VERs and slow ramping supply resources have a natural fit with an OLTM offering.* *• Buyers can procure the bulk of their energy needs ahead of time and can focus their attention on price risk from their marginal purchases, which they can more easily manage closer to real time.* *• Buyers with specific locational or other constraints can pay an objectively determined premium to incorporate these in their energy purchase.* *• Flexible resources have a choice of selling in OLTM to help shape long-term energy supply, or in spot markets to manage volatility and forecast errors — more possibilities for "value stacking."*

Table 1. Synthesis of benefits from OLTMs

An OLTM serves three important functions:

1. Contributions to unit commitment and planning
2. Customer and producer risk management
3. Alignment with buyer needs

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[18] Note that from private conversation with Brendan Pierpont, his concept of a long-term market, see Pierpont, Brendan, and David Nelson. "Markets for low carbon, low cost electricity systems." (2017), entails energy prices that are not necessarily strongly coupled with or conditioned by spot market prices—it is a market for physical delivery and no longer a derivative market, but a separate parallel market.

A well-functioning OLTM facilitates low-cost procurement of new resources, in line with resource adequacy and other public policy goals. The planning equivalent of unit commitment and unit-commitment timelines in sequential markets for OLTMs is project construction and construction timelines. While a day-ahead market may coordinate which units to commit for the following day based on bids and offers that clear, an OLTM looks through a set of offers for new (or existing) resources to put together a portfolio, and then segments that portfolio into a steady stream of deliveries for a variety of buyers. The equivalent of the security-constrained economic dispatch engine at the heart of the spot markets would be a combined capacity-expansion and production cost model like Vibrant Clean Energy's WIS:dom model. Like day-ahead markets, an OLTM trades in the same underlying unit of energy as the real-time market. Participants can re-dispatch, i.e., buy and sell in downstream markets to adjust their positions.[19]

Apart from time scale differences, two main qualitative differences exist between an OLTM and a day-ahead market. First, the OLTM trades in a schedule of deliveries[20] akin to what financiers call a swap contract rather than delivery on a fixed hour and day. Second, an OLTM is not a clearing market. Producers bid their long-term marginal costs and do not need the extra rents delivered by a clearing market to recover these. The price paid by buyers in an OLTM is fixed by the optimization process and is the same for all buyers of the basic commodity contract sold, though there are possible variations. Whether a single commodity or multiple commodities are sold depends on the design, participation, and maturity of the OLTM. These long-term contracts, in turn, would feed into and help satisfy planning constructs of LSEs and their regulators, which ensure the grid meets resource adequacy and policy goals.

OLTMs provide an important risk management tool that can be well integrated into existing risk management tools[11] because a natural set of counterparties help manage risk by both customers and producers. Suppliers of capital-intensive grid assets (e.g., wind or solar farms, transmission lines, or large storage projects) would like to find counterparties to buy their power over multiple years or decades to amortize their investment over the longest possible period and secure the cheapest possible financing. Meanwhile, electricity buyers want to be insulated from volatile prices. Thus, producers looking for certainty in pricing for their output that matches their interest and dividend obligations find a natural set of counterparties in buyers who want to avoid volatility in what they pay for electricity.

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[19] For an example of re-dispatch strategies for storage, see Madeleine McPherson, Brendan McBennett, Devon Sigler, and Paul Denholm, "Impacts of Storage Dispatch on Revenue in Electricity Markets," *Journal of Energy Storage* 31 (2020): 101573.

[20] For example, a contract might provide a schedule for MWh deliveries at a hub/zone on every weekday and weekend day for each season in a period from 2025 to 2040, with either a flat hourly profile, a shaped daily profile, or a variable profile.

The third important quality of an OLTM is alignment with buyer needs. The time characteristics of the portfolio sold through the OLTM should align with the market niche the OLTM is filling. Given technology trends toward least-cost variable renewables and policy shifts prioritizing rapid decarbonization of the grid, alignment between sellers and buyers of VREs favors a low-volatility tradeable obligation, defined over a long period of time, and many years in advance.

The complete picture of an OLTM's functional resource characteristics can only emerge after additional modeling or real-world experience, but we can outline the general shape of the energy contracts that are sold. First, a working high-penetration grid will likely involve the participation of many flexible, but energy-limited, complementary resources. From a technical point of view, if energy is reliably delivered in a consumption window of days to weeks, then other resources participating in the spot market, especially flexible energy-limited resources, will be able to redispatch the energy to match supply and demand on a more granular basis—much like in today's hydropower-dominated systems in Brazil, Canada, New Zealand, and Scandinavia.

Due to the long-term nature of OLTM offerings, energy contracts could vary based on customer appetite for specificity and the robustness of the flexible complementary resource's ecosystem. Products could be as amorphous as flat blocks of monthly energy, assuming customers manage their actual needs by complementing these contracts with transactions further down the markets cascade.[21] Alternatively, an OLTM could deliver energy within large blocks with specific daily, weekly, or seasonal shapes along the lines of Rens Philipsen et al.'s market design proposal[12] that creates schedules in day-ahead markets with smoother instantaneous supply and demand matching from interval to interval. This would pre-position the system, so it leans less on the real-time or intermediate markets for an overall efficiency gain. More efficient market design might also include intermediate markets to better coordinate reshaping energy delivery from the OLTM.[22]

On the supply side, an OLTM may start by packaging output from multiple VRE projects, creating PPAs based on diversified portfolios with less shape and basis risk than current PPAs.[23] The end product would be take-or-pay, and could be smoothed out by buying only certain lower-risk tranches of the portfolio production (just like debt arrangements have a seniority structure, some

[21] See, for example, Edward J. Anderson, Xinin Hu, and Donald Winchester, "Forward Contracts in Electricity Markets: The Australian Experience," *Energy Policy* 35, no. 5 (2007): 3089-3103.

[22] Longer market intervals are already relevant for hydropower-dominated systems, e.g., Peter Børre Eriksen, Claus Jørgensen, and Hans F. Ravn, "Hydro and Thermal Scheduling by the Decoupling Method," Electric Power Systems Research 38, no. 1 (1996): 43-49. Nord Pool has an active forward and futures markets with more than 60 percent of trades in the Nord Pool market based on these contracts; futures are settled daily and weekly and forwards in monthly, quarterly, and yearly time periods. Shahab Shariat Torghaban and Hamidreza Zareipour, "Medium-Term Electricity Market Price Forecasting: A Data-Driven Approach," in North American Power Symposium (IEEE, 2010): 1-7.

[23] For current trends on contractual structures and risk factors pertinent to various forward contracts and hedges, see Jay Bartlett, "Reducing Risk in Merchant Wind and Solar Projects Through Financial Hedges" (Resources for the Future Working Paper 19-06, 2019), https://media.rff.org/documents/WP_19-06_Bartlett.pdf.

buyers have first dibs on VRE project production ahead of less senior power purchasers). On the other hand, hybrid VRE-storage projects are increasing in today's market,[24] and are becoming more dispatchable (solar plus a six-hour battery can mimic the output of many combined cycled gas plants in many ISOs today).[13] Enabling technologies like battery storage and other flexible resources or various kinds of backup power can also be included in the portfolio to create a much more versatile package.[14]

Aligning supply and demand characteristics in long-term contracts entails packaging just enough flexibility in the OLTM to satisfy some criteria for the energy forward product and to avoid egregious deviations from forecasts, but no more. This leaves plenty of work for applied mathematicians and engineers to develop technically sound ways to achieve and characterize function separation in performance expectations, and more lawyers to formulate the appropriate contracts. It remains to be seen how sophisticated OLTMs will need to be in these matters, but current technology trends make the issues hard to avoid.

One last question about OLTM alignment concerns the number of portfolios it should build in each market iteration. One large portfolio divided up into energy contracts might make the most sense since it allows for the most optimization, but economies from scale and diversity might not grow much past a certain size. And given that existing syndicated deals today are in the 100 megawatt (MW) or less range, growing the portfolio as the OLTM matures might take a while. Policy or jurisdictional issues may also favor multiple portfolios, with some clustered in a specific sub-region of the OLTM. Finally, one large portfolio is more vulnerable to a single contracted element failing to materialize or running into long delays.

When: Timetables, commitments, tenor, and sequencing

Timeframe considerations are important to OLTM design. Apart from the timeframes involved in defining OLTM delivery units, more timeframes need to be considered moving toward practical implementation. For example, market frequency, timing, and duration are key design considerations.

Any OLTM will need a timetable for how frequently to run the market. Today most long-term investment commitments are done on an asynchronous basis, with timing determined idiosyncratically for each PPA as a function of counterparty needs. Moving to a fixed schedule for the OLTM portfolio assembly would allow potential portfolio suppliers to be compared at the same time. One-year intervals should be enough to regularly refresh price preferences, but quarterly

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[24] See, for example, Mark Ahlstrom, Andrew Gelston, Jeffrey Plew, and Lorenzo Kristov, "Hybrid Power Plants – Flexible Resources to Simplify Markets and Support Grid Operations" (ESIG, 2018), https://www.esig.energy/wp-content/uploads/2019/10/Hybrid-Power-Plants.pdf; Will Gorman et al., "Motivations and Options for Deploying Hybrid Generator-plus-Battery Projects within the Bulk Power System," The Electricity Journal 33, no. 5 (2020): 106739.

runs might also be feasible. This would likely depend on the size and number of the portfolios put together by the OLTM at each iteration of the market so the OLTM optimizer and portfolio construction tool would have adequate participants to select from. There might also be a need to synchronize with various banking processes for securing financing of projects. Ideally, consumers could take advantage of the OLTM's ability to divide up a portfolio into smaller contracts to purchase only a fraction of their need every year, creating vintage diversity in their own portfolio of long-term contracts.

Once a resource is selected for a portfolio and the corresponding issuance of energy obligations has been fully subscribed, it is committed—but when will obligations to deliver energy begin? Because new resources need time to get built, the portfolio will have a scheduled start date sometime after the initial portfolio construction and should expect a standard delay. Some resources may take longer to build than others, so the contracted output sold to energy buyers may come with a variable expected schedule. If this is not satisfactory (because the resulting contract doesn't result in a uniform product), the portfolio could contract with an existing supplier to fill in the gaps at the start date with a power purchase or tolling agreement (a contract for dispatchable demand could also work to fill in gaps here). Existing suppliers could also provide energy insurance to fill in later gaps in portfolio production or some combination of financial arrangements with forwards, futures, or spot market purchases. Penalty schedules[25] will have to be determined to ensure performance on construction and commissioning. Secondary market runs might also be necessary in the event of a major failure of some participants to live up to their contractual obligations.

Because the OLTM as a buyer is not a clearing market for a homogenous resource, but rather creates portfolios of heterogenous inputs, it is much more accommodating of differing timetables under which various resources operate. In contrast, today's forward capacity markets tend to be tuned, in terms of product definitions, to specific resources like gas generators.[15] The OLTM's flexible framework allows an existing supplier with a declining production profile to participate in a long-term portfolio. This is a useful way for policymakers and businesses to manage retirement[16] of uneconomic fossil resources incompatible with long-term public policy and customer desires.[17]

VRE developers and consumers may be natural counterparties, but the match is not perfect. Capital asset owners and some financiers tend to favor longer-duration contracts aligned with the lifetime of their assets, but this is in tension with the shorter return horizons and hedging durations consumers and other investors may favor. In the U.S., solar PPAs typically run for seven to 15 years, though of late they have been getting shorter, with longer "merchant tails"—trailing periods of

[25] In energy markets that are fully fiscalized, i.e., always have supply available at some cost, the provider may just have to cover its position in markets further down the cascade, as generators do with day-ahead markets. The provider will need to satisfy some credit requirements to ensure it can cover these. In less optimal markets, the OLTM administrator may impose stricter penalties so as to be less reliant on spot purchase to fill in.

time when a project's output is no longer contracted and assumes real-time market risk.[18] An OLTM could provide products with similar tenors to consumers. On the other hand, customers prefer instruments with shorter tenors. In a survey of risk management practices in the Australian National Energy Market,[19] the authors point out that electricity retailers are loath to purchase power further out than three years. The OLTM design will have to balance producer and consumer desires. While projects offering portfolios with tenures shorter than the life of their capital assets take on the risk of a merchant tail (which might push up their offer prices), they can still offer that tail in a later OLTM run.

There are at least three possible ways to bridge the risk-tenor gap between energy producers and buyers in an OLTM. First, secondary markets like existing futures exchanges could develop around energy contracts sold by the OLTM. Long-term energy contract shares could be resold as instruments with shorter tenor. Second, as the OLTM iterates, different vintages of energy contracts can exist with multiple maturity dates. Buyers interested in a shorter tenor could perhaps buy some of these existing older contracts. The possibility of a relatively uncomplicated resale of a long-term contract may be of particular interest to buyers who are facing a loss of customers to competition from other suppliers or distributed energy resources. For example, California IOUs might resell some of their contracts when they lose customers to CCAs. Finally, a mature OLTM could start offering its own shorter-tenor, long-term energy contract product. A key takeaway here is that part of the OLTM's usefulness as part of any stakeholder's risk management strategy will depend on having a standardized offering that can be easily evaluated, compared, repriced, and traded. This is how it satisfies the third principle: The need for liquidity should bias toward much slower evolutionary change in OLTM products.

A larger OLTM portfolio could also include regional or inter-regional transmission resources. If these transmission resources are financed as part of the portfolio, selected just because of their direct net benefit to the portfolio, this would avoid some contentious or complicated issues of cost allocation because all costs would be allocated to the portfolio (which would also collect related financial transmission rights in the spot market). Historically, transmission projects have taken much more time to get sited, licensed, or built than most generation assets and have tended to carry significant project risk. However, more mature projects could offer into an OLTM, and OLTMs might create better market targets when transmission projects are considered. From a policy point of view, there may still be a need to sponsor transmission and create renewable energy zones. Such renewable development zones could also engender their own dedicated OLTMs to make best use of the zone.

Where: Geographic footprint and resource locations

Since an OLTM is meant to be a derivative market on top of spot markets, it seems sensible to expect OLTMs to sell products within that footprint, but they do not need to cover an entire spot market territory. In the Western U.S., CAISO operates a real-time balancing market (the Energy

Imbalance Market) in a larger region than the footprint of its day-ahead market (which for now is restricted to California). Because Western states have plenary authority over the resource mix in their jurisdictions, and policy choices that might affect an OLTM change from state to state, an OLTM could be restricted to a specific state or group of states within a larger spot market. Finally, as we mentioned before, it might be useful to create an OLTM for specific transmission zones, multi-state utilities, or basins.

The most sensible arrangement for producers would be to contract for power at a specific locational marginal pricing (LMP) node. One role for the portfolios assembled by the OLTM is to take advantage of geographic diversity, pooling basis risk from individual projects. When offering into a portfolio it makes little sense for component projects to include charges for managing their specific basis risk. Producers may include not only traditional utility-scale projects but also aggregators for DERs, especially if they can deliver to constrained nodes within potential customers' territory. However, to keep OLTM energy products simple and liquid, some of the specific locational benefits of DERs or other beneficial attributes of producers or facilitating resources might need to be defined as separate property rights and sold independent of the OLTM.

Since most electricity buyers purchase power at the hub or zone level, the OLTM energy contract product should be delivered at the same level. In the more complex version of an OLTM, loads can take on a facilitator role in constructing portfolios. Because of more flexible loads, distributed generation, or other DERs, this kind of dynamic demand participation in the spot markets might require the rules to evolve to allow load bids at the nodal level to capture the specific local value of DERs in prices. In such a case, flexible loads are acting as producers more than buyers in these long-term contracts, and we would still expect OLTM energy contracts to settle at the hub or zone level.

Buyers with a specific geographic or resource type preference are a possible exception (e.g., a CCA, a rural electricity co-op, or a state with a preference to buy local). In this case, OLTMs could craft specific portfolios for the benefit of a single large buyer or group of buyers. However, the output contracts would be different and lose some of the fungibility and liquidity benefits of the broad OLTM design. Alternatively, buyers could have side agreements with the OLTM where, for a premium, some fraction of the resource mix in a given portfolio would conform to their more specific requirements. This constraint would have an associated Lagrange multiplier in the optimizer, like shadow-price LMPs for local nodes, which could be used to create an objective basis to show buyers the premium required to accede to their request. In other words, the OLTM could work with outside payment, unbundled from their main energy product, to satisfy these parties. This is the flip side of the variable demand agreements (create a constraint and you pay an unbundled premium; relax a constraint and you receive an unbundled payment).

How: Contracts and enabling policy environment

Many tariff design and contract arrangements must be worked out to make an OLTM operate effectively, which is beyond the scope of this paper. Presumably, these arrangements would be part of standard templates to minimize costs, as seen in syndicated power purchase[26] deals today. Contractual arrangements will have to consider different resource performance characteristics and construction timelines, as well as varied operational and ownership structures. Careful modeling would likely demonstrate significant potential savings from operating at scale for long-term procurement. Simpler financing and hedging from an OLTM, accessible as long-term supply to consumers of all sizes, should drive further benefits. Finally, OLTMs can create instruments naturally adapted to enabling policy goals.

For example, by helping developers access long-term funding, OLTMs can accelerate the build-out of clean energy. As mentioned above, they can also be part of a managed phase-out of existing dirty energy assets. Portfolios can consist of entirely clean energy resources, conform to a portfolio-level carbon intensity or criteria pollution ceiling, or purchase offsets to clean the portfolio. They can also provide renewable energy credits, integrate renewable portfolio standards, or be part of the state IRP process. The output contracts can also be graded by specific emissions levels. OLTMs provide policymakers visibility into the long-term contracting arrangements of market participants and can promote transparency and competition.

Different pathways can lead to an OLTM from existing market arrangements. OLTMs could evolve through state action out of the hybrid markets that exist today, like CAISO or MISO, where vertical utilities still operate. OLTMs could also evolve out of competitive single-utility IRPs,[20] or competitive renewable portfolio standards and long-term procurement processes led by state utility commissions. Contractual arrangements could also evolve from work by organizations like the Edison Electric Institute and International Swaps and Derivatives Associations, which are behind some of the standard term sheets for hedges and PPAs used today. It does not matter which structure emerges or which level of exclusivity each might have in each jurisdiction so long as the second principle for non-discriminatory access, transparency, and liquidity is satisfied.

If policymakers see an important role for OLTMs, they might legislate or otherwise stimulate their creation by subsidizing some of the start-up costs, providing incentives, providing a balance sheet through a green bank, or mitigating some of the risk in the portfolio through loan guarantees or

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[26] A syndicated power purchase is when many buyers come together to buy power from one project—a one-to-many arrangement as opposed to a bilateral deal. See, for example, Sophie Vorath, "Telstra Signs Up for 429MW Wind Farm, at Stunning Low Cost," *RenewEconomy*, December 21, 2017, https://reneweconomy.com.au/telstra-signs-up-for-429mw-wind-farm-at-stunning-low-cost-13414/; Bryce Smith, "LevelTen Creates Groundbreaking Renewable Energy Portfolio to Support More Than 3,000 U.S. Starbucks Stores," *LevelTen Energy Blog*, June 5, 2019, https://leveltenenergy.com/blog/company-news/starbucks-ppa-portfolio/. This is a natural precursor to the OLTM's many-to-many structure.

first-loss protection instruments.[21] Even though natural logic exists for the emergence of an OLTM, policymakers should consider such nudges when other issues are at stake like transmission planning, clean energy targets, structural changes to who buys electricity, integrating new technology, or tensions between policymaking bodies.

REAL-WORLD APPLICATIONS OF OLTMS

Considering the OLTM proposal in the context of today's existing power markets helps to better understand how it might work in practice. These cases show how an OLTM might help resolve issues tied to power sector transformation and reveal how an OLTM might operate once much higher VRE penetration levels than seen today eventually arise. This paper considers one example from each type of power market: ERCOT (energy-only), CAISO (hybrid), and ISO-NE (with capacity market).

ERCOT

ERCOT already has a very efficient market design and should be considered a success from the point of view of long-term procurement and grid integration of VREs. Year after year, ERCOT adds more clean generation, with wind, solar, and grid-tied energy storage dominating the queue. Uneconomic coal exits have also been swifter than in other systems. Until the events of February 2021, resource adequacy concerns were managed with help from scarcity payments in the form of an Operation Reserve Demand Curve adder and increasing price-sensitive load-reducing consumption during periods of high demand. The system performed well in the last summer period of grid stress in August and September 2019, with low planned outages and substantial demand-side participation[27] at a time of historically low planning reserve margin brought on by new demand and coal retirements. New generation added to the grid has significantly increased the forecast planning reserve margin for the near future. ERCOT is arguably the most investor-friendly organized market in the U.S. on a tech-neutral basis, and that has tremendously helped clean energy deployment, despite the lack of state-level policy support for decarbonization.

Along with tragic outcomes for the people of Texas, the February 2021 grid failure created major questions for the ERCOT market model.[28] The Texas policy apparatus is currently focused on centrally contracted specific physical contract requirements to head off future such events, instead

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[27] On day 2 of Brattle's Load Flexibility Symposium (https://www.brattle.com/news-and-knowledge/events/brattle-hosts-symposium-on-load-flexibility-in-the-energy-sector), Paul Wattle from ERCOT stated that 3 gigawatts of flexible load helped the ERCOT system weather this period of system stress.

[28] For more analysis on that event, see Eric Gimon, "Lessons From the Texas Big Freeze" (Energy Innovation: Policy and Technology LLC, May 2021), https://energyinnovation.org/wp-content/uploads/2021/05/Lessons-from-the-Texas-Big-Freeze.pdf.

of fiscal prudency requirements to try to avert future such events. This is unfortunate because it is not clear that a simple capacity requirement would have done much to avert the problems seen during the big winter storm of 2021. Focusing on a single modality (effectively more fossil generators) cuts off creativity in addressing the risks of such a high-impact event. Focusing on interventions more in line with the energy markets cascade might provide better outcomes. Financial penalties in long-term supply contracts connected to financial prudency standards on LSEs would create incentives to prepare for extreme events without mandating specific solutions, and OLTMs could support this process.

OLTMs would work best in coordination with other market interventions that reinforce the health of the energy markets cascade. If ERCOT could facilitate additional battery storage and dynamic demand participation,[22] much of the need for out-of-market payments and the reliability-unit-commitment process that tends to favor expensive, legacy fossil assets could be entirely avoided. Financial prudency standards would favor investments in efficiency upgrades in homes and business that could provide extra benefits during extreme weather events, on top of benefits during regular periods of operation. With very high VRE penetration, the ERCOT market might benefit from the extra step in the energy markets cascade that a week-ahead market could provide. This would give market participants more visibility and agency regarding how much energy delivery is committed a few days ahead to allow batteries and load-shifting demand to reliably balance supply and demand over several days.[29] Similarly, as the cost of energy becomes more weighted toward fixed costs and lower fuel costs, it makes sense for more public and open market activity to migrate up the energy markets cascade, prompting interest in OLTMs.

Apart from the general upstream migration of market activity with increased VRE deployment, an OLTM would generate other benefits for ERCOT market participants. Texas policymakers might want to repeat the successful CREZ experience to connect another round of cheaper, clean generation to dense urban centers. This time, however, with VREs already holding a large market share, fewer existing resources would be available to accommodate the variability of increased VRE deployment. Some of the increased variability could be managed by new clean flexible resources, but the overall effort would be cheaper and simpler to manage if the aggregate portfolio output from these CREZ areas were less variable from the get-go by being optimized through an OLTM. Transmission planning would also benefit from coordination with portfolio optimization at the front end of an OLTM.

Large power marketers and large buyers like municipal utilities are the only entities that can currently build a balanced and diversified portfolio of long-term contracts. For example, five large corporations and three municipalities had to band together to buy from one single large project,

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[29] MISO considered and shelved ("hibernated") a proposal for a multi-day market (https://www.rtoinsider.com/articles/20473-miso-scales-back-multiday-market-proposal) it may be that the time was not quite right yet.

the new 1,310 MW Samson Solar Energy Center under construction in northeast Texas.[23] An OLTM would allow additional smaller players to develop long-term diversified exposure to many clean energy resources and access to portfolio efficiencies, thus reducing barriers to entry for emergent and innovative retailers and avoiding the Panda Energy problem. The greater the share of long-term purchases the OLTM touches, the less likely the resource mix will be to experience the big up-and-down capacity swings we have seen over the last few years. The OLTM is a natural dampener because long-term procurement is no longer happening in isolated silos.

In turn, with a more measured investment environment, investors face less risk and gain more certainty about the future value of a particular resource, be it supply side or demand side. Widespread OLTM participation can preemptively address some resource adequacy questions, especially questions about sequencing (i.e., what happens when large amounts of VRE enter the market before the matching complementary resources have a chance to ramp up) before more expensive near-term investments or interventions become necessary. By anchoring a healthier energy markets cascade, an OLTM would allow ERCOT to lean into its market-based approach to grid management.

CAISO and CCAs

The California restructured power market[30] includes transmission assets and real-time markets managed by CAISO and is regulated by FERC working alongside the California Energy Commission (CEC) and the California Public Utility Commission (CPUC). CAISO faces multiple market design challenges, including the need to improve coordination of long-term procurement among LSEs, increased demand-side participation for balancing the grid, and recent reform of the resource adequacy framework. A well-designed OLTM, if combined with a thoughtful move to heavier reliance on scarcity pricing, could significantly contribute toward addressing all three of these challenges. We will focus here on the first challenge—coordination of long-term procurement.

In California, CAISO's long-term procurement process is aiming for a moving target because the state legislature has passed a series of power sector renewable portfolio standards out to 2045. Concurrently, California must contend with customers migrating from IOUs closely regulated by the CPUC to less-regulated CCAs, as well as competition from distributed energy resources like rooftop solar.

But these are not marginal factors. California's largest IOU, Pacific Gas and Electric, has already seen 42 percent of its 2021 load forecast migrate to CCAs,[24] with the CPUC "Green Book" estimating this level could top out at 85 percent.[25] Meanwhile, distributed solar is growing fast,

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[30] A significant fraction (20 percent) of California load is served by publicly owned utilities, of which SMUD and LADWP are the two biggest. CAISO does not manage publicly owned utilities' significant fleet of generators and transmission assets.

with cumulative capacity currently just under 12 gigawatts[31] (providing roughly 7 percent of annual electricity consumption for the state), with more to come. Finally, long-term energy clean energy buyers everywhere face a deflationary environment. Past long-term contracts look expensive compared to current and likely future contracts, and the value of take-or-pay VREs is declining through the value suppression effect. An OLTM would be extremely helpful in managing these sources of uncertainty in long-term procurement.

Historical Trend of All Load Serving Entities' RPS Contract Costs by Technology and Year of Execution from 2003-2025 (Real Dollars)

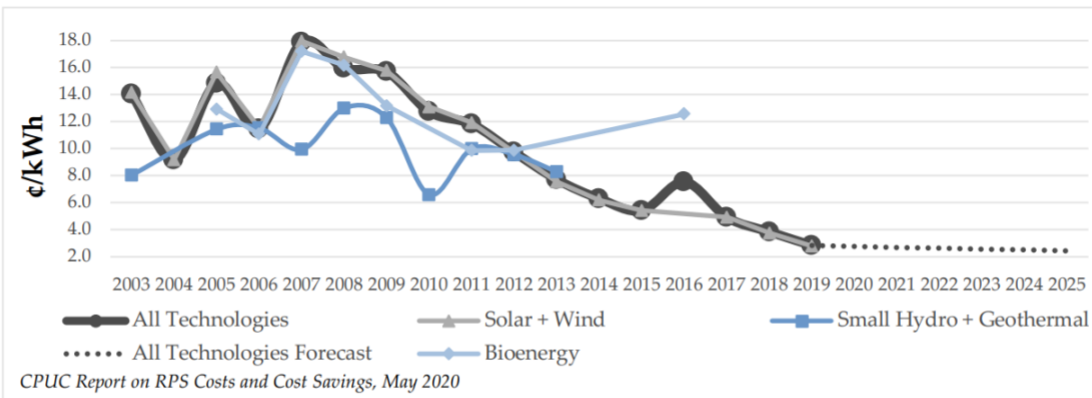

Figure 3. Declining long-term VRE contract costs in California

CCA cooperation plant a promising seed for the development of an OLTM.[26] The California Community Choice Association (CalCCA) explains how CCAs currently manage their energy portfolio risk: "CCAs manage their energy supply portfolios to ensure the right amount of energy is available when it is needed. CCAs ensure that energy purchased is diversified by supplier, location, duration, and technology type to provide stable rates for customers and stable revenues and costs for CCAs."

Given this approach, it makes sense for CCAs to collectively contract for energy through syndicated purchases. As an example of this kind of collaboration, in October 2020 eight CCAs issued a joint request for offers for 500 MW of long-duration storage.[27] Although this collaboration is purely a facilitator resource[32] and not a generation resource, it is possible this type of resource could be packaged with a portfolio of generation resources to provide the kind of stability mentioned above.

[31] Currently Interconnected Data Set according to https://www.californiadgstats.ca.gov/charts/.

[32] In this case, the CCAs are mainly interested in satisfying their resource adequacy requirements, but part of the argument in this paper is that issues like resource adequacy become more manageable with a well-constructed

A simple OLTM could start with a group of CCAs contracting for a portfolio of generation and facilitator resources together. This could include new VRE resources or new clean flexible resources, but also balancing services from existing resources coming off contract with the IOUs. Such a contract would create a standardized portfolio output with shares that could be traded among the CCAs and future OLTM participants. It would also be an evolution away from straight take-or-pay PPAs with electric generators to long-term contracts for energy delivery with a pre-negotiated firm daily or seasonal shape.

Many CCAs are particularly interested in acquiring local resources, on both the demand and supply sides. An OLTM could allow this while still generating more liquid generic tradeable shares from each portfolio. CCAs could specify a fraction of their long-term energy contract to be supplied from within their territory, which would then become a constraint for the portfolio assembly optimizer with an associated shadow price. Each CCA with a particular local content requirement would then pay for the privilege of acquiring those resources, getting an exact accounting of the cost of going local, while the portfolio spits out standard contracts for delivery with no strings attached. It would still be attractive for CCAs with local mandates to participate this way because the cost of a standard share of output from the optimized portfolio with the local price adder is still likely to be cheaper than what a CCA could procure for itself directly.[33] CCAs could also create additional customers savings by bidding local demand-side resources into the portfolio.

If an OLTM can be made to work well for a collective of CCAs, its ability to generate standard contracts for shaped output might also make it attractive for other participants to join. Direct-access customers (grandfathered California customers that can buy electricity directly from the wholesale market), municipal utilities,[34] and even IOUs might become interested in buying long-term supply contracts from the OLTM. This participation would increase liquidity and create more demand for resources to participate in this long-term market. Entities that hold existing arrangements with dispatchable resources (from their own portfolio or through tolling agreements) could also offer them to the portfolio optimizer. Greater participation would help lower procurement costs for everyone while providing more transparency in the long-term energy market across the state.

One benefit of more transparency and liquidity through increased OLTM participation is that shares of the OLTM contract could be marked to market, helping a market value for shares from a given vintage or portfolio emerge with sufficient trading volume. This could help reduce credit assurance

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portfolio of shaped delivery contracts that commit more deliveries during periods of estimated high demand and vice versa.

[33] If a CCA buys some of its long-term energy from a local project under a PPA along with some balancing service and more shaped energy from the OLTM, it is exploring a smaller parameter space than if it would contract all three via a constrained bid to the OLTM, so the cost is likely to be higher.

[34] Municipal utilities, such as Southern California Public Power Authority, already do lot of cooperative purchasing and management of generation and transmission assets.

requirements[35] and facilitate negotiations for customers leaving IOUs. A transparent and liquid market for long-term obligations would also allow participants to better manage the risk of losing customers. For example, a transparent and liquid market should be able to find third parties to underwrite options for long-term energy contracts. An IOU could then purchase an option on energy delivery and choose not to exercise that option in case of customer migration to a CCA. They would then pass on the incremental cost of this option above the energy price to all their existing customers, and no longer require an exit payment to cover obligations they were free not to exercise. For the counterparty, a liquid market and the knowledge that customers are likely to only be moving and not disappearing would assure them the energy contracts they bought to cover their position could easily be sold to another customer. Broad participation, transparency, and liquidity, as well as the business arrangements that flow from these, create a context with less friction for customers moving back and forth between retail providers (here the IOU and a CCA).

Finally, an OLTM would expedite implementing state clean electricity standards. Because the CPUC has less jurisdiction over CCAs than IOUs, a cooperative voluntary framework from long-term procurement provides rich information for the CPUC to update its IRP assumptions without reaching into questionable jurisdictional territory. It also allows the state government to monitor clean energy standard compliance more holistically and gauge future resource adequacy. As long as the market participants who don't perform on obligations or competently manage their risk exposure face strong penalties (mostly from having to cover positions at steeper prices in downstream markets), a healthy energy markets cascade can do the bulk of the work of guaranteeing resource adequacy and help wean the state from an overcomplicated resource adequacy regulatory structure.

ISO-New England

In October 2020, five New England governors issued a statement directed at ISO-NE reflecting mounting tensions between ISO rules and practices, and state-led electricity sector decarbonization efforts.[28] Their statement called on the ISO to "proactively develop market-based mechanisms, in concert with state policymakers, that facilitate growth in clean energy resources and enabling services, while fully accounting for on-going renewable energy investments made pursuant to enacted state laws." These governors view capacity market designs like the Competitive Auctions with Sponsored Policy Resources as unfairly penalizing state-sponsored clean energy resources. In contrast, an OLTM would foster better coordination between states and the ISO both because it is market based and optimized to work with existing energy markets and because the optimizer function would work with state mandates and state priorities.

[35] It is easier to underwrite an obligation to a consumer and pay for energy if the underwriter believes that another consumer or buyer can easily be found.

The OLTM concept bears some resemblance to another market design concept conceived in New England, Brattle's Forward Clean Energy Market (FCEM).[29] Both are meant to work hand in hand with energy markets and facilitate state policy goals. But in many ways the FCEM is a band-aid solution, as it does not address the bigger capacity market design challenge, and the market distortion resulting from the ISO's or FERC's treatment of state clean energy policy. It may well fix some of the conflicts that led to Competitive Auctions with Sponsored Policy Resources by attempting to efficiently price a policy externality.[36] However, the FCEM doesn't do much to help energy markets to evolve to work better with a mix of VREs and their complementary resources in the wake of concerted public efforts to clean the grid. In this context, capacity markets are a flawed construct for ensuring resource adequacy. Instead, procurement and market activity need to move upstream to consider the more capital-intensive clean technologies an FCEM is meant to help foster.

ISO-NE states can regain a measure of control over their resource mix by pushing for higher price caps and scarcity pricing at the ISO, promoting much more flexible demand participation in the market to fiscalize risk, thus putting the energy markets cascade on more of an even keel with an OLTM.

However, given that the FCEM seems to have already attracted some attention in the policy community as means to mitigate tension between state policy and organized markets, a brief side-by-side comparison may be useful. This comparison also clarifies some of the policy choices that policymakers will face going forward.

OLTM vs FCEM

- Basic product: The commodity traded by the proposed FCEM is called a Clean Energy Attribute Credit (CEAC) that unbundles the *clean energy attribute* from energy sales. That is the FCEM's purpose, along with delivering economies of scale, market efficiency, and market access for this attribute. In contrast, the OLTM focuses on improving the market for *long-term energy sales*. The clean energy attributes beyond least cost are a matter of consumer demand, either driven by voluntary goals or public policy rules and legislation.
- Goals: The genesis of the FCEM was an attempt to resolve conflict between discrimination in the capacity market design along the lines of a minimum price offer requirement and state policy goals for long-term procurement. In theory, the FCEM allows resources to avoid "out-of-market" designation in capacity markets, and thus reduces double payment for capacity and the cost of achieving low-carbon goals. By contrast, the OLTM is all about priming the market to succeed without a capacity market.

[36] It fails, however, to address some other crucial externalities, like criteria pollutants, that disproportionally affect vulnerable communities.

The OLTM's goal is least-cost reliable energy within policy constraints, which can be heterogeneous among participants.

- Buyers: The FCEM white paper refers to states buying an allocation of clean energy, with extra volunteer demand on top. Different buyers for energy and for the "clean" attribute makes some sense within an unbundling paradigm. In an OLTM, any participant that posts credit assurance can buy long-term energy contracts, but buyers are expected to consist mostly of wholesale traders and LSEs. These buyers will demand bundled environmental attributes or offsets as required by law and their consumers.
- Timeframes and adaptability: FCEM design proposes three-year purchases of annual obligations as a compromise timeframe between the long-term investment signals needed by investors and the need for states and electricity buyers to maintain flexibility, because buyers don't want to lock in any technology set too early and their needs may change over time. The FCEM interacts with energy markets at an intermediate stage in the energy markets cascade. By contrast, the OLTM sits further upstream in the energy markets cascade alongside auctions, PPAs, hedges, and other bilateral agreements seen today. As such, it can inform and interact with long-term planning processes.
- Price formation: The FCEM is a clearing market where the price of all CEACs for buyers and sellers is set by the highest clearing offer. Sellers offer resources at various prices, creating a supply curve, and a demand curve aggregates individual buyer demand curves. The clearing price is set where the two curves intersect. This choice reflects the need for sellers to gather rents to cover capital costs, like the downstream markets, in the energy markets cascade. In contrast, OLTM portfolio resources are paid as bid. On the buyers' side, purchase of OLTM output shares contracts is purely voluntary—even after they have signaled their desires to the optimizer, buyers still have the choice to buy or not to buy.
- Administering agency: The FCEM proposal states that such a market could be administered "*by a state agency, a multi-state organization, or an RTO.*" The OLTM design is similarly open, although given how far upstream it sits in the energy markets cascade, it makes more sense for it to be regulated by the CFTC rather than FERC. This might rule out involving an ISO/RTO. The organization can also be a nonprofit, B-corporation, or for-profit entity like a commodity exchange or power authority.

There is no direct conflict between the FCEM and OLTM, or the principles for healthy energy markets cascade we began with. Buyers in the FCEM are buying an unbundled environmental attribute that is mostly decoupled from energy.[37] For this reason, policymakers can have both markets at once. OLTMs can even work within a regulatory structure that includes capacity markets, but ideally the market design would evolve toward a focus on a more functional energy markets cascade, scarcity pricing, and backstop measures that don't interfere with price formation and the principles we started with.

In fact, with any effort to set up an FCEM, participating states should also consider setting up an OLTM at the same time. Clearly, the proposal for an FCEM was driven by state commitment to procure, or make retailers procure, CEACs. At a minimum, an OLTM provides a good cost referent to compare against other long-term procurement. States can also help ensure the OLTM grows into an attractive option by underwriting some of the start-up costs and signaling interest in buying from the initial contracts. One advantage of an OLTM is that it is market friendly, but is not clearly within FERC jurisdiction, so cooperative work on an OLTM can be done without direct FERC or ISO involvement or approval.

An OLTM has other possible design features that ISO-NE states might find attractive. For one, an OLTM can accommodate slightly different state priorities and standards through shadow prices similar to California CCAs. An OLTM could also be part of a state strategy for fostering offshore wind. In a May 2020 report prepared for the transmission company Anbaric, the Brattle Group detailed how a more coordinated transmission approach to offshore wind development could reduce new transmission and onshore upgrade costs by around $1.5 billion (albeit with significant uncertainty).[30] Most of these savings come from better coordination with the existing onshore transmission system to avoid excess congestion and overloads. Further coordination of this offshore development with complementary resources onshore likely could provide further cost savings and deliver firmer[38] power to consumers. Any coordinated effort by states[39] to capitalize on the savings Brattle identified should concurrently consider a special-purpose OLTM for this or future rounds of offshore wind development. If successful, this OLTM could begin to foster a healthier energy markets cascade across the region.

The creation of an OLTM offers ISO-NE states the possibility of leaning into their competitive approach to electricity markets while meeting decarbonization goals. It interfaces well with real-time markets, making them more efficient and less reliant on work-around solutions like capacity

[37] Well, not entirely. The attribute only exists if potential energy sales are likely to happen, and for some resources like storage it is not clear how much of the "clean" attribute they will be able to provide until emissions are netted out in real time.

[38] Just as a reminder, by "firm" here in the context of the long-term contract shares coming from an OLTM, we are describing contracts that agree to deliver power on a firm preset schedule. The portfolio behind these obligations may contain various amounts of dispatchable or "firming" resources depending on how efficiently the portfolio optimizes across its range of input resources.

[39] The Clean Energy States Alliance's Northeast Wind Resource Center has been leading information sharing in the region, but no concrete efforts to operationalize cooperation, like a power authority, have so far materialized.

markets, while offering a useful venue for interfacing with state policy priorities and control over their resource destiny.

CONCLUSIONS AND FUTURE DIRECTIONS

The OLTM concept shows how policymakers can improve organized energy markets in anticipation and support of strong future investment in VRE resources. Given the uncertainties that still need to be navigated, market reform requires a principles-based approach. Policymakers should focus their attention on the whole energy markets cascade, with particular focus on the upstream portion since it is currently much neglected.

This paper begins a conversation about fostering a healthier energy markets cascade to better achieve public policy goals like market efficiency, shared benefits, reliability, and a faster clean energy transition. Well-regulated energy-only markets could conceivably accomplish all these goal on their own, but a more thoughtful and considered design make things much easier. An OLTM is not the only way to better manage the energy markets cascade, but hopefully its design will stimulate further thought about what can be done to improve electricity markets within a solid set of market-friendly principles.

More work needs to be done to spell out the rules and contracts that will govern an OLTM. For example, this paper did not touch on important topics like governance. Given that the motivation for this work stems from climate mitigation, it may seem strange that we have not devoted much space to the environmental attributes accompanying OLTM energy contracts. As it turns out, OLTMs have a rich set of options to address such concerns with instruments including RECs, time-stamped RECs, or direct emissions accounting, which warrant further consideration. Suffice to say, at the cost of extra complexity and slightly reduced liquidity, it is quite feasible to incorporate various environmental compliance regimes into an OLTM.

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