Smart Grid Program:

Market Characterization and Evaluation Baseline Appendices

Final

Prepared For:

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Appendix A. Expert Panel Summary

IEc

MEMORANDUM | December 18, 2015

TO Jennifer Phelps, NYSERDA

FROM Claire Santoro, Grace Lambert, and Cynthia Manson, IEc

SUBJECT Summary of Results from the Smart Grid Market Characterization Panel

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INTRODUCTION

The New York State Energy Research and Development Authority's (NYSERDA) Smart Grid program aims to accelerate the market readiness of new and emerging technologies and strategies to improve the reliability, efficiency, security, resiliency, and overall performance of New York State's electric power delivery system.[1] To support subsequent impact evaluations of NYSERDA's Smart Grid programming under both the recent Technology & Market Development (T&MD) initiative and the proposed Clean Energy Fund (CEF), Industrial Economics, Incorporated (IEc) is working with NYSERDA to characterize the market for smart grid development in New York State. The primary goal of the market characterization analysis (MCA) is to identify a reasonable baseline scenario for smart grid development in New York from which improvements supported by NYSERDA programming can be measured. To accomplish this, the MCA was designed to assess:

- Trends in smart grid development since the initiation of NYSERDA's Smart Grid program, both within and beyond New York State;
- The role that NYSERDA has played in that development; and
- The potential future contributions of the Smart Grid program to New York State's energy goals.

IEc is employing two primary methods of analysis to provide this information: a panel of strategic expert advisors, and a benchmarking assessment. This memorandum summarizes the results of the expert panel. The results of the benchmarking assessment are described in a separate report, and a final MCA report will integrate findings from both efforts into a comprehensive assessment.

Key features of the expert panel process include:

- The five-member panel was selected to ensure that the panel collectively included expertise on each of the key market segments involved in smart grid development in New York State: distribution, transmission, policy, and technology development.[2]

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[1] NYSERDA. 2015. "Smart Grid Systems Program" presentation. October 15, 2015.

[2] A sixth expert, a representative of distribution utility, was not able to participate fully in the panel but provided limited technical input.

- The panel process was designed to be conducted informally, thereby allowing NYSERDA the flexibility to engage with the experts as questions arose.
- Because definitions of “smart grid” vary across programs and states, IEc and NYSERDA were careful to clarify that NYSERDA defines smart grid under its T&MD program as “smart wires,” meaning that the program does not provide funding for customer-sited technologies, such as smart meters. However, IEc ultimately allowed the experts to define the relevant technologies and systems according to their market perspective. The experts’ discussion of customer-sited technologies is therefore intended to provide context for program-specific recommendations.

Additional detail on the structure and process of the panel is provided in the final section of this memorandum.

RESULTS SUMMARY

The following sections summarize the experts’ final responses to the questionnaire. Changes from the initial responses were generally limited to clarifications and elaborations, rather than substantive revisions. The discussion in this memorandum also incorporates information provided by the panelists during the webinar discussions.

MEASUREMENT AND EVALUATION

One of the primary objectives of the panel was to identify a baseline year and appropriate metrics to use in subsequent impact evaluations of NYSERDA’s Smart Grid program. The panel agreed on several points:

- **Despite some uncertainty about the timing of smart grid technology adoption, 2005 is likely to be an appropriate baseline year for evaluation**. Although the exact year when impacts of smart grid investments first became apparent is uncertain, smart grid technologies were not widely used prior to 2005, the year when NYSERDA began funding smart grid projects. One expert noted that the Northeast Blackout of 2003 likely provided the impetus for the current focus on smart grid development. However, due to lags in utility planning and investment cycles, technologies introduced after the 2003 blackout may not have been widely adopted – and therefore are unlikely to have significantly affected grid performance – prior to 2005. Two other experts suggested that smart grid technologies likely only began having visible impacts on grid performance in the last few years.
- **Certain aspects of smart grid development, including grid efficiency, reliability, and environmental performance, can be measured using currently available data.** For example, the experts suggested that congestion costs and uplift payments could be useful metrics for assessing the impacts of NYSERDA’s program on grid efficiency; SAIDI[3] and SAIFI[4] are appropriate reliability metrics; and the frequency of curtailment actions is an appropriate metric for renewables integration, as a proxy for the grid’s environmental performance. In addition, two

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[3] System Average Interruption Duration Index

[4] System Average Interruption Frequency Index

experts noted that the ongoing planning process for New York State's Reforming the Energy Vision (REV) initiative involves developing a set of metrics for utilities (the "utility scorecard"); wherever possible, NYSERDA should aim to align its evaluation metrics with those policy metrics.

Several recommended metrics – including congestion costs and reliability metrics – are tracked and made publicly available by the New York Independent System Operator (NYISO) for years back to 2005. The remaining two metrics – uplift payments and curtailment actions – are also tracked by the NYISO but are only made publicly available in aggregated reports extending back to 2009. In these cases, NYSERDA could adopt a 2009 baseline, which would provide almost seven years of trend data as a baseline for evaluation; given the likely time lag for technology adoption, this appears adequate. If necessary, impact evaluations could include additional metrics (e.g., installed capacity of renewable resources, electricity generation by renewable resources, state-level emissions from electricity generation) for years since 2005 to qualitatively assess earlier trends.[5]

- **Other metrics are not currently defined and could benefit from a targeted research effort coordinated by NYSERDA.** In particular, metrics for assessing impacts on grid security and resiliency have not been well studied to date. One expert, a utility representative, pointed out that utilities are starting to think about defining and tracking grid security and could inform such a research effort. Other experts suggested that the prevalence of particular technologies could be used as an indicator of system "readiness" for cybersecurity or resilience.
- **Attributing change to NYSERDA will be difficult.** The experts agreed that potential methods of attributing grid-level changes to NYSERDA's Smart Grid program – such as benchmarking, expert elicitation, or system modeling – are likely to be time-consuming, complex, and imperfect. As an alternative, the experts suggested that NYSERDA track both technology adoption metrics (e.g., number of NYSERDA-supported devices installed and used) and grid performance metrics, or focus on providing anecdotal, case study support for the program's successes.

The experts also considered the potential long-term effects of NYSERDA's program, both within and beyond New York State. Overall, the panel agreed that the program and smart grid more generally are *critical enablers* of New York State's energy goals. NYSERDA's Smart Grid program can, for example, support increased penetration of distributed energy resources (DER), helping New York meet its grid performance and environmental goals. The Smart Grid program can also help reduce the frequency and duration of outages.

However, the experts agreed that additional workforce development and consumer education will be required before New York State can achieve these types of benefits. As one expert concluded: "REV cannot be implemented without smart grid." These issues

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[5] Historical NYSERDA program data may be more difficult to obtain than grid-level data in some cases. For example, NYSERDA's R&D metrics database does not generally include project data prior to 2008. Data availability at both the program and state levels should therefore be considered when designing impact evaluations.

should be factored into measurement, either as part of programs that address them or as external factors that may affect success of other efforts.

The experts also noted that, in many cases, smart grid development in New York is hindered by the lack of economic drivers for investment and by funding limitations that require utilities to choose between “traditional” grid investments (e.g., poles, wires) and smart grid investment. It will be important to consider these factors in both designing and measuring the impacts of NYSERDA efforts. Regardless, the panel believed that the research resulting from NYSERDA’s Smart Grid program is laying a strong foundation for smart grid development and that NYSERDA has advanced smart grid knowledge and expertise in New York State.

Opinions on the potential for spillover or replication effects outside of New York State, however, differed among experts. One expert suggested that these types of effects are likely due to the research focus of NYSERDA’s projects to date; another suggested that the ambitious nature of REV could increase attention from other states (“There are a lot of eyes on the State of New York”). Two experts noted that NYSERDA’s projects would likely result in replication effects due to interactions between the New York Independent System Operator (NYISO), PJM, and ISO-New England markets. These experts noted that transmission organizations already routinely share information with each other about best practices, and that existing organizations formed in part for information-sharing purposes, such as the North American Electric Reliability Corporation (NERC), could be instrumental in helping NYSERDA start conversations among key market actors regarding successful smart grid practices and strategies. In contrast, one expert suggested that replication effects are unlikely because New York lags behind other, comparable states in key aspects of smart grid development (e.g., smart meter deployment, grid automation). In general, the experts believed that replication effects are unlikely to occur in the short term due to time lags in market adoption, and were not aware of replications already occurring.

TRENDS IN SMART GRID DEVELOPMENT

The experts also considered broad trends in smart grid development since the initiation of NYSERDA’s Smart Grid program in 2005, both within and beyond New York State. The information provided by the experts focused on:

- The level of support provided by policies and planning decisions,
- Trends in the development of smart grid technologies and services, and
- The role that NYSERDA has played in that development.

Policy Support

In general, the panel believed that national policies and programs, particularly those of the United States Department of Energy (DOE), have encouraged smart grid development in recent years. One expert noted that this support has typically been in the form of research efforts rather than funding for widespread technology deployment. Many of the experts, however, emphasized the substantial financial support provided by the American Recovery and Reinvestment Act of 2009 (ARRA). More specifically, ARRA’s funding enabled DOE to implement Title XIII of the Energy Independence Security Act of 2007

(EISA). EISA provided the initial legislative backing for DOE’s smart grid work, including authorizing two large smart grid initiatives: the Smart Grid Investment Grant (SGIG) Program, and the Smart Grid Demonstration Program (SGDP). The experts emphasized that these initiatives contributed crucial support for advancing smart grid development.

At the state level, the experts identified REV as a key driver for smart grid development. The panel agreed that REV will encourage and support smart grid expansion through its emphasis on greater decentralization of the grid. One panel member predicted that investments in the smart grid will increase substantially over the next 10 years as the state strives to meet REV’s requirements. Another expert elaborated: “REV is resulting in a focus on the importance of a smart distribution system, and this should result in investments that support advancements in the planning, design, and operation of the distribution system.” In contrast, one expert – while agreeing that REV’s objectives are likely to encourage smart grid development – highlighted several short-term challenges associated with REV that have the potential to affect the market for smart grid technologies. This 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.”

Technology Development

Since 2005, there has been tremendous progress in smart grid technology development. The panel provided more than 25 examples of smart grid technologies and services that have been developed or implemented in New York during that time. Some recurring examples included: advanced monitoring and communications equipment, including advanced metering infrastructure (AMI); distributed energy generation and storage; cybersecurity systems; power system automation; microgrids; and advanced system modeling.[6]

The experts noted, however, that many of these technologies remain underdeveloped or underused in New York State, though they may be more widely used elsewhere. Recurring examples of underdeveloped or underused technologies included: customer-side technologies and services (e.g., DER, demand response, microgrids); communications standards and infrastructure; AMI; system automation; and advanced modeling.

Similarly, when asked to compare the status of smart grid development in New York to other states, the panel agreed that New York lags behind other states in the deployment of many key technologies. For example, the experts noted that various aspects of smart grid development - including the integration of distributed generation, AMI installation, and

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[6] 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 and drivers of a fully operational smart grid. To ensure successful implementation of the smart grid, NYSERDA’s Smart Grid program should therefore coordinate closely with the Public Service Commission (PSC) and other NYSERDA programs responsible for implementing these types of technologies.

power system automation - are relatively more developed in states such as California, Hawaii, Arizona, and New Jersey (distributed generation penetration); and Maine (AMI deployment and power system automation). One expert was careful to note, however, that much of this deployment has resulted from state-level policy decisions prioritizing funding for these particular technologies. As this expert noted, “This [lag] is not to say that NYSERDA didn’t do their job, just that access to capital makes a difference.”

NYSERDA’s Role

NYSERDA is only one of many stakeholders supporting the research and development of smart grid technologies in New York State. Accordingly, the information provided by the experts considered the role NYSERDA has played in the smart grid developments described in the previous section, as well as areas of potential coordination with other key stakeholders.

The experts suggested that, from their perspectives, NYSERDA tends to support a broader scope of technologies than similar organizations. Several experts also highlighted NYSERDA’s support for early-stage research and development and technology testing and validation; these experts noted that NYSERDA’s research focus has likely led to the development of significant smart grid expertise in New York State. In contrast, 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.

In addition to NYSERDA, the experts recognized more than 15 other agencies and organizations contributing to advancing smart grid development, including DOE and its national labs, the Electric Power Research Institute (EPRI), NERC, NYISO, and the New York State Public Service Commission (PSC), among others. The panel conveyed the roles of these key organizations as follows:

- As described previously, **DOE and its national labs** contribute substantial research and financial support to national smart grid development, including through the SGIG and SGDP initiatives.
- Similarly, **EPRI** has significantly advanced smart grid development across the country through technology research, development, and demonstration.
- **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.
- **PSC** provides regulatory support for various smart grid proposals and projects.

Despite the large number of organizations concurrently working on smart grid research and development, 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.

KEY BARRIERS TO SMART GRID DEVELOPMENT

Throughout the discussions, the panel identified several key barriers to smart grid development. Of these, the two most significant barriers were:

- The need for a workforce with appropriate smart grid expertise, and
- The lack of a business case for investment.

In terms of workforce development, the experts agreed that smart grid implementation will require a highly trained 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 successful operation of the smart grid.

The experts also provided several examples of workforce development initiatives taking place at the national and local levels. As one example, DOE recently launched the Grid Engineering for Accelerating Renewable Energy Deployment (GEARED) program, which supports increased power system research and development while simultaneously increasing the expertise of utility professionals working with DER. As part of GEARED, EPRI organized a group called GridEd that includes Clarkson University in New York and will develop training materials and curricula, and will lead courses for electricity industry professionals. Another expert highlighted the GridSTAR training center, which is located in Philadelphia and run by Pennsylvania State University. The GridSTAR center uses funding from DOE to serve "as an education and research resource for Smart Grid technologies, policy and business practices."[7] Another panel member noted that the New York Power Authority (NYPA) has engaged in internal workforce development discussions for western New York, but has not yet conducted any activity.

A second critical barrier to smart grid development is the lack of a business case for investment. Importantly, the experts noted that the market for smart grid technologies 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. As the experts noted, NYSERDA-funded demonstrations have not necessarily led to widespread market adoption by either segment.

The experts provided several possible explanations for this:

- **Data limitations**: Given that most smart grid technologies are novel and evolving, regulators do not always have sufficient data to understand a technology's effect on grid performance. As a result, utility cost recovery options for smart grid investments remain uncertain, and the value of customer-sited technologies can be difficult to communicate to ratepayers.

  The utility representatives on the panel also noted that the lack of a streamlined cost recovery process is particularly problematic given the PSC's emphasis on improving services for low- to moderate-income (LMI) customers. Because the private sector generally does not focus on LMI customers, utilities tend to be the "provider of last resort" for affordable energy services. The experts identified this

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[7] GridSTAR (2015). "Our Mission." Accessed at: https://smartenergyacademy.psu.edu/gridstar/mission.

as one area in particular where better data and streamlined policies could help New York State better achieve its energy goals.

- **Recent shifts in market focus**: A few experts noted that the smart grid market has seen a recent shift from utility-focused to customer-focused technologies and systems. In the past, utilities had research and development departments that encouraged utility-scale investment. With these efforts now led by agencies such as NYSERDA, these experts expressed concern that utilities may not have personnel that are able to work with, troubleshoot, and understand the new technologies and systems. The experts emphasized that workforce development has the potential to increase utilities' comfort level with new technologies, thus helping build a business case for investment.

  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**: The panel generally agreed that DER integration is a key economic driver for smart grid, but that DER adoption in New York lags behind other states. Efforts to increase smart grid investment and DER investment should therefore be closely aligned.

- **Need for peak load management**: The experts noted that the current need for peak load management in New York State does not require widespread smart grid investment. As New York's needs change – perhaps due to policies such as REV – new economic drivers for smart grid could appear.

PRIORITIES FOR PROGRAM FOCUS

Finally, 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;**
- **Technology barriers that will become increasingly important under REV**, including DER integration, communications infrastructure, and interoperability standards;
- **Business development support** for funding recipients to help increase market adoption of smart grid technologies; and
- **Workforce development.**

Testing and Validation

Although several experts emphasized the need for system testing and validation, one expert offered the additional suggestion that NYSERDA establish a dedicated testing facility rather than providing funding only. This expert noted that several existing testing centers have been shown to be effective means of testing technologies and systems under real-world environmental conditions. These include the EPRI Power Delivery Laboratory in Lenox, Massachusetts, and several research centers run by EDF, a French utility. In addition to its research centers, EDF recently announced the launch of its Smart Substations Project, which involves real-world trials of smart substation technologies intended to support the expansion of renewable generation and improvements in cybersecurity.[8]

Technology Barriers

As the experts noted, certain technologies and barriers will increase in importance due to REV. In particular, 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. Other barriers highlighted by the experts included the need for widespread communications infrastructure, technology interoperability standards, and technologies to address customers' security and privacy concerns.

Business Development

As described in the previous section, the experts noted that NYSERDA's research and demonstration efforts have not, to date, resulted in widespread market adoption. One expert suggested that NYSERDA could build on its product development work by providing business development support for funding recipients. This type of support could help organizations better communicate the value of their technologies to utilities and/or ratepayers.

Workforce Development

The previous section summarized the experts' concerns regarding the need for a highly trained workforce with increased expertise in software, modeling, and data analytics. The experts generally believed that NYSERDA could play an important role in helping universities, utilities, and other partners develop appropriate training courses and curricula. The experts emphasized that, without increased workforce development, New York cannot achieve the types of changes called for by REV.

PANEL PROCESS

As noted above, the five-member expert panel was selected to ensure that the panel collectively included expertise on each of the key market segments involved in smart grid development in New York State. The final selected panel (see Exhibit 1 below) 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. 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.

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[8] Alstom (2015). "Launch of Smart Substations Project, a World First in the Field of Smart Grids." Accessed at: http://www.alstom.com/press-centre/2013/6/launch-of-smart-substations-project-a-world-first-in-the-field-of-smart-grids/.

EXHIBIT 1. FINAL EXPERT PANEL

AREA OF EXPERTISE	EXPERT NAME AND AFFILIATION
Transmission	**Alan Ettlinger** New York Power Authority (NYPA) Manager – Research, Technology and Development
	Dejan Sobajic Grid Engineering LLC Contractor to the New York Independent System Operator (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.

The panel process was designed to be conducted informally so that NYSERDA could engage with the experts throughout. The process consisted of two rounds of solicitations, conducted via a written questionnaire and collaborative discussions. The process is summarized below:

- **Kickoff Call:** To begin, the experts each participated in one of two kickoff calls with IEc and NYSERDA, conducted via webinar. IEc used the calls to clarify the process, answer any questions, and ensure that all experts received the questionnaire and background materials.
- **Individual Responses:** During the first round, the experts completed the questionnaire individually, drawing on reference materials provided by IEc, their individual expertise, and any other resources that they considered relevant.
- **Initial Response Summary:** IEc compiled and summarized the experts' individual responses and communicated the aggregated, anonymous results back to the panel. The summary included the primary justifications provided for each question, allowing each expert to understand how their individual responses compared to the overall results.
- **Collaborative Discussion:** During the second round, each expert participated in one of two webinar discussions with NYSERDA and IEc. The collaborative process allowed the experts to discuss their rationale in responding to each question and to share information but was not intended to achieve consensus

around a set of collective responses from the group. Although all experts were not able to attend a single webinar due to scheduling constraints, detailed call notes were distributed to the panel after each webinar.

- **Final Responses:** Following the discussion, the experts had the opportunity to revise their initial responses based on new or additional information. At this time, IEc also asked individual experts to clarify or elaborate on particular questions, as necessary.

Appendix B. Expert Panel Questionnaire

Expert Panel Questionnaire:
Market Characterization and Baseline Assessment of Smart Grid Development in New York State

Industrial Economics, Inc. (IEc) is assisting the New York State Energy Research and Development Authority (NYSERDA) with characterizing the market for smart grid development in New York State and identifying a reasonable baseline scenario from which improvements supported by NYSERDA programming can be measured. To accomplish this, IEc has assembled an expert panel to provide information on:

- Trends in smart grid development since the initiation of NYSERDA's Smart Grid program, both within and beyond New York State;
- The role that NYSERDA has played in that development; and
- The potential future contributions of the Smart Grid program to New York State's energy goals.

This information will be used to inform data collection and methods to measure the impact of NYSERDA's Smart Grid research and development program under both NYSERDA's previous funding cycle (T&MD) and the newly-proposed Clean Energy Fund (CEF), which is scheduled to begin in 2016. In addition, your participation in this panel will be invaluable as NYSERDA contemplates the design and focus of its Smart Grid program under the CEF.

The objective of this panel is to solicit insight from subject-matter experts regarding the topics above. Please complete the following questionnaire individually, drawing on reference materials provided by IEc, your individual expertise, and any other resources you consider relevant.

After receiving your initial responses, IEc will compile and summarize the responses from all experts and will share the aggregated, anonymous results with the panel. The process will then involve a teleconference at which you will have the opportunity to discuss divergent views and share information with other members of the panel. The goal of this discussion is not to achieve consensus around a set of collective responses from the group; instead, the process seeks to ensure that each individual provides thoughtful judgments that are informed by the best available information. Following the discussion, you may, if desired, revise your responses to this questionnaire based on new or additional information.

Instructions: Please complete the following questionnaire individually, drawing on reference materials provided by IEc, your individual expertise, and any other resources you consider relevant. Please be sure to provide discussion of your rationale in each response. Please email your completed questionnaire to Claire Santoro (csantoro@indecon.com) by September 14, 2015.

You may contact IEc staff (Claire Santoro, 617-354-0074, csantoro@indecon.com, or Cynthia Manson, 617-354-0074, cjm@indecon.com) if you have questions at any time during this process.

Assessment of New York State's Current Smart Grid

1. **What smart grid technologies/services have been developed or implemented in New York State since 2005 (assumed to be the first year that NYSERDA funded smart grid-related projects)? Please describe the development of the smart grid market since 2005.**

2. **How have utility and governmental policies/planning decisions addressed or supported smart grid development since 2005?**

    a. **Within New York State:**

    b. **Beyond New York State:**

3. **What are the most significant barriers to smart grid development in New York State? These could be policy, technological, financial, or other barriers.**

4. **What underdeveloped or underused smart grid technologies/services are essential for New York State to reach its long-term energy goals (i.e., improved system-wide efficiency, increased fuel and resource diversity, improved reliability and resiliency, 80% reduction of carbon emissions by 2050)?**

- **Please rate your familiarity with the issues and research relevant to the questions in this section. Please use a scale of 1 to 5, with 1 representing a low degree of familiarity, 3 a moderate degree of familiarity, and 5 a high degree of familiarity.**

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- **What information – including studies, research findings, data, or reports, among other sources – was most influential in informing your views? Please provide citations below, or, if possible, provide us with a copy of the resource.**

NYSERDA's Role in Smart Grid Development

5. **In contrast to other programs, utilities, or organizations, what are the key characteristics of smart grid projects supported by NYSERDA?**
6. **What external initiatives, such as those carried out by utilities or DOE, contribute to advancing smart grid development?**
7. **How does the market adoption of smart grid technologies or the consideration of smart grid in planning decisions in New York State compare to other states?**
8. **Consider what you assume to be the likely trajectory of future smart grid development in New York State.**
    a. **Please describe this trajectory:**
    b. **To what extent can NYSERDA influence this trajectory?**
9. **What are the most significant barriers to smart grid development that NYSERDA could reasonably expect to address? In other words, where should NYSERDA focus its efforts to best support smart grid development?**
    a. **In the short term:**
    b. **In the long term:**
10. **What barriers could affect NYSERDA's ability to effectively support smart grid development?**
    a. **In the short term:**
    b. **In the long term:**

Please rate your familiarity with the issues and research relevant to the questions in this section. Please use a scale of 1 to 5, with 1 representing a low degree of familiarity, 3 a moderate degree of familiarity, and 5 a high degree of familiarity.

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- **What information – including studies, research findings, data, or reports, among other sources – was most influential in informing your views? Please provide citations below, or, if possible, provide us with a copy of the resource.**

Potential of the NYSERDA Smart Grid Program to Achieve State-wide Goals

11. What indicators (metrics) can be used to track smart grid development in New York State over time? In particular, what metrics can best measure grid efficiency, reliability, security, and resiliency?

   a. Where can we find data on these metrics (e.g., NYISO, utilities, etc.)? Please be as specific as possible to facilitate data collection.

12. Of the metrics you identified in Question 11, which would you expect NYSERDA smart grid projects to influence the most? That is, which metrics will provide the most meaningful information about the program's success and should therefore be tracked over time?

   a. In what year – or range of years, depending on your level of certainty – did NYSERDA's smart grid projects likely begin to influence these metrics (i.e., what year should serve as the baseline for NYSERDA's smart grid development efforts)? For reference, assume that NYSERDA began funding smart grid-related projects in 2005. We suspect, however, that benefits may lag behind project implementation for many smart grid projects due to factors such as the length of utility planning and investment cycles.

13. Consider the metrics you identified in Question 12.

   a. How have their values changed since the baseline year(s) you proposed in Question 12a?

   b. How would their values likely have changed if NYSERDA had not implemented its Smart Grid program (i.e., the business-as-usual scenario)?

   c. What methodology could be used to determine the change attributable to NYSERDA's Smart Grid program?

14. Is NYSERDA's Smart Grid program likely to influence grid-related metrics outside of New York State (due to the regional nature of many utilities operating in New York State, for example)? If so, please describe the effects you would expect to see.

15. Consider New York State's long-term energy goals (i.e., improved system-wide efficiency, increased fuel and resource diversity, improved reliability and resiliency, 80% reduction of carbon emissions by 2050). What progress can smart grid development (including both NYSERDA and non-NYSERDA efforts) reasonably contribute toward these goals?

   a. How much of that progress could reasonably result from the NYSERDA Smart Grid program?

- **Please rate your familiarity with the issues and research relevant to the questions in this section. Please use a scale of 1 to 5, with 1 representing a low degree of familiarity, 3 a moderate degree of familiarity, and 5 a high degree of familiarity.**

    - o

- **What information – including studies, research findings, data, or reports, among other sources – was most influential in informing your views? Please provide citations below, or, if possible, provide us with a copy of the resource.**

Appendix C. Benchmarking Assessment

SMART GRID PROGRAM:
BENCHMARKING ASSESSMENT

Final

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Abstract

To establish a baseline for subsequent impact evaluation of the New York State Energy Research and Development Authority's (NYSERDA) Smart Grid program, Industrial Economics, Inc. (IEc), with principal investigators Dr. Paulina Jaramillo and Dr. Eric Hittinger, conducted a benchmarking assessment of smart grid development in New York State compared to three other states comparable in energy policies, location, or size (California, Massachusetts, and Pennsylvania). The assessment reviewed state-level data on six metrics: (1) load management potential and deployment, (2) number of customers participating in load management programs, (3) installed distributed generation capacity, (4) number of smart meters deployed, (5) installed storage capacity, and (6) number and scale of power outage events.

The results of the assessment show that New York is leading similar states in some metrics, such as outage duration, but falling behind in others, such as load management and distributed generation. Direct comparisons can be misleading in some cases, however, due to the differing circumstances and policy goals of each state.

The assessment also indicates that some metrics are more useful for tracking state-level smart grid development than others. The most useful and clear metrics, which NYSERDA should consider tracking into the future, are: (1) power outage duration and customers affected, (2) number and scale of new energy storage projects, (3) number and percentage of price- and time-responsive customers, and (4) smart meter deployment. These metrics can be tracked using reliable and consistent data, are generally comparable across states, and indicate important trends relating to smart grid success.

Key words: smart grid, benchmarking assessment, load management, distributed generation, storage, outage

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Acronyms and Abbreviations

AMI	Advanced Metering Infrastructure, conventionally known as “smart meters”
CEF	Clean Energy Fund
DOE	U.S. Department of Energy
DSM	Demand Side Management
EIA	U.S. Energy Information Administration
FERC	Federal Energy Regulatory Commission
IEc	Industrial Economics, Inc.
NERC	North American Electric Reliability Corporation
NYISO	New York Independent System Operator
NYSERDA	New York State Energy Research and Development Authority
PSC	Public Service Commission
PUC	Public Utilities Commission
PV	Photovoltaic
REV	Reforming the Energy Vision
T&MD	Technology and Market Development

1 Introduction

As part of the New York State Energy Research and Development Authority's (NYSERDA) Technology and Market Development (T&MD) Power Supply and Delivery initiative, NYSERDA's Smart Grid program aims to accelerate the market readiness of new and emerging technologies and strategies to improve the reliability, efficiency, security, resiliency, and overall performance of New York State's electric power delivery system.[1] Currently, the Smart Grid program focuses on supporting technologies such as: grid-scale energy storage; transmission and distribution automation and management; renewable and distributed energy integration; advanced monitoring and controls; advanced sensors, devices and systems; microgrids; advanced cables and conductors; and advanced system modeling and applications. The T&MD program will be replaced by a similar smart grid program under the Clean Energy Fund (CEF) in 2016.

To characterize the market for smart grid technologies in New York State and to establish a baseline for subsequent impact evaluation of NYSERDA's Smart Grid program, Industrial Economics, Inc. (IEc) has undertaken two efforts: (1) conducting a benchmarking assessment, and (2) convening a panel of strategic expert advisors. The benchmarking assessment, which is the focus of this report, was designed to characterize the state of smart grid development in New York State as a whole, compared to other, similar states. In contrast, the expert panel focused on identifying evaluation metrics and trends specific to smart grid development supported by NYSERDA's Smart Grid program. The results of the expert panel are summarized in a separate memorandum, and the results of the two efforts will be integrated into a third document, a comprehensive market characterization report.

The benchmarking assessment considers 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 program activities, but 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 Table 1-1 below.

Table 1-1. 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
Note: Although some metrics, such as smart meters deployed and customers participating in load management programs, are outside the scope of NYSERDA's Smart Grid program, they are good indicators of the overall state of smart grid development.

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[1] NYSERDA. 2015. "Smart Grid Systems Program" presentation. October 15, 2015.

The analysis assessed these metrics for New York and three comparison states - California, Massachusetts, and Pennsylvania – which were selected to reflect comparable energy policies, location, or size. California is a leader in electricity system innovation and development. The state has high electricity prices, a large economy, a strong public utilities commission (PUC) and regulatory environment, and several large and innovative distribution companies. California was the first state to deregulate its electricity system, and has been a leader in the deployment of many electricity technologies and concepts, such as efficiency programs, demand response, utility-scale renewables, distributed solar, energy storage, and other smart grid technologies. In many ways, California leads the nation in energy policy and is a good comparison for progressive New York policies and technological innovation. Massachusetts 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. Pennsylvania is also the center of the PJM system operator, which is the largest system operator in the U.S. and a driver of innovative market and operational policies in Pennsylvania.

The metrics in Table 1-1 could help NYSERDA to identify areas where successful smart grid deployment has taken place, as well as identify areas that may benefit from additional support. The metrics are described in additional detail below:

1. **Load management potential, deployment, and customer participation:** Industrial demand response has a long history and serves as an important safety mechanism during periods of high demand. Demand aggregators and increasingly sophisticated system dispatch and control technologies now enable participation by smaller commercial or residential entities in load management programs. Furthermore, changes taking place under New York’s Reforming the Energy Vision (REV) initiative may provide new financial incentives for sophisticated demand response businesses and systems. Increasing the amount of load that can be managed by the operator is an outcome of successful smart grid development.

2. **Distributed generation capacity:** The integration of distributed generation resources into the grid is one of the primary smart grid applications. Increased distributed generation is an outcome of successful smart grid development. Distributed generation also indicates an actual change to the way that electricity is distributed through the system, rather than denoting potential changes to the system.

3. **Number of smart meters deployed:** In New York, smart meter deployment is managed by the Public Service Commission (PSC) rather than NYSERDA's Smart Grid program. This metric is important in considering the broader New York market, however, because it indicates the readiness of customer-sited technology to take on more complex roles (e.g., residential demand response programs). Under REV, the consumer-utility relationship will change, allowing customers greater participation in electricity markets. Many forms of participation require a smart meter or similar technology.

4. **Installed storage capacity:** Energy storage is a critical system operation tool that is growing in importance. Storage provides both operational flexibility for the grid and market benefits to both utilities and customers. As smart grid integration proceeds, markets will become

increasingly complex, but storage can provide a buffer against supply/demand imbalances and volatility in market operation. Advancing deployment and operation of energy storage devices also has a competitive benefit; it will provide New York companies with experience that they can apply in other markets.

5. **Frequency and extent of power outage events:** This metric addresses the capabilities and outcomes of successful smart grid integration rather than a specific technology. Effective smart grid development should benefit New York residents and businesses. Potential and expected benefits of smart grids include lower cost, greater choice, integration of renewables, but the effect on power outages is one that relies most directly on the enhanced operational flexibility of the grid. Improving monitoring, control, dispatch, and market integration should directly reduce the frequency, extent, and/or the duration of power outages in the state.

The remainder of this report is organized as follows. Section 2 describes the data sources used in the assessment. Section 3 summarizes the data collected for New York State and the three comparison states. Section 4 contains the primary discussion and interpretation of the findings. Section 5 offers conclusions and recommendations for NYSERDA’s Smart Grid program.

2 Data Sources

Most of the values required for this benchmarking assessment are for newer or less well-reported technologies, such as energy storage, or metrics, such as distributed generation, which is not as well-tracked as traditional generation. These data are currently limited, especially when looking for accessible, high-quality datasets that NYSERDA can use to track progress over the longer term. Ideal data sources would be: (1) consistent across states and over time and (2) sufficiently robust to demonstrate reliable trends.

While some data exist at the state-level, such as New York Independent System Operator (NYISO) filings to the Federal Energy Regulatory Commission (FERC), further examination revealed discrepancies in the methods used to collect and report data that would make it difficult to use the data to reliably assess trends and patterns across states and over time. For example, some states reported residential rooftop solar as distributed generation, while others considered the same technology as a "behind the meter" net load issue. Similarly, changes in the data collection and reporting methods over time make comparing data before and after such methodological change incomparable.

Accordingly, this benchmarking assessment relies on publicly available national data sets, primarily from the U.S. Energy Information Administration (EIA), that reflect on consistent reporting requirements across the country and also over time. Specifically, this benchmarking assessment relies on three data sets: EIA Form 861,[2] EIA's Annual Disturbance Events Archive,[3] and the U.S. Department of Energy (DOE) Energy Storage Database.[4] The following sections describe these sources in more detail.

2.1 EIA Form 861

Much of the following analysis uses data collected by EIA through forms EIA-861 and EIA-861S. From EIA's description:

> *"Form EIA-861 collects information on the status of electric power industry participants involved in the generation, transmission, distribution, and sale of electric energy in the United States, its territories, and Puerto Rico. The data from this form are made available in EIA publications and databases. The data collected on this form are used to monitor the current status and trends of the electric power industry and to evaluate the future of the industry."*

EIA further says:

> *"The Form EIA-861 is to be completed by electric power industry entities including: electric utilities, all Demand Side Management (DSM) Program Managers (entities responsible for conducting or administering a DSM program), wholesale power marketers, energy service providers, and electric power producers. Responses are collected at the operating company level (not at the holding company level)."*

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[2] U.S. Energy Information Administration, 2015.

[3] U.S. Energy Information Administration, 2014.

[4] U.S. Department of Energy, 2014.

Since 2012, EIA has also provided an alternative to form EIA-861 for smaller utilities:

> *"Form EIA-861S is to be completed by all electric utilities with annual retail sales in the prior year of 100,000 megawatt-hours or less, with the following exceptions: A respondent has retail sales of unbundled service; A full set of data is required from the respondent to ensure that statistical estimates for a state, sector, and balancing authority are of acceptable quality; A respondent reports in aggregate under the Tennessee Valley Authority (TVA) or WPPI Energy; or You report on the Form EIA-826.*
>
> *Utilities for which any of the exceptions apply must complete the long version of Form EIA-861 survey. Note that respondents can only complete one type of Annual Electric Power Industry Report, either the Form EIA-861 or the Form EIA-861S, but not both. Also note that responses are collected at the business (operating) level (not at the holding company level).*
>
> *Once every five years and in lieu of the short form, all entities that normally complete the Form EIA-861S will be required to complete the Form EIA-861. This is necessary to acquire the data needed to maintain the accuracy of the statistical imputation procedure used to estimate data not collected on the Form EIA-861S. As currently scheduled this requirement will not come into play for the first time until 2017."*

This benchmarking assessment relies on EIA-861 and EIA 861s data from 2005 through 2013. While EIA provides the data for individual survey participants, data were aggregated for the states of New York, Massachusetts, California, and Pennsylvania in order to assess statewide patterns and trends in relevant data. The data used in this report are summarized in Table 2-1 below.

Table 2-1. Summary of Benchmarking Data

Metric	Description	Notes About Use
Electricity sales	File 2 of EIA-861 provides data on annual electricity sales (in MWh) to each customer class, by each utility that completed the survey.	These data are used to normalize across states.
Total consumers	File 2 of EIA-861 provides data about the number of consumers, in each customer class, served by each utility that completed the survey.	These data are used to normalize across states.
Annual load management energy effects	Reported in MWh, these data summarize the reduction in electricity demand resulting from individual utilities' load management programs, by sector (residential, commercial, industrial, other).[5]	For each year, this report includes aggregated values by customer type by state, as well as a normalized value based on total electricity sales in each state.
Annual load management potential peak reduction	Reported in MW, these data summarize the capacity that could become available during peak times as a result of load management programs. For each year, this report includes aggregated values by customer type by state.	While EIA-861 provides peak data for each utility, the utilities' peak demand may not be coincidental. Therefore, this assessment considers absolute values rather than adding peak demand across utilities in each state. Caution is necessary when comparing across states, as the size of the electricity market in the states is different.

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[5] EIA defines the "other" category "as representing electricity consumers not elsewhere classified. This category includes public street and highway lighting service, public authority service to public authorities, railroad and railway service, and interdepartmental services."

Metric	Description	Notes About Use
Annual load management actual peak reduction	Reported in MW, these data summarize the actual reduction in peak power that resulted from calling on customers to reduce their demand for electricity during peak hours.	As noted above for potential peak reduction, this assessment reports total values for actual peak reduction in this report.
Number of price-responsive customers	These data summarize the number of customers that can respond to price signals to modify electricity use patterns.	Data are normalized based on the number of consumers served in the state by all utilities included in EIA-861.
Number of time-responsive customers	These data summarize the number of customers that can modify electricity use at specific, pre-defined times.	Data are normalized based on the number of consumers served in the state by all utilities included in EIA-861.
Number of customers participating in load management programs	These data summarize the number of customers that participate in load management programs. Customers can participate in only one type of load management program, so this value is the sum of price-responsive and time-responsive customers.	Data are normalized based on the number of consumers served in the state by all utilities included in EIA-861.
Grid-connected distributed generation	Reported in MW, these data report installed distributed generation capacity. The data disaggregate capacity by generation type: internal combustion engine, combustion turbine, steam turbine, hydroelectric, wind, solar photovoltaic (PV), and other.[6] The data also include distributed storage capacity.	EIA-861 does not provide information about total installed capacity in a balancing area. Further, since the peak load of individual utilities may not be coincidental, it is not possible to add utility-specific peak values to obtain a total peak value by state. Instead, distributed generation capacity data are normalized based on the number of consumers served by all utilities in each state included in EIA-861.
Advanced metering infrastructure	These data summarize the number of customers with advanced metering infrastructure (i.e., smart meters), as well as the energy served by smart meters.	Data on the number of smart meters in each state are normalized by the number of consumers. Data on the energy served by smart meters are normalized by energy sold by all the utilities in each state.

2.2 DOE Energy Storage Database

Energy storage projects can span a variety of scales, from household-sized, customer-sited projects to large pumped hydro projects meant to support energy time-shifting over an entire region of the U.S. As previously described, EIA Form 861 includes data on distributed storage assets. To supplement EIA-861 data, this assessment also collected data on large-scale grid energy storage projects as reported in DOE’s Energy Storage Database, which may include resources such as fuel cells, municipal solid waste, or wood.

2.3 EIA Annual Disturbance Events Archive

Transmission-level power outages reflect the capabilities of smart grid technologies in two important ways. First, successful smart grid integration should lead to fewer power outages, affecting fewer customers for shorter time durations. While mitigating power outages is not the primary goal of smart grid technology, interest in the relationship between power outages and smart grid technology dates

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[6] Other distributed generation resources may include fuel cells, municipal solid waste, or wood, among others.

back to the 2003 blackout that affected tens of millions of customers in the northeastern U.S.[7] Improved monitoring and control of the transmission system provided by smart grid technology should lead to a superior capability for predicting, preventing, and responding to power outages. Second, an unacceptably high frequency of power outages demonstrates a potential need for improved smart grid technologies. However, more frequent power outages shouldn't immediately be taken as indicating poor smart grid performance and should be assessed within the context of the local electricity grid. In other words, the current level of smart grid technology is not the only cause of power outages, attributes of the local electricity grid such as unpredictable loads, overloaded transmission, and/or problematic weather patterns, also contribute to unacceptably frequent power outages.

In this analysis, power outages in New York are compared to those in Massachusetts, California, and Pennsylvania. T EIA Annual Disturbance Events Archive is a database that tracks "major disturbances" to the U.S. electricity system based on mandatory reporting from Balancing Authorities, Reliability Coordinators, and some electric utilities on Form OE-417, "Electric Emergency Incident and Disturbance Report."[8] This dataset covers all large-scale power outages in the U.S.; these are normally the result of transmission-level incidents. [9] While there are occasional gaps in the data, such as cases where a Balancing Authority reports the number of customers affected but has no estimate of total lost load, the number of affected customers is the most reliably reported information available on power outages. Where appropriate, this analysis notes instances when critical data may be missing.

This report includes several different metrics related to power outages. It is important to emphasize that none of these metrics, in isolation, tells a complete story. Outage frequency, number of affected customers, duration, and total lost load are all relevant when considering the severity of power outages in a region. For each metric, the same data are presented several ways to facilitate comparisons. Data are presented in both absolute quantities and, where possible, normalized to the size of the state. Additionally, due to the annual variability in scale and frequency of power outages, metrics are reported in both annualized and cumulative figures. Annual data are best for comparing between years, while the cumulative data allow examination of long-term trends.

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[7] Tweed, 2013; and Hoffman, 2013.

[8] U.S. Energy Information Administration, 2014.

[9] Additional details on reporting and definitions can be found in the instructions for Form OE-417 (U.S. Energy Information Administration, 2014.)

3 Results

This section summarizes the data collected for New York State and the three comparison states for each of the six metrics selected for this benchmarking assessment. This section begins by summarizing data on electricity sales and customers in each state. These data are intended to provide context for subsequent discussions on data more closely related to the state of smart grid development in New York State as a whole, compared to other, similar states. Key findings from each category of data and implications for assessing smart grid development in New York State are provided in the subsequent section (Section 4, Summary of Findings).

3.1 Electricity Sales and Customers

As noted in Section 2, EIA-861 and EIA-861S collect data for all utilities in the U.S. This report aggregates utility-level data by state. As states vary in size, population, and electricity consumption patterns, when appropriate, metrics are normalized by the total amount of electricity sold by these utilities or by the number of consumers served by utilities in the state. Figure 3-1 and Figure 3-2 summarize the data on electricity sales and number of customers, respectively. Figure 3-3 shows the same data as Figure 3-1 and Figure 3-2, but uses a common y-axis for easier comparison of absolute values across states. These data provide further context when examining other indicators that can be used to assess the development of smart grid technologies in these states.

Figure 3-1. Total Annual Electricity Sold by Customer Class

Totals are the sum of all electricity sales reported in EIA-861/EIA-861s files. Note that y-axis is different for each sub-figure.

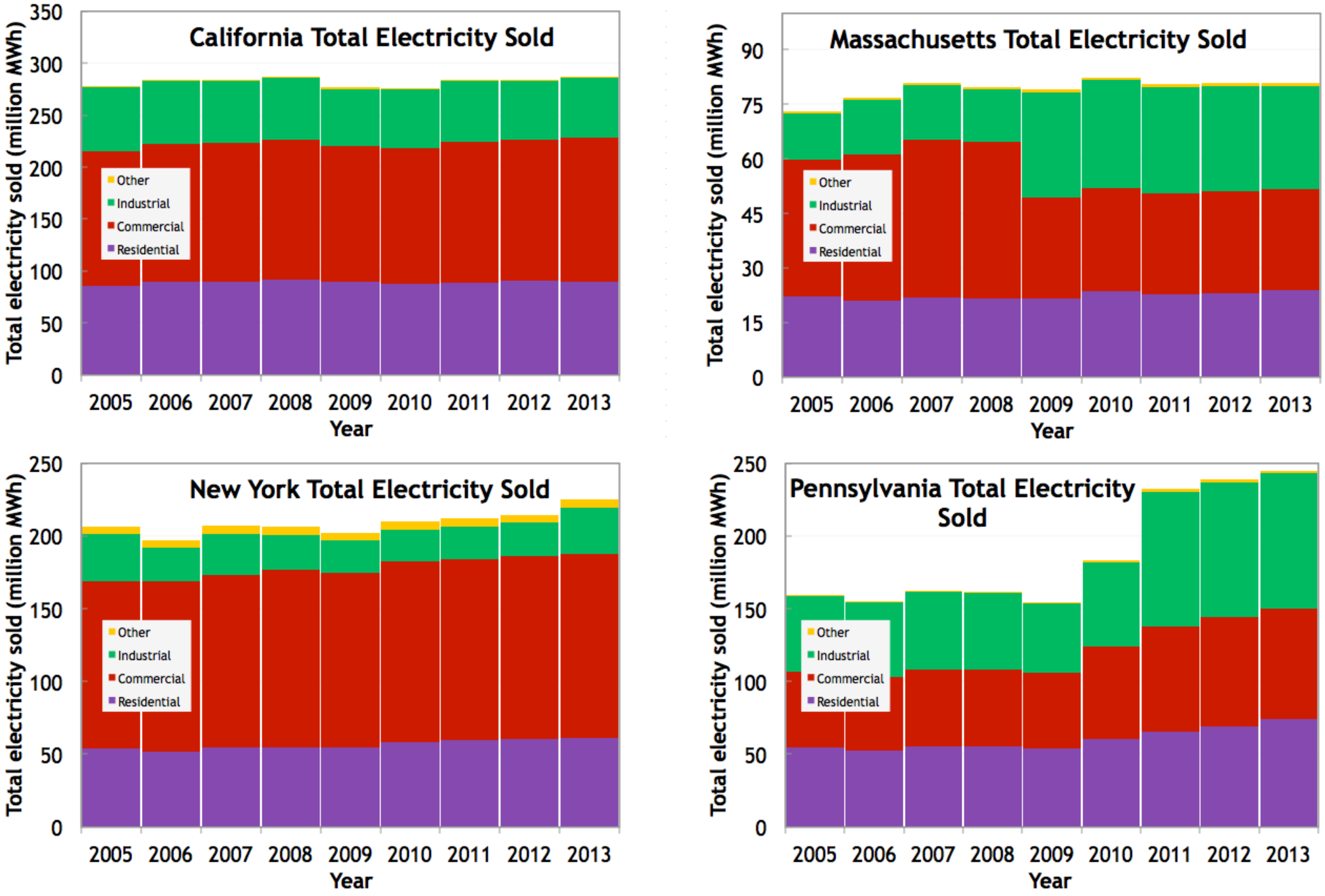


Figure 3-2. Number of Consumers in Each State by Customer Class

Totals are the sum of the number of consumers as reported by utilities in EIA-861/EIA-861s files. Note that y-axis is different for each sub-figure.

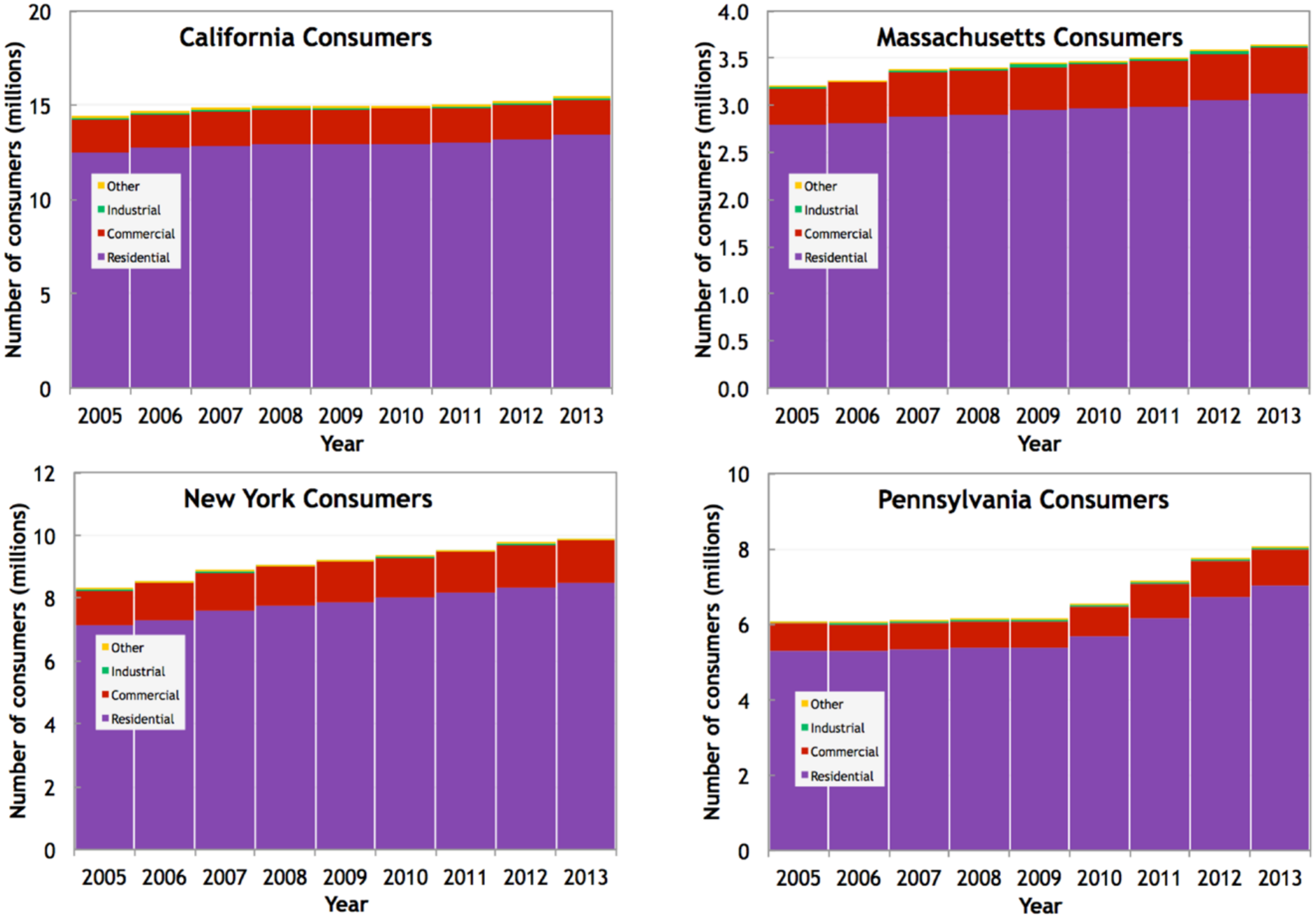
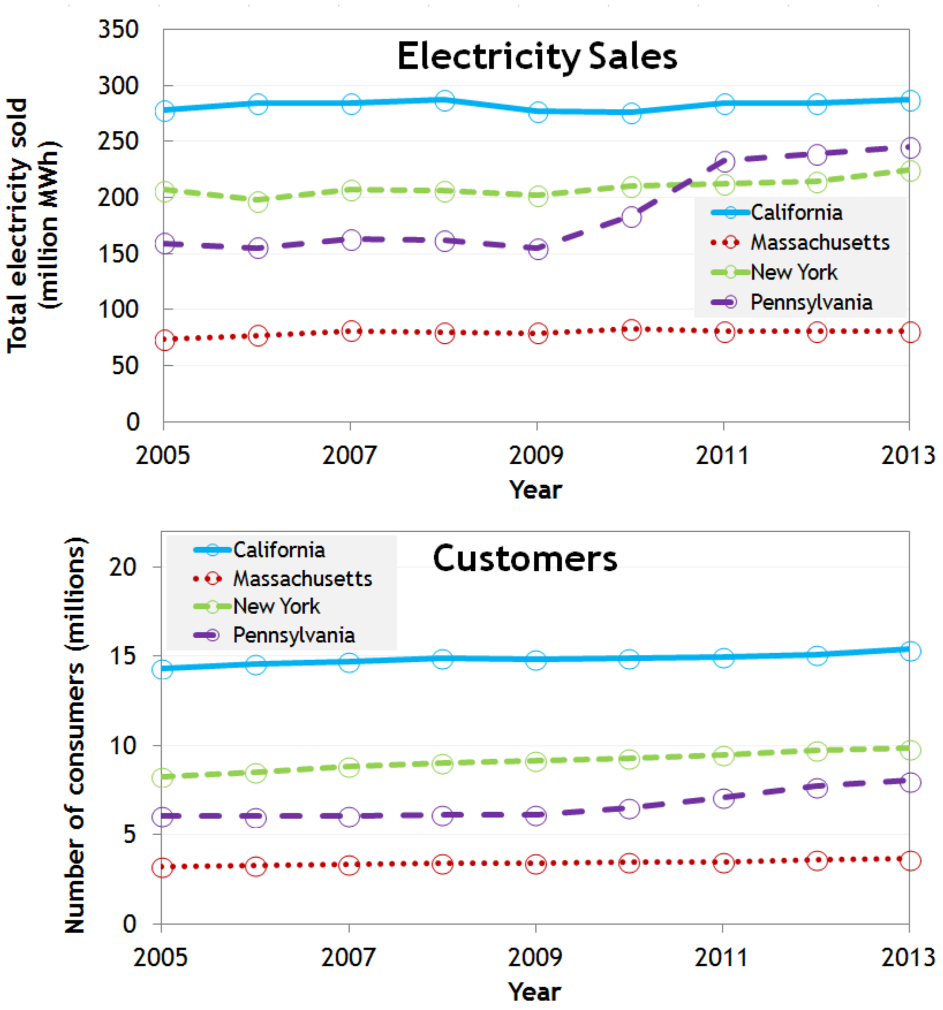


Figure 3-3. Total Electricity Sales and Customers in Comparison States over Time

These sub-figures present the same data as Figure 3-1 and Figure 3-2, but with common y-axes for easier comparison.



3.2 Load Management Programs

During periods of high demand, load management programs serve as an important reliability mechanism; load management also helps avoid costs to ratepayers associated with expansions in generation or distribution capacity. While load management programs have traditionally focused solely on large industrial customers, the growth of smart grid technologies is expected to enable greater participation by smaller commercial or residential customers. Accordingly, data on load management potential, deployment, and customer participation can identify areas where successful smart grid deployment has taken place or areas where opportunities for further development exist.

3.2.1 Energy and Capacity Savings

As part of EIA-861, utilities are required to report the amount of energy saved by load management programs and the potential capacity that load management programs could provide in each year (i.e., the total power capacity that these programs could access during peak demand periods).

Table 3-1 provides an overview of each state's load management program. On a per capita or per consumption basis, California far exceeds the other states in load management program participation, in terms of both reduction potential and actual reductions. New York is second in every metric, both absolute and relative.

Table 3-1. Selected Load Management Data for 2013 (Most Recent Year Available) For Comparison States

Metric	Units	California	Massachusetts	New York	Pennsylvania
Reduction Potential	MW	3,753	12	257	105
Actual Reduction	MW	2,589	11	147	103
Normalized Potential Capacity	percent of peak load	5.00%	0.09%	0.64%	0.25%
Normalized Potential Capacity	percent of customers	21.80%	0.03%	2.13%	1.75%
Energy Saved	GWh	202	0.019	2.374	0.863
Energy Saved	percent of consumption	0.0703%	0.0000%	0.0011%	0.0004%

The following figures provide greater detail on the potential and actual peak reduction achieved through load management programs in each state. Figure 3-4 shows the potential capacity that utilities could "call on" should the need arise. Figure 3-5 shows the actual peak reduction obtained by utilities from load management programs (i.e., the capacity called on by utilities). Significant variability in the potential and actual peak reduction from load management programs across years is not surprising. It is not uncommon for the number of customers willing to provide capacity load management services to vary year to year, whereas the amount of capacity called upon by utilities depends on constraints that exist each year on the power system. With that said, 2011 is an unusual year in all four states. While the difference in 2011 can be isolated to an increase in the "other" category, an explanation for the increase in this category is unclear.[10, 11]

Figure 3-4 and Figure 3-5 reinforce the patterns and trends seen in Table 3-1, with load management programs providing the highest peak savings in California and the lowest in Massachusetts (both in absolute and normalized terms). In New York, actual peak reductions were highest in 2012, when they reduced peak demand by 750 MW, which is equivalent to the capacity of a large natural gas combined cycle plant or several natural gas "peaker" plants. Finally, the figures highlight differences in the type of consumers that participate in load management programs. In California and

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[10] As previously noted, "other" includes unclassified demand such as public street lighting, public authorities, and railways services.

[11] Based solely on the timing of these effects, this effect may be related to the programs or technologies implemented with funds from the American Reinvestment and Recovery Act of 2009 (ARRA).

Pennsylvania, industrial consumers account for most of the potential peak reduction, while in Massachusetts, residential consumers are the largest contributors. The proportionally large share of residential participants in Massachusetts's load management programs could explain why the peak reduction potential is so much lower in Massachusetts. In New York, commercial customers account for most of the potential peak reduction.

Figure 3-6 examines trends in the proportion of potential peak reduction that each state accessed between 2005 and 2013. As shown, 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. For example, between 2005 and 2013, actual reductions in peak demand in California were on average 65% of the potential peak reductions available through load management programs. However, Massachusetts and Pennsylvania each called on nearly 100 percent of available capacity in several years. In 2012 and 2013, New York called on the lowest percentage of load management resources of the four comparison states—less than 30% in 2012 and less than 60% in 2013. 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.

Figure 3-4. Potential Peak Reduction Available through Load Management Programs

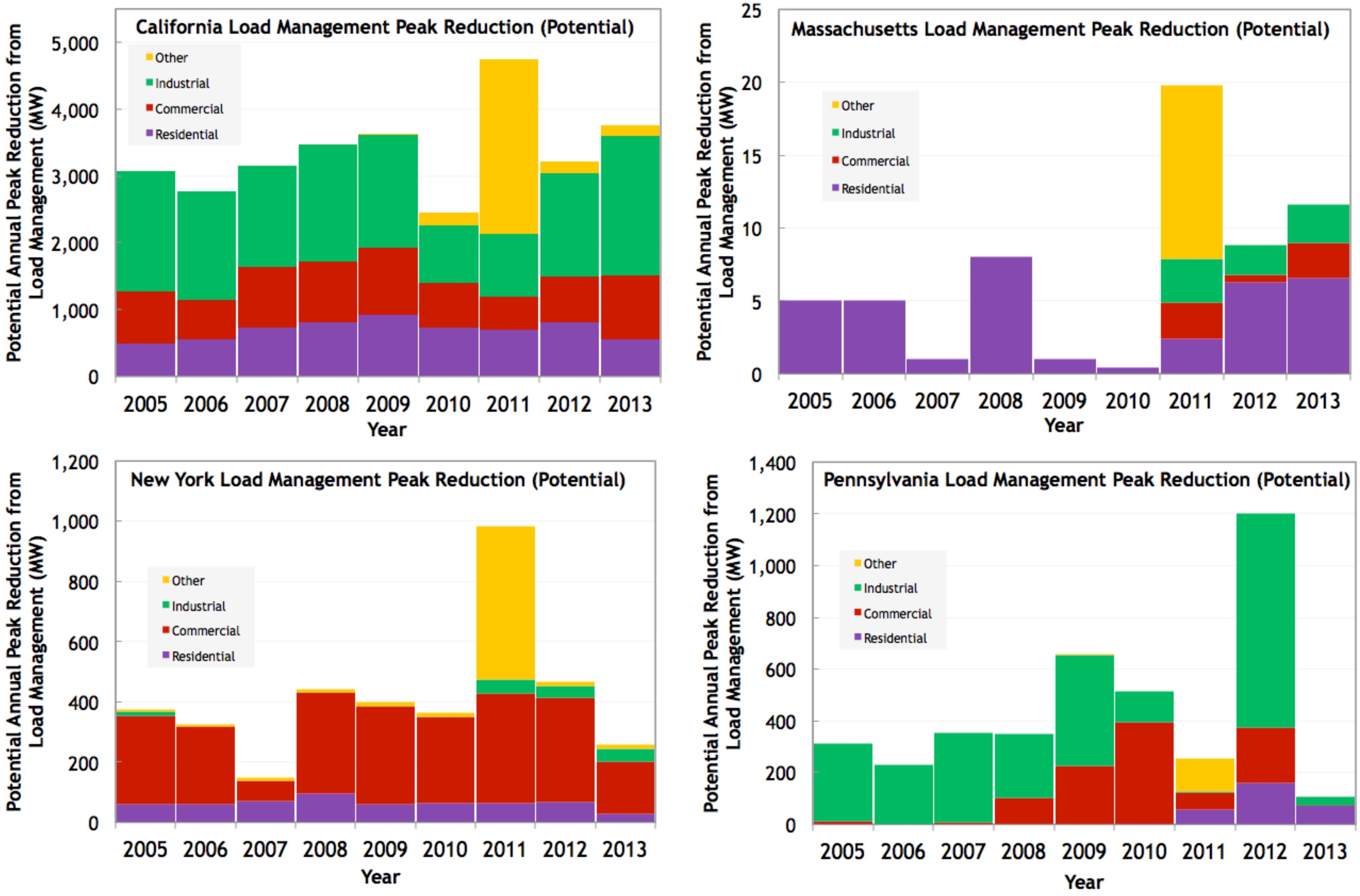
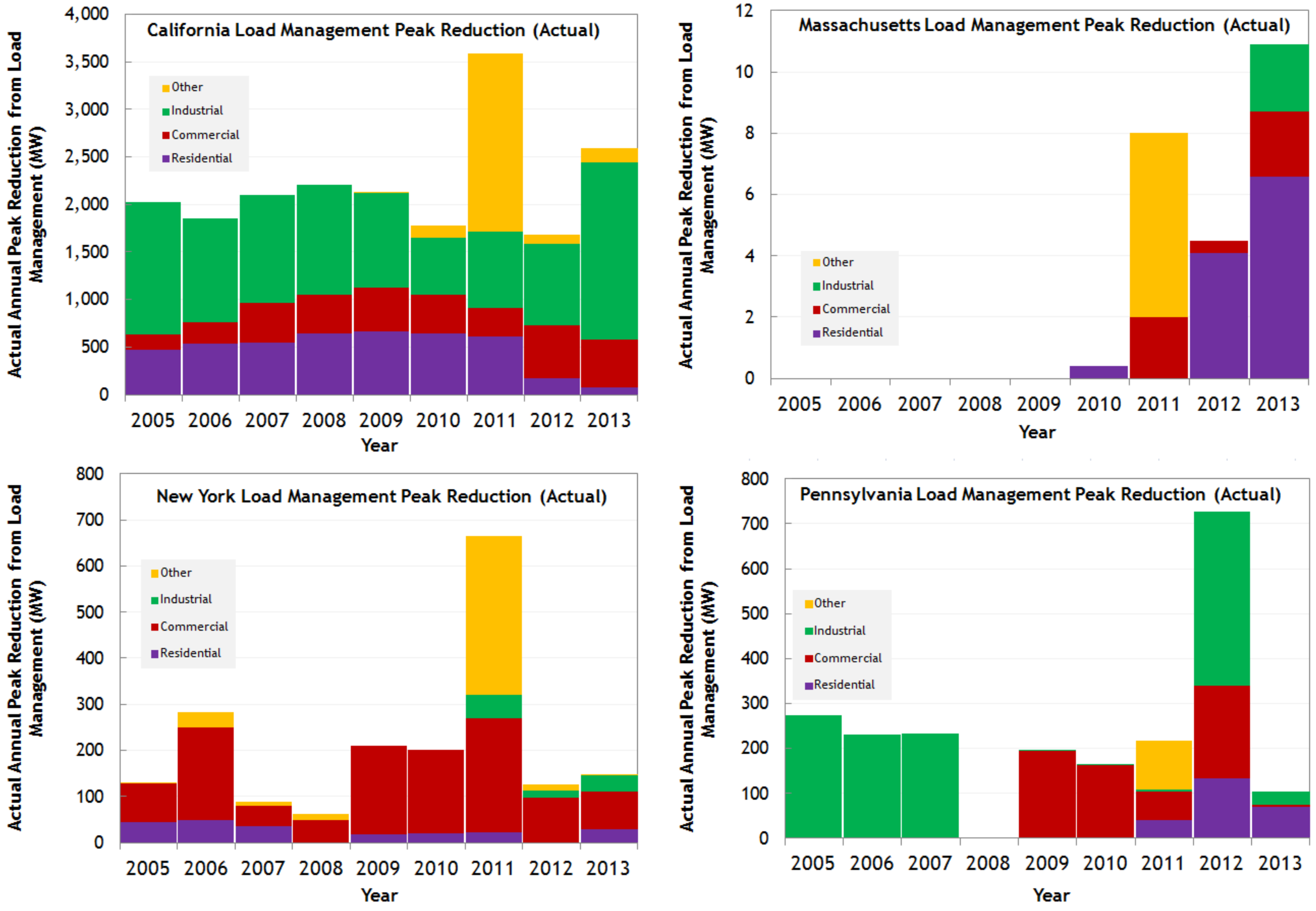


Figure 3-5. Actual Peak Reduction from Load Management Programs

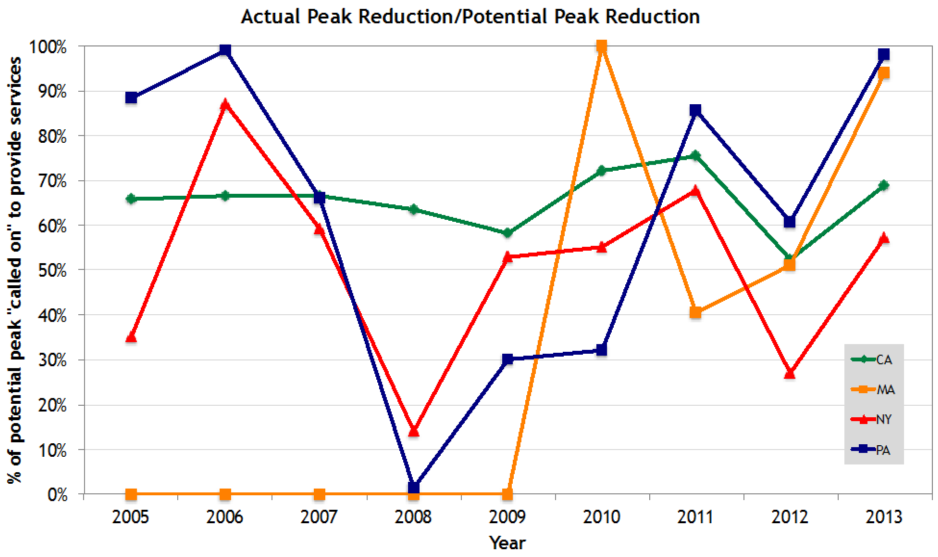

California Load Management Peak Reduction (Actual)

Massachusetts Load Management Peak Reduction (Actual)

New York Load Management Peak Reduction (Actual)

Pennsylvania Load Management Peak Reduction (Actual)

Figure 3-6. Actual Peak Reduction as Percentage of Potential Peak Reduction



3.2.2 Price- and Time-Responsive Customers

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 customers who participate in these types of programs thus provides a measure of the evolution of load management programs. EIA-861 reports the number of customers that are price-responsive and the number of customers that are time-responsive. Assuming that a single customer can only participate in one of these two programs,[12] Figure 3-7 shows the total number of participating customers and the percentage of the total number of customers served by the utilities in each state enrolled in these response programs. Figure 3-8 shows the same data as Figure 3-7, but uses a common y-axis to facilitate easier comparison among states.

Again, California leads other states with the largest number of customers participating in these two types of programs; in 2013, roughly 22% of California customers participated in these programs. In contrast, less than 2.5% of the customers in New York were enrolled in price- or time-response programs in 2013; although in absolute terms, the number of price- and time-responsive customers in New York has increased steadily since 2005. Massachusetts and Pennsylvania had similarly low shares of price- and time-responsive customers.[13] .

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[12] A customer can only be price-responsive or time-responsive at a given time, as these are different and incompatible ways of charging consumers for their time-varying consumption of electricity. It is possible that a single customer could enroll different portions of their load in different programs, or that a customer could switch back and forth between programs. This analysis, however, assumes that such double-counting does not exist and that the total number of demand response customers is equal to the sum of the two sub-types.

[13] There is an apparent gap in EIA data from Massachusetts in 2010, as the number of price- or time-responsive customers dropped to nearly zero in that year, although EIA provides no further explanation for this event.

Figure 3-7. Price- or Time-Responsive Customers

The columns in the primary y-axis show the number of customers enrolled in load management programs each year, while the black line in the secondary y-axis shows the percentage of all customers that enrolled in these programs. Note that the scale on the primary y-axis differs for Massachusetts.

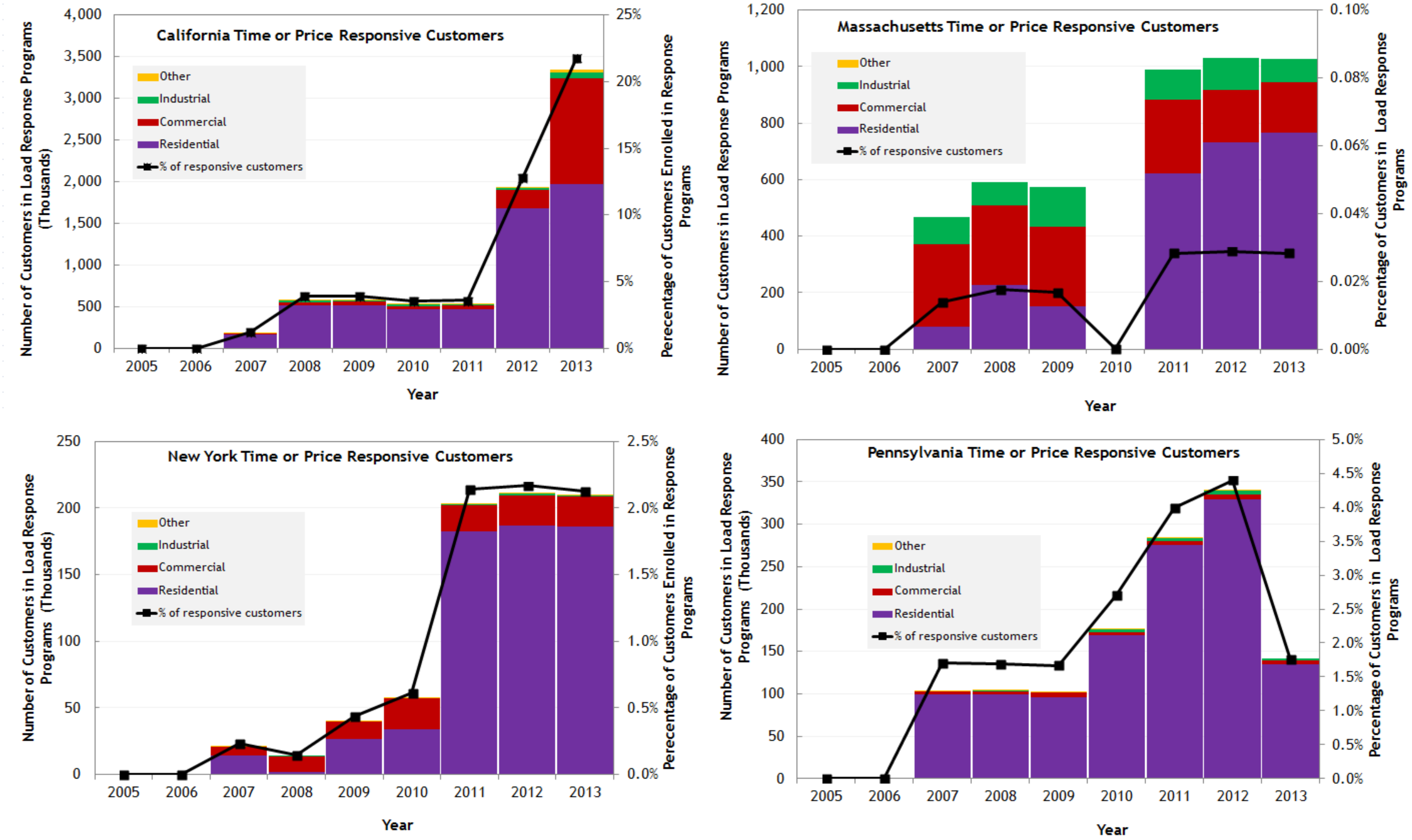
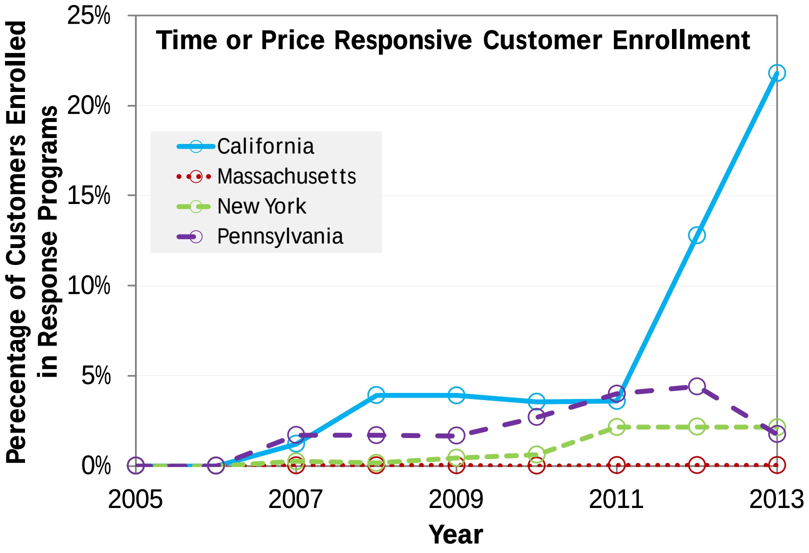


Figure 3-8. Customer Enrollment in Price- or Time-Responsive Programs as Percentage of Total Customers

This figure shows the same data as Figure 3-7 but collected and displayed with a single y-axis for comparison across states.



3.3 Distributed Generation

Large centralized generation stations, such as coal and natural gas-powered plants, are the backbone of the current power system. With increasing concerns about costs and environmental sustainability, however, many states are pursuing opportunities to expand distributed generation capacity. Distributed generation refers to small-scale generation assets connected to the grid at the distribution level. Historically, distributed generation assets were also based on fossil fuels. More recently, energy markets are shifting towards the development of distributed renewable resource generation like solar PV. Distributed generation could also reduce energy costs by, for example, reducing future investments in transmission and distribution infrastructure and reducing losses in electricity during transportation over power lines. To the extent that distributed generation assets are connected to microgrids, intentional islanding of distributed generation can support supplies to critical customers in the event of transmission system failures, thus improving power reliability. Figure 3-9 shows the installed distributed generation capacity (in MW) in each state by resource type since 2007, which is when EIA began collecting these data.

Consistent with trends in other data, California has the highest distributed generation capacity in all years. Notably, distributed generation capacity decreased between 2007 and 2008 in all states. Through 2007, internal combustion engines represented a large proportion of total distributed generation capacity. The drop in distributed generation capacity between 2007 and 2008 is likely due to mass retirement of these fossil-based resources because of environmental concerns and/or associated regulations. In New York, however, internal combustion engines continues to contribute a significant percentage to the state's total distributed generation capacity (32% in 2013), though solar PV capacity is growing rapidly. Figure 3-10 also shows total distributed generation capacity (in MW) per million customers served. When looking at normalized distributed generation capacity, Massachusetts saw a dramatic increase in distributed solar capacity in 2013, even higher than California in the same year. Figure 3-11 shows peak load-normalized distributed generation capacity in the four states. Because peak load is reported for different sets of utilities each year, analysis of peak load is therefore intended for general trend analysis only. Overall, the data show lower levels of distributed generation in New York and Pennsylvania, compared to Massachusetts and California. Solar PV accounts for about half of the distributed generation capacity in New York, whereas distributed solar PV is the primary type of distributed generation in each of the three comparison states.

Within Figure 3-9 is also information on distributed storage, an emerging technology that has the potential to substantially improve grid reliability, resiliency, and efficiency.[14] Figure 3-12 extracts these data to show the amount of distributed storage capacity in New York as compared to each of the three comparison states. The data on storage capacity refers to storage located below the distribution system, as opposed to transmission-level storage (which is discussed later in this report). Of note, only California and New York reported any distributed storage through 2013. Additionally, most of the installed capacity reflects test cases and sums to less than 1MW in the state with the greatest amount of installed capacity (California). It is reasonable to expect the amount of distributed storage capacity to grow over time, consistent with expectations for greater growth in the wider market for energy storage technologies.

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[14] NY-BEST, 2016.

Figure 3-9. Distributed Generation Installed Capacity

The columns in the primary y-axis show the installed distributed capacity in each year, while the black line in the secondary y-axis shows installed distributed capacity per million customers.

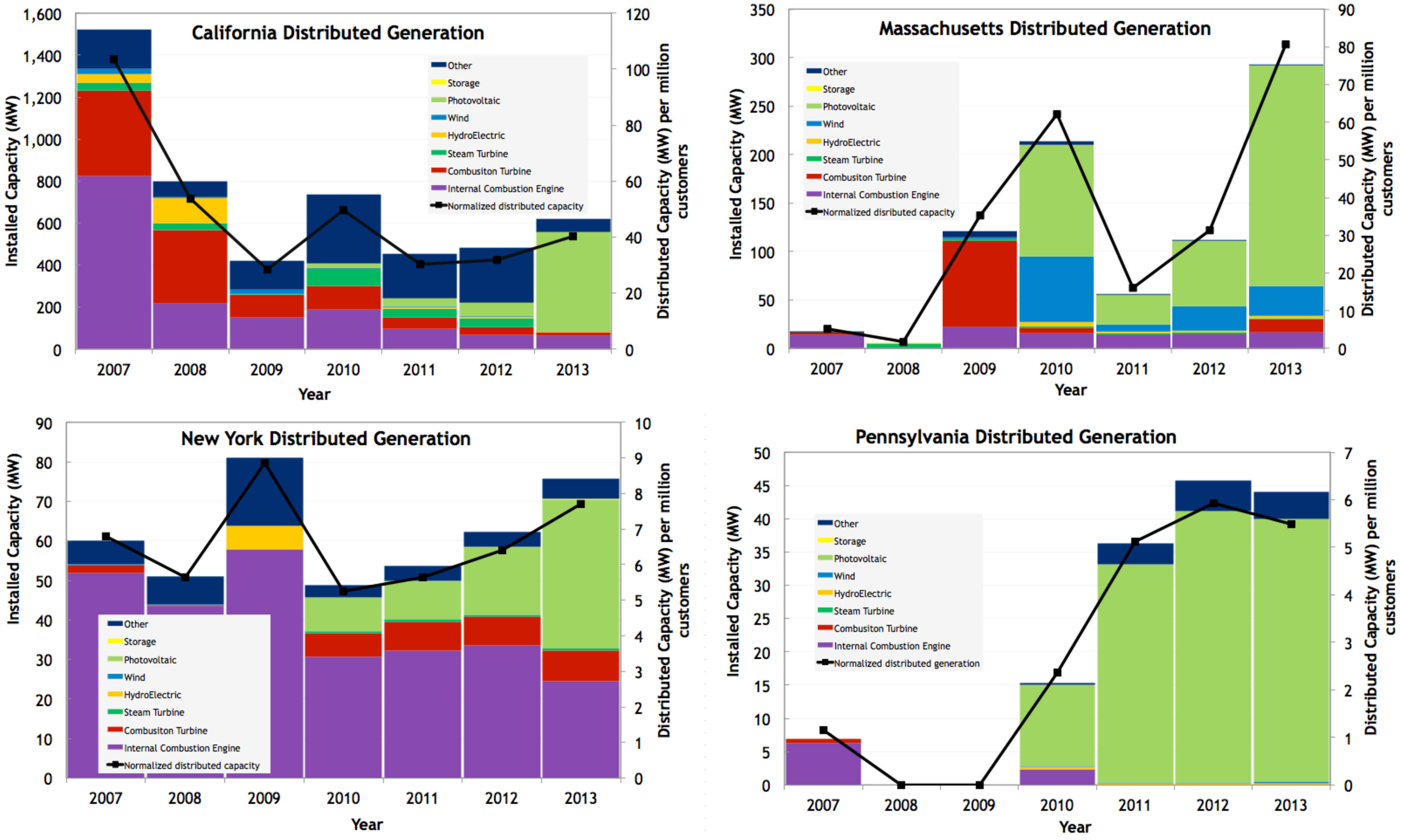


Figure 3-10. Normalized Distributed Generation Installed Capacity for Comparison States (Normalized to Number of Customers in State)

This figure shows the same data as the black lines in Figure 3-9, but with a common y-axis for comparison among states.

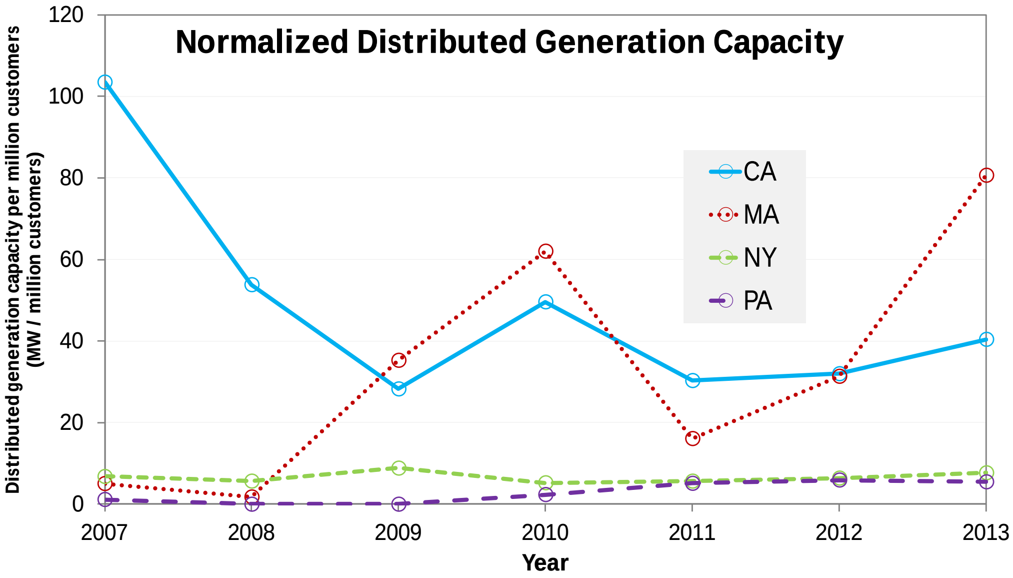


Figure 3-11. Normalized Distributed Generation Installed Capacity for Comparison States (Normalized to Peak Load in Each Electric Utility)

This figure shows the same data as the black lines in Figure 3-9, but with a common y-axis for comparison among states. Importantly, a different set of utilities reports each year, so the data can only show general trends.

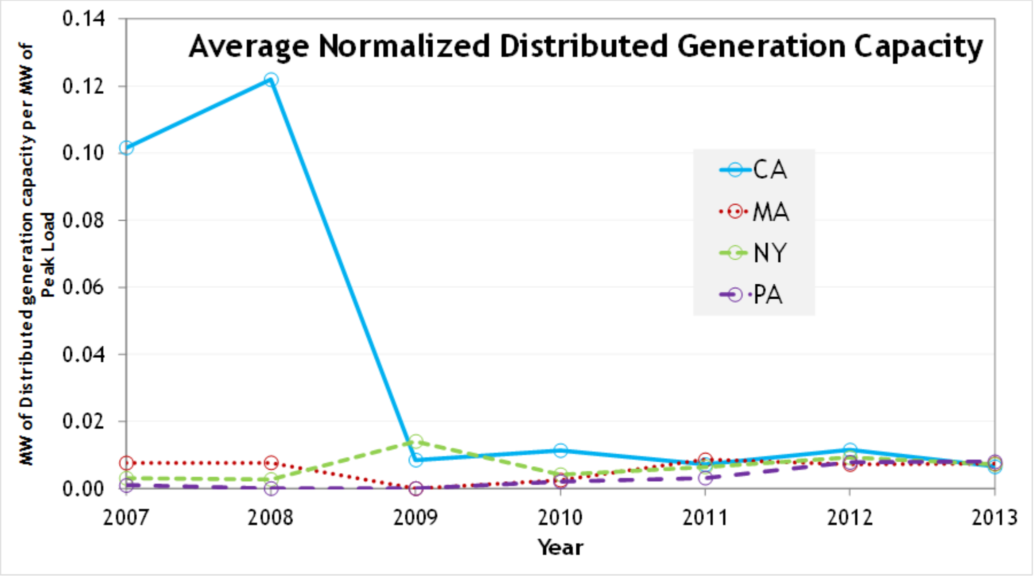
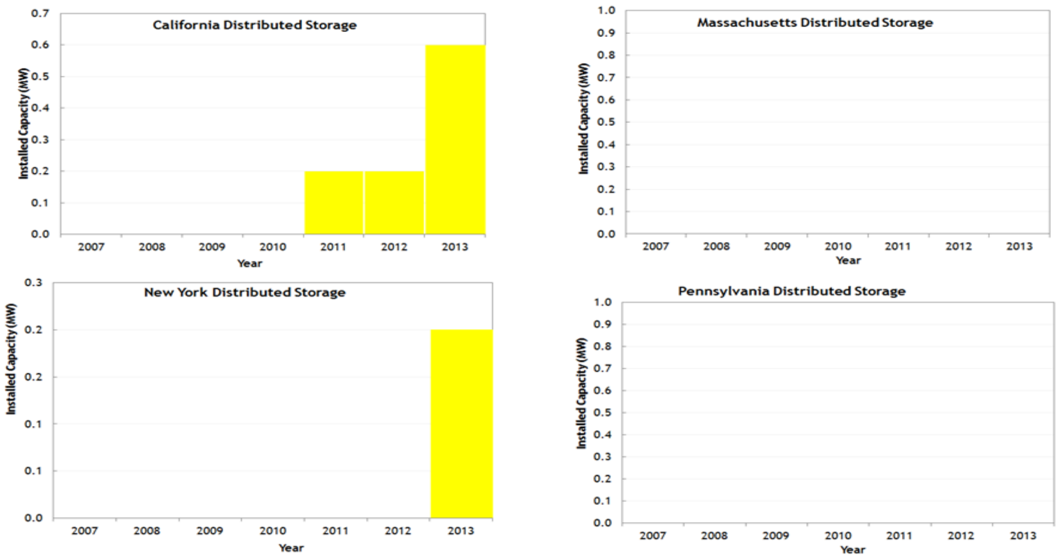


Figure 3-12. Distributed Storage Capacity (Extracted from Figure 3-9) in Comparison States



3.4 Advanced Metering Infrastructure

Advanced metering infrastructure (AMI) allows two-way communication between utilities and customers: utilities can instantaneously collect data on demand and consumption patterns, while customers can receive information about the conditions of the system and program response mechanisms. Smart meters, as AMI is conventionally known, are therefore a critical component of a fully operational smart grid. Figure 3-13 summarizes the number and percentage of customers in each state with smart meters. Figure 3-14 shows the total amount and percentage of energy served by smart meters.

As observed for the other metrics, California leads in AMI deployment. According to EIA data, by 2013, more than 80% of California customers had smart meters, and these meters served close to 30% of the energy sold in the state. In contrast, in the same year, EIA data indicate that less than 0.5% of New York customers had smart meters, serving roughly 5% of the energy sold in the state. Nationwide, approximately 10% of U.S. consumers have smart meters, but the primary contribution of the technology is still in automated meter reading.[15] In New York, smart meter deployment is managed by the Public Service Commission (PSC) rather than NYSERDA's Smart Grid program. To date, the New York PSC has not emphasized AMI deployment. In response to 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.[16]

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[15] U.S. Department of Energy, 2014.

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

Figure 3-13. Number of Smart Meters and Percentage of Customers Served by AMI

The columns in the primary y-axis show the number of customers with smart meters in each year, while the black line in the secondary y-axis shows the percentage of all customers that have smart meters.

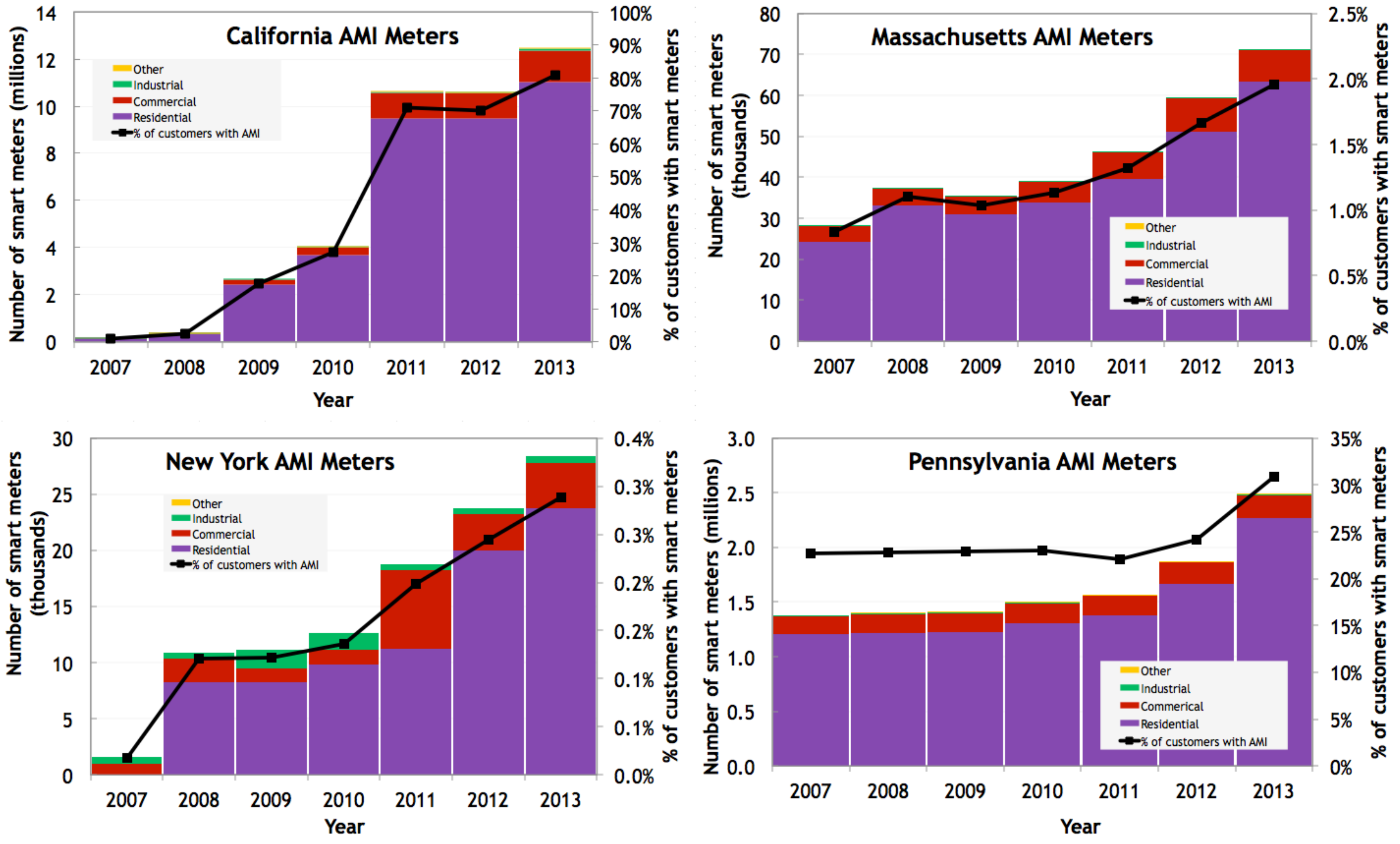
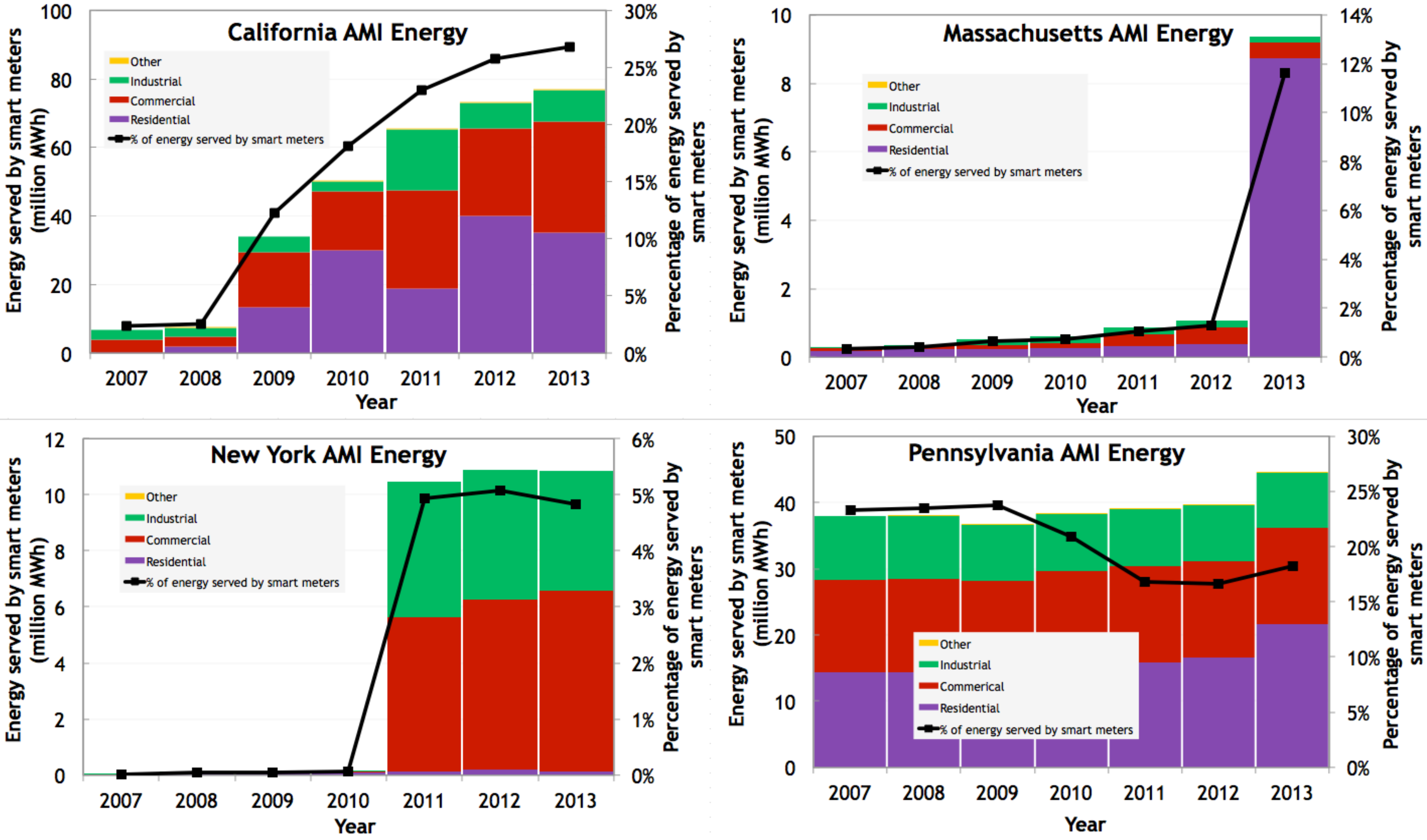


Figure 3-14. Energy Served by AMI

The columns in the primary y-axis show the amount of energy served by smart meters each year, while the black line in the secondary y-axis shows the percentage of energy served by smart meters.



3.5 Utility-Scale Storage

As noted in Section 2, energy storage projects span a variety of scales, from household-sized, customer-sited projects to large pumped hydro projects meant to support energy time-shifting over an entire region of the U.S. This section discusses large-scale grid energy storage projects as reported in DOE’s Energy Storage Database.[17] Maintained by Sandia National Laboratory, this database tracks worldwide energy storage projects and facilities.[18]

Figure 3-15 shows the cumulative number of grid energy storage projects undertaken in New York and the three comparison states. As expected, most energy storage projects have been installed recently, since 2008. California is also the clear leader in the total number of energy storage projects installed, though the state also has a larger population and a larger electricity system than the three other states. Figure 3-16 normalizes the data to population, revealing that California still has a much higher rate of new energy storage projects even when adjusted for population. This may be due, at least in part, to California’s recent energy storage mandate.[19] The state passed its first energy storage mandate in 2010, at which point California's rate of new projects diverges upwards from the three other states.

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[17] U.S. Department of Energy, 2014.

[18] Huff, 2014.

[19] California Public Utilities Commission, 2013; and AB 2514, 2010.

Figure 3-15. Cumulative Number of Grid Energy Storage Projects in Comparison States, 2001-2015

Most projects have occurred since 2008, and California shows a rapid growth in number of projects since 2011, possibly due to the state's energy storage mandate.

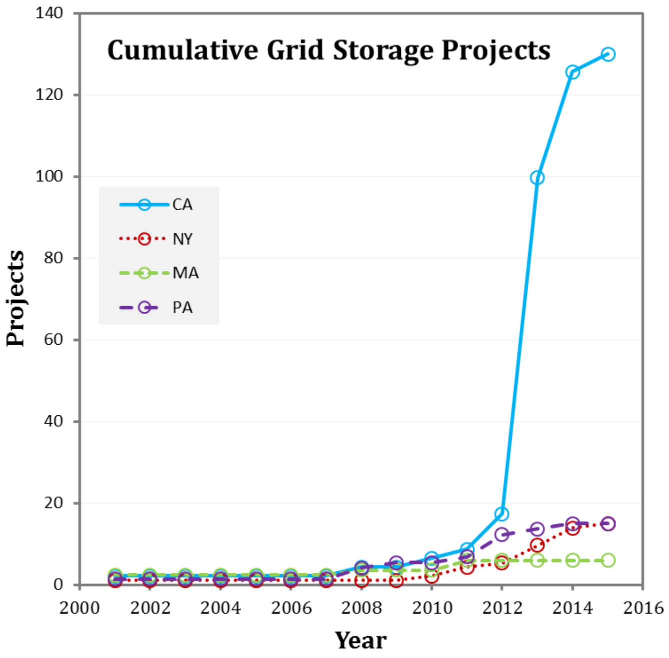

Figure 3-16. Cumulative Number of Grid Energy Storage Projects in Comparison States, 2001-2015, Normalized To Population

This figure uses the same data as Figure 3-15, divided by population (in millions).

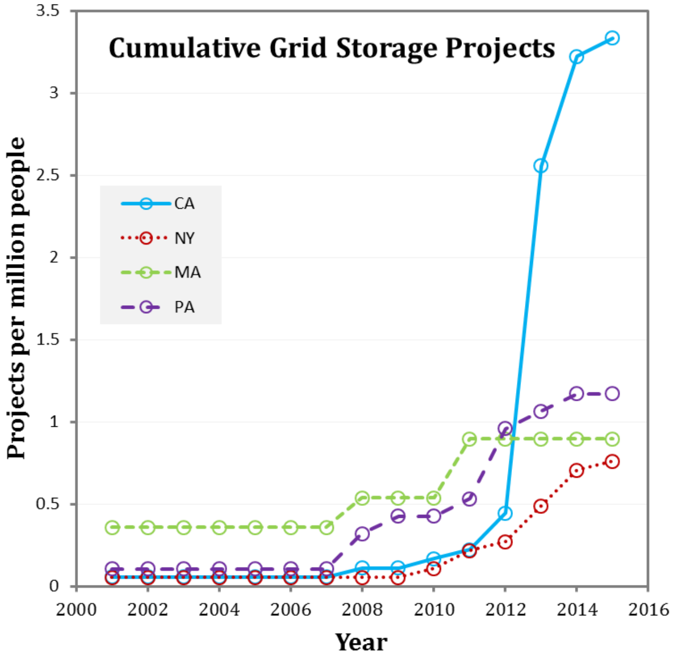

Figure 3-17 shows the cumulative amount of grid energy storage in each state, in terms of both power capability and energy capacity. Storage projects undertaken prior to 2001 are included, which explains why some states show installed capacity at the start of the figure. Prior to 2001, pumped hydro accounted for the vast majority (>99%) of U.S. energy storage; this is especially true in New York and Massachusetts where the geologic resources favor greater development of hydropower and pumped hydro.[20]

DOE's Energy Storage database includes a small subset of projects without dates. Undated projects are integrated into the cumulative total based on the proportion of projects with known commissioning dates. In other words, the projects with known dates are scaled up in terms of both power capability and energy capacity so that the total cumulative power and energy in 2015 is equal to the total power and energy of all projects, including those with unknown start dates.

Figure 3-18 shows the same data as Figure 3-17, but with pumped hydro projects removed. The comparison between figures demonstrates the prominence of pumped hydro in the energy storage landscape. Additionally, Figure 3-18 provides a comparison of the scale of deployment for emerging energy storage technologies. California leads in this regard, even when adjusted for population or load (not shown). To better understand the development of emerging utility-scale storage in each state, the following sections use data on the largest energy storage projects in each state to reveal wider trends in the types of energy services utility scale storage is meeting in each state.

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[20] In comparison, Pennsylvania uses non-pumped hydro for some services that are provided by hydropower or pumped hydro in New York, such as frequency regulation.

Figure 3-17. Cumulative Quantity of Grid Energy Storage in Comparison States (Power and Energy)

Note the split axis in each figure, with power (solid blue line) associated with the left axis and energy (dotted red line) associated with the right axis. Also note that y-axis scales change significantly between figures.

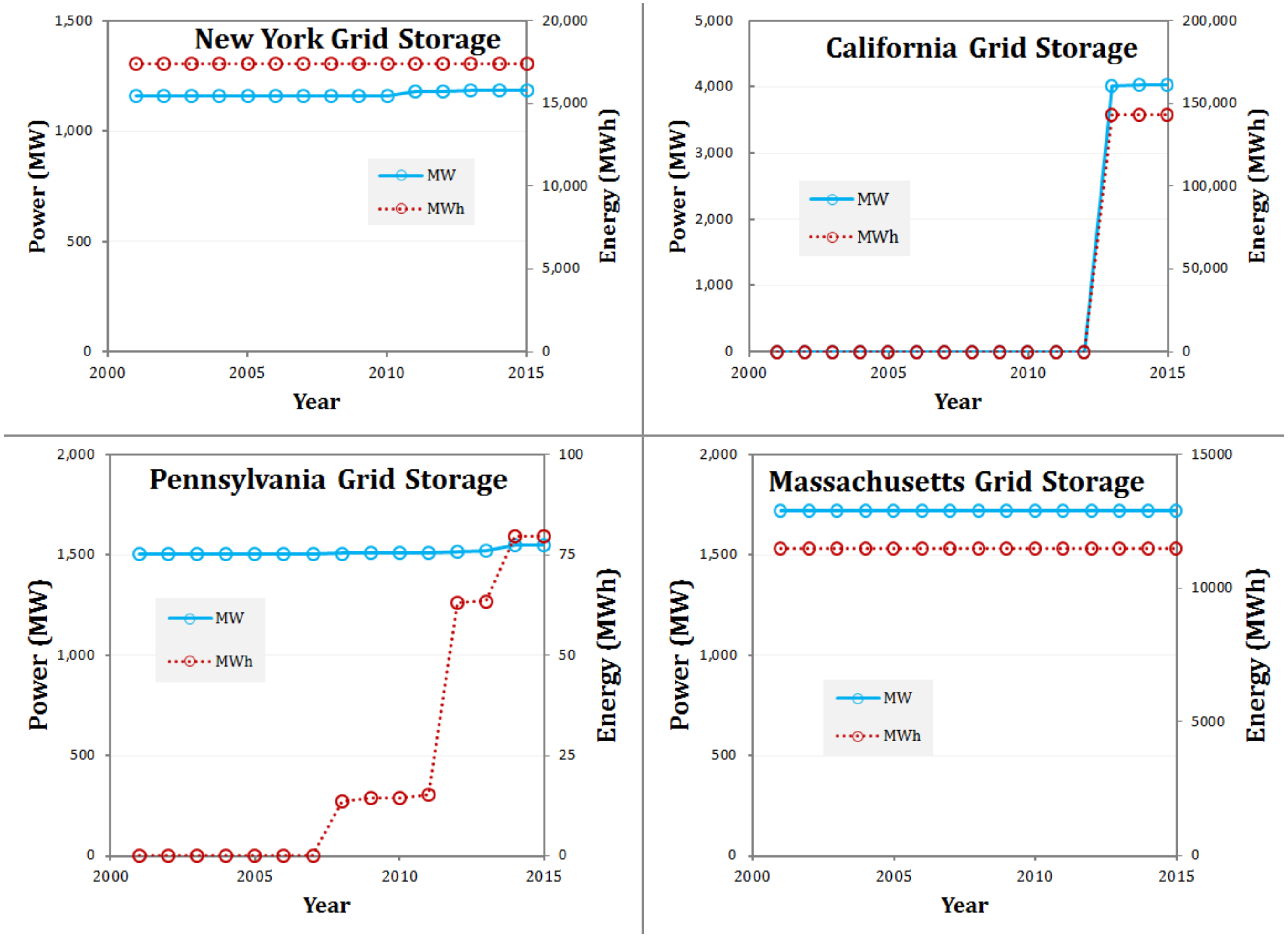
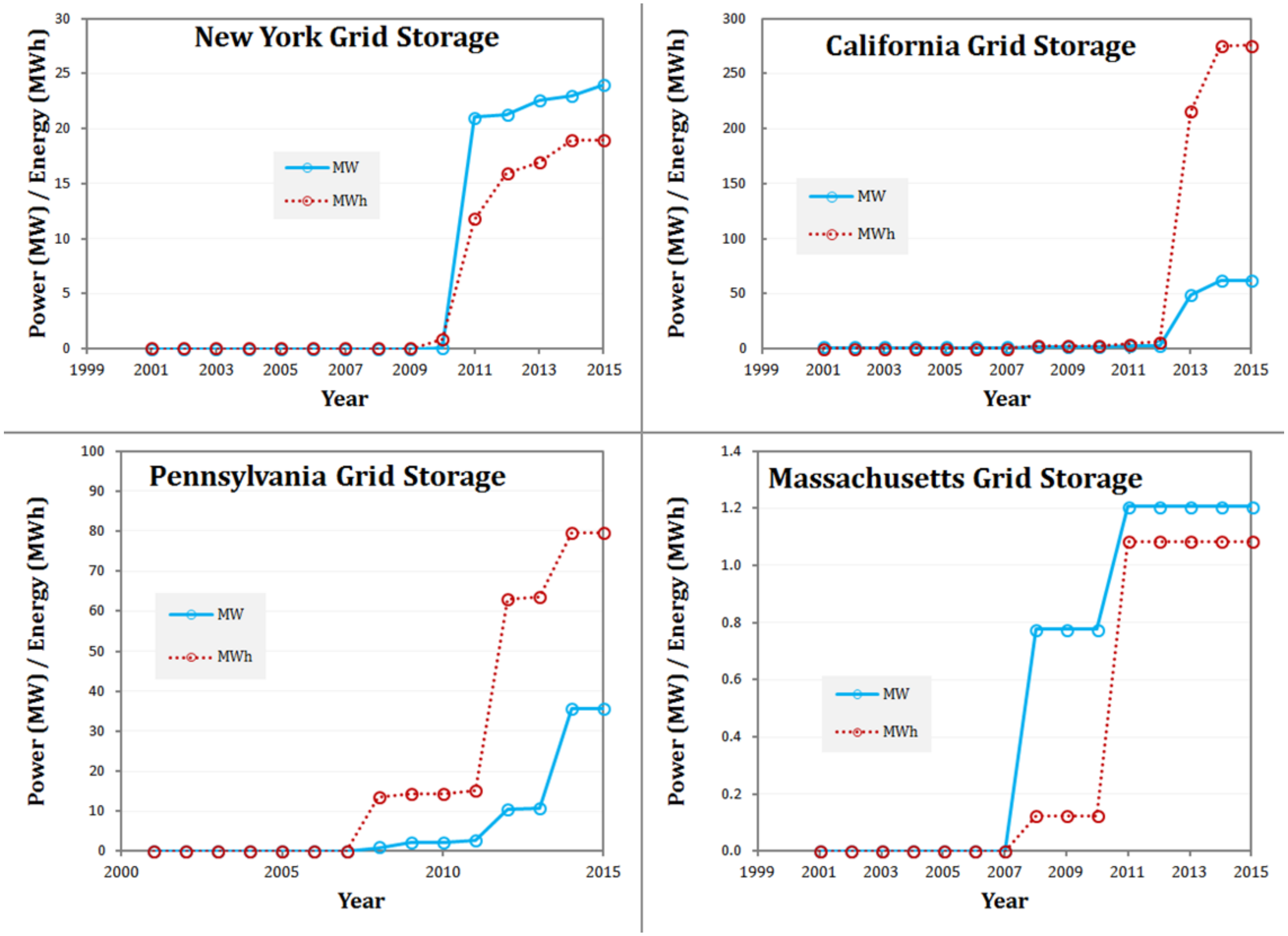


Figure 3-18. Cumulative Quantity of Non-Pumped Hydro Grid Energy Storage in Comparison States (Power and Energy)

Note that, compared to Figure 3-17, the axes are now combined, showing both power (solid blue line) and energy (dotted red line) on the left axis. Also note that y-axis scales change between figures. Pumped hydro installations are at a scale much larger than other technologies (in terms of both power and energy), but removing that technology provides information on the rate of installation of emerging energy storage technologies.



3.5.1 New York

As previously noted, data on the cumulative quantity of energy storage in New York between 2001 and 2015 consists primarily of pre-existing (constructed 1973) pumped hydro projects. More useful in assessing trends in non-pumped utility-scale storage is examining the five largest energy storage projects in the state, as measured by power (Table 3-2) and energy capacity (Table 3-3). These tables indicate that the largest storage projects in the state are focused on providing ancillary services, such as frequency regulation, voltage support, or electric bill management (customer-located load shifting).

Table 3-2. Five Largest Energy Storage Projects in New York Commissioned Between 2001 and 2015, Based on Rated Power

Name	Technology	Power (MW)	Energy (MWh)	Application	Commissioning Date
Beacon Power 20 MW Flywheel Frequency Regulation Plant (Stephentown, NY)	Flywheel	20	5.00	Frequency Regulation	6/1/2011
LIRR Malverne WESS: Maxwell Technologies	Electro-chemical Capacitor	1	0.02	Voltage Support	2/1/2013
LIRR Malverne WESS: Ioxus	Electro-chemical Capacitor	1	0.02	Transportation Services	6/1/2015
Schooner America 2.0 Electric	Lithium-ion Battery	0.25	0.63	On-Site Power	4/15/2014
Barclay Tower	Advanced Lead-acid Battery	0.225	1.99	Electric Bill Management	10/3/2012

Table 3-3. Five Largest Energy Storage Projects in New York Commissioned Between 2001 and 2015, Based on Rated Energy Capacity

Name	Technology	Power (MW)	Energy (MWh)	Application	Commissioning Date
Beacon Power 20 MW Flywheel Frequency Regulation Plant (Stephentown, NY)	Flywheel	20	5.00	Frequency Regulation	6/1/2011
Barclay Tower	Advanced Lead-acid Battery	0.225	1.99	Electric Bill Management	10/3/2012
Schooner America 2.0 Electric	Lithium-ion Battery	0.25	0.63	On-Site Power	4/15/2014
Brooklyn Army Terminal Smart Grid Demonstration Project	Electro-chemical	0.1	0.40	Electric Bill Management with Renewables	11/1/2010
UEP CCNY Demonstration	Zinc-nickel Oxide Flow Battery	0.1	0.20	Electric Bill Management	6/4/2013

3.5.2 California

Table 3-4 and Table 3-5 list the five largest California storage projects in terms of power and energy capacity, respectively. In California, several large pumped hydro plants that came online in 2013 dominate the results in Figure 3-17. While California had the highest number of energy storage projects (Figure 3-16), it also had several large scale arbitrage/peak shaving projects.[21] As a result, the total amount of energy storage (on an energy capacity basis) far exceeds any other state, even when normalized by population. On the other hand, while California has the most storage when measured by rated power (4 GW), this is only slightly higher than the other three states (all exceed 1 GW).

The character of California's energy storage projects is generally different than other states. California projects are more focused on primary electricity services, such as peak shaving or arbitrage. This may be due in part to better geography for pumped hydro technologies, but may also be driven by a critical need to manage peak demand. California's electricity system has a strong annual peak with a weaker, more linear transmission system than the East Coast. Energy storage is recognized as an important solution to some of these issues, a conclusion that ultimately drove the California PUC to mandate an additional 1.3 GW of storage by 2020.[22] In fact, California utilities may exceed the PUC’s storage mandate, suggesting that adoption of grid-level storage in the state is driven by economics rather than state policy. Because these factors are unique to California, direct comparison to East Coast states may be inappropriate.

Table 3-4. Five Largest Energy Storage Projects in California Commissioned Between 2001 and 2015, Based on Rated Power

Name	Technology	Power (MW)	Energy (MWh)	Application	Commissioning Date
Helms Pumped Hydro Storage Project	Open-loop Pumped Hydro Storage	1212	Unreported	Load Following (Tertiary Balancing)	12/26/2013
Edward Hyatt (Oroville) Power Plant	Open-loop Pumped Hydro Storage	819	Unreported	Electric Energy Time Shift	12/5/2013
San Luis (William R. Gianelli) Pumped Storage Hydroelectric Powerplant	Open-loop Pumped Hydro Storage	424	126378	Electric Energy Time Shift	12/26/2013
Big Creek (John S. Eastwood) Pumped Storage	Open-loop Pumped Hydro Storage	199.8	3531	Electric Energy Time Shift	12/5/2013
Olivenhain-Hodges Storage Project	Open-loop Pumped Hydro Storage	40	240	Electric Energy Time Shift	8/12/2013

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[21] Energy arbitrage is the term for moving large quantities of electrical energy from inexpensive to valuable times of day, with the goal of maximizing operating revenue on the wholesale electricity market. Peak shaving is the term for operating storage to reduce peak demand by discharging during peak periods. While there are a few minor functional differences in system design and operation, the outcome is functionally similar in both cases: a large-capacity storage device is charged during off-peak/inexpensive periods and discharged during peak/expensive periods.

[22] California Public Utilities Commission, 2013.

Table 3-5. Five Largest Energy Storage Projects in California Commissioned Between 2001 and 2015, Based on Rated Energy Capacity

Name	Technology	Power (MW)	Energy (MWh)	Application	Commissioning Date
San Luis (William R. Gianelli) Pumped Storage Hydroelectric Powerplant	Open-loop Pumped Hydro Storage	424	126378	Electric Energy Time Shift	12/26/2013
Big Creek (John S. Eastwood) Pumped Storage	Open-loop Pumped Hydro Storage	199.8	3531	Electric Energy Time Shift	12/5/2013
Olivenhain-Hodges Storage Project	Open-loop Pumped Hydro Storage	40	240	Electric Energy Time Shift	8/12/2013
Southern California Edison Tehachapi Wind Energy Storage Project	Lithium-ion Battery	8	32	Voltage Support	2/22/2013
PG&E Yerba Buena Battery Energy Storage Pilot Project	Sodium-sulfur Battery	4	28	Grid-Connected Commercial (Reliability & Quality)	3/21/2013

3.5.3 Pennsylvania

Cumulative energy storage installations for Pennsylvania are shown in Figure 3-17, while the largest storage projects since 2001 are shown in Table 3-6 (power) and Table 3-7 (energy capacity). Similar to New York, the data on cumulative energy storage installations in Pennsylvania are dominated by pre-existing (commissioned 1966) pumped hydro facilities (with an unreported energy capacity). In the period since 2001, frequency regulation projects, using a variety of technologies, account for the majority of Pennsylvania energy storage projects, an outgrowth of high frequency regulation prices and welcoming market rules in the PJM area during this period.[23]

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[23] Energy Storage Update, 2015.

Table 3-6. Five Largest Energy Storage Projects in Pennsylvania Commissioned Between 2001 and 2015, Based on Rated Power

Name	Technology	Power (MW)	Energy (MWh)	Application	Commissioning Date
Beacon Power 20 MW Flywheel Frequency Regulation Plant (Hazle Township, PA)	Flywheel	20	5.00	Frequency Regulation	7/30/2014
East Penn Manufacturing Co. Grid-Scale Energy Storage Demonstration Using UltraBattery Technology	Hybrid Lead-acid Battery/Electro-chemical capacitor	3	2.15	Frequency Regulation	6/15/2012
Pennsylvania ATLAS (Aggregated Transactive Load Asset)	Heat Thermal Storage	2.01	10.05	Frequency Regulation	10/1/2012
Altairnano-PJM Li-ion Battery Ancillary Services Demo	Lithium Ion Titanate Battery	1	0.25	Frequency Regulation	1/1/2009
Viridity SEPTA Recycled Energy and Optimization Project	Lithium-ion Battery	0.8	0.40	Frequency Regulation	4/15/2012

Table 3-7. Five Largest Energy Storage Projects in Pennsylvania Commissioned Between 2001 and 2015, Based on Rated Energy Capacity

Name	Technology	Power (MW)	Energy (MWh)	Application	Commissioning Date
Pennsylvania ATLAS (Aggregated Transactive Load Asset)	Heat Thermal Storage	2.01	10.05	Frequency Regulation	10/1/2012
Beacon Power 20 MW Flywheel Frequency Regulation Plant (Hazle Township, PA)	Flywheel	20	5.00	Frequency Regulation	7/30/2014
Duquesne University	Ice Thermal Storage	0.6	3.60	Electric Bill Management	6/1/2008
Bethel Park High School	Ice Thermal Storage	0.375	2.25	Electric Bill Management	1/30/2012
East Penn Manufacturing Co. Grid-Scale Energy Storage Demonstration Using UltraBattery Technology	Hybrid Lead-acid Battery/Electro-chemical capacitor	3	2.15	Frequency Regulation	6/15/2012

3.5.4 Massachusetts

As shown in Table 3-8, Massachusetts has constructed only three grid-level storage projects since 2001, compared with 13, 10, and 59 for New York, Pennsylvania, and California, respectively. While Massachusetts is the smallest of the four states, this low level of activity suggests a lack of economic need for utility scale storage. The New England electricity grid is well connected to neighboring regions, including a significant quantity of Quebec hydropower often used to help balance supply and demand. As with the other states, the scale, technologies, and applications of energy storage in Massachusetts reflect the unique needs of its electrical system. In the case of Massachusetts, the data affirm that there is limited need for the services that utility scale storage provides.

Table 3-8. Grid Energy Storage Projects in Massachusetts Commissioned Between 2001 and 2015

Name	Technology	Power (MW)	Energy (MWh)	Application	Commissioning Date
Beacon Power 500 kW Flywheel Tyngsboro, MA	Flywheel	0.5	0.13	Frequency Regulation	11/1/2008
VCharge Concord Pilot	Heat Thermal Storage	0.175	0.88	Frequency Regulation	9/1/2011
Exfob (Tricon) Ft. Devens Military Container	Lithium Iron Phosphate Battery	0.1	0.08	Load Following (Tertiary Balancing)	7/1/2011

3.6 Power Outages

Successful smart grid integration should help to reduce the frequency and extent of power outage events. This assessment considers three types of measures related to power outages: number of events, number of customers affected, and lost load. The latter two measures reflect the impact of power outages on residential and commercial or industrial customers, respectively.

By its nature, a power outage is an extreme electrical event driven by some form of electricity system emergency. As such, the available data on power outages are clearly influenced by extreme weather events such as 2003 Northeast Blackout and hurricanes. On the East Coast, strong hurricanes occur reasonably frequently, and such events are increasingly considered part of the standard operational framework. System reliability and resiliency have become especially important in light of uncertainty about the effect of climate change on the frequency and intensity of these types of storms. While California does not experience hurricanes, and Pennsylvania is less exposed to the effect of hurricanes than New York, similar extreme events exist in each of the comparison states. For example, California’s electricity system operations must consider the potential effect of events like earthquakes and wildfires. In the following sections, the impact of extreme events on power outage data is noted where relevant.

3.6.1 Number of Power Outage Events

The annual and cumulative numbers of reported events in each state are shown in Figure 3-19 and Figure 3-20, respectively. The total number of power outage events itself reveals little about the scale of power outages in a state, but it is presented here to provide context for the other power outage metrics analyzed. The data illustrate three important points:

- First, the number of power outage events is relatively consistent across the time period, suggesting that reporting patterns have not changed significantly within the period. Thus, temporal comparisons are legitimate.
- Second, the number of reported events seems to have little relationship to the scale of outages. For example, in New York State, while Hurricane Sandy and the 2003 Northeast Blackout were the most prominent recent events, they are counted as one or a few events each and therefore do not show up on an accounting of number of events.
- Third, the number of events scales approximately with the "size" of the state. In other words, states with the most outages are generally also largest in terms of people, load, or infrastructure. However, population, load and infrastructure are not appropriate means by which to normalize these data. For example, it is not necessarily the case that a state with double the population is expected to experience twice as many outages; a large-scale outage can easily affect most or all of a state, regardless of population. Similar disconnects exist if these data were normalized based on load or transmission system size.

Figure 3-19. Annual Number of Power Outage Events in Comparison States

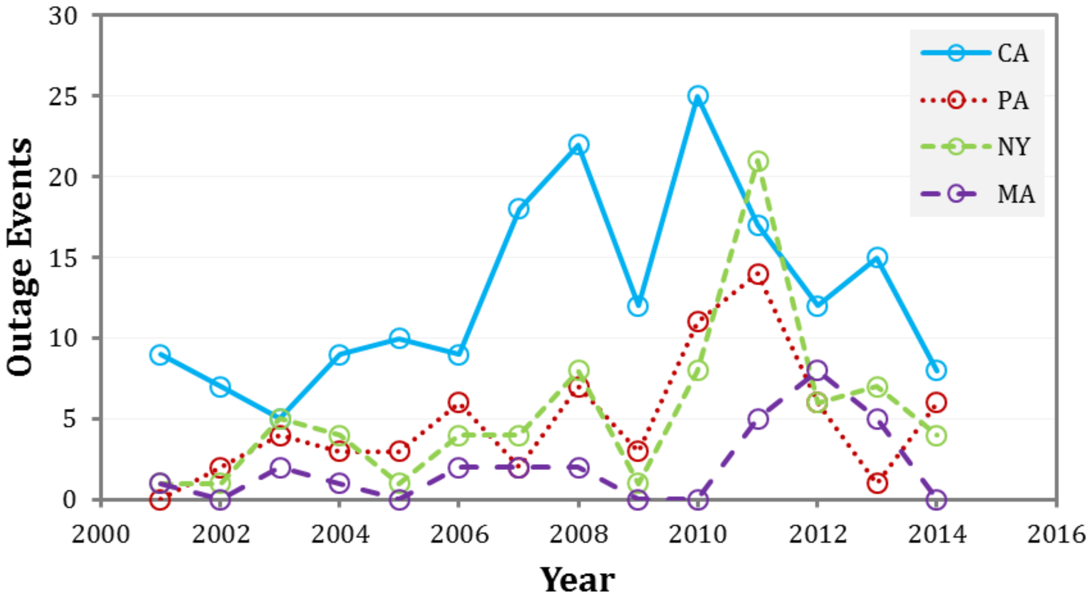
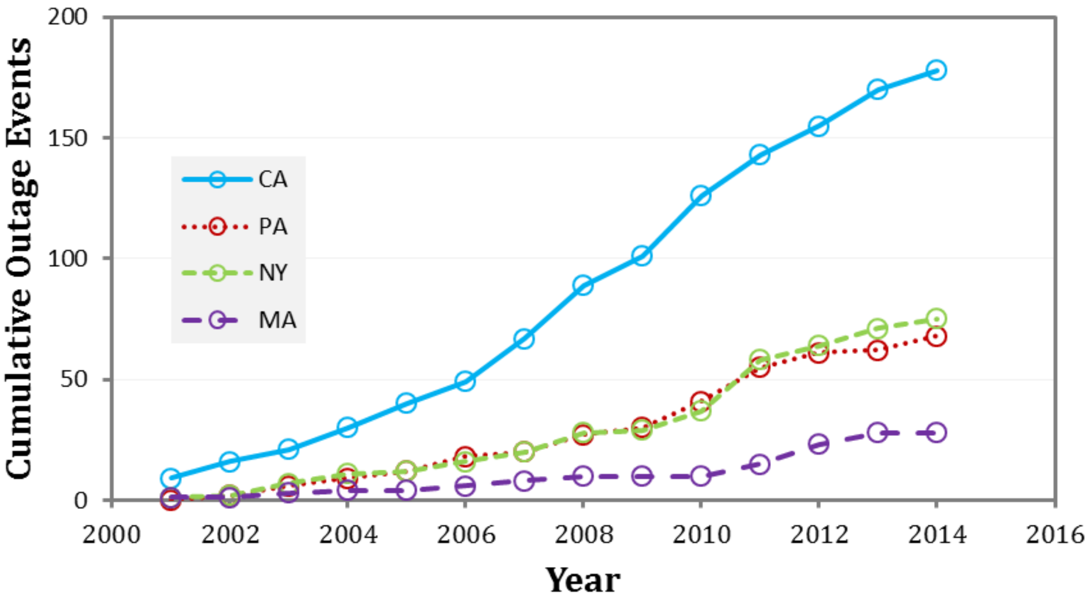


Figure 3-20. Cumulative Number of Power Outage Events in Comparison States

This figure uses the same data as Figure 3-19, displayed in cumulative form.



3.6.2 Customers Affected by Outages

As previously noted in Section 2, the number of customers affected by outages is the most reliably reported metric and thus is the most useful for comparisons. Figure 3-21 shows the number of customers affected by power outages in each of the four states over the 2001-2014 timeframe, while Figure 3-22 shows the same data in cumulative form. With the highest population, California has the largest number of affected customers in most years. For New York, the most notable data point is in 2003, when more than three million customers were affected by the Northeast Blackout. Hurricane Sandy caused the second highest peak in the year 2012, but even with all data reported, the total number of affected customers is lower than the year 2003. The 2011 Halloween Nor’easter has a larger effect than Hurricane Sandy in Massachusetts and Pennsylvania, though the effects of Hurricane Sandy can also be seen in these two states.

Figure 3-21. Annual Number of Customers Affected by Power Outages

This metric sums the number of customers affected in each outage. Some customers may have experienced more than one interruption in a given year, so in that case, those customers would be counted multiple times.

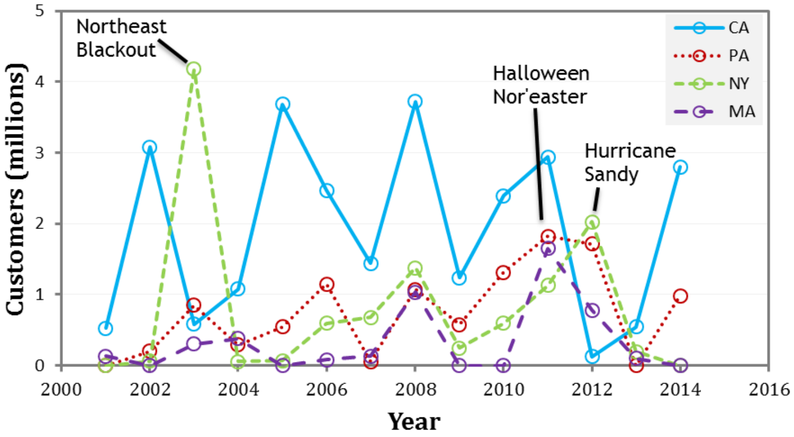
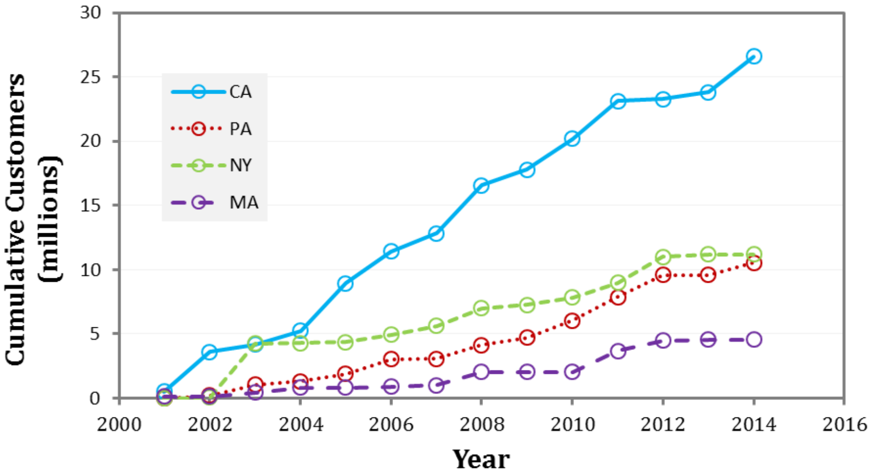


Figure 3-22. Cumulative Number of Customers Affected by Power Outages

This metric sums the number of customers affected in each outage. Some customers may have experienced more than one interruption in a given year, so in that case, those customers would be counted multiple times. This figure uses the same data as Figure 3-21, displayed in cumulative form.



The number of customers affected by power outages in a given state depends naturally on the total number of customers within that state. Accordingly, Figure 3-23 (annual affected customers) and Figure 3-24 (cumulative affected customers) present the same data normalized to total state population. While population is not equal to the number of customers because households often contain multiple people and omit non-residential customers, the two quantities should scale relatively well.

When the customer data is normalized to population, the four states appear to be very well matched on average. While there are several notable events in each state (Figure 3-23), the rate at which customers experience power outages is very similar over the long term (Figure 3-24).

Figure 3-23. Annual Number of Customers Affected by Power Outages, Normalized to Population

This figure reports the same data as Figure 3-21, normalized to total population in the state.

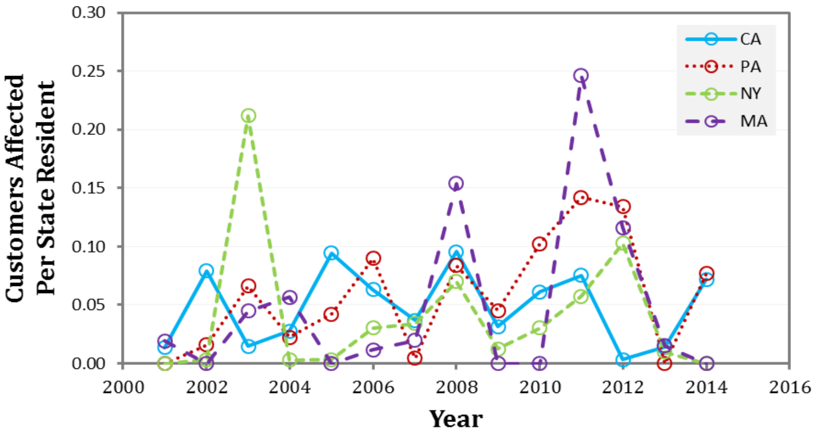
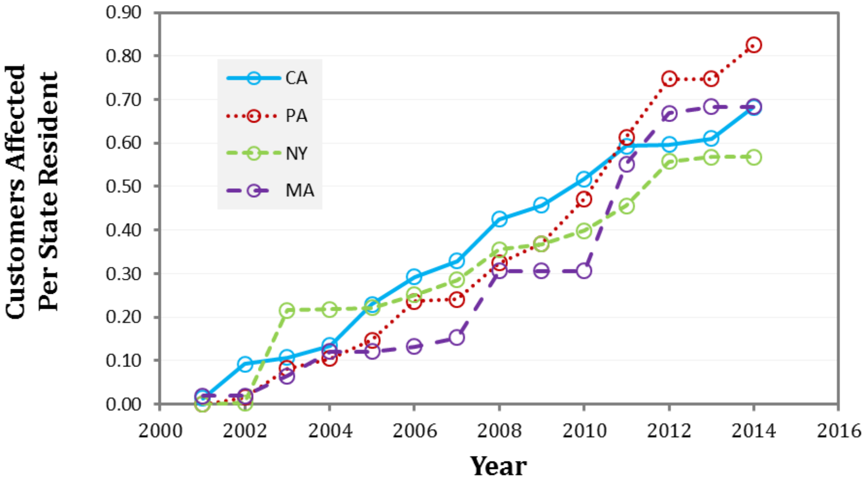


Figure 3-24. Cumulative Number of Customers Affected by Power Outages, Normalized to Population

This figure reports the same data as Figure 3-22, normalized to total population in the state.



“Customer-days of outage” is an alternative metric that integrates the duration of outages.[24] The market adoption of smart grid technologies should help to reduce not only the number and physical extent of outages, but also the duration of those outages. The “customer-days” metric integrates all three measures (number, physical extent, and temporal extent). Figure 3-25 shows

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[24] For each outage, outage duration (in days) was multiplied by the number of customers affected. Because both of these metrics are well tracked in the dataset, the resulting metric should be reliable.

the annual duration of power outages, in millions of customer-days, in the four comparison states. These data can be difficult to interpret; for example, the duration of outages in California is generally greater when measured in customer-days (Figure 3-25), but the state also has the greatest number of customers. Hurricane Sandy is noticeable in New York and Pennsylvania when examining annual customer-days of outage.

Figure 3-25. Annual Duration of Power Outages, in Millions of Customer-Days of Outage

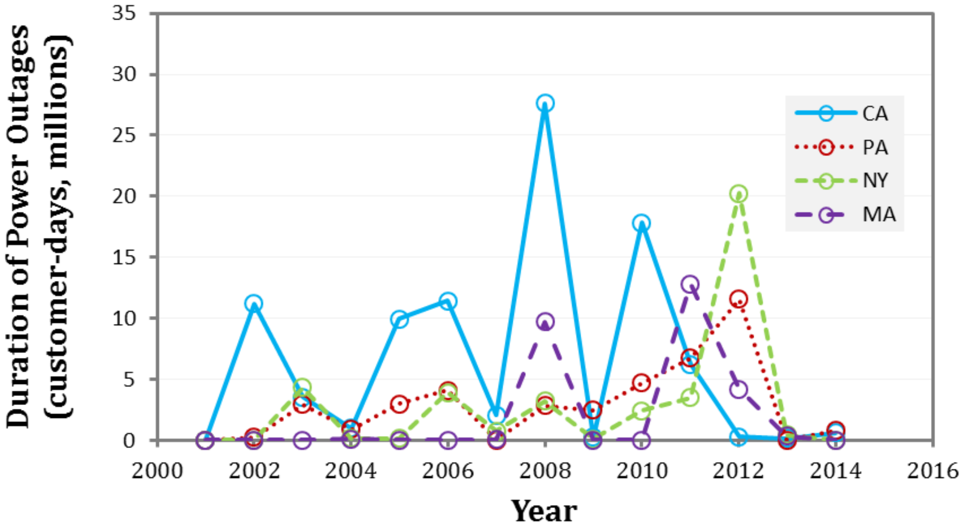
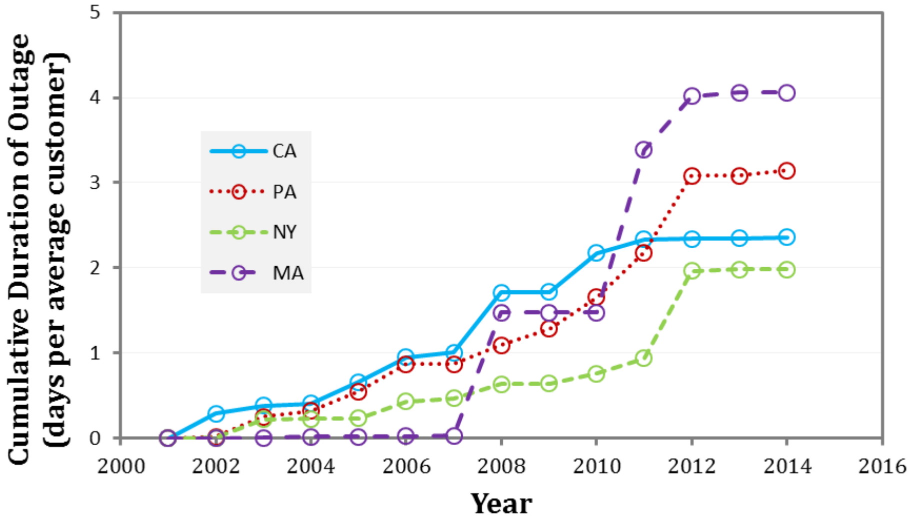


Figure 3-26 shows the same data as Figure 3-25 but normalized to population and cumulative over time, making the data more easily comparable across states and over time. The duration of power outages is generally similar among the four, ranging from two to four total days over the 13-year study period. Over the last 13 years, the average customer in New York experienced the shortest cumulative outage duration at only two days, although over half of that value is attributable to Hurricane Sandy.

Figure 3-26. Cumulative Duration of Power Outage for an Average Customer, Normalized to Population



3.6.3 Lost Load Due to Power Outages

The amount of lost load reflects the total electrical scale of a power outage and can be used as a comparison point to the number of customers affected. The number of customers affected most strongly reflects the effect of outages on residential customers, whereas lost load better captures the effect of outages on larger industrial or commercial customers.

Figure 3-27 shows the annual lost load due to power outages in each of the four examined states over the 2001-2014 timeframe, while Figure 3-28 shows the same data in cumulative form. There are two standout events: the 2003 Northeast Blackout, which affected New York more than the other states, and Hurricane Danielle (8/20/2004), which had the greatest impact on Massachusetts. Pennsylvania and California generally experienced more consistent loss of load. Notably, the quantity of lost load from Hurricane Sandy in 2012 is unreported in the source dataset and appears, incorrectly, as zero on these figures. There are several other outages that also report a lost load of zero, presumably because lost load is more difficult to estimate than duration or affected customers. This makes the lost load data less reliable than other measures examined, such as customers affected and outage duration.

Figure 3-27. Annual Lost Load (MW) Due to Power Outages

This metric sums the MW of lost load in each outage. Some customers may experience more than one interruption in a given year; in these cases, those MWs of lost load are counted multiple times.

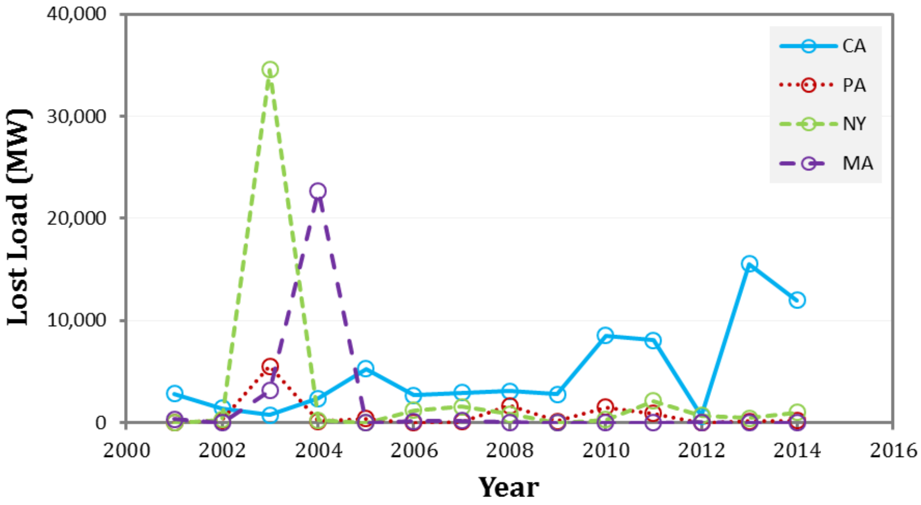
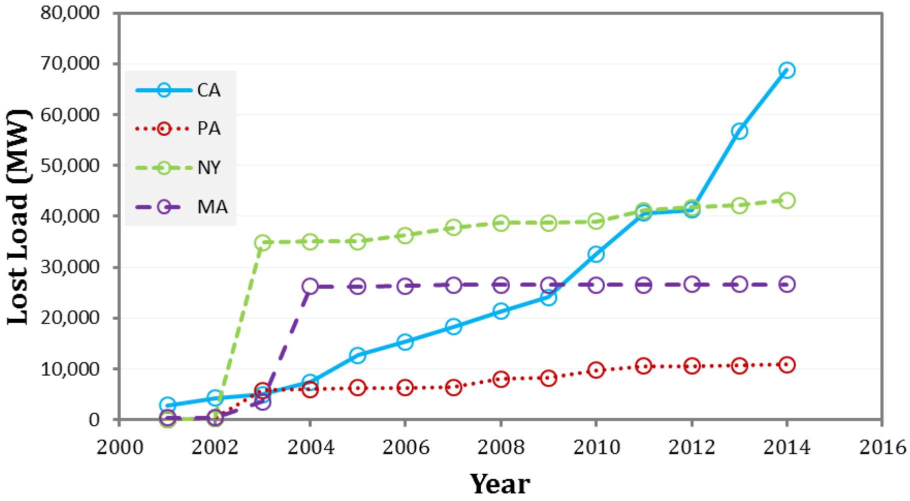


Figure 3-28. Cumulative Lost Load (MW) Due to Power Outages

This figure uses the same data as Figure 3-27, displayed in cumulative form.



As with the customer data, lost load is relative to the total load base within a state. To normalize the data, the MW of lost load was divided by the total net summer generation capacity in the state. Figure 3-29 and Figure 3-30 present lost load - normalized based on total load base - on an annual and cumulative basis, respectively. Generally, adjusting for the size of the electricity grid in each state further amplifies the patterns identified in the unadjusted data. The 2003 Northeast Blackout and Hurricane Danielle again dominate the results. Examining cumulative lost load

(Figure 3-30), the highest rates of lost load occur in New York and Massachusetts, driven primarily by the 2003 Northeast Blackout and the 2004 Hurricane Danielle.

Figure 3-29. Annual Lost Load (MW) Due to Power Outages, Normalized to Net Summer Capacity

This figure reports the same data as Figure 3-27, normalized to net summer generation capacity in each state. If the same load experiences interruptions several times, it is counted multiple times.

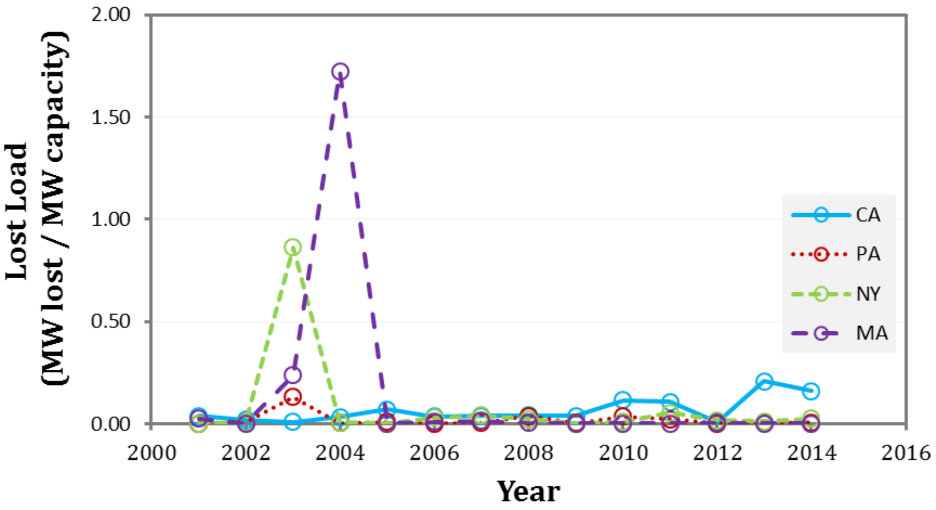
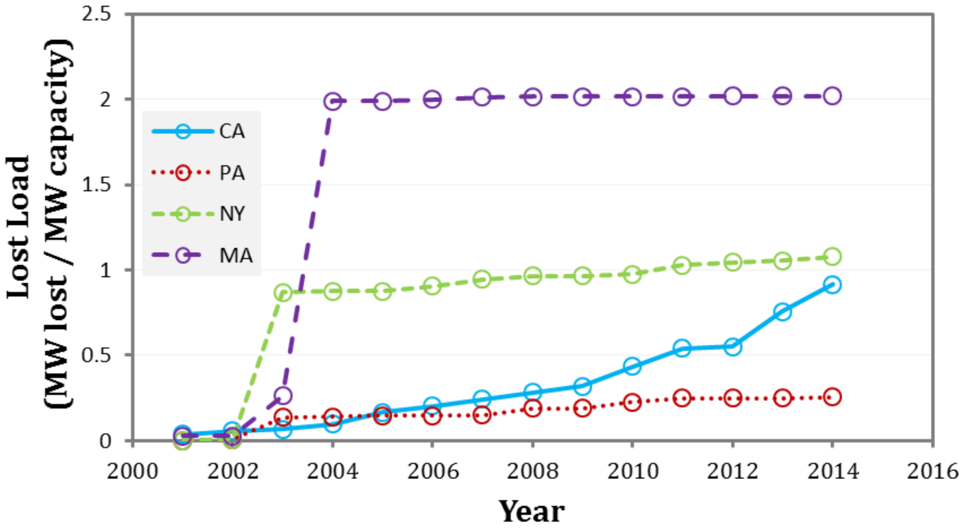


Figure 3-30. Cumulative Lost Load (MW) Due to Power Outages, Normalized to Net Summer Capacity

This figure reports the same data as Figure 3-28, normalized to net summer generation capacity in each state. If the same load experiences interruptions several times, it is counted multiple times.



4 Summary of Findings

The data presented in Section 3 provide NYSERDA with a baseline for tracking future smart grid development at the state level. The results ultimately show that New York is leading similar states in some metrics, such as outage duration, but falling behind in others, such as load management and distributed generation. The following sections summarize key findings for each metric examined in this benchmarking assessment.

4.1 Load Management

- Data on load management programs suggest that the primary goal of such programs to date is on reducing peak demand rather than reducing total demand for electricity. Accordingly, to date, the total energy savings achieved through load management programs comprises a very small proportion of total electricity sold in all four states. For example, in California in 2013, load management programs reduced electricity consumption by roughly 202 GWh. While this value may seem significant in absolute terms, it represented only 0.07% of the total electricity sold in California in the same year. In New York, based on EIA data, the largest energy savings from load management programs occurred in 2011, when energy savings totaled 181 GWh, or 0.09% of the total electricity sold.

- When comparing New York against the three comparison states, New York is lagging behind in most metrics related to load management. While a detailed investigation of the underlying reason was beyond the scope of this assessment, this result could be due to the robust installed reserve margin NYISO has maintained from excess generation capacity over the studied period. In the summer of 2015, for example, the North American Electric Reliability Corporation (NERC) estimated reserve margins (including both generation and load management) to be 19% in PJM (Pennsylvania), 27% in New York, 22% in New England, and 27% on the West Coast.[25, 26] Furthermore the NYSIO is heavily reliant on natural gas for electricity generation.[27] While natural gas prices were at their highest levels in 2005, they decreased significantly after 2007, making natural gas power plants more economically viable than load management.

4.2 Distributed Generation

- The majority of installed distributed generation capacity in New York throughout the period analyzed consisted of fuel-based internal combustion engines. Installed distributed generation capacity decreased as internal combustion engines were

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[25] West Coast is used instead of the California data because California is heavily reliant on electricity imports from neighboring states. Thus, the state’s effective reliability is a function of the reliability of the larger system in which it participates.

[26] North American Electric Reliability Corporation, 2015.

[27] U.S. EIA, 2015.

decommissioned. Starting in 2010, however, installations of distributed solar PV grew to account for half of New York's installed distributed generation capacity by 2013.

- Distributed energy storage capacity in New York (and across all states analyzed) was negligible throughout the period analyzed.

4.3 Advanced Metering Infrastructure

- Deployment of smart meters in New York was significantly lower than in the other states; by 2013 only 0.4% of New York customers had smart meters. In most states, adoption of smart meters is driven by either utility interest in the technology (i.e., because of decreased meter reading costs) or in the case of California, through the direction of the state PUC. 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.[28]

4.4 Utility-Scale Storage

- Making direct comparisons between utility-scale energy storage projects in different states is difficult, as the development of such technologies in each state responds to each state's unique needs and capabilities. For example, California has recently focused on constructing large pumped hydro facilities to provide load shifting, while Pennsylvania storage projects have focused on providing frequency regulation. New York already has a large quantity of pumped hydro storage in the form of dispatchable hydropower plants. Additionally, New York has somewhat lower frequency regulation prices than Pennsylvania. The five largest energy storage projects between 2001 and 2015 suggest that utility scale storage in New York has been focused on providing ancillary services, such as frequency regulation, voltage support, or electric bill management (customer-located load shifting).

- Generally, New York has a similar quantity of utility-scale storage projects as Massachusetts and Pennsylvania, in terms of total number of projects, power capability, and energy capacity. California exceeds the other states in each of these metrics, but this is likely due in part to a stronger need for energy storage services. While New York lags behind California in terms of utility-scale energy storage deployment, this should not necessarily be taken as a sign that insufficient effort is being invested. Furthermore, the outcome in California should not be attributed only to the state's energy storage mandate. The mandate is not exogenous to the market; rather, the mandate represents a direct response to a perceived need for more storage, and a significant quantity of storage would likely have come online even without the mandate. While a similar mandate in New York would likely result in a significant increase in storage projects, it is not clear that this is necessary or desirable.

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

4.5 Power Outages

- The number of outage events in New York State was highly variable across years, but similar to the comparison states, with fewer outages than the much larger California system and approximately the same number of outages as the similarly sized Pennsylvania. The year 2011 saw the largest number of outages in both New York and Pennsylvania due to severe weather associated with Tropical Storm Irene (8/28/2011) and the Halloween Nor’easter (10/29/2011).

- The impacts of large events in New Yok are clear. While removing the 2003 Blackout and Hurricane Sandy lowers New York’s rate of customer outages, these types of events are an important feature of New York’s electrical system. Of note, while the normalized data in Figure 3-24 are in line with comparison states, most of New York’s affected customers are associated with only two events: the 2003 Northeast Blackout and Hurricane Sandy. This may indicate that the New York grid is generally less vulnerable to small disturbances but more likely to experience large disturbances than California or Pennsylvania (Massachusetts demonstrates a similar effect). This may be due to the large population concentrated in the relatively vulnerable New York City area or to other weather or grid features of New York, and may point towards a focus for smart grid investment in the future.

- 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.

- Comparing the lost load in New York to the other states, New York appears to have a generally low rate of lost load due to power outages, with the important exception of the 2003 Northeast Blackout (note again that the data for lost load does not include lost load from Hurricane Sandy). If losses from Hurricane Sandy scaled approximately with affected customers, that event would appear as a large loss, although smaller than the 2003 event. California serves as an interesting comparison for the other three states. Even when normalized for electricity system size, California has a higher rate of lost load in most years. However, California does not have many large outage events and its lost load is spread fairly evenly over time. The EIA data source provides a cause for each outage, and the California outages are driven primarily by load shedding, power shortages, and wildfires, which are all likely to be limited in scope. This reinforces the relative importance of large-scale events in New York.

5 Conclusions and Recommendations

The data presented in this report primarily provide insight into New York's relative state of progress toward smart grid development and serve as a baseline from which to measure the effect of future interventions. Comparing metrics across is states difficult because external factors may change metrics over time. The benchmarking assessment identified a few areas where differences are significant enough to prompt recommendations for New York's policy goals. Of note, the following recommendations pertain to smart grid development at a state level, rather than the focus of NYSERDA's Smart Grid program.

- **Continued focus on distributed generation:** Distributed generation capacity in New York is low relative to the comparison states, especially California: New York has 1/20th the amount of distributed generation of California, but half the population. Total distributed generation in New York has been relatively constant over the last ten years, although new solar PV has displaced declining diesel generation. Given the potentially significant effects of low-frequency, high-impact outages, a continued focus on distributed resources seems appropriate.

- **Increased focus on AMI, given its importance for meeting REV's goals:** Deployment of smart meters in New York is also significantly lower than in the comparison states; by 2013 only 0.4% of New York customers had smart meters. Although the deployment of smart meters is not managed by NYSERDA's Smart Grid program, AMI is likely to be essential in a post-REV New York system. REV is set to change the relationship between distribution utilities and customers, and many of the proposed services and interactions (e.g., price-responsive customers, customer-sited storage) require smart meters.

- **Continued focus on system reliability:** Power outages in New York suggest a pattern of low-frequency and high-impact events. The outage data also suggest that New York electricity system operators are effective at minimizing the duration of power outages. This suggests that a focus on reliability in the face of extreme events is particularly significant in New York.

The benchmarking assessment also indicates that some metrics are more useful for tracking smart grid development than others, although two key factors limit the ability to draw direct and effective conclusions about the metrics' relationship to smart grid development in New York. First, comparisons across states can be confounded by fundamental differences in the nature of each state's electricity system. This makes direct comparison difficult or impossible. Second, many of the observed effects are strongly influenced by external factors or trends, making attribution to smart grid programs difficult. Overall, investment in smart grid technology and infrastructure should demonstrate long-term effects on the presented metrics; these effects would have been small until now.

The most useful and clear metrics, which NYSERDA should consider tracking into the future, are:

- Power outage duration and customers affected,
- Number and scale of new (not total) energy storage projects,
- Number and percentage of price- and time-responsive customers, and
- Smart meter deployment.

These metrics can be tracked using reliable and consistent data, are generally comparable across states, and indicate important trends relating to smart grid success.

Other metrics, such as potential and actual load management, are likely less useful because data are highly variable from year to year, and strongly affected by external factors, such as the price of natural gas. Similarly, distributed generation capacity is highly dependent on external factors such as market forces and system idiosyncrasies. Total energy storage capacity is heavily skewed by pre-existing pumped hydro plants, making comparisons difficult. The data on lost load due to power outages are not reported consistently (e.g., many large outages incorrectly report lost load as zero), making that metric less useful than the other, better-reported power outage metrics recommended above.

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