White Paper on Developing Competitive Electricity Markets and Pricing Structures

Prepared for:

New York State Energy Research and Development Authority (NYSERDA)

and

New York State Department of Public Service

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April 2016

NYSERDA Contract: 64271

White Paper on Developing Competitive Electricity Markets and Pricing Structures

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PREFERRED CITATION: Tabors, R., Parker, G., Centollela, P., and Caramanis, M. (April 2016). *White Paper on Developing Competitive Electricity Markets and Pricing Structures*. Boston, MA. Tabors Caramanis Rudkevich, Inc. Prepared under contract for the New York State Energy Research and Development Authority.

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ACRONYMS AND ABBREVIATIONS	
BAU	Business as usual
CHP	Combined Heat and Power
Commission	New York State Public Service Commission
DA	Day-Ahead (Markets or Prices)
Department	New York State Department of Public Service
DER	Distributed Energy Resources
DG	Distributed Generation
DLMP	Distributed Locational Marginal Price
DR	Demand Response
DSP	Distributed System Platform
eLMP	Extended Locational Marginal Price
ES	Energy Storage
ESCO	Energy Service Company
EV / PHEV	Electric Vehicle/ Plug-in Hybrid Electric Vehicle
GW / GWh	Gigawatt/ Gigawatt-hours
HVAC	Heating, Ventilation, and Air Conditioning
ICAP	Installed Capacity
ISO	Independent System Operator
kW / kWh	Kilowatt/ Kilowatt-hours
KVA	Kilovolt-ampere
kVAR / KVARh	kilovolt-ampere-reactive / kilovolt-ampere-reactive hour

ACRONYMS AND ABBREVIATIONS	
LMP	Locational Marginal Price
M&V	Measurement and Validation
MHP	Mandatory Hourly Pricing
MW/ MWh	Megawatt/ Megawatt-hours
nLMP	nodal Locational Marginal Pricing
NYISO	New York Independent System Operator
NYS or State	New York State
NYSERDA	New York State Energy Research and Development Authority
NYC	New York City
Framework Order	Case 14-M-0101, Proceeding on Motion of the Commission in Regard to Reforming the Energy Vision, Order Adopting Regulatory Policy Framework and Implementation Plan (issued February 26, 2015).
PV	photovoltaic
REV	Reforming the Energy Vision
TCR	Tabors Caramanis Rudkevich
T&D	Transmission and Distribution
TOU	Time-of-Use
VAR	Volt Ampere Reactive
VVC	Volt VAR Control

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Executive Summary

This white paper (paper) describes the design of a new, distribution level market for energy and related electric products from Distributed Energy Resources (DER) and of a statewide digital Platform to animate and facilitate the financial transactions in that market.[1] Tabors Caramanis Rudkevich (TCR) has prepared this paper as an input to the Reforming the Energy Vision (REV) proceedings of the New York State Public Service Commission (the Commission). The paper presents the rationale for establishing this new market structure, explains how the establishment of a digital platform would support the operation of the market, and describes the steps required to implement the Platform and Platform Market.[2]

The Commission initiated the REV proceeding in April 2014. The February 26, 2015 Order in the REV proceeding (referred to as the Framework Order or the Track One Order) states that the general goal of REV is to move the electric industry and ratemaking paradigm toward a "consumer-centered approach that harnesses technology and markets."[3] The Framework Order introduces the concept of a Distributed System Platform (DSP) provider, an entity responsible for three major functions at the distribution level: integrated system planning, grid operations, and market operations. The Order assigns the role of DSP provider to the State's utilities (hereafter referred to as the Distribution Utilities).[4] The Framework Order places particular emphasis on improving and increasing the integration of DER into the planning and operation of the State's electric distribution systems. The Framework Order expects that better integration will lead to "optimal system efficiencies, secure universal, affordable service, and enable the development of a resilient, climate-friendly energy system."

The New York State Department of Public Service (the Department) and New York State Energy Research and Development Authority (NYSERDA) jointly retained TCR to analyze possible changes in market design, with specific emphasis on the potential role of platform-based markets to achieve the State's REV goals.[5] This paper presents a potential roadmap for market development and operations to create a *level playing field* for DER, improve system efficiency and reliability, and provide benefits to customers based upon the market guidelines identified in the Framework Order. It considers opportunities to:

- Promote fair and open competition and reduce barriers to the development and use of DER.
- Identify, quantify, and reflect in market design the temporal and spatial value of DER within the larger utility system.

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[1] DER are principally located on customer premises, but also potentially located at distribution system facilities. This paper refers to solar photovoltaics (PV), energy storage (ES) via either batteries or electric vehicles (EV), demand response (DR), end-use energy efficiency, and combined heat and power (CHP).

[2] The paper does not capitalize platform when referring broadly to the concept of an economic platform. It capitalizes Platform when referring to the Platform design offered for consideration in New York State and capitalizes Platform Market when referring to the market / price formation function of the Platform.

[3] Case 14-M-0101, Proceeding on Motion of the Commission in Regard to Reforming the Energy Vision, Order Adopting Regulatory Policy Framework and Implementation Plan (issued February 26, 2015).

[4] The paper capitalizes Distribution Utilities to indicate specifically the utilities within New York State referenced as having the responsibilities of the DSP provider.

[5] The Framework Order uses the term market design synonymously with market structure.

- Capture the economic benefits of digital platforms to support market operations, for example as a mechanism for price discovery and a means of integrating electric products with digitally based services.

Creating a Market for DER

REV calls for facilitation of a market for DER products and services. This paper describes how New York State could create a new power market for DER products at the distribution level. DER would sell three core electric products in that market: real energy, reactive power, and reserves. Real energy and other products that derive from it have the greatest economic value because customers consume those products directly. Distribution Utilities require reactive power to maintain voltage within an acceptable band that prevents damage to voltage sensitive equipment such as drive motors, compressors and many electronic devices. Reserves represent a commitment to deliver energy in the future. These core products can be bundled or unbundled, sold day ahead or in real time, or aggregated individually in time and space. In addition, they may be valued and / or sold forward as a basis for the calculation of the avoided cost of future capital investments.

The design of this new market would draw upon the extensive experience with electric market design at the wholesale level. A key lesson from that experience is the importance of *getting the prices right*. Prices in this new market should reflect the value of core electric products from DER as a function of the time at which DER produces those products and the location at which DER produces them. This approach, referred to in this paper as more granular pricing, would identify where, when and how DER could provide significant value through reduction in system operating cost or where their ability to respond reduces the need for additional capital investment. This value is incremental to the environmental or other policy benefits of DER.

The Value Proposition for Creating a Platform Market is Significant

As conceived in this paper, a Platform Market would combine the benefits of a digital platform with the economic efficiency of more granular pricing that reflects the location- and time-specific value of DER.

Establishing a Platform Market would create additional value for DER owners and consumers within the State by:

- **Expanding market access for DER.** Demand Response (DR) programs typically provide the only available paths for active DER participation in the existing wholesale power markets, and there are significant gaps in DER participation in those markets. A Platform Market would expand DER access to markets for electric products and services by creating a new market and by reducing the transaction costs of accessing existing wholesale markets. The Platform Market would enable DER to provide real energy, reactive power, and reserves to Distribution Utilities, default service suppliers, energy service companies (ESCOs), aggregators who would bundle and market DER resources, and even directly to other consumers. Additionally, Distribution Utilities initially can use the Platform to obtain option contracts or firm commitments from DER, and ultimately to rely on increasingly more granular distribution level pricing to promote the development of DER, in quantities and locations where DER can avoid investment in new substations and other major distribution investments.

- **Supporting new combinations of products and services.** By creating a market with a significant number of buyers and sellers with varying needs, and by enabling those buyers and sellers to find and execute transactions electronically, the Platform would support transactions for new, innovative combinations of products and services from DER and third parties at low transaction cost. In addition, The Platform, by supporting the provision of price forecasts, data analytics, and other smart technology services would enable price responsive flexible demand, more efficient electric vehicle charging, and bring to market other distributed resources to consume or supply power when it is economical to do so consistent with given customer preferences. (Price responsive demand is a method by which customers, such as space conditioning in commercial buildings and charging of electric vehicles, can reduce their energy costs by scheduling the flexible portion of their load according to the forecast price of electricity in each hour.)
- **Improving distribution system efficiency.** Maintaining voltage within limits, or Volt VAR control (VVC), is critical to maintaining the operational integrity of energy consuming devices on the distribution system. Distribution Utilities traditionally manage voltage through investments in capacitor banks, line voltage regulators, and load tap changers located on the primary, higher voltage elements of the distribution system. The implementation of new technologies like smart inverters on rooftop solar and electric vehicle systems provides a local source of Volt VAR control at a lower cost and at higher efficiency.

A number of studies have identified the technical potential for responsive demand to reduce system peak to be as much as 25%.[6] More granular pricing could ensure that these changes in demand and distributed supply occur where they can provide the greatest value to the system as a whole.

The combination of the Platform and the Platform Market has the potential to improve the overall efficiency of the distribution system. This paper illustrates that potential by modelling a representative radial distribution feeder located in the Capital Region on a summer and a winter peak day under several different market structures. The structures range from business as usual (BAU), e.g., flat average rate per day, to highly granular pricing by hour. The modelling for summer peak days indicates potential improvements in economic efficiency, i.e., total cost of energy delivered to consumers on the feeder, of approximately 5%. This improvement results from changing pricing from the BAU approach, e.g., a single price in all hours of the day charged to all load on the feeder, to highly granular prices for real and reactive power at each node or pricing point on the feeder. This same analysis indicates that the cost of reactive power charged to consumers could be roughly 24% lower under highly granular pricing as compared to BAU. In addition, the quantitative analysis suggests that commercial buildings that shift

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[6] As examples see: J. Goellner, et al., Demand Dispatch – Intelligent Demand for a More Efficient Grid, National Energy Technology Laboratory (August 2011). A 2015 analysis based on the use of transactive controls in the Pacific Northwest Smart Grid Demonstration Project produced a comparable estimate of demand reduction potential. Battelle Memorial Institute, *Pacific Northwest Smart Grid Demonstration Project: Technology Performance Report Volume 1: Technology Performance* (June 2015). See also: J. Hagerman, *U.S. Department of Energy Buildings-to-Grid Technical Opportunities* (2015), and Rocky Mountain Institute, The Economics of Demand Flexibility: How "Flexiwatts" Create Quantifiable Value for Customers and the Grid (August 2015).

their demand in response to locational prices may be able to reduce their summer peak day energy costs by 12% under highly granular pricing as compared to BAU. Inflexible customers would see a cost reduction of 4%.

Potential Structure for a Statewide Digital Platform and Platform Market

Acknowledging these opportunities for creating value for and from DER, this paper introduces and describes the design of a potential digital Platform that would support a new Platform Market structure for transacting electric products from DER and related services. As conceived in this paper, the central element in the Platform is a financial marketplace that facilitates continuous transactions for core electric products and related services. The paper describes a forward (*ex ante*) market for electric products, and a separate (*ex post*) clearing market, at an extended set of pricing nodes within the distribution system. Both markets would operate on the Platform.

Each Distribution Utility is a DSP under this market structure. In that role, each Distribution Utility would continue to plan and operate its respective physical distribution system, and to monitor the topology of, and physical flow on, its distribution system. In addition, in that role, each Distribution Utility would be a co-owner of a single statewide digital Platform to enable market transactions, which an independent entity could operate to minimize the potential for conflict of interest.

The forward market provides the structure through which location- and time-based bids, and offers, can be bilaterally matched and price formation can occur. Bids and offers are visible on the Platform to all market participants but the Platform does not identify the entities making the bids or offers. This market is continuous in that market participants can transact trades days ahead, at the time of the wholesale day ahead market or at any time up to the point of market closure (production and consumption). The Platform provides the mechanism for bilateral distribution transactions in the forward market in much the same manner as other bilateral trading markets such as Intercontinental Exchange (ICE) and the New York Mercantile Exchange (NYMEX) operate for energy and other commodities.

The separate clearing market resolves the imbalances between scheduled supply and actual consumption that would occur under this market structure. Imbalances would occur because demand forecasting is not and cannot be perfect, and because electricity is produced and consumed simultaneously. As a result, *ex post,* the Platform would financially clear all positions from the forward market. DSP providers would provide the Platform the information it needs to calculate imbalances, i.e., metered quantities of real energy and reactive power actually consumed and the measured flows on the system. The Platform would run a mathematical load flow calculation, with the substation LMP as the reference price, to determine a clearing price at each of the nodes at which trading occurred. This calculation is conceptually comparable to the New York Independent System Operator calculation of real-time Locational Marginal Prices (LMP) used financially to clear all positions in the wholesale market. While the complexity of the Platform load flow calculations would increase with greater levels of granularity, the logic of the calculation is independent of the level of granularity of the nodal system.

Benefits of a Single Statewide Platform Co-Owned by the DSPs

A platform is a business ecosystem that matches producers with consumers who wish to transact directly with each other. The platform ecosystem provides parties with easy access to useful products or services through an infrastructure and a set of rules designed to facilitate interactions among users. A platform's overarching purpose is to facilitate matches between users and the exchange of goods and services resulting from those matches. This market facilitation is how the platform creates value for all participants.[7] The value of a platform is its ability to bring a significant number of transacting buyers and sellers together at a common point. New York has two basic options in this regard, establishment of a single statewide platform or establishment of Distribution Utility specific platforms. This paper describes the merits of a single statewide platform relative to multiple Distribution Utility specific platforms in terms of the need for a broad market within the State and the inefficiencies in cost and implementation of establishment of multiple platforms.

The establishment and operation of a platform requires a platform sponsor and a platform provider. The sponsor of the platform is the overall designer and intellectual property rights holder. The sponsor sets the direction and controls the underlying platform technology. The sponsor also provides the overall organizing structure for the platform via rules, governance, and ecosystem support. The sponsor can be an individual entity or a joint venture of the Distribution Utilities.

The platform provider is the day-to-day operator/implementer. The provider is in contact with the parties on both sides of the transaction. The provider is in a position to see which products and services are valuable to participants, which products and services create activity, and the trends in those products and services. The platform sponsor needs to be working with the platform provider to be able to identify commonly used/needed functionality and how/when to implement additional functionality into the platform's digital structure.

Under this new structure, Distribution Utilities would play multiple roles as DSP providers and as providers of default supply service. Those multiple roles create the potential for conflict of interest. Distribution Utilities could mitigate that potential if they were sponsors or co-sponsors of the Platform but create an independent entity to be the Platform provider.

Launch Strategies for the Statewide Platform

This paper presents two alternative strategies for launch of a statewide Platform. The first strategy is to launch a Platform with an initial emphasis on financial transactions for core electric products; this would support near-term development of a Platform Market and create opportunities for third-party development of other products and services. The second strategy is to launch a Platform with an initial emphasis on information transactions. Under this option, the Platform would provide information that would help ESCOs and DER asset suppliers/developers find prospective customers and would provide market information on those suppliers to prospective customers. The second strategy may eventually lead to the establishment of a Platform Market for trading of core electric products from DER. The first strategy, proceeding with the alternative focused on facilitation of a financial market for electric products offers greater incentives for the development of DER and moves more quickly to achieve the

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[7] Parker, Geoff and M. Van Alstyne (2014). "Platform Strategy." In the Palgrave Encyclopedia of Strategic Management. M. Augier and D. Teece (editors).

network externalities that are the hallmark of platforms in other industries.

The launch of either strategy will require the development of the Platform and its associated capabilities. The development of the Platform would require roughly 18 months. This activity would include structuring of Distribution Utility ownership of the Platform, including initial funding and ongoing cost and revenue allocation; definition of the initial functions to be provided; development of the infrastructure in hardware and human resources; acquisition of the market solution and other Platform-based software; and establishment of the governance and regulatory environment.

If the Commission chooses the financial Platform strategy, development of the Platform Market would occur during this same 18-month launch period. During that period, parties would need to define the core electric products to be traded and to choose the granularity of pricing for those core electric products. This paper discusses that the first step in increased granularity of pricing is to move from the current zonal LMPs reported by NYISO. The zonal LMPs mask significant locational price differences within the state even at the wholesale level. The paper has called this first step a move to extended LMP (eLMP). Moving to finer granularity could provide greater locational benefit of the development and efficient location of DER assets. The eLMP values would provide far more granular 5-minute or hourly prices at the substation level (the interface between the transmission and distribution systems). These eLMPs would provide the prices to which DER producers and consumers could respond. These values would also provide the pricing information DSP providers need to plan for future investment, i.e., to evaluate core products from DER as substitutes for traditional capital investments in infrastructure.

If the second launch strategy were chosen, it would be necessary to establish the rules by which Distribution Utilities could market prequalified customer information to asset developers along with the incentives needed to attract third party providers of services to the Platform. As TCR does not anticipate that a market for core electric products would be an initial part of the second strategy, there would not be a need to deal with the issue of increased granularity in pricing until some period after the initial launch.

Platform Fees, Revenues, and Costs

This paper assumes that the Platform would have a financial structure that recovers its costs while at the same time minimizing financial friction or transaction costs for DER and other parties executing transactions on the Platform.

The paper describes a fee option for core electric products under which the Platform would apply its fees for core electric products to completed transactions and charge those fees to the seller (DER). The rationale for this option is the fact that DER do not have a strong alternative location to sell their products while the buyers of their products (ESCOs and Distribution Utilities) can acquire alternatives in the wholesale market. For these core product transactions, the paper puts forward a 5% transaction fee.

The Platform would need to develop additional supporting products and functions. These elements would include distribution system baseline engineering (topology) data and aggregate demand, supply, and flow data. The paper describes an option for dissemination of distribution system operating data under which the Platform provides these data at no cost. The rationale for this option is that the data is routinely collected today and is critical to reducing transactional friction on the platform.

Another set of products on the Platform would be value added analytics and information that third parties would develop and sell directly to users of the platform. The paper describes a fee option for value added analytics and information under which the Platform charges fees that are transaction based and in the range of 5% to 10%.

Finally, the platform could charge fees for matching consumers to asset or service providers based on the customer knowledge held only by the Distribution Utilities. These matchings have a high value to asset and service providers that may range between $50 and $100 per match. The fees for this service should reflect that value while keeping transaction costs to a minimum.[8]

This paper estimates the cost of establishing a single statewide Platform for New York to be $100 million, with annual operating and maintenance costs of $40 million.[9] The fee structure discussed above represents a base source of revenue with other revenue opportunities becoming available as the Platform matures.[10] As examples of transactional opportunities and possible revenues, the paper provides three case studies of the Platform's use by specific technologies: DR, energy storage, and solar photovoltaic (PV). The studies provide snapshot estimates of the sources of revenue the Platform could generate.

Evolution of the Potential Platform Market

Assuming that the Commission chooses to move forward with the development of the Platform Market as described in this paper, it would evolve toward increasingly granular prices in three broad stages: Initial Market, Interim Market, and Ultimate Market. This paper discusses this implementation process in three time periods:

- **Start-up (T_0).** This period begins with the Commission decision to move forward and ends when the DSP providers launch the Platform. This phase could be completed in 18 months;
- **Initial Platform Market (T_1).** This period begins with initial operation of the Platform and operation of an Initial Platform Market based upon eLMP. This phase could last three to five years, or possibly longer,
- **Interim and Ultimate Platform Markets (T_2 and T_3).** The Interim Platform Market period (T_2) begins with operation of an Interim Platform Market based on pricing within the distribution system that is more granular than eLMP. The period ends with the evolution to an Ultimate Platform Market based on Distributed Locational Marginal Prices (DLMP).

Table ES-1 provides an overview of the changes in market structure, responsibilities of individual market entities, evolution of market products, and regulatory oversight as the process evolves from the current market structure initiation through to full implementation of the DLMP market.

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[8] For comparable costs in matching of consumers to rooftop solar providers see: U.S. Department of Energy Technical Report DOE/GO-10212-3834, November 2012.

[9] The costs are conservative order of magnitude estimates. They are small relative to the system size of New York and are relatively invariant in terms of the number of transactions on the Platform.

[10] It is worth noting that if the $40 million annual cost were to be recovered uniformly over all kWh delivered to New York State ratepayers in 2013, the impact would be *de minimus* at 0.03 cents/KWh, or roughly $0.16/customer per month.

Table ES-1 Evolution of Platform and Platform Market

Key Steps / Elements	**TIME PERIODS**			
	Start-Up (T_0) (18 months from decision)	**Initial Platform Market (eLMP)(T_1) (3 to 5 years)**	**Interim Platform Market (T_2)**	**Ultimate Platform Market (DLMP) (T_3)**
Development of the Platform and Associated Capabilities				
Platform	Joint Utility Development of Structure & Selection of Provider (Operator)	Platform launches with eLMP market & value added services	Platform evolves market to greater granularity in location and pricing and value added services leading to full DLMP	
Utility / DSP Capabilities	Utilities Evolve to DSPs and Develop Roadmaps for Transition to more Granular Market Pricing	Utilities/DSPs provide NYISO continuously updated ESCO load data and complete deployment of capability to collect interval customer data	DSPs track distribution power flows & calculate marginal losses	DSPs able to provide data for Platform to calculate market clearing prices based on full DLMP
	Utilities/DSPs Accelerate Deployment of Capability to Collect Interval Customer Data		Utilities/DSPs support increasingly granular settlements that are calculated by/on the Platform leading to full DLMP	
NYISO Wholesale / Retail Market interface	NYISO adjusts market software to report eLMPs	NYISO reports eLMP to DSPs	NYISO coordinates with the Platform provider to provide wholesale data that allows for locational price settlements required for full DLMP	
	NYISO provides / publishes Day Ahead quantity and price commitments for eLMP pricing points (load nodes)			
Regulatory Oversight	Commission approves Platform Structure & Governance		Ongoing oversight of Platform Governance and Independence	

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Key Steps / Elements	**TIME PERIODS**			
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Development of Platform Market - Core Electric Products				
Energy	No Changes	eLMP settlements for DER	Interim DLMP settlements	DLMP markets
Reserves	No Changes	Targeted Procurements for local reserve requirements	DLMP for Local Reserves; Frequency Response Pilots	Coordinated local & system DLMP reserve markets
Reactive Power	DSPs pilot VVC with utility VAR on secondary distribution	Utilities deploy VVC architecture & utility VAR sources	Utilities pilot integration of customer VAR sources	Integration of utility & customer VAR in reactive power market

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Key Steps / Elements	TIME PERIODS			
	Start-Up (T_0) (18 months from decision)	**Initial Platform Market (eLMP)(T_1) (3 to 5 years)**	**Interim Platform Market (T_2)**	**Ultimate Platform Market (DLMP) (T_3)**
Development of Platform Market - Applications				
Targeted Procurement to Defer Distribution	Utility planning identifies where DER might defer investment	Utility commits to regular purchases of option contracts from liquid DER market for energy & reserves	Utility option contracts become increasingly granular as they recognize losses in interim pricing	Where liquid forward markets exist, DLMP could replace targeted procurements
Default Supply Service Rates	No Changes	Transition MHP customers from DA to RT eLMP for energy imbalance. Provide MHP capability to forward contract for hedging, to respond to retail rates with energy @ eLMP (e.g. smart control rate) and new demand management services	Ability to support new retail rates with energy at granular prices; ability to support new demand management services and retail rates	

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Key Steps / Elements	**TIME PERIODS**			
	Start-Up (T_0) (18 months from decision)	**Initial Platform Market (eLMP)(T_1) (3 to 5 years)**	**Interim Platform Market (T_2)**	**Ultimate Platform Market (DLMP) (T_3)**
Development of Platform Market - Applications				
Demand Response	Utilities Pilot Targeted DR programs for Distribution constraints	Flexible demand & smart EV charging expand outside DR programs		Price response overtakes capacity & energy DR programs
			Smart technologies expand the role of DR in ancillary services	
		Price responsive DR in Targeted Procurements such as large commercial buildings		Price responsive DR in at all customer levels
Value Added Service Support for DER	Platform identifies utility information services & recruits key third party service providers	Potential services include: Price forecasts; on-bill repayment financing; smart technologies for building energy management, EV charging and other DER operations; data analytics for DER investment & management; customer-to-customer retail transactions; targeted utility procurements of DER; DER product aggregation; bill comparison apps; clean energy tracking; retail shopping / supplier matching; & other innovations		

Organization of this Paper

The paper is organized as follows.

Chapter 1 describes the context of analyses relative to the objectives of the REV proceeding in general, and to the market operation responsibilities of the DSP providers. The chapter summarizes the logic of moving to more granular locational pricing supported by a digital marketplace, which is called the Platform Market, and the associated value proposition in terms of enabling the integration of DER into Distribution Utility planning and operations.

Chapter 2 presents an overview of the economic principles that guided the analysis of a distribution-level market design. The key market design principles include defining the needs of buyers in terms of the core electric products those buyers could obtain from DER; identifying the range of buyers and sellers who could participate in these markets; developing a market-based method of price formation for core electric products from DER that recognizes their temporal and locational value; and identifying the information required for market transparency. The chapter also introduces the results of the quantitative modeling exercise that offers insight into the economic benefits of increased granularity in pricing. The chapter recognizes that the methods for DER procurement and price formation would need to evolve over time as Distribution Utilities develop the necessary supporting infrastructure and market participants gain experience with the market design. The chapter concludes with a detailed discussion of the value proposition surrounding the development of the conceived Platform Market.

Chapter 3 presents the principles that guided the analysis and design of the Platform conceived to support REV objectives. The key components of platform markets are the participants (i.e., buyers and sellers), the information those participants exchange regarding their specific needs and products on a dynamic basis (information units), and the filters they use to find a match. The chapter explains how Distribution Utilities would be able to use a digital platform to procure products from DER and to animate a competitive market for the development of and products from DER.

Chapter 4 presents a roadmap of the vision of the energy market's development in New York State that would result from the implementation of REV, given the developmental paradigm of a market centered on a digital platform. The pictures presented move from the existing, highly centralized electric market to a decentralized model with far greater granularity in pricing (spatial and temporal); from a market in which DER plays a minor role to one in which DER is on an equal footing with centralized generation.

Chapter 4 is an effort to "connects the dots" between the market operation responsibilities of the DSPs, the market design required to fulfill those responsibilities, and the role of the Platform in animating and supporting that market design. The new distribution-level markets enabled by the Platform would have far greater granularity in pricing for DER in the distribution system. The chapter describes the implementation and evolution of the market at three stages: Platform launch, market initiation / interim market, and market maturity. In each instance, it discusses the types of products that would be in the market, the role of the platform in facilitating transactions and price formation, the likely participants in the market, and implications for major categories of stakeholders.

Chapter 5 presents the detailed results of the quantitative scenarios that address the economic benefits of moving to a more granular pricing structure. It compares the total cost of supply to a prototypical feeder given BAU, standard LMP, eLMP and DLMP. Chapter 5 also describes qualitative scenarios that identify a range of DER technologies, the benefits that accrue to those technologies through the existence of the Platform, and the possible maximum revenue that transactions of those technologies could bring to the Platform.

Primary Decision Points

The paper presents decision points and steps required to proceed from the objectives of the REV process and move toward specific elements of implementation for the conceived Platform Market. Organized under five headings – platform, products, pricing, process and regulatory oversight – the key decision points follow.

Platform

- Choose a Platform approach that will animate and support markets in core electric products and value-added services. The option of a single statewide Platform co-owned (sponsored) by, and operationally independent of, the State's Distribution Utilities has several advantages over the option of multiple Distribution Utility specific platforms.
- Choose an initial Platform design option. Launching the Platform initially as a market trading (financial) platform has several advantages over the option of an initial Platform designed as a customer information portal, based on experience presented from comparable applications.
- Choose a Platform fee structure that reduces friction to Platform participation. The paper presents a rationale for setting fixed fees for access to the Platform as low as possible and for setting transaction fees of 5% on completed transactions for core electric products, charged in general to the seller.
- Choose a policy option for dissemination of distribution system operating data. The paper presents a rationale for providing basic physical distribution system information at no cost to Platform participants.
- Choose a Platform fee structure that encourages the packaging of analytic service products offered at subscription fees.

Traded Products

- Choose the core electric products to be transacted on the financial digital platform. The paper presents a rationale for choosing real energy (real power), reactive power, and reserves. The paper also presents a rationale for the Platform to provide the capability for parties to trade those products in conjunction with the complex energy products that derive from them, such as forward contract options for location-specific resources and forward hedges tied to the price of delivered natural gas or weather.
- Determine whether the Platform should additionally provide the capability for Distribution

Utilities and Energy Service Companies (ESCOs)[11] to solicit specific products and services as call options or firm obligations through auctions.

- Determine how the Platform should recruit third-party providers of key value-added services to the platform. Such services could include price forecasting, energy management and DER-related data analytics, and smart technologies.

Product Pricing

- Determine the functionality for price discovery and for *ex post* transaction clearing and settlements the Platform should have to establish a fully transparent market.
- Develop the more granular pricing points representing eLMPs. The paper presents evidence that this is a critical step to increased granularity of prices, and as a result, finds it is important that the Commission coordinate with NYISO toward posting of eLMPs for the State.
- Consider whether to use eLMPs to settle transactions based on interval LMPs at an extended set of 500 to 2,000 NYISO pricing nodes (in place of average hourly Load Zone LMPs). This option would enable and allow reporting out the significant variations in the locational value of DER and require comparatively little investment for implementation.
- Determine whether Distributed Locational Marginal Prices (DLMP) should be used for determining variations in the value of DER. If full implementation of DLMP markets is pursued, the market design described in this paper requires that Distribution Utilities, as DSP providers, would provide the Platform provider with real time data on electric product delivery and consumption at each node.
- Determine whether and how the market should evolve to allow for peer-to-peer transactions on the Platform.

Process

- Authorize additional analysis to evaluate the cost and feasibility of using an extended number of NYISO pricing nodes in settlements and the development of indicative look-ahead price forecasts.
- Authorize additional analysis of a range of radial and mesh distribution systems to evaluate the benefits, feasibility and costs of implementing the conceived market structure with increased granularity in pricing.
- Recognizing that the thermal inertia in commercial buildings and homes and other types of flexible demand could provide virtual energy storage, authorize additional analysis of potential benefits of combining increasingly granular pricing with advances in smart technologies and data analytics.

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[11] Staff defines an ESCO as a lightly regulated business entity, other than the utility, that sells electric commodity/energy service (delivered by distribution utilities) and related services to users.

Regulatory Oversight

- Plan and structure an approach to regulatory oversight for (but not limited to) market manipulation, assurance of privacy, environmental oversight, and the relationship between increasingly granular pricing and customer rates in advance of Platform Market implementation.

1. Context and Background

The electric power industry worldwide is undergoing a fundamental change: a paradigm shift from a highly centralized system designed to supply virtually all electrical energy requested by consumers to one in which consumers are now able to produce electrical energy, and sell that energy into the larger electrical grid. Continuing developments in both microprocessor-based technologies and communication and control technologies are primary causes of this paradigm shift, as they are moving electricity production and smarter consumption closer to the end consumer. Further, government policies have encouraged the development of renewable and small-scale technologies that can effectively, and increasingly economically, operate within the distribution system and improve overall environmental quality.

Distributed Energy Resources (DER) such as rooftop solar and distributed storage combined with advances in information and communication technologies (ICT) and controls have become increasingly critical elements of the physical and economic structure of the electric system. Technological innovation has convincingly moved the industry to recognize that these new entrants into the electric system provide significant gains in overall economic efficiency and that these gains can and would lead to new markets for products and services within the distribution sector.

The New York State Public Service Commission (the Commission) initiated its Reforming the Energy Vision (REV) proceeding in April 2014 with the aim of reorienting the regulatory model for the electric distribution system to support the technological and market trends that promise consumer and environmental benefits. The goals and scope of the REV proceeding are ambitious. For consideration by the Commission and stakeholders, this white paper presents market design principles and options that focus on accelerating the market for DER products and services that exist or are likely to emerge. Notably, this paper describes the design and development of a statewide Platform structured to facilitate financial transactions in energy and related electric products provided by DER.

A. DER Markets Under the REV Policy Framework

The February 26, 2015 Order in the REV proceeding, referred to as the Framework Order, states that the general goal of REV is to move the electric industry and ratemaking paradigm toward a "consumer-centered approach that harnesses technology and markets." [12] The Order places particular emphasis on improving and increasing the integration of DER into the planning and operation of the State's electric distribution systems. It expects that improved, increased integration will lead to "optimal system efficiencies, secure universal, affordable service, and enable the development of a resilient, climate-friendly energy system." [13]

The Framework Order articulates the Commission's desire to achieve its goals through policy changes

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[12] Case 14-M-0101, Proceeding on Motion of the Commission in Regard to Reforming the Energy Vision, Order Adopting Regulatory Policy Framework and Implementation Plan (issued February 26, 2015).

[13] Ibid.

that move the electric industry toward a greater reliance on market mechanisms and digital innovations. The Order assigns Distribution Utilities the role of Distributed System Platform (DSP) providers within their respective service territories, to be responsible for three major functions: integrated system planning, grid operations, and market operations. Under the market operations function, DSP providers are responsible for (i) integrating DER into their system operations and planning and (ii) supporting the development of DER markets in general.

The Framework Order outlines the Commission's expectations regarding the structure of the ultimate market for DER products and the role to be played by the DSP provider in that market:

> The structure of the market will be a function of the needs defined by the DSP and customers, the products available in the market and procurement mechanisms for those products, the identity and capabilities of market participants and their interactions among each other and with the DSP, and policy guidance of the Commission. Customers will realize the greatest benefits from open, animated markets that provide clear signals – both long and short term - for benefits and costs of participants' market activity. [14]

The Framework Order indicates that the Commission expects that the utilities' DSP procurement procedures for DER will evolve over time. In the near-term, the Commission expects utilities may begin with requests for proposals (RFPs) and load modifying tariffs, and in time evolve toward an auction approach. It also indicates that it expects DSP providers to animate and support the development of DER markets by establishing a single, uniform "market platform" across the State, with uniform market rules and technology standards.

With the Distribution Utility acting as DSP, the Commission has defined multiple functions for the utilities and related platform capabilities. The REV process is using the term "platform" in multiple ways and multiple contexts. This paper specifically addresses the utilities' market operations function, applying principles of platform economics and focusing on financial transactions for DER electric products rather than on the physical operations of the electric grid.

Each Distribution Utility is a DSP under this market structure. In that role, each Distribution Utility would continue to plan and operate its respective physical distribution system, and to monitor the topology of, and physical flow on, its distribution system. In addition, in that role, each Distribution Utility would be a co-owner of a single statewide digital Platform to enable market transactions, which an independent entity could operate to minimize the potential for conflict of interest.

This paper introduces and describes the design of a statewide digital Platform with the primary function of facilitating financial transactions for energy and related electric products and services that are provided by DER. Hereafter, the paper capitalizes the terms "Platform" and "Platform Markets" when referring to the market design conceived in this paper within the REV context. The paper refers to "platform" in lowercase in its general discussion of platform principles. While acknowledging the potential for linking DER providers with retail customers as envisioned in the "digital marketplace" customer portal discussed by the Commission, this paper argues that the primary function of an

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[14] Ibid. page 33.

economic platform-based market should be to facilitate more liquid and transparent markets for the products and services of DER.

Potential Steps to Implement a Competitive Market for DER products

The REV calls for the facilitation of a market for the products and services of DER. Three key criteria for a competitive market are well-defined products, multiple buyers and sellers who can enter and exit freely, and transparency. The first step in meeting the Commission’s objectives is to design a market structure for products and services at the distribution level that will meet those three criteria. The design of that market structure can draw upon the extensive experience with electric market design at the wholesale level. One of the many lessons learned from that experience was the criticality *of getting the prices right*. In wholesale energy markets, including the Day-Ahead and Real-Time Markets operated by the New York Independent System Operator (NYISO), getting the prices right has meant setting Locational Marginal Prices (LMPs). LMPS recognize that the value of energy is a function of the specific point in time when that energy is produced and consumed as well as the specific point in space where that energy is produced and consumed. The arithmetic calculation of LMP takes into consideration the offer-based economics of generation, the physical energy losses in transmission, and the ability of the transmission network to deliver the energy given constraints in system topology.

A parallel logic applies to getting the prices right for electric products and services from DER at the distribution level. As with LMP, the objective is to value those products and services as a function of the time at which they are produced and consumed and the location at which they are produced and consumed. The three core products of real energy, reactive power, and reserves represent the building blocks of all electric product transactions in the market. Real energy and other products that derive from it have the greatest economic value because customers consume those products directly. Distribution Utilities require reactive power to maintain voltage within an acceptable band that prevents damage to voltage sensitive equipment such as drive motors, compressors and many electronic devices. Reactive power is less economically valuable but no less essential to distribution system operations. The third core product is reserves. Reserves represent a commitment to deliver energy in the future. Those three core products can be bundled or unbundled, sold day ahead or in real time, or aggregated individually in time and space. In addition, they may be valued and/or sold forward as a basis for the calculation of the avoided cost of future capital investments.

This paper presents the extension of the concept of LMP from wholesale markets to the development of more granular pricing to reflect the short run marginal value (production and consumption) of real energy and of reactive power at any point in time and space within the distribution system. Chapter 2 describes Distributed Locational Marginal Prices (DLMP) and extended Locational Marginal Prices (eLMP), two methods of pricing that are more granular than LMP. Under a REV market design, all parties would be able to use a method of more granular pricing to establish the value of DER products in the short term as well as to estimate the long-term economic benefits of DER products.

With a method of more granular pricing as the foundation, the next step in the development of the market structure conceived in this paper is the definition of the framework in which the market will operate. Chapter 3 of the paper presents the concept of a platform as defined in the economic literature, i.e., a business ecosystem that matches producers with consumers, who continuously transact directly with each other using resources provided by the platform itself. A platform ecosystem provides outside parties with easy access to useful products or services through an infrastructure and a set of rules designed to facilitate interactions among users.

The conceived Platform is a market place, which this paper refers to as a "Platform Market," in which advantage to both sides is gained through the presence of large numbers of buyers and sellers with high visibility to both the products and the market transactions taking place. The Platform Market provides the generally digital point of contact that facilitates the transaction and facilitates the development of new products and services that could not or would not exist but for the Platform. The Platform Market provides a continuous location for matching of offers and bids at a specified time and location for the core products: real energy, reactive power, reserves, and their derivatives. It provides this location for continuous price formation up to the time at which market participants actually produce and consume energy. The Platform settles *ex post* market clearing based on the quantities of actual production and consumption.

Chapter 4 provides a general discussion of the operation of the Platform Market. Appendix D provides detailed descriptions of the operation of the Platform Market under eLMP and DLMP respectively.

While this paper focuses on the pricing, products and services and the structure of the Platform Market as a financial market for near real time transactions, the Platform can and will also provide the logical location for the implementation of the other types of transactions the Commission identified in the Order. Those potential transactions include the acquisition of more traditional load management services from DER that can substitute for or delay the need for capital investment in the distribution system. The Platform would have the functionality needed to needed to enable Distribution Utilities to acquire specific electric products they need to meet their projected requirements from DER through standardized auctions.

B. Organization of the Paper

Chapters 2 through 5 of the paper are organized as follows:

- Chapter 2 presents the key principles to guide the market design. These involve defining the needs of buyers in terms of the core electric products those buyers could obtain from DER and the associated procurement timeline for each product, developing a method for valuing the core electric products from DER, identifying the information required for market transparency and describing the range of buyers and sellers who could participate in these markets. The Chapter recognizes that the method of procurement and compensation will need to evolve over time as market participants gain experience with the new market design. Chapter 2 also presents a detailed discussion of the value proposition surrounding the development of the Platform Market.

- Chapter 3 presents principles to guide the development of a statewide digital Platform to support the REV market design, which we refer to as the Platform Market. The key components of platform markets are the participants (i.e., buyers and sellers), the information those participants exchange regarding their specific needs and products on a dynamic basis (information units), and the filters they use to find a match. The Chapter explains how Distribution Utilities could use platform markets to procure products from DER and to animate a competitive market for products from DER.

- Chapter 4 presents the specific steps that New York State should take to begin its transition to the REV market design, and discusses the implications of that transition for major stakeholder groups.
- Chapter 5 presents qualitative scenarios and quantitative modeling that illustrates the value proposition for creating the Platform Market.

The appendices to the paper include a description of eLMP and DLMP products and services, the simulation model and assumptions used to prepare the quantitative analysis presented in Chapter 5. They also provide detailed chronological examples of the daily operation of the Platform Market, i.e., “a day in the life of the Platform,” under two different levels of granular pricing, an eLMP market and a DLMP market.

2. Market Design Principles and Value Propositions

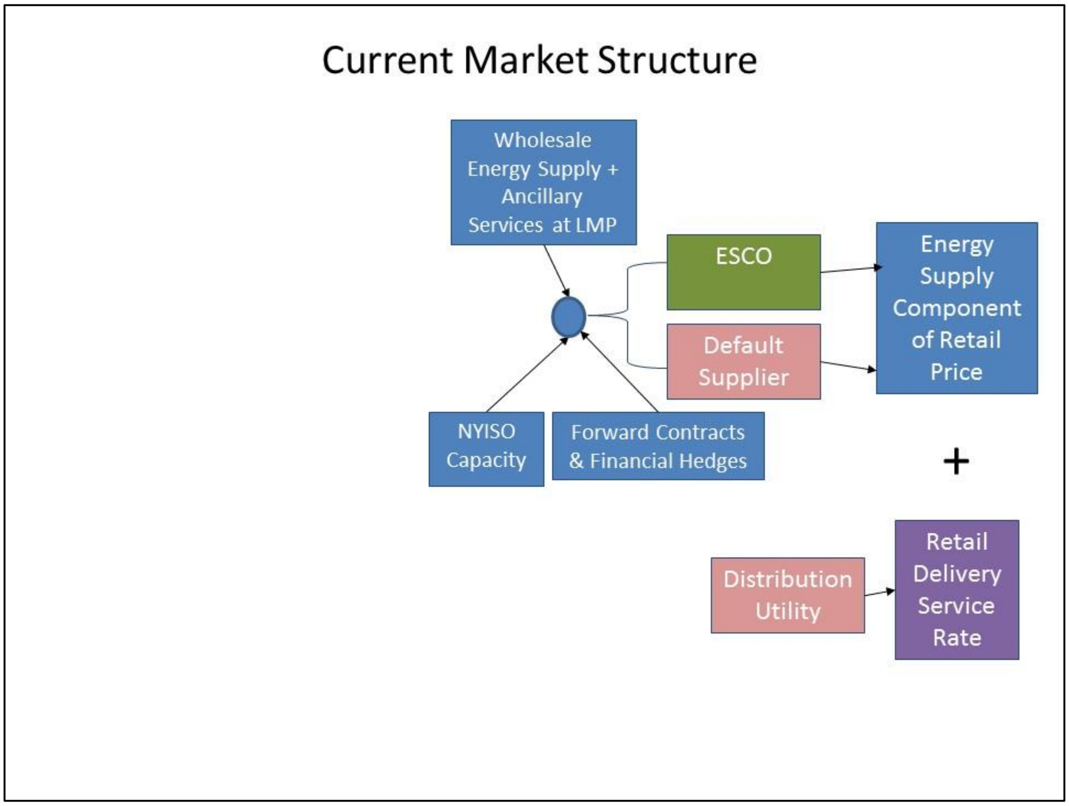
This chapter focuses on the principles of market design needed to accelerate the market for DER products and services. Section A provides a high-level illustration of how a Platform-based market structure could differ from the current market structure. Section B moves to a discussion of core electric products in terms of the needs of Distribution Utilities, ESCOs and customers. Section C describes market participants, i.e., the range of parties who may participate in these markets. Section D discusses methods for valuing and pricing core electric products that recognize the temporal and locational value of those products. These methods reflect the fundamental economic principle that markets are competitive when product prices are set at the point where the marginal cost of production intersects with the marginal value of consumption. This discussion recognizes that the method of procurement and compensation will need to evolve over time as market participants gain experience with the new market design. Section E discusses the information required for market transparency. Section F describes and provides examples of key value propositions of a Platform Market that derive from expanded market access for DER, new combinations of products and services, reduced transaction costs and improved distribution system efficiency.

Chapter 3 will describe how a Platform would animate the development of, and support the operation of, a market for core products at the distribution level based on these market design principles, i.e., a Platform Market.

A. Current Market Structure versus Platform-Based Market Structure

The current market structure for regulated retail electric service in New York State consists of two basic services, energy supply and delivery, as illustrated in Figure 1.

Figure 1. Current Market Structure



Retail customers have the ability to acquire energy supply at market prices from an Energy Service Company (ESCO) and have it delivered by their Distribution Utility. Customers who do not shop through an ESCO acquire a bundled service from their Distribution Utility, consisting of a default supply service plus their delivery service. In 2013, ESCOs supplied 72% of commercial and industrial (C&I) sector annual usage and 21% of residential sector use. Distribution Utilities provided the remaining megawatt-hours as default supply service within their bundled services. (In 2013, C&I sector use accounted for 67% of annual state electric use and residential use accounted for 33%).[15]

Under the conceived market structure illustrated in Figure 2, Distribution Utilities would continue to provide two services: delivery service and default supply service. However, as DSP providers, Distribution Utilities would be responsible for integrating DER into their provision of delivery service in their respective service territories and would have a financial incentive to do so. One component of that financial incentive would be net revenue that Distribution Utilities would receive due to the difference between charging for losses at the marginal cost of power and their actual cost of supplying those losses. Figure 2 shows that component as the “DLMP Marginal Loss Net Revenue.”

Thus, under this market structure, this paper expects Distribution Utilities to procure electric products

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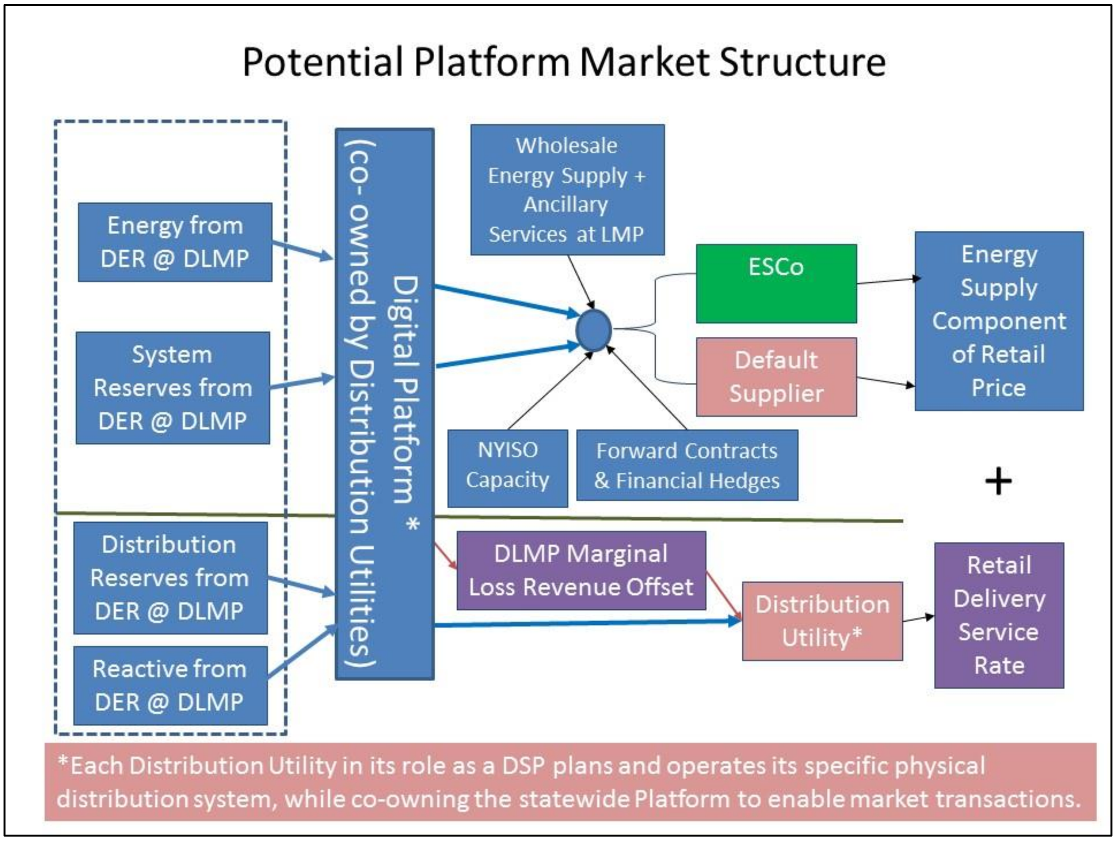
[15] TCR calculation per 2013 data reported in Form EIA-861 for Distribution Utilities and in LIPA Biennial Report, August 2014 for LIPA. (Calculation assumes LIPA use is all bundled since report does not report bundled and delivery service MWh.)

and services from DER to the extent they can use those DER products as alternatives to investments in physical infrastructure. In addition, it is assumed that Distribution Utilities will begin, sooner or later, procuring electric products from DER to provide a portion of their default supply service to the extent that they can legally use those products to cost-effectively displace purchases of energy, ancillary services, and capacity from the relevant NYISO wholesale markets.[16] The paper also assumes that ESCOs will also procure electric products from DER to provide a portion of their supply services. Finally, the Platform could open opportunities for customers to purchase electric products from DER.

Figure 2. Illustration of Potential Platform Market Structure



The balance of this chapter describes the design of a market that would enable Distribution Utilities, ESCOs and other buyers to purchase electric products from DER owners. As shown in Figure 2, this design relies upon a Platform to animate the market for DER products, and to support the operation of that market. The resulting Platform Market will facilitate the sale/purchase transactions for core electric products from DER in various ways that will reduce the costs of executing those transactions and will provide market transparency by posting a range of market information. Chapter 3 will describe the general principles of the Platform Market, and Chapter 4 will describe its role in a REV market design.

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[16] The Framework Order states that utilities would not purchase power that would constitute a sale for resale under the Federal Power Act, except for purchases that are otherwise required by law. This paper takes a broader view based upon TCR's understanding that FERC may not interpret transactions in which the buyer acts as an agent of the seller, rather than holding title as a sale for resale.)

B. Electric Products from DER

DER is typically discussed in terms of technologies such as energy storage (ES), electric vehicles (EVs), solar photovoltaic (PV) or combined heat and power (CHP) or programs such as demand response (DR) and energy efficiency. However, to develop a power market at the distribution level in which DER can participate, it is necessary to define clearly the core electric products central to the operation of the power systems. These definitions are essential to identify the electric products and services that Distribution Utilities could procure from DER to integrate into their distribution system operations, which various parties could procure to aggregate and sell as alternative sources of ancillary services in the wholesale market; and which Distribution Utilities and ESCOs could procure as alternatives to purchases of energy plus ancillary services and/or capacity from the bulk market.

Core Electric Products

This paper distinguishes three categories of core electric products that are central to the operation of power systems: real energy, reactive power, and reserves.

- **Real energy,** measured in kWh, is the fundamental physical electric commodity underlying the electric products required by utilities, ESCOs and customers. This fact is particularly relevant to the formation of prices for the other core electric products.
- **Reactive power or Volt Ampere Reactive,** measured in kVAR, sustains the electrical field in alternating-current systems while maintaining voltage within specific limits required by regulation,
- **Reserves,** measured in KW, represent the potential to deliver real energy (kWh) at a point in the future.

The other electric products discussed in the paper are all derivatives of, or combinations of, these three core products.

Reactive power and certain types of reserves are particularly important to the operation of distribution systems. Utilities must maintain voltage within specified limits and have traditionally done so through the design of distribution circuits and investments in capacitors. However, reactive power from DER represents a supplemental if not alternative source. Moreover, significant PV penetration causes capacitors to exceed their design daily duty cycles and quickly wear out, suggesting that services for voltage control will become increasingly valuable at locations where utilities are integrating greater quantities of PV. Similarly, operating reserves from DER that can ramp their output up and down quickly may be particularly valuable at specific locations on distribution systems where the Distribution Utility would otherwise have to make a traditional infrastructure investment. The ability of DER to provide core electric products that can serve as alternatives to capital investments in distribution system infrastructure and/or to procurement of electric products from wholesale markets varies by DER technology. PV can provide real energy and reactive power, EV and ES can provide all three core products, and DR can provide real energy and reserves.

One of the economic factors that will affect the quantity of each core product a specific DER will choose to provide during any given time interval is the fact that any unit (kW, for instance) of a specific resource can provide only one of the three products during that time interval, i.e., either real energy, or reactive power or reserves.[17] [18] [19]As a result, the party controlling operation of a DER must choose which product to provide during a given time interval. According to economic theory, the party making this choice will consider the relative value of providing each product. For example, if a party is considering providing reactive power he or she will consider the prices they would receive for providing either real energy or reserves. The prices for those latter products represent the party's opportunity costs of not being able to use its DER to provide either of those products during that time interval. Since real energy is the dominant core product the prices for reactive power and for reserves, the value of providing those products tends to be heavily affected by the opportunity cost of not producing real energy.

The contractual and operational attributes of these core products will also affect their value. Appendix A summarizes those attributes, which include:

- **Product location.** This is the geographic location at which the product may be bought or sold and for which product prices are set. It identifies the geographic granularity of the product market. Locations may be region-, zone-, or utility-wide; at an aggregated pricing node or trading hub; or at a location as specific as the meter for customer or resource.
- **Product period.** The product period refers to the time period for which the product may be transacted and prices are determined. It identifies the time granularity of the product market. For energy products, this interval might five minutes. However, forward capacity products can be traded on a monthly, seasonal, or annual basis.
- **Financially binding forward commitment and associated financial penalty for nonperformance.** A forward commitment is as agreement to provide a quantity of a specific product, in a specified period, when specified conditions are realized, and a dispatch signal or notice is issued or to purchase or use a quantity of a specific product in a specified period. Forward commitments may be physical with penalties for a failure to perform or financial when the obligation may be settled financially or covered by an offsetting transaction in a market that clears at a future point in time.
- **Resource qualifications.** To make a forward commitment to perform physically a resource may have to meet and maintain specified physical, deliverability, measurement, testing, or other qualifications. Forward commitments also may require additional credit qualifications.
- **Response or ramp rate (rate of change in output or usage)**. Reserves (including Frequency Response, Regulation, and Operating Reserves) are dynamic products in that resources are required to change their output or usage at a specific rate commonly specified the movement of

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[17] Caramanis, Michael. "It Is Time for Power Market Reform to Allow for Retail Customer Participation in Distribution Network Marginal Pricing," *IEEE Smart Grid* (2-12).

[18] Ntakou, Elli and Michael Caramanis. "Distribution Network Electricity Market Clearing: Parallelized PMP Algorithms with Minimal Coordination," *53rd IEEE Conference on Decision and Control* (December 2014).

[19] Ntakou, Elli and Michael Caramanis. *Distribution Network Spatiotemporal Marginal Cost of Reactive Power*, Proceedings of the 2015 IEEE Power & Energy Society General Meetings, pp. 1-5.

output or demand per second over a specified period. The required change in output or demand may be specified as a percentage of the called upon Reserve quantity.

DER Technical Ability to Provide Core Products

Table 1 summarizes the technical ability of various DER technologies to provide electric products that are direct derivatives of real energy, reactive power, and reserves and that have a value in the current wholesale market. DER are not typically interconnected at transmission voltages and, under current rules, they are generally unable to sell either core electric products, or their derivatives, directly in the current wholesale market. (Although DER currently have the right to participate in certain NYISO markets through Demand Response programs, requirements of these programs limit their involvement in the current market. A Platform could enable DER to engage in the direct sale of electric products and facilitate an expansion of responsive demand if unencumbered by limitations in existing Demand Response programs.

Table 1 speaks only to the technical capabilities of the DER technology mapped against existing and future market products. It does not address the likelihood or the ability of the different market participants to provide the service. Some of these technologies are too costly today to provide the defined services.[20] The terms in the cells have the following meanings:

- **Today** means that the particular technology is now providing the particular market product in the wholesale markets or is technically capable of providing the product were that product/market accessible to it as a distributed resource given current performance requirements, technology capabilities, and a Platform that supplemented current markets and extended product definitions to incorporate DER.
- **Future** means that the technology is capable of providing a market product subject to certain conditions. These conditions are typically advances in the inverters or controls typically deployed today. Some ancillary products do not exist as market products today (frequency response, as an example) but may become important ancillary products in the future as the need grows due to conventional generation plant retirement. Demand response and EV charging provide energy on an implicit basis by shifting demand in time. This strategy refers to responsive demand and smart charging shifting the timing of demand in response to anticipated prices outside of conventional demand response programs.
- **Blank cells** indicate that the technology is not suitable for providing a given market product for technology performance reasons.

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[20] As an example, ES can provide a capacity product but most storage technologies are expensive sources of capacity products, particularly for capacity product durations greater than one hour.

Table 1. Technical Ability of DER Technologies to Provide Core Electric Products

Market Product		**Demand Response**	**Photo voltaic**	**DG (fossil)**	**EV Charging**	**Storage**
DA Energy	**Delivered**		Today	Today		Today
	Reduced (DR)	Future	Today	Today	Future	Today
	Time Shifted	implicit		Today	implicit	Today
RT Energy	**Delivered**		Today	Today	Future	Today
	Reduced	Today	Today	Today	Future	Today
	Time Shifted	implicit			implicit	Today
Wholesale Ancillary Services	**Spinning Reserve**	Future		Future	Future	Future
	Frequency Regulation (traditional)	future reg down only		Today	Future	Today
	Black Start		Future	Today		Future
Reactive Power	**Var Support**		with advanced inverters	with advanced controls	future with advanced inverters	Future with advanced inverters
	Voltage Control		with advanced inverters	with advanced controls	future with advanced inverters	
Reserves	**Up**			Today		Future but requires charge state held aside
	Down (DR)	Today		Today		

C. Prospective Participants in a Platform Market

This discussion categorizes and summarizes the likely participants in a Platform Market. It categorizes those prospective participants as either asset-backed or non-asset-backed.

Asset-backed Participants

Distribution Utilities as DSP providers. In grid operations, Distribution Utilities, as DSP providers, will be able to realize distribution system cost savings and reliability benefits and avoid capital investments in infrastructure by purchasing reactive power from DER to provide local Volt VAR control (VVC) as well as purchasing real energy and local reserves. In addition, the Platform Market would provide certain DER technologies, such as ES, the opportunity to provide energy to the DSP provider or, via an aggregator, to provide wholesale market services to the ISO.

DER owners. Many entities may either own, or control the operation of, DER technologies such as distributed generation (DG) that produce electricity or DER technologies such as ES, EV, buildings that can take advantage of their thermal inertia, and other forms of responsive demand that can store or release electricity or shift the timing of electric demand. Commercial buildings and other forms of responsive demand may be early participants in the Platform Market. EV charging and discharging may also be an early participant because of its potential to be a large electrical load and the ability of parties to control it relatively easily because charging systems have built in communications, metering, and control capabilities without causing inconvenience to EV owners.

It is likely that many individual DER owners will want to participate in the Platform Market through their ESCOs or aggregators who could provide applications for managing demand consistent with their customers' preferences and focus on the core electric products those DER owners have to offer. However, it is reasonable to expect the Platform Market will animate suppliers of small-scale energy management systems, such as the NEST thermostat and the Tesla Storage Wall, to develop consumer-based Platform applications for those individual DER technologies.

Distributed generation developers or financiers. The Platform will offer both potential benefits as well as risks to DG developers and financiers. Increased granularity in pricing provides the potential to identify locations for DER with higher value to the system and therefore higher potential return over time than may be possible with current pricing structures that include net metering. On the other hand, the fact that pricing will be variable as opposed to predictable will create risk for developers and their financial backers. This represents a shifting of risk from ratepayers in today's market structure to the developers under a platform-based market that reflects both the temporal and spatial value of DER. To offset this risk, the Platform will offer a well-structured market for the output of DER and the opportunity for forward contracting for resources that meet specific distribution system requirements. Forward option contracts will help developers secure financing for DER investment by providing a firm commitment for utility purchases of needed DER products at a known price.

ISO/Bulk power resources. Given the emergence of DER, the NYISO will have to forecast and serve the demand appearing on the bulk power system net of that supplied by DER. Central station generation and other bulk power resources are expected to participate primarily in NYISO wholesale markets. However, to the extent a bulk power system resource has transmission rights enabling it to transfer power to the substation where a given local distribution system connects to transmission, that resource could offer products on the Platform to directly and transparently compete with local DER.

Non-Asset-backed Participants

ESCOs and Distribution Utilities as default service suppliers. ESCOs currently supply the majority of large industrial and commercial customer load in New York State while Distribution Utilities currently provide default supply service to the majority of residential and small commercial load. ESCOs and default service suppliers should see the Platform Market as an additional source of energy to balance economically their portfolios and of additional services to lower their costs and their customers' costs. ESCOs may respond to the Platform Market by becoming aggregators of DER, purchasers of DER products, providers of value added services, and/or developers of DER.

Aggregators. This paper uses the term aggregator in the generic sense of a market participant that brings together a number of smaller market participants to provide a larger product package that better meets the needs of other participants in wholesale and/or retail markets. Currently, aggregators predominantly offer DR in the wholesale market. For aggregators the Platform Market has the potential to be an opportunity or a threat.

As an opportunity, the Platform Market provides aggregators easier access to a larger set of resources to buy from and customers to sell to, including the possibility of providing increased services to the wholesale markets (its primary customer today). It also provides new opportunities to offer DER to DSPs to support operation of the distribution grid. Aggregators will likely seek to aggregate core electric products from both DR and other DER technologies such as ES, EV or PV. However, the availability of those additional products will depend on the extent to which customers invest in DER. Thus, as part of their business model aggregators may provide financing for those end user investments in DER, thereby morphing from being solely an aggregator to being a DER developer. Some market participants may perceive the method of price formation in the Platform Market, i.e., continuously clearing, and reserve based ancillary service products at the distribution level as adding complexity. Those perceptions may favor aggregators, as more likely than individual DER owners, to be participants in the Platform Market.

As an alternative to aggregation, individual DER owners and consumers will have the opportunity to participate in the Platform Market directly, rather than going through an aggregator that has its own proprietary platform. By providing increased price transparency to individual DER owners and customers, the Platform Market may reduce the margin on transactions that the aggregator has under the current market structure.

Financial participants. Financial participants include traders and other entities that are not asset-backed. Currently these entities primarily operate in the wholesale day-ahead markets as "virtual" participants. For example, there are reports that NYISO wholesale energy markets see virtual trading volumes more than two times the physical market trading volumes. Traders are attracted to markets with transparent prices, clearly defined settlements procedures, provisions for credit and credit risk management, standardized products, and especially, liquidity. It is not clear whether traders currently operating in the NYISO wholesale markets would see the Platform Market as having sufficient volumes to warrant their participation or whether they would see a benefit that could occur from bringing more volume to existing wholesale markets via aggregators, ESCOS and Distribution Utilities as providers of default supply service..

Customers. Individual electric consumers will have the opportunity to purchase power and services on the platform. Larger and more sophisticated customers could use the continuous trading on the platform to hedge risk by locking in a price when they schedule their demand for electricity or when they modify that schedule. Most consumers can be expected to participate through their ESCO or default supply service provider who may be purchasing power in NYISO bulk power markets, engaging in wholesale transactions with DER on the Platform, brokering retail transactions for their customers through the Platform, enabling customers to manage the timing of their power usage in response to anticipated prices, or employing a combination of these strategies. Customers could also elect to purchase renewable energy credits or other forms of clean energy through the Platform. To the extent a distribution system permits islanding during an outage, customers could have an incentive to buy service directly from a local generator. In addition, given either a future application or an alternative launch strategy, customers could use the Platform to find an ESCO whose service offering matched their preferences.

D. Valuation and Price Formation of DER Electric Products

A key premise of REV is that the LMP energy prices in the NYISO wholesale market do not fully capture the system value of electric products from DER – specifically their locational value within the distribution system. The Commission and the New York State Department of Public Service (the Department) have identified a number of potential benefits one could reflect in in the distribution level value of specific DER.

The Department Staff White Paper on Ratemaking and Utility Business Models (July 28, 2015) presents a conceptual approach to estimating the system value of DER:[21]

> The system value of DER is divided into two components: the energy value and all other values associated with distribution-level resources. The energy value in New York is established by power markets and is called the LMP. The distribution delivery value (i.e., value of D) can be added to the LMP to create “LMP+D”—the full value of a DER on a time and location-specific basis.
>
> Determining LMP+D is particularly important in the context of REV, because REV markets will be multi-sided; they will consist of transactions among customers and service providers, and also transactions between utilities and prosumers or DER providers acting as intermediaries on their behalf. For purposes of the utility transaction, it is essential to quantify the distribution system value that DERs can provide. It is also essential that the market have access to data and price information on an appropriately dynamic basis.
>
> While the LMP is already well established and transparent, the value of D is not. Values can include load reduction, frequency regulation, reactive power, line loss avoidance, and resilience.

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[21] ____. *Staff White Paper On Ratemaking And Utility Business Models*. Case 14-M-0101. July 28, 2015, page 90.

Other values not directly related to the distribution system are installed capacity requirements (ICAP) and emission avoidance.

Conceptually the value of a specific electric product from DER would be the value of the corresponding product in the wholesale market in the relevant NYISO pricing zone or at the closest point of LMP measurement plus an adjustment for the incremental value of acquiring that product at, or near, its specific location in the distribution system. Under this concept, the value of energy from a DER at location X would be the real time LMP plus an adjustment for losses plus any other marginal costs (positive or negative) that the distribution utility would incur to deliver energy to location X during that time interval.

The Commission has directed the Department to commence work on a report on the valuation of distribution system benefits provided by DER. At this time, there is not a consistent definition of the "value of D."

Applying the traditional administratively determined approach to calculating the "D" adjustments would raise a number of issues. The traditional approach would be for the Distribution Utility to periodically develop and update estimates of the losses and other marginal costs it incurs to deliver energy to location X. The first problem would be that the estimates of D would typically only be made and updated periodically, e.g. annually, and for representative system conditions. As a result, they would not be specific to the actual system conditions at or close to the time of the actual transaction. The second problem is that the resulting price would represent the maximum value to the distribution utility but it might significantly exceed the marginal cost of procuring the product from the DER in that time interval. The determination of D under this administrative approach, particularly for periods further out in the future, is subject to wide interpretation as to the future investments that could be avoided and their value. Further, as was painfully learned with the application of avoided cost methodologies to set standard offers for distributed generation under the Public Utility Regulatory Policies Act (PURPA), forecasting future prices is fraught with the reality that "the forecast is always wrong." The forecast is either too high – the more common case – or occasionally too low and it is the residual ratepayers who are stuck with the long run obligation. One need only look at the results of feed-in tariffs in the US and more specifically in Europe to see that fine and continuous tuning is required but only occasionally implemented.

Given the market emphasis of REV, and the problems with administrative determinations of "D," this paper provides the option of a market-based approach to determining the value of DER products and to price formation for those products. This paper refers to that preferred market based approach as the Distributed Locational Marginal Price (DLMP). To understand price formation under the DLMP approach, one needs to understand the fundamental process of price formation in markets for real energy and reactive power.

Price Formation and Settlement in Markets for Real Energy and Reactive Power

Markets for real energy and for reactive power are somewhat unique because those two products are consumed at the moment they are produced, and because the quantity of electricity that will be consumed during a given moment in time cannot be forecast with 100% accuracy. As a result of these two characteristics, there is always a difference between the quantity and marginal cost of electricity scheduled to be produced and consumed during a given moment and the quantity and marginal cost of electricity actually produced and consumed during that moment. This difference in quantity and price, referred to as an imbalance, is calculated after the moment is over and may be positive or negative relative to the scheduled quantity and price.

Because of these two characteristics, markets for real energy and for reactive power must have two distinct processes for price formation.

The first process sets prices for the electricity scheduled to be produced and consumed, i.e., these prices are set prior to consumption or *ex ante.* As is the case for the majority of energy traded in the NYISO wholesale energy markets, prices under a DLMP market structure would form through an *ex-ante* process in which individual traders (buyers and sellers) enter bilateral contracts for products to be delivered at specific locations on the distribution system during specific time periods, for instance, in a specific hour.[22] Parties could continue to enter such bilateral transactions up to a set point in time preceding the time specified for delivery.

The second process is a separate clearing market to resolve the imbalances between scheduled supply and actual consumption that will occur under this market structure. Imbalances will occur because demand forecasting is not and cannot be perfect, and because electricity is produced and consumed simultaneously. As a result, *ex post,* the Platform will financially clear all positions from the forward market. DSP providers will provide the Platform the information it needs to calculate imbalances, i.e., metered quantities of actually consumed real energy and reactive power and the measured flows on the system. The Platform will run a mathematical load flow calculation, with the substation LMP as the reference price, to determine a clearing price at each of the nodes at which trading occurred. This calculation is conceptually comparable to the New York Independent System Operator calculation of real-time Locational Marginal Prices (LMP) used to clear financially all positions in the wholesale market. While the complexity of the Platform load flow calculations will increase with greater levels of granularity, the logic of the calculation is independent of the level of granularity of the nodal system.

Under the conceived market design, the Platform Market, described in Chapters 3 and 4, would support the first, *ex ante* market transactions, by providing the mechanics for and facilitating the trading of core electric products within each distribution service territory. In addition, as discussed in Chapter 4, the Platform provider would run the analyses required to calculate the imbalance prices required to financially clear all positions from the forward market in each Distribution Utility service territory, i.e. the *ex post* market.

The following example illustrates price formation in the *ex-ante* market.

- ESCO A places a *bid* on the Platform to buy 2 MW of energy for delivery at a specific node during the afternoon peak hours ending 15:00 to 19:00 on each weekday of the following week at a specific price of $35/MWh. ESCO A has forecast that price would be less than the nodal LMP for

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[22] It is theoretically possible that a market participant could specify a product period as short as a single interval or as long as a defined set of hours each day for a several month period.

that location during those peak hours on those weekdays. Aggregator XYZ sees this bid on the Platform and makes an *offer* to supply 2 MW at the location during those hours at $37/MWh. If the difference between the bid and the offer is within the acceptance band defined by the Platform Market rules, the Platform confirms the transaction at $36/MWh after agreement by both parties. Independent of other transactions for the same or overlapping time blocks, the Platform Market has recorded a 2-MW transaction for each of five weekdays for the periods of 15:00 to 19:00 for a specific location within the distribution system. As in other commodity markets, the Platform Market posts the bids and offers but not the identities of the buyers and sellers who executed those transactions.

- On the Friday before the delivery week, ESCO A perceives that it has committed to buy 2 MW more energy for the Monday peak hours than it now expects to need, i.e. it is “long” for Monday. ESCO A places an offer to sell the 2 MW it bought at $36 for $34, because it has also revised its forecast of Monday’s market clearing prices. A financial trader sees this offer and makes a bid to buy at $32/MWh, but ESCO B makes a bid to buy the 2 MW at $34/MWh. ESCO A accepts the $34/MWh bid of ESCO B, and transfers its contract for Aggregator XYZ to deliver that quantity on Monday to ESCO B. The Platform reports the $34/MWh price, which reduces the price visible on the Platform for the Monday hours by $2/MWh.
- On the Friday before the delivery week, ESCO A also perceives that it will be “short” for Thursday. It places a bid to buy an additional 1 MW for the peak hours on Thursday at $38/MWh, having revised its forecast of market prices for peak hours on that day. A trader without 1 MW under its control but with a willingness to find it posts an offer to provide 1 MW on Thursday at $45/MWh. ESCO A believes that price is higher than the clearing price it forecasts it will have to pay for being short on Thursday; as a result, it does not contract for the incremental 1 MW. If ESCO A is actually short by 1 MW on Thursday, i.e., its customers use 1 MW more than it has under contract, ESCO A will have to pay the price set in the second, imbalance or clearing price formation process, for that additional use.

Continuing the illustrative example to the *ex-post* market, after the close of the *ex-ante* market the Platform calculates the imbalance quantities of each party and the relevant settlement prices based upon measured quantities provided by the DSP provider.

- Assuming Aggregator XYZ actually delivered 2.5 MW to ESCO B in the hour ending at 15:00 on Monday, the DSP provider would know this quantity because it is monitoring the flows on the distribution system and tracking injections and withdrawals within the distribution system and at substations where distribution connects with the transmission system. The DSP provider would report injections and withdrawals by location, power flows, and the physical topology of the distribution system to the Platform. The incremental 0.5 MW delivered by Aggregator XYZ was consumed somewhere within the larger network by another entity who consumed more than its *ex-ante* contract quantity. Given that consumption plus losses account for all energy delivered into the distribution system in a point in time, for that point in time, the Platform can arithmetically balance all financial transactions once it knows the actual quantities at each measured node.

- Assuming ESCO A customers consumed 1 MW more on Thursday afternoon than the quantity for which they had contracted for that afternoon; ESCO A would pay the imbalance price the Platform calculated for an additional 1 MW at the location during those hours.

The price formation process in the *ex-post* clearing market relies upon the Platform's calculation of settlement prices. The platform then uses those prices to determine the incremental amount that entities whose actual consumption exceeded their supply position at market close must pay to the Platform. The Platform in turn uses those revenues to compensate entities who under consumed. The solution results in a zero sum balance.

To make these *ex-post* price calculations, the Platform requires the following information:

- Actual real energy and reactive power flows (kWh and KVARh) at each node in each time period. These power flows can be recorded by interval kWh and KVARh meters or recording devices and communicated by DSP providers to the Platform as time stamped data. (The settlement process does not require real-time or synchronous communication.)
- A calculation of locational clearing prices at each node in each time period from a distribution load flow model. This calculation requires a sufficient number of data points, determines the *ex post* value of real energy and reactive power at each measured node in the distribution system. The value is a function of voltage and other distribution constraints, the marginal value of distribution losses, impacts on the life of distribution transformers, the physical topology of the distribution system and *ex post* LMPs at the transmission substation.[23]

DLMP: a Market-Based Approach to Valuation and Price Formation of DER Products

The value of electricity varies by time interval and location within any utility distribution system. With continuing advancements in information, communications, and control technology, it is feasible to extend time- and location-specific markets to reflect these differences. Establishing distribution level markets for DER products at more granular pricing would accomplish this outcome. These markets could rely upon DLMPs much like the NYISO wholesale energy markets rely upon LMPs.

Implementation of more granular pricing for core electric products at the distribution level is a key focus of this paper and provides the economic logic of the Platform Market conceived in it. The paper does recognize that DLMP is only one of various possible approaches to calculation of the value of DER. However, an analysis of the DLMP approach is fundamental to understanding the gains in economic efficiency from moving the pricing point for electric product production and consumption deeper into the distribution system.

The mathematical structure for the calculation of DLMP is analogous to, and can be coordinated with

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[23] In an ultimate DLMP, market with large numbers of DER, near real-time exchanges of information between the DSP and DERs, as well as among electrically proximate DERs, would enable distributed devices to converge rapidly on increasingly efficient solutions. *Ex post* valuations also would tend to reflect these efficient solutions. For a description of solution algorithms, see: Ntakou, Elli and Michael Caramanis. "Distribution Network Electricity Market Clearing: Parallelized PMP Algorithms with Minimal Coordination, *Proceedings of 53rd IEEE Conference on Decision and Control* (December 2014).

the NYISO calculation of LMPs. DLMP measures the locational value of real energy and reactive power at specific nodes within the distribution system, and therefore can measure the value of core electric products from DER.[24] [25] The calculation of DLMP is distinct from and more complex than that for LMP but arrives at the same conceptual point from an economic perspective – it defines the precise market value of electric products and services at any point in time at any location within the distribution system. Appendix B presents an illustrative calculation of DLMP; Appendix C provides the mathematical formulation.

A key point to note with respect to the establishment of the distribution markets is the importance of the price of real energy in the wholesale or bulk market. The price of real energy is the key driver of all the electric products against which DER products are competing because at the most basic level it represents the opportunity cost. As noted in the preceding section, the same kW of capacity can only provide one core product during any given time period, e.g., real energy, reactive power, or reserves. Any given asset can deliver a mix of core products but cannot do so beyond the maximum capacity of the unit. Thus, when deciding which and what mix of core products to produce the resource owner has to decide which product or products will yield the greatest compensation. The price of real energy is the most common reference point for those decisions.

Chapter 4 provides a detailed description of how the DLMP market would operate. Appendix D provides an example of a day in the life of the Platform under a DLMP Market. In general, when fully implemented, the Platform would support transactions for the three core products along with a breadth of other related and ancillary products. The DLMP market would transact those core products separately from, but in conjunction with, the NYISO wholesale markets.

Fundamentally, the mechanics of the market for core products on the Platform occur in three blocks:

- **Block 1.** The time period in advance of the NYISO Day-Ahead Market. During this time, the Platform is the site of long term agreements for core products.
- **Block 2.** The time period after the close and posting of the NYISO Day-Ahead Market and before the Real-Time Market. During this time period, this paper expects the market to be liquid at DLMP locations. Based on their position in the wholesale market, a potential buyer of DER services will post on the Platform price bids to purchase if short or offers to sell if long. DER and other purely financial players will be highly likely to do the same from the other side of the market. The continuous market matching function of the Platform would be available to match bids and offers in much the manner that the Inter Continental Exchange (ICE) does at the wholesale level today (though for many more products). Both the buyer and the seller would have calculated in advance their expected alternatives and have entered the market with offers and bids to do no worse than, and hopefully better than, their other alternatives. The matching of buyers and sellers at agreed prices on the Platform creates the bilateral price formation process that will continue until the time at which the market closes in real time. At market close,

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[24] Ibid.

[25] Ntakou, Elli and Michael Caramanis. *Distribution Network Spatiotemporal Marginal Cost of Reactive Power,* Proceedings of the 2015 IEEE Power & Energy Society General Meetings, pp. 1-5.

both buyers and sellers hold their forward positions.

- **Block 3.** The time period after the close of the Block 2 market previously described, when market participants have consumed or called their actual quantities of real energy, reactive power and reserves. Block 3 is the time at which settlement of financial positions takes place, i.e., when the Platform determines the financial adjustments required to resolve imbalances. At the point of closure, the DSP reports all closing positions to the Platform. If, at closure, a given position is net long it will clear at, i.e., be paid, the DLMP for its location in the distribution system. The reverse is true for a given position that is net short at the market close. The Platform clears with net short positions at the relevant DLMP for their locations.

eLMP as the Initial Step Toward DLMP

This paper expects development of DLMP markets to take time and require some new investment. A key first step in moving from the current market design to more granular pricing and toward DLMP is to start using the LMPs that NYISO calculates for each generator node within each zone. This paper refers to these prices as eLMPs. NYISO currently calculates those eLMPs at 800+ generator nodes. However, NYISO software currently does not retain and report these values. (In fact, the power flow that NYISO files with FERC include more than 2,200 points and commercially available simulation models can calculate LMPs for these points.) Moving to day-ahead eLMPS and real-time eLMPs would more accurately identify locations where DER have and therefore could claim the greatest value.

Illustration of Benefits of DLMP and eLMP over LMP or BAU

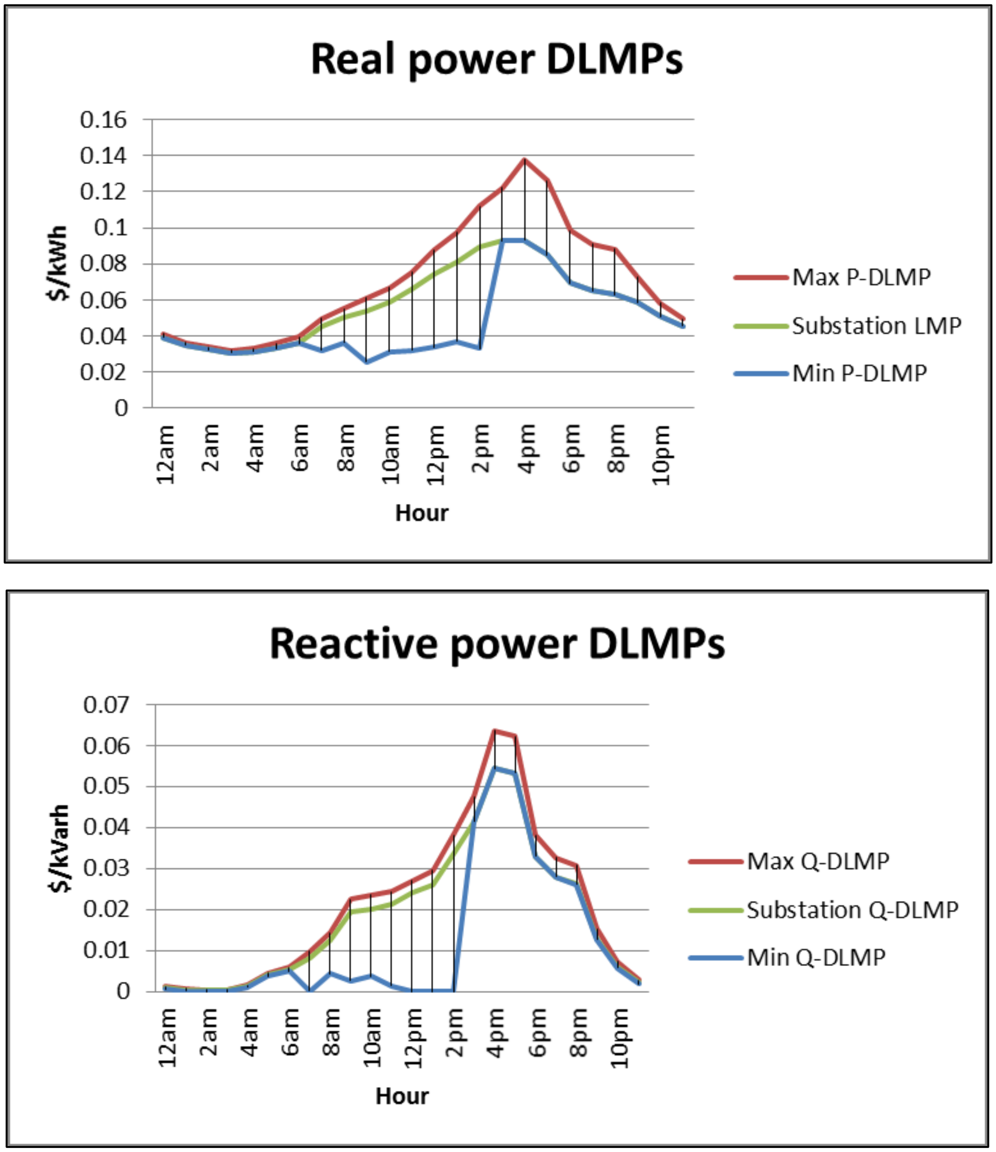
TCR prepared a quantitative assessment of the value of moving to more granular locational prices under a Platform Market by using the DistCostMin (DCM) model, an optimization modeling system developed by Boston University and described in Appendix B. Chapter 5 provides a full discussion of the analysis and results.

In summary, DCM calculated the total cost of meeting retail demand on a representative single radial distribution system feeder with 800 nodes serving a mix of residential and commercial loads and assumed to be located in the Capital Region of New York State (Capital Feeder), under four levels of increasingly granular pricing:

- Business as Usual (BAU), under which DER see and respond only to the average energy value for the day, i.e., a flat value for energy throughout the 24-hour period.
- LMP, under which DER see and respond to the LMP in each hour of real energy only at the substation node to which their feeder is connected.
- eLMP, under which DER see and respond to an eLMP of real energy in each hour. The eLMP is directly related to, but more granular than, the substation node LMP.
- DLMP, a full marginal cost based market that discovers the DLMPs of both real energy and reactive power and that schedules DER transactions for both real energy and reactive power based upon those DLMPs.

The modeling results illustrate the criticality of location within the distribution feeder and thus of the relative value (positive and negative) of energy within the system. DCM valued real energy plus reactive power at each node, i.e., at commercial customer meters and at residential pole transformers, for a peak summer day and a peak winter day for each market structure under low and high levels of DER penetration. Figure 3 provides a graphic summary of the results of the DLMP (dollar value) for real energy and reactive power indicating the maximum and minimum values that occurred at any point within the system for each hour and the LMP nodal value (the nearest point to the wholesale market). At 2 p.m. on the test day, the value of real energy ranges from a low of $0.033 per kWh to a high of $0.112 per kWh. The value of reactive power at 2 p.m. ranges from a low of zero to a high of $0.038 per KVARh.

Figure 3. Maximum and Minimum Real Energy and Reactive Power DLMPs, Summer High DER Scenario



The modeling results presented in Chapter 5 and Appendix B demonstrate significant economic efficiency benefits from moving to a DLMP market structure (maximum granularity in pricing) from either a BAU, LMP, or eLMP market structure. For example, under the Summer Peak day High DER scenario reported in Chapter 5, there is a 5% reduction in total cost to consumers on the feeder. This reduction is brought about by increasing pricing granularity from a single average price per day, with no separate pricing of reactive power, to hourly DLMPs for both real energy and reactive power at each of the 800 nodes.

It is not surprising that DLMP provides the largest benefits (i.e., the greatest reduction in societal costs) based on the ability of DER to respond to granular locational prices and to provide both real energy and reactive power in response to those DLMPs. In addition, from the perspective of consumers in the modeled distribution system, all load benefits from the reduction in the average cost of serving the total load, whether or not the load directly responds to DLMP prices. The modelling also finds significant energy cost savings from price responsive demand at commercial buildings, which this paper expects to be an early adopter of more granular pricing.

E. Market Transparency

The valuation of DER, and the success of the Platform Market, will require a dramatic increase in the type, quantity, and quality of relevant market information made available to market participants. Currently most if not all relevant knowledge and information concerning the distribution systems resides with the Distribution Utilities. This includes the detailed topological information of the substations, wires and capacitor location and operation. In addition, the Distribution Utilities hold the relevant data with regard to customer patterns of consumption virtually all of which exists only at the level of distribution substations. Market participants such as suppliers of DER, aggregators of load, buyers, or sellers of core products or derivatives or traders will all need these data to participate intelligently in the market.

Within the REV process, it has been suggested that the Distribution Utilities could offer their data as a market product. While the data is valuable, there are serious concerns associated with any attempt to capitalize on its sale. First, current regulations limit the distribution, and certainly the sale, of Distribution Utility data. Second, charging for the data would create an additional transaction cost, or level of friction, in the early stages of the market that, depending on the cost, may be a non-trivial deterrent. Experience in the development of platforms, as discussed in Chapter 3, indicates that making uniform data available to market participants whereby analytic capabilities can develop both on the consumer facing side of Distribution Utility and with third party suppliers is likely to provide a boost to the development of the market. Working from common and accepted data also provides a level playing field for new and existing entities in the market.

F. The Platform Market Value Proposition

At its core, a Platform Market will create significant value by expanding market access for DER. Today, DER have, for a variety of legal and practical reasons only limited opportunities to participate in power markets. Not being interconnected at transmission voltages, DER cannot sell energy directly into the NYISO wholesale market and they lack a market for selling supply to ESCOs or directly to other retail customers. Although DER can participate in NYISO demand-response programs, the requirements of these programs have limited their access. There is no participation in NYISO's energy market demand-response program and only three customers participate as demand-response in NYISO ancillary service markets. Although there is significant participation in the installed capacity (ICAP) demand-response program, it involves costs and risk that tend to exclude smaller customers, similar capacity programs have been legally challenged, and such programs can be inequitable and subject to abuse.[26] Moreover, DER are unable to offer net supply in the ICAP program, as program rules limit their participation to the host facility's average coincident load. Most retail customers do not have interval meters. As a result, DER owners and their suppliers have little incentive to invest in DER that could reduce demand on peak or to shift demand to lower cost periods. NYISO settles with their suppliers based on Commission-approved, standard rate-class demand profiles without regard for when customers actually use power. Finally, existing markets largely do not reflect the time- and location-specific variation in the value of DER, which denies DER the opportunity and incentive to participate when use of these resources could lower total system costs.

The conceived Platform Market could help lift restrictions and provide DER expanded access to power markets. Increasingly granular time- and location-specific pricing would help identify where DER are, and are not, cost-effective. In the cases where DER are the efficient option, the existence of a Platform Market would reduce barriers and provide greater opportunities for DER to compete. This expansion could occur in two stages: first, through greater integration of DER into distribution planning and operations; and second, by providing DER access to a market with a range of potential purchasers that is outside utility and NYISO programs.

Greater Integration of DER into Distribution Planning and Operations

Distribution Utilities are responsible for planning and investment to maintain service reliability consistent with Commission requirements. There will be opportunities to defer distribution investments by relying on DER. Identifying when and where DER may represent a cost-effective alternative requires forecasting the value of specific DER, including their impact on operating costs including congestion, marginal losses, and equipment lives in the distribution system. In market terminology, this process is equivalent to a forecast of DLMP prices. DER could be procured using fixed tariffs or requests for proposals and long-term contracts that place the risk of forecasting errors and purchasing uneconomic DER largely on the distribution company and its captive customers, or using other market mechanisms that allocate more of the risk to stakeholders who choose to invest in DER.

A Platform Market could facilitate the entry of DER, deferring distribution investments through, for instance, forward option contracts for location-specific resources. Today there is no standard market in which to contract for DER to meet local distribution requirements. Forward option contracts could be competitively offered on the Platform under a set schedule and structured to match the specific

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[26] *FirstEnergy Service Co. v. PJM Interconnection,* Complaint of FirstEnergy Service Company, Docket No. EL14-55-000 (May 23, 2014); *Electric Power Supply Association v. FERC*, 753 F.3d 216 (D.C. Cir. 2014); Sheppard, J. and Lamken, J., Brief of Robert L. Borlick, Joseph Bowring, James Bushnell and 19 other Leading Economists as *Amici Curiae* in Support of Respondents, *FERC v. EPSA* and *EnerNOC v. EPSA,* Cases No. 14-840 and 14-841, In The Supreme Court of the United States (September 2015); S. Bresler, et al., "Smarter demand response in RTO markets: The evolution toward price responsive demand in PJM," *Energy Efficiency: Towards the End of Electricity Demand Growth*, Fereidoon P. Sioshansi, Editor (February 2013).

requirements of a Distribution Utility /DSP provider. The DSP provider may wish to use DER in a distribution load pocket only during limited hours, when there is localized congestion. To ensure cost-effective DER are available in those hours, the DSP provider may have to offer a financial incentive, e.g., an option contract to reflect the value of DER in relieving local constraints. An option contract can be structured to include a fixed payment to ensure DER availability and provide the DSP provider an ability to call on the DER to provide location-specific voltage support or operating reserves at set strike prices when local constraints occurs. The DSP provider would monitor volt VAR controls, Platform transactions, demand, available resources, and local conditions in determining when to call on DER under these contracts.

This structure will tend to reduce costs in comparison to a contract that pays a fixed price for supply without regard for whether it is cost-effective for the resource to operate on a continuous basis. The quantity of option contracts offered would be based on planning requirements, with the maximum contract payments capped, and based on the value of deferring alternative investments. The option contract could be structured as a multi-year agreement, to facilitate financing DER that displace similarly long-term distribution investments.

Alternatively, a DSP provider could commit to a series of forward procurements for shorter capability or delivery periods, to avoid shifting greater risk to the utility and its customers. In either case, the DSP provider could offer to enter forward contracts sufficiently in advance of when resources will be required to allow it to fall back to making distribution investments if needed DER cannot be secured. Option contracts, with their related obligations and locational specifications, potentially could be traded among qualified DER on the Platform prior to the beginning of their delivery period. Such contracts could provide a comparatively flexible, competitive, transparent and standardized approach to obtaining DER to address local distribution requirements.

Ultimately, products that reflect local congestion, reactive power costs, marginal distribution losses and equipment impacts in congested areas will provide the most accurate valuation of DER to meet local requirements. Forward contracting for these products in a Platform Market will reflect higher prices in congested areas of the distribution system and could, in the future, provide incentives for DER investments that simply avoid the need for distribution investments and minimize congestion within distribution systems.

Open Access Distribution Markets

Nearly 20 years ago, the Federal Energy Regulatory Commission (FERC) opened generation markets to competition by requiring transmission owners to provide open access so independent power producers could transfer power and sell it to others.[27] Platform Markets provide the opportunity to apply to DER the principles that have worked in organized wholesale markets. The Commission expects that Platform

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[27] Federal Energy Regulatory Commission, Promoting Wholesale Competition Through Open Access Non-discriminatory Transmission Services by Public Utilities; Recovery of Stranded Costs by Public Utilities and Transmitting Utilities, Order 888, 75 FERC 61,080 (April 24, 1996).

Markets in their initial stages will consist primarily of open access tariffs.[28] Platform Markets can create additional pathways for the sale of electric products provided by DER in addition to and outside of utility and NYISO programs. The Platform can provide a standard means of settling transactions occurring within distribution networks.[29]

A Platform Market can reflect throughout the year, and for all locations, the time and location-specific value of DER without the limitations of a location- or event-specific programs offered by Distribution Utilities or NYISO. It is important to provide opportunities outside the limitations of such programs because the value of DER changes with both time and location, even within the same distribution feeder. As shown in Figure 3, the value of DER on a given feeder can vary significantly by hour and by location on the feeder. Chapter 5 presents a quantitative analysis of the value of DER, as reflected in marginal cost-based real energy and reactive power prices, for an illustrative distribution feeder on summer peak days and winter peak days respectively. That analysis demonstrates that there is not a single value for electric products from an individual DER on a given feeder. Rather, the value of electric products from DER can vary significantly by time, and by location within the distribution system.

A Platform Market with highly granular prices would enable DER to compete with bulk power resources and enter the market when and where they can do so cost-effectively. In this way, a Platform Market can support cost-effective DER development independent of any support that might be available for renewable or other targeted resources.

In the interim period, before it is feasible to move to a full DLMP market, settlement of loads based on eLMPs at transmission substations rather than on a zonal basis will have a similar directional effect. Chapter 4 presents examples of nodes whose eLMPS differ significantly from their respective zonal averages during many hours. For example, in 11% of 2014 the nodal price at the Astoria generator in New York City differed from the corresponding zonal price by more than $1.00/MWh. In the Capital Region, the price at the Empire CC generating node in 2014 differed from the corresponding zonal price by more than $1.00/MWh during nearly 30% of the year. Thus, an eLMP market would begin to identify where DER can compete cost-effectively with bulk power resources, independent of any support that might be available for renewable or other targeted resources. Settling loads based on eLMPs at transmission substations will identify locations that have eLMPs exceeding the zonal average LMP. Locating DER near, or on, distribution feeders served from substations with eLMPs higher than the zonal average will, all else being equal, will tend to be more cost-effective than locating DER distribution feeders served from substations with eLMPs lower than the zonal average.

A Platform Market can provide the standard means for scheduling and settling local energy transactions involving DER. If a retail customer purchases energy from DER located on the same distribution network, the platform would be able to settle such transactions while still allowing the customer (or its NYISO Load Serving Entity) to obtain energy on the bulk power system to meet any additional requirements that the customer has. The Platform would net Platform transactions that close with the delivery of

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[28] Framework Order at 44.

[29] A “distribution network” refers to a portion of a utility’s system served by the same transmission substation, or set of substations, interconnected at distribution voltages that can support internal transfer of DER transactions.

energy within the distribution network out of metered customer demand, reporting the result to the customer's retail supplier. The bulk power system would see only the net energy supplied (and priced) at the substation. While this paper does not address jurisdictional issues, the Platform could make comparable calculations for energy purchased by a Distribution Utility or ESCO. The energy market and settlement system provided by the platform can provide DER access to a broader range of customers. With the existence of the Platform Market, the DER would not be limited to selling into and under the terms and conditions of NYISO DR programs or specific Distribution Utility/DSP programs. The Platform would reduce transaction costs for DER owners and make it easier for DER to compete when and where it is cost-effective compared to other resources. As markets become more time- and location-specific, the opportunities available to well-positioned DER will expand. Additionally, the Platform could evolve to facilitate transactions that reflect environmental or local reliability benefits of specific DER.

Under the current market structure, DER's cannot participate in the NYISO wholesale energy market and can only participate in the ICAP market as demand response. Moreover, the rules of the ICAP market do not allow DER to compete with central station generators on a level playing field. Instead, the maximum reduction a DER can bid into the NYISO ICAP market is limited to the average coincident load of its host facility; the DER cannot submit a bid in excess of its host's average coincident load. While jurisdictional issues are outside the scope of this paper, a Platform Market could enable a DER with capacity incremental to its host's average coincident load to transact directly with an electrically adjacent facility that could use that incremental capacity. Therefore, a Platform Market has the potential to allow the two facilities to effectively pool their average coincident load and participate in the ICAP market much like a single host facility. That in turn represents another potential new market for incremental distributed generation.

Combining Products and Services in a Platform Market

A Platform Market will also create value by supporting new combinations of products and services. A Platform Market can provide the opportunity to combine electric products with information, data analytics, financial services and access to smart technologies to improve asset utilization, animate retail markets and reduce costs to customers. Across other comparable industries, platform markets are creating value by efficiently matching demand and supply, improving asset utilization, and providing for ancillary product markets, much as is being anticipated for the distribution sector of the power industry.

The power industry invests in capacity to meet peak demand. Given the limited ability of existing markets to affect the timing of demand, system capacity must be built and maintained to meet peak demands that occur in a small fraction of hours. Average generation capacity factors are below 50%, and the average utilization of transmission and distribution facilities is often even lower. By contrast, asset utilization in other capital-intensive industries typically averages more than 75%. Comparatively low asset utilization increases investment requirements and makes power less affordable for consumers.

Increasing Price Responsive Demand

Facilitating the use of smart devices to shift flexible demand to lower cost intervals will create the greatest near-term value from DER. A Platform Market can provide and communicate the necessary incentives by modifying, through access to smart technologies, the ability for load-serving entities to shift the timing of demand and thereby minimize costs consistent with customer preferences.

The potential benefits are large. Space conditioning, water heating, and refrigeration represent more than one-third of residential and commercial electricity use. The few degrees of pre-cooling or pre-heating that these loads can store can provide significant energy and capacity benefits, such that optimizing the timing of demand for these end uses could shift a significant portion of peak demand to other time intervals.[30] Similar strategies could take advantage of flexibility in the timing of pumping loads, batch processes, and charging electric vehicles. A 2011 National Energy Technology Laboratory study concluded that smart technologies could reduce U.S. peak electric demand by more than 25% and produce billions of dollars per year in benefits.[31] A recent Rocky Mountain Institute analysis of flexible demand suggests that smart residential air conditioning, water heating, and EV charging could provide annual net savings up to $250 without an adverse impact on service quality.[32] Moreover, intelligent systems are also capable of reducing up to 20% of building energy use that is wasted by inefficient air handling systems, and in cooling and heating spaces that will not be in use.[33,34] Additional impacts could include facilitating integration of variable renewable energy, making the power system more flexible and resilient, and deferring the need for distribution investments.

Flexible demand does not play a large role in New York today because existing retail markets do not settle demand on an interval basis, and most customers are unable to derive any direct benefit from shifting demand to lower cost periods. Market settlements based on interval meter data as it becomes available (or, as an interim option, continuously updated load profiles) can provide the incentive for managing flexible demand. This could occur without deployment of the communications network for advanced metering infrastructure (AMI) or major changes in retail pricing.[35] Modifications of settlement practices for different groups of customers would include:

- **Mandatory hourly pricing (MHP) customers served by a default service supplier.** These customers have interval meters and rates based on day-ahead hourly prices. A modest change in

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[30] For example, studies estimate that during 2,000 hours a year California could shift more than 20 GW of residential electric demand to lower price hours and provide 8 to 11 GWh of energy storage. Smart devices could do this using a combination of thermal inertia of air conditioning given no more than 1°C of temperature flexibility, water heaters with up to 4°C of flexibility, and refrigerators with up to 2°C of flexibility. J. Mathieu, Modeling, Analysis, and Control of Demand Response Resources, LBNL-5544E (May 2012). J. Mathieu, et al., "Using Residential Electric Loads for Fast Demand Response: The Potential Resource and Revenues, the Costs, and Policy Recommendations, Proceedings of the 2012 ACEEE Summer Study on Energy Efficiency in Buildings (August 2012).

[31] J. Goellner, et al., Demand Dispatch – Intelligent Demand for a More Efficient Grid, National Energy Technology Laboratory (August 2011). A 2015 analysis based on the use of transactive controls in the Pacific Northwest Smart Grid Demonstration Project produced a comparable estimate of demand reduction potential. Battelle Memorial Institute, *Pacific Northwest Smart Grid Demonstration Project: Technology Performance Report Volume 1: Technology Performance* (June 2015). See also: J. Hagerman, *U.S. Department of Energy Buildings-to-Grid Technical Opportunities* (2015).

[32] Rocky Mountain Institute, The Economics of Demand Flexibility: How "Flexiwatts" Create Quantifiable Value for Customers and the Grid (August 2015).

[33] R. Meyers, et al., "Scoping the potential of monitoring and control technologies to reduce energy use in homes," Energy and Buildings, Vol. 42 (2010) at 563–569; M. Piette, et al., Responsive and Intelligent Building Information and Control for Low-Energy and Optimized Grid Integration, Lawrence Berkeley National Laboratory, LBNL-5662E (May 2012). See also E. Mills, "Building Commissioning: A Golden Opportunity for Reducing Energy Costs and Greenhouse Gas Emissions in the United States," Energy Efficiency Vol. 4, No. 2 (2011); S. Somasundarum, et al., Reference Guide for Transaction-based Building Controls Framework, Pacific Northwest National Laboratory PNNL-23302 (April 2014).

[34] For a general discussion on the role of smart technologies, see: P. Centolella, Next Generation Demand Response: Responsive Demand through Automation and Variable Pricing, Prepared for NRDC Sustainable FERC Project (2015).

[35] Deployment of AMI may be justified by a range of other factors.

MHP rates to include a reconciliation adjustment for energy imbalances between scheduled usage and actual usage would provide customers the opportunity to benefit from managing the timing of flexible loads during the operating day. Each customer would start with a default hourly demand schedule, which the customer could modify in advance of the day-ahead market. Rates based on day ahead prices would be applied to scheduled usage. If the customer departs from its usage schedule, decreases and increases would be credited or billed based on interval prices applied to the imbalances of each individual MPH customer. This approach avoids socialization of energy imbalance costs.

- **Customers with interval meters and served by ESCOs.** NYISO settlements for ESCO customers with interval meters are based on the customers' actual hourly load shapes. A shift to interval settlements could improve the management of energy costs and the incentive for ESCOs to reduce their supply risks and compete for customers based on helping them manage energy costs. With expanded use of smart devices, ESCOs could avoid the complexity of dynamic retail pricing. For example, they might offer a discounted flat price to customers using smart technology to manage their energy demand.
- **ESCO customers currently without interval meters.** NYISO settlements for these customers are based on fixed-average-rate-class hourly load profiles approved several years ago by the Commission. ESCOs and their customers receive no direct benefit from managing demand. The Commission could provide ESCOs the incentive to help such customers manage demand by approving the deployment of "bridge" meters (or other devices) that record interval data, or, as an interim step, replacing fixed-load profiles with continuously updated profiles for each major ESCO based on statistical samples of the ESCO's customers. After accounting for meters already capable of recording interval data, such sampling might require gathering data from a few thousand additional customers.
- **Other default service customers.** The Commission could provide incentives for Distribution Utilities as default suppliers to improve the load profiles, intra-day price elasticity and energy efficiency of their default customers. Performance could be measured with meters that record interval data based on statistical samples, or using residual load profiles. A range of rate or rebate options could be used to share the savings with consumers.

Such market reforms would work in combination with products available on a Platform. To help manage demand, ESCOs, MHP customers and default suppliers would first obtain through the Platform a combination of products and services such as:

- NYISO "look-ahead" LMP forecasts.
- Real-time feeds of Platform settlement prices.
- Commercially available forecasts of locational prices.
- Customized, real-time data analytics, demand management and other information services to enable the efficient operation of building energy-management systems and smart devices.

Parties could also use the Platform to access third-party financing products for the purchase of building energy-management systems and smart devices. Financing could be offered on the Platform at a lower cost by leveraging New York's on-bill repayment financing program[36] and utility data on customer credit quality.

Second, smart devices would use information services purchased on the Platform and, together with the information, they have on customer requirements and preferences, shift flexible demand to intervals that are expected to have lower prices.

Finally, ESCOs, MHP customers and default service suppliers would be able to hedge their risk and lock in lower prices whenever customer schedules are set or modified, by purchasing energy contracts on the Platform's continuous energy market.

The shift of flexible demand to lower cost intervals could begin in an LMP market. The value of shifting demand will increase as pricing points are extended, first from zones to a larger number of points in the transmission system, eLMP, and ultimately to points throughout the distribution system. Chapter 5 provides and illustration of the impacts for price responsive demand of moving to more granular pricing. That illustration models the operation of a representative feeder under high and low levels of DER penetration and under summer and winter load conditions for four pricing structures, beginning with BAU, in which suppliers and customers see an average LMP for the day, and ending with DLMP. The scenarios assume a modest quantity of flexible demand in the form of commercial building heating and cooling load and electric vehicle charging. The High DER penetration scenario assumptions for energy loads with some flexibility represent approximately 5.6% of total energy consumption. Under that DER penetration scenario, commercial buildings with price responsive demand see a 5% reduction in summer peak day costs (i.e., real energy plus reactive power) when the market structure moves from a BAU structure to an eLMP structure. They see a further 7% reduction in energy costs on a summer peak day when the market structure moves from eLMP to DLMP. It is important to note that total energy costs (i.e., real energy plus reactive power) to customers with inflexible load also decline when the market structure moves from BAU structure to DLMP. For example, the reduction is 4% on the summer peak day. This reduction is largely attributable to reductions in real energy prices that benefit both flexible and inflexible loads.

The overall impact of moving to more granular pricing could be to shift the way in which demand participates in power markets. Historically capacity was built to meet demand. Enabling flexible demand could change this paradigm; demand would increasingly respond to the availability of resources as reflected in anticipated locational prices. To compete on cost in the retail market, ESCOs will have to help their customers manage the timing of their electricity demand. The Platform positions retail suppliers and customers to take advantage of the increasing number of connected devices and smart systems, and the rapidly falling cost of enabling devices to obtain and respond to information about anticipated costs.[37] The Platform provides access to information and data analytics services and will

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[36] See: http://www.nyserda.ny.gov/All-Programs/Programs/On-Bill-Recovery-Financing-Program.

[37] The cost to an original equipment manufacturer of incorporating a chip that permits a device to determine its location and receive broadcast information on anticipated prices for that location is less than a dollar per device and continuing to decline. The number of network-connected devices in use is rapidly increasing and expected to reach more than 20 billion by 2018.

create demand-side economies of scale for these services.

Flexible demand can rapidly ramp down or up over a defined period, to provide regulation and operating reserves. Retail regulation and operating reserve products could be created, tailored to the capabilities of flexible demand, and traded on the platform. Such retail products could reduce reliance on and ultimately demand for wholesale ancillary services. Alternatively, a platform could facilitate real-time aggregation and bidding into NYISO ancillary service markets, where NYISO-compliant telemetry is in place.

Management of flexible demand is a distributed and a continuous process that could occur largely outside of capacity market demand-response programs. Automatically shifting demand away from high-price periods reduces future capacity obligations and may reduce the baselines from which any further ICAP demand reductions would be calculated. Thus, a significant portion of the expansion in demand participation may occur through the development of new retail business models supported by the Platform.

Capacity programs will continue to play a role in balancing demand with supply in shortage conditions, given that energy prices remain capped under wholesale market rules. Some of the programs to meet this need may become utility programs offered through the Platform. DR aggregators may find it economic to move all or portions of their operations from their own proprietary platforms to a statewide utility-sponsored Platform that offers greater visibility and access to a broader range of services.

The Platform Market expands the opportunity for market participation of demand. That expanded participation would reduce the total and societal costs of meeting customer requirements for electric energy services.[38] This cost reduction is likely to be reflected, in part, by reduced investment requirements and lower costs for ratepayers generally, including for customers who are inflexible in their electricity use.

Efficient Charging of Electric and Plug-in Hybrid Electric Vehicles

Smart charging of electric (EV) and plug-in hybrid electric vehicles (PHEV) is a special case of using smart technology to manage a potentially significant source of flexible demand. In this case, extending pricing points into the distribution system could help manage charging in EV clusters and influence siting for the charging of EV fleets. This application will develop with the growth of EVs and PHEVs. It could take advantage of existing vehicle communication and computing capabilities. It may involve additional participants: vehicle manufacturers that include charging management systems in their vehicles, providers of public charging stations and fleet operators. It may also require addressing additional policy issues, such as ownership and metering of public charging stations, and the integration of incentives for

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Most of these 20 billion connected devices will be ordinary energy-using objects, not the personal computers, smart phones, tablets, and televisions that historically have constituted the majority of networked devices. M. Iansiti and K. Lakhani, “Digital Ubiquity: How Connections, Sensors, and Data are Revolutionizing Business,” Harvard Business Review (November 2014).

[38] Responsive demand may expand outside of conventional DR programs and involve the purchase of information services and price hedges on the Platform, through new utility programs on the Platform, through aggregators who shift portions of their operations from their own proprietary platforms to the statewide utility-sponsored Platform to reach additional customers, and / or through conventional DR programs not on the Platform.

smart charging with other public policies. However, the products and transactions involved in shifting of energy use to lower price periods, and providing regulation and operating reserves, will be generally comparable to those for other forms of flexible demand.

Distribution Efficiency: Reactive Power Management

An additional and important way in which a Platform Market will create value is by improving distribution system efficiency. Reactive power establishes and sustains the electric and magnetic fields in alternating current systems when current and voltage are not in phase with one another. Reactive power management at the distribution level can have a large impact on distribution efficiency, customer costs, and environmental impacts, as well as upon the system's ability to host renewable resources.

Distribution Utilities traditionally managed reactive power and voltage using the comparatively slow and limited control capabilities of capacitor banks, line voltage regulators and load tap changers located on the primary (higher voltage) distribution lines. These Volt VAR control techniques are used to maintain voltage within limits set by applicable standards over the full length of distribution feeders.[39] As a result, additional voltage is often added upstream to avoid low-voltage violations at the ends of distribution feeders. Customers located on the secondary (lower voltage) side of distribution circuits may experience significant voltage variations. Consumers with similar load profiles might experience variances in their bills of as much as 10 to 15% due to voltage differences. Moreover, an inability to manage voltage can reduce the transfer of useful energy, increase losses, and cut the lifespan of distribution equipment. Additionally, the PV hosting capabilities of distribution feeders are limited by the ability to implement effective Volt VAR control. Conventional control techniques are not able to achieve the precise control needed to address dynamic voltage changes associated with clusters and larger-scale deployments of distributed PV.

With active monitoring, some utilities have been able to implement conservation voltage reductions and achieve 1 to 2% reductions in generation requirements. However, these approaches generally have little impact on voltage variations in secondary distribution lines. This limits the voltage reductions that can be implemented consistent with meeting applicable standards.

Emerging technologies that intelligently coordinate power electronics on the edges of the distribution system have demonstrated an ability to achieve superior results. This new approach equalizes voltages across secondary distribution lines even when voltages would otherwise fluctuate due to events such as clouds passing over a PV cluster. This has enabled utilities to demonstrate the feasibility of maintaining voltage across circuits within a narrow range. Utilities can use this additional control to reduce peak demand and overall generation requirements consistently by 5 percent or more, as well as to maintain standards compliance while expanding the ability to host distributed PV systems.[40] Such results could be achieved with utility-owned VAR sources and a market that enrolls smart inverters and other distributed

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[39] ANSI Standard C84.1.

[40] D. Divan, R. Moghe, and A. Prasai. "Power Electronics at the Grid Edge," IEEE Power Electronics Magazine (December 2014). R. Moghe, D. Tholomier, D. Divan, J Schatz, and D. Lewis. "Grid Edge Control: A New Approach for Volt-VAR Optimization." Proceedings of the IEEE Power Engineering Society Transmission and Distribution Conference (May 2016) Forthcoming.

resources into a common distributed communication and control architecture.

Many of the inverters in existing PV systems were designed to maximize the energy output of these systems. The California Public Utilities Commission and leading standards organizations, among others, have worked to develop smart inverters that could contribute to Volt VAR control. Providing VAR support will reduce the ability of these inverters to provide real energy during periods of maximum solar output. However, smart inverters could provide VAR support during many more hours than a typical PV installation would be generating real energy.

Development on the Platform of a distribution-level reactive power market could incent owners to enroll smart inverters and other distributed resources into the communication and control architecture needed to equalize secondary distribution voltages and achieve system-wide demand and energy savings, compensate owners of these systems for associated reductions in the output of real energy, and provide them access to on-going software and technical support services.

While the previously provided examples represent key opportunities for DER and a Platform Market to create significant value, they are not an exhaustive list of potential opportunities. Other opportunities are anticipated to emerge from relatively straightforward future Platform functions, such as connecting individual customers with specific ESCOs and the development of green products with more specifically defined attributes. The combination of DER and the Platform are also likely to spur innovations that we cannot readily specify, such as the provision of warranties for service quality, or cannot now even anticipate.

G. Chapter 2 Summary

Chapter 2 presents the principles that guided analysis of a distribution-level market design. The key market design principles involve defining the needs of buyers in terms of the core electric products those buyers could obtain from DER, developing a method for valuing the core electric products from DER, and identifying the information required for market transparency. Chapter 2 also describes and provides examples of key value propositions of a Platform Market that derive from expanded market access for DER, new combinations of products and services, including expanded price responsive demand, electric vehicle charging and reactive power pricing that combine to reduce transaction costs and improve distribution system efficiency.

3. Principles of Platform Markets Applicable to REV

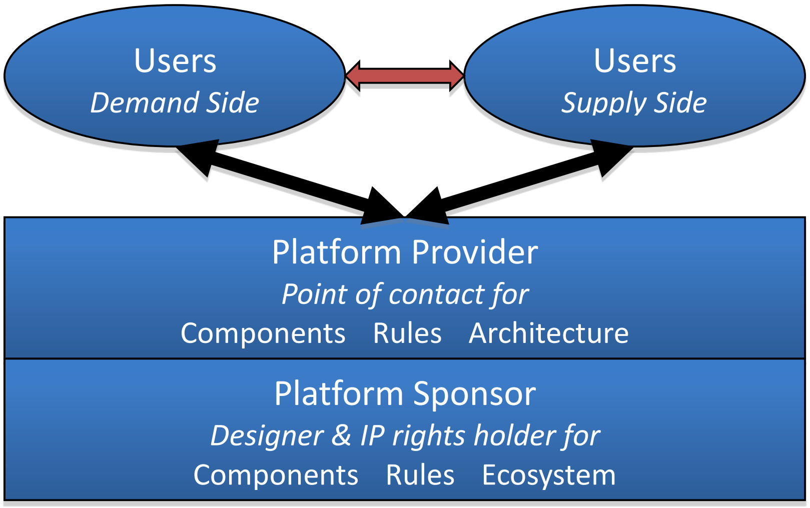
This chapter presents the principles that guided the analysis of the platform markets applicable to REV.

A. What is a Platform?

A platform is a business ecosystem that matches producers with consumers, who transact directly with each other using resources provided by the ecosystem itself, as indicated in Figure 4. The platform ecosystem provides outside parties with easy access to useful products or services through an infrastructure and a set of rules designed to facilitate interactions among users. A platform's overarching purpose is to consummate matches among users and to facilitate the exchange of goods and services, thereby enabling value creation for all participants.[41]

Platform components include hardware, software, and service modules, along with an architecture that specifies how they fit together. Platform rules coordinate network participants' activities. They include standards that ensure compatibility among different components, protocols that govern information exchange, policies that constrain user behavior and contracts that specify terms of trade and the rights and responsibilities of network participants. The platform can be divided into a provider role and a sponsor role.[42]

Figure 4. Platform Roles



Providers. This is the point of contact for common components, rules, and architecture. The provider is typically the contact point for the users of the platform – both the consumer of the service and the

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[41] Parker, Geoff and Marshall Van Alstyne (2014). "Platform Strategy." In the Palgrave Encyclopedia of Strategic Management. M. Augier and D. Teece (eds.).

[42] Eisenmann, Parker, Van Alstyne (2009). "Opening Platforms: How, When, and Why." Chapter in Platforms, Markets and Innovation, Ed. A. Gawer. Edward Elgar Publishing. http://ssrn.com/abstract=1264012.

provider of the service. *This role can be done by one firm or many firms*.

Sponsor. This is the overall designer and intellectual property rights holder. The sponsor sets direction and controls the underlying platform technology. It also provides the overall organizing structure for the platform via rules, governance, and ecosystem support. It can help the ecosystem work by helping participants see how they are better off by being part of the system rather than outside of it. *This role can be done by one firm or many firms*.

The platform provider and sponsor roles form the basis of the platform and ecosystem. Eisenmann, Parker, and Van Alstyne (2006) provide models for how to organize platforms in the provider and sponsor roles.[43] The sponsor is critical to success and serves as a social planner providing the organizing structure for the ecosystem ensuring that the right balance of openness and access is achieved to encourage participation and innovation and discourage "takeovers."

The sponsor also needs to be aware of how the underlying technology is evolving and recognize where markets are still determining the best underlying technology and be prepared the change directions as the users evolve. Other critical decisions include determining which functionality is part of the platform and which is supply-side content, which components are parts of the provider layer and which are part of the sponsor layer.

The provider role is the contact with the user on both side of the network. This is a valuable position as the provider quickly learns what is of value to platform participants. They are in a position to see what is valued, what creates activity, and where the trends are. The ecosystem sponsor needs to be working with the providers to be able to identify commonly used/needed functionality from the supply side and how/when to absorb functionality from the ecosystem into the core platform.

B. Platform Organization Structure Options

A platform's sponsor and provider roles each may be filled by one company or shared by multiple firms. These possibilities define a 2×2 matrix depicting four possible structures for platform governance. With a proprietary platform such as Apple iTunes, eBay, or Nintendo Wii, a single firm plays both the sponsor and provider role. A shared platform such as Linux has multiple sponsors who collaborate in developing the platform's technology then compete with each other in providing differentiated but compatible versions of the platform to users.

Some platforms combine proprietary and shared elements in hybrid governance structures. With a joint venture model, several firms jointly sponsor the platform, but a single entity serves as its sole provider. For example, the major airlines jointly sponsored the travel website Orbitz in order to compete with the independent website Travelocity.

Other platforms also combine proprietary and shared elements but instead of joint venture, there is a licensing model where a single platform sponsor licenses the rights to provide the platform to multiple user facing firms. For example, Google effectively licenses Android to numerous hardware

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[43] Eisenmann, Parker, Van Alstyne (2006). "Strategies for Two-Sided Markets." Harvard Business Review.84.10 (2006): 92.

manufacturers who then sell that hardware to end-users. Figure 5 illustrates the 2×2 matrix of possible organization configurations.

Figure 5. Platform Organization Structures

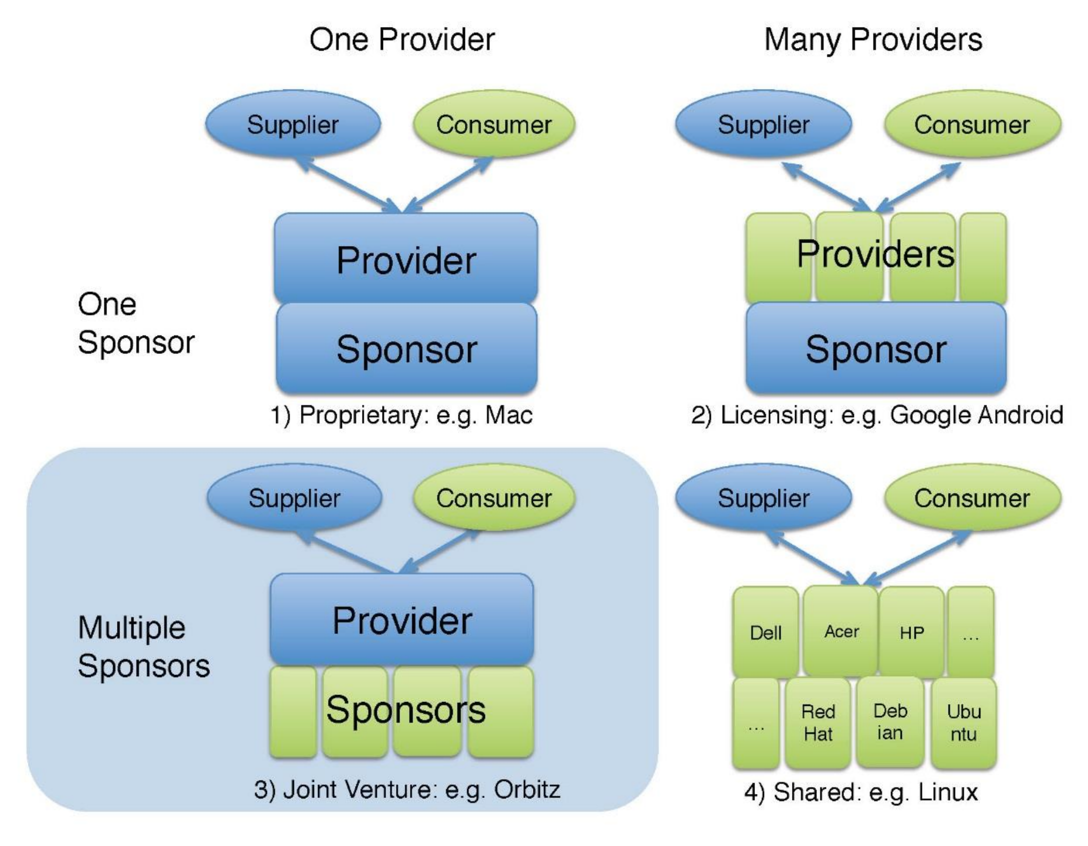

Table 2 summarizes the advantages and disadvantages of each potential platform organization structure. The following sections describe some of the implications of the alternate organization form choices.

Table 2. Advantages (+) and Disadvantages (-) of Alternative Platform Organization Structures[44]

	One Provider Firm	**Many Provider Firms**
One Sponsor Firm	***Org Type: Proprietary*** + Easier mobilization through cross subsidies without subsidizing rival platforms. + Larger payoff if platform is successful and wins the market. - One organization must bear all of the costs of starting and maintaining the platform. - More likely to spur a fight to dominate the market in a winner take all contest.	***Org Type: Licensing*** + Attractive if providers can offer differentiated platform services that are valued by end customers. - Division of profits will cause tension - Fixed costs are duplicated across multiple providers; if there is low variety in the type of platforms (not the services offered on top) desired by the market, this is wasteful. - Tension likely to arise over technological trajectory of the platform.
Many Sponsor Firms	***Org Type: Joint Venture*** + Easier mobilization through cross subsidies without subsidizing rivals. + Cooperation among rivals who would otherwise compete; larger market with compatibility ensured. - Smaller payoffs to sponsors since rewards must be split. - Long run tension likely to arise over technological and business strategy of platform.	***Org Type: Shared*** + Low cost can lead to wide adoption by users. - Difficult to launch with cross-subsidies since all versions can be compatible - Evolution slow; requires standards setting organization process with lower economic incentives. - No central coordination; leads to fragmentation and possibly to incompatibility.

Multiple Provider Firms: One Platform per Distribution Territory

There has been significant support in the REV process for having each distribution utility invest in and operate an independent platform to serve the customers in their territories. On one level, this strategy could make sense because there are no data access issues and each distribution utility would be able to capture the benefits of any activity on their respective platforms. However, this decision would likely lead to some significant difficulties. The following sections describe how the multiple platform decision could play out under different market structures.

Competing Proprietary Platform Model

If there is no common platform sponsor, then the implication is that multiple proprietary platforms would develop their own competing standards. Such an arrangement would retard adoption because the larger buy-side participants (ESCOs and Distribution Utilities) would have to invest in adopting multiple communications standards, data standards, financial contracting, product definition, and more

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[44] Table adapted from Eisenmann, Parker, Van Alstyne (2009), "Opening Platforms: When, Why and How?" Chapter in Platforms, Markets and Innovation. Gawer, Annabelle (ed.), Edward Elgar: Cheltenham, UK. http://ssrn.com/abstract=1264012.

to gain access to supply across New York State. From the sell side perspective, there might be less of an issue except that desirable intermediaries who can assist small market participants (e.g., individual households) would also have to invest in the necessary technology and standards to work across multiple platforms. The bottom line is that this choice would introduce significant friction to adoption of a platform because it would impose large additional costs to market participants.

Shared Governance Platform Model

Some participants in the REV process have stated several Distribution Utilities could have platforms as long as they all adopt the same standards, i.e., multiple Platforms. There are two scenarios under which this could happen. The first scenario is that the Distribution Utilities voluntarily cooperate to set standards and align product definitions. Table 2 describes this Shared model. Such standard setting bodies tend to work better with mature technologies that are not rapidly evolving because there is more time for a slow decision-making process. Further, in a more mature market, there is less immediacy because the market is not changing quickly. Shared governance also tends to work better when customers have already adopted the platform because there is less need to offer subsidies and other enticements for certain customer types to participate. In the case of a new platform that requires significant technical development and could require financial incentives for user adoption, the shared governance model is likely to fail because of slow decision-making, conflict over technical standards, and unwillingness to make large investments to serve a small market.

Licensing Platform Model

The second way in which it might be possible for each distribution utility to establish its own platform is if there were a single platform sponsor that would develop technology, set standards, define products, and then license the technology to each Distribution Utility. Then each Distribution Utility would be responsible for making the investments necessary to deliver platform services to their territories. This licensing model solves the problem of common standards and product definitions, but requires significant duplication of investment. It also introduces an important question: who would serve as platform sponsor? It is difficult to envision that any of the Distribution Utilities would be willing to license technology from a direct competitor. It is even less clear that the Distribution Utilities would be willing to cede control of their platforms to an outside party such as one of the major technology platforms.[45] It is not clear who, beyond the distribution utilities themselves, would have credibility and authority to serve in the platform sponsor role. Finally, even though Distribution Utilities might recover platform investments through the rate base, it is not clear that there is a need for multiple duplicate platforms.

One Statewide Platform, Multiple Sponsoring Firms: Joint Venture Model

As previously explained, there are significant disadvantages of the competing proprietary platform model, the sole-sponsor licensing model, and the shared governance model. The implications of a joint venture model mean the Distribution Utilities would be the owners of the Platform. Instead of having each Distribution Utility invest in the design, launch, and ongoing operation of separate platforms, they

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[45] Major technology platforms include Amazon, Apple, Facebook, Google, IBM, Microsoft, Oracle and SAP.

would instead benefit from spreading the fixed costs across the entire state. Supply and demand side users would be able to invest in the adoption of a single platform instead of incurring multiple startup costs. Intermediaries who can help market participants would also have only one platform in which to invest.

A single statewide platform co-sponsored by the Distribution Utilities would be consistent with the position Staff has expressed regarding tools to operate a modern grid capable of dynamically managing distribution resources and supporting retail markets that coordinate significant DER investment:

> “Staff recognizes that many of the operating tools and functionality required to incorporate and rely on large scale DER deployment, including the requisite algorithms to price the marginal value of DER as efficiently as practicable, should be developed collaboratively to capture, where possible, economies of scale, but also to ensure interoperability, state-wide transparency and energy markets that avoid seams or rifts at utility service territory borders. For example, there should be a uniform interface with the markets and very extensive interactions and interoperability among the utilities.”[46]

The Distribution Utilities would have significant incentives to cooperate in order to grow a functioning Platform quickly. The Platform could then begin generating revenues for them as well as providing them access to core electric products from DER. In the long run (several years after launch), platform sponsors may begin to disagree about the best technological trajectory of the platform. Other joint venture platforms have solved this problem by spinning off the platform as an independent organization with ownership residing in the original sponsors, but with decision-making in the new single-sponsor organization. An arms-length relationship helps to speed decision-making.[47] Visa faced exactly this problem; although initially owned by multiple banks, Visa eventually spun off as a separate entity.[48] For the reasons described above, this paper finds that the Joint Venture organization form (i.e., shared sponsorship of a single user-facing platform) dominates the alternate choices.

C. Who Uses a Platform and How Do They Transact?

The market participants. Two participants exist in any core interaction—the *producer*, who creates value, and the *consumer*, who consumes value. The definition of any core interaction needs to describe explicitly the roles of the producer and the consumer.

In the context of the Platform conceived in this paper, the producers are typically the owners and aggregators of the DER who can use their assets to deliver part or all of a core electric product. The consumers are typically either the Distribution Utilities or ESCOs. Participants who are delivering DER may also consume value added services over the platform, and in later versions of the platform, it might

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[46] Case 14-M-0101, Proceeding on Motion of the Commission in Regard to Reforming the Energy Vision, *Staff Proposal Distributed System Implementation Plan Guidance*..October 15, 2015, page 5.

[47] Eisenmann, Parker, Van Alstyne (2009), "Opening Platforms: When, Why and How?" Chapter in Platforms, Markets and Innovation. Gawer, Annabelle (ed.), Edward Elgar: Cheltenham, UK. http://ssrn.com/abstract=1264012.

[48] "Visa plans stock market floatation", BBC News - Business, October 12, 2006. http://news.bbc.co.uk/2/hi/business/6043406.stm

be possible for DER owners and aggregators to become direct consumers of electric products over the platform. Thus, the platform design should make it easy for users to move from role to role between transactions, much as guests on Airbnb in one period can easily be hosts in another period.

The product. As a result of information exchange, the platform participants can decide whether to exchange the core electric products described in this paper, notably energy and operating reserves over the initial Platform. Over time, this paper expects the Platform to support exchange of additional services. For example, market participants might exchange analytics services and specialized forecasts directly through the platform. An item exchanged among platform users is called a *unit of value.* Information about the delivery can be tracked and exchanged on the platform in the same way that transportation services requested via Uber are delivered on real city streets using actual cars, but are all tracked in real time using Uber platform resources.

The design of the platform should start with the design of the *core interaction* that it enables between producers and consumers. The fundamental purpose of the platform is to facilitate that core interaction. Consider three key components of the core interaction and how they connect to create value on the platform.

The information unit. The core interaction starts with the creation of an *information unit* by the producer or consumer. A seller creates a product/service listing, i.e., an information unit, which that seller then offers to buyers (who themselves may be sellers of other products) based on the search queries of those buyers. In each case, the information unit provides users with a basis for deciding whether or not they want to proceed to some further exchange.

The filter. The *filters* that market participants use determine the information units delivered to them. A search query is an example of a filter. Participants search for information of interest to them by specifying particular search terms: “1 MW of load reduction for a period of 1 hour beginning at 14:00 on” XX-July-201X). The filter selects specific units that match the search terms and delivers them to the consumer or producer. By providing accurate filters, platforms reduce the search costs that users must incur to find potential matches.

In one way or another, every platform makes use of filters to manage the exchange of information. The Uber platform, for example, tracks its drivers in time and space and has the ability to announce their availability. The platform therefore has the data and the functionality to develop the information units to match prospective customers with nearby drivers. When a prospective customer pulls out her phone and requests a car, she sets up a filter based on her location at the time of the request. The filter enables the exchange of information about the most relevant possible driver(s). Although this seems straightforward, the design and choice of filter settings requires the platform to make (or allow the user to make) trade-offs. In the Uber example, if the platform widens the radius, there will be a larger pool of possible drivers for matching, but the wait times will increase. The platform search engine must incorporate this information.

The core interaction. Parties can schedule delivery once parties complete the exchange of information and reach an agreement. The core interaction is completed, the parties have created and exchanged value, and there is a settlement. The basic structure is thus:

Market Participants + Information + Search/Filter → Core Interaction

When designing a platform, the first job is to decide what the core interaction will be, and then to define the participants, the information units, and the filters needed to make such core interactions possible.

As seen in cases like LinkedIn and Facebook, platforms often expand over time to embrace many kinds of interactions, each involving different participants, information units, and filters. However, successful platforms begin with a single core interaction that consistently generates high value for users. A valuable core interaction attracts participants and makes positive network effects possible. Network effects refer to the impact the number of users has on the value of the system for other users. Network effects are a demand side economy of scale that can make a system more valuable as more users join the network (the case of positive network effects) or less valuable (the case of negative network effects). For example, the user of a telephone derives little value if no one else has a phone. However, as more and more people join the network, the system becomes more valuable as it becomes possible to reach anyone a user wishes to call. This effect, described several decades ago, became known as "Metcalfe's Law."[49] Key phenomena that well designed platforms must manage are two-sided or multi-sided network effects where different types of users experience more or less value depending upon the number of users of different types.[50]

Pull. To begin with, platforms need to solve a chicken-or-egg problem. Users will not come to a platform unless it offers valuable interactions, and a platform cannot offer value unless it has a sufficient number of users. Most platforms fail simply because they never overcome the chicken-or-egg problem. The startup issue is such an important challenge that we discuss it in more detail below.

Facilitate. Platforms do not control value creation. Instead, they create an infrastructure in which value can be created and exchanged, and lay out principles that govern these interactions. One way to facilitate transactions successfully is to make it as easy as possible for producers to create and exchange valuable goods and services via the platform.

Facilitating interactions may also involve reducing barriers to usage. Not so long ago, a Facebook user who wanted to share photos with friends would have had to use a camera, transfer the images to a computer, use Photoshop or another software package to edit them, and finally upload them to Facebook. Instagram enabled users to take, modify, and share pictures in just three clicks on a single device. Lowering barriers to usage in this way encourages interactions and helps expand participation on the platform.

Match. A successful platform creates efficiencies by matching the right users with one another, thereby enabling them to exchange the most relevant goods and services. To do so, the platform uses data about producers, consumers, the information units created, and the goods and services available for exchange. The platform's search and matching algorithms work better when they have more data. In addition, the better designed the algorithms for collecting, organizing, sorting, parsing, and interpreting the data—the more accurate the filters, the more relevant and useful the information exchanged, and

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[49] Gilder, George. "Metcalfe's law and legacy." Forbes ASAP 13 (1993).

[50] Eisenmann, Thomas, Geoffrey Parker and Marshall W. Van Alstyne. "Strategies for two-sided markets." Harvard Business Review 84.10 (2006): 92.

the more value the platform can create with the match between producer and consumer.

The data required for optimal matching in the DER context may be extremely diverse. They range from static information such as resource type, nameplate capacity, and interconnection locations to dynamic information such as time of day, predicted cloud cover, or expected temperature. Sophisticated data models must include filters that consider all these factors as well as the participant's previous activities on the platform. Consider the Thomson Reuters Enterprise Platform or the SAP Netweaver or Cloud Computing system. Customers who adopt these systems must adhere to precise data formats and descriptions of individual units within the system. For example, Thomson Reuters uses the Reuter's instrument code (RIC) to identify financial instruments and indices. Customers who have developed systems using these codes and standards have a coherent and precise way of referring to specific financial instruments such as a contract to trade the crude oil front month. However, customers who use build their systems around specific data models can also face significant switching costs.

D. General Platform Launch Strategies

This section describes key issues platforms face when they startup. The classic difficulty for building a platform is the chicken-and-egg launch problem. Producers and consumers are each prospective users of a platform. They both want the platform to offer a variety of product and service offerings before they will use it. Each side wants the other side to commit before it will spend resources to adopt the platform. This is a "critical mass" problem.

To illustrate the criticality of launch, Ming Zeng, chief strategy officer for Alibaba, described the following "Three Paradoxes of Building Platform:"[51]

- **The Control Paradox.** Platforms must exert some control in order to be able to provide critical governance. However, Zeng's control paradox cautions platform sponsors against exerting too much control lest the cost and hassle of compliance drive potential participants away. Zeng describes the issue as follows: "Being a platform means you must rely on others to get things done, and it is usually the case that you do not have any control over the "others" in question. Yet your fate depends on them."
- **The Weak Partner Paradox.** In the weak partner paradox, Zeng notes that platforms rely upon smaller players inherently less capable than existing firms. He states "…the giants did not want to join us, considering us their future competitors. But could we realize our vision by working with startups who were willing to believe, but whose ability was really not up to snuff?"
- **The Killer App Paradox.** In the killer app partner, Zeng emphasizes that users do not buy platforms. Instead, they buy the valuable products and services that platforms facilitate. The implication is that platforms must launch with a valuable product/service. Otherwise, they risk being a "ghost town" of infrastructure without any activity. Over time, if the platform is successful, it will grow to serve markets beyond the original offerings. The challenge then becomes how to serve new verticals and balance platform services across them.

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[51] Zeng, Ming. 2015. "Three Paradoxes of Building Platforms." Communications of the ACM. Vol. 58 No. 2, 27-29.

With these thoughts in mind, the following strategies that have been successful in promoting successful launch.

Follow-the-Rabbit Strategy. This strategy uses a demonstration project to model success, thereby attracting both users and producers to a new platform. Intel coined the term "rabbit strategy" for targeting a platform product with a high probability of success and assisting the supplier in a highly public and visible fashion.[52] Other investors can follow, after observing that supplier succeed. This strategy would entail choosing a small- to mid-size firm that has much to gain from a visible success in supplying critical technology or services to the DER Platform. This concept is akin to Ming Zeng's weak partner example where Taobao partnered with smaller firms to build out its logistics capability.[53]

Reference Design Strategy. Similar to the "Follow-the-Rabbit" strategy, a platform can also encourage adoption by absorbing the initial engineering costs to adopt a new standard. The platform can engineer working prototypes of products and/or services and then make the designs freely available to innovators who might wish to adapt the designs to build their own unique product offerings. Adobe succeeded in driving innovation in the postscript laser printer industry by designing a boilerplate controller design for printers and then making the designs freely available to hardware manufacturers who licensed the computer language Postscript.[54] Adobe benefited through sales of its proprietary fonts. Google pursued a similar strategy when it launched the Android platform. To encourage handset manufacturers, it made reference hardware designs freely available. In the New York context, this could mean absorbing the engineering costs for hardware firms to connect their equipment to the platform and then making the solutions available to all as open source hardware designs that the firms could inspect and then modify to suit their particular applications. New York could allow the platform firms to patent or copyright their innovations under a Berkeley Software Distribution license at reasonable and non-discriminatory (RAND) terms.[55] Parker and Van Alstyne explain the distinction between different open source license terms in a 2009 article.[56]

Seeding and Subsidy Strategy. Platforms can go even further than publishing open source designs. By directly investing in the creation of specific products, the platform can create value for users. There is precedence for this practice. Google paid $5.5 million in prizes for the best new Android applications within 10 pre-defined categories to promote Android adoption. The total stock of mobile phones supporting Android now surpasses Apple's iPhone. In the New York State energy context, this strategy would entail defining categories of applications that the platform would need to have significant functionality for users. The Platform could run contests to encourage developers to supply applications in areas such as efficiency management, scheduling, remote sensing, and more.

An additional way to encourage users to join the platform could be to offer participants in the first $10

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[52] Cusumano & Gawer (2002) "Elements of Platform Leadership" Sloan Management Review 43(3); pp 51-58.

[53] Zeng, Ming, 2015. Ibid.

[54] Tripsas, Mary. 2000. "Adobe Systems Incorporated." Harvard Business School Case 9-801-199.

[55] Swanson, Daniel G., and William J. Baumol. "Reasonable and nondiscriminatory (RAND) royalties, standards selection, and control of market power." Antitrust Law Journal (2005): 1-58.

[56] Parker, Geoff and Marshall Van Alstyne (2009) "Six Challenges in Platform Licensing and Open Innovation." Communications and Strategies, No 74. http://ssrn.com/abstract=1559013.

million of transaction value a reduced participation fee for the following six months. This incentive would encourage participants to join the platform so as to be among the group that received the discount.

Marquee Strategy. Another common launch strategy is to identify key user groups or key developers and offer them attractive reasons to participate. Microsoft, for example, convinced Electronic Arts to offer popular sports games on the Xbox to give users a reason to buy Xbox. Once a platform attracts highly visible users, it will draw other sets of users who want to engage in transactions with those highly visible users. Translating this idea to the New York State energy context would mean encouraging a high-profile firm that is already successfully serving commercial and industrial customers to adopt the new platform and begin to transact. Alternatively, a major firm in the telecommunications or cloud computing industry could become a partner. The advantage of this strategy is that such a firm would already have a data exchange relationship with a large fraction of the target customers, which could significantly accelerate platform adoption.

Market Participation Strategy. The State of New York controls a large asset base of buildings, and thus is a potentially significant market participant. Under this strategy, the State of New York could demonstrate platform feasibility as both a producer of core energy products, from DR and other DER, and a consumer of core energy products. This strategy could also help the Platform Market get to minimum viable scale more quickly.

E. Platform Monetization

The monetization of platform services poses unique challenges. Network effects make a platform attractive by creating a self-reinforcing feedback loop that often grows the user base without commensurate effort or investment in user acquisition. Higher value creation by producers on the platform attracts more consumption, which in turn, attract further value creation. The failure of either of these sides leads to a collapse of network effects. This dynamic makes monetization more complicated than for a traditional linear value chain model where the end-customer pays the entire cost of a product or service.

Every decision regarding a platform should work toward strengthening network effects, or at the very least, should avoid weakening network effects. Monetization, too, should work in a way that strengthens not weakens network effects.

Therefore, three key questions are critical when deciding how to monetize the platform:

- For what products and services does the platform charge?
- Whom does the platform charge?
- How much does the platform charge?

Traditional non-platform businesses deliver value to their customers in the form of a product or service. They may charge for ownership of the product as most companies do, or for use of the product such as how GE charges aircraft makers for its engines based on actual usage.

Platforms rarely charge for the technology they create. Doing so would discourage users from coming on board and would thus prevent the creation of network effects. Instead, platforms that facilitate a monetary transaction between buyers and sellers often try to monetize by charging a transaction cut, i.e., a percentage of the actual transaction value. In some cases, the platform may instead charge a fixed fee per transaction. The fixed fee approach is especially relevant in applications with a high frequency of transactions and little or no significant variation in transaction value. In the New York State REV context, TCR expects transaction values to differ significantly by time and location, which mitigates against the application of a fixed fee per transaction.

Charging a transaction cut works because it does not come in the way of building network effects. Under this approach, the platform only charges buyers and/or sellers when an actual transaction occurs. However, these platforms face a unique challenge. To charge a transaction cut, these platforms need to ensure that they capture the transaction on the platform. In contrast, buyers and sellers have a natural incentive to find a match using the platform but to execute their transactions off the platform in order to avoid the platform's fee. This problem is especially rampant with platforms that connect service providers with service consumers.

Thus, this paper distinguishes between core energy product transactions, that market participants cannot easily execute outside or off the platform, and value added service transactions, that parties could easily consummate off-platform. The core energy products require significant data and computation support from the platform because the market or eLMPs that determine prices are only available on the platform and are highly time variant. In addition, they occur frequently, so there are significant savings to users who use platform resources to complete their transactions. By contrast, sellers of services such as energy efficiency improvements, building monitoring systems, and analytics support services may not continue to execute a specific transaction on the platform once they have made the match because they are highly motivated to avoid paying the platform a fee for the services it provides.

Note that there is considerable variation in the percentage fees that platforms charge for completed transactions. Bill Gurley, a venture capitalist who has invested in multiple platforms, describes his preference for lower fees in terms of friction:

> When evaluating new marketplace investments, we are naturally biased towards entrepreneurs who understand the strategic rationale behind the argument for a lower rake. If your objective is to build a winner-take-all marketplace over a very long term, you want to build a platform that has the least amount of friction (both product and pricing). High rakes are a form of friction precisely because your rake becomes part of the landed price for the consumer.

Table 3 summarizes examples of fees that Gurley reports in his article "A Rake Too Far."[57]

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[57] http://abovethecrowd.com/2013/04/18/a-rake-too-far-optimal-platformpricing-strategy/

Table 3. Examples of Platform Fees

Company	**Transaction Fee**	**Who Pays fee?**	**Notes**
OpenTable	1.9%	Seller	Reservation fee/average meal cost/person
Homeaway	2.5%	Seller	Estimated
Comparison Shopping	6.0%	Seller	Estimated
eBay	9.9%	Seller	Listing fees, marketing fees
oDesk	10.0%	Seller	10% on top of work billed
Airbnb	11.0%	Seller	3% + 6-12% depending on transaction size
Expedia	11.9%	Seller	Per 2012 10-K
Amazon Marketplace	12.0%	Seller	Estimate based on rate table
Fandango	12.5%	Buyer	Fee charged user / ticket price
PriceLine	18.5%	Seller	Per 2012 10-K
TicketMaster	26.0%	Buyer	Estimate for tickets sold by TM
Steam	30.0%	Seller	Rate card
iTunes	30.0%	Seller	Rate card
Facebook Credits	30.0%	Seller	Rate card
GroupOn	38.2%	Seller	Per 2012 10-K
Shutterstock	70.0%	Seller	From S-1

Who to Charge

As previously noted, the general principle is that monetization should not weaken network effects. This principle is particularly important when deciding whom to charge on the platform. Platforms rarely charge all their users in the same manner as standard linear value chain businesses. In most cases, charging all platform users would discourage user participation, thereby reducing network effect.

Certain platforms may subsidize super users. Malls offer attractive terms to large retailers like Macy's or Nordstrom, whose presence as anchor tenants guarantees the consumer traffic that other mall tenants will pay to gain access to.

A general principle to preserve and strengthen network effects is to discount or subsidize the set of users who are more sensitive to pricing. Users that are more sensitive to pricing are more likely to abandon the platform when charged, reducing or eliminating the network effect. A related principle that often works equally well is to charge the side that needs the other side more.

In the REV context, one of the goals of creating a platform is to facilitate valuable transactions that are not currently taking place. This partly relies on the assumption that a significant number of DER owners are not making full use of their capacity due to the lack of a market or to high transaction costs. Thus, the Platform should be able to charge DER sellers because they do not have an alternate market. In response to DER sellers who might ask why they should pay a platform fee to sell DER products when the buyers of those products do not, the answer is that those buyers have the ability to choose other resource options, such as capital investments and purchases from the wholesale market. Interestingly, Table 3 from Gurley shows that platform markets for financial transactions tend to charge the seller. In most of the examples (eBay, iTunes, Airbnb), the sellers are getting access to larger markets Finally, note that this approach is consistent with the recommendations of the Department Staff White Paper on Ratemaking and Utility Business Models in that DER/prosumers who most actively use the platform would bear a larger share of the platform's costs through transaction fees.

F. Regulatory Oversight of Platforms

The overarching goal of the platform is to facilitate valuable transactions that are not currently taking place. If there is too much regulatory oversight, participants may conclude that the cost of compliance is too high, so there needs to be a balance between making the market safe for participants and keeping the friction as low as possible. This subsection discusses some of the most significant regulatory issues that have come to the fore because of the rise of platform businesses over the last two decades.

Platform access. When a platform excludes certain potential participants, it raises questions about who benefits from the exclusion, whether that exclusion is fair, and what its long-term impact on the overall marketplace is likely to be. The issue of exclusion is especially significant when network effects are strong, as business professor Carl Shapiro argues, "posing a danger that new and improved technologies will be unable to gain the critical mass necessary to truly threaten the current market leader."[58] Thus, excluding certain potential participants may slow the pace of innovation, thereby denying consumers the full benefits of technological progress that a dynamically competitive market would offer.

The difficulty for regulators is that it can be hard to predict what the impact of a particular competitive strategy may be. In some instances, the conclusion can change significantly when viewed over a longer time span. In a 2014 article, Parker and Van Alstyne argued that platforms that limit competition among suppliers can actually benefit consumers by fostering higher rates of innovation.[59] The reason for this counterintuitive result is that, over time, the core platform tends to incorporate supplier innovations. Thus, they become available to all consumers for their direct consumption and become available to all participants to facilitate innovation.

Research into two-sided networks has overturned the existing conventional wisdom and required regulators to retool their predation tests to incorporate network effects.[60] [61] In particular, regulators have viewed the practice of selling goods or services at or below cost as evidence of intent to drive competitors out of business with the intent of then raising price once those competitors were gone. However, when firms take cross-market externalities into account, they can rationally price their goods or services at zero when selling to certain groups of customers even in the absence of competition.

Data and Privacy. As a result of the growth of network access and usage, issues regarding the use of consumer data have grown in scale and complexity. Many consumers may not understand that services provided by "free" information service businesses are collecting large volumes of personally identifiable information to power data-driven marketing. The sale of the underlying personal information about consumers is a significant source of income for many platform businesses.

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[58] Shapiro, Carl. "Exclusivity in network industries." Geo. Mason L. Rev. 7 (1998): 673.

[59] Parker, Geoff and Marshall Van Alstyne, "Innovation, Openness, and Platform Control," 2014. http://ssrn.com/abstract=1079712

[60] Rochet, Jean-Charles, and Jean Tirole. "Platform competition in two-sided markets." Journal of the European Economic Association (2003): 990-1029

[61] Evans and Schmalensee. "The Antitrust Analysis of Multi-Sided Platform Businesses," The Oxford Handbook of International Antitrust Economics, Volume 1, Edited by Roger D. Blair and Edited by D. Daniel Sokol, 2015.

This paper describes a platform that will have the potential to capture large volumes of potentially sensitive customer information. The platform will have to appropriately protect consumer privacy and be sensitive to the trade-off in using that information to create value for the users as opposed to creating an alternate revenue stream that only benefits the platform owners.

Private Governance. Platforms have strong incentives to institute systems to monitor and control the behavior of their users. Good governance is so important because we cannot rely upon markets in which people and organizations interact with no rules or safeguards to produce results that are fair and create value for those involved.

Platforms work to eliminate the main causes of market failures: information asymmetry, externalities, monopoly power, and risk. Market designer and economist Alvin Roth has four broad levers that platforms can use to address market failures.[62] According to Roth, a well-designed platform increases the safety of the market via transparency, quality, or insurance. The platform provides "thickness," which enables participants from different sides of a multisided market to find one another more easily. The platform also minimizes congestion, which hampers successful searches when too many people participate or low quality drives out high, and minimizes repugnant activity that people find objectionable. According to Roth, good governance occurs when platform managers use these levers to address market failures.

Of course, governance will never be perfect. Whatever the rules, system users will find novel ways to create private advantage. There will always be information asymmetries and externalities. Interactions lead to complications, which lead to interventions, which lead to new complications. Indeed, if good governance allows third parties to innovate, then as they create new sources of value, they will simultaneously create new struggles to control that value. When such conflicts arise, governance decisions should favor the greatest sources of new value or the future direction of the market, not where the market is or used to be.

Guidance for Regulators. To provide guidance for regulators on when to allow private governance versus when to step in with government regulation, this paper offers two framework options for regulators to consider. The first framework, provided by economists Heli Koski and Tobias Kretschmer, suggests that industries with strong network effects can indeed generate market inefficiencies and that the goal of public policy should be to minimize those. The market inefficiencies of particular concern are abuse of dominant position and the failure to ensure that new and better technologies are adapted as soon as they become available.[63]

The second framework, developed by David S. Evans, proposes a three-step process to test for the desirability of government regulatory action. The first step is to examine whether the platform has a functioning governance system in place. The second step is to see whether the governance system is primarily reducing negative externalities that would harm the platform (such as criminal behavior by users) or if it is primarily reducing competition to take advantage of a dominant market position. If on

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[62] A. Roth, A. E., “The art of designing markets,” Harvard Business Review, 85(10), 118, 2007.

[63] Koski, Heli and Tobias Kretschmer. "Entry, standards and competition: firm strategies and the diffusion of mobile telephony," Review of Industrial Organization 26.1 (2005): 89-113.

balance, the firm is using its governance system to deter negative externalities, then no further action is necessary. However, if the governance system appears to be acting in an anti-competitive fashion, then a third and final step is required. This step involves asking whether the anticompetitive behavior outweighs the positive benefits of the governance system. If so, then a violation has occurred, and a regulatory response is required. If not, the regulator need take no further action.[64]

In the context of the Platform described in this paper, the option for Distribution Utilities to own the Platform jointly creates some advantages and some potential issues. Because Distribution Utilities will have the operational details that the Platform will need to calculate DLMPs for market clearing, there will need to be close level of cooperation between these entities. However, when Distribution Utilities act in the role of default service suppliers or DSP providers contracting for core electric products, they become buyers on the Platform, which puts them into a potential conflict of interest relative to the suppliers of core electric products from DER. This possible conflict of interest is an area for regulatory oversight.

Adherence to U.S. Commodities Futures Trading Commission Guidelines

As part of the platform setup, a determination will need to be made as to whether the platform market will be a Designated Contract Market (DCM) and need to follow the of the U.S. Commodities Futures Trading Commission guidelines. To obtain and maintain such a designation, a DCM must also comply, on an initial and ongoing basis, with the twenty-three Core Principles established in Section 5(d) of the CEA, 7 USC 7(d) and Part 38 of the CFTC's regulations and with the implementing regulations under Part 38 of the CFTC's regulations.

The preceding discussion presents the broad principles applicable to platform regulation. The Regulatory Oversight section of Chapter 4 discusses specific regulatory oversight issues that the Commission should address in the New York State REV context.

G. Chapter 3 Summary

Chapter 3 presents the principles that guided analysis and design of the Platform conceived to support REV objectives. The key components of platform markets are the participants (i.e., buyers and sellers), the information those participants exchange regarding their specific needs and products on a dynamic basis (information units), and the filters they use to find a match. The chapter also highlights some of the challenges that platforms face, including launch, monetization, and regulatory issues as they mature.

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[64] Evans, David. "Governing Bad Behavior by Users of Multi-Sided Platforms." (2012).

4. Enabling DER Markets via a Digital Platform

Chapter 4 provides a vision for the development and implementation of a new, Platform-enabled energy market in New York State that would animate and integrate DER products and services. This would be a decentralized market with far greater granularity in spatial and temporal pricing than the existing NYISO wholesale markets. The implementation of this market would enable New York State to reduce its reliance of wholesale markets in which DER play a minor role, by increasing its reliance on a Platform Market in which DER are on an equal footing with large scale, centralized assets.

The objective of Chapter 4 is an effort to “connect the dots” of transitioning from the current physical and financial systems of today’s utilities to the market design, pricing, and participation of the Platform Market described in this paper. Key to making the connections is the launch of the Platform on which price formation takes place at an increasingly granular level and where increased numbers and types of transactions occur as the market matures.

Chapter 4 begins with an overview of the steps and timeframe required to implement the conceived Platform and Platform Market. The second section discusses the market and regulatory developments needed to reach the point at which DSP providers can launch the Platform. The third section presents two alternative Platform launch strategies. The fourth section of the chapter introduces the initial Platform Market in terms of its structure and processes, its likely participants and the role and position of significant stakeholders. The final section of the chapter introduces a vision of the ultimate market, which we acknowledge may take significant time to develop. That section discusses the products and services we can foresee today, recognizing that additional products and services we cannot currently imagine are likely to develop in the ultimate Platform Market.

A. Overview of Platform Implementation Steps and Timeframe

The Commission will ultimately decide whether to approve or reject the implementation of a platform and a platform market. If the Commission decides to approve a particular platform and platform market, the steps and timeframe required to implement that decision will vary according to the specific designs the Commission approves. This section provides an overview of options and implementation steps under two broad headings: “development of the Platform and associated capabilities” and “development of the Platform Market.”

This Chapter presents two possible Platform launch strategies, each of which has different implications for development of a Platform Market. The first strategy is to launch a Platform with an initial emphasis on financial transactions for core energy products; it will support near-term development of a Platform Market and create opportunities for third-party development of other products and services. The second strategy is to launch a Platform with an initial emphasis on information transactions; it will initially provide customer identification support for asset suppliers/developers and market information for their customers that may eventually lead to the establishment of a Platform Market in which the core energy products of the assets can be traded. This paper argues that proceeding with the financial alternative that is focused on facilitation of a market for electrical products will offer greater incentives for the development of DER and move more quickly to achieve the network externalities that are the hallmark of platforms in other industries.

Assuming the Commission approves the financial platform strategy, development of the Platform will occur during this same 18-month launch period. This phase must define the core electric products and choose the granularity of pricing for those core electric products. If the second launch strategy were chosen, it would be necessary to establish the rules by which prequalified customer information could be marketed to asset developers along with the incentive needed to attract third-party providers of services to the Platform. As it is not anticipated that a market for core products would be an initial part of the second strategy, there would not be a need to deal with the issue of increased granularity in pricing until after the initial launch.

The paper discusses the implementation process for a financial Platform and Platform Market in three time periods, which are discussed in the following sections:

- **Start-up (T_0).** Begins with the Commission decision to move forward and ends when the DSP providers launch the Platform. This phase could be completed in 18 months;
- **Initial Platform Market (T_1).** Begins with initial operation of the Platform and operation of an Initial Platform Market based upon eLMP. This phase could be last three to five years, or longer,
- **Interim and Ultimate Platform Markets (T_2 and T_3).** Begins with operation of an Interim Platform Market based upon pricing that is more granular than eLMP. It evolves over time to an Ultimate Platform Market based upon DLMP.

Development of the Platform and associated capabilities. This series of steps includes structuring of DSP ownership of the platform, including initial funding and ongoing cost and revenue allocation; definition of the initial functions to be provided; development of the infrastructure in hardware and human resources; acquisition of the market solution and other Platform-based software; and establishment of the governance / regulatory environment. The DSP providers could implement the initial Platform in an estimated 18 months. This Platform development path would be coordinated with the Development of the Platform Market path (summarized below) that develops the details of the market design

Development of the Platform Market. The critical steps to develop the market design are to define the core electric products and to choose the granularity of pricing for those core electric products. The first step along the path towards development of the Platform Market will likely need to be the establishment of an Initial Market in which eLMPs provide granular price information. This paper expects larger customers with the ability to be price-responsive to be early participants in this market.

The individual Distribution Utilities operating as DSP providers within New York State are proceeding with plans for the roll out of interval meters to their retail customers. The pace of installation of interval meters for retail customers need not hinder the transition to more granular pricing for core electric products. Large customers are the most likely to be price responsive DR providers, and thus the most likely early adopters, and because many large customers may already have interval meters. Moreover, large customers who do not have interval meters are likely to be first in line for receipt of new interval meters.

The second and further steps along the path toward development of the Platform Market are moves to increased granularity of locational information for DER and other players in the distribution market. The ultimate point of price formation is at the individual customer node or customer meter. The envisioned structure of continuous, bilateral price formation to the point of market closure, followed by detailed market clearing, assumes that interval metering and increased communications and control technology will evolve to allow distributed decision-making coordinated primarily by locational pricing within the distribution system.

This ultimate market design and level of price granularity is achievable, but it will take time and involve costs that will require evaluation. The transition to that Ultimate Market could begin with a move from the Initial Platform Market based on eLMP to an Interim Platform Market with increased granularity in pricing within the distribution system. It should be possible to implement that move over a three- to five-year time period. It is important to note that the Platform Market structure will allow for increased granularity that can occur at a different pace within different individual DSP providers. The pace at which each DSP provider moves from eLMP to more granular pricing will be a function of many factors including the availability of interval-metered data that can capture and report the quantity of production and consumption at and behind the distribution nodes in order to settle the nodal locational market.

Table 4 provides a point of reference for the discussion of the implementation of the Platform and Platform Market throughout Chapter 4. It provides a summary of major steps, Platform functions and Platform Market products and services by time period.

Table 4. Evolution of Platform and Platform Market

<table>
<tr><th rowspan="2">Key Steps / Elements</th><th colspan="4">TIME PERIODS</th></tr>
<tr><th>Start-Up (T_0) (18 months from decision)</th><th>Initial Platform Market (eLMP)(T_1) (3 to 5 years)</th><th>Interim Platform Market (T_2)</th><th>Ultimate Platform Market (DLMP) (T_3)</th></tr>
<tr><td colspan="5">Development of the Platform and Associated Capabilities</td></tr>
<tr><td>Platform</td><td>Joint Utility Development of Structure & Selection of Provider (Operator)</td><td>Platform launches with eLMP market & value added services</td><td colspan="2">Platform evolves market to greater granularity in location and pricing and value added services leading to full DLMP</td></tr>
<tr><td rowspan="2">Utility / DSP Capabilities</td><td>Utilities Evolve to DSPs and Develop Roadmaps for Transition to more Granular Market Pricing</td><td rowspan="2">Utilities/DSPs provide NYISO continuously updated ESCO load data and complete deployment of capability to collect interval customer data</td><td>DSPs track distribution power flows & calculate marginal losses</td><td>DSPs able to provide data for Platform to calculate market clearing prices based on full DLMP</td></tr>
<tr><td>Utilities/DSPs Accelerate Deployment of Capability to Collect Interval Customer Data</td><td colspan="2">Utilities/DSPs support increasingly granular settlements that are calculated by/on the Platform leading to full DLMP</td></tr>
<tr><td rowspan="2">NYISO Wholesale / Retail Market interface</td><td>NYISO adjusts market software to report eLMPs</td><td>NYISO reports eLMP to DSPs</td><td colspan="2">NYISO coordinates with the Platform provider to provide wholesale data that allows for locational price settlements required for full DLMP</td></tr>
<tr><td colspan="2">NYISO provides / publishes Day Ahead quantity and price commitments for eLMP pricing points (load nodes)</td><td colspan="2"></td></tr>
<tr><td>Regulatory Oversight</td><td colspan="2">Commission approves Platform Structure & Governance</td><td colspan="2">Ongoing oversight of Platform Governance and Independence</td></tr>
</table>

Table 4. Evolution of Platform and Platform Market				
Key Steps / Elements	**TIME PERIODS**			
	Start-Up (T_0) (18 months from decision)	**Initial Platform Market (eLMP)(T_1) (3 to 5 years)**	**Interim Platform Market (T_2)**	**Ultimate Platform Market (DLMP) (T_3)**
Development of Platform Market - Core Electric Products				
Energy	No Changes	eLMP settlements for DER	Interim DLMP settlements	DLMP markets
Reserves	No Changes	Targeted Procurements for local reserve requirements	DLMP for Local Reserves; Frequency Response Pilots	Coordinated local & system DLMP reserve markets
Reactive Power	DSPs pilot VVC with utility VAR on secondary distribution[65]	Utilities deploy VVC architecture & utility VAR sources	Utilities pilot integration of customer VAR sources	Integration of utility & customer VAR in reactive power market

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[65] The objective of Volt VAR Control is to minimize the peak power and energy losses while keeping the voltage within specified limits under varying load conditions. See J.J. Granger, “Volt/Var Control on Distribution Systems with Lateral Branches Using Shunt Capacitors and Voltage Regulators Part I: The Overall Problem,” IEEE Power Apparatus and Systems No. 104 Issue 11, November 1985.

Table 4. Evolution of Platform and Platform Market

Key Steps / Elements	**TIME PERIODS**			
	Start-Up (T_0) (18 months from decision)	**Initial Platform Market (eLMP)(T_1) (3 to 5 years)**	**Interim Platform Market (T_2)**	**Ultimate Platform Market (DLMP) (T_3)**
Development of Platform Market - Applications				
Targeted Procurement to Defer Distribution	Utility planning identifies where DER might defer investment	Utility commits to regular purchases of option contracts from liquid DER market for energy & reserves	Utility option contracts become increasingly granular as they recognize losses in interim pricing	Where liquid forward markets exist, DLMP could replace targeted procurements
Default Supply Service Rates	No Changes	Transition MHP customers from DA to RT eLMP for energy imbalance. Provide MHP capability to forward contract for hedging, to respond to retail rates with energy @ eLMP (e.g. smart control rate) and new demand management services	Ability to support new retail rates with energy at granular prices; ability to support new demand management services and retail rates	

<table>
<tr><td colspan="5">Table 4. Evolution of Platform and Platform Market</td></tr>
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<tr><td colspan="5">Development of Platform Market - Applications</td></tr>
<tr><td rowspan="3">Demand Response</td><td rowspan="3">Utilities Pilot Targeted DR programs for Distribution constraints</td><td colspan="2">Flexible demand & smart EV charging expand outside DR programs</td><td>Price response overtakes capacity & energy DR programs</td></tr>
<tr><td></td><td colspan="2">Smart technologies expand the role of DR in ancillary services</td></tr>
<tr><td colspan="2">Price responsive DR in Targeted Procurements such as large commercial buildings</td><td>Price responsive DR in at all customer levels</td></tr>
<tr><td>Value Added Service Support for DER</td><td>Platform identifies utility information services & recruits key third party service providers</td><td colspan="3">Potential services include: Price forecasts; on-bill repayment financing; smart technologies for building energy management, EV charging and other DER operations; data analytics for DER investment & management; customer-to-customer retail transactions; targeted utility procurements of DER; DER product aggregation; bill comparison apps; clean energy tracking; retail shopping / supplier matching; & other innovations</td></tr>
</table>

B. T_0 Start-Up / Pre-Launch of the Platform Market

Moving from the current structure of the electric market in New York State to the market envisioned in REV will be an evolutionary process. If the Commission decides to move forward with implementation of the Platform and Platform Market as described in this paper, the start-up phase will begin with the Commission decision and end when the Platform and its associated market are operational. The start-up phase has four key steps. The first step is a regulatory decision that approves the structure and governance of the platform. The second step is to reach an agreement with NYISO to provide eLMPs at the interface nodes between the transmission system and the various distribution systems. The third and fourth steps are, respectively, development of the Platform and development of the products and services for the initial Platform Market. Steps three and four will build upon the ongoing efforts of the Distribution Utilities under the REV and the Commission in guidance and evaluation of that process.

Regulatory Decision on Platform Structure and Governance

This paper has focused on the design of a distribution level market with active DER participation based on the implementation of a digital Platform that would facilitate a Platform Market. The paper has provided the rationale for the creation of a Platform Market with far greater granularity in pricing and for the existence of a breadth of products that begin with the core of real energy and reactive power and reserves and build upon these and logical ancillary products that are most likely to be early arrivals on the Platform. The paper concludes that a Platform Market, with increased granularity in locational prices, will best fulfill the objectives of the Commission as articulated in its Framework Order.

The Commission will base its decisions on whether to move forward with the Platform Market, approval of a Platform structure, and governance of the Platform and Platform Market on a range of considerations, only a portion of which are within the scope of this paper. This paper provides analysis concerning the following criteria:

- How to structure the Platform in terms of its sponsors (Chapter 3).
- What products and services the Platform will support (Chapter 2).
- Whom the Platform will serve (Chapters 2 and 4).
- What transactions and types of transactions are anticipated (Chapters 2 and 3).
- What data the Platform is likely to transact, and between what players (Chapters 3, 4, and the Appendices).

For the reasons laid out in Chapter 3, this paper argues that there be only one statewide user-facing Platform to facilitate the participation of DER as actors in the power generation and distribution system. This approach is justified by the need for a broad market within the State and the inefficiencies in cost and implementation of establishment of multiple platforms.

Independent of whether a single or multiple platform structure is chosen, its sponsors and providers need to agree upon the platform's functionality prior to launch. As discussed in Chapter 3, this paper expects the Distribution Utilities to be co-sponsors of the single, statewide Platform. Their role, subject to approval by the Commission, will be to set (but not implement) the rules of the Platform. These rules are generic in that they represent the underlying requirements of all trading markets. The Platform provider or operator is an independent implementing entity that provides the mechanics of price formation and settlement based on the sponsor's rules and structure.

The listing below provides a summary of the sponsor and platform functions of a market focused on facilitating transactions in the electric distribution sector.

The Platform Sponsor will be responsible for core information and connection standards such as:

- Standard definitions to describe the product and service providing assets – the Distributed Energy Resource.
- Definitions of the core and other products traded on the Platform analogous to commodity definitions available on commodity trading platforms.
- Definitions of / statement of the locational points at which granular prices will be traded and the calculation procedures for market clearing.
- Standard formats for data submission and storage.
- Market timing (frequency) for information submission and updates including transfer standards and protocols in terms.
- Definition of market structure and its functional elements.
- Participant financial (banking) information for flows transfer including credit limits.
- Standard contracts formats for transactions.
- Pricing principles for fees charged by the Platform for Platform transactions.

The Platform will provide information that is updated frequently such as:

- DER resource profiles – for specific resource types:
    - Supply side user profile definitions.
    - Demand side user profile definitions.
- Credit and risk profiles for specific supply and demand side user types.
- Value added service provider profile definitions.
- User identity and security management systems.
- Pricing polices:
    - Core product transaction fee schedule.
    - Data service subscription price schedule.

The other players in the market that are critical to the decision to move forward include, but are not limited to the following parties:

- DER Owners (household and commercial) who are also retail customers.

- Distribution Utilities/DSPs.
- Energy Service Companies (ESCO).
- Aggregators and financial intermediaries (traders) who would transact on behalf of DER owners.
- DER developers and system installers (PV rooftops, etc.).
- Value added service providers (forecasting, analytics, etc.).

Table 5 illustrates the range of transactions one could design a platform to support.

Table 5. Range of Possible Platform Transactions

Distribution Utility <==> DER Owner: Buy and sell Core Products to one another ESCO <==> DER Owner: Buy and sell Core Products to one another ((An intermediary could also transact on behalf of DER owners)
Distribution Utility ==> Sells prequalified leads to ESCOs[66,67] Distribution Utility ==> Sells prequalified leads to DER system installers
DER system installers ==> sell systems to DER owners ESCOs ==> sell full service supplier service to DER owners/households
Value added service providers ==> sell analytics support to ESCOs Value added service providers ==> sell analytics support to Distribution Utilities

Market participants on the supply side, the demand side and as value added service providers will want to exchange information on/with the Platform. The type of information exchange depends upon the role the participant is playing. The following list, while not exhaustive, provides examples of the types of data market participants will need to exchange in order to transact:

Supply Side Platform Users (DER Resource Owners)

- Provide data on resource profile.
- Provide data on which products will be offered.
- Provide financial transaction data for banking.

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[66] As discussed under issues in regulation, leads would be specific to customers based on the Distribution Utility / DSP identifying likely acceptors and providing information to the ESCO or DER system installer after the customer as "opted in" to being individually identified.

[67] See as example http://www.retroficiency.com where third parties provide qualified leads as targets for utilities and energy services companies in this instance focused on the commercial sector

Demand Side Platform Users (Distribution Utilities, ESCOs; DER Owners)

- Provide data on types of services requested.
- Provide financial transaction data for banking.

Value Added Services Provider Platform Users

- Provide data on services offered.
- Set prices for services.

DER Systems Vendor Platform Users

- Provide data on desired customer profile for lead purchases.
- Provide data on types of services offered.

The Platform with the participants described will have significant complexity, both at the development stage as well as for ongoing operations.

The decision to move forward, as indicated is a sine qua non but not simple nor one that can be made without taking into account the complexities of the players, the services, and the evolution of the market itself. The positive conclusion, however, is that not all decisions need to be made for once and for all. The critical decisions, as discussed later in this chapter, relate to the initial structure and goals of the Platform. Once initiated, the Commission and stakeholders can guide the platform toward the ultimate objective.

Increasing the Granularity of Price Information

The second step during the startup/pre-launch phase is a joint effort between the Commission and the NYISO to increase the granularity of price information available to the market and most specifically to DER. In operating the wholesale market, the NYISO calculates the marginal value of energy in 5- minute intervals at each of roughly 2,000 nodes and links between those nodes (the Locational Marginal Prices). However, NYISO individually only retains and reports the LMPs at the generator nodes as required for settlement. It aggregates the more granular LMP, primarily load node data, into LMPS for 11 zones within the State. Significant locational price information is lost due to the aggregation of granular LMPs.

Reporting the value of energy to (and from) load for only 11 zones does not adequately reflect the variation in cost / value of energy in the state and as a result does not accurately reflect either the benefit of DER in supply or price responsive demand[68] in the state. In many hours, there is a significant difference between the prices at individual nodes and the average LMP for the zone. Figure 6 presents the distribution of difference between the nodal price for the Astoria generator in NYC and the zonal price. In 11% of the 8,760 hours in the year the absolute value of the price difference is greater than $1.00/MWh. Figure 7 presents the same information for the Empire node in the Capital Region where

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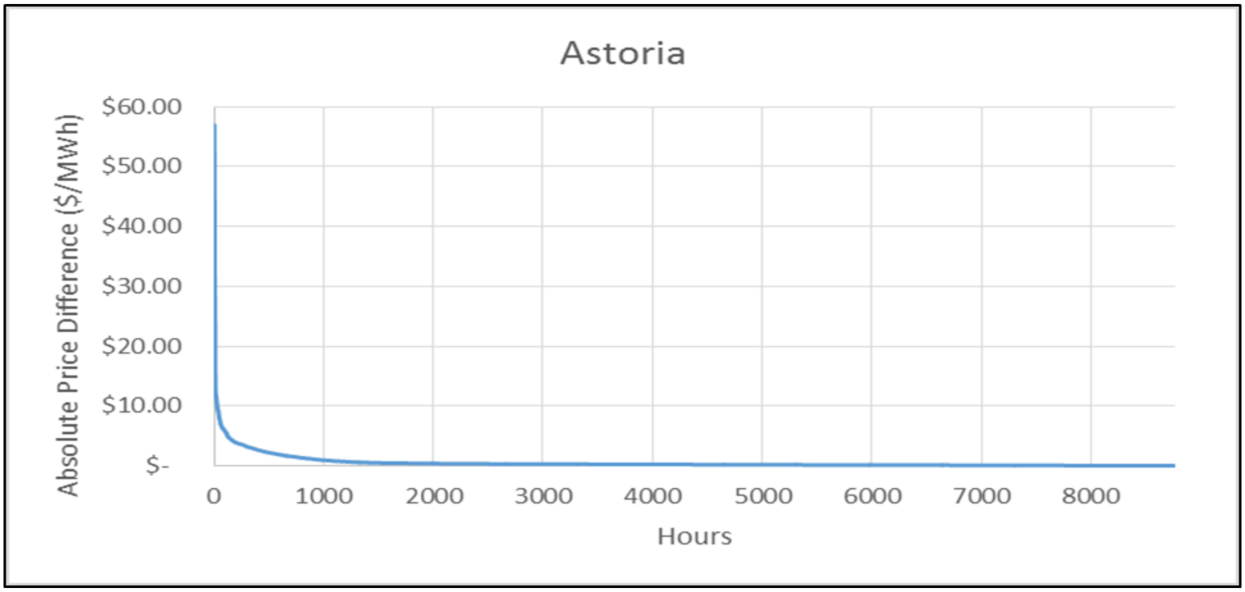
[68] Price Responsive Demand (PRD) is demand that predictably responds to changes in wholesale prices.

nearly 30% of the hours show a price difference greater than $1.00/MWh.[69]

Moving forward with the market design and implementation of the platform will benefit greatly from the development of eLMP, which NYISO would calculate for roughly 2000 load and supply nodes. The exact number and their spread through New York State will be a matter for analysis as to where the differences are material to the development of DER and what the impact of increased reporting will be upon the NYISO. As previously discussed, the NYISO calculates these values as a part of the security constrained dispatch analysis undertaken but does not retain the values.

Figure 6. Absolute Value of the NYC Zonal LMP minus Nodal LMP by hour, 2014



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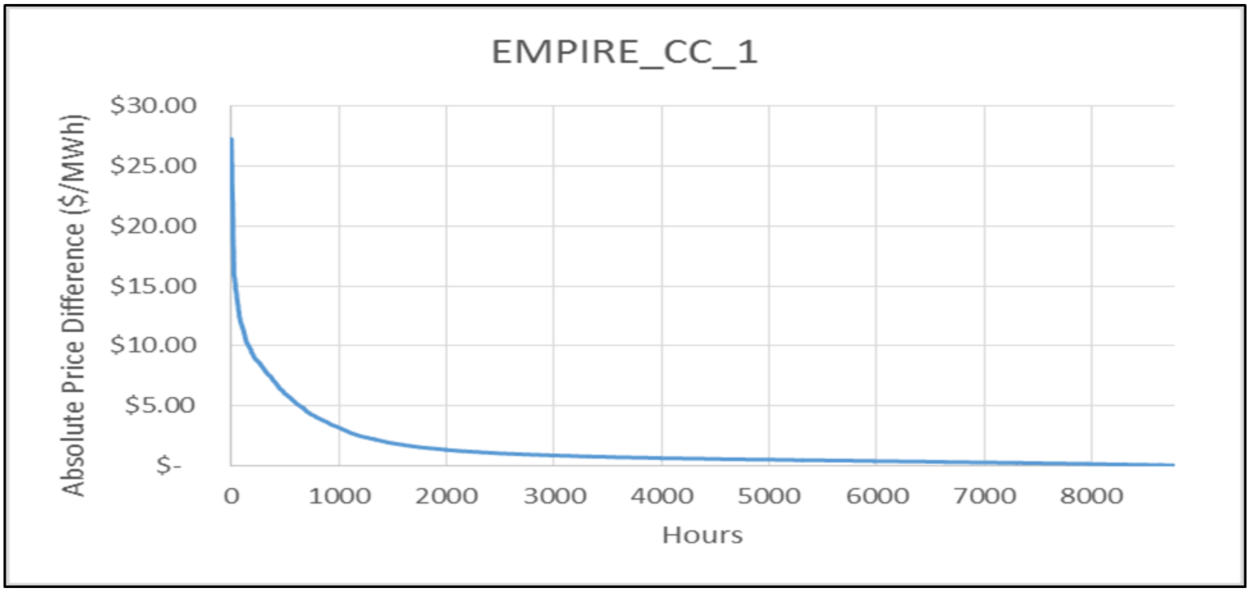
[69] TCR acquired hourly data from the NYISO web page for Astoria and Empire Generating unit buses and for the same hour Zonal Prices for the NYC and Capital Region pricing zones.

Figure 7. Absolute Value of the Capital Region Zonal LMP minus Nodal LMP by hour, 2014



Development of Products and Services

Distribution Utilities already have initiatives underway to develop DER products and related services suited to transacting on a platform. Distribution Utilities have initiated or proposed pilot projects in response to the Framework Order. Development of a single statewide Platform will provide a different set of opportunities in the Initial and Interim phases of the Platform Market. While much of the discussion in the REV proceeding to date has been on deferral of distribution system investment and on moderate expansion of DR programs, a platform with accompanying granularity in prices will encourage more localized focus on DER that can provide greater system benefits to the utility.

C. Platform Launch Strategy

The previous section of the paper discussed the go/no go decision process for the Platform. This section presents the next phase in that decision-making, namely the specific structure that the Platform will assume, the specifics of the launch strategy and the structure of revenue generation. The section presents two options for launch of the Platform.

Option 1. Launch as Market Trading platform to facilitate core product transactions

The first option is to launch the platform as a marketplace to trade core electrical products. Chapter 2, Section B describes the anticipated core electric products to be traded upon launch. The following points help to define what a market trading platform would be, particularly in its initial or early stages, and what it would not be.

- The design of a market trading platform would initially focus on facilitating financial transactions between buyers and sellers.
- In parallel with, and independent of, the financial transactions on the Platform, individual participants schedule physical consumption and physical delivery of real energy and reactive

power.

- The platform matches participants in a continuous market where it facilitates transactions in electric products by providing infrastructure and rules.
- Market participants will include DER owners, aggregators of DER, consumers, ESCOs on behalf of consumers, Distribution utilities, and financial participants.
- The design of a market trading platform would provide useful information to ESCOs. In addition, the platform could eventually add the functionality needed to be a portal for consumers to shop for ESCOs.

Option 2. Launch as Customer Information Platform to provide efficient access and improved marketing efficiency for primarily ESCOs and DER providers

The second option is to launch the platform as an information and matchmaking source that initially would focus on helping ESCOs and DER vendors identify prospective customers. The cost of acquiring individual retail customers in the electricity sector, particularly residential and small-commercial customers, has traditionally been significant. In its 2012 Benchmarking Report on soft costs for solar photovoltaics, the National Renewable Energy Laboratory reported marketing/acquisition costs of $1.650 for 5-KW solar installations costing less than $25,000.[70] A platform focused on identifying qualified leads for both ESCOs and DER vendors could represent significant savings for those players as well as savings for consumers through reduced marketing and acquisition costs.

Under this launch option, the platform's core transactions would take place between the providers of fine-grained customer data (Distribution Utilities/DSP providers) and ESCOs and DER system providers who wish to reduce their marketing costs. The second transaction, which may or may not take place on the platform, is a system sale to the consumer in the case of DER providers. Another version of the second transaction would be for an ESCO to sign up a consumer to be their primary energy service provider. Repeating from the table of transactions above, the marketing platform would facilitate the following:

- Distribution Utility sells leads to ESCOs
- Distribution Utility sells leads to DER system installers
- DER system installers sell systems to DER owners
- ESCOs sell supplier service to DER owners/households

Option 2 provides a mechanism that can reduce the transactions costs of acquiring new customers for ESCOs; it can increase customer knowledge of and engagement with optional utility tariffs when they are bundled with vendor technologies and, it may increase demand side elasticity through the availability of incremental information and options. Effectively matching consumers to potential product

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[70] Ardani, Barbose, Margolis, Wiser, Feldman and Ong. "Benchmarking Non-Hardware Balance of System (Soft) Costs for U.S. Photovoltaic Systems Using a Data-Driven Analysis from PV Installer Survey Results" U.S. Department of Energy Technical Report DOE/GO-10212-3834, November 2012.

and service offerings may require that Distribution Utilities / DSPs provide to the Platform detailed customer data. As an example of the role that the Platform could play in order to protect privacy, the Platform could take seller requests for buyers with a particular profile and then match those sellers with prospective buyers who (1) fit the sellers' profiles or screening criteria and (2) who had indicated a willingness to being contacted by potential marketers, which is referred to as having "opted in." There is significant precedent for such opt-in systems and a number of strategies are available to encourage consumers to allow marketing access. These include accepting discounts on other products and service or simply checking a box in response to surveys and mailings. Table 6 presents a summary of the advantages and disadvantages of the two launch options.

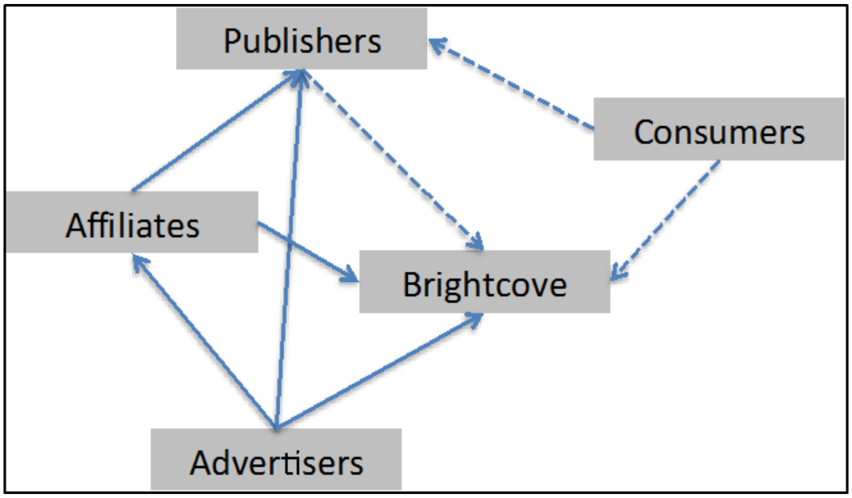
Table 6. Advantages (+) and Disadvantages (-) of Alternative Launch Options

Option 1 **Platform to facilitate trading core products**	**Option 2** **Platform to facilitate marketing**
+ Creates value for DER owners by providing access to markets that they cannot currently participate in. **+** High volume of transactions ensures constant interaction and user engagement and data generation. **+** High volume of transactions provides platform with its own data source. **+** Participation of DER owners, who are a large group, attracts other types of participants to the platform. **+** Provides the potential for development of related products – network externalities.	**+** Significant pull from market participants looking to lower customer acquisition costs. **+** Increases customer access to information concerning rate and service options **+** Small number of market participants makes it easier to mobilize the market. **+** Can provide for additional demand side elasticity of response through greater awareness of program opportunities.
- DER owners are a large group and therefore more difficult to mobilize. **-** Distribution Utilities / DSPs need to make investments to support the platform by providing detailed system state information in time and space.	**-** Success depends upon Distribution Utility / DSP and Commission willingness to provide fine-grained customer data to the platform to facilitate matching. **-** Success in facilitating customer identification for DER installers and ESCOs does little to attract current or potential DER owners to the market. **-** Transactions are already possible and do not require a platform to realize.

To help put the choice of launch option into context, consider the launch of two platforms in the

Internet television market in the mid-2000s, as illustrated in Figure 8.[71] Brightcove launched with a focus on Publishers (such as MTV, Wall Street Journal, and The New York Times) and advertisers. The ultimate plan was to then line up affiliates and consumers. Figure 8 shows that the Brightcove multi-sided platform plan has much of the complexity of the mature platform.

Figure 8. Brightcove Internet Video Platform



Launching with publishers as the initial user had the advantage of a simpler sales cycle and generated early revenue. However, the strategy did little to attract consumers and in fact led to conflicts between Brightcove and publishers over who owned the customer relationship.[72]

The second platform, YouTube, focused heavily on users who would be both content providers and consumers. YouTube's goal was to facilitate one core transaction, the exchange of short video clips between users. This relatively simple strategy facilitated rapid growth that quickly dominated the market. Interestingly, the long-term vision of the two platforms was nearly identical and YouTube has since gone on to line up publishers, create syndicated channels, and facilitate advertising. It was able to attract the additional market participants because of the strong network effects from the consumer users to the other participants.

Relative to the two previously discussed launch options, the focus of platform launch Option 1 is content (like YouTube), while the focus of platform launch Option 2 is the participant (like Brightcove).

TCR finding: Launch Option 1 is more likely to succeed

Based upon our analysis and experience, launch Option 1 has the greater chance of success because it creates stronger network effects that can be used to attract additional participants, it creates a stronger data layer that can be used to facilitate additional transactions, and it creates more initial value by

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[71] Hagiu, Andrei, and David B. Yoffie. "Brightcove, Inc. in 2007." Harvard Business School Case 712-424, September 2011. (Revised March 2014).

[72] Hagiu, Andrei. "Strategic decisions for multisided platforms." MIT Sloan Management Review 55.2 (2014): 71.

facilitating transactions that are not currently taking place.

Under this option, the Platform will need to be able to provide sufficient functionality to support core product financial transactions and provide the necessary information to complete transactions. These include a system for sellers to make product offers and a system for buyers to request core products. It is important to focus the platform's initial transactions to a small set that will generate value for users. Once the basic Platform building blocks are in place, they can easily scale to accommodate more users. In addition, computation and storage capacity are available as commodity resources.

Mobilizing Market Participants (DER Owners, ESCOs, Distribution Utilities)

For the Platform to provide value to both supply- and demand-side users there must be a sufficient number of both user types to create market liquidity. As noted in the description of Platform roles, the Platform will require a set of technical standards to specify how to connect, how to trade, how to settle transactions, and how to describe products. Further, market participants will need a reason to want to buy products on the platform. For example, from a strictly business perspective Distribution Utilities and ESCOs would purchase core energy products from the Platform Market to reduce their cost of supply and/or delivery. Other reasons why certain market participants might purchase products in the Platform Market include the need to comply with regulatory procurement standards or the desire to meet demand from a segment of customers who want clean and/or locally produced energy.

To mobilize a significant number of DER owners it will likely be necessary for the Platform partner with key user groups that have existing commercial relationships to help DER owners manage their resources. A primary example would be the State of New York as a significant owner and occupant of commercial and educational space mobilizing leveraging is assets to move the Platform activities forward. In addition, using the language from the previous chapter, mobilizing organizations such as the New York Power Authority (NYPA) would represent a Marquee strategy. NYPA could choose to purchase core electric products from DER or an aggregator wishing to sell core electric products acquired from local renewable DER. Their presence would provide the impetus both for DER to sell their core products to NYPA and for buyers wishing to acquire green products to use the Platform to acquire them from DER. In the current market, a number of intermediaries transact on behalf of DER owners. These organizations can be early Platform adopters and should be encouraged to connect their systems to the platform so that they can use the platform to transact on behalf of their own customers. One such encouragement might be to offer reduced transaction fees for higher volumes of transactions.

In addition, there may be certain functionality that ESCOs or Distribution Utilities/DSP providers need to develop to successfully connect to the Platform and participate in transactions. In this case, market participants could co-develop the necessary technology and the Platform could publicize its success stories. Chapter 4 described this strategy as "Follow the Rabbit." In order to employ this strategy, there needs to be budget to support joint engineering to solve adoption challenges for users.

Beyond the Core Product: Value-added Service Transactions

Over time, successful platforms tend to scale by layering new interactions on top of the core interactions. In some cases, the gradual addition of new interactions is part of the long-term business plan that platform founders had in mind from the beginning. Other interactions evolve over time.

Successful platforms remain open to the possibility that users will discover new and valuable elements of value to exchange over the platform. Peter Coffee (VP Platform Strategy at Salesforce.com) expressed the idea behind such emergence: "your users will let you know when you have a platform. It's a platform when they do something with it that you didn't expect." [73]

One path toward increased Platform functionality would be for ESCOs or others on the Platform to integrate sets of services tailored to the needs and preferences of individual consumers. Market participants can capture value through the integration of core electrical products with adjacent or ancillary higher value markets. The adjacent markets could include:

- Electricity with hedged risk - core products with hedging of price variability.
- Energy resilience - guarantees of differentiated qualities of service.
- Green energy - procurement of clean energy or the equivalent of Renewable Energy Credits (RECs) for industries that look to be still greener. Google in its efforts at carbon neutrality is an example of one such potential buyer. This represents a demand for renewable energy that is in excess of the Renewable Portfolio Standard (RPS) or carbon reduction credits in excess of the carbon emission limits required to comply with the Regional Greenhouse Gas Initiative (RGGI).
- Electric transportation - smart charging (and in the future potential discharge from car batteries into the grid), rapid changes in charging to provide grid ancillary services, as well as a range of other services.
- Electric heating - thermal storage (e.g., fire brick options) and the potential to expand electric heating (or heating and cooling, e.g. heat pumps) by virtue of identifying where it is most cost effective.
- CHP - identifies increased opportunities for CHP where CHP can provide value to the grid.
- Home/building monitoring, security, and automation - can incorporate monitoring and control that "optimizes" multiple objectives including productivity, retail experiences, security, or directional information in commercial spaces and in residences for different users.
- Home/building improvement, maintenance, and repair - integrates home and building services markets as well as improvements, maintenance, and repair related to DER related equipment and software.

To spur the development of value added services, a working group could identify different categories (e.g., maintenance/repair, forecasting, house monitoring). Once the working group agrees upon a set of categories, the Platform could offer prizes for the first and second best applications/services in each category. This is exactly how Google was able to foster the creation of new applications for its Android operating system. Google offered $500,000 of prize money in each of 10 categories (e.g., productivity,

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[73] Peter Coffee, VP Platform Strategy, Salesforce.Com. Remarks at the MIT Platform Summit, Co-chairs: Geoffrey Parker and Marshall Van Alstyne. July 26, 2013.

social, photography, productivity) for a total of $5 million.[74] This strategy created applications to attract users during the critical early stages of Android's launch.

Fee and Price options

This paper presents a rationale for the Platform to base its fees for core product sales on completed transactions. To reduce friction for adoption, the fixed fees for access to the platform should be as low as possible or be set at zero. Only in the event that there are significant costs to qualify participants would it be reasonable to recover those costs as a setup fee. For example, it might be necessary to verify that a user's equipment is capable of supplying the products and services that they plan to offer to the market place. In this case, a small inspection fee might make sense, though the Platform may even waive this type of fee during the launch phase to encourage adoption.

In the case of core product transactions, there is a rationale for the DER owner (seller) to pay the transaction fee. The reason is that the prospective sellers do not have a strong alternate market for their resource while the prospective buyers (e.g. Distribution Utilities, ESCOs) do have access to a strong alternate market for their supplies, i.e., the NYISO wholesale markets. In this market situation, transaction fees should be less of a deterrent to prospective sellers than to prospective buyers, as long as the fees are reasonable.

Launch Option 2 is a platform designed to enable ESCOs and DER providers to find and acquire prospective customers at less cost. This type of transaction is likely to generate significant value if consummated. However, the challenge is to ensure these transactions take place once the participants make a match. As a result, platforms that offer this type of service tend to charge for customer leads instead of completed transactions. For example, Google charges a fixed pay-per-click-through for advertising placement on its search engine and advertising placement services. In the event that New York State elects to launch with Option 2, the Platform fee could be a charge per customer lead consummated as a percentage of the value of completed transactions. Under Option 2, the asset or service provider (ESCOs and DER provider) pays the platform fee for those successful customer leads.

Over time, TCR envisions that there might arise new participants who are in the business of supplying information services. The example comes from the Thomson Reuters Eikon platform where some users use a data feed to create a new information product such as advanced price forecasts. Third parties could create a new information product using that type of a data feed from the Platform and sell it to market participants. The Platform can monetize that type of transaction in one of two ways. It either can charge a subscription to the information provider for access to granular Platform transaction and system state data, or can charge a percentage of the subscription fee that the provider charges to its customers. To encourage such innovations to emerge on the platform, the Platform could take a percentage of the subscription fee. In this context, the entrepreneurial firm that gains access to the Platform's data feeds is getting a subsidy while the trading firms that purchase the entrepreneur's analytics products are the paying users. The rationale is to ensure that an entrepreneurial firm does not face a large fixed cost to

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[74] Haller, Dipl-Kfm Jörg BA, Angelika C. Bullinger, and Kathrin M. Möslein. "Innovation contests." Business & Information Systems Engineering 3.2 (2011): 103-106.

attach to the platform before it realizes its own revenues. The challenge will be for the Platform to ensure that the transactions take place on the Platform so that it can monetize them. The Platform will need to ensure this contractually.

To summarize, the Platform revenues would be generated as follows:

- Fees for core product transactions in Option 1: 5% of completed transaction paid by the seller.
- Fees for matching consumers to asset or service providers in Option 2: These matchings have a high value to asset and service providers that may range between $50 and $100 per match. The fees for this service should reflect that value while keeping transaction costs to a minimum.[75]
- Fees for Distribution Utility / DSP baseline engineering (topology) data and aggregate demand, supply and flow data: Provide to users of the platform at no fee.
- Fees for third parties providing analytics on the Platform: based upon transaction fees greater than those for core products (above 5% to 10%).

Platform Investment and Operating Expenses

To provide some very preliminary guidance as to the investment required to develop a platform for New York State, TCR has done some analysis of the investments in the NYISO and the California ISO. These entities were chosen because of their market functions and because they trade electricity products. Because the Platform described in this paper is primarily financial and does not have the same system operating functions, TCR would anticipate a lower investment than that recorded for the ISOs; however, there will be significant complexity in managing a contract marketplace. The regulatory oversight section below discusses those implications and requirements.

Initial Platform Investment

While there has been significant experience in development of platforms, initiation costs have varied significantly. In estimating the cost for the Platform described in this paper, a comparison has been made between those that are significantly smaller single (or simple) product based and those that are significantly more complex. An example of a smaller and less complex platform is Receivables Exchange, and its initial capital cost was roughly $30 million. A more complex and larger entity that operates in many ways as a platform is the NYISO or other of the ISOs in the Northeast. The initial capital cost of the NYISO, including building was roughly $300 million of which $100 million was physical facilities. Removing the physical facility and scaling the REV platform leads to a rough order of magnitude level of investment for the platform’s technology and systems setup of $100 million. As previously noted, this paper developed this estimate by analyzing the required functionality of the system as well as analyzing the investments in power market systems that are currently operating.

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[75] For comparable costs in matching of consumers to rooftop solar providers, see U.S. Department of Energy Technical Report DOE/GO-10212-3834, November 2012.

Ongoing Platform Expenses

Based on platform commodity market making and monitoring functions as well as an analysis of ISO operating expenses; DLMP calculations; maintaining application programming interfaces (APIs) and system developer kits (SDKs), we estimate that the platform's annual operating expenses will be roughly $40 million/year. We developed this estimate based on the following:[76]

- $10 million annual rate of return on capital invested.
- $10 million annual capital depreciation (which incurs a reinvestment cash outflow).
- $10 million personnel compensation/benefits (fifty people at $200k/head).
- $10 million software licenses, facilities, travel expenses, miscellaneous.

The paper estimates the capital cost to establish a single Platform for New York at $100 million, with annual operating and maintenance costs of $40 million. The cost estimates are on the order of magnitude at this time, but intended to be conservative. These estimates imply a Platform annual revenue requirement of roughly $40 million per year. The Platform could design its fee strategy with the goal of annual revenues rising to recover annual operating costs fully within 2 to 3 years of initial operation. Focusing only on the case study examples in Chapter 5, the annual revenues estimates would cover more than half the platform costs, with the case examples being only a fraction of the applications anticipated.[77] After 2020, as the use of DER products increases, it is reasonable to expect annual revenues to cover well more than the Platform annual operating costs.

D. T_1 The Initial Market

The Initial Market will begin operation when the Platform begins operation. The estimated start date is 18 months from the time of decision for the conditions for initial implementation that include the development of the rules as well as the digital analytics of the Platform to have been established. As discussed in the previous section, development and operation of the Initial Market are expected to benefit from some level of activity during the start-up phase. Market participants will likely be able to begin transacting a limited number of market products prior to their eventual implementation on the platform based on their lesser needs for granular price information and formal market making and market clearing capabilities. For example, market participants could begin transacting some products with LMP as a positive step in the transition from existing situations in which load does not see any temporal differentiation by hour or any locational differentiation. However, based upon the principles presented in Chapters 2 and 3, and the value propositions presented in Chapter 5, it is clear that moving toward DLMP will provide the greatest incentive both to DER and to Distribution Utilities in planning and DER resource acquisition.

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[76] It is important to note that the estimate is for the cost of the digital platform only. The estimated capital and operating costs explicitly do not include the cost of AMI or the cost of communications infrastructure that would, in all likelihood, be needed or certainly augmented by the Distribution Utilities.

[77] As indicated earlier in this paper, the annual cost of the Platform is *de minimus* for New York ratepayers. If the platform sponsors were to recover the $40 million, annual cost uniformly over all kWh delivered to New York State ratepayers in 2013, the impact would be 0.03 cents / kWh, or roughly $0.16 / customer per month.

Initial Products

Price responsive load and EV charging are two easily identifiable early applications in which the Platform will provide both financial access to core products and the pricing of those products as well as access to additional complementary services that increase the ability of market participants to receive, and respond to, NYISO LMP and eLMP information. The critical additional complementary services the Platform is likely to animate and support are third party forecasting of forward prices. These forecasts are of importance to price responsive load and EV charging as well as to other market participants who have the capability and desire to lock in prices when their schedules for energy use are developed or modified. In this way, the distribution market on the Platform is similar in function to the Day-Ahead market at the wholesale level but without the fixed timing.

Additional early products in the Platform Market could include traditional DR products, such peak load reduction programs offered by utilities. These products will use the capabilities of the Platform in two ways. The first way is in terms of the definition and the pricing of DR products. The Platform will also quickly become the most visible and most efficient location upon which the Distribution Utility/DSP providers and others can post open season offers and auctions for specific demand response actions as well as for new packages of energy and reserve products.

Price Formation / Price Discovery

In the Initial market, the Platform will not play a price formation role; instead, its role will be limited to price discovery in that Initial Market prices will be based on LMP and/or eLMP.[78] DER will see and use these prices to value their willingness to buy or sell products and services on the platform. As defined, price discovery on the Platform approaches price formation as DER either takes or rejects the posted price for the product or service. DER is expressing willingness to transact but not making a direct price offer into the market.

As Distribution Utilities move forward with programs to use DER to defer distribution investments, the Platform will provide the neutral environment upon which to post and undertake auctions or to structure bids for services focused on specific actions of value to the Distribution Utility. These could include, as discussed in Chapter 2, standard requests for forward option contracts that enable the utility to call on DER to provide energy or operating reserves in congested areas of their distribution system. The utility industry today uses Web-based auction structures for purchase and sale of energy and capacity at the wholesale level. The Platform has the potential to provide a standard, Commission vetted, mechanism for Distribution Utilities to conduct auctions for the purchase forward commitments of energy or load reduction from DER that will allow for asset replacement or deferral. Well-designed auctions can generate the information needed by the Distribution Utility to value the deferral of the investment and the mechanism by which the Distribution Utility can contract for/acquire these deferral services. In this manner, the Platform is providing the location and accepted and likely uniform location for price discovery – the willingness of DER to adjust supply and load to achieve a specific deferral.

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[78] Note that LMP+D or eLMP+D is also an option if D is calculated at average or possibly marginal losses from the point of LMP calculation to the DER.

Market Clearing

Clearing of the Initial market is less complex than that of the ultimate market. As discussed the Initial market will use eLMP as the pricing point. eLMP is a calculated value available at each of the eLMP nodes that represents the marginal value of transactions at that point both in space and time. As a result, the Platform will use the real time value of eLMP for clearing of any imbalances during the Initial market.

Under the Initial, Interim, and Ultimate markets, the Platform will provide Market Participants financial clearing information, provide detailed transaction data (e.g., hourly, daily, weekly, monthly) and provide net position data between individual Market Participants. The Platform will be the bookkeeping entity of the market based on its transactional neutrality. In its role, it will operate and maintain a data record of auditor/legal quality available to answer any challenges on transactions that have occurred on the Platform.

Distribution Utility Support for Market Operations

The role of the Distribution Utility remains critical at the point of market initiation and as the market evolves. Coordinating the actual consumption of core products transacted on the Platform is central to system control and will require the utilities' real-time knowledge of system conditions and estimates of power flows on equipment that may be constraining operations. The Commission recognized the need for this coordination in its February 2015 Framework Order which assigns Distribution Utilities the role of DSP providers and maintains their responsibility for default supply service. Under the Platform Market structure, Distribution Utilities retain their operational responsibilities; however, the availability of electric products from the Platform Market may challenge their role as default service supplier.

Distribution Utilities fulfill two distinct roles under the current market structure, and will continue to do so under the Initial and Interim Markets and may continue into the Ultimate Market. In their first role, as the monopoly provider of delivery service and DSP providers under the Order, they are responsible for the day-to-day real time operation of the distribution system as well as its maintenance and expansion when and if required. In their second role, as providers of default supply service for customers who have not shopped for an ESCO, they are customer-facing suppliers providing a supply service in competition with ESCOs.

Looking toward a more market based delivery of real energy to consumers, it will likely be preferable if, over time, the Commission consider separating the DSP provider role of Distribution Utilities financially and administratively from their role as default service supplier, and monitor Distribution Utilities for potential conflicts between those two roles.

The DSP provider as system operator takes on an expanded, data intensive analytic role as the market evolves. The role of the DSP as system operator will be in physical operations (topology control) and in measuring and monitoring the flows on the distribution network. The DSP provider will be in continuous contact with the Platform as the source of all physical conditions and physical flows both as a source of information on the platform and as the source of the injection and withdrawal data required for transaction settlement.

The Platform will be the entity that maintains the accounts for both the bilateral and the imbalance/settlement transactions, prepares the statements and interacts with the financial players – one of whom is the Distribution Utility in its customer-facing role.

The DSP provider will need to be seen as an independent and unbiased system operator in the same manner in which the NYISO is independent of generation and load. It is the potential divergence of interests between the Distribution Utility as customer facing supplier and as Distribution System Operator that could lead to internal conflict in its roles and thereby to a need for regulatory oversight.

To expand to the full DSP provider role will require more transparent distribution planning, coordination (to assure parallel inputs and outputs) with NYISO, as well as Commission approval of the expansion of the distribution operations and real-time market functions of the current Distribution Utilities. It will fall to the Commission to assure that the presence of customer-facing functions do not create incentives for perverse, anti-competitive actions on the part of the Distribution Utility implementing its DSP system operations functions.

The Platform from the Perspective of DER

Looking at the Platform capabilities from the DER side that is providing the service to the Distribution Utility, the Platform becomes the source of information directly from the Distribution Utility concerning the state of the market and transmission and distribution delivery systems. The Platform will provide a continuity or flow of data to allow building and EV owners to shift demand to lower price periods and become participants in, for example, peak load reduction programs to track likely forward changes in the market that may trigger the calling of a contracted peak load reduction and provide the source of information on likely duration of the reduction. Today, most of such programs are for fixed blocks of time whereas in the future the reduction sizes and periods are likely to be more flexible.

While some early DR products may continue to look similar to those available today, the character of those products and services will, in all likelihood evolve. Distribution Utilities and other buyers are expected to become more attuned to products defined with more temporal and spatial granularity and shorten the time periods for required response and forward duration of the contract. At the same time, DER market participants will likely become more accustomed to products bid on the Platform that are temporally and spatially focused, i.e., far more granular and, for them, containing far less long term performance risk as they will neither be tied to years of performance nor long hourly blocks of interruption. They will become increasingly accustomed to purchasing Platform-based products in more discrete quantities and more discrete time intervals. This paper expects customers will increasingly rely on smart technologies to manage their use of energy and electricity bills efficiently without the hassle and risk of DR program obligations. This evolution of products, in part, brings third-party players who provide additional products and services in terms of offering smart technologies, forecasting of conditions, and hedging of risk.

Market Data / Transparency

The Initial Market and the Platform will be a source of additional information concerning the structure, operation and current and future operational needs of the distribution system and of each of the Distribution Utilities. These data are important: they represent a cost in collection and in presentation and they have a high value to the market and market participants. Chapter 3 cautioned that selling basic distribution system data could create a level of friction that might impede the development of the market itself. The basic data of the topology of the distribution system, of the distribution of and timing of demand on the systems and of the relative cost of losses and reactive power, as examples, are critical products on the Platform. What is clear is that today Distribution Utilities are recovering the costs of collecting the majority of the data from ratepayers. As a result, the incremental costs of providing the data on the Platform are small. In addition, these data are known / available only to or through the Distribution Utilities. Given the single source and the fact that Distribution Utilities are recovering their cost of data collection today, the Platform can provide data on basic topology, demand, supply and power flows at no cost. It is important to note that third party analyses of data are the value added products, not the raw data the Platform would provide at little or no cost.

Participants

Distribution Utilities, ESCOs and mandatory hourly pricing (MHP) default customers are likely to be the dominant participants on the buy side in the Initial market. Distribution Utilities in their role as default service suppliers, ESCOs, and MHP customers will be seeking to manage demand and lock in prices to hedge risk. Additionally, Distribution Utilities may purchase the products and services of DER to defer distribution investments. The sell side will initially be both existing wholesale market participants and large industrial or commercial consumers who are able to benefit from providing DER based on more granular pricing available through eLMP. These consumers are most likely to be customers of the ESCOs in increasing numbers as it becomes apparent that the eLMP offers them greater economic flexibility and opportunities to reduce costs. Costs can be reduced by managing their use of electricity costs against forecasted market prices and therefore avoiding unwanted interruption requirements – accepting the fact that they will be subject to higher costs at times of scarcity or delivery constraints. As previously discussed, price formation at this stage will be more similar to price discovery in terms of willingness for DER to participate rather than DER offering into the market as larger players will dominate and the more granular pricing information will be from the wholesale market.

The newer participants in the Initial market are likely to be matched participants. These will be smaller customers on one side and aggregators on the other. We expect aggregators to create mini markets on the Platform in which they can package the smaller commercial customers including multi-family units into directed, price responsive groups, which they can then sell for specific responses to the Distribution Utility or to the ESCOs.

For aggregators and small customers, the Platform provides the tools that allow for the efficient gathering of smaller participants and sale of their services in competition with the larger players to the Distribution Utilities and the ESCOs. Without the Platform and the data it provides concerning disaggregated patterns of consumption and/DER supplies, finding willing customers has been shown to be of a higher cost (customer acquisition) than the benefit derived (load shifting in response to time varying prices).

Utility Procurement of DER via the Platform

The Distribution Utilities have some experience with, and proposals for, acquiring electric products from DER in order to defer investment in distribution system infrastructure. These initiatives are essential stepping stones to the eventual procurement of core electric products via the Platform and the Platform Market through posted solicitations. A Distribution Utility desiring to avoid investment in a new substation or a significant reinforcement is the only entity that can identify the actions and the location and timing of those actions that will provide the deferral desired. These forward decisions require one or more years of advanced commitment. Similarly, arranging for a DER to provide core products at a location where investment is required must also be done one or more years in advance through a forward option contract. The key is that the DER will not be able to receive the financial support without a forward, firm financial commitment. The timing of the deferral and the investment are, at least roughly, in line.

The process that would take place on the Platform would be that the Distribution Utility would provide a solicitation that indicated the details of the location, timing, quantity, and quality of DER required to meet their objective of service supply. The solicitation would also present all contracting terms and conditions such that the respondents would know forward what level of response was required and what the results of nonresponse would be. The solicitation would explicitly NOT provide any value information, i.e., a sense of how much the Distribution Utility would be willing to pay per MW or per needed action. The objective of the utility is to minimize their cost both between investing in new plant and paying for DER investment or response. In addition, the objective of the utility (and therefore their customers) is to purchase the service at as low of a total cost as possible.

The Distribution Utility informs the market of its needs by posting them on the Platform. Market participants are then able to make offers given their individual capabilities in quantity and timing. The utility is able to create, from these offers the portfolio that best meets its forward needs. The utility would then execute a firm forward contract for the portfolio of DER. The utility would pay nothing in advance, i.e., there would be no avoided cost payment guaranteed to participants. The DER would have a firm and bankable contract from the utility at a price certain (or price known with escalations and contingencies). The DER would be responsible (as independent power producers are today in the wholesale market) of forecasting forward its stream of revenues that include (or may be entirely a function of) those from the Distribution Utility. In so doing, it would look to the increased granularity of pricing information as its point of analytic departure.

There are multiple market advantages and significant policy advantages from use of the Platform as previously discussed. From the perspective of the development of the market, requiring that solicitations for service as described be posted and implemented on the Platform provides the incentive for DER (and aggregators of smaller players) to focus all attention on the Platform. This both increases volume on the Platform and significantly reduces the transaction costs for those participating on the Platform. In addition, for the Distribution Utility/DSP in this interim period the process provides a cost effective and administratively efficient means of acquiring services. [79]

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[79] As an example of the use of internet based solicitations see: SOUTHERN CALIFORNIA EDISON (SCE), SOLAR PHOTOVOLTAIC PROGRAM, REQUEST FOR OFFERS ("SPVP 5, 4, 3, 2, 1 RFOs"),

It is logical to ask why the previously described process is superior to the current procurement procedures of Distribution Utilities.[80] The answer is that procuring DER via the Platform through a standard Commission-approved process should dramatically reduce the administrative cost of procurement. The further market development benefit of procurement via the Platform is, as previously mentioned, the fact that with greater acceptance of the Platform functionality in applications of this nature will come a greater demand for the use of the functionality. Distribution Utilities should see benefits from this approach due to the focus on increased granularity and the ability to create and implement solicitations that meet highly specific spatial needs as well as short time horizon response planning needs. There will be a need for regulatory oversight to assure that the incentive of revenue from the Platform fees does not overshadow the decision process in the solicitations.

From the perspective of State regulatory policy, the implementation of DER acquisition via the Platform through a uniform solicitation will reduce oversight requirements and assure still further cost effectiveness in the market.

E. T_2 and T_3 The Intermediate and Ultimate Markets

Table 4 provides a summary of the changes that take place in the market as it develops from the initial platform with eLMP through an interim step to the ultimate DLMP structure. The changes are evolutionary as the Platform shifts the currency to DLMP and continues to add products and services beyond those of the core. The functions of Distribution Utilities as DSP providers require greater granularity in monitoring injections, withdrawals, and flows on the distribution system to provide these data to the Platform. The Platform would use these data in conjunction with eLMP prices provided by the NYISO for the interface between the transmission system and the local distribution network to calculate DLMP. This process will maintain a connection between the NYISO and the DSP.

With the development of the ultimate market at the distribution level, the wholesale market will see a reduction in demand/change in the pattern of demand at the interface with the NYISO. This change will impact the LMP of energy from the wholesale market supplied to the distribution market. The result will be greater efficiency for both markets.

Market Clearing

The most significant changes that will occur due to the move from eLMP to DLMP will be is the functioning of the market and market clearing. Continuing advances in information, communications, and control technologies will permit markets to develop, price formation to occur and positions to clear at points within the distribution system closer to the consumer and DER location. As we have discussed, the value of DER and the cost of electricity can vary significantly both between the points at which distribution connects to the transmission system and at locations within an individual distribution

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https://scepv.accionpower.com/_pv_1501/accionhome.asp. Also see: California Public Utility Commission General Renewables Solicitation at: http://www.cpuc.ca.gov/PUC/energy/Renewables/RPSProcurementPrograms1.htm

[80] See as an example from New York, Consolidated Edison Company of New York, Inc. *Request for Information: Innovative Solutions to Provide Demand Side Management to Provide Transmission and Distribution System Load Relief and Reduce Generation Capacity Requirements*. JULY 15, 2014

circuit. In the ultimate market, DLMPs will reflect differences in short-run marginal costs by location, including environmental compliance costs.[81] Supply offers from DER will reflect their marginal costs as well as their opportunity costs (e.g., the forward value of options the DER would miss during a period if it were to commit to provide a reserve product.). The bids of buyers to acquire those core products will reflect the value they place on those products including the benefits attributes such as clean power.

The Platform would use real time DLMPs to settle imbalances between contracted and actual supply and bilateral purchases on the platform. In Platform transactions, energy contracts would be entirely financial and all contracts would settle contract quantities at agreed upon prices. If, for example, a DER physically delivers less or more than its contract quantity in a given period, an imbalance would occur. In Platform settlements, participants with short falls would pay the imbalance price for the short quantity and participants with excess quantities would receive compensation for the excess at the imbalance price. In a distribution level market, the imbalance price would be equal to the *ex post* calculated DLMP. Additionally, to the extent, a Distribution Utility is purchasing reactive power or reserves to maintain system reliability, contracts between the utility and DER could include liquidated damages provisions that might apply in the event of non-performance.

The operation of DLMP markets will be impacted by conditions in, and the topology of, the distribution system. Constraints in the distribution system will be predominately volt/VAR, not thermally related. In addition, constraints may become less likely to occur to some point well in the future as DLMP encourages the development of resources and controls that address distribution requirements while load growth is likely to remain low in New York State.

In the Ultimate Market with DLMP, utilities will have and deploy capabilities to manage reactive power and maintain adequate voltage at required standards. Moreover, advances in power electronics and control systems are making it possible to improve utility management of reactive power so as to provide significant economic benefits. In addition, the distribution utilities will continue to maintain operational control in planning and assured service quality of the distribution system.

The conditions of sufficient capacity are relatively common and with the increased deployment of technologies for shifting demand to lower price periods contributing to headroom in distribution systems, they are likely to characterize significant portions of distribution systems for some time. When these conditions are present – a radial circuit without internal congestion and effective reactive power management –DLMPs can be estimated using the electrically adjacent LMP transmission node as a reference node and making a straightforward calculation of distribution system marginal distribution losses. Under this approach, one can estimate the difference between the LMP at the transmission node and DLMP at different locations on the distribution circuit based on distribution system marginal losses

Constraints occur within the distribution system just as in the transmission system. Unlike the transmission system, however, constraints in the distribution system are only infrequently caused by thermal limits but are generally a function of system voltage being outside of the prescribed range. Volt

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[81] This paper expect bids from DER will reflect the marginal costs they will incur to comply with State and Federal environmental regulations.

VAR control represents a significant challenge for the DSP providers, but one that can in the ultimate market be met in part by resources of the DER.

In areas that might eventually be affected by constraints within the distribution system, utilities will face a choice between either expanding the capabilities of the distribution system to avoid constraints or obtaining adequate DER to meet energy and reserve requirements within the load pockets defined by the elements constraining power flows in these areas of the distribution system. As we have suggested, utilities could acquire voltage support from the Platform as needed or could use forward option contracts to acquire the resources. The use of option contracts could provide greater assurance of the availability of DER to meet localized real and reactive power requirements.

An urban mesh network, such as the distribution system in portions of the Consolidated Edison (ConEdison) system, presents the additional complication that operators can change the topology of the network. Parts of the system might look like an unconstrained radial system in one point in time and act very differently at another after a change in the configuration of the system. Changes occur seasonally in most instances, but can occur with greater frequency with maintenance, outages, and constraints. DLMP pricing for platform imbalances under the interim approach would follow actual real-time system conditions. However, it will be important to participation and liquidity in the platform market that market participants have information on both anticipated topology for the operating day and actual system configuration used in calculating imbalance prices.

The majority of constraints within the distribution system relate to voltage. The Distribution Utility will need to manage reactive power in the distribution (AC) system by either or both relying on their own VAR sources or recruiting distributed resources, such as smart inverters and variable speed drives for Volt VAR Control (VVC). An optimal system for VVC will provide VAR support and use distributed sources of dynamic VARs to equalize voltages across the distribution circuit while minimizing the power required to comply with standards for maintaining adequate voltage.[82] Utility-owned VAR sources are likely to provide core capabilities for such VVC. However, where customer or third-party capabilities could cost-effectively contribute, the utility will need to procure the option to engage those capabilities competitively, integrate the equipment into its communication and control architecture, and compensate VAR sources for foregoing the ability to provide real energy.

The fundamental design of DLMP markets has been modeled and described in the engineering literature and is being tested against different distribution system configurations (as previously discussed in this paper).[83] DSP providers will take some time to develop the capabilities to both support real-time DLMP

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[82] D. Divan, R. Moghe, and A. Prasai. “Power Electronics at the Grid Edge,” IEEE Power Electronics Magazine (December 2014); R. Moghe, D. Tholomier, D. Divan, J Schatz, and D. Lewis, “Grid Edge Control: A New Approach for Volt-VAR Optimization,” publication forthcoming (2015).

[83] M. C. Caramanis, E, Goldis, P. A. Ruiz, and A. Rudkevich, “Power Market Reform In the Presence of Flexible Schedulable Distributed Loads. New Bid Rules, Equilibrium and Tractability Issues” Proc., Allerton Conference on Communication, Control and Computing, pp. 1089-1096 October 1-5, 2012; M. Kranning, E. Chu, J. Lavaei, S. Boyd, Dynamic Network Energy Management via Proximal Message Passing, in Foundations and Trends in Optimization, Vol.1, No. 2, 2013, pp.70-122; Ntakou, Elli and M. Caramanis. “Distribution Network Electricity Market Clearing: Parallelized PMP Algorithms with Minimal Coordination”, Proc. of the CDC, pp. 1687-1694, December 2014; Ntakou, Elli and M. Caramanis. “Spatiotemporal Marginal-Cost-Based Retail Electricity Markets: Efficiency, Structure and Feasibility,” downloaded at: http://www.bu.edu/pcms/caramanis/ElliDistr.pdf , September 2015.

markets and efficiently manage increasingly complex distribution systems including:

- Modeling and state estimation to provide operators real-time awareness of power flows within more complex distribution systems.
- The ability to manage significant growth in operational data and integrate new information systems and applications.
- An information and control architecture that facilitates coordination between transmission and distribution system operators.
- The ability to identify the need for and purchase forward for DER on an economic basis, forecast responsive demand, and estimate the impacts of DER technologies not actively offered into the market.

This paper previously discussed how price responsive demand was expected to figure into the evolution of the market. This role becomes increasingly significant in the Ultimate Market where the ability of demand to modify usage patterns will provide an important element of liquidity for congested DLMP markets and a check on the potential exercise of market power. The combination of flexible demand and development of other DER will tend to make these markets increasingly liquid.

When DLMP markets interact with the services available on the platform, demand becomes flexible, the market more liquid, and the system more reliable and efficient. Customers, in most cases working through aggregators and retail suppliers, who have an incentive to reduce their costs and price risks, would be able to obtain from the platform a look ahead forecast of prices for their location. Given smart technologies and energy management services that take advantage of advanced data analytics, and financing for investing in smart devices energy management systems, customers will be able to respond with technology rather than human interaction. Their flexible loads will automatically and continuously respond to anticipated prices shifting from higher price periods when supplies are tight to lower cost periods including times when renewable resources that have low variable costs are likely to be operating. These shifts in demand will tend to smooth and flatten net load on the system, deferring the need for additional generation and network investments.

The evolution of smart charging for electric vehicles should follow the same evolution as the Platform Market. The Platform will provide a means to access both price forecasts for different locations where the vehicle will be and applications for smart charging. The combination of DLMP and smart charging will help avoid overloading equipment in clusters of EV owners, enable vehicles to shift between charging or not to provide ancillary services, and, when EV owners do not need to charge their vehicles immediately, enable the charging to occur at the times when prices are low.

A DLMP market will lead to the operation of DER when it is efficient for them to operate and provide an incentive to invest in DER where that investment can create the most foreseeable value. Continuous trading of contracts on the platform will enable customers or their suppliers and DER lock in prices quickly and easily whenever they set or modify their schedules for using or supplying energy. Additionally, the development of forward contracts on the platform will allocate risk and help support DER investment.

F. Implications for Major Stakeholders

The development of a Platform for core energy and value added transactions, as described in this paper, is expected to provide long-term net benefits to the major stakeholder groups in the State.

- Developers and owner operators of DERs, including "prosumers," will benefit through the creation of a transparent, liquid retail market that provides for investment value assessment as well as for real-time and forward opportunities to sell their core products at their locational, temporal, and environmental value.
- Energy supply providers (ESCOs and default service suppliers) will have access to a transparent and liquid retail market that will augment their access to the wholesale market in New York State. The new market will provide access to DER across the State (as opposed to only within the service territory) and will allow for the tailoring and fine tuning of their supply portfolio position on an hour-by-hour basis.
- Distribution Utilities will gain in their ability to plan and operate their distribution systems through greater market access to DER and thereby to incremental resources for voltage control. Their role in systems operations will increase through assuming the role of DSP where they will be the source of injection and withdrawal and flows information as well as physical topology that is supplied to the Platform for market clearing. Finally, Distribution Utilities will gain financially through their ownership of the conceived Platform.
- Ratepayers should experience lower bills for electric energy through more granular pricing and access to forecasting services and aggregation services made possible by the platform. In addition, with the evolution of greater DER in the distribution system consumers will see improvements service quality and reliability as ESCOs and Distribution Utilities take advantage of the existence and location of incremental DER in the system and increase in knowledge of consumer behavior.

G. Regulatory Oversight

This section addresses specific regulatory oversight issues associated with the Platform Market. These issues are market power, consumer privacy, environmental, and rate-related.[84]

Market Power

The former Chair of the Commission Alfred Kahn wrote that, "The single most widely accepted rule for the governance of the regulated industries is to regulate them in such a way as to produce the same results as would be produced by effective competition, if it were feasible."[85] In large part, this idea has meant regulating utilities so as to avoid or mitigate the undue exercise of market power. The greater participation of DER in power markets, the transparency and liquidity provided by a platform market,

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[84] The New York Public Service Commission faced similar issues in at the time of restructuring of the telecommunications industries in the state. See: CASE 98-C-1357 - Proceeding on Motion of the Commission to Examine New York Telephone Company's Rates for Unbundled Network Elements, February 2000.

[85] Kahn, Alfred. The Economics of Regulation: Principles and Institutions, Vol. I (New York: John Wiley & Sons, 1970), at 17.

and enhancing the ability of demand to respond to price changes should reduce opportunities for suppliers to exercise of market power. Nonetheless, market power will remain, in part, a function of ownership patterns, network constraints, and local requirements such as the need for reserves or reactive power in a specific area of the power grid. While the possibility of circumstances in more granular markets raising market power concerns cannot be excluded, regulators will have options for addressing any such concerns, including:

- Expanding demand participation. If customers or their intelligent devices can observe prices and have, a sufficient ability to reduce or shift demand, responsive demand could be effective in mitigating the exercise of supplier market power.[86] Regulators may want to ensure that customers can readily switch suppliers to minimize the risk that a supplier could pursue interests contrary to its customers after locking them into a long-term agreement.
- Contestable forward markets. If barriers to market entry and exit are relatively low and market transactions occur sufficiently in advance to allow relevant entry, the potential for participation of new resources may be sufficient to constrain the abuse of market power. For example, the potential that, with the installation of inexpensive communications, an existing backup generator could provide real or reactive power may limit the ability of other suppliers to increase prices in a forward reactive power or localized reserve market.
- Expanded deliverability. The concentration of resource ownership can be a function of the size of particular market. When necessary, the Commission can require dilution of ownership concentrations through network improvements or changes in network configuration. For example, changing the configuration of distribution such that more than one primary feeder can serve a given load pocket might eliminate the ability of local suppliers to exercise market power. Where utilities are procuring resources to meet requirements in a constrained local area of the gird, in some cases it could be valuable to begin the procurement process and assess the liquidity of the local DER market well before resources would be required to perform. This procurement could enable the utility to expand distribution capacity in the event the DER market appears to lack sufficient liquidity to meet the utility’s requirements.
- Offer mitigation. In cases where the market operator has identified the potential to abuse market power, either the operator or an independent monitor can actively track and mitigate offers, reducing them to levels based on estimates of the supplier’s marginal cost such that the market will clear at competitive price levels. The Commission could require mitigation where the market operator or monitor identified abuses of market power that affected or could affect market prices.
- Scarcity pricing and offer caps. An alternative approach for addressing market power within network constraints could be to place a cap on supply offers within the constrained area while

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[86] S. Borenstein and S. Holland, “On the Efficiency of Competitive Markets with Time-Invariant Retail Prices.” Rand Journal of Economics, 36(3): 469-493 (2005); S. Rassenti, V. Smith, & B. Wilson, “Controlling Market Power and Price Spikes in Electricity Markets: Demand Bidding,” PNAS, Vol. 100, No. 5 (March 4, 2003).

allowing the market to clear at prices that reflect both any scarcity of available resources and price induced reductions or shifts in customer demand. Under a strict version of this option, revenues for existing supplier resources might be limited to the offer cap. However, in any event, resource users would only pay the lower of the cap or the market clearing price.

- Price ceilings. Policymakers could decide to place a cap on offers or prices for certain products. Price ceilings have the disadvantage that they do not distinguish between the potential abuse of market power and genuine shortages when prices would naturally tend to rise to attract additional resources or reduce demand so that the market would clear.

The options previously discussed involve successively greater degrees of market intervention. Future regulators would have the opportunity select among these options based on the product under consideration, the stage of market development, the extent of ownership concentration, and the potential for market power abuse among other factors.

In addition to the options previously discussed, as noted earlier in this paper, Distribution Utility/DSP provider sponsorship of the Platform creates a potential for a conflict of interest with utilities' role as default service suppliers. The Commission should have the authority to review Platform governance and the relationship between the Platform's operator and its utility sponsors. It should seek to maintain the independence of platform operations.

Consumer Privacy

Utilities generally follow policies designed to protect customer data. In other industries, consumers are increasingly sharing information, such as the location of their cell phones or the websites that they recommend, with service providers in exchange for information and services that they value. The development of interval and platform markets along with retail products that combine electricity with information and other services will give rise to questions about the treatment of customer data. While it is true that inferences regarding patterns of occupancy or EV usage could be gathered from detailed information about electricity use, advanced data analytics can also make it possible to help customers reduce their energy costs, as well as enabling new products and services such as observing changes in the usage patterns of elderly or ailing consumers, potentially enhancing their safety and security. Public policy will need to balance these competing interests in a context where privacy remains a significant concern for many consumers while consumer attitudes and behaviors related to sharing information with service providers appear to be changing.

These issues have been the subject of discussions among regulators, utilities, technology companies, government, consumer advocates, and privacy experts. Much of this discussion has focused on the application of Fair Information Practices to customer data captured in a smart grid environment[87] The Platform will need to build in privacy protections and practices for utility data sharing. Utilities, the platform operator, ESCOs, and third-party service providers will need to conduct assessments of privacy-related risks and follow privacy and information security practices to safeguard personal

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[87] For a more detailed discussion of these issues, see: National Institute of Standards and Technology (NIST), Interagency Report 7628, Revision 1, Volume 2, Privacy and the Smart Grid, (September 2014).

information effectively and consistently. This process may include the adoption of practices for aggregating data to render it anonymous and encrypting data when handling customer information. The report's discussion on platform governance includes examples of such practices by platforms in other industries. Additionally, consumers, who may not understand their privacy exposures, will need clear and easily understood information regarding the use of their information and their options for both mitigating exposure and sharing data in ways that might enable service providers to deliver greater value.

Environmental Issues

Markets for energy, including DLMP markets, reflect environmental and resource diversity values to the extent these values are internalized through market-based public policies (e.g., the Regional Greenhouse Gas Initiative, Sulfur Dioxide Allowance trading program, other emission credit trading programs, and Renewable Portfolio Standards), supplier perceptions of environmental and resource risks, or customer demand for green and renewable energy products.

The combination of DLMP and distributed platform markets could further advance the development of clean energy:

- The platform will facilitate access to services, contracts, and financing that could accelerate development of cost-effective DER.
- Initially, utility procurements of DER for congested areas of distribution systems and ultimately DLMP markets will identify areas for the cost-effective DER development.
- ESCOs will be able to market products to customers with green energy preferences through the platform. Third parties could develop environmental applications for the platform that might provide information and facilitate transactions that account for factors not currently addressed by Renewable Energy Credit (REC) and environmental markets.
- By enabling smart devices to efficiently shift demand and manage the charging of electric vehicles, the platform will tend to move demand, all else being equal, into periods when renewable resources with low variable operating costs are generating power and to balance the ramping up and down in generation from variable renewable resources with price driven shifts in customer demand.
- Smart technologies often help customers use energy more efficiently and thereby might reduce environmental impacts.
- Development of reactive power markets and advances in Volt VAR control could expand the capability of distribution circuits to host PV generation, equalize voltages across distribution circuits, minimize VAR requirements, and reduce demand and apparent energy required to serve load.

However, it is important to note that some DER, such as diesel generators, may increase negative environmental impacts. DLMP and platform markets alone will not completely address environmental externalities. Environmental externalities are environmental impacts not reflected prices and not covered by an emissions fee or market based environmental regulation such as a cap and trade program. Where utility regulators lack direct authority, they can consider indirect, although potentially less efficient, options such as targeted procurements of clean energy or distribution rate designs that ensure volumetric electricity rates approximate social costs to address certain environmental impacts. However, mitigation of certain environmental impacts such as the particulate emissions from diesel generators might depend on public policies developed outside of utility regulation.

Rate-Related Issues

There is a rationale for recovering the costs of platform development and some portion of operating costs initially in regulated rates. Recovery of this investment from ratepayers is appropriate given the likelihood of system benefits, platform transaction and subscription fees that in time are expected to cover operating costs, the availability of revenue for recovery of distribution costs from the treatment of marginal losses in DLMPs, changes in energy settlement practices, contracting for DER, incentives for utilities as default service suppliers to take advantage of services available on the platform, and modifications in default supply service rates.

Distribution Utility purchases of core products from the Platform Market should have a downward impact on their retail rates. The Commission approves the rates as Distribution Utility charges for its delivery services and for its default supply service. Those rates are set at a level that provides the Distribution Utility an opportunity to recover the “just and reasonable costs” it incurs to provide those services, which include whatever financial incentive the Commission allows. (For delivery service, this financial incentive has historically been a rate of return on investment in rate base). These rates are re-set periodically to reflect changes in Distribution Utility costs and earnings. Thus, as Distribution Utilities begin achieving reductions in their costs of providing delivery services and/or default supply service due to their purchases of products from DER, the Commission will require them to re-set their rates to reflect those cost reductions.

The Commission will have to address many other rate related issues in the REV proceeding that are outside the scope of this White Paper.

H. Chapter 4 Summary

Chapter 4 presents a vision of the energy market in New York State that will result with the implementation of REV that takes advantage of the Platform paradigm with far greater granularity in pricing (spatial and temporal) for DER in the distribution system. As such it acts to “connect the dots” of market design, pricing, and participation. It describes the implementation of the Platform and the Platform Market in three phases: start-up (i.e., getting organized), the Initial Market, and the Interim and Ultimate Markets. For each phase, the classes of products that will be in the market, the role of the platform in price formation and facilitation, the likely participants in the market, and the role and position of significant stakeholders in the broader energy market structure in the State are discussed.

Chapter 4 arrives at the following conclusions regarding the design of a Platform and Platform Market that could enable more granular pricing and increased market participation by DER within the electric distribution sector:

1. The option of a single statewide Platform co-owned (sponsored) by, and operationally independent of, the State's Distribution Utilities has several advantages over the option of multiple Distribution Utility specific platforms.
2. Launching the Platform initially as a market trading (financial) platform has several advantages over the option of an initial Platform designed as a customer information portal.
3. Applying Platform fees to completed transactions for core electric products at a level of 5% charged to the seller has several advantages over higher fees and/or fees charged to buyers.
4. Providing basic distribution system information on the Platform at no cost to Platform participants has several advantages over charging participants for that basic information.
5. Developing the pricing points representing eLMPs is a critical step to increased granularity of prices. As a result, it is important that the Commission coordinate with the NYISO toward posting of eLMPs for the State.
6. The Initial market for core electric products could begin using eLMPs to settle transactions based on interval LMPs at an extended set of 500 to 2,000 NYISO pricing nodes (in place of average hourly Load Zone LMPs). This option would enable and allow reporting out the significant variations in the locational value of DER and require comparatively little investment for implementation.
7. Allowing the market to evolve to include and support peer-to-peer transactions on the Platform should attract greater market participation.
8. Providing the Platform with the capability to enable Distribution Utilities as DSP providers to solicit specific products and services as call options or firm obligations should attract greater market participation.
9. Providing regulatory oversight for (but not limited to) market manipulation, assurance of privacy, environmental oversight and relationship between eLMP and DLMP and customer rates is important to ensure a level playing field.

5. Assessment of Granular Prices under a Platform Market

This chapter describes a quantitative analysis that illustrates the impacts of moving from the current system of pricing electric products at a transmission LMP pricing node, to more granular pricing points within the distribution system that are closer to or at the point of production and/or consumption. The chapter also presents a set of qualitative scenarios that illustrate several ways in which a Platform Market could animate and support sale and purchase transactions for DER products while generating revenues from those transactions to sustain its operation.

A. Quantitative Assessment

This section presents a quantitative assessment of several scenarios to illustrate the value of moving to more granular locational prices under a Platform Market.

The scenarios use the DistCostMin (DCM) model, described in Appendices B and C and discussed later in this section, to estimate the total cost of meeting retail demand on a radial feeder of a distribution system located in New York's Capital Region, referred to as the "Capital Feeder." The modeled distribution feeder is adapted from a prototypical feeder (Feeder 9) from the Pacific Northwest National Laboratory (PNNL). It contains 800 nodes comprised of 202 residential nodes, each of which serves three residences, and 72 commercial nodes. The cost of the modeled scenarios is estimated under the following levels of increasingly granular pricing:

- BAU, in which DER see and respond only to an average LMP for the day in their transmission zone (i.e., a flat value for energy throughout the 24- hour period.
- LMP, where DER see and respond to the LMP in each hour of real energy only at the substation node to which their feeder is connected (i.e. the zonal LMP by hour).
- eLMP, where DER see and respond to an eLMP of real energy in each hour. The eLMP is calculated by aggregating DLMPs to a limited number of locations (17) within the distribution system close to, but not at, the substation node. Based on the system topology, the eLMP is directly related to and, in this analysis numerically very close to but more granular than, the substation node LMP in Scenario 2.
- DLMP, a full marginal cost-based market that discovers the DLMPS of both real energy and reactive power and that schedules DER transactions for both real energy and reactive power based upon those DLMPs. In this market structure, energy can flow between elements of the distribution system (e.g., residential and commercial nodes) as well as upstream to the substation node.

The scenarios estimate these costs for a peak summer day (July 2, 2014) and a peak winter day (December 28, 2014). Data for those days includes Capital Region Day-Ahead Market (DAM) hourly LMPs, solar insolation, and temperatures.

The scenarios estimate these costs for low and high penetration levels of DER (i.e., PV, EV, flexible end-use demand.) Flexible demand is capable of responding to forecasts of hourly prices by shifting a portion of its scheduled use within a 24-period, from hours with forecast higher prices to hours with forecast lower prices; this can be either DR or price-responsive demand.

The Low DER penetration (Low DER) scenario represents a future with slow growth in PV, EV, and flexible load in commercial buildings. It assumes 10% of commercial demand is flexible, EV at six residential nodes on the feeder and PV at 13 residential and two commercial nodes on the feeder. The High DER penetration (High DER) scenario represents a future with more rapid growth in those DER technologies. It assumes 20% of commercial demand is flexible, EV at 150 residential nodes, and PV at 202 residential and 25 commercial nodes on the feeder. (PV ranges in size from 40 to 500 kVA in commercial installations and 4 kVA in residential installations.)[88]

The Low and High DER penetration scenarios have the following common assumptions for PV and EV:

- All PV installations have smart inverters that enable them to provide reactive power and voltage support from their excess capacity to the extent economically efficient based on the price for reactive power and their marginal costs of providing reactive power.
- All EVs are able to provide reactive power and voltage support from the excess capacity of their charger electronics to the extent economically efficient.

The scenarios define retail demand as either flexible or inflexible. Figure 9 presents the assumed hourly shapes for residential and commercial load, expressed as a percentage of the maximum load in the summer or winter peak hour.

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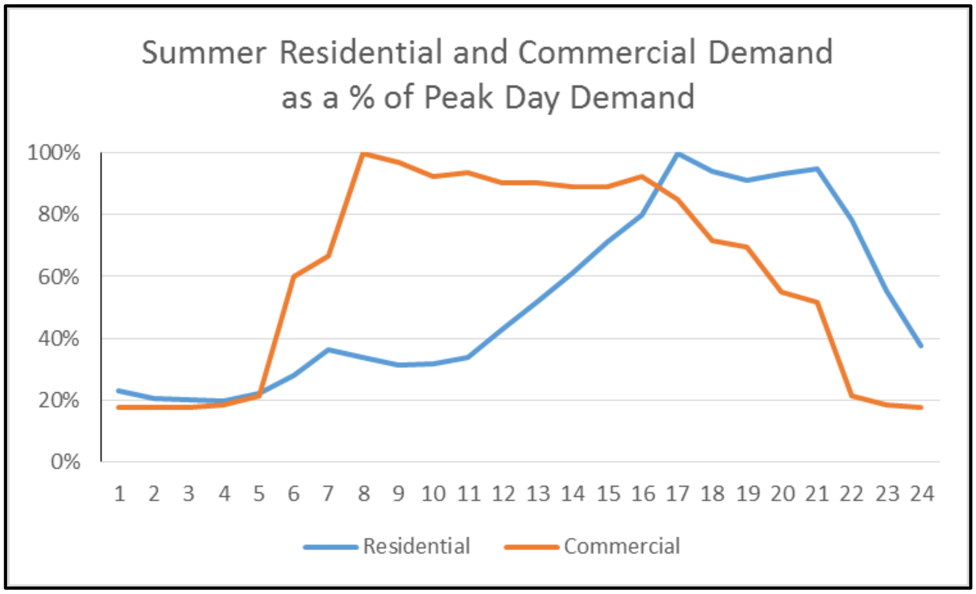
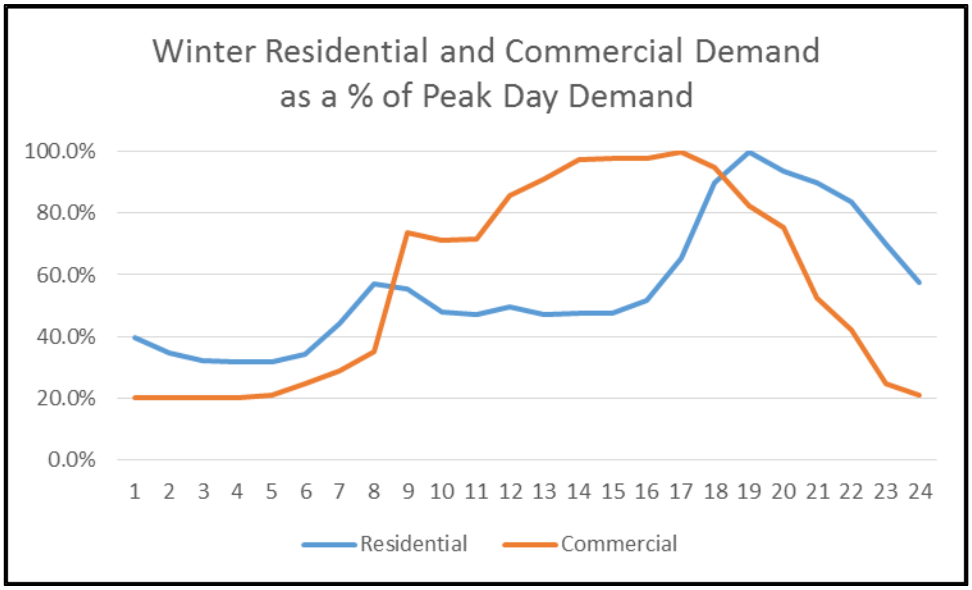
[88] Each EV is assumed to have a real energy demand of 24 kWh. The increase in total real energy demand caused by the high penetration of EVs is roughly 30% of the peak hourly demand. However, given that the charging rate capacity per EV is 3.3kW, the maximum impact on demand in a given hour is 3.3*150/12000 = 4.1% of the peak hour real energy demand of the inflexible loads.

Figure 9. Residential and Commercial Demand as Percent of Peak Demand, Summer and Winter Scenarios





DistCostMin (DCM) is an optimization model that has underlying algorithms to minimize the cost of serving forecast load within the modeled distribution network over a 24-hour period for a given set of DAM LMPs, subject to constraints on AC load flow, DER capacity, and voltage magnitude. The DCM model calculates the shadow price of real energy and reactive power at each of the 800 nodes on the radial distribution system feeder. The model optimizes the scheduling profiles of DER load with flexible demand and DER, to meet all demand on the feeder in each hour given the hourly substation LMP, maximum available hourly PV output (real energy and reactive power), and maximum available hourly

EV demand and supply (real energy and reactive power). The model simulates the scheduling of flexible demand via “smart thermostatic logic” by modeling commercial building thermal storage as electrical storage. The logic allows the building to advance cool to a level acceptable to occupants during lower-price hours and to then “coast” during higher-price hours to a set point acceptable to consumers.

The DCM model determines the optimal level of DER production and consumption under each of the four market structures. Under the first three, (i.e., BAU, LMP, eLMP) DER production and consumption decisions are based on less granular pricing information, and no pricing of reactive power independent of real energy. This results in less economically efficient operating decisions. For example, under the first three market structures, the simulation acquires additional reactive power at the cost of incremental real energy at the wholesale node, rather than from DERs, because those market structures do not independently price and compensate DER reactive power. Under the DLMP market structure, decisions are based on the most granular pricing information and on independent pricing of reactive power. This process results in the most economically efficient operating decisions.

The model results include the total cost of supply, the value of real energy and reactive power sold and purchased, and the cost of real energy and reactive power purchases at the substation node LMP.

Quantitative Scenario Results

The results of these quantitative scenarios yield three major conclusions. First, the DLMP market structure (maximum granularity) provides greater societal cost-reduction benefits than the BAU, LMP, and eLMP market structures. The benefits are most significant under the High DER penetration summer peak day scenarios. These benefits are a function of the ability of DER to respond to, and profit from, providing real energy and reactive power under the DLMP structure and from the increased granularity of hourly pricing under that structure. Second, price-responsive demand from electric vehicles and in commercial buildings could yield significantly greater savings under DLMP than other, less-granular market structures. Third, all load benefits from these cost reductions, even load that is not price-responsive, because of the average cost reduction serving all load.

The results of these simulations demonstrate the beneficial impact of moving the pricing point for DER closer, both in time and location, to the DER assets. The results are significant and strongly directional, but they must be interpreted with caution in light of the following caveats:

- The results are for a feeder intended to be representative of a prototypical Capital Region feeder. One cannot use these results to estimate the efficiency gains that would occur across the State. Further detailed modeling of actual feeders with multiple topologies over a full-year period will provide greater confidence on the magnitude of societal benefits.
- The topology of the distribution feeder provides minimal price differentiation between the BAU and LMP market structures and a more granular eLMP structure. Given the radial design of the Capitol Region feeder the results for simulations of the BAU, LMP, and eLMP market structures are very close in value. The actual differentiation in prices between an LMP and an eLMP structure was illustrated in Figure 6, which plotted the absolute difference in prices by hour in 2014 between eLMP prices at the Empire Combined Cycle node and LMPS for the Capital Region. That analysis showed differences between the two prices to be greater than $1.00/ MW

in approximately 30% of the hours in 2014.

- The modelling takes DAM LMPs as given and implicitly assumes those LMPs do not change between the DAM and real-time markets.

Therefore, the scenario cost reduction results for moving from BAU to LMP to eLMP to DLMP must be interpreted conservatively. However, with those caveats, the scenario results do indicate that under a DLMP market design:

- All load is served at an acceptable voltage level (i.e., within accepted standards). This is indicative of distribution network resilience to demand growth ensured by marginal cost, price-driven demand response.
- The Distribution Utility realizes positive rent, i.e., net revenue.

These conclusions are based upon the results reported in this section as well as on the materials presented in Appendices B and C.

Table 7 presents a matrix of the percentage reductions in total cost (i.e., societal cost to energy consumers) on the Capital Feeder under the Summer Peak, High DER scenario due to moving from BAU to LMP to eLMP to DLMP. Table 7 indicates the greatest percentage reduction, i.e., 5%, in total cost to consumers on the feeder is brought about by the increasing pricing granularity from the current single average price to a DLMP price.

Table 7. Change in Total Costs (%) with Increasing Pricing Granularity. Summer Peak, High DER

	% Reduction in Cost from BAU	**%Reduction in Cost from LMP**	**%Reduction in Cost from eLMP**
To LMP	1.44		
To eLMP	1.51	0.07	
To Full DLMP	5.01	3.61	3.55

As previously discussed, the topology of the modeled feeder results in minimal differentiation between modelled prices under the BAU, LMP, and eLMP market structures, which is the case for each of the scenarios described in this section.

Figure 10 plots the total cost of supply to consumers on the feeder under the Summer Peak, High DER scenario for each of the four market structures. The total cost under the BAU, LMP, and eLMP structures range from $18,374 to $18,096. That total cost drops to $17,454 under the DLMP structure.

Figure 10. Total Cost Summer Peak, High DER

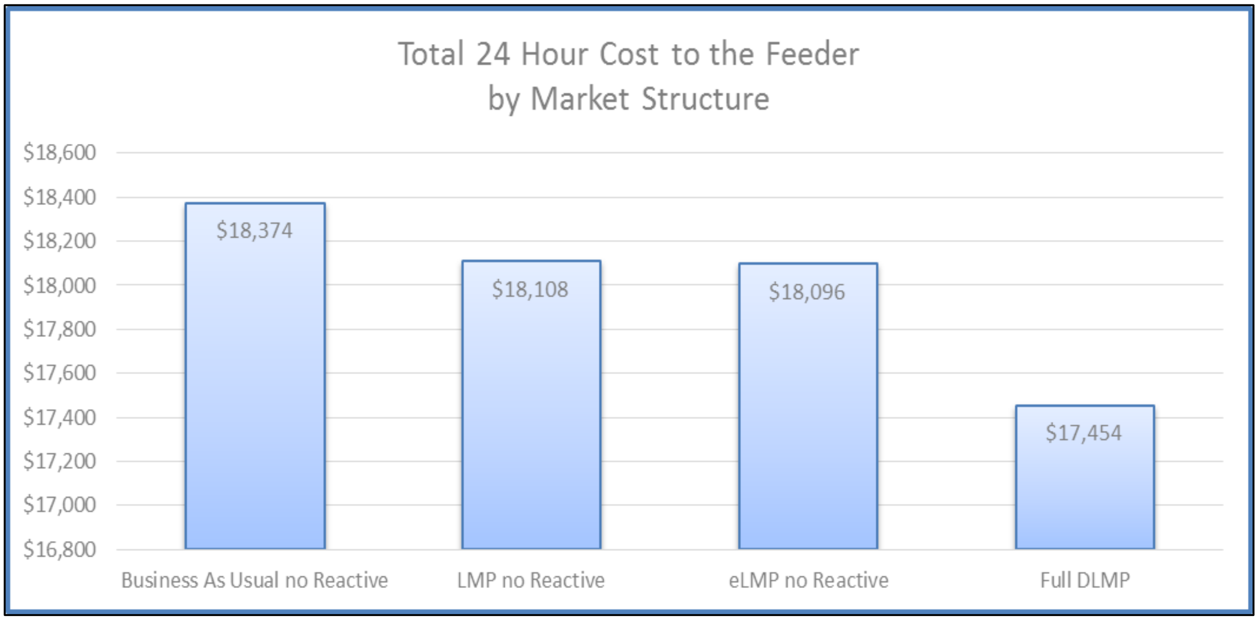


Table 8 provides a full set of cost results for the Summer Peak, High DER scenario and Table 9 provides the underlying set of physical results for that scenario.

The results in Table 8 demonstrate that an important part of the benefits of moving to DLMP are a function of the ability of DER to respond to, and profit from, providing reactive power under the DLMP structure. Row B shows a significant drop in the amount of reactive power purchased from the wholesale (substation) market under the DLMP market structure as compared to the BAU market structure. Under the DLMP market, those purchases are replaced by purchases of reactive power from electric vehicles and PV as shown in Rows H and J respectively.

Table 8. Cost Results. Summer Peak, High DER Scenario

Row	Results	Market Structure			
		Business As Usual no Reactive	LMP no Reactive	eLMP no Reactive	Full DLMP
A	Substation Transaction Costs for Energy	$ 13,280	$ 13,171	$ 13,171	$ 13,234
B	Substation Transaction Costs for Reactive Power	$ 1,185	$ 1,136	$ 1,133	$ 779
	Total Substation Trans Costs (A+B)	$ 14,465	$ 14,307	$ 14,304	$ 14,013
C	Charges to Space Conditioning for Energy	$ 743	$ 721	$ 721	$ 703
D	Charges to Space Conditioning for Reactive Power	$ 212	$ 188	$ 185	$ 140
	Total Space Conditioning Charges (C+D)	$ 955	$ 909	$ 906	$ 843
E	Charges to EV for Energy	$ 220	$ 127	$ 127	$ 127
F	Charges to Inflexible Loads for Energy	$ 15,106	$ 15,041	$ 15,037	$ 14,872
G	Charges to Inflexible Loads for Reactive Power	$ 2,092	$ 2,030	$ 2,026	$ 1,612
	Total Inflexible Load Charges (F+G)	$ 17,198	$ 17,072	$ 17,063	$ 16,484
H	Income of EV for provision of Reactive Power	$ -	$ -	$ -	$ 135
	Net EV Charges (E-H)	$ 220	$ 127	$ 127	$ (8)
I	Income of PV for provision of Energy	$ 1,494	$ 1,493	$ 1,493	$ 1,408
J	Income of PV for provision Reactive Power	$ -	$ -	$ -	$ 169
	Total PV income (I+J)	$ 1,494	$ 1,493	$ 1,493	$ 1,577
K	Total Charges (K=C+D+E+F+G)	$ 18,374	$ 18,108	$ 18,096	$ 17,454
L	Total DER income (L=H+I+J)	$ 1,494	$ 1,493	$ 1,493	$ 1,712
M	Net Cost of Distribution Participants (M=K-L)	$ 16,879	$ 16,615	$ 16,603	$ 15,742
N	Distribution Network Rent (N=M-A-B)	$ 2,414	$ 2,308	$ 2,299	$ 1,729
	Substation Transaction Costs for Energy ($/MWh)	$ 65.48	$ 64.49	$ 64.48	$ 64.48
	Substation Transaction Costs for Reactive ($/MVarh)	$ 15.50	$ 14.76	$ 14.71	$ 13.55
	Charges to Space Conditioning for Energy ($/MWh)	$ 83.78	$ 69.38	$ 69.09	$ 66.52
	Charges to Space Conditioning for Reactive ($/MVarh)	$ 46.22	$ 34.90	$ 34.17	$ 25.54
	Charges to EV for Energy ($/MWh)	$ 61.17	$ 35.35	$ 35.33	$ 35.18
	Charges to Inflexible Loads for Energy ($/MWh)	$ 73.94	$ 73.63	$ 73.60	$ 72.80
	Charges to Inflexible Loads for Reactive ($/MVarh)	$ 34.31	$ 33.30	$ 33.23	$ 26.44
	Income of EV for provision of Reactive Power ($/MVarh)	$ -	$ -	$ -	$ 10.41
	Income of PV for provision of Energy ($/MWh)	$ 75.34	$ 75.29	$ 75.29	$ 74.73
	Income of PV for provision of Reactive Power ($/MVarh)	$ -	$ -	$ -	$ 27.29

Table 9 indicates the quantities of energy (MWh) and reactive power (MVarh) purchased from the wholesale (substation) market as well as the quantities produced and consumed by DER. The quantity of reactive power purchased from the substation is reduced by approximately one quarter under the DLMP market structure as compared to the BAU market structure due to displacement by reactive power from EV plus PV, which increases from zero under BAU to over 19 MVarh under DLMP. As shown in Table 9, the PV output in MWh for the BAU, LMP and eLMP market structures is identical. The difference under DLMP is that a portion of PV real energy MWh is converted to MVarh, which has a higher marginal value to the PV owner, and to the Capital Feeder as a whole, than does real energy. The bottom section of Table 8 shows those changes in value under DLMP as compared to BAU. The marginal value of energy to PV decreases slightly under DLMP while the marginal value of reactive power to PV increases from zero to $27/MVarh.

Table 9. Real Energy and Reactive Power Results. Summer Peak, High DER Scenario

Results	Units	Market Structure			
		Business As Usual no Reactive	LMP no Reactive	eLMP no Reactive	Full DLMP
Substation Energy	**MWh**	202.81	204.23	204.27	205.23
Substation Reactive Power	**MVarh**	76.46	76.97	76.99	57.52
Space Conditioning Load - Energy	**MWh**	8.87	10.39	10.43	10.57
Space Conditioning Load - Reactive Power	**MVarh**	4.59	5.40	5.43	5.48
Inflexible Load - Energy	**MWh**	204.30	204.30	204.30	204.30
Inflexible Load - Reactive Power	**MVarh**	60.97	60.97	60.97	60.97
EV - Energy	**MWh**	3.60	3.60	3.60	3.60
EV - Reactive Power	**MVarh**	0.00	0.00	0.00	12.92
PV - Energy	**MWh**	19.84	19.84	19.84	18.84
PV - Reactive Power	**MVarh**	0.00	0.00	0.00	6.19

The results of the quantitative analysis of the Summer High DER penetration scenario presented in Table 8 and Table 9 provide the basis for additional significant conclusions related to the positive impact of moving to highly granular pricing for customers with price-responsive demand. The High DER penetration scenario assumes 20% of commercial demand is flexible, a portion representing space conditioning. This paper models that portion as price-responsive demand.

- The first conclusion is that the savings from price responsive demand are higher under DLMP than under less granular pricing. The results reported in rows C and D of Table 8 indicate that the total cost of real energy plus reactive power for space conditioning under DLMP is 11.7% lower than under BAU. This cost reduction is not caused by a reduction in real energy and reactive power consumption. Table 9 shows those quantities remain nearly constant across the four market structures and actually are greatest under the DLMP market structure. Instead, the cost reductions under DLMP are attributable to pre-cooling prior to projected high-price hours and then coasting through those high-priced hours, while maintaining full customer comfort.
- The second conclusion is that all load benefits from the cost reductions under DLMP, even load that is not price-responsive, because of the reduction in the average cost of serving all load. In the Summer High DER scenario, the total cost of real energy plus reactive power for inflexible loads (Table 8, Rows F plus G) is 4.2% less on average under the DLMP market structure than under the less-granular market structures.

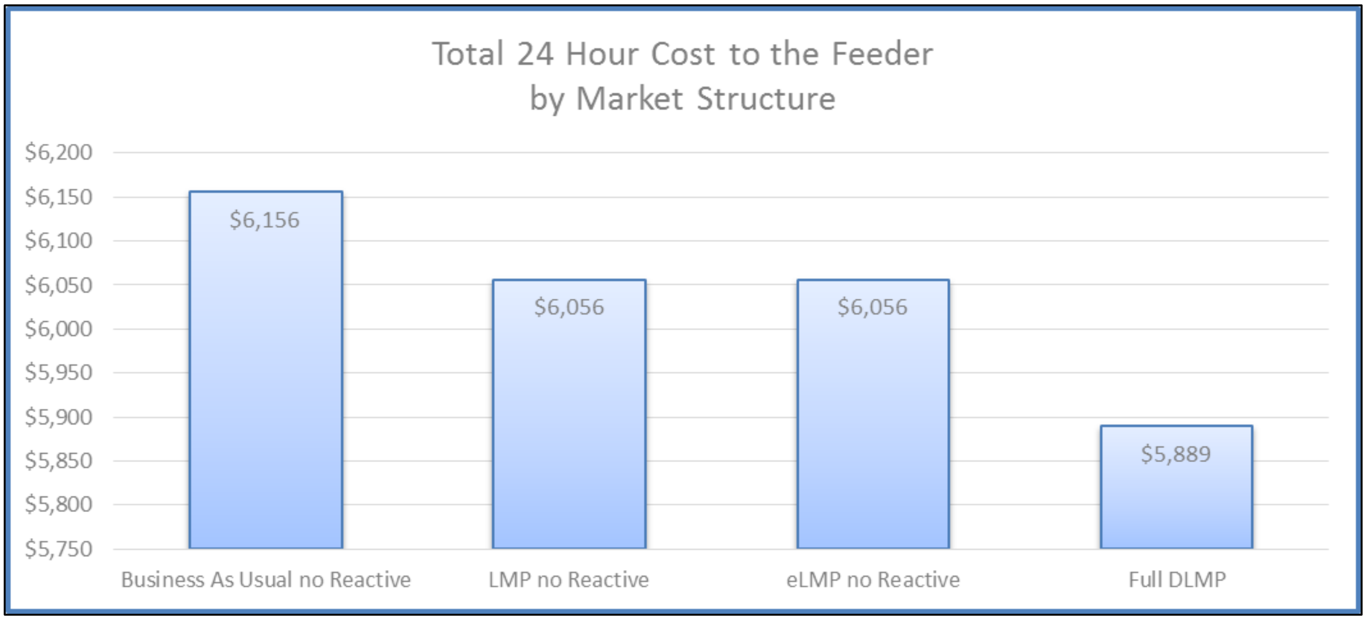
The next conclusion is based on comparing the Summer Peak, High DER scenario results for the four market structures, from Table 7, with the corresponding results for the Winter Peak, High DER scenarios, presented in Table 10. The key conclusion from that comparison is that the percentage savings of moving to DLMP from BAU is less in winter than in summer (4.3% compared to 5.0%).

Table 10. Change in Total Costs (%) with Increasing Pricing Granularity. Winter Peak, High DER

	% Reduction in Cost from BAU	%Reduction in Cost from LMP	%Reduction in Cost from eLMP
To LMP	1.61		
To eLMP	1.62	0.01	
To Full DLMP	4.32	2.76	2.75

Figure 11 plots the total cost of supply to consumers on the feeder under the Winter Peak, High DER scenario for each of the four market structures shows a parallel cost reduction pattern. (Total costs under each market structure on the winter peak day are about one-third of costs on the summer peak day, primarily due to differences between LMPs on those winter and summer days.)

Figure 11. Winter Peak, High DER Total Cost



The production and consumption patterns for real energy and reactive power in the winter and summer scenarios are the same, with variations based on solar insolation and DR customer response as shown in Table 11.

Table 11. Cost Results. Winter Peak, High DER Scenario

Row	Results	Market Structure			
		Business As Usual no Reactive	LMP no Reactive	eLMP no Reactive	Full DLMP
A	Substation Transaction Costs for Energy	$ 4,788	$ 4,740	$ 4,740	$ 4,746
B	Substation Transaction Costs for Reactive Power	$ 362	$ 350	$ 350	$ 256
	Total Substation Trans Costs (A+B)	$ 5,150	$ 5,091	$ 5,091	$ 5,001
C	Charges to Space Conditioning for Energy	$ 193	$ 185	$ 185	$ 184
D	Charges to Space Conditioning for Reactive Power	$ 42	$ 37	$ 37	$ 30
	Total Space Conditioning Charges (C+D)	$ 235	$ 222	$ 222	$ 213
E	Charges to EV for Energy	$ 93	$ 47	$ 47	$ 46
F	Charges to Inflexible Loads for Energy	$ 5,181	$ 5,157	$ 5,156	$ 5,107
G	Charges to Inflexible Loads for Reactive Power	$ 646	$ 631	$ 631	$ 522
	Total Inflexible Load Charges (F+G)	$ 5,828	$ 5,788	$ 5,787	$ 5,630
H	Income of EV for provision of Reactive Power	$ -	$ -	$ -	$ 64
	Net EV Charges (E-H)	$ 93	$ 47	$ 47	$ (18)
I	Income of PV for provision of Energy	$ 185	$ 186	$ 186	$ 176
J	Income of PV for provision Reactive Power	$ -	$ -	$ -	$ 19
	Total PV income (I+J)	$ 185	$ 186	$ 186	$ 195
K	Total Charges (K=C+D+E+F+G)	$ 6,156	$ 6,056	$ 6,056	$ 5,889
L	Total DER income (L=H+I+J)	$ 185	$ 186	$ 186	$ 259
M	Net Cost of Distribution Participants (M=K-L)	$ 5,970	$ 5,871	$ 5,870	$ 5,631
N	Distribution Network Rent (N=M-A-B)	$ 820	$ 780	$ 779	$ 630
	Substation Transaction Costs for Energy ($/MWh)	$ 21.15	$ 20.91	$ 20.91	$ 20.91
	Substation Transaction Costs for Reactive ($/MVarh)	$ 4.63	$ 4.48	$ 4.48	$ 4.11
	Charges to Space Conditioning for Energy ($/MWh)	$ 21.43	$ 19.60	$ 19.55	$ 19.40
	Charges to Space Conditioning for Reactive ($/MVarh)	$ 8.96	$ 7.54	$ 7.53	$ 6.03
	Charges to EV for Energy ($/MWh)	$ 25.82	$ 12.97	$ 12.97	$ 12.90
	Charges to Inflexible Loads for Energy ($/MWh)	$ 24.04	$ 23.92	$ 23.92	$ 23.70
	Charges to Inflexible Loads for Reactive ($/MVarh)	$ 10.55	$ 10.30	$ 10.29	$ 8.52
	Income of EV for provision of Reactive Power ($/MVarh)	$ -	$ -	$ -	$ 4.95
	Income of PV for provision of Energy ($/MWh)	$ 21.57	$ 21.61	$ 21.62	$ 21.54
	Income of PV for provision of Reactive Power ($/MVarh)	$ -	$ -	$ -	$ 6.97

The final conclusion is drawn from a comparison of results for the High DER and Low DER penetration scenarios for summer peak days. Table 12 summarizes the reduction in total costs under Low DER due to moving from BAU to LMP to eLMP to DLMP. Table 12 indicates a reduction in total cost from moving to more granular pricing even with limited DER in the Capital Feeder. There is a 0.81% reduction in total cost for the feeder from moving to DLMP from BAU, and a 0.34% cost reduction in moving from LMP.

Table 12. Change in Total Costs (%) with Increasing Pricing Granularity. Summer Peak, Low DER

	% Reduction in Cost from BAU	%Reduction in Cost from LMP	%Reduction in Cost from eLMP
To LMP	0.48		
To eLMP	0.53	0.05	
To Full DLMP	0.81	0.34	0.28

Figure 12 shows the total cost of serving consumers in the Summer Peak, Low DER scenario. That Figure indicates that total costs under the BAU, LMP and eLMP market structures under the Summer Peak, Low DER scenario are only slightly greater than under the Summer Peak, High DER scenario, plotted in Figure 10. The noteworthy point is that the total cost under the DLMP market structure is approximately 4%

greater under the Summer Peak, Low DER scenario than under the Summer Peak, High DER scenario. This result illustrates the cost reduction benefit of increasing the penetration of PV and DER under a DLMP market structure. Table 13 provides the Summer Peak, Low DER scenario results.

Figure 12. Total Cost. Summer Peak, Low DER

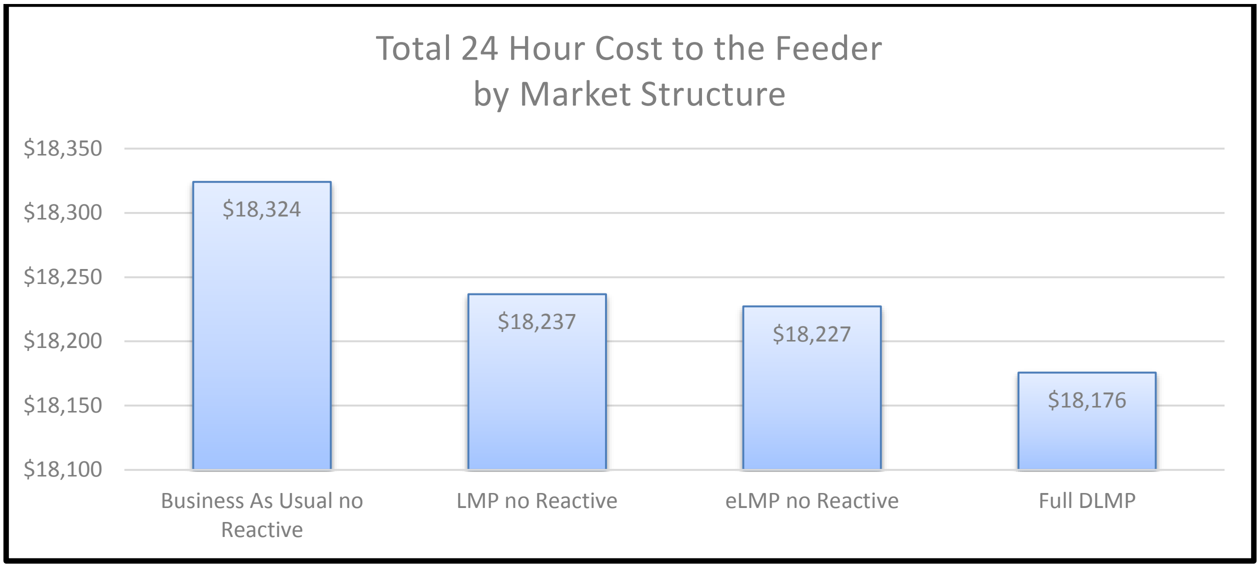


Table 13. Cost Results. Summer Peak, Low Penetration Scenario

Row	Results	Market Structure			
		Business As Usual no Reactive	LMP no Reactive	eLMP no Reactive	Full DLMP
A	Substation Transaction Costs for Energy	$ 14,468	$ 14,454	$ 14,454	$ 14,461
B	Substation Transaction Costs for Reactive Power	$ 1,224	$ 1,201	$ 1,198	$ 1,175
	Total Substation Trans Costs (A+B)	$ 15,691	$ 15,654	$ 15,653	$ 15,636
C	Charges to Space Conditioning for Energy	$ 375	$ 358	$ 359	$ 357
D	Charges to Space Conditioning for Reactive Power	$ 107	$ 91	$ 89	$ 85
	Total Space Conditioning Charges (C+D)	$ 482	$ 450	$ 448	$ 442
E	Charges to EV for Energy	$ 5	$ 5	$ 5	$ 5
F	Charges to Inflexible Loads for Energy	$ 15,606	$ 15,581	$ 15,577	$ 15,559
G	Charges to Inflexible Loads for Reactive Power	$ 2,231	$ 2,201	$ 2,197	$ 2,169
	Total Inflexible Load Charges (F+G)	$ 17,837	$ 17,782	$ 17,774	$ 17,728
H	Income of EV for provision of Reactive Power	$ -	$ -	$ -	$ 8
	Net EV Charges (E-H)	$ 5	$ 5	$ 5	$ (3)
I	Income of PV for provision of Energy	$ 61	$ 61	$ 61	$ 55
J	Income of PV for provision Reactive Power	$ -	$ -	$ -	$ 12
	Total PV income (I+J)	$ 61	$ 61	$ 61	$ 67
K	Total Charges (K=C+D+E+F+G)	$ 18,324	$ 18,237	$ 18,227	$ 18,176
L	Total DER income (L=H+I+J)	$ 61	$ 61	$ 61	$ 76
M	Net Cost of Distribution Participants (M=K-L)	$ 18,263	$ 18,175	$ 18,166	$ 18,100
N	Distribution Network Rent (N=M-A-B)	$ 2,572	$ 2,521	$ 2,513	$ 2,464
	Substation Transaction Costs for Energy ($/MWh)	$ 65.80	$ 65.51	$ 65.51	$ 65.49
	Substation Transaction Costs for Reactive ($/MVarh)	$ 15.61	$ 15.24	$ 15.20	$ 15.06
	Charges to Space Conditioning for Energy ($/MWh)	$ 84.50	$ 69.08	$ 68.68	$ 67.28
	Charges to Space Conditioning for Reactive ($/MVarh)	$ 46.58	$ 33.81	$ 32.74	$ 30.91
	Charges to EV for Energy ($/MWh)	$ 35.95	$ 35.96	$ 35.96	$ 35.92
	Charges to Inflexible Loads for Energy ($/MWh)	$ 74.41	$ 74.28	$ 74.27	$ 74.18
	Charges to Inflexible Loads for Reactive ($/MVarh)	$ 34.98	$ 34.51	$ 34.45	$ 34.00
	Income of EV for provision of Reactive Power ($/MVarh)	$ -	$ -	$ -	$ 16.05
	Income of PV for provision of Energy ($/MWh)	$ 77.72	$ 77.69	$ 77.70	$ 77.21
	Income of PV for provision of Reactive Power ($/MVarh)	$ -	$ -	$ -	$ 38.16

For completeness, Table 14, Figure 13 and Table 15 present the corresponding Winter Peak, Low DER scenario results. Again, the results for each of the four market structures shows a parallel cost reduction pattern as the Winter Peak, High DER scenario results.

Table 14. Change in Total Costs (%) with Increasing Pricing Granularity. Winter Peak, Low DER

	% Reduction in Cost from BAU	%Reduction in Cost from LMP	%Reduction in Cost from eLMP
To LMP	0.35		
To eLMP	0.35	0.00	
To Full DLMP	0.48	0.13	0.13

Figure 13. Total Cost. Winter Peak, Low DER

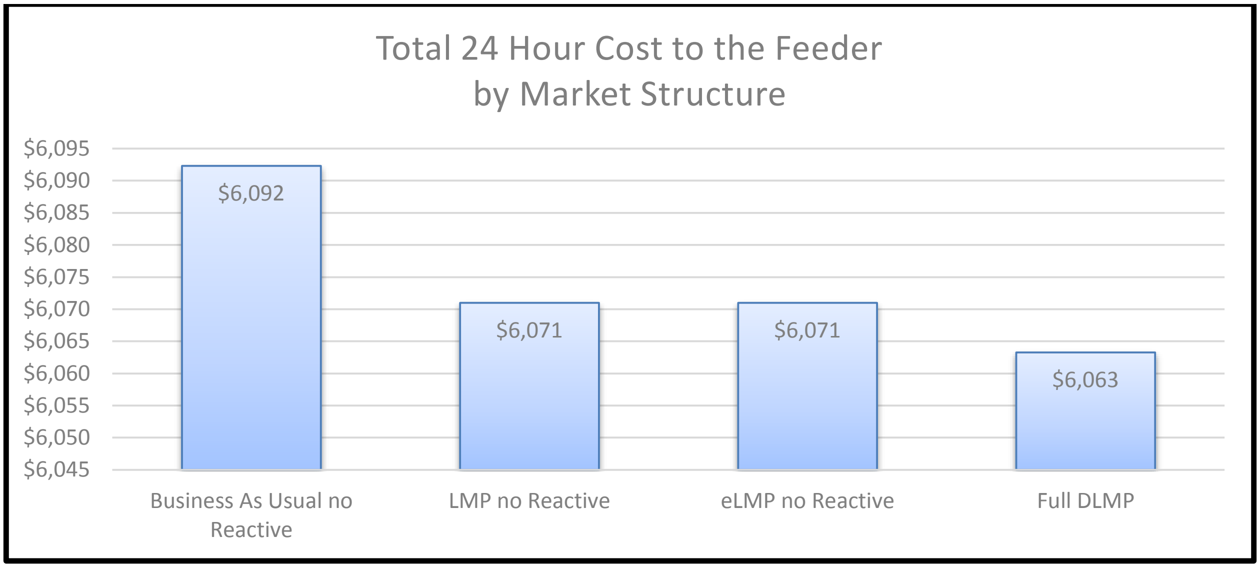


Table 15. Cost Results. Winter Peak, Low DER Scenario

Row	Results	Market Structure			
		Business As Usual no Reactive	LMP no Reactive	eLMP no Reactive	Full DLMP
A	Substation Transaction Costs for Energy	$ 4,886	$ 4,881	$ 4,881	$ 4,881
B	Substation Transaction Costs for Reactive Power	$ 368	$ 363	$ 363	$ 359
	Total Substation Trans Costs (A+B)	$ 5,254	$ 5,244	$ 5,244	$ 5,240
C	Charges to Space Conditioning for Energy	$ 97	$ 93	$ 93	$ 93
D	Charges to Space Conditioning for Reactive Power	$ 21	$ 18	$ 18	$ 18
	Total Space Conditioning Charges (C+D)	$ 118	$ 111	$ 111	$ 111
E	Charges to EV for Energy	$ 4	$ 2	$ 2	$ 2
F	Charges to Inflexible Loads for Energy	$ 5,292	$ 5,286	$ 5,286	$ 5,283
G	Charges to Inflexible Loads for Reactive Power	$ 678	$ 672	$ 672	$ 667
	Total Inflexible Load Charges (F+G)	$ 5,970	$ 5,958	$ 5,958	$ 5,950
H	Income of EV for provision of Reactive Power	$ -	$ -	$ -	$ 11
	Net EV Charges (E-H)	$ 4	$ -	$ -	$ -
I	Income of PV for provision of Energy	$ 8	$ 8	$ 8	$ 7
J	Income of PV for provision Reactive Power	$ -	$ -	$ -	$ 1
	Total PV income (I+J)	$ 8	$ 8	$ 8	$ 8
K	Total Charges (K=C+D+E+F+G)	$ 6,092	$ 6,071	$ 6,071	$ 6,063
L	Total DER income (L=H+I+J)	$ 8	$ 8	$ 8	$ 19
M	Net Cost of Distribution Participants (M=K-L)	$ 6,085	$ 6,063	$ 6,063	$ 6,044
N	Distribution Network Rent (N=M-A-B)	$ 831	$ 819	$ 819	$ 804
	Substation Transaction Costs for Energy ($/MWh)	$ 21.13	$ 21.09	$ 21.09	$ 21.09
	Substation Transaction Costs for Reactive ($/MVarh)	$ 4.68	$ 4.62	$ 4.62	$ 4.60
	Charges to Space Conditioning for Energy ($/MWh)	$ 21.49	$ 19.57	$ 19.57	$ 19.54
	Charges to Space Conditioning for Reactive ($/MVarh)	$ 9.03	$ 7.46	$ 7.46	$ 7.36
	Charges to EV for Energy ($/MWh)	$ 27.80	$ 13.33	$ 13.33	$ 13.33
	Charges to Inflexible Loads for Energy ($/MWh)	$ 24.05	$ 24.02	$ 24.02	$ 24.01
	Charges to Inflexible Loads for Reactive ($/MVarh)	$ 10.66	$ 10.56	$ 10.56	$ 10.48
	Income of EV for provision of Reactive Power ($/MVarh)	$ -	$ -	$ -	$ 21.14
	Income of PV for provision of Energy ($/MWh)	$ 22.10	$ 22.14	$ 22.14	$ 22.14
	Income of PV for provision of Reactive Power ($/MVarh)	$ -	$ -	$ -	$ 8.52

B. Qualitative Assessment

This section presents three scenarios to illustrate, qualitatively, the manner in which a digital Platform might facilitate a market for products and services provide by DERs. It provides high-level, best-scenario estimates of potential revenues that could accrue to the Platform provider(s) if DERs transact over the Platform. Each scenario is independent of the others, therefore the estimates of Platform revenues from each scenario cannot be summed to arrive at an estimate of Platform revenue potential. The scenarios do not represent all transactions anticipated on the Platform, nor do they capture any of the network externalities expected to evolve on the Platform.

The three scenarios listed in Table 16 discuss the implications of a Platform Market for statewide DR, localized Peak Load Reduction via DER and statewide peak reduction via ES. Each scenario provides order-of-magnitude estimates for the year 2020 of potential annual transactions on the Platform and associated revenues that could flow to the Platform provider(s). Each scenario is a separate “what if” example. As a result, the estimates of potential annual transactions on the Platform and associated revenues are not additive.

Table 16. Key Aspects of Qualitative Scenarios

Platform Market Scenario	**Resource Target, 2020**	**Potential annual transactions (MWh), 2020**	**Potential Annual Platform Revenues, 2020**
1. DR, System Peak Reduction, statewide	2.1 GW	8,964,000	$ 18.1 million
2. DER, Targeted Location Peak Reduction at a Distribution Utility	1.5 GW reduction, targeted locations, 2-6 p.m. weekdays,	350,047	$ 0.99 million
3. ES, System Peak Reduction, statewide	0.47 GW peak reduction, ES	522,222	$ 1.15 million

Common Input Assumptions

Summaries of the major input assumptions common to all scenarios are:

- **Loads by hour (8,760) in 2020 by NYISO zones.** These projections are based on NYISO 2014 historical load data and assumptions of annual average growth rate (0.48%) and summer and winter peak growth rates (0.96% and 0.44%, respectively).

- **Nodal LMPs (nLMP) at the New York City, Albany, and Montauk nodes for every hour of the various scenarios.** These projections are from a TCR simulation of the NYISO wholesale energy market, using their Power System Optimizer (PSO) model.[89] The TCR team calculated representative statewide nLMPs as load weighted average nLMPs from the New York City, Albany, and Montauk nodes. The TCR team developed estimates of Platform transactions and revenues on a statewide basis by scaling up results from the zones. New York City node results were considered representative of New York City, Millwood (Zone H), Dunwoodie (Zone I), and half of Hudson Valley (Zone G). Albany node results were considered representative of the entire upstate region (Zones A-F and half of the Hudson Valley). Montauk node results were considered representative of Long Island (Zone K).
- **Statewide DR potential in 2020.** A potential of 2.1 GW is assumed based on a DNV GL study of retail customer flexible energy use for end-uses such as lighting, heating ventilation and air conditioning (HVAC), refrigeration, and behind-the-meter capabilities to control that energy use.[90] Hourly load reduction potential by end-use, customer type and utility is obtained from the same DNV GL study, in which DER profiles were calculated based on utility hourly load profiles by rate class and day type, as well as KEMA's work on DER with Lawrence Berkeley National Laboratory for the California Energy Commission. The portion of that potential that could be controllable by NYISO is assumed to be participating in the Platform.
- **Statewide PV and ES potential in 2020.** The scenarios assume statewide PV potential in 2020 to be 2.5 GW based upon the NY-Sun target of 3 GW of installed PV capacity by 2023. Statewide ES potential is assumed to be 0.47 GW, an estimate derived from the statewide PV assumption and from assumptions regarding the ratios of ES system capacity to PV capacity of 1 to 3 and 1 to 1 for commercial and residential PV installations, respectively. The sizing is based on common ES applications for each sector, namely demand management for commercial customers and power backup for residential customers.[91] The assumed regional distribution of installed PV capacity, and thus the distribution of ES capacity, follows the NYISO 2015 Gold Book forecast for Retail Solar PV by zone for 2020.[92] Projected hourly ES charge and discharge profiles at the NYC, Albany and Montauk node, as well as projected hourly profiles of PV output in NYC, are drawn from PSO simulations for the relevant scenarios.

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[89] PSO, developed by Polaris Systems Optimizations, Inc., is a detailed, mixed integer programming MIP based, unit commitment and economic dispatch model that simulates the operation of the electric power system. The TCR team used PSO to determine the security-constrained commitment and dispatch of each modeled generating unit, the loading of each element of the transmission system, and LMP by hour for each generator and load area.

[90] ___, Integrating Increased Dispatchable Demand Response and Dynamic Price Response into NYISO Markets, Customer Behavior Dynamics Modeling – Preliminary Findings, KEMA, FERC Conference on Market Efficiency, June 2011. http://www.ferc.gov/CalendarFiles/20110629082153-Jun29-SesB1-Masiello-KEMA-NYISO.pdf

[91] Industry Practice, Supplier data, DNV GL NYSERDA Study

[92] NEW YORK INDEPENDENT SYSTEM OPERATOR 2015 LOAD & CAPACITY DATA, http://www.nyiso.com/public/webdocs/markets_operations/services/planning/Documents_and_Resources/Planning_Data_and_Reference_Docs/Data_and_Reference_Docs/2015%20Load%20and%20Capacity%20Data%20Report.pdf.

Scenario 1: DR and System Peak Reduction, Statewide

Background

DR is currently in widespread use to provide energy in the form of a capacity product. The buyers of this capacity product have the right to call upon it with advance notice of one hour, or possibly longer, to reduce load or "deliver energy down" for durations of an hour or more in day-ahead or real-time energy markets. The compensation for this type of DR product is typically an annual payment for capacity, regardless of whether it is actually called upon, and in some cases an additional payment when actually called upon. Another type of compensation could be based on real-time settlement upon DR deployment.

Depending on the DER used to provide this capacity product, some or all of the load reduction during the DR period will be replaced after the end of the DR period.

Air conditioning is an example of DR for which some or all of the load reduction during the DR period will be effectively replaced either prior to, or after, the end of the DR period. For example, setting a thermostat higher to reduce A/C during a DR period usually implies that the user will use extra energy to pre-cool the space prior to the DR period and/or to cool down the space to the target temperature after the DR period. This type of DR simply shifts a portion of their total energy requirement for the day from a high-price DR period to lower-price periods prior to and /or subsequent to the DR period. As a result, this type of DR reduces the need for generating capacity, and possibly distribution system capacity, and reduces their total cost of energy for the day. However, it does not reduce, and may increase, the total quantity of energy required over the 24-hour period while reducing the cost of delivered energy.

Lighting is an example of a DR load reduction, which will not be replaced after the end of the DR period. Turning lights back on after a DR period does not result in additional energy use to restore light that was "lost" during the DR period.

DR has the potential to provide delivery of energy, or megawatts, down in day-ahead or real-time energy markets. The compensation for that type of DR product would be the granular pricing offered by the Platform. The DR best suited to participate in those markets are load types that can be controlled quickly with committed control paths (as opposed to Internet notification for day-ahead DR), that can respond quickly to those controls, and whose response will not unduly inconvenience end-users.

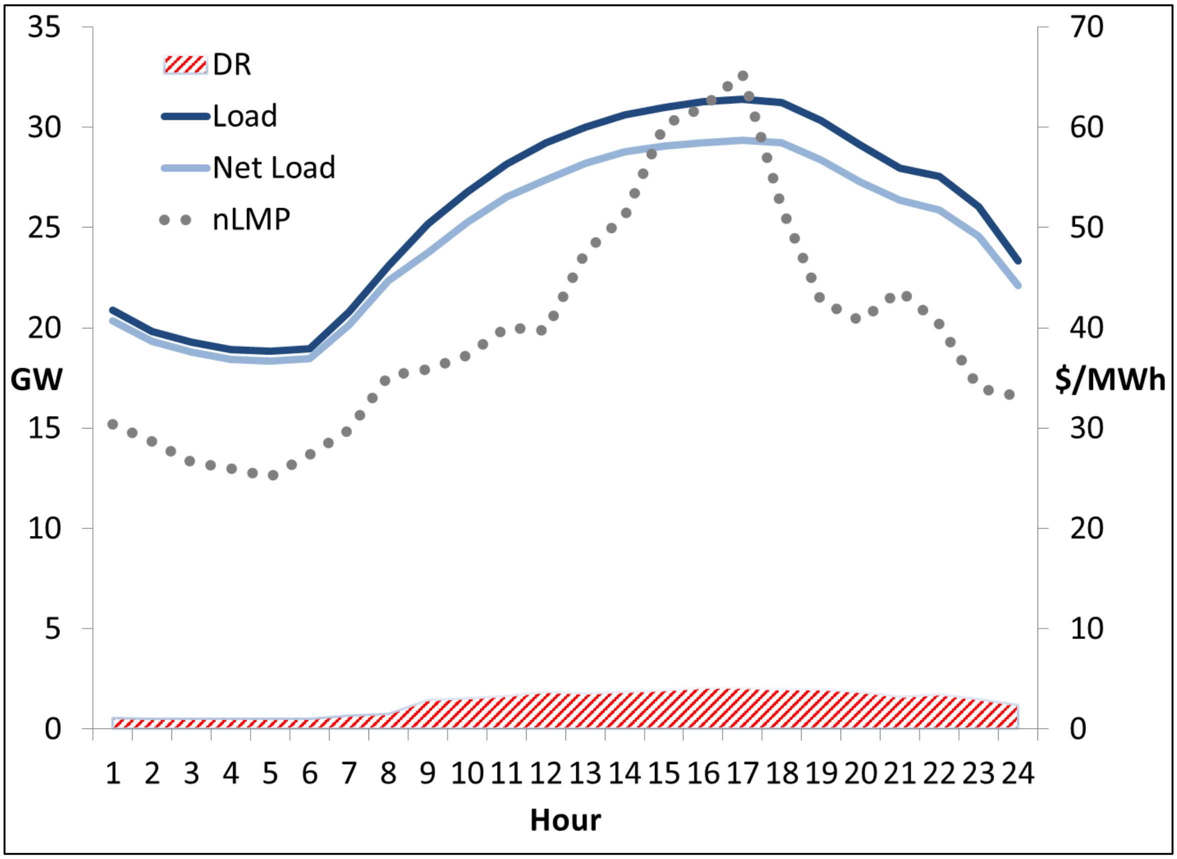
DR with those attributes, i.e., directly controllable and fast responding, has the potential to also provide energy and reserves for ancillary services in the wholesale market. DR with those attributes are generally not providing ancillary services today because of the economic barrier posed by the cost of telemetry and controls required for grid monitoring and control, as well as assessments of capacity factor and measurement and validation.

Platform Market Scenario

Under this scenario, the Platform Market enables sellers and buyers of controllable, load-shedding DR achieved from retail customers with flexible energy use for end-uses such as lighting, HVAC, refrigeration and behind-the-meter capabilities to control that energy use. Technical potential estimates for this type of DR are approximately 2.1 GW of peak reduction. This potential consists of load-shedding capability of room and central A/C and water heater for residential sector as well as lighting, cooling, ventilation, and refrigeration for commercial sectors. These estimates are based on the ability to control end-uses and on load shedding enabled by existing technologies under a Distribution Utility sponsored DR program; they do not correspond to price responsive demand. Reductions from price responsive demand are an additional potential source of peak reductions.

Consider what 2.1 GW of peak reduction-related transactions across the state in 2020 might look like in terms of Platform transactions and revenues. Here, nLMP is used as a proxy for transaction compensation. Figure 14 illustrates the daily profiles of load, DR production, and nLMP for a peak summer day (July 2).

Figure 14. Daily Load, DR, and nLMP Profiles for Peak Summer Day (July 2)



The Platform Market could support controllable DR energy products in several ways:

- **Providing DR products access to a large market.** For example, Distribution Utilities could offer standardized forward option contracts for DR on the Platform. The contracts could be structured with a fixed payment, to ensure the Distributed Utilities' ability to call on the DR at the location when local congestion occurs, and an energy strike price to be paid if and when the Distribution Utility actually calls upon the DR.
- **Reducing the cost of selling and buying DR products by minimizing the transaction costs associated with those sales and purchases.** This option enables more DR owners to participate in the market and Distribution Utilities and ESCOS to buy more DR products. In addition to

establishing standard products such as the forward option contracts previously noted, it also provides a standard method for scheduling transactions and for settling energy transactions. The Platform provides a matching function, which enables sellers and buyers to find each other at minimal cost by providing them access to algorithms and filters that collect, organize, sort, parse, and interpret their relevant data. It enables sellers and buyers to automate the optimal scheduling of reductions in flexible demand based upon a combination of forecast prices, forecast weather conditions and communication, and control technologies such as those built into smart appliances. Because of these features, the Platform could open the DR market to residential customers who would otherwise not participate due to barriers such as size eligibility, complexity of rules around operations requirements and coordination among different DR programs. By reducing or eliminating these barriers to participation, the Platform will support the aggregation of DR from residential customers depending on their availability, response time, and duration.

- **Supporting market transparency.** For example, it posts granular location- and time-specific prices that indicate where and when DR has been most valuable in the recent past, as well as forecasts of where and when DR is likely to be most valuable in upcoming periods. A DER will see and use these prices to value their willingness to buy or sell products and services on the platform. In addition, the platform could post location- and time-specific reliability adders that policymakers wish to apply to DER products.

Potential Annual Transactions and Platform Revenue in 2020

The scenario assumes that all of the energy reduction from DR is bought as an energy product transacted over the Platform and paid the statewide nLMP. The scenario assumes sellers pay a Platform fee equal to 5% of the value of the transactions. Table 17 reports the potential annual transactions and associated estimate of Platform revenue. This estimate is an upper bound for these assumptions in 2020 because it assumes all of the energy reduction from DR is bought as an energy product. The quantity of DR that will actually sell energy via the Platform will be influenced by the opportunities available to sell other DR products, and the compensation for those other DR products. Price spread and demand-side price elasticity could impact the baseline and DR load reduction capabilities and, in turn, the amount of platform revenue from DR transactions.

Table 17. Maximum Platform Revenue Assuming 100% Market Participation

Resource Focus	Potential Annual Transaction (MWh)	Potential Annual Revenue
2.1 GW of DR	8,964,000	$18.4 million

Scenario 2: DER (PV, DR, ES) Targeted Location Peak Reduction

Distribution Utilities currently have the ability to reduce peak load on a localized basis by procuring DER energy for delivery during specific times at specific locations on their systems. Under a Platform Market, a Distribution Utility could enter transactions for energy products from a variety of DERs, including PV, DR, and ES to relieve localized peaks at specific locations and times of day. (Separate reserve contracts or physical back-up investments, such as ES, might exist to support grid reliability in the event that 'regular' transactions fall short).

Platform Market Scenario

Under this scenario, a Distribution Utility uses the Platform Market to enter transactions for energy products from a combination of PV, DR and ES to relieve localized peaks at specific locations on its system and thereby defer distribution-related investments. This scenario is not an analysis of ConEdison's targeted Demand Side Management program. Instead, this scenario is an illustration of how a Distribution Utility might use a Platform Market to reduce load during summer peak periods, i.e., 2–6 p.m. on June through September weekdays. The scenario assumes the potential reductions available for peak shaving from PV, DR, and ES are 0.79 GW, 0.71 GW, and 0.18 GW, respectively.[93] It assumes the resources are deployed according to their marginal production cost, i.e., PV, DR, and then ES. Where contracts would require specified time periods of reduction that do not overlap with PV production, ES could be paired with PV. Under this pairing, the operating cost of storage is greatly reduced.

Figure 15 illustrates the hourly profiles of load on a peak summer day (July 2) and of the total DER deployed for peak shaving during peak periods (i.e., 2-6 p.m.) on that day. As shown in Figure 16, maximum peak shaving for this day is approximately 1.5 GW, which reduces peak by 4% and shifts the time of the new, lower peak to 7 p.m. (hour 19) from 5 p.m. (hour 17).

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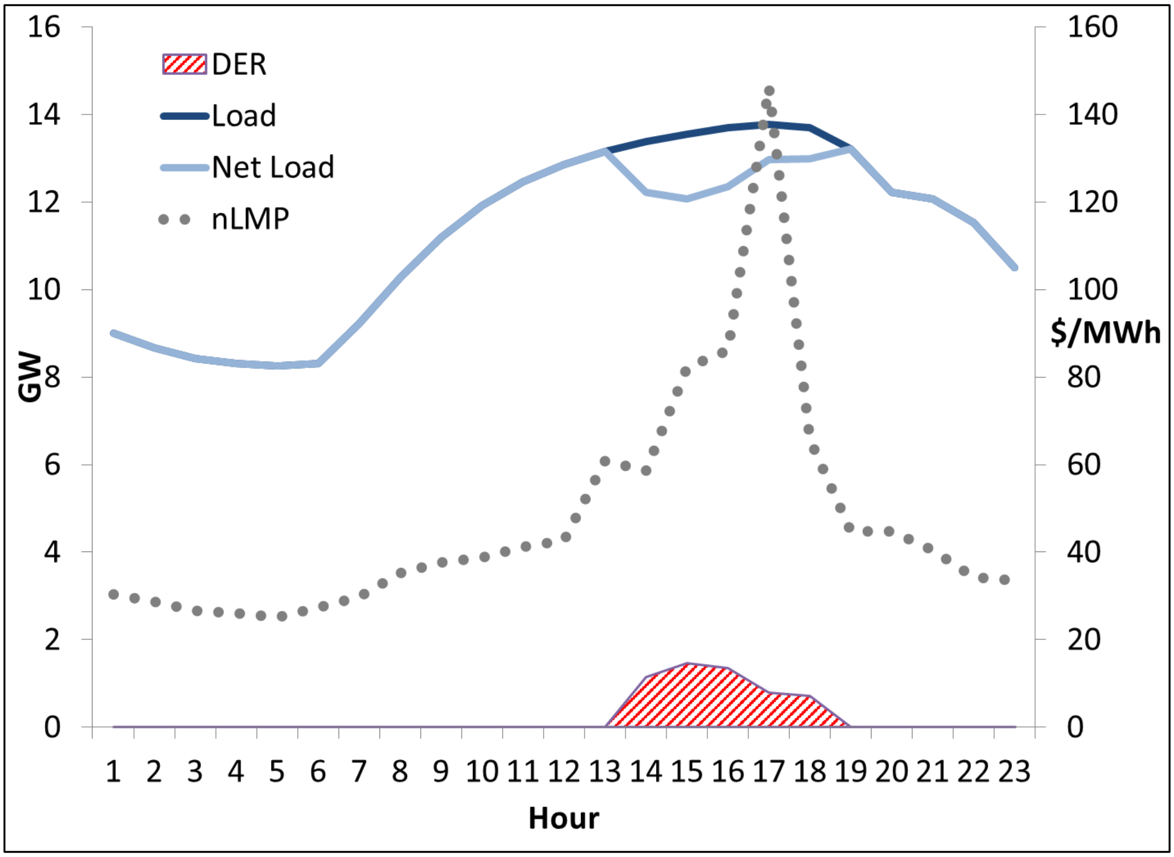
[93] These are the NYC portions of the statewide input assumptions for PV, DR, and ES.

Figure 15. Daily Load, DER Peak Shaving Over 2-6 p.m. and nLMP Profiles for Peak Summer Day (July 2)



The Platform Market enables Distribution Utilities to reduce peak load on a localized basis by procuring DER energy for delivery at specific locations in several ways:

- **Reducing the cost of selling and buying DR products** by minimizing the "transaction costs"' associated with those sales and purchases, as noted in Scenario 1. This strategy enables more DER owners to participate in the market and Distribution Utilities to buy more DER products. As noted in Scenario 1, the Distribution Utility could post standard forward option contracts for DER energy on the Platform, and use the Platform to support a standard method for scheduling and settling energy transactions. The Platform "matching" functionality would enable sellers to find the Distribution Utility at minimal cost via algorithms and filters that collect, organize, sort, parse and interpret their relevant data. The Platform would enable the Distribution Utility and sellers to automate the optimal scheduling of energy deliveries and reductions.
- **Supporting market transparency.** For example, when determining whether to enter a particular forward option contract, DER owners could review historical prices and forecast prices posted on the Platform.

Potential Annual Transactions and Platform Revenue in 2020

The scenario assumes that the Distribution Utility buys all of the energy reduction from DERs as energy products transacted over the Platform and pays the relevant nLMP. The scenario assumes the sellers pay a Platform fee equal to 5% of the value of the transactions. Table 18 estimates the potential annual transactions and associated Platform revenue for each DER. As with Scenario 1, the quantity of DR that would actually sell energy via the Platform will be influenced by the opportunities available to sell other DR products, and the compensation for those other DR products.

Table 18. Maximum Platform Revenue Assuming 100% Market Participation

Resource Focus	Potential Annual Transaction (MWh)	Potential Annual Revenue (millions)
PV	67,732	$0.17
DR	228,320	$0.59
ES	53,995	$0.22
Total	350,047	$0.99

Scenario 3: ES, System Peak Reduction, Statewide

Background

ES at the distribution and end-user scale is a new and unique resource in the electric power industry. ES technologies range from batteries to thermal energy.

ES allows capture of production in excess of demand (e.g., PV production during low load) and its storage for delivery to customers in later hours, when demand is high. Thus ES provides a mechanism for reducing imbalances between scheduled production and demand in a given time period, and for maximizing use of lower-cost sources of real energy. ES, depending upon the technology, can respond nearly instantaneously to control for changed charge-discharge. ES can respond much faster than any conventional resource, and some ES technologies can do operate for thousands of duty cycles. This makes ES attractive for high cycling/low duration service such as frequency regulation and balancing energy.

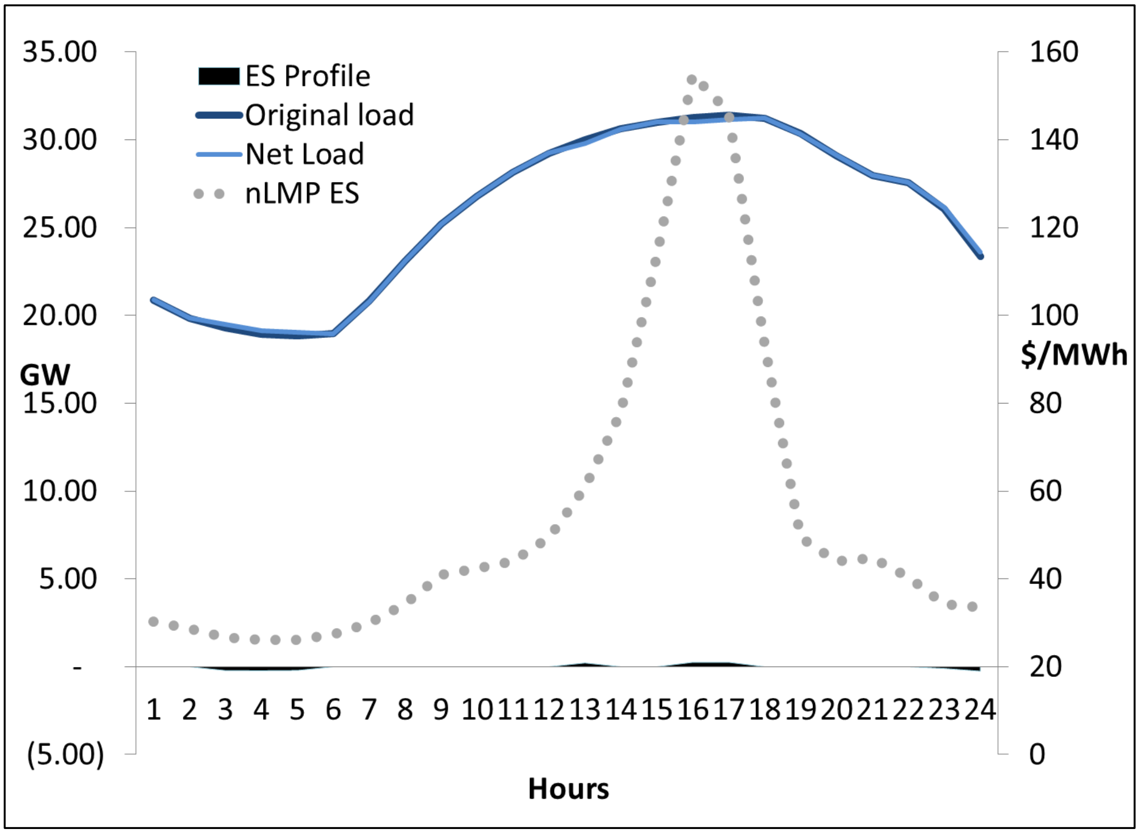
ES is competitive today as a provider of frequency regulation and energy services in wholesale markets. ES, when combined with PV installations, is competitive for demand response. It has the potential to be competitive in providing spinning reserve services if and when inverter-based resources capable of rapid response are allowed to participate in the markets for those services. ES with advanced inverters also has the ability to provide VAR support, voltage control and other ancillary services. If future inertial and governor response were to be become inverter-based products, fast storage is one technology that could economically provide these products. California has gone through extensive evaluation of ES for multiple use cases, which range from wholesale frequency regulation and balancing to supplying end-users. These cases specifically include deferral of investments in distribution infrastructure and smoothing supply from PV.

Current trends indicate that ES systems (stand-alone or coupled with PV) are not being used to their full potential in New York State or elsewhere. ES is primarily being installed in the commercial sector to enable retail customers to manage their electric bills and as power backup for reliability purposes. In terms of controlling electric bills, customers in regions with high demand charges can use ES to shave their peak load and/or shift their use from peak to off-peak hours to take advantage of time-of-use (TOU) rates.

Platform Market Scenario

While ES has the potential to provide various electric products and services, this scenario, consistent basis with the other scenarios, explores potential transactions and revenue associated with ES providing real energy. Under this scenario, the Platform Market enables buyers to acquire energy from behind-the-meter ES installations to achieve 0.47 GW of peak reduction across the State in 2020. Figure 16 illustrates the daily profiles of load, ES charge/discharge, and nLMP for peak summer day (July 2).

Figure 16. Daily Load, ES and nLMP Profiles for Peak Summer Day (July 2)



The Platform Market enables buyers to acquire this level of energy from ES in several ways:

- Provides ES access to a large market for its various products. As noted, ES has the potential to be a competitive source of several services - balancing energy service, frequency regulation, demand-response VAR support, voltage control and other ancillary services.
- Reduces the cost of selling and buying those products by minimizing the associated "transaction costs," as described in the preceding scenarios.
- Supports market transparency, as described in the preceding scenarios.

Potential Annual Transactions and Platform Revenue in 2020

The scenario assumes that all ES discharge is sold as an energy product transacted over the Platform and paid the statewide nLMP, and all energy required to charge ES is purchased through the Platform. The scenario assumes sellers pay a Platform fee equal to 5% of the value of the transactions.

Table 19 reports the potential annual transactions and associated estimate of Platform revenue. This estimate is an upper bound for these assumptions in 2020 because it assumes all of the energy discharged and for charging is bought as an energy product. As with the preceding scenarios, the quantity that will actually sell as energy via the Platform will be influenced by the opportunities available to sell other ES products, and the compensation for those other ES products. Owners of ES will optimize the usage of their asset against value they get from transactions via Platform versus financial and reliability benefits they acquire from other applications.

Table 19. Maximum Platform Revenue Assuming 100% Market Participation

Resource Focus	Potential Annual Transaction (MWh)	Potential Annual Revenue
0.47 GW of ES	522,222	$ 1.15 million

C. Chapter 5 Summary

Chapter 5 illustrates the value provided by creating a Platform Market. The qualitative scenarios describe the value of a Platform Market to various DER technologies. The quantitative analysis provides an estimate of the value of moving to more granular locational pricing under a Platform Market.

APPENDICES

White Paper on Developing Competitive Electricity Markets and Pricing Structures

Prepared for:

New York State Energy Research and Development Authority (NYSERDA)

and

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April 2016

NYSERDA Contract: 64271

LIST OF APPENDICES

Appendix A. DLMP and eLMP Product Features and Forward Commitment Features

This appendix summarizes the electrical products essential for efficient power system operation and their attributes in an eLMP and DLMP market design. We classify these electricity products as belonging to one of three categories:

- *Real Energy:* Active power (P) or the portion of the AC waveform that results in a directional transfer of energy, measured in watts (W) of power or kilowatt-hours (kWh) of energy.
- *Reactive Power (Q):* The portion of the AC waveform resulting from a time separation or phase angle between voltage and current resulting from Capacitance and / or Inductive elements in the circuit, measured in volt-amperes reactive (VAR). Providing Reactive Power can have direct costs as well as opportunity costs as a result of a resource being limited in its ability to simultaneously provide Real Energy.
- *Reserves:* Reserves represent the ability and a forward commitment to provide or change the supply or consumption of real energy or reactive power when called upon under specified terms and performance conditions. Buyers may acquire reserves to be able to respond to shortages or contingencies as well as to have the flexibility to adjust output up or down at a specified ramp rate. Reserves, broadly classified, may include Frequency Control (primary reserves) that today is provided by governors or Automatic Generation Control (AGC) on conventional generating units, Regulation Services (secondary reserves), and Operating Reserves (tertiary reserves). Each reserve product specifies a time within which the resource must respond and a rate at which the resource's output or demand must change. Providing Reserves can have direct costs and opportunity costs.

Within these categories, we can distinguish and define different electrical products by their operational characteristics and by the markets in which they operate. Those characteristics and markets include:

- *Qualifying Resources:* Product qualifications may be set based on the ability of specific technologies to provide the product and by market rules or tariffs.
- *Product Components:* Price components are the elements and features of the product that fix or contribute to variations in prices. For example, LMP may include the marginal cost of energy, the impacts of network congestion, and marginal losses.
- *Product Location:* This is the delivery location for products. It identifies the geographic granularity of the product market. Locations may be region-, zone- or utility-wide; at an aggregated pricing node or trading hub; or as specific as the meter at customer or resource site.
- *Product Period:* The product period refers to the time period for which the product may be transacted and prices are determined. It identifies the time granularity of the product market. For energy products, this might be a five-minute interval. However, forward capacity products can be traded on a monthly, seasonal, or annual basis.
- *Reserve Response or Ramp Rate (Rate of Change in Output or Usage*): Reserves are required to change their output or usage at a specific rate commonly specified the movement of output or

demand per second over a specified period. The required change in output or demand may be specified as a percentage of the called upon Reserve quantity. Additionally, some reserve products include a maximum quantity that or duration for which the reserve product can be purchased from any given resource. These are products designed to facilitate market participation by storage technologies and flexible demand. For example, a battery could provide Regulation Services, but would be able to do only for a limited period of time.

Electrical products offered or transacted on a forward basis often have additional characteristics, including:

- *Forward Commitment:* A forward commitment is as agreement to provide a quantity of a specific product, in a specified period, when specified conditions are realized, and a dispatch signal or notice is issued or to purchase or use a quantity of a specific product in a specified period. Forward commitments may be physical with penalties for a failure to perform or financial when the obligation may be settled financially or covered by an offsetting transaction in a market that clears at a later point in time.
- *Resource Qualifications:* A resource wishing to commit to, and receive compensation in, a forward market may have to meet and maintain specified physical, deliverability, measurement, testing, or other qualifications.
- *Performance Conditions:* Performance conditions specify the conditions under which a resource may become obligated to perform. For example, a contract may have a provision excusing a generator from performance during an approved maintenance outage. Performance conditions may include a dispatch signal or a call on the resource to perform issued in accordance with any advance notice specifications.
- *Performance Requirements:* Products will include specific definitions of expected performance. Performance may be specified as the provision of a quantity of power; in the case of reserves, as both being available and changing output or usage at a specified ramp rate; or in a capacity market, submitting offers in a day-ahead energy market and generation or demand reductions when clearing in that market.
- *Consequences of Non-Performance:* Resources that make physical commitments, clear in the forward market, and fail to perform when called upon may face consequences beyond the financial settlement of the transaction. In such instances, the resource provider may be liable for penalties, liquidated damages, reductions in or disqualifications from their future market participation, or other consequences.

Providing a commitment from demand response or energy efficiency resource can raise additional issues. Conventional demand response and efficiency resources are synthetic resources in that a buyer cannot directly measure the reduction in demand or energy consumption. These resources may be compensated based on an estimated change in demand from what otherwise would have occurred. It is, of course, not possible to directly measure the counter factual: the demand or energy use that would have occurred in the absence of the demand response or efficiency resource. Instead, buyers infer these impacts from measurement and verification procedures or a specified baseline level of consumption that is computed based on a model or from recent usage during a comparable period. In such cases, a demand response or energy efficiency resource would have the additional attribute of:

- *A Measurement and Verification and / or a Baseline Estimation Procedure:* One would use these procedures to calculate a reduction demand or energy that may be used in planning, compliance, or resource compensation.

Not all demand and efficiency related resource definitions require a Measurement and Verification or Baseline Estimation Procedures to participate in markets. For example, a customer that reduces their demand or energy use will automatically benefit by avoiding payments for demand and energy not consumed. Moreover, it is possible to structure a forward demand commitment as a not to be exceeded level of demand, in which instance compliance with the demand ceiling can be observed directly.

Electrical product attributes in an eLMP and DLMP market design.

Product Features: General							
Product	**Qualifying DER**	**Potential Net Sellers**	**Potential Purchasers**	**Product Components**	**Product Location**	**Product Period**	**Ramp Rate**
DLMP Real-Time Real Energy	Responsive Demand, Generation, Storage	ISO Resources, Aggregators, Distributed Generation & Storage, Financial Participants	ESCOs, Default Suppliers, Financial Participants, Consumers	Energy + Distribution Congestion and Marginal Losses	Transformer or Meter in Distribution System	5 minute	NA
DLMP Day-Ahead Real Energy	Responsive Demand, Generation, Storage	ISO Resources, Aggregators, Distributed Generation & Storage, Financial Participants	ESCOs, Default Suppliers, Financial Participants, Consumers	Energy + Distribution Congestion and Marginal Losses	Transformer or Meter in Distribution System	Hourly: NYISO Hourly Day-Ahead Price + Distribution Components	NA
ELMP Real-Time Real Energy	Responsive Demand, Generation, Storage	ISO Resources, Aggregators, Distributed Generation & Storage, Financial Participants	ESCOs, Default Suppliers, Financial Participants, Consumers	NYISO LMP at Extended NYISO Pricing Nodes	500+ to 2,200+ Extended NYISO Pricing Nodes	5 minute	NA
ELMP Day-Ahead Real Energy	Responsive Demand, NYISO Day Ahead DR, Generation, Storage	ISO Resources, Aggregators, Distributed Generation & Storage, Financial Participants	ESCOs, Default Suppliers, Financial Participants, Consumers	NYISO LMP at Extended NYISO Pricing Nodes	500 + to 2,200+ Extended NYISO Pricing Nodes	Hourly	NA
Distribution System Reactive Power	Distribution Equipment & Generators capable of providing & absorbing Reactive Power, Smart Inverters, Advanced Power Electronics	Distribution Utility, Distributed Generation and Storage with Smart Inverters or Advanced Power Electronics	Distribution Utility	Reactive Power and Dynamic Voltage Control	Co-Optimized with Energy at Distribution Locations	TBD: Reactive Power Targets may be set by Interval with Control implemented on a Sub-cycle basis	TBD
Frequency Responsive Reserves	Generators & Loads that Respond Autonomously	Generators and Loads with advanced autonomous controls	Distribution Utility	Capability + Response Threshold & Characteristics	Co-Optimized with Energy at Distribution Location	Response measured in rate per second	Percent per second for 30 seconds
Regulation Reserves (A)	Generation	To NYISO: Generators, DG Aggregators; To Distribution Utility: Aggregators + Distributed Generators	Distribution Utility, NYISO	Capacity + Ramp	Co-Optimized with Energy at Distribution Location	Response measured in rate per second	Percent per second for up to 5 minutes

Product Features: General

Product	Qualifying DER	Potential Net Sellers	Potential Purchasers	Product Components	Product Location	Product Period	Ramp Rate
Limited Regulation Reserves (B)	Demand Response, Storage	To NYISO: DR & Storage Aggregators; To Distribution Utility: Aggregators + ESCOs, Default Suppliers, & Consumers providing DR; & Distributed Storage	Distribution Utility, NYISO	Capacity + Ramp	Co-Optimized with Energy at Distribution Location	Response measured in rate per second	Percent per second for up to 5 minutes, with limited quantity or duration and requiring a balanced response
Localized Distribution Contingency Operating Reserves	Generation, Storage, Demand Response	Distributed Generators & Storage; Aggregators; & ESCOs, Default Suppliers, & Consumers providing DR	Distribution Utility	Capacity + Ramp	Co-Optimized with Energy at Distribution Location	Response measured in rate per second	Percent per second for up to 10 minutes or up to 30 minutes
Localized Distribution Supplemental Operating Reserves	Generation, Storage, Demand Response	Distributed Generators & Storage; Aggregators; ESCOs, Default Suppliers & Consumers providing DR	Distribution Utility	Capacity + Ability to provide Contingency Reserves	Co-Optimized with Energy at Distribution Location	Based upon need to replace Contingency Reserves when they are called	Contingency Reserves Replaced within a TBD period, no more than 105 minutes after a disturbance

Product Features: Forward Commitments

Product	Forward Commitment	Resource Qualifications	Performance Conditions	Performance Requirements	Non-Performance Consequence	M &V / Baseline Estimation
DLMP Real-Time Real Energy	NA	NA	NA	NA	NA	NA, responsive demand settles at a market price
DLMP Day-Ahead Real Energy	Non-binding, imbalances settle at real-time price	NA	NA	NA	Imbalances Settle at Real-time Price	NA, responsive demand settles at a market price
ELMP Real-Time Real Energy	NA	NA	NA	NA	NA	NA, responsive demand settles at a market price
ELMP Day-Ahead Real Energy	Non-binding, imbalances settle at real-time price, except in NYISO DA DR program	NA, except for registration requirements and size limitations in NYISO Day Ahead DR Program	NA, except NYISO Day Ahead DR must clear in NYISO Day Ahead Market	NA, except NYISO Day Ahead DR obligated to curtail if clears in Day Ahead Market	Imbalances Settle at Real-time Price, except NYISO DA DR non-performance settles at higher of Day Ahead or Real-time Price	NA (responsive demand settles at a market price), except for NYISO Day Ahead DR with baseline based on 5 highest loads in prior period
Distribution System Reactive Power	TBD	TBD	TBD	VAR support, Voltage Equalization across Circuit	TBD	NA
Frequency Responsive Reserves	Yes	Physical deliverability, Bidirectional Responses	TBD	Frequency Stabilization	TBD	For load: Measured rate of change in net energy usage
Regulation Reserves (A)	Yes	Physical deliverability, Bidirectional Responses	TBD	Speed & Accuracy in following Regulation Signal	TBD	NA
Limited Regulation Reserves (B)	Yes	Physical deliverability, Bidirectional Responses	TBD	Speed & Accuracy in following Regulation Signal	TBD	For Demand Response: Measured rate of change in net energy usage; for Storage: NA
Localized Distribution Contingency Operating Reserves	Yes	Physical deliverability and response	TBD	Timely ramping & delivered energy	TBD	For Demand Response: Measured rate of change in net energy usage; for Generation: NA
Localized Distribution Supplemental Operating Reserves	Yes	Same as for Contingency Reserves	TBD	Ability to Provide Contingency Reserves	TBD	Same as for Contingency Reserves

Appendix B. Quantitative Scenarios

Input Discussion

Our simulations use a network topology based on Feeder 9 of the Pacific Northwest National Laboratory (PNNL) prototypical feeders. This feeder is appropriate for upstate New York State, as it is a suburban feeder in the cold-climate zone. The simulation models this feeder with 800 distribution nodes.

We present results for two days, a summer peak day and a winter peak day, under four market structures for each day: business as usual (average cost), LMP trajectory with a single bus approximation of the network, LMP trajectory with a 17-node approximation/aggregation of the network, and Full DLMP with complete 800-node network representation. The majority of the load that we model is inflexible, i.e. price-unresponsive for real energy consumption with an associated reactive power consumption corresponding to a fixed power factor. We model Low and High Distributed Energy Resource (DER) penetration scenarios. DERs include rooftop PV, EVs, and Smart Thermostat electric space conditioning with price-responsive demand (DR) at selected commercial nodes.

For the summer peak day, we use Albany-area LMP values and hourly PV output profiles of 07/02/2014, as found in NYISO data.[1] For the winter peak day, we use Albany-area LMP values and PV shapes of 12/28/2014, as found in NYISO data. For both days, we develop the peak real energy load at each demand point (inflexible loads) from the PNNL load values with adjustments to avoid severe overloading of the corresponding transformer rated capacity. We also use typical hourly shapes for commercial and residential loads. These loads are inflexible, i.e. not price-responsive, and are assumed to consume reactive power according to a fixed power factor based on PNNL reported data for Feeder 9.

With respect to the distributed resources, we model:

(i) Non-dispatchable resources in the form of photovoltaics, whose real energy output is non-dispatchable but whose inverters can be put into dual use[2] to provide reactive power compensation and voltage control when their capacity is not fully used to invert DC produced by the PV panels to AC that can be fed into the grid,

(ii) Dispatchable or storage-like resources in the form of electric vehicles that may use their chargers to store energy in the EV battery. When the charger capacity is not fully utilized for EV charging it is available for use as a volt/VAR control device[3] to provide reactive power compensation and voltage control in a manner similar to that of a PV inverters,

(iii) Smart thermostat electric space conditioning appliances that can respond to LMPs or DLMPs and exploit allowable preheating or precooling to minimize their electricity consumption.

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[1] Because of unusual recorded temperature behavior, we have modeled the temperature of July 1, 2014.

[2] This dual use must conform to capacity constraints and the availability of a DC bus from which the inverter operates and is subject to conversion losses. As a result the reactive power compensation at night or when the sun is unavailable may require a small battery and a capacitor that provide the DC bus during the sun-less hours.

[3] This is subject to real DC power losses accompanying the production of AC reactive power operating from the DC bus of the battery.

Our simulations reflect a future network configuration, around 2030, with increased penetration of distributed resources. The Low DER penetration ("Low DER") scenario represents a future with slow growth in PV, EV and flexible load in commercial buildings. The High DER penetration ("High DER") scenario models a greater penetration of those DER technologies.

Photovoltaics (PV) are located at both residential and commercial nodes under the High and Low DER scenarios. We model a variety of PV installations, with capacity ranging from 500kVA in the commercial nodes to 4kVA in residential nodes. Under the High DER scenario, total installed capacity of PVs is 3.4 MW, which is about 30% of total peak real energy demand in 2030. Under the Low DER scenario, total PV is 132 kW. All PVs are assumed to have smart inverters, thus are able to provide reactive power and voltage support using their excess capacity to the extent this is desirable as indicated by marginal costs.

We assume electric vehicles (EV) only at residential nodes locations under the High and Low DER scenarios, 150 and 6 respectively. Each EV battery is assumed to have 24kWh in real energy demand to reach a full state of charge. Under that assumption, the total real energy demand increase that the penetration of EVs causes under the High DER scenario is about 30% of the peak hourly demand for the whole day. However, given that the charging rate capacity per EV is 3.3kW, the maximal impact on the demand of a given hour is 3.3*150/12000=4.1% of the peak hour real energy demand of the inflexible loads. As with the PV inverters, in the full DLMP scenario, EVs can put the excess capacity of their charger power electronics to dual use to provide reactive power and voltage support to the extent this is economically desirable as indicated by marginal costs.

We place electric space conditioning (heating in winter, cooling in summer) at 25 commercial nodes. We calibrate the size of the electrically space-conditioned buildings so that for typical building properties (heat storage and heat loss coefficients), they require, over 24 hours, energy that corresponds to 20% of the daily inflexible demand under the High DER scenario and 10% under the Low DER scenario. We assume that space conditioning appliances are equipped with smart thermostats that detect inside and outside temperature and provide electric heating or cooling sufficient to maintain, during business hours, a user-set minimum temperature in winter and a maximum-set temperature in summer (we allow these set temperatures to be relaxed during non-business hours.) The smart thermostats are able to also engage in pre-heating (in winter) and pre-cooling (in summer) to exploit natural building heat storage and minimize the cost of maintaining e desired temperature levels.

With these inputs, we model four market structures:

i. An average and time-invariant *average price* market structure, representing BAU. Under this market structure, DERs have no incentive to consume, except in an opportunistic fashion (no preheating or precooling), EV charging at full charging capacity once an EV plugs in until a full state of charge is achieved, and, of course, no proper information for reactive power compensation;

ii. A single location/single node power-market structure, where the distributed resources respond only to the LMP of real energy at the substation node to which their feeder is connected. Reactive power compensation is not offered under this market structure since it would be somewhat arbitrary without locational signals;

iii. An intermediate market structure, where the distributed resources respond to 17 aggregated location/zone DLMPs of real energy only. We calculate the aggregated DLMPs at aggregated zones/nodes close to, but not coincident with, the distribution substation. Reactive power compensation is also not considered under this market structure for similar reasons as above; and finally,

iv. A full, marginal-cost-based full network topology market cleared by the DMC model, that discovers real and reactive power Distribution Locational Marginal Prices (DLMPs) and schedules real and reactive power DER transactions

Note that under market structures (i.), (ii.) and (iii.), DERs contribute no reactive power due to the lack of location-specific information.

Under the full DLMP market structure (iv), DER consumption behavior and DLMPs are mutually adaptive, hence socially optimal marginal-cost- based prices for real and reactive power are discovered. The model calculates the reactive power marginal cost at the substation as an opportunity cost, as described later. The model uses these real and reactive power DLMPs to estimate:

- The marginal cost of real and reactive power purchased by the substation from the wholesale market, namely the real and reactive power consumed in the distribution feeder by inflexible load net of the real and reactive power produced by distribution network-connected DERs
- The cost of meeting inflexible, price non-responsive, loads and the associated reactive power they consume through their constant power factor
- The income of PVs for Real Energy generated
- The income of PVs for reactive power compensation
- The cost of charging EV batteries
- The income of EVs from reactive power compensation
- The cost of supplying Real Energy to smart thermostat electric space- conditioning appliances
- The rent (or net revenue) of the distribution network construed as purchasing at the substation, paying PV for real and reactive power provided, paying EVs for reactive power provided, and charging inflexible loads for real and reactive power that they consume, and EVs and space- conditioning appliances for the Real Energy they consume.

Under the network aggregation and average price market structures (i.), (ii.) and (iii.), we implement a two- phase approach.

In the first phase, we estimate the Real Energy consumption of EVs and space-conditioning appliances. Whereas under the average cost/price market structure (i.), consumption is opportunistic due to the lack of intertemporal variation, under the aggregated network LMP market structures, (ii.) and (iii.), the forecast LMP trajectory affects the consumption trajectories of EV and space-conditioning. Note that the resulting consumption behavior in the aggregated network market structure, and even more so for the average cost market structure, will be different from the adaptive DER behavior under the full network and DLMP market structure.

In the second phase, we apply the consumption trajectories obtained in the first phase to the full 800-node distribution network. We treat this load as fixed – i.e. as if they are non-adaptive to

DLMPS – and calculate the ex-post locational marginal costs using full network load flow relationships. These marginal costs will differ; in fact, they will be higher than the corresponding marginal costs obtained under adaptive DER behavior. Using these locational marginal costs, we estimate for each market structure:

- The marginal cost of real and reactive power purchased at the substation from the wholesale market, namely the real and reactive power consumed in the distribution feeder by inflexible- load DERs net of the Real Energy produced by distribution network-connected DERs. This cost will be higher relative to market structure (iv.) given the absence of adaptation and reactive power provision by DERs.
- The cost of meeting inflexible, price non-responsive, loads and the associated reactive power they consume through their constant power factor. This cost will, again, be higher since lack of or limited DER adaptation will result in higher marginal costs relative to market structure (iv.).
- The income of PVs for Real Energy generated. This income will be higher relative to market structure (iv.) since marginal costs will be higher in the absence of DER adaptation.
- The cost of Real Energy used in charging EV batteries. Again, this cost will be higher relative to market structure (iv.).
- The cost of supplying Real Energy to smart thermostat electric space-conditioning appliances. Again, this cost will be higher relative to market structure (iv).
- The rent (or net revenue) of the distribution network construed as purchasing at the substation, paying PV for Real Energy provided and charging inflexible loads for the real and reactive power they consume, and EVs and space-conditioning appliances for the Real Energy they consume. Network rent will be higher relative to market structure (iv.), reflecting the suboptimal operation of DERs that renders the distribution network less resilient to load growth and thus commanding a higher rent.

Quantitative results

Chapter 5 of the White Paper presents the key quantitative results. Following are additional general observations.

The DCM model provides us with optimal primal and dual variables, and can therefore calculate the minimum cost of serving the load, optimal DER income, and demand-side payments.

By modeling the four market structures discussed above, we see the increase in the cost of reduced DLMP information and sub-optimal DER consumption scheduling. This cost increases progressively as we move from

- complete locational marginal cost (DLMP) pricing, Market Structure (iv.), to
- aggregated/zonal DLMP pricing, Market Structure (iii.), to
- distribution location insensitive LMPs, Market Structure (i.) to
- daily average cost pricing, Market Structure (i.)

Under the DLMP Market Structure (iv.) we observe that:

- All load is served at an acceptable voltage magnitude (i.e. within standards of quality). This is indicative of distribution network resilience to demand growth ensured by marginal-cost, price- driven demand response.

- Total cost (line losses, asset life loss, wholesale energy) is also reduced under marginal-cost, price-driven demand response.
- Distribution network realizes positive rent under marginal-cost, price-driven demand response.

Departure from marginal cost prices results in a deterioration of performance in all three of the above categories. The actual deterioration of performance increases as DER pricing becomes more distant from the DLMP market structure (iv.).

DistCostMin model

In order to quantitatively assess the benefits of introducing distribution locational marginal pricing (DLMP) in the distribution network, TCR is using the cost minimization model *DistCostMin* (DCM). DCM solves a 24-hour, day-ahead market clearing problem, where the underlying algorithm minimizes the cost of serving load within the modeled distribution network, subject to constraints on AC load flow, DER capacity and voltage magnitude. As such, the model calculates the shadow price – the DLMP – at each node in the system.

The model optimizes the consumption and generation profiles of the distribution resources, given the substation LMP that result in a lower cost relative to the business as usual (BAU) market structure in which energy is priced only from the substation LMP. The DCM model allows for energy to flow between elements of the distribution system and in reverse to the LMP substation. Distributed Energy Resources (DERs) compete with energy from the wholesale system to provide a least-cost supply.

DCM discovers the real and reactive power DLMP relative to a fixed Locational Marginal Price (LMP) at the transmission interface. The model calculations begin from the assumption that the transmission- level market has cleared and that the NYISO has set the Day Ahead (DA) LMP at the relevant nodes for each hour of the next day. As a result, the optimal real and reactive power consumption and generation of the distribution-level locations, that DCM will discover, will not have an effect on the DA LMP. I reality the real and reactive power consumption and generation at distribution-level locations will affect Real Time prices, but the current structure of DistCostMin does not estimate that impact. The model's calculation of cost savings relative to purchasing only at LMP assumes that load serving entities (LSE) commitments to purchase a quantity at DA LMP are less than the LSE actual requirements, and therefore LSE acquisition of energy from DER does not cause LSE to buy less than its DA LMP quantity and incur a penalty for that imbalance

The real- and reactive-power DLMPs demonstrate the variation in DLMP from the substation LMP throughout the distribution network. (The model assumes generation at substation to be a price taker). This variation is a function of distribution-level losses, electrical equipment degradation and distribution network congestion (that is expressed through voltage magnitude constraints).

More specifically, the cost components explicitly included in the objective function of the model are[4]:

- The cost of Real Energy procured at the substation, plus
- The cost of required voltage modulation at the substation as needed to maintain voltage levels throughout the network within acceptable bounds, minus
- The distribution-operator opportunity cost associated with the production of reactive power at the substation, as needed[5], plus
- substation-generator reactive power production fuel costs, plus
- The cost of transformer loss of life, plus
- Distributed generation costs, plus
- EV uncharged battery penalties.

The model minimizes the cost of meeting the objective function described above subject to the following constraints:

- AC load flow relationships
- Real and reactive power injections by loads and generators
- Power conditioning assets accompanying loads such as asynchronous motor HVAC systems, Elevator banks, PV installations and EVs
- Reactive power output of shunt capacitors, which depends on their location voltage
- Voltage magnitude constraints, and
- EV charge-related constraints. Those are intertemporal state-of-charge dynamics, non-negativity of uncharged EV battery and charging-rate constraints. Note that the model can use similarly time- coupled state dynamics to represent other flexible schedulable loads, such as HVAC and duty-cycle appliances.

Following are illustrative examples:

PV Reactive Power Compensation

A Pythagorean Theorem relates PV production of real and reactive power to the capacity of the PV inverter. Consider, for example:

- PV has installed capacity of 6 KW (i.e. max production at noon in summer of 6 KW),
- PV inverter capacity (usually ~10% higher than installed power production capacity) is 6.6 KW or 6.6 KVAR
- During a given hour, there is enough sunlight to produce 5 KW across the PV panels
- During this hour, if we assume for this example that the inverter incurs negligible losses, it can provide **up to** 5 KWH of DC real power. If it decides to sacrifice 1 KWH of real power

---

[4] Load utility, or customer willingness to pay, is not considered, since load can always be served from the wholesale market at LMP.

[5] The opportunity cost of reactive power provided at the substation is the value of lost sales of Real Energy.

and inject into the grid 4 KWH of real power, then it will be able to provide $(5^2-4^2)^{0.5}$=3 KVAR of reactive power compensation. As long as the DLMP of reactive power is larger than 1/3 the DLMP or real power at that location, it is desirable to sacrifice 1 KWH or real power for the production of 3 KVARH of reactive power.

- When the sun is down, the inverter could provide up to 6.6KVARH of reactive power during each sunless hour, but it would need to consume some real power to do so, either from battery storage or from a DC charged capacitor. In this version of the model, we assume that this advanced type of PV inverter will not be available and do not model this type of reactive power compensation from PV installations. In conclusion:

Under market structures (i.), (ii.) and (iii.), PV provides as much Real Energy as the sun allows, but no reactive power compensation as it does not know the real and reactive power DLMP that would allow it to do the optimal trade off as explained above. Under the full DLMP market structure, on the other hand, PV provides real as well as reactive AC power, depending on the ratio of reactive to real DLMP.

EVs provide less reactive power than PVs because:

- EVs plug in for ~ 14 hours.
- EVs split their charger capacity between Real Energy consumption to charge the battery with the Pythagorean Theorem residual used for reactive power compensation.
- Since charging energy requires use of the full charger capacity for almost eight hours, their ability to provide reactive compensation is limited.

This is in contrast to PVs, which have excess inverter capacity for most of the hours that the sun is up. As noted, the DisCostMin model employed is adopting the conservative assumption that PV inverters are not equipped to provide reactive power compensation during the night.

Reactive Power Compensation Opportunity Cost at the Substation

We note that in today's wholesale markets, there are no reactive power LMPs since at the transmission network, reactive power compensation is taken care of through average cost-priced ancillary services, procured by long-term contracts. We thus assign a short-term marginal cost on the basis of the opportunity cost associated with the provision of reactive power compensation through modification of the operation of a centralized generator located at or close to the distribution substation. This model does this as follows:

- We consider a centralized generator, at or close to the substation, with capacity Cg. This generator provides reactive power that reaches the substation to the extent that distributed inverters/capacitors associated with DERs or sizable Distribution Utility-owned shunt capacitors did not meet those requirements.
- We reasonably assume that this generator optimizes the use of its capacity by generating energy and selling it at the substation LMP, or promising reserves and selling them at the substation reserve LMP. (Recall that NYISO co-optimizes energy and reserves in today's wholesale markets).
- When asked to provide Q (h) reactive power during hour h, the generator will have to adjust its provision or Real Energy and or reserves to accommodate the request. The remaining

capacity is $[C^2 – Q(h)^2]^{0.5}$, and hence the request to provide Q (h) kVAR of reactive compensation impacts its ability to sell energy or reserves, incurring a cost. We define this as the opportunity cost. It can yield the marginal opportunity cost by taking derivatives w.r.t. Q (h) etc. Which we use as an estimate of "the reactive power LMP". The simulations assume that the reserves LMP at the substation is approximately equal to the real power LMP.

Model Inputs

As implied by the objective function and constraint description, the model requires inputs that detail the network topology, as well as line characteristics and market participant capabilities and costs. The table below lists the inputs to the model (parameters in the optimization) in further detail.

Model Inputs		**Specified to Hour**	**Specified to Location**	**Input value range**	**Unit of Measurement**
Substation Related Inputs	Locational Marginal Prices at Substation	✓	-	0.0307-0.093	$/kWh
	Substation Generator Capacity	-	-	10000	kVA
Distribution Network Related Inputs	Transformer Rated Capacity	-	✓	9-866	kVA
	Transformer Cost (per hour of economic life)	-	✓	0.57	$/hour
	Line Resistance	-	✓	0-1.139	Ohms
	Line Reactance	-	✓	0-0.6645	Ohms
	Voltage Upper Limit	-	-	+10% of nominal	Volts
	Voltage Lower Limit	-	-	-10% of nominal	Volts
Demand Related Inputs	Peak Real Energy Demand	-	✓	3.8-589	kW
	Peak Reactive Power Demand	-	✓	0.9-365	kVAR
	Hourly Real	✓	-	0-1	-

Model Inputs		Specified to Hour	Specified to Location	Input value range	Unit of Measurement
	Energy Demand as percentage of peak Real Energy demand				
Non-dispatchable Distributed Energy Resource Related Inputs	Non-dispatchable Distributed Energy Resource Capacity	-	✓	4-500	kVA
	Non-dispatchable Distributed Energy Resource Location	-	-	1-800	Node Number
	Non-dispatchable Distributed Energy Resource Hourly Output as a percentage of capacity	✓	-	0-0.9	-
Dispatchable Energy Resource Related Inputs	Dispatchable Distributed Energy Resource Location	-	-	599-800 (residential load nodes)	Node Number
	Dispatchable Distributed Energy Resource Capacity	-	✓	-	kVA
	Electric Vehicle Connection Time	-	✓	6pm	Hour
	Electric Vehicle Departure Time	-	✓	8am	Hour
	Electric Vehicle Battery Capacity	-	✓	24	kWh
	Electric Vehicle Maximum Allowable	-	✓	3.3	kW/h

Model Inputs		Specified to Hour	Specified to Location	Input value range	Unit of Measurement
	Charging Rate				
	Electric Vehicle Charger Capacity	-	✓	6.6	kVA

Model Outputs

The model discovers the unique optimal primal and dual variables. These include, amongst others, the real and reactive power consumed or produced at each point in the network, load flows, as well as the location-specific hourly real and reactive power Distribution Network Locational Marginal Prices. The table below lists the model outputs (variables in the optimization) in further detail.

Model Outputs		Specified to Hour	Specified to Location	Unit of Measurement
Substation Related Outputs	Real Energy Procured at Substation	✓	-	kW
	Reactive Power Procured at Substation	✓	-	kVAR
	Real Energy Cost	✓	-	$
	Reactive Power Opportunity Cost	✓	-	$
	Substation Voltage	✓	-	Volts
Distribution Network Related Outputs	Real Energy Flow on each line and transformer	✓	✓	kW
	Reactive Power Flow on each line and transformer	✓	✓	kVAR
	Transformer Utilization as percentage of rated	✓	✓	-

Model Outputs		Specified to Hour	Specified to Location	Unit of Measurement
	capacity			
	Voltage Magnitude	✓	✓	Volts
Demand Related Outputs	Real Load Met	✓	✓	kW
	Reactive Load Met	✓	✓	kVAR
Non-dispatchable Distributed Energy Resource Related Inputs	Non-dispatchable Distributed Energy Resource Real Energy Output	✓	✓	kW
	Non-dispatchable Distributed Energy Resource Reactive Power Output	✓	✓	kVAR
Dispatchable Energy Resource Related Outputs	Dispatchable Energy Resource Real Energy Output	✓	✓	kW
	Dispatchable Energy Resource Reactive Power Output	✓	✓	kVAR
	Electric Vehicle Uncharged Battery	-	✓	kWh
	Electric Vehicle Penalty for Uncharged Batteries	-	✓	$
Dual Variables	Real Energy Distribution Locational Marginal Price	✓	✓	$/kWh
	Reactive Power Distribution Locational Marginal Price	✓	✓	$/kVAR

Appendix C. DCM Equations

Extending Locational Marginal Cost Pricing to Retail Electricity Markets and Distributed Energy Resources

APPENDIX C

NYSDPS and NYSERDA Discussion
November 18, 2015

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$$\pi^{x}_{n(s)}(t), x \in \{P, Q, R\}$$

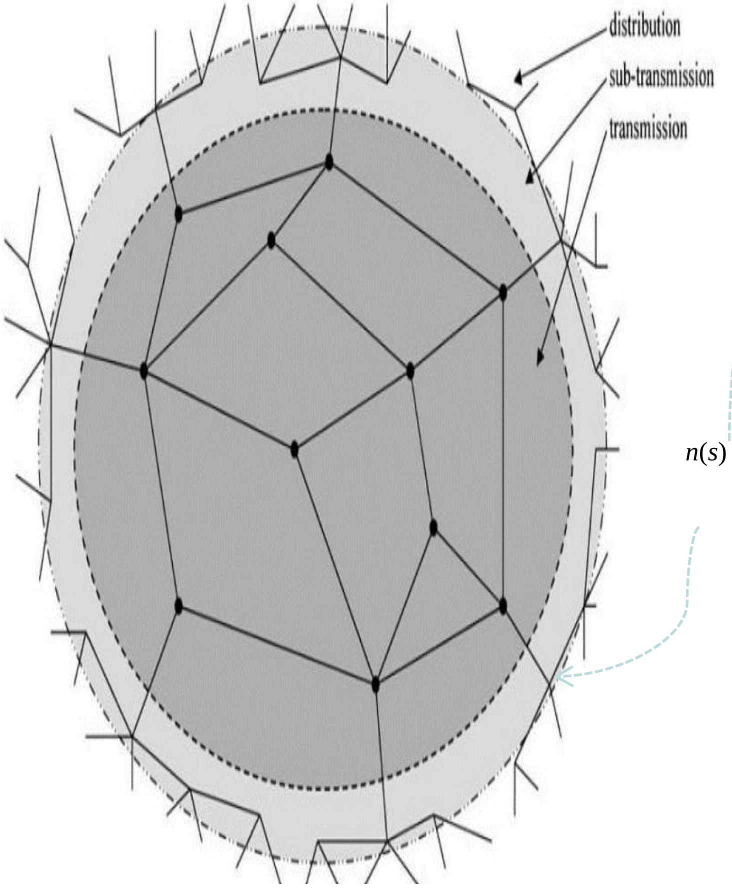
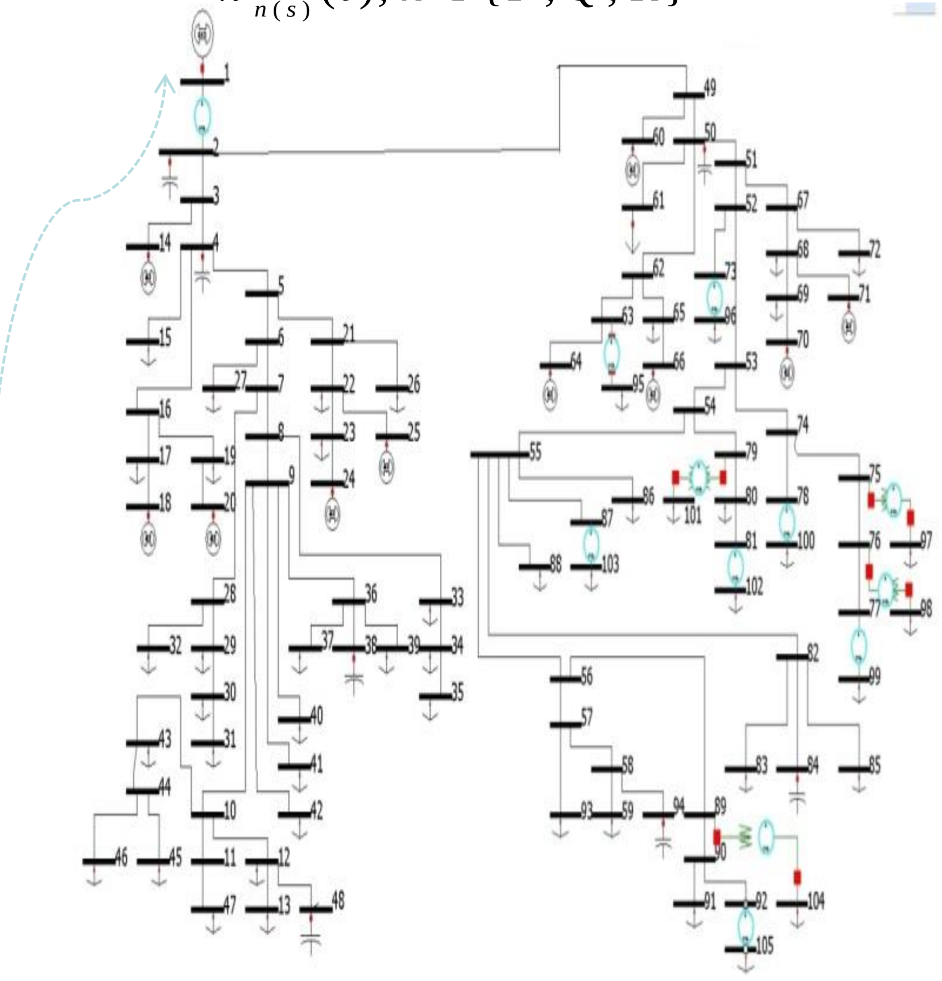


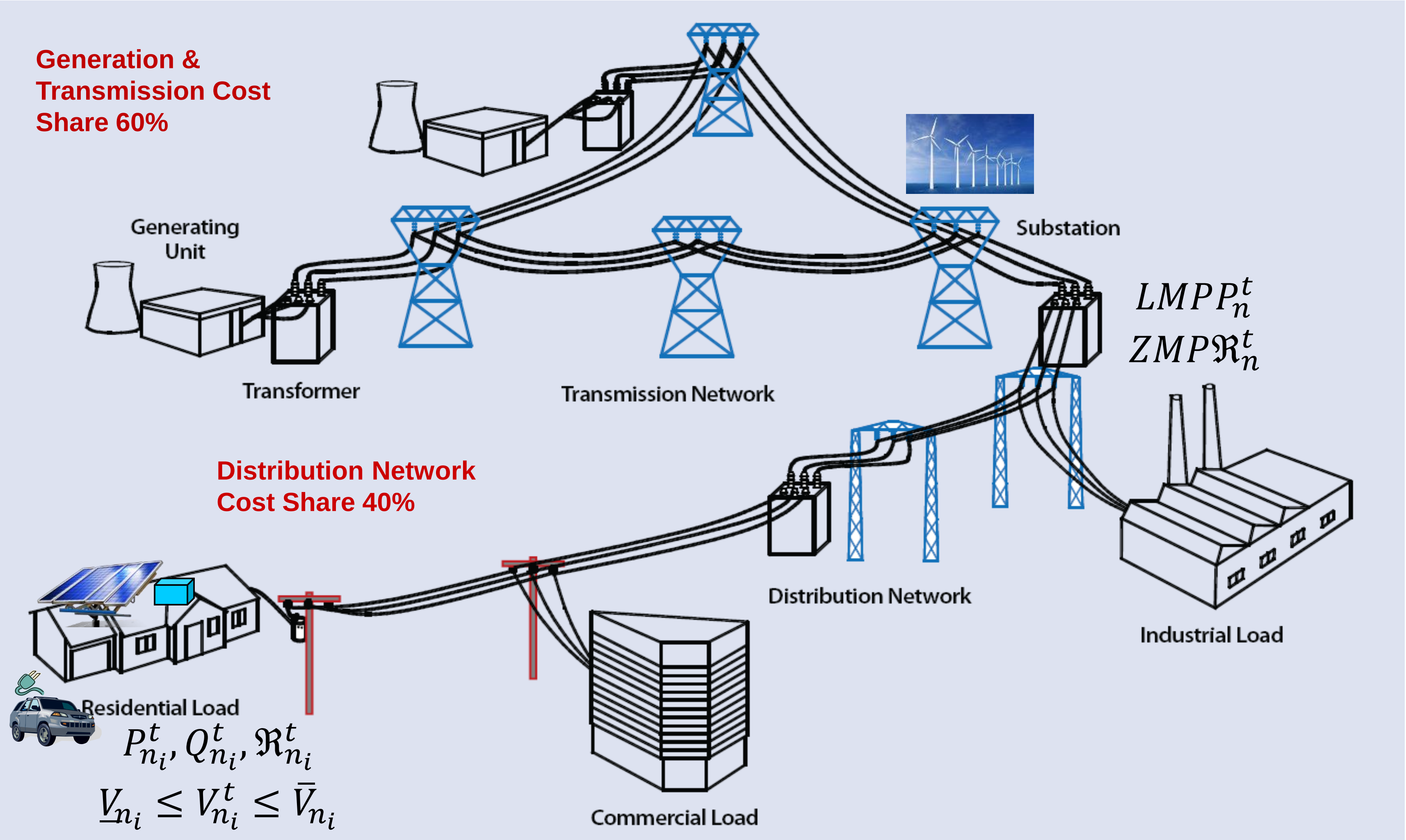
Fig. 1: Tr., Sub-tr, and Distr. Schematic



$$\pi^{P}_{n(b)}(t), \pi^{Q}_{n(b)}(t), \pi^{R}_{n(b)}(t), \mu^{R,i+1}_{n(b)}(t), \mu^{v}_{n(b)}(t)$$

Fig. 2: Distribution Feeder example

Incurred Cost Distribution, Congestion, Reserves, Voltage Control, Losses, Transformers, Deliverability



Generation & Transmission Cost Share 60%

Distribution Network Cost Share 40%

$$LMPP_n^t$$
$$ZMP\Re_n^t$$

$$P_{n_i}^t, Q_{n_i}^t, \Re_{n_i}^t$$
$$\underline{V}_{n_i} \le V_{n_i}^t \le \bar{V}_{n_i}$$

$LMPP_n^t = \Pi_n^{E,t}$ = Locational Marginal Price of Real Power at bus n, during hour t

$ZMP\Re_n^t = \Pi_n^{\Re,t}$ = Locational Zonal Price of Reserves at bus $n \in$ zone Z, during hour t

Interface between Transmission & Distribution

$$R_n \approx \sum_i \{R_{n_i} + 2 r_{n,n_i} P_{n,n_i}\}$$

$$Q_n \approx \sum_i \{Q_{n_i} + x_{n,n_i}[(P_{n,n_i})^2 + (Q_{n,n_i})^2]\}$$

$$P_n \approx \sum_i \{P_{n_i} + r_{n,n_i}[(P_{n,n_i})^2 + (Q_{n,n_i})^2]\}$$

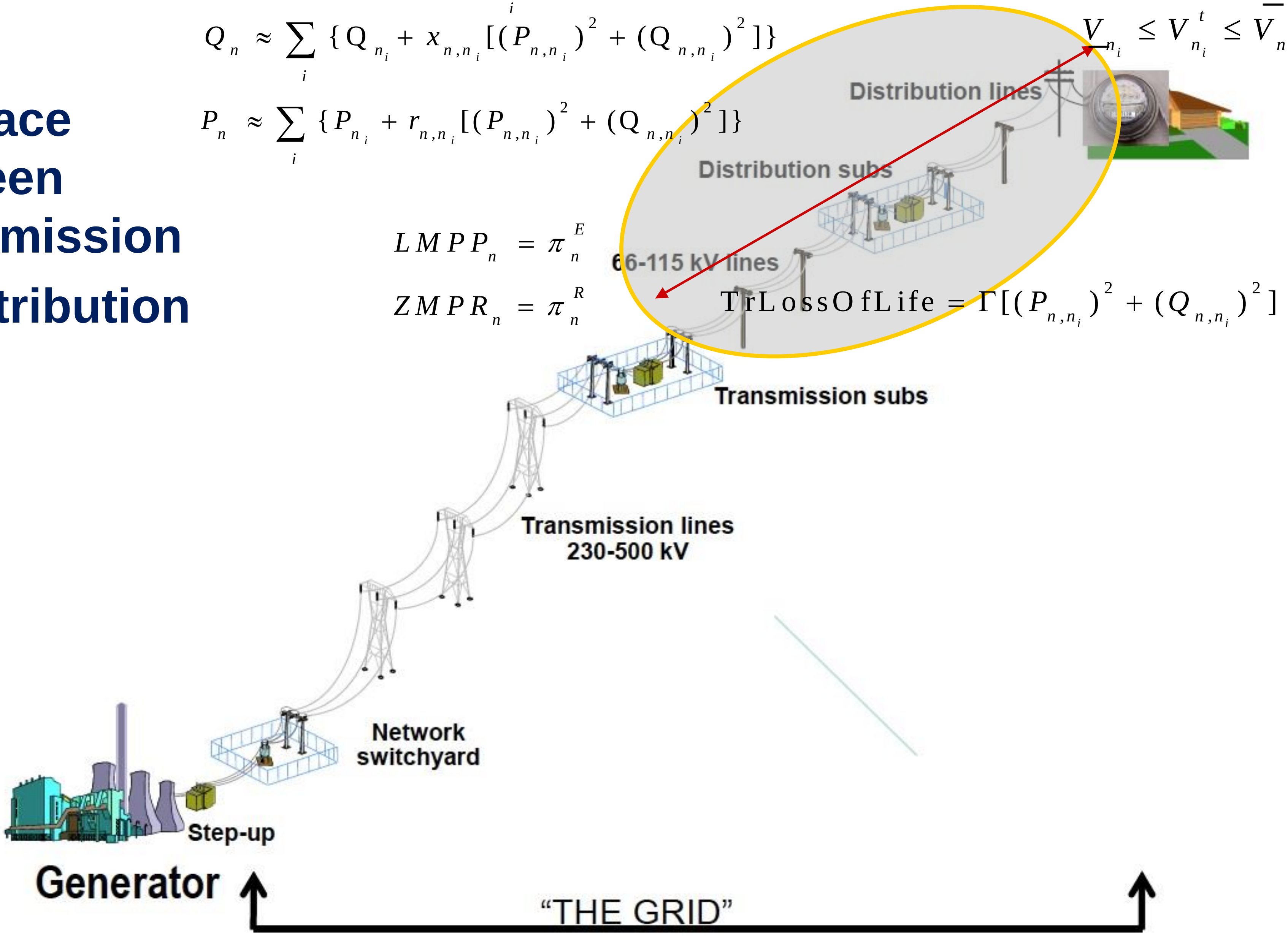
$$P^t_{n_i}, Q^t_{n_i}, R^t_{n_i}$$

$$\underline{V}_{n_i} \le V^t_{n_i} \le \overline{V}_{n_i}$$

$$LMPP_n = \pi^E_n$$

$$ZMPR_n = \pi^R_n$$

$$TrLossOfLife = \Gamma[(P_{n,n_i})^2 + (Q_{n,n_i})^2]$$



Reactive Power Affects All Costs and Voltage magnitudes!

$P_{n_i}, \quad Q_{n_i}$ Real and Reactive Consumption at Distribution Network Location i below Sub-Transmission bus n

$$Q_n \approx \sum_i \{Q_{n_i} + x_{n,n_i}[(P_{n,n_i})^2 + (Q_{n,n_i})^2]\}$$ Reactive Power at Sub

$$P_n \approx \sum_i \{P_{n_i} + r_{n,n_i}[(P_{n,n_i})^2 + (Q_{n,n_i})^2]\}$$ Real Power at Sub

$$\text{Transf Loss Of Life} = \Gamma[(P_{n,n_i})^2 + (Q_{n,n_i})^2]$$

$$\underline{V}_{n_i} \le V_{n_i} \le \overline{V}_{n_i}$$ Voltage Level Control

$$\Delta V^2 \approx (V_n^t)^2 - (V_{n_i}^t)^2 \approx 2(r_{n,n_i} P_{n_i}^t + x_{n,n_i} Q_{n_i}^t)$$

Simulation of Distribution Network Marginal Cost Based Rates

- $\pi_n^x(t)$ □ the Marginal/Incremental cost to the Power System associated with Delivering a unit of Service x to location n at time t. **This results in optimal operating decisions**.
- x in {P, Q, R}
- n ranges over T&D busses. We use

$n = \infty$ to denote substation bus,

$n \in \{b, b', \tilde{b}, \hat{b}, \ldots\}$ for distribution network nodes/busses

Planning to Operation Practices Incorporated in Today’s Wholesale Power Markets are Surprising Useful (and Adaptable?)

- Generation Capacity and Transmission Congestion (FTR) Markets – <u>Years to Months</u>
- Forward Energy Commodity Markets – <u>Months</u>
- Energy and Reserve Co-Clearing Markets:
  - Day Ahead: Multiple <u>Hours</u>
  - Hour Ahead/Adjustment Market – <u>Hour</u>
- Reserve Deployment Dynamics:
  - Operating: 5 min.,
  - Regulation Service (AGC Centralized): 2-4 sec
  - Frequency Control (Decentralized): Real-Time

LMPs : Wholesale – High Voltage -- Market Clearing (DC approximation)

$$\min_{P_n^j, R_n^j} \sum_{j,n,t} u_n^j P_n^j(t) + \sum_{j,n,t} \bar{J}_n^j(R_n^j(t))$$

subject to

$$\sum_{j,n,t} P_n^j(t) + Losses = 0 \quad \rightarrow \lambda(t); \quad \forall t \quad P_n^{j\in \text{gen}}(t) \ge 0,\ P_n^{j\in \text{dem}}(t) \le 0$$

$$\sum_{j,n\in Z,t} R_n^j(t) \ge \Re_Z \quad \rightarrow \pi_Z^R(t); \quad \forall t$$

$$\bar{P}_{n,n'}(t) \le P_{n,n'}^{\text{lin gap}}(t) + \sum_{\hat{n}} P_{\hat{n}}(t)\,\text{ShF}_{n,n'}^{\hat{n}}(t) \le \bar{P}_{n,n'}(t) \rightarrow \underline{\mu}_{n,n'}(t), \bar{\mu}_{n,n'}(t); \ \forall t$$

$P_n(t) = \sum_j P_n^j(t);$ plus capacity constraints

$$\text{ShF}_{n,n'}^{\hat{n}}(t) \equiv \frac{\partial P_{n,n'}}{\partial P_{\hat{n}}}$$ the line flow shift factor -- linearization -- at t

LMP price Relations

$$\pi^{P}_{\hat{n}}(t) = \lambda(t)\left(1 + \frac{\partial Losses}{\partial P_{\tilde{g}(\hat{n})}}\right) + \boxed{\sum_{n,n'} \mu_{n,n'}(t) P_{n}(t) \mathrm{ShF}^{\hat{n}}_{n,n'}(t)}$$

$$\text{where } \mu_{n,n'}(t) \equiv [\bar{\mu}_{n,n'}(t) - \underline{\mu}_{n,n'}(t)]$$

$$\pi^{R}_{\hat{n}}(t) = \pi^{R}_{Z}(t) = \max_{j,\hat{n}\in Z, R^{j}_{\hat{n}}>0} [|\pi^{P}_{\hat{n}}(t) - u^{j}_{\hat{n}}| + \partial \bar{J}^{j}_{\hat{n}}(R^{j}_{\hat{n}}) / \partial R^{j}_{\hat{n}}]$$

Proposed Distribution Market Problem formulation:

Minimize Utility Loss, Real and React. Power Cost (incl Losses), Asset Life Loss, and Volt. Control Costr, *s.t.* Load Flow , Capac., Volt. Magnitude Constr.

Minimize

Over DER real, reactive power and reserves and substation voltage V_∞:

Sum over all hours. Note Sum over *t* and (*t*) argument not shown to avoid notational Clutter.

$$\pi_\infty^P P_\infty + \pi_\infty^{OC}\left(C_\infty - \sqrt{C_\infty^2 - Q_\infty^2}\right) + \pi_\infty^R \frac{P_\infty^{R,up} - P_\infty^{R,down}}{2} + c_\infty^v (v_\infty - 1)^2$$

Substation Real P

Opportunity Cost of Q at Substation

Value of Sec. Reserves at Substation

Cost of deviating from Nominal V a substation

$$+\sum_{j,b} u_b^j(X_b^j) + \sum_{j,b} \overline{J}_b^j(R_b^j) + \sum_{b,b' \in tr} \Gamma(S_{b,b'})$$

Utility (- or +) of State X at the end of hour *t*

Expected Average cost of deployment of R_b^j during hour t

Cost of Transf. life loss.

Subject to: constrains shown below

Real Power DLMP Components

Note: Cost of modulating V_∞ modeled approximately and conservatively low

$$\pi_b^P = +\pi_\infty^P \frac{\partial P_\infty}{\partial P_b} + \pi_\infty^{OC} \frac{Q_\infty}{\sqrt{C_\infty^2 - Q_\infty^2}} \frac{\partial Q_\infty}{\partial P_b} +$$

$$\sum_{b'} \mu_{b'} \frac{\partial V_{b'}}{\partial P_b} + \sum_{\hat{b},\hat{b}' \in \{\mathrm{tr}\}} \frac{\partial \Gamma(S_{\hat{b},\hat{b}'})}{\partial P_b} +$$

$$\text{Note:} \qquad \frac{\partial P_\infty}{\partial P_b} = (1 + \frac{\partial \mathrm{TotalPLosses}}{\partial P_b})$$

$$\frac{\partial Q_\infty}{\partial P_b} = \frac{\partial \mathrm{TotalQLosses}}{\partial P_b}$$

Reactive Power DLMP Components

Note: Cost of modulating V_∞ modeled approximately and conservatively low

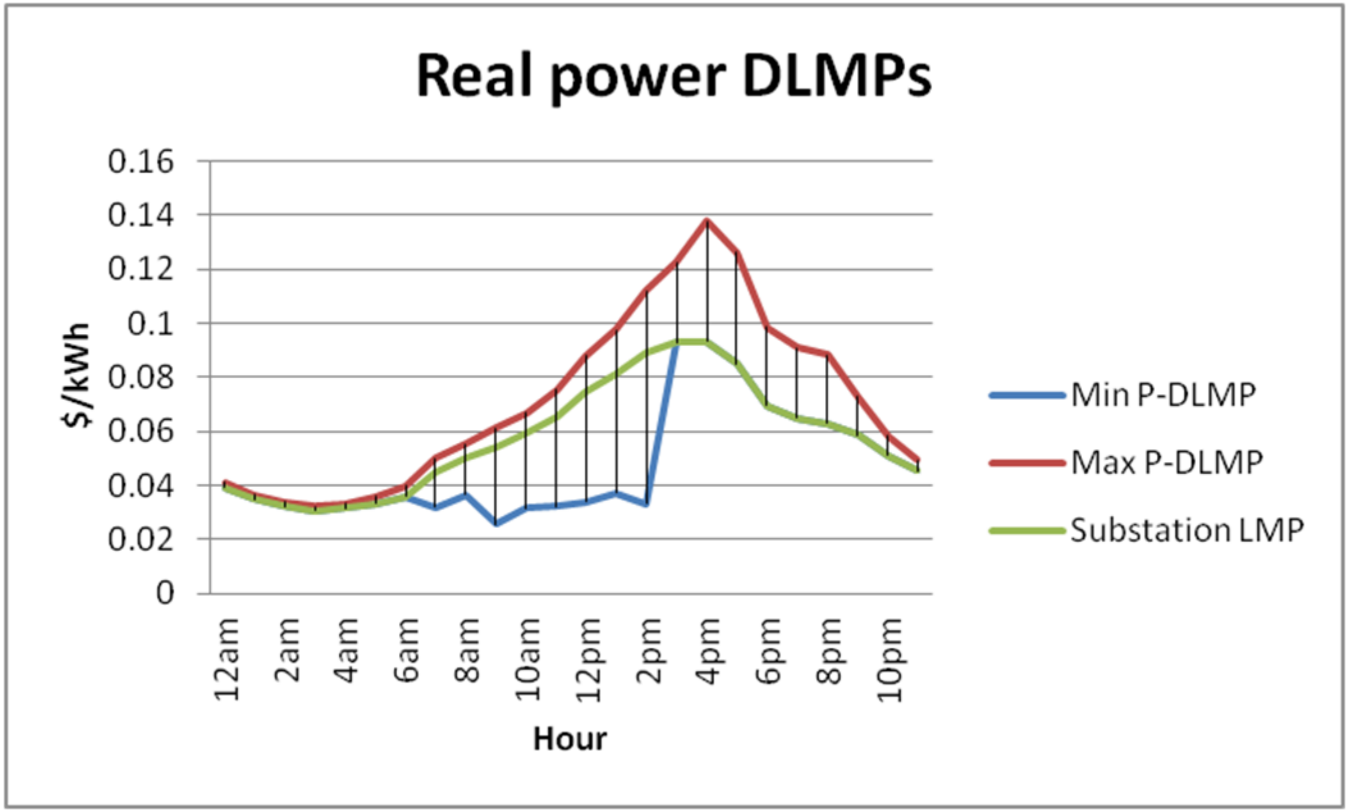
$$\pi_b^Q = \pi_\infty^P \frac{\partial P_\infty}{\partial Q_b} + \pi_\infty^{OC} \frac{Q_\infty}{\sqrt{C_\infty^2 - Q_\infty^2}} \frac{\partial Q_\infty}{\partial Q_b} +$$

$$\sum_{b'} \mu_{b'} \frac{\partial V_{b'}}{\partial Q_b} + \sum_{\hat{b},\hat{b}'\in\{\mathrm{tr}\}} \frac{\partial \Gamma(S_{\hat{b},\hat{b}'})}{\partial Q_b}$$

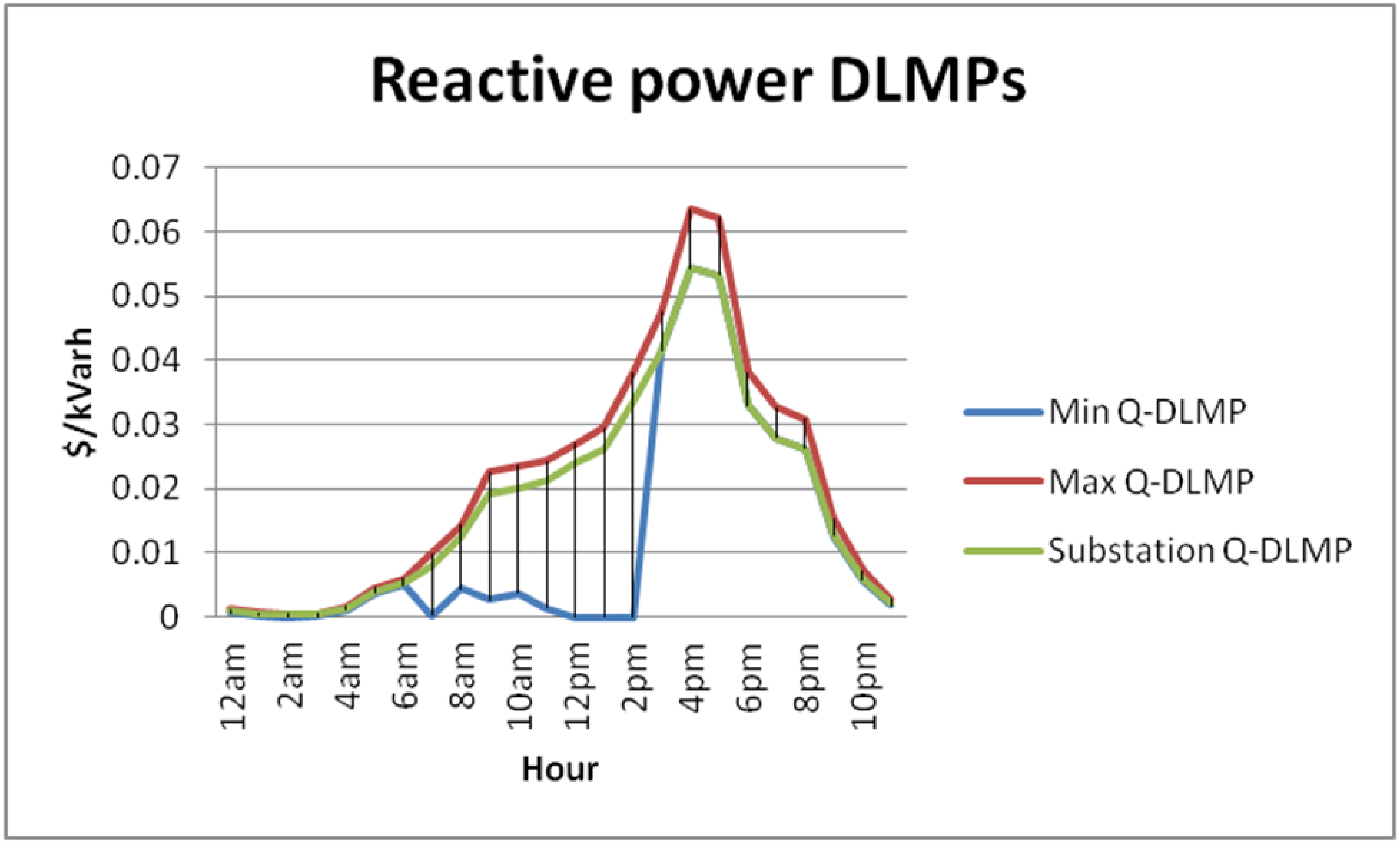
$$\text{Note:} \quad \frac{\partial P_\infty}{\partial Q_b} = \frac{\partial \mathrm{TotalPLosses}}{\partial Q_b}$$

$$\frac{\partial Q_\infty}{\partial Q_b} = (1 + \frac{\partial \mathrm{TotalQLosses}}{\partial Q_b})$$

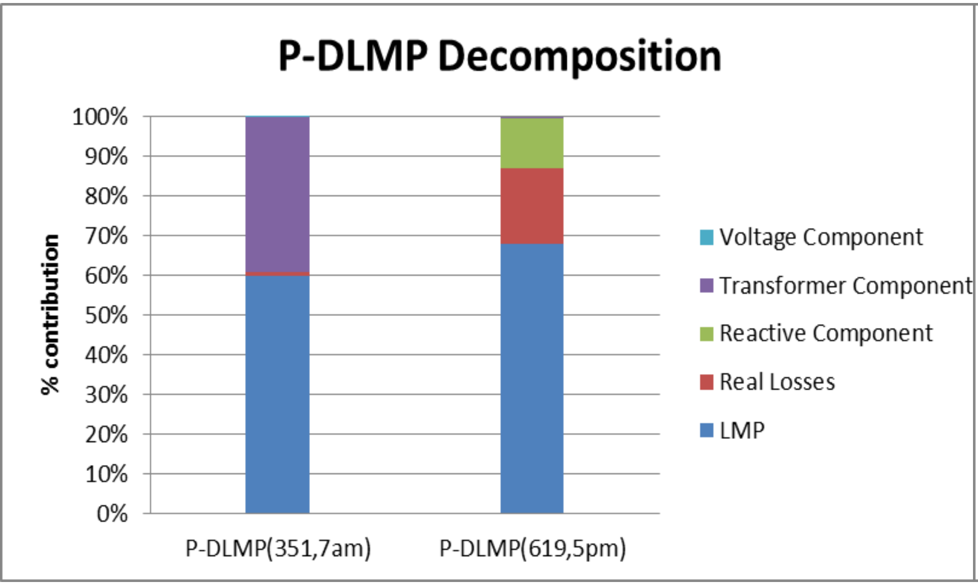
Simulation Results: Summer Peak Day Real DLMP Behavior

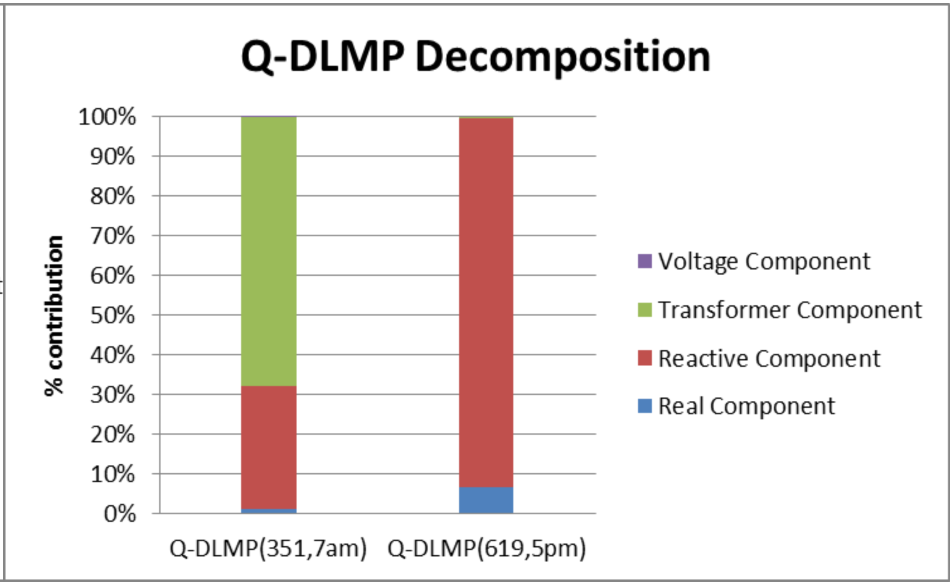


Simulation Results: Summer Peak Day Reactive DLMP Behavior



DLMP Components: Max DLMP/LMP examples



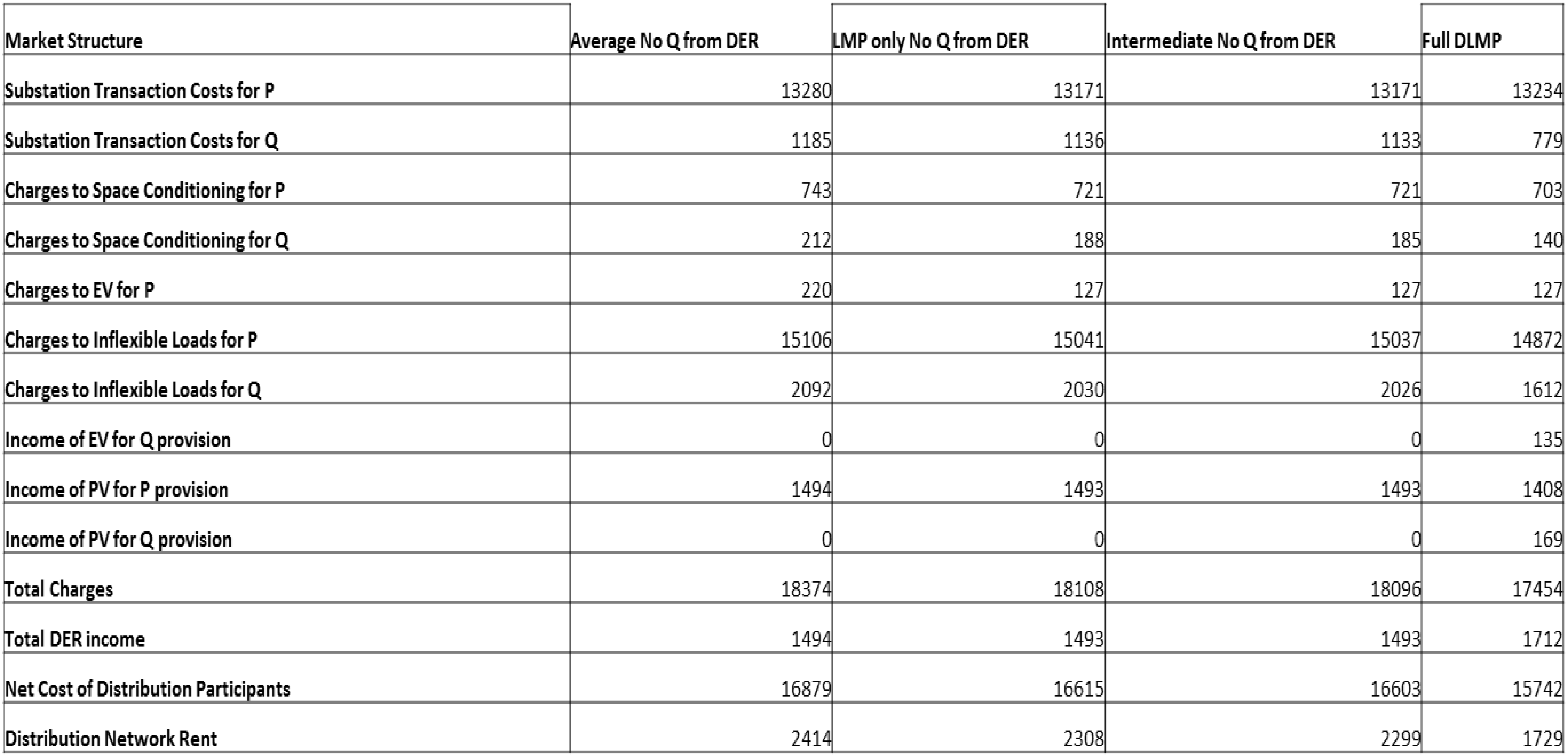


	P-DLMP(351,7am)	P-DLMP(619,5pm)		Q-DLMP(351,7am)	Q-DLMP(619,5pm)
LMP	45.1	85.04	Real Component	0.270599982	4.166960043
Real Losses	0.721599986	23.55608022	Reactive Component	7.859643732	56.97063807
Reactive Component	0.105444136	15.98801817	Transformer Comp.	17.19	0.21
Transformer Comp	29.4	0.459999999	Voltage Component	0.005611093	0
Voltage Component	0.007508159	0	TOTAL	25.32585481	61.34759811
TOTAL	75.33455228	125.0440984			

Example from Summer Peak day demonstrating that DLMPs Provide Locational Incentives and Optimal Reactive Power Compensation (negative Q is possible)

Hour 2pm					
	PV real (% of max allowed)	**PV reactive (% of max allowed)**	**P-DLMP**	**Q-DLMP**	**LMP**
Bus 689, V=1.1! BINDING	100	99.8	33.06	3e-6	89.21
	PV real (% of max allowed)	**PV reactive (% of max allowed)**	**P-DLMP**	**Q-DLMP**	**LMP**
Bus 619, V=0.99, not Binding	100	100	111.89	37.78	89.21

Summer Peak Day Simulation Results: Total Charges/Income/Rent



Market Structure	Average No Q from DER	LMP only No Q from DER	Intermediate No Q from DER	Full DLMP
Substation Transaction Costs for P	13280	13171	13171	13234
Substation Transaction Costs for Q	1185	1136	1133	779
Charges to Space Conditioning for P	743	721	721	703
Charges to Space Conditioning for Q	212	188	185	140
Charges to EV for P	220	127	127	127
Charges to Inflexible Loads for P	15106	15041	15037	14872
Charges to Inflexible Loads for Q	2092	2030	2026	1612
Income of EV for Q provision	0	0	0	135
Income of PV for P provision	1494	1493	1493	1408
Income of PV for Q provision	0	0	0	169
Total Charges	18374	18108	18096	17454
Total DER income	1494	1493	1493	1712
Net Cost of Distribution Participants	16879	16615	16603	15742
Distribution Network Rent	2414	2308	2299	1729

Calculation of *Ex Post* Market Clearing values

- The *Ex Post* calculation of DLMPs is far simpler than the Optimization Problem that is described in equations in this Appendix.
- Calculation of the *Ex Post* DLMP values are based on the fact that all DER consumption decisions (the primal quantities) are fixed to their time period average cost or LMP or intermediate ELMP response level after the fact.
- Given these values a “mock optimization” is run and the marginal cost of the fixed primal quantities is calculated as the dual variables associated with the fixed primal quantities.
- This calculation represents the exact ex post DLMP, i.e., the marginal cost change w.r.t. the relaxation of the fixed primal values.
- -these marginal costs are then used to charge/reward the DERs for over or under supply *Ex Post*

Thank you

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references available upon request

Appendix D. A Day in the Life of a Platform

1. A Day in the Life of a Platform: Initial Market (eLMP)

Assumptions underlying this chronology

- The central element in the Platform is a financial marketplace. It enables/facilitates transactions in electricity and other products and services. Transactions occur on a continuous basis. Trading in core electric products (real and reactive power and reserves) for delivery during specified time periods will have closing times in advance of the delivery period. The Platform also supports and enables the purchase of electricity combined with informational, analytical and forecasting services; financial services; and contracts for other energy-related goods and support services.

- The unit of measure for marginal cost of energy is eLMP[6]. (NYISO calculates eLMPs for real energy at specific load nodes within the state. These are wholesale (transmission level), not distribution-level, prices that can be calculated at roughly 2000 substations in the NYISO network.)

- There is only one statewide digital Platform, and it interacts and exchanges critical information and data with the entities that oversee the physical system.

- NYISO operates the wholesale markets and physical transmission system as it does today. The differences involve changes in NYISO reporting of nodal prices (eLMP) and indicative "look ahead" price forecasts of eLMP. .

- The Distribution Utilities will continue to be the planner and operator of the physical distribution system (wires, transformers, switches, capacitor banks, etc.).

- The Distribution Utility will continue to monitor the topology of, and physical flow on, its distribution system. It will report that information to the Platform in near real time.

- The Distribution Utility as an operator is assumed to provide to the Platform:
    - Requests, specifications, and periodically updated set points for any local distribution system reactive power management capabilities it wishes to procure from DER;
    - Requests and specifications for any location-specific reserves or option contracts it wishes to procure from DER to address local constraints within its distribution system

- ESCOs are market participants that provide energy or offerings including energy and other products and services to end-use consumers. They are financially responsible parties for the acquisition and settlement of energy and other products and services transacted in the market, generally and on the Platform.
    - ESCOs may aggregate the requirements and resources of small consumers and

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[6] eLMP may be adjusted for losses and other marginal costs of delivery if those costs can be calculated by the Distribution Utility.

prosumers (generation and load response) into packages assembled on the Platform and offered to Distribution Utilities or to NYISO or other wholesale market participants.

- Distribution Utilities, as the default suppliers, function similarly to ESCOs as a regulatory requirement. They are subject to regulatory oversight and potentially performance-based incentives.
- Distribution Utilities, as distribution system operators, may contract for and hold as contingencies DER assets within the distribution system, for use in the case of constraints.[7]
- Market participants are ESCOs, Distribution Utilities, non-ESCO aggregators, third- party product and service providers, financial participants, end- use customers participating on their own account, and DERs and prosumers.
- Aggregators are market participants that purchase core electric products at the distribution and/or bulk market level, and bundle them for resale.

Initial Conditions on the Platform

- Because the initial and ultimate market on the Platform will be continuous, some market participants (users) will have standing positions (bids to buy, offers to sell) for standard products for extended time blocks, i.e., directly analogous to the standard transactions that are traded in today's wholesale market that focus on peak and off-peak hourly blocks. Bids to buy and offers to sell include a pricing provision.
- Standard contract terms and conditions (market operation rules) for transactions will be available to market participants.
- The Platform will publish the (transparent) operating mechanisms for market settlement.
- The Platform will have available at all times forecasts of supply and demand at eLMP nodes prepared by NYISO (wholesale) and by third-party suppliers (wholesale and distribution over time). The Platform will also provide indicative forecasts of eLMP, made available by NYISO or provided by third-party suppliers. These forecasts will be dynamic, changing as conditions change and as the clock moves forward.

Prior to the Day Ahead wholesale (ISO) energy market

- ESCOs and Distribution Utilities will forecast their hourly needs for the next day. They will then

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[7] Distribution Utilities may be able to purchase distribution-reactive power management capabilities and location-specific reserves for constraint management from DER, under conditions in which these resources are made available on the Platform.

prepare and bid into the NYISO Day Ahead Market for supplies, as is generally the case today.

- Distribution Utilities providing default supply service to customers on MHP riders will purchase the supply for those customers from the NYISO Day Ahead Market. However, prior to making those purchases, Distribution Utilities will give MHP customers the option to accept or modify their respective supply requirements for the delivery day. MHP customers will do so with knowledge that they either hold long-term positions purchased on the Platform or have the ability to purchase short-term positions both positive and negative from offers that will emerge on the Platform after the close of the NYISO Day Ahead Market.

After the close of the Day Ahead wholesale market and before the close of each real-time (hourly[8]) market on the Platform

- All market participants now have the information on the Platform as to the (hourly) expected value (eLMP) at the measured load nodes (as well as any other day-ahead ancillary services).
- Market participants wishing to create a market position (for instance aggregators, ESCOs and the Distribution Utilities themselves) enter additional bids and offers.
- The Platform continuously matches bilateral bids and offers, providing for continuous price formation at individual load nodes or at aggregations of those nodes.

At the time of closure of the Platform electric product markets

- The Platform will continue to match bids and offers until the close of the time period in which the electric product will be finally "delivered." "Delivery" in this context is purely financial i.e., the market participant that has financially contracted to supply or buy energy is financially obligated to supply or consume against terms of the standard contract. The Platform settles any imbalance between market positions for real energy at market close and actual delivery or consumption at interval NYISO eLMPs.
- The Platform will collect a transaction fee from each seller. The fee will be a percentage of the value of the transactions logged on the Platform by each seller.
- The Distribution Utility will monitor, meter and report to DERs, ESCOs and aggregators their near-real-time supply and demand data. The Platform will clear, ex post, any imbalances between actual consumption and delivery, and contracted purchases and

After the closure of the Platform electric product market

- The Platform will report the eLMP for each monitored and measured load node as provided through the NYISO reporting system.

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[8] "Hourly" is used only to indicate an agreed time step. The NYISO "interval" is likely to be the time step to which the market will evolve, if not begin.

- Based on the supply quantities contracted at each node and the actual net consumption at the load node, the Platform's market clearing function will calculate the value of imbalances, clearing them at the real time eLMP.
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- The Platform will provide all financial clearing information to market participants, provide hourly, daily, weekly and monthly detailed transaction data, as well as net-position data between individual market participants. The Platform is the bookkeeping entity of the market, based on its transactional neutrality. In its role, it will operate and maintain a data record of auditor /legal quality available to answer any challenges on transactions.

For non-electric products and services transacted on the Platform

- The Platform will provide market rules and standards to facilitate transactions, as well as the information and access required to create net system value, and achieve network externalities from access to the broad range of electric energy consumers on the Platform.
- The Platform will collect a transaction fee as a percentage of non-electric product and service transactions logged on the Platform as a function of the structure of transactions, i.e., assuring subsidization of the more price-elastic market participants in keeping with the theory of efficient Platform pricing.

2. A Day in the Life of a Platform: Ultimate DLMP

Assumptions underlying this chronology

- The central element in the Platform is a financial marketplace. It enables/facilitates transactions in electricity and other products and services. Transactions occur on a continuous basis. Additionally, the Platform will support and integrate discrete real-time markets conducted by distribution system operators for congested portions of distribution networks that enable dispatch of resources to address distribution constraints and the development of efficient pricing of energy imbalances in these portions of the distribution system. Trading in core electric products (real energy, reactive power, reserves) for delivery during specified time periods will have closing times in advance of the delivery period. The Platform also supports and enables the purchase of electricity combined with informational, analytical and forecasting services; financial services; and contracts for other energy-related goods and support services.
- The unit of measure for marginal cost of core energy products is the DLMP – the Distribution Locational Marginal Price, calculated for real energy, reactive power and reserves at the level of the retail meter and points of interconnection for supply resources connecting in the distribution system, or a point within the distribution system that is reflective of multiple retail meters and interconnection points.
- There is only one statewide financial Platform, and it interacts and exchanges critical information and data with the entities that oversee the physical system (see next bullet).
- DSPs will monitor, operate and maintain the physical distribution system (e.g., wires, transformers, switches, capacitor banks.) This White Paper assumes each Distribution Utility as DSP has a system-monitoring and state-estimation process, analogous to that used at the transmission level, enabling it to provide the Platform, in near-real-time, descriptions of what the distribution system's actual topology has been on an interval-by-interval basis, and what the physical flow on the distribution system has been on an interval-by-interval basis.
- The Distribution Utility, as the Distribution System Operator, is assumed to provide the Platform:
    - specifications for any local distribution system reactive power management capabilities that it wishes to procure from DERs;
    - specifications for any location-specific reserves that it wishes to procure from DERs to address local constraints within its distribution system; and
    - information on its dispatch of DERs for reactive power management, on its location-specific reserves for settlements, and on the performance of DERs it dispatched.
- ESCOs are market participants that provide energy or offerings that include energy and other products and services to end-use consumers. They are financially responsible parties for the acquisition and settlement of energy and other products and services transacted over the Platform.

    - ESCOs may aggregate the requirements and resources of small consumers and prosumers (generation and load response) into packages they can then trade in standard units on the Platform.
    - ESCOs will combine energy with other potentially high-value products and services available on the Platform to provide offers tailored to the preferences and requirements of specific customers, including both large and small consumers and prosumers.

- Distribution Utilities, as the default suppliers, function similar to the ESCO as a regulatory requirement. They are subject to regulatory oversight and potentially performance-based incentives.
- Distribution Utilities purchase distribution-reactive power management capabilities and location -specific reserves from DERs.
- Distribution Utilities, as distribution system operators, will monitor activity and forward market liquidity in the Platform's DLMP markets, paying particular attention to areas in their distribution systems that rely on DER for service reliability, and, if needed, will contract for and hold in reserve the output of DER assets that may be required to address future local constraints.
- Market participants are ESCOs, Distribution Utilities, aggregators, third-party product and service providers, financial participants, end -use customers participating on their own account, and DERs and prosumers.
- Aggregators are market participants that purchase and bundle the capabilities of smaller customers for resale to ESCOs, default suppliers, and NYISO.

Initial Conditions on the Platform

- Because the market on the Platform will be continuous, some market participants will have standing positions (bids to buy, offers to sell) for standard products for extended time blocks, i.e., similar to the standard transactions traded in today's wholesale market that focus on peak and off-peak hourly blocks. Bids to buy and offers to sell include a pricing provision.
- The Platform will provide a continuous matching of bids and offers (the market-making function) that, as part of the Platform functionality, will include standard contract terms and conditions (market operation rules) for transactions, as well as the mechanisms for market settlement.
- The Platform will have, at all times, multiple third-party forecasts of locational prices. These forecasts will be dynamic, changing as conditions change and as the clock moves forward.

Prior to the Day Ahead wholesale (ISO) energy market

- ESCOs and Distribution Utilities will forecast their hourly needs for the next day and, if they elect to do so, bid into, the ISO market for supplies, as is the case today.

- Distribution Utilities providing default supply service to customers on MHP riders will purchase the supply for those customers from the NYISO Day Ahead Market. However, prior to making those purchases, Distribution Utilities will give MHP customers the option to accept or modify their respective supply requirements for the delivery day. MHP customers will do so with knowledge that they hold long-term positions purchased on the Platform, as well as have the opportunity to balance their requirements (positive or negative) from offers that will emerge on the Platform after the close of the ISO day ahead.

After the close of the Day Ahead wholesale (ISO) energy market and before the close of each real time (hourly[9]) market on the Platform

- All market participants now have the information reported by the Platform as to the (hourly) expected value of nodal LMP, and the value for Real Energy and reserves (as well as any other day-ahead ancillary services) that have cleared the day-ahead market.
- Additional bids and offers are entered onto the Platform by market participants wanting to create a position in the Platform's real-time (hourly) market (for instance DERs and prosumers) or improve their market position (such as ESCOs or Distribution Utilities).
- The Platform will continuously match bilateral bids and offers providing for continuous price formation.
- The Platform will collect a transaction fee from the sellers (least-elastic entity) as a percentage of each buy/sell transaction logged on the Platform.

At the time of closure of the Platform electric product markets

- The Platform will continue to match bids and offers until a time certain before the close of the time period in which the electric product will be finally "delivered." ***"Delivery" in this context is purely financial*** i.e., the market participant that has contracted to supply or buy energy is financially obligated to supply or consume against the terms of the standard contract. The Platform will settle any imbalance between market positions for real energy at market close and actual delivery or consumption at interval marginal prices based on actual distribution system topology and power flows, as discussed below.

After the closure of the Platform electric product market

- The Platform will query and receive from the Distribution Utility a record of energy produced and consumed by location within the distribution system and system information needed to carry out the load flow analysis needed to calculate imbalance prices.
- Based on the contracted values of the closed (hourly) market and Distribution Utility record of energy produced and consumed (by specific location), the Platform will calculate the nodal

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[9] "Hourly" is used only to indicate an agreed time step. Sub-hourly time steps are equally likely.

clearing prices for energy and reactive power by location *ex post* based upon the physical information production, consumption, flow and topology data provided by the DSP.

  - The nodal clearing price calculation will take place as a function of the difference between the *ex post* actual real energy and reactive power consumed and the *ex ante* real energy and reactive power contracted for by parties on the Platform (integrated over the Platform trading period).
  - The nodal clearing price calculation will be referent to the LMP at the substation bus or busses that are the points of interaction with the wholesale system and that will have been calculated prior to the calculation of the nodal distribution prices for settlement.
  - The nodal clearing price calculation will be based on the distribution topology at the time of clearing.
  - The nodal clearing price calculation will be based on a load flow model given the above criteria.
  - The Platform will collect transaction fees for all settlements.
- The Platform will provide all financial clearing information to market participants, provide hourly, daily, weekly and monthly detailed transaction data, as well as net position data, between individual market participants. The Platform is the bookkeeping entity of the market based on its transactional neutrality. As such, it will operate and maintain a data record of auditor/legal quality available to answer any challenges on transactions.

For non-electric products and services transacted on the Platform

- The Platform will provide market rules and standards to facilitate transactions, as well as the information and access required to create net system value and achieve network externalities from access to the broad range of electric energy consumers on the Platform.
- The Platform will collect a transaction fee as a percentage of non-electric product and service transactions logged on the Platform as a function of the transactions' structure, i.e., assuring subsidization of the more price-elastic market participants in keeping with the theory of efficient Platform pricing.

Appendix E. Bibliography – Platform Economics

The references below include many of the core works that have informed the platform economics and strategy literature. Although, by nature, the list cannot be exhaustive, it does include much of the relevant literature.

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