Smart Grid Program:

Market Characterization and Evaluation Baseline

Final

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Section 1. Introduction

The New York State electric grid is a large and complex system, encompassing more than 39 GW of generating capacity and 160,000 GWh of electricity usage per year.[1] The system, and the policy context in which it operates, are changing rapidly. Since 2000, the power industry has added 11 GW of generating capacity, installed 2,300 MW of transmission capacity, and invested substantially in the distribution system.[2] These investments are intended, in part, to address changes in the state's temporal pattern of consumption. As is the case in many areas across the country, New York's peak demand is increasing while annual electricity usage remains relatively constant, likely as a result of increased use of air conditioning, advances in energy efficiency, and an economy that is transitioning from industrial to service-based activities.[3]

Because the grid must be built to support peak demand, this pattern results in substantial costs for assets that are rarely used; the New York Public Service Commission (PSC) estimates that the top 100 hours of demand cost ratepayers up to $1.7 billion annually.[4] Because New York already has some of the highest retail electric rates in the country, policymakers are forging a renewed effort to improve system efficiency and performance.

Other factors also stress the system. In particular, New York's grid is characterized by a geographic disconnect between highly concentrated load centers (downstate) and generation resources (upstate). As a result, the grid requires significant transmission capacity to move electricity to load centers. In addition, like other regions of the country, New York's grid is aging and requires substantial investment to maintain reliability and comply with increasingly stringent national and state environmental regulations.[5] Finally, the grid has experienced an increasing number of severe weather-related outages in recent years, including the prolonged outages associated with Superstorm Sandy in 2012 and the 2003 Northeast blackout.

To address these and other challenges, system managers have to date prioritized strategies such as industrial demand response and installation of large-scale renewables. In 2015, however, New York began the process of redesigning its electric system through the ongoing Reforming the Energy Vision (REV) initiative. REV seeks to create a new role for New York utilities as distributed system platform providers (DSP), to serve as intermediaries between "behind-the-meter" distributed energy resources (DER) and customers seeking to procure power. The operation of this distributed energy market is intended to help optimize the balance between electricity generation, demand, transmission, and distribution, leading to increased system efficiency and a lower overall cost of power production. REV represents a fundamentally different way of managing the provision of electric power.

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[1] New York Independent System Operator (NYISO), 2015.

[2] New York Battery and Energy Storage Technology Consortium (NY-BEST), 2016. (12)

[3] U.S. Energy Information Administration (EIA), 2014.

[4] NY-BEST, 2016. (12)

[5] NYISO, 2015.

The Smart Grid

Across the country, computer-based remote sensing, automation, and control technologies – referred to as "smart grid" technologies – are beginning to transform the electric grid's operations. Although many of these technologies are still new and evolving, they have the potential to improve system efficiency, reliability, resiliency, and environmental performance when deployed at a broader scale. In New York, operation of the distributed energy market called for by REV depends on the integration of smart grid technologies and tools. Examples of smart grid technologies include:

- **Devices for gathering data** on the flow of electricity through the electric grid, such as computerized power meters, voltage sensors, and fault detectors;

- **Tools enabling two-way communications** between customer-sited devices, grid sensors, and a utility's network operations center; and

- **Automation technologies** that allow a utility to respond in close to real time to incoming data and maintain centralized control over individual customer-sited devices. Examples include smart inverters and other advanced power controls, optimization software, and advanced energy management systems.[6]

The potential benefits of a "smarter" grid are substantial. According to the State of New York Department of Public Service (DPS), a marginal improvement in system efficiency – specifically, a one percentage point increase in system load factor[7] – could save between $150 million and $219 million per year in energy and capacity costs.[8]

NYSERDA's Smart Grid Program

As proposed under the Clean Energy Fund (CEF), the Smart Grid program will build on more than a decade of previous NYSERDA research to accelerate the market readiness of new and emerging smart grid technologies and strategies. The program has identified several desired long-term outcomes:

- Reduced DER interconnection costs;
- Increased system efficiency and asset utilization through development of a dynamically managed grid; and
- Improved ability of the grid to predict, withstand, and recover from power outages.

In the short term, the Smart Grid program will prioritize reducing DER interconnection costs.

To meet its objectives, the Smart Grid program funds research and engineering studies, product development and commercialization projects, and demonstration projects. Importantly, the program focuses on in-front-of-the-meter technologies instead of behind-the-meter technologies. This distinction is important when considering NYSERDA's efforts in the context of the national smart grid movement, which often emphasizes the adoption of smart meters. In New York, the adoption of smart meters is overseen by the PSC and managed by utilities.

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[6] For an overview of smart grid functions, see DOE's Smart Grid website: http://energy.gov/oe/services/technology-development/smart-grid. For a description of several smart grid technologies, see Speer et al., 2015.

[7] Load factor is defined as the ratio of average electricity use to peak electricity use.

[8] DPS, 2014. (10)

Section 2. The Smart Grid Market

While the simplest definition of "smart grid market" at this time is the market for the technologies that will enable a fully operating smart grid, in its full implementation, the smart grid will be synonymous with the electric grid. In this evolving context, the term "market characterization" is itself difficult to define. Many smart grid technologies are still nascent; others have a limited customer base (e.g., phasor measurement units for transmission networks) or are strongly influenced by political priorities (e.g., smart meters). In these cases, market metrics such as sales and employment are less meaningful than grid performance metrics such as percent of system affected. Thus, this market characterization discusses the adoption of technologies qualitatively and focuses on the trends, policies, barriers, and dynamics affecting the development of a fully integrated smart grid in New York State, as well as metrics for assessing its progress.

Characterizing the smart grid market therefore first requires understanding the market for "traditional" grid technologies and services. As shown in Exhibit 1, this market can be viewed as comprising six groups of stakeholders:

- Governmental agencies and other organizations focused on providing policy or financial support, or facilitating knowledge sharing;

- Universities, private companies, or other research organizations – including national labs – that are focused on technology development;

- Providers of energy resources, including centralized generation, large- and small-scale storage, and distributed generation;

- Transmission organizations, including the New York Independent System Operator (NYISO) and utilities;

- Distribution utilities; and

- Ratepayers that represent the system load.

> **Market Quick Facts**
>
> - $18 billion: U.S. spending on smart grid technology deployment from 2010-2013
> - $5.2 billion: greatest annual smart grid spending, in 2011 (largely ARRA funding)
> - For comparison:
>   - $8.5 billion: average annual utility spending for transmission upgrades (2003-2012)
>   - $17 billion: average annual utility spending for distribution upgrades (2003–2012)
> - $338-$476 billion: estimates, by EPRI, of spending required over a 20-year period to fully implement the smart grid
>   - $82-$90 billion for transmission systems and substations
>   - $232-$339 billion for distribution systems
>   - $24-$46 billion for consumer systems
>
> *Source: DOE, 2014. (2-3)*

Each of these actors also plays a role in the emerging market for smart grid technologies and strategies. The market for behind-the-meter technologies generally resembles markets for other consumer products, encompassing product developers, manufacturers, retailers, and a large number of potential customers. In contrast, the market for grid-level technologies involves a smaller number of "customers," which are typically limited to utilities, transmission owners, and other electric power providers. A report by GTM

Research identifies the leading providers of smart grid technologies and tools, organized by market segment (e.g., DER integration, grid optimization, communications).[9] The report shows that many smart grid technologies and tools are being developed by existing large companies already involved in the grid market (e.g., GE, ABB, Cisco); many of these companies also participate in multiple market segments. In addition, governmental agencies and policymakers help shape the rules and priorities of the grid-level market because of the public benefit nature of the grid.

NYSERDA's Smart Grid program is only one of many actors in the market for smart grid technologies and strategies. As highlighted in Exhibit 1 and discussed in more detail in Section 5, NYSERDA plays a role similar to that of several other agencies and organizations providing policy and financial support or knowledge sharing. It is therefore critical that NYSERDA avoid crafting projects and activities that duplicate or hinder other market actors' efforts. Because the Smart Grid program supports both product development and demonstration projects, NYSERDA's target audience is also varied, and includes both technology developers and transmission and distribution utilities, the end-users for grid-level technologies. Similarly, because of the program's current focus on DER interconnection, DER providers may be a key part of the Smart Grid program's audience. Ratepayers are not typically a focus for program activities, though some projects may involve input from specific ratepayers (e.g., large industrial facilities participating in demand response). The program's current focus on reducing DER interconnection costs may result in increased focus on ratepayers as part of the program's target audience.

Consistent with the focus of smart grid technologies on issues affecting performance of the traditional grid, the potential long-term outcomes of the Smart Grid program can be arrayed across four focus areas: efficiency, reliability, environmental impact, and resiliency.[10] To illustrate how the program may affect different parts of the market, Exhibit 1 illustrates how six specific issues within the four focus areas involve each category of market actor.

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[9] Leeds, 2009. (21)

[10] DOE's Quadrennial Technology Review (QTR) also identifies increased national security as a desired outcome of smart grid development. [DOE, 2015. (60)] To date, employing smart grid technologies to increase the physical or cyber security of the grid has not been a primary objective of NYSERDA's program.
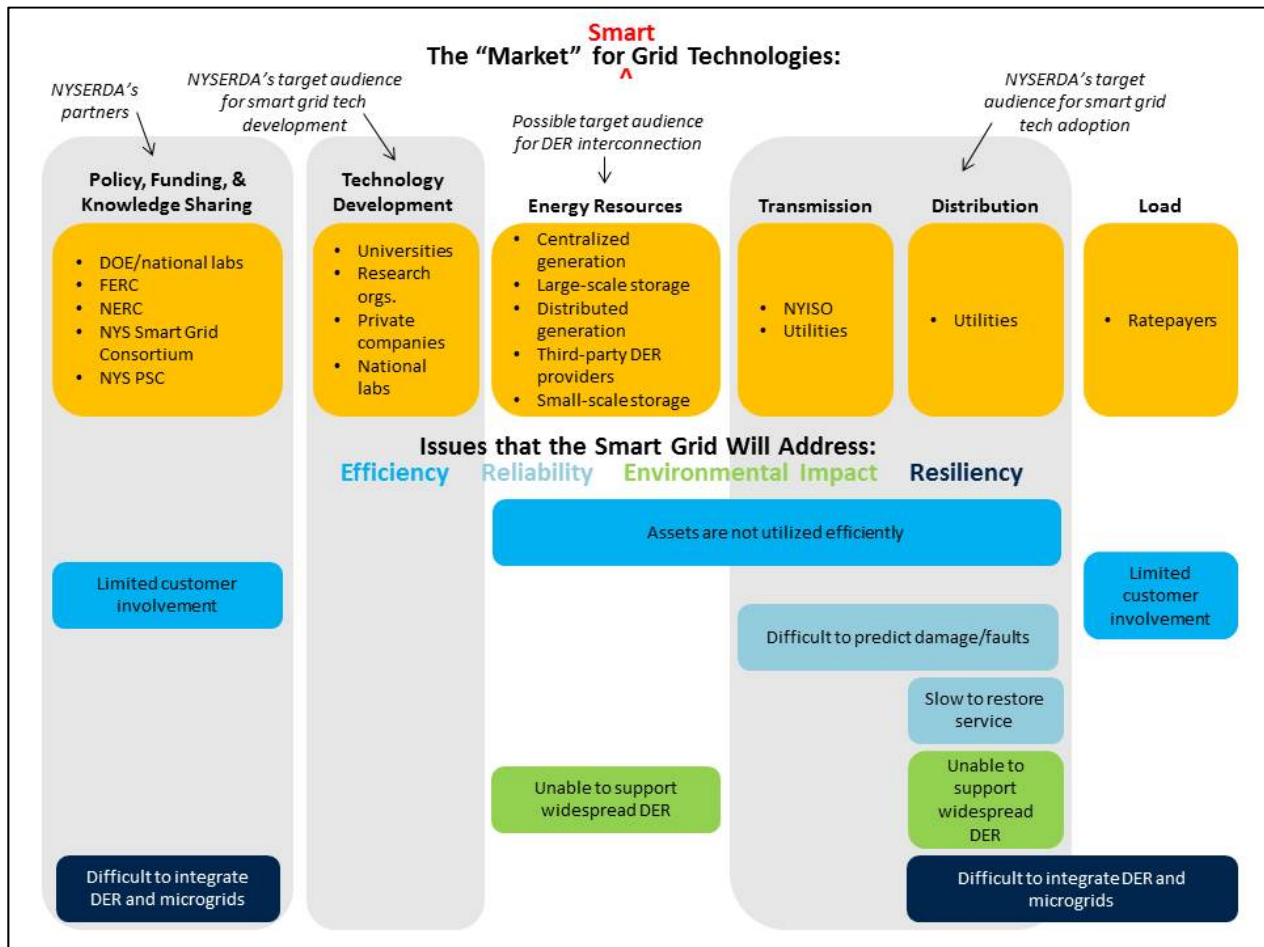
Exhibit 1. The Smart Grid Market

Exhibit 2 presents the information from Exhibit 1 in a tabular format to illustrate how grid performance goals map to specific smart grid market segments. The exhibit uses representative technologies associated with potential program outcomes, identified based on earlier drafts of NYSERDA's CEF Investment Plan, as examples.

Exhibit 2. Market Segments Affected by the Smart Grid Program

Grid Performance Goals	Potential Outcomes[1]	Representative Technologies	Associated Market Segments
Efficiency and optimization	Reduced DER interconnection costs and increased DER penetration	Smart inverters	• Tech Development • Energy Resources • Distribution • Load
	Increased system efficiency (e.g., increased system asset utilization factor)	Improved system models	• Energy Resources • Transmission • Distribution
	More efficient transmission asset utilization	Phasor Measurement Units (PMUs) and Wide-Area Measurement Systems (WAMS)	• Transmission
	Increased throughput	Dynamic line rating systems	• Transmission • Distribution
	Development of a dynamically managed grid	Distribution Management Systems (DMS)	• Transmission • Distribution
Reliability	Improved outage avoidance	Fault current limiters (FCLs)	• Transmission • Distribution
	Faster and more effective service restoration	Automated Fault Detection, Isolation, and Restoration (FDIR)	• Distribution
Resilience	Improved ability to withstand and recover from severe weather impacts	Microgrids	• Tech Development • Distribution • Load
Environmental performance	Greenhouse gas emissions reductions	Distributed renewables	• Policy • Distribution • Load
1. Potential outcomes were identified from the March 15, 2016, draft of the Smart Grid Systems – Efficiency and Performance logic model and the Grid Modernization – Phase 1: DER Interconnection logic model released as part of NYSERDA's April 29, 2016, CEF Investment Plan. Outcomes were revised slightly in NYSERDA's August 1, 2016, CEF Investment Plan and may continue to evolve as the CEF matures; these examples are for illustrative purposes only.			

Section 3. Evaluation Scope

Because the smart grid market is evolving and will, in its full implementation, be synonymous with the market for all electrical services, this market characterization discusses the adoption of technologies qualitatively and focuses on the trends, policies, barriers, and dynamics affecting the development of a fully integrated smart grid in New York. The primary objectives of this market characterization are twofold: (1) to identify a reasonable baseline scenario for smart grid development in New York State from which improvements supported by NYSERDA programming can be measured, and (2) to inform program strategy and design under the CEF. To accomplish this, the assessment considered the following research questions:

Trends in Smart Grid Development (Section 4)

1. How have smart grid technologies and tools developed over time?

2. How have policies and planning decisions, including those of utilities, incorporated smart grid research and development (R&D) in recent years?

3. What trends in New York's grid performance can be identified?

4. How does smart grid development in New York State compare to other states?

NYSERDA's Role and Potential Future Contributions (Section 5)

5. What external (non-NYSERDA) initiatives, such as those carried out by utilities or the U.S. Department of Energy (DOE), contribute to advancing smart grid development?

6. What role does NYSERDA play compared to these other initiatives?

7. What are the gaps in market readiness for smart grid technologies in New York, and how can NYSERDA help address them?

Measuring Trends in Smart Grid Development (Section 6)

8. What is a reasonable baseline scenario (e.g., expected future trajectory) for smart grid technology development?

9. What metrics can be used to track future improvements smart grid development in New York?

Industrial Economics, Inc. (IEc) relied on two primary methods of analysis to answer these questions: a panel of strategic expert advisors, and a benchmarking assessment. The panel was designed to provide qualitative insight into all research questions. The benchmarking assessment provided analysis in support of Questions 3, 4, and 9. In addition, IEc observed a workshop conducted by NYSERDA and Meister Consultants Group, Inc. as part of their effort to develop an inventory of "smart grid" companies in New York State. The workshop was conducted on March 10, 2016, in Albany, New York, with a small group of industry participants. Notes from this workshop are incorporated into the discussion of Question 7.

Expert Panel Overview

In August 2015, IEc convened a group of five individuals with expertise in smart grid development within and beyond New York State. The panel was designed to reflect a range of perspectives on the emerging smart grid market and enough overlap in expertise across panelists to allow for areas of relative consensus or difference of opinion. Panelists were selected to ensure that the panel collectively included expertise on each of NYSERDA's target market segments (see Exhibit 1). As shown in Exhibit 3 below, the final selected panel included two experts working for transmission organizations, one expert working for a distribution utility, one academic researcher, and one expert working for a research organization. All five experts agreed to be named as part of the panel in this report. A sixth expert, a representative of another distribution utility, was not able to participate fully in the panel but provided limited technical input. This expert requested anonymity as a result of his limited participation.

Exhibit 3. Expert Panel

Area of Expertise	Name	Affiliation
Transmission	Alan Ettlinger	New York Power Authority (NYPA) Manager – Research, Technology and Development
	Dejan Sobajic	Grid Engineering LLC Contractor to NYISO
Distribution	Laney Brown	Iberdrola USA[1] Director, Smart Grid Planning and Programs
Policy and Research	Seth Blumsack	Pennsylvania State University Associate Professor, Department of Energy and Mineral Engineering
	Mark McGranaghan	Electric Power Research Institute (EPRI) Vice President of Power Delivery and Utilization
1. Laney Brown is now Vice President of Grid Modernization Strategy at Modern Grid Partners, Inc., but was at Iberdrola USA for the duration of the panel.		

To obtain information on the research questions above, IEc conducted two rounds of solicitations with these experts through a combination of a written questionnaire and collaborative discussions. The panel process employed many standard expert elicitation techniques, but – unlike traditional expert elicitations – was designed to be conducted informally so that NYSERDA could engage with the experts throughout. The six-stage process employed for this assessment is described in additional detail in the expert panel summary memorandum in Appendix A; the questionnaire is provided as Appendix B.

Because definitions of "smart grid" vary across programs and states, IEc and NYSERDA were careful to clarify that NYSERDA considers only in-front-of-the-meter technologies in its program. However, IEc ultimately allowed the experts to define the relevant technologies and systems according to their market perspective. This report's discussion of behind-the-meter technologies is therefore intended only to provide context for program-specific recommendations.

Benchmarking Assessment Overview

Concurrently with the expert panel, IEc conducted a benchmarking assessment to provide insight into the trajectory of smart grid development in New York State, compared to other similar states. Given the complexity of the smart grid market in terms of interconnected effects and diffuse technology impacts, the most reliable, though indirect, way to identify trends in adoption of smart grid technologies is to examine grid-level performance metrics and changes over time. The benchmarking assessment considered six metrics, selected by IEc and principal investigators Dr. Paulina Jaramillo and Dr. Eric Hittinger in collaboration with NYSERDA. Four of these metrics relate directly to activities supported by the Smart Grid program. The remaining two metrics – smart meter deployment and the number of customers participating in load management – are not directly related to NYSERDA's Smart Grid program activities, but address a specific smart grid technology and grid-level performance, respectively, and are important drivers and indicators of state-level smart grid development. The inclusion of these metrics in the benchmarking assessment reflects the different focus of the benchmarking compared to the expert panel. The selected metrics are shown in Exhibit 4.

Exhibit 4. Metrics Selected for Benchmarking Assessment

Metrics
Load management potential and deployment
Number of customers participating in load management programs
Installed distributed generation capacity
Number of smart meters deployed
Installed storage capacity (grid-level and distributed)
Number and scale of power outage events

The benchmarking assessment evaluated these metrics for New York and three comparison states: California, Massachusetts, and Pennsylvania. These states were selected because of their comparable energy policies, location, or size. Specifically, California was selected because it is known to be a leader in electricity system innovation, with high electricity prices, a large economy, a strong regulatory environment, and several large and innovative distribution companies. Massachusetts was selected because it is a physical neighbor to New York and shares a similar physical climate and mix of generation resources. In addition, some utilities operate in both New York and Massachusetts due to their proximity. Pennsylvania is another physical neighbor, with similar size, population, and population distribution to New York.

Data for the benchmarking assessment were collected from publicly available sources, including the U.S. Energy Information Administration (EIA) Form 861, EIA's Annual Disturbance Events Archive, and the DOE Energy Storage Database. State-level data sets were also considered, but key discrepancies across states and over time prevented the IEc team from using the data. The final report for the benchmarking assessment is incorporated into this report as Appendix C.

Section 4. Trends in Smart Grid Development

Technology Development

Over the last decade, the market for smart grid technologies has seen both supply-side and demand-side growth. On the supply side, increases in computing power have enabled the development of new technologies for grid communication, control, and automation. On the demand side, factors such as aging infrastructure, increasing peak load, and state-level policy changes have stimulated utility and ratepayer demand for smart grid technologies. As DOE wrote in its Quadrennial Technology Review (QTR), "Consumers are increasingly becoming 'prosumers' who both use and produce electricity," a change that requires the grid to become more flexible, agile, and dynamic.[11]

The expert panel confirmed the rapid pace of smart grid technology development by providing more than 25 examples of smart grid technologies and tools that have been developed or implemented in New York in recent years. Chief among these were advanced monitoring and communications equipment (including advanced metering infrastructure, or AMI), distributed generation, distributed storage, cybersecurity systems, power system automation, microgrids, and advanced system modeling.[12] Many of these technologies remain limited in use in New York State, although they may be more widely used elsewhere as a result of differing state-level priorities—a sign that the smart grid market is still relatively young and evolving. The experts emphasized several technologies and tools for which additional market development may be necessary to ensure a fully operational smart grid in New York. These include customer-side technologies and services (e.g., DER, demand response, microgrids), communications standards and infrastructure, AMI, system automation, and advanced system modeling. Importantly, as DOE notes in its QTR, the transition to a fully operational smart grid depends not only on technology development but also on a number of other concurrent changes, including infrastructure improvements and changes in market structures and public policies.[13] Thus, technology development may remain slow until new market structures and policies are in place.

The results of the benchmarking assessment also reveal general trends in technology development and adoption. Exhibit 5 shows installed distributed generation capacity (in MW) in each year since 2007. As shown, distributed solar has grown significantly since 2010, both in terms of absolute capacity and as a share of installed distributed generation. Although New York and Pennsylvania currently lag in terms of per-capita installed distributed generation, all four states show similar trajectories. The Smart Grid program's preliminary focus on reducing DER interconnection costs should support continued growth in the market for distributed generation.
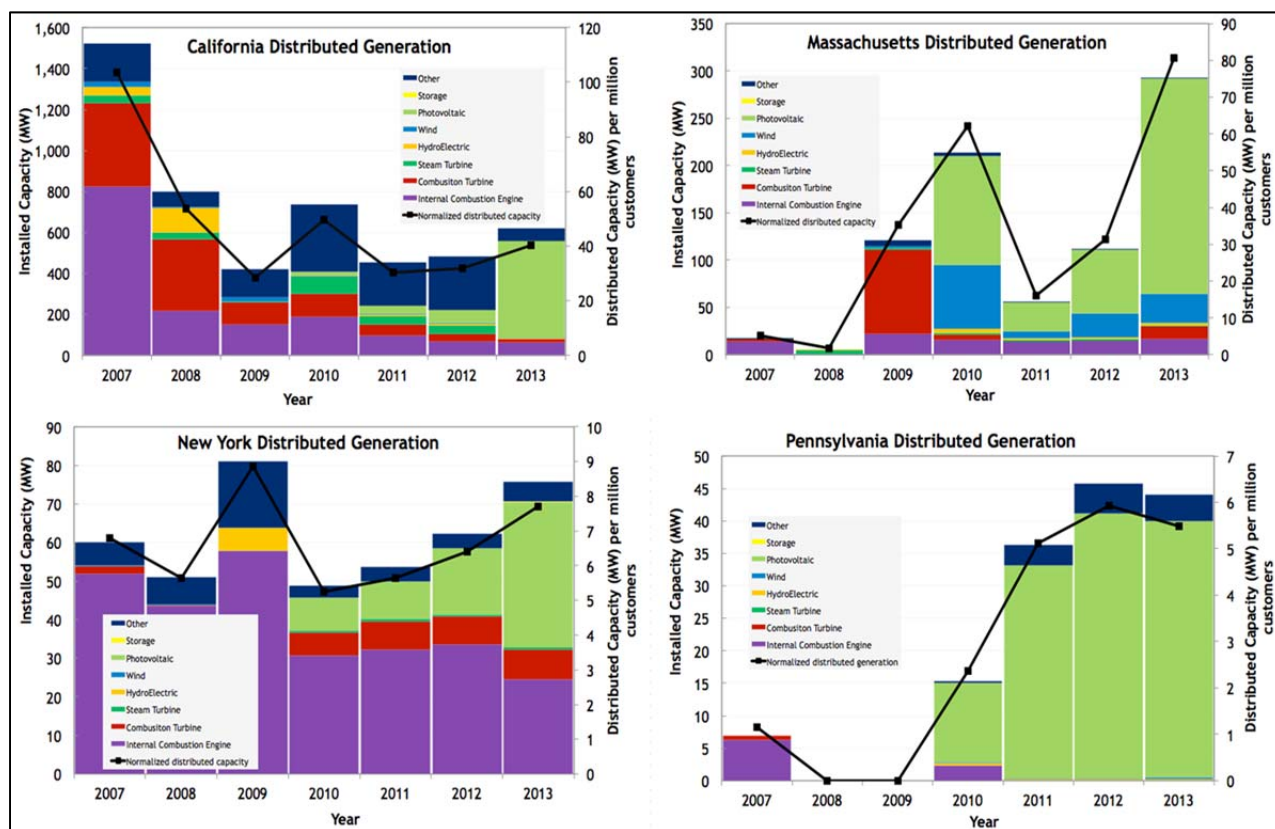
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[11] DOE, 2015. (57 and 93)

[12] Although NYSERDA's Smart Grid program is not responsible for the deployment of AMI or customer-side technologies and services, the experts highlighted these as critical components of a fully operational smart grid.

[13] DOE, 2015. (55)

Exhibit 5. Installed Distributed Generation by State

Source: Analysis of data from EIA forms EIA-861 and EIA-861s conducted by Dr. Paulina Jaramillo and Dr. Eric Hittinger; see Appendix C.

Within Exhibit 5 is also information on distributed storage, an emerging technology that has the potential to substantially improve grid reliability, resiliency, and efficiency.[14]   Exhibit 6 extracts these data to show how installed capacity has grown in recent years. Of note, only California and New York reported any distributed storage through 2013. The data – and recent advances in distributed storage technologies by companies such as Tesla – suggest that storage capacity is likely to continue increasing as states such as California and New York demonstrate the technology's potential.

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[14] NY-BEST, 2016.
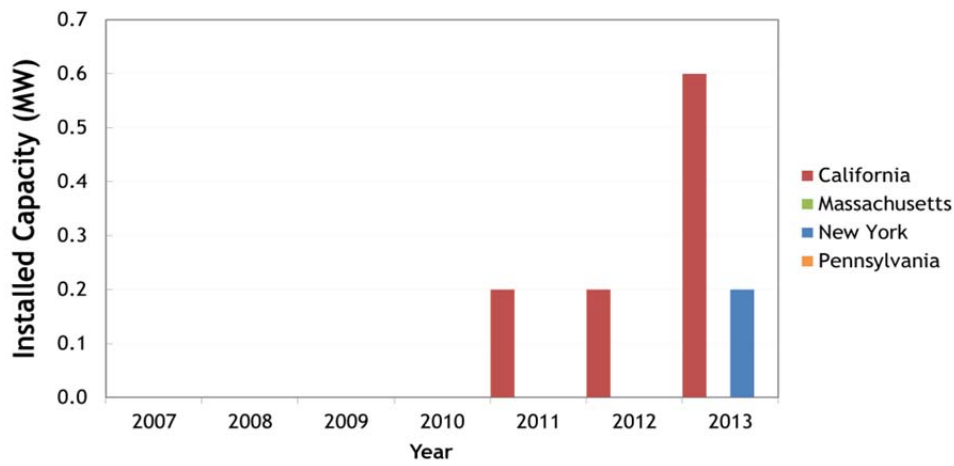
Exhibit 6. Distributed Storage Capacity by State

Source: Analysis of data from EIA forms EIA-861 and EIA-861s conducted by Dr. Paulina Jaramillo and Dr. Eric Hittinger; see Appendix C.

Growth can also be seen in the market for utility-scale storage. Exhibit 7 shows installed capacity of non-pumped hydro utility-scale storage by state. Although pumped hydro is an important storage technology, inclusion of pre-existing, large pumped hydro facilities in the figure masks the much smaller installations in recent years; to highlight recent trends, the IEc team therefore excluded pumped hydro capacity from the figure. As shown, the trajectory is similar in each of the four states, although California leads in terms of capacity installed.

The benchmarking assessment also validated the experts' discussion of AMI deployment. To date, the New York PSC has not emphasized AMI deployment. As a result, less than 0.5 percent of New York customers had smart meters by 2013, compared to more than 80 percent in California. Given the widespread market changes called for by REV, the New York PSC has indicated that an increase in advanced metering deployment will be necessary in the coming years, although the exact functionality and extent of deployment required is uncertain.[15]

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[15] DPS, 2015. (22-23)

Exhibit 7. Utility-Scale, Non-Pumped Hydro Storage Capacity by State
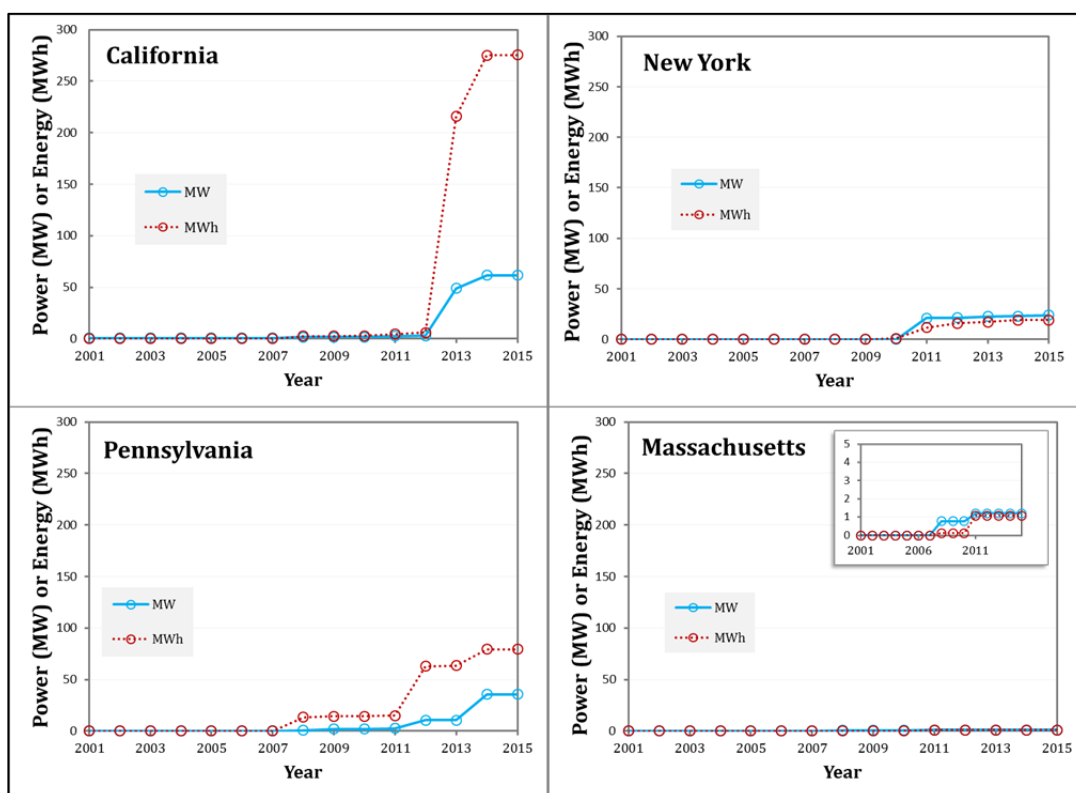
Note: Massachusetts inset graph uses different y-axis scale to illustrate trend. Source: Analysis of data from DOE's Energy Storage Database conducted by Dr. Paulina Jaramillo and Dr. Eric Hittinger; see Appendix C.

Consideration of Smart Grid in Recent Policy and Planning Decisions

The expert panel unanimously agreed that national policies and programs, particularly those of DOE, have advanced smart grid development in recent years. One expert noted, however, that this support has typically been in the form of research efforts rather than funding for widespread technology deployment. The most important exception, according to the panel, was the funding that the American Recovery and Reinvestment Act of 2009 (ARRA) provided. This funding enabled the initiation of two large smart grid programs: the Smart Grid Investment Grant (SGIG), and the Smart Grid Demonstration Program (SGDP). As discussed in DOE's 2014 Smart Grid System Report, the U.S. electricity industry spent approximately $18 billion on smart grid technologies between 2010 and 2013; of this, ARRA investments accounted for $8 billion, or nearly half.[16] Approximately 60 percent of spending in each year 2010-2012 was for smart metering (AMI), with the remainder going to advanced smart grid projects or distribution automation.[17] The experts emphasized that DOE's funding and initiatives contributed crucial support for advancing smart grid development.

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[16] DOE, 2014. (2)

[17] Ibid. (3)

Other national and state policies have the potential to substantially change the smart grid market in the future. For example:

- **Federal Energy Regulatory Commission (FERC) Order 745:** In late January 2016, the Supreme Court upheld FERC's authority to regulate demand response through FERC Order 745, which stipulates that the rate that demand response providers receive for reducing load must be equal to the rate that electricity suppliers receive for meeting that load with new generation.[18] This decision has the potential to substantially advance markets for demand response, DER, and the smart grid technologies that enable those services.

- **REV:** All of the experts agreed that REV will encourage smart grid expansion through its emphasis on greater decentralization of the grid. At the same time, one expert noted that the widespread changes called for by REV have the potential to be disruptive "in terms of business models for both incumbent firms and new types of entrants to the New York electricity market; for regulators seeking to evaluate the performance of electricity services; for firms who may face a shortfall in trained workforce; and potentially for consumers who will be asked to achieve a high level of sophistication in choosing among competing electricity service providers and technologies." These challenges are discussed further in Section 5.

At the utility level, three experts – including both utility representatives – noted that uncertainty surrounding cost recovery for smart grid technologies and overall funding limitations have affected investment decisions. Nevertheless, utilities have begun to invest in smart grid technologies and strategies in New York and beyond. A few prominent examples noted by the panel include:

- ConEdison's use of load management as a distribution resource in New York State;

- Iberdrola's efforts on substation and recloser automation in Maine and New York State; and

- The Pacific Northwest Smart Grid Demonstration Project, funded by ARRA, which was one of the largest smart grid demonstrations to date.

Both utility representatives also noted that smart grid will continue to be an important consideration in utility planning decisions. These experts emphasized that state-level policy decisions have the potential to accelerate market development, particularly through the dedication of funding for continued research, development, and deployment.

Recent Trends in New York's Grid Performance

The panel concluded that smart grid technology deployment is not yet widespread enough to have resulted in substantial changes in grid performance. This conclusion was validated by the benchmarking assessment, which evaluated several metrics related to grid performance in New York.

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[18] Tweed, 2016.

The assessment first considered trends in demand response, which is typically used to reduce peak demand and maintain service reliability. Findings include:

- Since 2005, the capacity available for peak load reduction in New York has hovered around 400 MW.

- Actual peak load reduction (i.e., the capacity ultimately called on to reduce peak demand) has generally remained well below the amount of participating capacity (see Exhibit 8).

- However, Massachusetts and Pennsylvania each called on nearly 100 percent of available capacity in several years.

This suggests that: (1) New York has been able to keep up with system demand, and (2) New York may be able to manage its system at a lower overall cost if it is able to defer future investments in generating capacity by increasing load management.

Exhibit 8. Actual Peak Reduction as a Percentage of Potential Peak Reduction
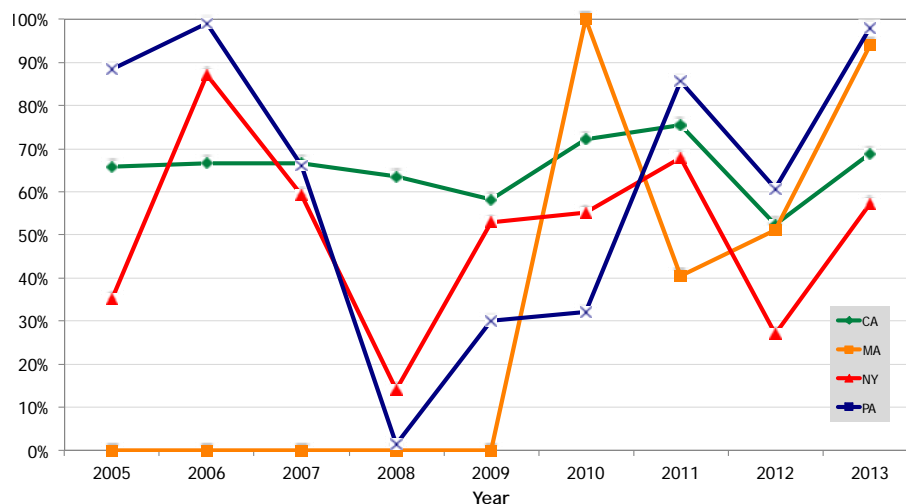
Source: Analysis of data from EIA forms EIA-861 and EIA-861s conducted by Dr. Paulina Jaramillo and Dr. Eric Hittinger; see Appendix C.

Similarly, the benchmarking considered trends in the number of price- and time-responsive customers as a proxy for the potential to reduce peak demand and improve overall grid efficiency.[19] Findings include:

- The percentage of customers participating in these programs seems to follow the percentage of customers with smart meters.

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[19] Price-responsive customers are those who can change their demand for electricity based on real-time pricing signals, while time-responsive customers are those who can change their demand patterns based on time-of-use pricing.

- The number of price- and time-responsive customers in New York has increased steadily since 2005, although participation in these programs remains extremely low (approximately two percent of customers in 2013; see Exhibit 9).

- Massachusetts and Pennsylvania had similarly low shares of price- and time-responsive customers, compared to more than 20 percent of customers in California.

Exhibit 9. Number and Percentage of Price- and Time-Responsive Customers in New York

Source: Analysis of data from EIA forms EIA-861 and EIA-861s conducted by Dr. Paulina Jaramillo and Dr. Eric Hittinger; see Appendix C.
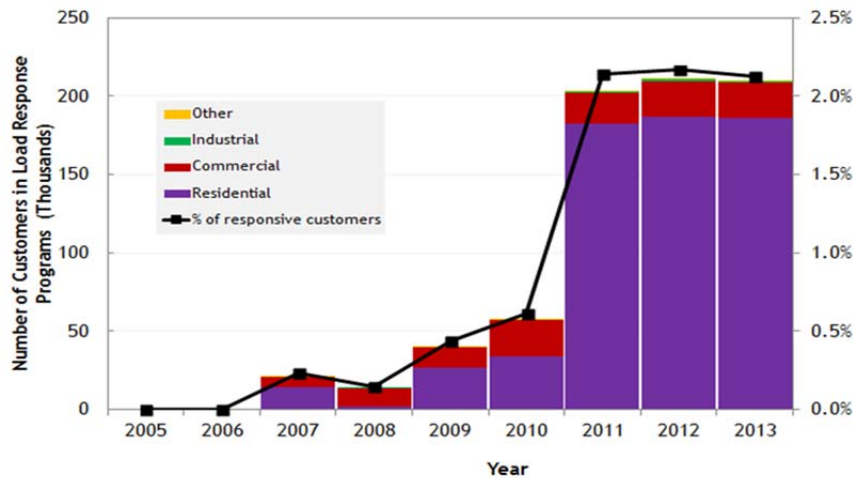
Finally, the benchmarking assessment considered trends in system reliability and resiliency, as measured by outage extent and duration. Findings include:

- New York ratepayers have historically been less susceptible to extended outages than ratepayers in other states (i.e., the population-adjusted number of customers affected and cumulative outage duration for the average customer are both generally lower in New York). As shown in Exhibit 10, between 2001 and 2014, approximately 0.6 customers were affected for every resident in New York, compared to 0.8 customers per resident in Pennsylvania.[20] The exhibit uses the metric "customers per resident" to normalize the data because the number of customers affected is strongly influenced by the number of customers in the state.

- Exhibit 11 shows that the cumulative outage duration for the average customer in New York was approximately half that in Massachusetts.

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[20] Note that because some customers may have been affected multiple times and others not at all, the statistic should not be interpreted as saying that 60 percent of residents were affected.

- Although outages affect approximately the same percentage of the population each year in each state, restoration time has been quicker in New York, leading to lower cumulative outage duration.

- The impacts of Superstorm Sandy are clear in 2012; since that time outages have been limited in extent and duration.

Exhibit 10. Cumulative Number of Customers Affected by Outages, Normalized to Population
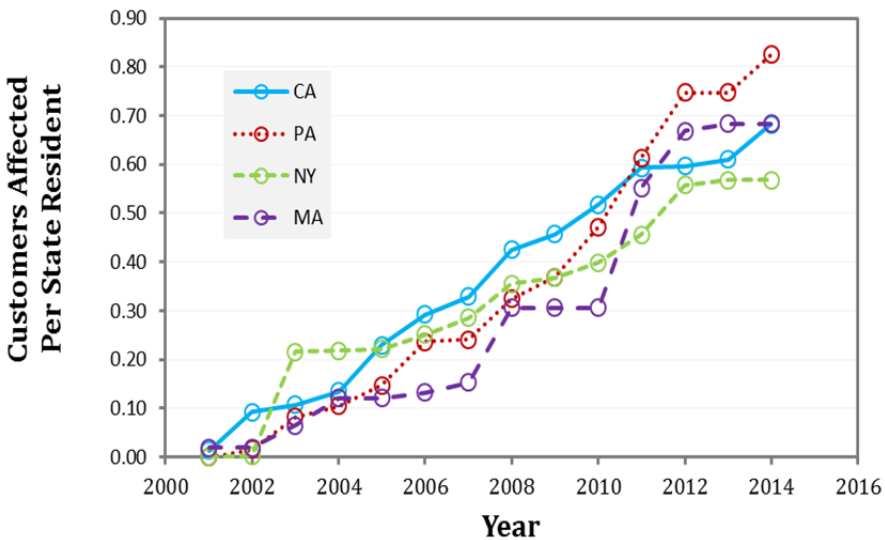
Source: Analysis of data from EIA Annual Disturbance Events Archive conducted by Dr. Paulina Jaramillo and Dr. Eric Hittinger; see Appendix C.

Exhibit 11. Cumulative Outage Duration for Average Customer, Normalized to Population
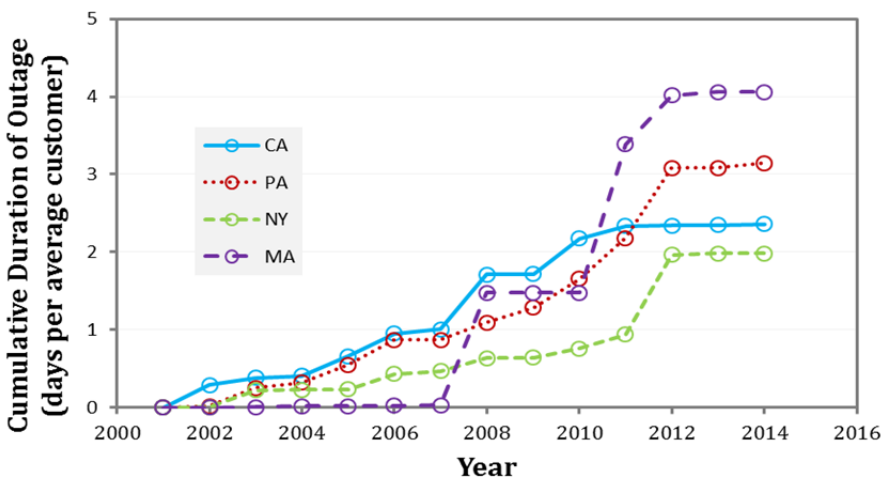
Source: Analysis of data from EIA Annual Disturbance Events Archive conducted by Dr. Paulina Jaramillo and Dr. Eric Hittinger; see Appendix C.

Section 5. NYSERDA's Role and Potential Future Contributions

NYSERDA is only one of many stakeholders supporting the research and development of smart grid technologies in New York State. The experts suggested that NYSERDA tends to support a broader scope of technologies than similar organizations and more heavily emphasizes support for early-stage R&D and technology testing and validation. Some experts suggested that NYSERDA has played less of a role in the market development and adoption of particular technologies than other organizations with a more targeted focus. This is consistent with the program theory and logic models of the Smart Grid program.

In addition to NYSERDA, the experts recognized more than 15 other agencies and organizations contributing to advancing smart grid development, as shown in Exhibit 12. The panel conveyed the roles of key organizations as follows:

- DOE and its national labs contribute substantial research and financial support, including through the SGIG and SGDP initiatives.

- The Electric Power Research Institute (EPRI) focuses on technology research, development, and demonstration.

- The North American Electric Reliability Corporation (NERC) facilitates information sharing among utility representatives.

- NYISO maintains data on topics such as power outages and market costs for grid-related services that can inform smart grid investment decisions as well as program evaluations.

- The New York PSC provides regulatory support for various smart grid proposals and projects.

The Complementary Roles of DOE and NYSERDA

NYSERDA's role in the New York market mirrors that of DOE at the national level. Both agencies focus on supporting projects with large public benefits that can help catalyze innovation and private investment.

As described in DOE's QTR: "DOE invests in grid-related energy RDD&D [research, development, demonstration, and deployment] projects that have large societal and system-wide benefits and are too risky for the private sector to develop on its own. [R]esearchers at federal laboratories can help develop new ideas and concepts, promote information sharing and technology transfer, and facilitate collaborations among industry groups and academia to spur innovation and invention."

Similarly, as described on NYSERDA's website, NYSERDA works "to develop, invest, and foster the conditions that:

- Attract the private sector capital investment needed to expand New York's clean energy economy

- Overcome barriers to using clean energy at a large scale in New York

- Enable New York's communities and residents to benefit from energy efficiency and renewable energy"

Despite the large number of organizations concurrently working on smart grid R&D, one expert emphasized that NYSERDA has, to date, coordinated well to ensure that the organizations' roles are differentiated and that there is no duplication of effort.

Exhibit 12. Organizations Advancing Smart Grid Development

Federal and State Regulation	Federal and State Research Support	Standards Development and Info Sharing	Research and Tech Development	Utility Info Sharing
• FERC • NYS PSC	• DOE: SGIG, SGDP, ARPA-E, SmartGrid.gov, and national labs • Federal Smart Grid Task Force • NYS Smart Grid Consortium	• American National Standards Institute (ANSI) • Institute of Electrical and Electronics Engineers (IEEE) • International Electrotechnical Commission (IEC) • National Electrical Manufacturers Association (NEMA) • National Institute of Standards and Technology (NIST) • Organization for the Advancement of Structured Information Standards (OASIS) • TRUSTe (Smart Grid Certification Standards)	• CURRENT Group (now Ormazabal) • EPRI • Power Systems Engineering Research Center	• NERC • NYISO

Gaps and Barriers

As noted by the panel and validated by the benchmarking assessment, the market for smart grid technologies is still developing. Advancements in smart grid technologies are occurring, but R&D needs remain. The benchmarking assessment identified two key technologies that both (1) have the potential to significantly influence the smart grid market, and (2) remain limited in use in New York. These are:

- **Distributed generation**: The experts unanimously agreed that DER penetration is one of the primary drivers of smart grid investment. Installed distributed generation capacity is low in New York compared to other states, even when normalized to population (see Exhibit 13).[21] Furthermore, although distributed solar is growing rapidly, nearly one-third of distributed capacity in New York still consists of fuel-based internal combustion engines.

- **Advanced metering functionality**: Smart meters or other advanced metering functionality will become increasingly important under REV. As DOE's QTR noted: "As more distributed energy resources are deployed, visibility deep into the system (e.g., along a feeder to a utility meter and possibly beyond) will be needed to ensure reliability and power quality, as well as to enable advanced applications. The installation of approximately 50 million smart meters, covering 43% of U.S. homes, has been a tremendous advancement in improving distribution visibility."[22] To date, the New York PSC has not emphasized smart meter deployment, although it has expressed interest in supporting some form of AMI under REV.[23]

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[21] As shown in Exhibit 13, per-customer distributed generation in Massachusetts is substantially higher than the other states. While Massachusetts has made concerted efforts to advance distributed generation in recent years, this result is also in part due to the state's small population. Massachusetts currently has approximately 3.5 million utility customers, compared to eight million in Pennsylvania, 10 million in New York, and 15 million in California.

[22] DOE, 2015. (71)

[23] DPS, 2015. (22-23)

Exhibit 13. Installed Distributed Generation Capacity, Normalized to Number of Customers
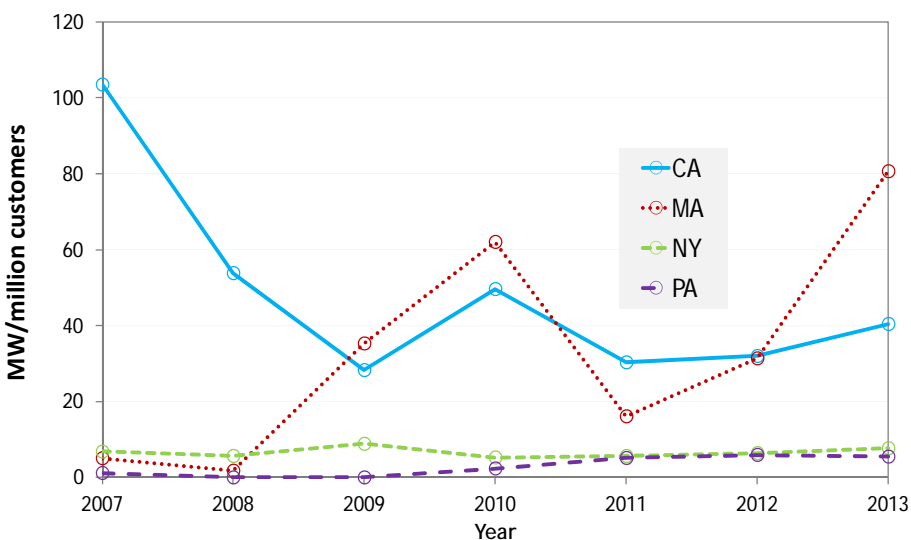
Source: Analysis of data from EIA forms EIA-861 and EIA-861s conducted by Dr. Paulina Jaramillo and Dr. Eric Hittinger; see Appendix C.

The panel identified several additional areas for further R&D, including improved system modeling and controls, communications infrastructure, technology interoperability standards, and cybersecurity. DOE draws similar conclusions about gaps in smart grid development in the QTR.

The panel also identified barriers that may hinder smart grid development in New York. The most significant barriers were:

- **The need for system testing to validate new technologies and tools.** Several experts, as well as participants in the inventory workshop, emphasized the need for system testing to demonstrate the performance of new technologies and systems under real-world environmental conditions. Testing could help advance the market by providing much-needed data to regulators, investors, and customers regarding the value of specific technologies and tools.

- **The need for a workforce with appropriate smart grid expertise.** All of the experts, as well as the participants in the inventory workshop, emphasized that smart grid implementation will require a highly trained utility workforce with expertise in new areas, including communications, data and signal processing, data analytics, advanced technologies, and system modeling, among others. These skills are typically not required for utility linemen and technicians today but are essential for development and successful operation of the smart grid. The expert panel provided several examples of workforce development initiatives currently taking place at the national and local levels; these include DOE's Grid Engineering for Accelerating Renewable Energy Deployment (GEARED) program, EPRI's GridEd group, and the GridSTAR training center.

- **The difficulty that individual market actors have making a business case for investment.** The smart grid market includes two key customer segments: utilities, who have the ability to

invest in grid-scale systems, and individual ratepayers, who can invest in the types of DER that will play an increasingly important role under REV. The experts noted that NYSERDA-funded demonstrations have not necessarily led to widespread market adoption by either segment as a result of challenges in communicating the value of smart grid technologies and strategies.

The Gap between Demonstration and Market Adoption

The expert panel and participants in the inventory workshop provided several possible explanations for why smart grid demonstration projects have not led to widespread market adoption:

- Data limitations: Because smart grid technologies are still evolving, regulators do not always have sufficient data to understand a technology's effect on grid performance, utility cost recovery options remain uncertain, and the value of customer-sited technologies can be difficult to communicate to ratepayers. At a more fundamental level, technology developers do not always understand the needs of the market because of utilities' hesitance to share data. The Smart Grid program's logic model identifies this sort of coordination and information sharing as a priority.

- Recent shifts in market focus: The smart grid market has seen a recent shift from utility-focused to customer-focused technologies and systems. With R&D efforts now led by agencies such as NYSERDA, utility personnel are not always able to troubleshoot or understand the new technologies; NYSERDA's program should therefore consider prioritizing utility workforce development.

- In addition, customer-focused technologies such as DER and demand response have become increasingly central to smart grid planning. As a result, market adoption requires new strategies for communicating the value of customer-sited technologies to ratepayers.

- Lag in DER adoption: DER integration is a key economic driver for smart grid, but DER adoption in New York lags behind other states. Efforts to increase smart grid investment and DER investment should be closely aligned (as they are in the Smart Grid program's current logic model).

- Need for peak load management: The current need for peak load management drives much of the investment in New York's grid, but does not require a "smart" grid. As New York's needs change – perhaps due to REV – new economic drivers for smart grid may appear. Collaboration between the Smart Grid program and other stakeholders may be essential for advancing smart grid development.

Emerging Opportunities for NYSERDA

Based on their understanding of the gaps and barriers in the market for smart grid technologies and strategies, the experts identified the areas where they thought NYSERDA's Smart Grid program should focus its effort in the future. These are:

- **Testing and validation of technologies and systems:** Building the new market structure envisioned by REV will require detailed data on grid-level and customer-level operations, both to inform technology development and to encourage customer adoption of proven technologies. Several experts discussed the potential value of establishing a facility dedicated to testing technologies and systems under real-world environmental conditions, as a means of spurring investment and innovation.

- **Workforce development:** The experts and inventory workshop participants regarded the need for a highly trained utility workforce with increased expertise in software, modeling, and data analytics as one of the key barriers to further market development. NYSERDA has the opportunity to help establish New York as a smart grid leader by collaborating with universities, utilities, and other partners to develop:

  - Training courses and curricula for the next-generation utility workforce; and

  - 'Knowledge capture' tools to share information from existing experts.

- **Technology barriers that will become increasingly important under REV:** Many experts emphasized the importance of demonstrating effective strategies for systems integration, including technologies to manage the interface between (1) DER and the distribution system and (2) the distribution system and the transmission system. The Smart Grid program's current focus on DER integration should help address these R&D needs.

- **Business development support** for funding recipients to help increase market adoption of smart grid technologies and tools. In particular, one expert suggested that NYSERDA could help organizations develop strategies for communicating the value of their technologies to potential customers (i.e., utilities or ratepayers). The participants in the inventory workshop emphasized that utility engagement (e.g., through the proposed REV Connect online platform) is essential for the development and adoption of well-functioning smart grid technologies and tools. Because other programs already provide business development support, the most effective role for the Smart Grid program may be to facilitate introductions to potential business partners and support networks (e.g., Entrepreneurs in Residence).

For each of the areas, the Smart Grid program can further contribute to New York's energy goals – and encourage replication effects elsewhere – by supporting information sharing among market actors and coordination between market segments. This type of coordination is currently emphasized in the Smart Grid program's logic model.

Section 6. Measuring Trends in Smart Grid Development

The experts and benchmarking assessment provided insights into two key elements essential for measuring the impacts of the Smart Grid program: the baseline trajectory for smart grid development, and metrics to document future changes.

Baseline Scenario

The five panelists, despite some uncertainty about the timing of smart grid technology adoption, agreed that 2005 (the year in which NYSERDA first funded smart grid projects) is an appropriate baseline year for evaluating the emergence of smart grid technologies and the impacts of NYSERDA's efforts. One expert, as well as DOE's QTR, cited the Northeast Blackout of 2003 as a formative event in the history of smart grid development.[24] Due to lags in utility planning and investment cycles, technologies introduced after the 2003 blackout are unlikely to have significantly affected grid performance prior to 2005.

Experts also noted that widespread implementation of smart grid technologies in New York did not begin until 2010, in part due to substantial support from federal DOE and ARRA funding. Indeed, the QTR reports spending on smart grid technologies going back only to 2008, which lends support to the idea that the market for smart grid technologies is still relatively young.[25] Because of the evolving nature of the market, the experts agreed that smart grid technologies have not led to significant changes in reliability, efficiency, resiliency, or other grid-level performance metrics yet. This conclusion is also supported by the benchmarking assessment, which did not reveal discernable changes in grid performance.

Looking forward, the expert panel agreed that REV will encourage greater decentralization of the grid, and result in a corresponding increase in smart grid investment. In particular, the panelists believed that certain key smart grid technologies will become more widespread in the next few years, most notably distributed storage and AMI. As emphasized by the experts, NYSERDA's Smart Grid program can both contribute to and build on these broader market developments by increasing system efficiency, increasing DER penetration, and reducing the frequency and duration of outages. However, as noted in the previous section, additional workforce development and consumer education will be required before New York State can achieve widespread grid performance benefits.

Potential Metrics

One focus of this market characterization is to support the identification of appropriate market metrics for evaluating the Smart Grid program's progress over time. Unlike programs that focus on the commercialization or deployment of specific technologies, the long-term objectives of NYSERDA's Smart Grid program are directly linked to broader market shifts and overall improvements in grid performance. These outcomes are likely to manifest over a longer period of time and at a state level, and involve a mix of technology and policy solutions.

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[24] DOE, 2015. (61)

[25] Ibid. (58)

To capture and identify changes related to the Smart Grid program, then, the program will likely require a suite of metrics that include:

- Long-term market development and grid performance indicators;

- Short-term "leading indicators" of likely success; and

- Metrics that identify and highlight the specific role of NYSERDA-related efforts.

Attributing changes in the smart grid and electricity markets directly to NYSERDA's program is particularly challenging. External factors – such as R&D support from non-NYSERDA organizations, policy changes (e.g., REV), or advances in complementary markets (e.g., software development) – can affect outcomes and confound efforts to isolate impacts. The expert panel confirmed that attribution will be difficult given the broad scope of smart grid efforts, and recommended use of multiple, related metrics to examine each outcome and correct for, or document, confounding trends and developments.

For example:

- Direct program metrics or short-term impacts can be used as "leading indicators" to document specific progress and achievements related to the Smart Grid program's activities and contributions. Examples could include:

    o The number of dynamic management tools successfully demonstrated as part of the program.

    o The number of technologies enabling system condition prediction and restoration installed and used by utilities following successful testing of the technology through the program.

- Related long-term metrics can document the extent of overall progress toward the program's desired outcomes to ensure that program activities are part of a measurable effect. Examples could include:

    o Improvements in grid efficiency, as measured by an increase in load factor.

    o Reductions in outage frequency and duration, as measured by standard reliability indices.

Phasor measurement units (PMUs) illustrate the program's evaluation challenges clearly. In 2010 and again in 2012, the Smart Grid program worked with the New York Power Authority (NYPA) to demonstrate the use of PMUs for grid reliability and efficiency. PMUs allow grid managers to assess system conditions such as voltage and frequency in real time, increasing the amount of power that can safely move through transmission lines. The use of PMUs can therefore lead to decreases in transmission congestion and reductions in widespread power outages. An evaluation of the impacts of NYSERDA's PMU demonstrations might consider:

- Short-term market adoption impacts: the number of PMUs in use across the state and the percent of the transmission system covered.

- Long-term performance impacts: changes in transmission congestion and the frequency of widespread power outages after installation of the PMUs.

- NYSERDA's role: NYSERDA's influence, according to NYPA and other utilities that installed PMUs, and external market trends, such as NYISO's receipt of ARRA funding for PMU installations in 2011.[26]

As illustrated in this example, multiple lines of evidence can strengthen NYSERDA's conclusions regarding its role in smart grid market development, even when causality cannot be definitively determined.

Targeted benchmarking, either to document overall market transformation and grid performance or to consider specific market features such as adoption of key technologies, may also be important in documenting the impacts of the Smart Grid program. Because changes in grid performance will require widespread market adoption of smart grid technologies and strategies, they cannot be evaluated at a project level; benchmarking can therefore help identify ways in which New York is leading other markets, as well as market barriers and opportunities that remain. Other methods that could be used to validate and supplement the metrics assessment include case study analysis, surveys, and interviews.

Exhibit 14 presents a complete list of evaluation metrics suggested by the expert panel and the benchmarking assessment, organized according to the long-term outcomes identified in the Smart Grid program logic models.[27] The **bolded** metrics represent those that align clearly with program goals and rely on data that are more readily available. Metrics include both leading indicators and measures of long-term success, as well as metrics that could be used to benchmark New York's progress against other states.

The exhibit also identifies:

- **Data source:** For each metric, the exhibit notes whether the metric is currently tracked using readily available data and, if so, where the data can be found.

- **Available timeframe:** The table highlights metrics with publicly available historical data that can support evaluation of trends since 2005 (the baseline year identified by the expert panel) and notes key data limitations.

- **Experts' recommendations:** Metrics with asterisks (*) were identified by at least one expert as likely to be influenced by the Smart Grid program. However, the Smart Grid program updated its logic model after the expert panel had convened; bolded metrics conform to the newer goals.

- **Metrics for further research:** Experts identified some areas where metrics are not currently defined but may be important to NYSERDA activities and could benefit from a targeted research

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[26] For more information on NYISO's PMU project, see the SmartGrid.gov project website: https://www.smartgrid.gov/project/new_york_independent_system_operator_inc_new_york_capacitorphasor_measurement_project.html.

[27] NYSERDA, March 15, 2016 Draft Smart Grid Systems – Efficiency and Performance Logic Model; NYSERDA, 2016a; and NYSERDA, 2016b.

effort to solidify their use. In particular, metrics for assessing impacts on grid security and resiliency have not been well studied to date but reflect important program and state goals.

- **Metrics not related to the program's current focus:** The experts suggested several metrics that, while related to key features of the smart grid, do not align with the specific focus areas identified by NYSERDA for emphasis under the CEF. These are categorized as "other," and may become more central if the program's focus shifts or expands over time.

When selecting metrics for evaluation, the Smart Grid program should also consider the extent to which it can align its metrics with those of other, similar programs and initiatives. For example, two experts noted that the ongoing REV planning process involves developing a set of metrics for utilities (the "utility scorecard"). Although the scorecard is still under development, NYSERDA may wish to align its evaluation metrics with those policy metrics wherever possible to ensure consistent expectations for utilities. As another example, one expert, a utility representative, pointed out that utilities are starting to think about defining and tracking grid security and could potentially inform NYSERDA's choice of metrics in this area.

Exhibit 14. Potential Evaluation Metrics for the Smart Grid Program

NYSERDA's Desired Long-Term Outcomes[1]	Potential Metrics[2]	Data Source	Available Since 2005?
Efficiency and Optimization			
Faster, less costly, and less restrictive DER interconnection process, and increased DER penetration	**Ratio of distributed generation to total generation**	**EIA data**	**No; available since 2007**
Development of a dynamically managed grid	Accuracy of system models*	Not currently tracked	No
	Proxy for ability to manage distribution assets: Number or percentage of customers participating in energy markets*	**EIA data**	**Yes**
	Proxy for ability to manage distribution assets: Percentage of price- and time-responsive customers (benchmarking)	**EIA data**	**Yes**
	Proxy for ability to integrate DER at scale: smart meter deployment (benchmarking)	**EIA data**	**No; available since 2007**
Other efficiency and optimization outcomes	Ratio of peak to average electricity prices, and/or load factor	NYISO data (locational-based marginal prices (LBMPs), load)	Yes
	Transmission and distribution losses	Could be approximated by NYISO data on LBMPs (loss component); possibly in utility Implementation Plans required to be filed annually under REV	Yes
	Congestion costs*	NYISO LBMP data (congestion component)	Yes
	Proxy for transmission limitations: Uplift payments	Historical data available in studies using aggregated NYISO data; otherwise not available	No; available only in studies using aggregated NYISO data since 2009
	Duration of >90% transmission line loading	Not currently tracked	No

NYSERDA's Desired Long-Term Outcomes[1]	Potential Metrics[2]	Data Source	Available Since 2005?
Reliability			
Improved system condition prediction and reduced outages	**System Average Interruption Duration Index (SAIDI), System Average Interruption Frequency Index (SAIFI)***	**DPS annual reliability reports**	**Yes**
	Customer Average Interruption Duration Index (CAIDI), Customer Average Interruption Frequency Index (CAIFI)	DPS annual reliability reports (CAIDI) and EIA Annual Disturbance Events Archive (CAIFI)	Yes
	Loss of Load Probability (LOLP) or Loss of Load Expectation (LOLE)	Because NYSRC requires LOLP (or LOLE) not to exceed 0.1 days/year, the system is designed around that criterion and, as a result, this is not likely to be a particularly meaningful metric.	Yes, although this metric is not recommended for evaluation because the value is set by NYSRC
	Momentary outages and power quality disturbances	Not currently tracked	No
Faster and more effective service restoration	**SAIDI, SAIFI***	**DPS annual reliability reports**	**Yes**
	CAIDI, CAIFI	DPS annual reliability reports (CAIDI) and EIA Annual Disturbance Events Archive (CAIFI)	Yes
	Cost of interruptions and power quality disturbances	Not currently tracked	No
	Power outage duration and customers affected (benchmarking)	**EIA Annual Disturbance Events Archive**	**Yes**
Resiliency			
Panel agreed that development of resiliency metrics should be separate research effort			
Improved ability to withstand and recover from major outages	**Number of program-supported microgrid installations and replications**	**NYSERDA R&D metrics database and evaluation surveys**	**Yes**
	Number and scale of new storage projects (benchmarking)	**DOE Energy Storage Database**	**Yes**
Other resiliency outcomes	Percent of system with "resilient" equipment (i.e., system readiness)	Not currently tracked--could be measured through evaluation surveys	No; would require evaluation surveys
	Customer satisfaction with resiliency	Not currently tracked--could be measured through evaluation surveys	No; not able to assess historical trends

NYSERDA's Desired Long-Term Outcomes[1]	Potential Metrics[2]	Data Source	Available Since 2005?
Direct Program Contributions			
Projects initiated and completed	**Dollars invested and leveraged***	**NYSERDA R&D metrics database and evaluation surveys**	**Yes**
Increased knowledge sharing and identification of technology and research gaps	**Knowledge and expertise developed in New York State***	**Evaluation surveys**	**No; would require evaluation surveys**
Other: Environmental Performance			
Other environmental performance outcomes	Emissions per kWh delivered	EIA data on state-level emissions and generation	Yes
	Ratio of renewable generation to total generation	EIA data	Yes
	Frequency of curtailment actions*	Historical data available in studies using aggregated NYISO data; otherwise not available	No; available only in studies using aggregated NYISO data since 2009
Other: Security			
Panel agreed that development of security metrics should be separate research effort			
Other security outcomes	Proxy for security of energy supply: Number or percentage of consumers participating in energy markets (e.g., use of smart meters, load management participation, use of distributed generation or storage)*	EIA data on demand-responsive program participation, smart meter deployment, state-level capacity and generation	Yes; load management participation is available since 2005, but all other metrics are available since 2007
	Proxy for security of energy supply: Ratio of distributed generation to total generation	EIA data on state-level capacity and generation	No; available since 2007
Other: Technology Adoption			
Other technology adoption outcomes	Number of devices deployed or percentage of system using devices (e.g., fiber for advanced communication, voltage optimization, feeders to isolate outages)*	Program-supported installations should be in NYSERDA R&D metrics database; replications could be assessed during impact evaluation	Yes

Notes:
1. Long-term outcomes were initially identified from the March 15, 2016, draft of the Smart Grid Systems – Efficiency and Performance logic model and the Grid Modernization – Phase 1: DER Interconnection logic model released as part of NYSERDA's April 29, 2016, CEF Investment Plan. NYSERDA subsequently revised its desired outcomes in the August 1, 2016, CEF Investment Plan; this table was updated to ensure consistency in content, although the language used to describe the outcomes may differ.
2. **Bolded** metrics represent those that align clearly with program goals and rely on data that are more readily available. Metrics with asterisks (*) were identified by at least one expert as likely to be influenced by the Smart Grid program; these may not align with the bolded metrics due to changes in the Smart Grid program logic model after conclusion of the expert panel.

Section 7. Conclusion

The expert panel, benchmarking assessment, inventory workshop, and multiple public-sector reports consulted for this evaluation converge on the following conclusions:

- The smart grid market is still relatively young and evolving, both in New York State and nationally.

  - Initial efforts on smart grid development began around 2005, with widespread implementation taking off after 2010 (e.g., PMUs, distributed storage).

  - Grid-level impacts are still emerging, but several widely-tracked metrics are beginning to show changes in grid performance consistent with adoption of smart grid technologies and strategies.

  - Much of the market potential for adoption of smart grid technologies and strategies is at the grid-level, and will require the involvement of many stakeholders, including utilities, regulators, and technology developers.

- Several key challenges to market development remain, including:

  - System testing and data collection to demonstrate the value of smart grid technologies and strategies and facilitate larger-scale adoption;

  - Utility engagement;

  - Utility workforce development;

  - Knowledge sharing to promote replication; and

  - Communication of the value of smart grid technologies and strategies to potential customers (both utilities and ratepayers).

- NYSERDA is well positioned to act as a catalyst for the emerging smart grid market, by:

  - Encouraging testing and validation of emerging technologies to help demonstrate benefits to regulators, investors, and customers;

  - Supporting development of training tools and curricula for the next-generation utility workforce, to establish smart grid leadership and expertise in New York;

  - Supporting R&D efforts that will reduce risk and validate the benefits of key smart grid technologies and strategies; and

  - Facilitating increased coordination and knowledge sharing among market actors.

As confirmed by the expert panel, NYSERDA's work to date has begun to establish smart grid expertise in New York, but key gaps and barriers remain. In particular, the panel noted that one of the greatest remaining technical barriers to smart grid development is the interconnection between DER, the distribution system, and the transmission system. The Smart Grid program's initial focus on reducing DER interconnection costs is well-targeted to help address these issues. Overall, the Smart Grid program is likely to play an increasingly important role in the context of REV and New York's ambitious energy and environmental policy goals, since, as several experts concluded, "REV cannot be implemented without smart grid."

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