The NSERC Energy Storage Technologies Network Project

Comparative Survey of Energy Storage Policy Frameworks

Jurisdictional Case Studies:

U.S. and Select States

Working Paper:

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Main Objectives:

The main two objectives of the Policy theme of the NSERC Energy Storage Technology Network projects are [1].

- Assess of the existing legislative information and policy frameworks at different government levels as they relate to the development and use of energy storage technologies, particularly in support of the large-scale integration of intermittent renewable energy sources, such as wind and solar.

- Make recommendations regarding policy frameworks at the federal and provincial levels to advance the further development and deployment of energy storage technologies in an environmentally and economically sustainable approach.

1. Summary of Observations and Key Findings

Energy storage technologies are emerging as a key component to the evolving electric grids and future energy systems, where electricity generation mostly relies on renewable energy sources. In addition to managing the intermittent nature of wind and solar energy, energy storage can also provide potential grid services and applications in operating and ramping reserves, frequency response and regulation, as well as transmission and distribution upgrades deferral.

To promote effective deployment and integration of various energy storage technologies, appropriate policy and regulatory plans are required. As part of the overall objective of this study, i.e., assessing policy frameworks in different jurisdictions and at different government levels, this study provides a discussion of major findings and observations in the U.S. and Canada, followed by a summary and overview of the existing plans in selected states.

1.1. Major Findings and Observations

a. Policy Goals

- The underlying rationales behind storage procurement are still unclear. In some cases, like California and Hawaii storage is envisioned as part of a clean and low-carbon energy transformation with high penetration of intermittent renewable energy.
- In other states and jurisdictions framing is a useful set of services and capacities to have available to electricity systems and market, like those identified and discussed by the Federal Energy Regulatory Commission (FERC). However, the

main challenge is that currently the market rules are not allowing for full utilization [2].
- Economic development around storage technology is the other important policy goal, for example, in the US at the federal level, and in the states of New York and Massachusetts. In Canada, the National Research Council's Storage Roadmap and Alberta Storage Alliance's document in 2016 fall under this goal [3], [4].

b. Emerging Economic Models

- Operate within market rules in the organized markets model, for example, in energy, ancillary, demand side management (DSM), and transmission and distribution (T&D) upgrades deferral services.
- Targeted procurement in monopoly or hybrid markets, where storage is seen as grid management assets and to be paid on capacity rather than energy basis.
- In some cases, the economic model for storage is embedded with generation assets, where generators are required to provide dispatchability regardless of technology.
- In some cases, like the FERC, the role of storage is seen as part of distributed energy source aggregation services.

1.2. Key Barriers to Commercial Scale Deployment

The distinction between electricity market organizations and structures, whether vertically integrated monopolies or organized markets, is key to the study and analysis of different approaches and plans for widespread deployment of energy storage in different applications on the electric grid. Following are the highlights of the monopoly and organized markets characteristics related to energy storage integration [5], [6].

a. Monopoly markets

- Vertically integrated monopolies are more cautious in approach. In such markets, targeted procurement of storage is at discretion of utility if useful for ancillary services, balancing, avoided costs of deferred T&D infrastructure.
- Canadian Hydro monopolies have long history of providing balancing services using their hydro storage assets. For example, Quebec and Manitoba have had specific projects and programs on modern storage, including batteries and electric vehicles.

b. Organized markets

- In organized markets, which is the focus of this study, there are more possibilities of technological innovation. In such markets, theoretically, qualified parties can offer services to the energy market or the ancillary services, DSM, or the services in the capacity, reserves, and balancing applications. In these markets, role of grid operators is more facilitative, such as in California and FERC regulated markets, and similarly, in Ontario and Alberta in Canada.

Therefore, the key barriers to commercial scale deployment of energy storage can be summarized as below:

- Market rules largely formulated during liberalization of markets in the past, which modern storage technologies did not exist, and were not designed for technologies that can function as generators and consumers [2].
- New resources may need to participate under one of the existing participation models developed for some other type of resources.
- Participation in energy markets does not make full use of potential contributions and value of assets.

Examples of barriers include:

- Rules limit which type of market resources can participate in energy, DSM, capacity, and ancillary services.
- Bidding characteristics, i.e., the physical and operational constraints that a resource would identify per the grid operator requirements when submitting offers to sell capacity, energy, or ancillary services or bids to buy energy in the organized wholesale electric markets. A common instance is the minimum size requirements.
- Lack of rules about the behind-the-meter activities and distributed resource aggregators.
- Restrictions on ability to act as both generators and consumers in same market, which is the role of storage.

1.3. Proposed Solutions

In the US, the FERC has proposed to amend its regulations to remove barriers to the participation of electric storage resources and distributed energy resource aggregations in the capacity, energy, and ancillary service markets operated by regional transmission organizations (RTO) and independent system operators (ISO) [2].

Some proposed solutions by the FERC include:

- Ensure that electric storage resources are eligible to provide all capacity, energy and ancillary services.
- Incorporate bidding parameters that reflect and account for the physical and operational characteristics of electric storage resources. For example, establish a minimum size requirement for participation in the organized wholesale electric markets that does not exceed 100 kW.

- Ensure that electric storage resources are both seller and buyer in the wholesale market consistent with existing market rules.

- Create a new form of market actor, role of aggregators, to manage and integrate behind-the-meter activities and distributed energy systems. Similar proposals were proposed recently in other jurisdictions, e.g., in Ontario by the Electricity Distributors Association, that envisions local distributor companies (LDCs) will assume a critical function in the province's energy transition as a *Fully Integrated Network Orchestrator* that will enable, control and integrate distributed energy resources within its distribution service territory [7].

2. Overview of US Energy Storage Policy Landscape

Energy storage systems and their potential services they can provide on the electric grid can be purchased in regulated and deregulated markets. However, most of storage services, market opportunities, cost-recovery methods and incentive programs are governed by a well-established regulatory system. In the US, the rules and regulations that govern energy storage deployment are enforced by agencies at federal and stale levels including FERC, public utility commissions (PUC), and grid operators such as ISOs and RTOs [8], [9].

The FERC is an independent agency that regulates the interstate transmission of electricity and wholesale sales, as well as transportation and sales of natural gas, and oil. FERC also reviews project proposals to build liquefied natural gas terminals, natural gas pipelines, licensing hydropower projects [9]. Furthermore, the Energy Policy Act of 2005 has given FERC additional responsibilities to protect the reliability of the power system through mandatory standards, as well as additional authority to enforce FERC regulatory requirements [10]. ISOs and RTOs are similar entities that are federally regulated and are responsible for the control and management of the electric transmission grid within a region. Unlike RTOs, an ISO usually controls single states or smaller regions. Public Utility Commission is another agency that acts at the state level and regulates the rates and services provided by utilities. Table 1 summarizes main regulatory agencies and organizations affecting the US electricity storage systems.

As presented in the table, these organizations provide regulations and enforce critical rules to the energy industry. While ISOs provide oversight of transmission and generation in control areas, FERC regulates interstate transactions and determines rules and tariffs, and PUC's major role at the state jurisdiction is to regulate utility management, operations, and capacity acquisition.

These rules and regulations impact the growth of the storage industry, where policies can create or impede market opportunities for storage [9]. A key observation to the commercial scale deployment of energy storage systems is when ISO's jurisdiction does not cross a state borders.

Figure 1 shows North American energy market with RTOs and ISOs across the Continent. Central to analyzing the energy storage policies and projects at the state level is to note that most RTOs and ISOs cross state borders, and several states are divided between more than one operator.

Table 1 – US organizations regulating electricity storage systems [9].

Agency	Activities
FERC	• Regulates wholesale electricity market operations. • Sets rules for ISO and RTO operations and procurement rules. • Sets rules for energy storage participation and demand response in grid operation and sale of ancillary services in wholesale markets.
ISO	• Manages electric transmission in a region. • Buys ancillary services on its transmission grid for supply and demand balance. • Establishes procurement rules of resources such as ancillary services, spinning reserves for the transmission system stability.
PUC	• Regulates utilities' energy and capacity acquisition, management and operations. • Sets rates for retail electricity, and assesses cost-recovery of resource acquisition and operations.

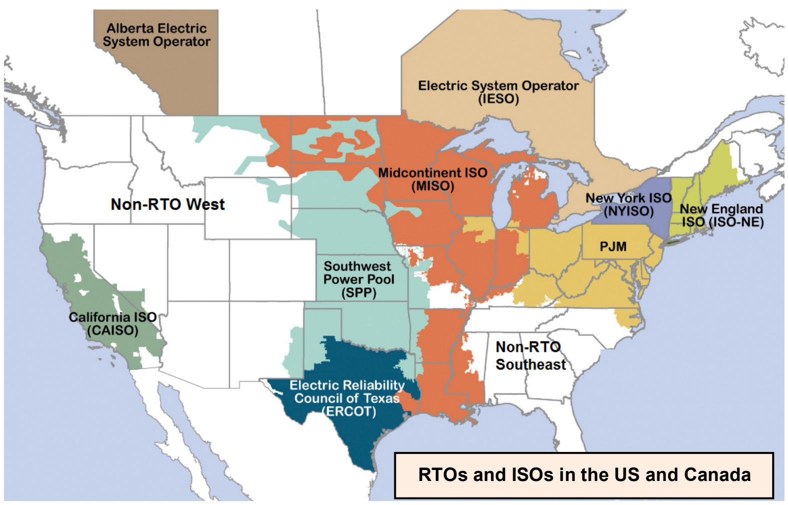

Figure 1- RTOs and ISOs are independent entities that control the electric grid and coordinate generation and transmission of electricity for more than 65% of North America [11].

US Department of Energy (DOE) as well as several national laboratories including National Renewable Energy Lab (NREL) and Sandia Laboratory provide technical and NREL's research facilities and equipment, including the Energy Storage Laboratories at Denver West Building and the Thermal Test Facility help component developers and automobile manufacturers improve battery and energy storage system designs by improving performance and battery life [12].

DOE has launched the energy storage systems program to develop advanced energy storage technologies and systems, in collaboration with stakeholders such as industry, government organizations and academia to increase the reliability, performance, and competitiveness of electricity generation and transmission in the grid [13]. DOE has published several publications including journal articles, books, patents, and has presented technical procurement plans across its laboratories, including Office of Electricity (DOE-OE), Sandia National Laboratories (SNL), Pacific Northwest National Laboratory (PNNL), and Oak Ridge National Laboratory (ORNL). Table 2 summarizes regulatory agencies and organizations affecting the US electricity storage systems.

Table 2 – Selected DOE's ESS publications across various national laboratories [13].

Laboratory

PNNL	**Title**
2016-June	Energy Storage System Guide for Compliance with Safety Codes and Standards.
2014-June	Determination of Duty Cycle for Energy Storage Systems Integrated with Microgrids
2014-June	Protocol for Uniformly Measuring and Expressing the Performance of Storage Systems
SNL	**Title**
2016-Sept	Energy Storage Procurement - Guidance Documents for Municipalities
2016-March	PV Firming Duty Cycle PV Smoothing Duty Cycle
2016-Aug	Energy Storage Financing - A Roadmap for Accelerating Market Growth
2016-June	Energy Storage System Guide for Compliance with Safety Codes and Standards
2016-April	Determination of Duty Cycle for Storage Systems in a Renewables Firming Application
2016-March	PV Firming Duty Cycle - PV Smoothing Duty Cycle
2016-Feb	Estimating Potential Revenue from Electrical Energy Storage in PJM
2013-Sept	Market and Policy Barriers to Energy Storage Deployment
DOE-OE	**Title**
2015-Mar	DOE – EPRI Energy Storage Handbook
2014-Dec	DOE OE Grid Energy Storage Report
2014-Dec	DOE OE Safety Strategic Plan
NREL	**Title**
2016-Feb	Energy Storage – Possibilities for Expanding Electric Grid Flexibility
2015-Mar	NREL Energy Storage Projects: Annual Reports
ORNL	**Title**
2014-June	Membrane Separator for Redox Flow Batteries that Utilize Anion Radical Mediators
2011-June	Final Report: Economic Analysis of Deploying Used Batteries in Power Systems

DOE's Office of Electricity Delivery and Energy Reliability has also created a global energy storage database that presents information on federal and state storage projects and policy programs [14].

2.1. Federal Energy Regulatory Commission:

In the US electricity market structure that the states are linked through RTOs and ISOs that embrace more than one state/region, the FERC has played a central role in promoting storage and distributed energy resources, addressing barriers to their participation in the energy, capacity and ancillary services market, and in providing guidance and clarification on the cost, market and cost recovery opportunities. The main challenges that all efforts are trying to address are the clear definition of storage for the operator, i.e., whether storage is a load or a generator asset; what applications storage can provide, and where on the system, and for how long they are able to sustain them; and finally, how the provided services should be paid for and who is responsible for that. One of the major actions the FERC has taken to remove barriers to the wide adoption of storage is the proposed rulemaking appeared in November 2016 to allow energy storage and distributed energy resource aggregators to participate in the wholesale electric market [2]. The proposed reforms in this document are to be implemented to remove barriers and establish a participation model in the organized wholesale electric markets, recognizing physical and operational characteristics of electric storage resources. In another recent effort to maximize the full benefit of storage, in the form of a policy statement, the FERC is providing clarification and guidance on the energy storage resource services enabling them to provide multiple services at a mixed cost- and market-based rate. The statement presents three major areas of concern, and proposes to (i) avoid double recovery from both cost-based and market-based rates without returning the credit to the ratepayers, (ii) remove/lower the possible impacts to the competition in the wholesale market, and (iii) protect the independence of the RTOs/ISOs from the market participants.

All these efforts highlight the crucial facilitative role of the FERC. A summary of the quotes and excerpts taken from the above discussed documents as well as the links to the full reports are provided in Appendix A.

2.2. CALIFORNIA:

California is a global pioneer in shifting its energy system to a sustainable paradigm, incorporating renewable energy sources, especially solar and wind energy with the goal to reduce environmental emissions. The state’s drastic growth in renewable energy has been dominated by solar photovoltaic installations more than doubling in recent years, achieving the first place in the national ranking [15]. The next step in this rapid transition to a more sustainable system is adoption of energy storage. Incorporating intermittent renewable energy resources requires integration of storage systems and contract provisions to maintain operational flexibility of the electric grid and quickly match production and consumption. Energy storage resources are flexible resources that help the transition to achieve reliable and low-carbon grid operations. Maximizing energy storage resources in California’s state market as a leading jurisdiction requires a comprehensive plan incorporating effective policies, incentives and rebates, and processes to support innovation and manage risk in the near- and long-term future [16].

Key players:

With energy storage resources entering the market of the California's market, the following are the key organizations that identify actions and priorities at the state level and implement future regulatory initiatives and policies.

- The California Independent System Operator (CAISO) is a non-for-profit and independent system operator that provides non-discriminatory access to the bulk of the state's wholesale transmission grid, supported by a competitive energy market and comprehensive infrastructure planning efforts [17].
- As the state's primary energy policy and planning agency, the California Energy Commission (CEC) is committed to reducing energy costs and environmental impacts of energy use while ensuring a safe, resilient, and reliable supply of energy. The CEC website provides a comprehensive collection of information on the state's energy policy, demand forecasting, energy conservation and efficiency standards, as well as renewable energy supply systems [18].
- The California Public Utilities Commission (CPUC) regulates privately owned electric, natural gas, telecommunications, water, railroad and passenger transport companies. The CPUC protects consumers by ensuring the provision of safe, reliable utility service and infrastructure at reasonable rates, with a commitment to environmental conservation.
- Investor Owned Utility companies (IOUs) are private electricity and natural gas providers overseen by CPUC. The three California IOUs (Pacific Gas and Electric, San Diego Gas and Electric, and Southern California Edison) have performed resource procurement for fulfillment of the energy storage targets.

To identify policy and technology requirements to address challenges faced by the storage sector in the California market, the CAISO, CPUC, and CEC developed an energy storage roadmap to address challenges and concerns and identify actions along the State's priorities [16]. Three main identified challenges are: (i) expanding revenue opportunities; (ii) high costs of integrating and connecting to the grid; and (iii) streamlining policies and processes to increase certainty. The actions required to address these challenges can be summarized as: enhancing existing products and creating new market opportunities; clarifying operational constraints for grid connecting of energy storage; lowering costs of metering and connection; and creating a predictable process and transparent system for commercializing and connecting storage projects [16].

Current policy foundation:

In 2010, California Assembly Bill 2514 was signed into law, requiring the CPUC to determine appropriate utility procurement targets for commercially available and cost-effective energy storage systems [19]. Below is the summary of the bill:

- California Assembly Bill 2514:
  - Approved in 2010
  - Entered the CPUC code in 2014
  - The CPUC energy storage procurement total target of 1.325 GW to be completed by 2020, and implemented in 2024.
- CPUC funding programs including:
  - Permanent Load Shifting and the Self Generation; and
  - Incentive Program to provide rebates for customer-side energy storage.
- CEC's Electric Program Investment Charge to:
  - provide funding for critical research to advance the effectiveness of various energy storage technologies as a viable grid resource.

The state has identified five major areas for the clarification and facilitation of the procurement of energy storage resources and to address the key challenges the state has identified. These areas include planning, procurement, rate treatment, interconnection, and market participation [16].

The following is the outline of the required priority actions by each of the key organizations involved in the electricity grid and for the further development and integration of storage systems within the state obtained from the California Energy Storage Roadmap [16].

Planning:

- CPUC: Distribution grid operational needs and required resources characteristics.
- CPUC: Facilitate clarification by IOUs of operational constraints that can limit the ability to accommodate interconnection on the distribution system.
- CPUC: Examine and clarify opportunities for storage to defer or displace distribution upgrades.

Procurement:

- CPUC/Energy Commission: Consider refinements to the valuation methodologies used by IOUs to support CPUC decisions on storage procurement and make models publicly available.
- CPUC: Clarify rules for energy storage qualification and counting in an evolving Resource Adequacy framework.
- CPUC: Consider unbundling flexible capacity Resource Adequacy counting.

Rate treatment:

- ISO: Clarify wholesale rate treatment and ensure that the ISO tariff and applicable business practices manuals and other documentation provide sufficient information.
- CPUC: Clarify and potentially modify net energy metering tariffs applicable to cases where energy storage is paired with renewable generators.

Interconnection:

- CPUC/ISO: Clarify existing transmission and distribution interconnection processes, including developing integrated process flow charts and check lists.
- CPUC/ISO: Evaluate opportunities to coordinate and streamline interconnection processes and ability to efficiently move between processes.
- CPUC/ISO: Evaluate the potential for a streamlined or 'fast track' distribution interconnection process for storage resources that meet certain use-case criteria.

Market participation

- ISO: Clarify existing ISO requirements, rules and market products for energy storage to participate in the ISO market.
- ISO: Identify gaps and potential changes or additions to existing ISO requirements, rules, market products and models.
- ISO: Where appropriate, expand options to current ISO requirements and rules for aggregations of distributed storage resources.

State's policy and legislations updates:

<u>Assembly Bill 2868:</u>

- While the state's three main IOUs (PG&E, SDG&E and SCE) are in the process of acquiring 1.325 GW of energy storage capacity by 2020 as mandated by California AB 2514, the new bill requires CUPC to direct state's IOUs to accelerate their acquisition of distributed energy storage capacity by exploring the feasibility of new programs and investing an additional 500 MW capacity, which directly increases the energy storage market from the already signed procurement goal of 1.325 GW [20].

<u>Assembly Bill 1637:</u>

- Increases the Self Generation Incentive Program (SGIP) funding by $249 million, sending a clear market signal to industry stakeholders that behind-the-meter energy storage will play a key role in reducing greenhouse gas emissions and supporting the next-generation electric grid. Based on the CPUC's recent SGIP reforms, three quarters of the program budget is now reserved for energy storage [21].

Assembly Bill 2861:

- Authorizes the CPUC to create an objective, expedited dispute-resolution process for distributed, behind-the-meter energy resources attempting to establish an interconnection to an IOU's electricity distribution network. This bill and resulting dispute resolution process will accelerate and reduce interconnection costs [22].

Assembly Bill 33:

- Directs the CPUC and the state's CEC to evaluate and analyze the potential for all types of long duration bulk energy storage, such as pumped hydro, to help integrate renewable generation into the grid. This bill ensures broader consideration of bulk energy storage's unique capabilities and market roles [23].

As indicated by the California Energy Storage Alliance, these new legislations and rules particularly will grow behind-the-meter and utility-scale energy storage markets, and address interconnection challenges of energy storage, ensuring the role of bulk energy storage in the state's renewable energy future.

2.3. NEW YORK:

Current electric grid status:

According to the New York Battery and Energy Storage Technology Consortium, the state's electric grid faces several challenges, including:

i. The households annual energy costs are significantly above the country's average and pay some of the highest electricity rates nationwide.
ii. New demands on the state electric system are increasingly stressing its aging grid infrastructure the transmission and distribution systems.
iii. Low-carbon energy resources and renewable energy to mitigate environmental pollutions and harmful impacts are driving the transition to a whole new system.

To address these challenges, the state has set several priority actions, such as the State Energy Plan that sets aggressive goals for reducing the greenhouse gas emissions including 40% by 2030 and 80% by 2050, and generating 50% of the state's electricity from renewable energy by 2030 [24]. In addition, the New York State Public Service Commission has launched the initiative Reforming the Energy Vision (REV), to modernize and transform the state's aging electric grid through increasing the deployment of distributed renewable energy resource, adopting new business models that incorporate technological advances and engaging customers in their energy choices, while maintaining the reliability and quality of the electricity system, and the affordability and competitiveness of electricity generation [25].

Distributed energy resources, including energy storage as a cost-effective solution for several grid applications, are key elements to achieving the goals of the REV initiative, and in the transformation of state's electric grid.
The three major areas for the services and benefits energy storage systems can provide in the state's electric grid, as identified by the NY-BEST Storage Roadmap [26], are:

i. Improving the efficiency and capacity factor of the electric grid;
ii. Integrating greater share of renewable energy sources into the electric grid; and
iii. Enhancing the overall reliability and resilience of the electric grid.

Key players:

- ***NYSERDA***: The New York State Energy Research and Development Authority is a public benefit corporation, aiming to help the state meet its energy goals. These goals include reducing energy consumption, adopting higher share of renewable energy, and conserving the environment, which are key to developing a less more reliable and affordable energy system for the state, accelerating the economic growth and reducing energy bills [27].
- ***NYISO***: The ISO for the state of New York operates the high-voltage transmission network, and controls and monitors the wholesale electricity markets. The NYISO is also responsible for the state's energy planning [24].
- ***NY-BEST:*** The state's Consortium on battery and storage systems was created in 2010, with the goal to position the state as a worldwide leader in the energy storage industry, including applications in transportation, grid storage, and power electronics. The NY-BEST includes different stakeholders across the industry and from manufacturers, academia, utilities, materials developers, government entities, engineering firms, and end-users [25].

Storage applications and policy status

In 2012, NY-BEST created an Energy Storage Roadmap to provide a reference guideline to all stakeholders in the energy storage industry, and to assess the state's landscape for energy storage technologies [28]. This industry includes a wide range of storage technologies including chemical batteries, fuel cells, mechanical systems such as flywheels and compressed air, pumped hydro, and thermal storage, among others. The roadmap examined the roles of technology, industry and policy in the state and attempted to establish key recommendations for these areas.
Given the drastic changes, growth and cost improvements in the energy storage industry, the state revisited its ten-year goal of 1 GW of storage capacity by 2020 to the new plan of having 2 GW and 4 GW of multi-hour storage capacity on the electric grid by 2025, and 2030, respectively [26]. Table 3 summarizes overall goals and policy recommendations for energy storage in the state of New York and under the REV initiative [26].

Table 3 – NY-BEST goals and policy recommendations for energy storage and under the state's "reforming the energy vision" policy [26].

Time	Goals and Recommendations
2017	Establish standardized safety regulations
2018	Modify NYISO rules for storage participation in wholesale markets
2019	Provide detailed distribution data with locational pricing
2020	Reduce energy storage soft costs by one third
2022	Achieve 1 GW installed storage capacity
2025	Achieve 2 GW installed storage capacity
2030	Achieve 4 GW installed Storage capacity: ⇒ New York's goal of 50% renewable energy penetration ⇒ New York's goal of 40% GHG reduction
2050	New York's goal of 80% GHG reduction

The state's new Energy Storage Roadmap was updated in 2016 to outline the strategy for the energy storage industry to achieve full potentials in the fundamentally changing electric grid, and to set out the specific actions required to overcome key barriers. Suggested specific recommendations include the following:

- *Create new regulatory and market mechanisms to monetize the full value of energy storage;*
- *Create common financing vehicles that help provide access to capital, simplify project finances and reduce perceived project risks;*
- *Reduce soft costs of energy storage installations related to siting, permitting, interconnection and other transactional costs;*
- *Create standardized methodologies, codes, and regulations that are recognized by all jurisdictions to increase commercial confidence in energy storage solutions and reduce soft costs;*
- *Perform a study to evaluate options and assess requirements for storage and other assets needed to support the State's renewable energy and greenhouse gas emissions goals;*
- *Increase the availability of information related to electric grid system needs and capabilities in order to enhance industry decision-making; and*
- *Implement a declining bridge incentive for storage that monetizes the value energy storage delivers to the electric system and provides long-term revenue confidence to investors.*

To overcome the current constraints of regulatory policies and market rules preventing the full benefits of energy storage, specific policy and regulatory recommendations for a modern electric grid for the New York state are [26]:

- *Allow smaller behind-the-meter resources to participate in wholesale markets, and reduce the threshold for participation.*
- *Modify NYISO tariff definitions to allow front-of-the-meter storage to simultaneously qualify as Energy Limited Resources and Limited Energy Storage Resources.*
- *Create/modify markets for ancillary services and demand response programs to enable energy storage customers to offer those services, either individually, or in the aggregate.*
- *Allow storage to provide and be compensated for multiple services to both retail and wholesale markets in a straightforward fashion.*
- *Require utilities to evaluate storage as an alternative when planning capital investments.*
- *Include societal benefits in cost-benefits analyses of grid infrastructure investments.*
- *Update interconnection standards to ensure that energy storage systems have efficient access to the electrical grid and create an expedited approval process for systems not intended to export power.*
- *Create rate structures that send economic signals to energy storage customers to encourage them to operate their system in a manner that benefits both the electric grid as well as the customer.*
- *Provide full value for the locational and temporal aspects of storage.*

2.4. MASSACHUSETTS:

Current electric grid status:

Energy Storage has potential to provide various benefits and values to the Massachusetts ratepayers. These may include reducing the price of electricity, lowering peak demand and the deferral of required investment in the T&D infrastructure, improving the cost competitiveness and reliability of renewable energy integration, and reducing environmental emissions. Adoption of energy storage also increases the state's grid flexibility and resiliency, and has the potential of creating nearly $600 million in new jobs [29]. While recognizing these values and benefits, stakeholders have identified several challenges and barriers in the state's energy storage industry, including: uncertainty regarding regulatory treatment, wholesale market rules barriers, limitations and unclear regulations to monetizing the value of their energy storage project for project developers, and the need for specific policies and programs to encourage the use of innovative storage technologies.

Key players:

- ***DOER***: Massachusetts Department of Energy Resources develops and implements policies and programs to ensure the adequacy, security, diversity, and cost-effectiveness of the state's energy supply towards a clean, affordable and resilient energy future [30].
- ***MassCEC***: Massachusetts Clean Energy Center is a publicly funded organization dedicated to accelerating the success of clean energy technologies and projects [31].
- ***DPU***: Department of Public Utilities is responsible for oversight of investor-owned electric power, natural gas, and water utilities, and developing alternatives to traditional regulation.

Storage applications and policy status

The Massachusetts Government created the Energy Storage Initiative in 2015 to assess and demonstrate the benefits of energy storage deployment in the state. To this end, the DOER and the MassCEC conducted a study[1] to analyze the economic benefits and market opportunities for energy storage, and to examine potential policies and regulatory recommendations along with cost-benefit analysis to better support both energy storage deployment and growth of the storage industry in the state [29]. Some of the major challenges faced in the state to wide adoption of energy storage are:

- Energy storage cannot fully participate in all markets and current rules only allow limited participation,
- The independent system operator (ISO-NE) cannot utilize energy storage as a flexible resource, and does not have designated rules for advanced energy storage beyond frequency regulation.
- Energy storage for behind the meter is not defined, and there are yet no considerations of specific requirements for demand response, sub-metering and duration for capacity.
- Rules at ISO-NE do not consider energy storage as a transmission solution, where other markets, like California, consider how storage can be used to mitigate congestion and defer transmission upgrades requirements in their planning process.

[1] The study team also includes Customized Energy Solutions Ltd, Sustainable Energy Advantage LLC, Daymark, Alevo Analytics, and Strategen.

Below are highlights of policy and program recommendations for monetizing benefits and increasing the amount of new advanced energy storage in Massachusetts aiming at establishing and clarifying regulatory treatments of storage, funding and rebate programs, recommendations for ISO market rules, integration of storage into State Portfolio Standards, and possible statutory changes to include storage in long-term clean energy procurements [29].

- Grant and Rebate Programs:
    - Launch project demonstrations for use case business models to boost market.
    - Encourage behind-the-meter storage to reduce cost of electricity and create system benefits through reduced peak demand and greater utilization of on-site generation.
    - Launch commercial and industrial solar and storage feasibility grant programs to assist businesses and manufacturers to evaluate adding behind-the-meter storage.
- Storage in state portfolio standards
    - Conduct rulemaking to amend alternative portfolio standards to include all types of advanced energy storage.
    - Monetize the ratepayer system benefits of storage.
    - Encourage use of storage where the combined system of solar and storage can provide more value to both the system owner and ratepayer versus the case a net-metered facility would be able to provide.
- Establish and clarify regulatory treatment of storage
    - Ability to include storage as a utility asset.
    - Use storage as peak demand savings tool in energy efficiency plans, including examining a variety of business models such as competitive non-utility owned solutions aggregating behind-the-meter storage.
- Potential options for statutory changes
    - Allow bids that have energy storage components in future possible long-term clean energy procurements. Therefore, a clear definition of a qualifying "Energy Storage System" within the statutory program is required.
- Integration of energy storage by the ISO includes the following proposed areas to be studied:
    - Market rules for energy storage in energy, capacity, and ancillary services; and developing optimization, scheduling, dispatching and bidding parameters.
    - Defining minimum participation requirements, aiming at reducing it from 1 MW to 0.1 MW.
    - Behind-the-meter participation.
    - Energy storage in the transmission planning process as a reliability solution.

2.5. TEXAS:

With California and New York leading in energy storage development across the US through mandates and incentive programs, Texas is leading through its innovative applications of storage that further defines the key role of storage systems in enhancing grid reliability and lowering electricity rates [32]. Most of storage technologies including compressed air systems, flywheel, thermal, supercapacitors, and solid and flow batteries are utilized in various applications such as T&D assets, off-grid behind-the-meter storage, generation efficiency improvement component, as well as R&D projects. The major exception in the state's system is pumped hydro storage [32]. As of 2016, there were 24 operational energy storage projects, which places the state in the 3rd place across the country [33].

Key players:

- ***ERCOT:*** The Electric Reliability Council of Texas, as the independent system operator for the region, is a membership-based non-profit corporation, governed by a board of directors. The members include various stakeholders across the industry such as generators, power marketers, consumers, retail electric providers, investor-owned electric utilities, T&D providers, and municipally owned electric utilities [34].
- ***PUCT:*** The Public Utility Commission of Texas was originally created in 1975 to provide regulation of the rates and services of electric and telecommunications utilities across the state [35]. While the PUC of Texas performs its traditional regulatory function for electric T&D utilities across the state, it is increasingly involved in efforts to implement wholesale electric competitive market structures and transmission planning across multiple states and in the Southwest Power Pool (SPP) and Midcontinent Independent System Operator (MISO) areas [35].

With high-penetration of renewable energy, Texas has been exploring energy storage possibilities through new policy and regulations. The state enacted Senate Bill 943 in 2012 and the state's PUC project number 39657 to address the legislation. The bill classifies energy storage installations as generation assets when they are utilized to provide energy and/or ancillary services in the wholesale market [33]. The classification provides storage projects with the rights (i) to interconnect, (ii) to obtain transmission service, and (iii) to sell electricity or ancillary services at wholesale. This classification further supports storage project economics as the ERCOT puts the interconnection costs on transmission utilities [19].

Following the Texas PUC activities to support energy storage deployment, a rulemaking in 2012 was introduced to clarify how charging and discharging would be treated. Under Project Number 39917 [36], the PUC decided to treat the energy as a wholesale market resource because, although energy storage can be considered a load when charging, the facilities are not consuming the energy, feeding it back to the grid [19]. The latest part of the study “The Texas Energy Storage Market” [37], identifies the major takeaways of the state performance in the storage market. The report highlights that municipally owned utilities and cooperatives are more able to utilize storage resources for multiple functions compared with entities in the restructured market of ERCOT. The report also concludes that storage projects at large end-user sites can keep the electric grid peak from growing at the electricity rate ($/kWh) growth driven by the competitive retail market [37].

2.6. HAWAII:

The main drive for adoption of energy storage systems in Hawaii is to increase share of renewable energy sources to address their intermittent nature. The state has set a goal of achieving 100% renewable energy by 2045 [38].

The state’s key players are:

The Hawaiian Electric Company and its subsidiaries provide electricity and services to 95 percent of the state’s residents, committed to providing quality service and clean local energy sources to power generations of Hawaiian people and businesses [39].

The Hawaii Public Utilities Commission is a public utilities commission, which, among others, regulates all chartered, franchised, certificated, and registered public utility companies operating in the state, and reviews and approves rates, tariffs, and fees [40]. The Hawaii PUC regulates electricity, gas, telecommunications, private water and sewage, and motor and water carrier transportation services.

In 2017, the Hawaiian Electric Company and the PUC have proposed a new plan to achieve the 100% renewable goal five years earlier than the previously outlined plan, in which, energy storage plays a key role [41].

Storage policy and programs

Hawaii House Bill 2618 was introduced to establish tax credits for grid connected energy storage projects in the state in 2014, which died in conference committee [42]. The bill noted that Hawaii recognizes storage as a key factor in maximizing renewable energy penetration [19].

In December of 2014, another bill by the Hawaii Senate (SB 2932) was introduced attempting to require the state’s PUC to establish an energy storage portfolio standard, which failed as well [43]. Two other bills, SB 2738 and HB 2291, failed in 2016 which were aiming at providing rebates for storage installation, and extending the state's renewable energy technologies income tax credit to include storage system, receptivity [44], [45]. The other effort to provide income tax credit for energy storage property, SB365, which was first introduced in January of 2017, was deferred by the Senate transportation and energy committee, and failed in March, 2017 [46].

The latest development is the House Bill 1593 to provide tax incentives and establish a cash rebate system for energy storage installations in March, 2017 [45].

APPENDIX

A. FERC

The following sections consist of a summary the quotes and excerpts taken from the below cited documents. For the full report, refer to the respective links below.

> A1. FERC, Policy Statement, "Utilization of Electric Storage Resources for Multiple Services when Receiving Cost-Based Rate Recovery," January 19, 2017.
> https://www.ferc.gov/whats-new/comm-meet/2017/011917/E-2.pdf
>
> A2. FERC, Notice of Proposed Rulemaking: "Electric Storage Participation in Markets Operated by RTOs and ISOs," November 17, 2016.
> https://www.ferc.gov/whats-new/comm-meet/2016/111716/E-1.pdf

A1. **Utilization of Electric Storage Resources for Multiple Services**

The main purpose of the issued policy statement is to clarify its precedent and provide guidance on the ability of electric storage resources to provide services at and seek to recover their costs through both cost-based and market-based rates concurrently. By providing electric storage resources the opportunity to receive cost-based rate recovery concurrently with other revenue from market-based services (e.g., through organized wholesale electric markets), there can be implementation details that may need to be addressed, including protections against the potential for double-recovery of costs from cost-based ratepayers, adverse market impacts, and RTOs and ISOs independence from market participants.

The provided guidance in this policy statement provides clarity regarding how electric storage resources seeking to receive cost-based rate recovery for certain services (such as transmission or grid support services or to address other needs identified by an RTO/ISO) while also receiving market-based revenues for providing separate market-based rate services could address these concerns.

Background

Electric storage resources' ability to charge and discharge electricity results in a variety of grid services to multiple entities such as RTO/ISOs, and transmission and distribution utilities, or in multiple markets. These resources are also able to provide multiple services can switch from one service to another almost instantaneously. These abilities enable electric storage resources to fit into traditional asset functions in generation, transmission and distribution, and provide multiple services in both the cost-based market and market-based market. Given how the industry is looking at utilizing energy storage resources in different ways, the present policy statement by the FERC provides guidance and clarification regarding the ability of electric storage resources to receive cost-based rate recovery for certain services such as transmission or grid support services or to address other needs identified by an RTO/ISO while also receiving market-based revenues for providing separate market-based services. Therefore, the key question is not whether to allow multiple applications for storage resources but how to allow and enable such applications.

As identified by the policy statement, there are some issues need to be addressed if an electric storage resource is to recover its costs through both cost-based and market-based rates concurrently. These issues include: (i) combined cost-based and market-based rate recovery may potentially lead to double cost recovery by the storage resource owner or operator to the detriment of cost-based ratepayers; (ii) the potential for cost recovery through cost-based rates to inappropriately suppress competitive prices in the wholesale electric markets to the detriment of other competitors who do not receive such cost-based rate recovery; and (iii) the level of control in the operation of an electric storage resource by an RTO/ISO that could jeopardize its independence from market participants.

To address the first issue, one solution is crediting any market revenues back to the cost-based ratepayers. The amount of this crediting may vary depending on how the cost-based rate recovery is structured.

The statement also confirms that storage resources may concurrently receive cost- and market-based revenues for providing separate services, stating that allowing these arrangements will not adversely impact other market competitors.

And finally, the statement clarifies that coordination between the RTO/ISO and the storage resource owner or operator will be necessary for resources that concurrently provide services compensated through cost-based rates and those compensated through market-based rates. It also provides guidance that RTO/ISO dispatch of the storage resource to address the need for the service compensated through cost-based rates should receive priority over the market-based rate services. And, to ensure RTO/ISO independence market-based rate services should be under the control of the electric storage resource owner or operator, rather than the RTO/ISO.

A2. **Electric Storage Participation in Markets Operated by RTOs and ISOs**

Under the Federal Power Act (FPA), the FERC has proposed to amend its regulations to remove barriers to the participation of **electric storage resources** and **distributed energy resource aggregations** in the capacity, energy, and ancillary service markets operated by RTOs and ISOs (organized wholesale electric markets). The FERC takes actions pursuant to the legal authority under section 206 of the FPA to ensure that the RTO and ISO tariffs are just and reasonable and not unduly discriminatory or preferential. The main two objectives of the newly proposed amendments to the regulations for RTOs and ISOs are:

1. Establish a participation model consisting of market rules that, recognizing the physical and operational characteristics of electric storage resources, accommodates their participation in the organized wholesale electric markets; and

2. Define distributed energy resource aggregators as a type of market participant that can participate in the organized wholesale electric markets under the participation model that best accommodates the physical and operational characteristics of its distributed energy resource aggregation.

Reforms are to be implemented to remove barriers to the participation of electric storage resources and distributed energy resource aggregations in the organized wholesale electric markets.

Problem Statement

According to the FERC, resource participation in the organized wholesale electric markets is currently governed by (i) participation models consisting of market rules designed for different types of resources and (ii) the technical requirements for market services that those resources are eligible to provide. Each RTO/ISO establishes the participation models for different types of resources and the technical requirements for providing services in a slightly different way. Sometimes RTO/ISO participation models place limitations on the services that certain types of resources are eligible to provide.

In addition, sometimes the technical requirements for providing a service may limit the types of resources that can provide it, such as the requirement for a resource to be running and synchronized to the grid to provide spinning reserves. Many tariffs in the participation models were originally developed when traditional generation resources were the only resources participating in the organized wholesale electric markets. As new and innovative resources have reached commercial maturity, RTOs and ISOs have updated their tariffs to establish participation models for these resources and, to some degree, reviewed the technical requirements for each service or determined which service the new resource could provide.

If an RTO/ISO cannot update its market rules before a new resource becomes commercially able to sell into the organized wholesale electric markets, the new resource may need to participate under one of the existing participation models for some other type of resource. This may limit the market opportunities for new resources and the potential supply of some services.

Further, new resources may have difficulty creating momentum for the market rule changes necessary to facilitate their participation and may thus need to spend considerable time and effort to gain entry to the organized wholesale electric markets. Where rules designed for traditional generation resources are applied to new technologies, where new technologies are required to fit into existing participation models, and where participation models focus on the eligibility of resources to provide services more so than the technical ability of resources to provide services, barriers can emerge to the participation of new technologies in the organized wholesale electric markets.

Proposed Actions

First, it is proposed to require each RTO/ISO to revise its tariff to establish a participation model consisting of market rules that, recognizing the physical and operational characteristics of electric storage resources, accommodates their participation in the organized wholesale electric markets. The proposed participation model must:

- ensure that electric storage resources are eligible to provide all capacity, energy and ancillary services that they are technically capable of providing in the organized wholesale electric markets;
- incorporate bidding parameters that reflect and account for the physical and operational characteristics of electric storage resources;
- ensure that electric storage resources can be dispatched and can set the wholesale market clearing price as both a wholesale seller and wholesale buyer consistent with existing market rules that govern when a resource can set the wholesale price;
- establish a minimum size requirement for participation in the organized wholesale electric markets that does not exceed 100 kW; and
- specify that the sale of energy from the organized wholesale electric markets to an electric storage resource that the resource then resells back to those markets must be at the wholesale locational marginal price (LMP).

Second, it is proposed to require each RTO/ISO to revise its tariff to allow distributed energy resource aggregators, including electric storage resources, to participate directly in the organized wholesale electric markets. Specifically, each RTO/ISO is required to establish distributed energy resource aggregators as a type of market participant and allow the distributed energy resource aggregators to register distributed energy resource aggregations under the participation model in the RTO/ISO tariff that best accommodates the physical and operational characteristics of the distributed energy resource aggregation.

Also, each RTO/ISO must establish market rules on:

- eligibility to participate in the organized wholesale electric markets through a distributed energy resource aggregator;
- locational requirements for distributed energy resource aggregations;
- distribution factors and bidding parameters for distributed energy resource aggregations;
- information and data requirements for distributed energy resource aggregations;
- modifications to the list of resources in a distributed energy resource aggregation;
- metering and telemetry system requirements for distributed energy resource aggregations;
- coordination between the RTO/ISO, distributed energy resource aggregator, and the distribution utility; and
- market participation agreements for distributed energy resource aggregators.

Definitions:

An electric storage resource as a system that receives electric energy from the electric grid and stores it for injection the electricity back to the grid regardless of where the resource is located on the electrical system. These resources are defined to include all types of electric storage technologies, regardless of their size, storage medium like batteries, flywheels, compressed air, pumped-hydro, and etc.; or whether located on the interstate grid or on a distribution system.

Distributed energy resources are a source or sink of power located on the distribution system, on any subsystem thereof, or behind a customer meter. These resources may include, electric storage resources, distributed generation, thermal storage, and electric vehicles and their supply equipment.

Organized wholesale electric markets are the capacity, energy, and ancillary service markets operated by RTO and ISO.

A participation model is a set of tariff provisions that accommodate the participation of resources with particular physical and operational characteristics in the organized wholesale electric markets of the RTOs and ISOs.

Bidding parameters are the physical and operational constraints that a resource would identify per RTO/ISO requirements when submitting offers to sell capacity, energy, or ancillary services or bids to buy energy in the organized wholesale electric markets.

Locational marginal prices (LMPs) for energy and ancillary services ideally would reflect the true marginal cost of production, taking into account all physical and operational system constraints, and fully compensate all resources for the variable cost of providing service[2].

Demand response resource type I: Demand Response that can offer into the energy market or spinning/supplemental reserve markets.

Demand response resource type II: Demand Response that can offer into the energy market and regulation/spinning/supplemental reserve markets and is treated identically to a generation resource[3].

Discussion:

1. **Elimination of Barriers to Electric Storage Resource Participation in Organized Wholesale Electric Markets:**

Needs creation of a participation model for electric storage resources, and determining requirements for the participation model for electric storage resources.

(i) Creation of a participation model for electric storage resources

Resource participation in organized wholesale electric markets is currently governed by (1) participation models consisting of market rules designed for different types of resources and (2) the technical requirements for market services that those resources are eligible to provide. The FERC has previously allowed flexibility for each RTO/ISO to approach the integration of electric storage resources in its organized wholesale electric markets differently. RTOs/ISOs developed most of their participation models before

2 Price Formation in Energy and Ancillary Services Markets Operated by RTOs and ISOs, Notice, Docket No. AD14-14-000 (June 19, 2014)

3 MISO - Demand Response Resources - Markets Committee (August 24, 2014).

electric storage resources achieved their current technical capability and commercial viability, so some markets rely on these existing models for the participation of electric storage resources. Providing a participation model that recognizes the unique characteristics of electric storage resources will help eliminate barriers to their participation in the organized wholesale electric markets and promote competition and economic efficiency.

Current rules:
The RTOs/ISOs describe opportunities for electric storage resources to provide various energy and ancillary service market services.

In **CAISO**, electric storage resources are eligible to participate in the energy and ancillary service markets as Participating Generators, Non-Generator Resources, Pumped Storage Hydro Units, or Demand Response Resources, even as part of distributed energy resource aggregations.

In **ISO-New England (ISO-NE)**, electric storage resources can provide all services when they qualify as a generator, provide all services except 10-minute spinning and 10-minute non-spinning reserves when they qualify as demand response, and provide regulation as an Alternative Technology Regulation Resource.

In the **Midcontinent ISO (MISO)**, electric storage resources are eligible to participate as a Stored Energy Resource (which is only eligible to provide regulation), a Generation Resource, a Use-Limited Resource that is unable to operate continuously daily, and several types of demand response resources (some of which are limited in the products that they are eligible to provide).

NYISO allows electric storage resources to qualify as Energy Limited Resources, Limited Energy Storage Resources (which are eligible to provide regulation service only), or demand response resources.

PJM allows electric storage resources to participate as generation resources or demand-side resources (which are not eligible to provide non-synchronized reserves).

Southwest Power Pool (SPP) allows electric storage resources to qualify as Demand Response Resources, Dispatchable Resources, External Resources, External Dynamic Resources, and Quick-Start Resources, if they can sustain output for 60 minutes.

Proposed reforms:
Each RTO/ISO is required to revise its tariff to include a participation model consisting of market rules that, recognizing the physical and operational characteristics of electric storage resources, accommodates their participation in organized wholesale electric

markets. To this, the participation model should satisfy:

i. Electric storage resources must be eligible to provide all capacity, energy and ancillary services that they are technically capable of providing in the organized wholesale electric markets;
ii. The bidding parameters incorporated in the participation model must reflect and account for the physical and operational characteristics of electric storage resources;
iii. Electric storage resources can be dispatched and can set the wholesale market clearing price as both a wholesale seller and a wholesale buyer consistent with existing rules that govern when a resource can set the wholesale price;
iv. The minimum size requirement for electric storage resources to participate in the organized wholesale electric markets must not exceed 100 kW; and
v. The sale of energy from the organized wholesale electric markets to an electric storage resource that the resource then resells back to those markets must be at the wholesale LMP.

Furthermore, the qualification criteria for the proposed participation model must not limit participation to any particular type of electric storage resource or other technology.

(ii) Requirements for the participation model for electric storage resources

a. Eligibility to participate in organized wholesale electric markets

Electric storage resources have the potential to provide a wide array of services to the organized wholesale electric markets. However, in many cases the existing participation models that electric storage resources are eligible to use in the RTOs/ISOs preclude electric storage resources from providing all of the services that they are technically capable of providing.

Current rules:
Several of the RTOs/ISOs identify limitations on the services that electric storage resources may provide.

ISO-NE states that the non-dispatchability of Settlement Only Resources and non-dispatchable generators prohibits such resources from providing operating reserves. In addition, resources that cannot provide energy within 10 minutes cannot provide 10-minute spinning or 10-minute non-spinning reserves.

ISO-NE also states that demand response resources with one or more controllable generators, including storage resources, are not eligible to provide 10-minute spinning reserve. In ISO-NE, electric storage resources can only provide regulation as an

Alternative Technology Regulation Resource.

MISO states that a Stored Energy Resource is not qualified for capacity, energy, ramp capability and contingency reserves.

MISO states that Demand Response Resource (Type I) is not eligible for regulating reserve and ramp capability products and that Dispatchable Intermittent Resources are a subset of Generation Resources that are not eligible to provide regulating reserves and contingency reserves.

MISO states that the Load Modifying Resource category is designed to provide energy in emergency conditions and is only intended for the provision of capacity.

MISO also states that Emergency Demand Response can only provide emergency energy, on a voluntary basis.

NYISO states that Limited Energy Storage Resources are limited to selling only regulation service in the ancillary service market.

NYISO further states that Emergency Demand Response Program resources are only eligible to provide energy, Special Case Resources are only eligible to provide energy and capacity, and Demand Side Ancillary Services Program Resources are only eligible to provide ancillary services.

PJM states that demand response resources, including electric storage resources, are ineligible to provide non-synchronized reserves because demand response resources are already synchronized to the grid when consuming power, and so would always be classified as sync reserves when curtailing.

Proposed reforms:
RTOs/ISOs require to modify their tariffs to establish a participation model consisting of market rules for electric storage resources under which a participating resource is eligible to provide any capacity, energy, and ancillary service that it is technically capable of providing in the organized wholesale electric markets.

Electric storage resources should be able, as part of the participation model, to be eligible to provide services that the RTOs/ISOs do not procure through a market mechanism, such as blackstart, primary frequency response, and reactive power, if they are technically capable. Where compensation for these services exists, electric storage resources should also receive such compensation commensurate with the service provided.

RTO/ISO requires to revise its tariff to clarify that an electric storage resource may de-rate its capacity to meet minimum run-time requirements to provide capacity or other services.

Participation in ancillary service markets should be based on a resource's ability to provide services when it is called upon rather than on the real-time operating status of the resource. This is because electric storage resources tend to be capable of faster start-up times and higher ramp rates than traditional synchronous generators and are therefore able to provide ramping, spinning, and regulating reserve services without already being online and running.

b. Bidding parameters for electric storage resources

Bidding parameters allow resources participating in the organized wholesale markets to identify their physical and operational characteristics so that the RTO/ISO can model and dispatch the resource consistent with its operational constraints. As energy storage resources storage and discharge electricity at varying speeds and duration and to transition between operating modes, it is more efficient for the RTOs/ISOs to model, optimize, and dispatch electric storage resources differently than they do traditional generation.

Current rules:
Under current market rules, resource bidding parameters vary greatly between the RTOs/ISOs. Some RTOs/ISOs require the same bidding parameters from all resources offering into a specific market, regardless of the participation model under which these resources participate, while others tie bidding parameters to specific participation models.

ISO-NE requires the same bidding parameters from all resources, including electric storage resources, participating in its capacity, forward reserve, and regulation markets. In **ISO-NE**'s energy market, bidding parameters reflect the physical characteristics of each participation model such as maximum daily starts, maximum consumption for dispatch asset related demand, and minimum time between reductions for demand response resources.

SPP requires all resources participating in its day-ahead and real-time markets under any participation model to provide a specific set of bidding parameters to validate their offers.

CAISO's market rules also require a defined list of parameters for all bids. In addition, however, **CAISO** requires supplemental parameters depending on the participation model under which a resource is participating in its market: participating generator, participating load, or non-generator resource.

NYISO does not require Limited Energy Storage Resources, unlike other generators, to provide regulation capacity response rates, normal response rates, or emergency response rates with their regulation service bids

In **NYISO**, electric storage resources acting as a component of a Demand Side Ancillary Services Program resource may only submit one normal response rate equaling the electric storage resource's emergency response rate, while traditional generators may submit up to three normal response rates

In **MISO**, bidding parameters vary between markets and participation models. MISO's market rules allow common bidding parameters for each participation model, with a few exceptions; for example, the following additional parameters are required: hourly maximum energy storage level; hourly maximum energy charge rate; hourly maximum energy discharge rate; hourly energy storage loss rate; and hourly full charge energy withdrawal rate.

Bidding parameters in **PJM** also vary between markets and participation models. Additionally, pumped storage resources offering into the **PJM** energy markets may either self-schedule or have **PJM** dispatch their unit pursuant to the pumped storage optimization tool. In either case, the resource must submit the following parameters: initial storage; final storage; maximum storage; minimum storage; pumping efficiency factor; and min/max generating and pumping limits.

Proposed reforms:

Bidding parameters designed for slower storage technologies or other types of generation resources that are not capable of charging and discharging energy may limit the opportunity for faster electric storage resources to participate in the organized wholesale electric markets. Appropriate bidding parameters will allow electric storage resources to provide all services they are technically capable of providing and allow the RTOs/ISOs to procure these services more efficiently.

Specifically, the RTOs/ISOs need to establish state of charge, upper charge limit, lower charge limit, maximum energy charge rate, and maximum energy discharge rate as bidding parameters for the participation model for electric storage resources that participating resources must submit, as applicable.

Also, it is proposed that the participation models for electric storage resources include the following bidding parameters that market participants may submit, at their discretion, for their resource based on its physical constraints or desired operation: minimum charge time, maximum charge time, minimum run time, and maximum run time.

Additionally, where the RTO/ISO has reserved for itself the right to manage the state of charge of an electric storage resource, it is proposed to require that the RTOs/ISOs allow electric storage resources to self-manage their state of charge and upper and lower charge limits.

c. Eligibility to participate as a wholesale seller and wholesale buyer

Improving electric storage resources' opportunity to participate as both wholesale sellers of services and wholesale buyers of energy improves market efficiency by allowing the RTO/ISO to dispatch these resources according to their most economically efficient use. Moreover, electric storage resources in the organized wholesale electric markets as dispatchable load would allow these resources, under certain circumstances, to set the price in these markets.

Current rules:
Each RTO/ISO's market rules that govern the eligibility of electric storage resources to participate in the organized wholesale electric markets as a demand resource are different.

CAISO explains that an electric storage resource interconnected to the CAISO grid with a participating generator agreement and participating load agreement can submit offers to sell and bids to buy energy in the wholesale market.

According to **SPP**, submitting bids to purchase energy in its market is within the resource owner's discretion

In contrast, **PJM** explains that electric storage resources do not submit wholesale bids to buy electricity

ISO-NE states that, because it is dispatchable, an electric storage resource participating as a Dispatchable Asset Related Demand resource may submit bids to buy energy in both the day-ahead and real-time energy markets; however, if it is participating as a load asset or an Asset Related Demand, it may submit bids to buy energy in the day-ahead market but would be a price taker in real-time.

MISO explains that, in the day-ahead market, electric storage resources may submit bids to buy energy at the LMP when they need to recharge as dispatchable demand or may submit virtual bids. **MISO** further explains that in the real-time market, most load buys energy as fixed demand and only Demand Response Resources - Type II can submit demand response offers to buy energy.

NYISO states that a demand-side resource may submit price-responsive load bids to take advantage of off-peak prices to charge its electric storage resource. **NYISO** adds that electric storage resources are not required to bid to buy electricity from the **NYISO** market, but, like any load, may bid into the day-ahead market as a price cap load bid.

The eligibility for an electric storage resource to set the price in the organized wholesale electric markets also varies among the RTOs/ISOs:

> **<u>CAISO</u>** states that an electric storage resource that is the marginal resource may set the price of energy and ancillary services in **<u>CAISO's</u>** markets based on its economic bid.
>
> **<u>PJM</u>** states that, with the exception of demand-side resources in the non-synchronized reserve market, electric storage resources may set the price as either a generation or as a demand-side resource in the capacity, energy, and ancillary service markets.
>
> **<u>SPP</u>** states that any resource, including an electric storage resource, qualified to participate in an **<u>SPP</u>** market may set the price for the relevant market.

<u>ISO-NE</u> states that, in each of its markets, electric storage resources may be able to set the clearing price, depending on the participation model that they are using to participate.

<u>MISO</u> states that electric storage resources may set prices for products in the markets in which they are eligible to participate. MISO explains that an electric storage resource registered as a Load Modifying Resource may set the price in the capacity market. MISO states that an electric storage resource registered as a Stored Energy Resource may set the price for regulating reserve.

<u>NYISO</u> explains that supply offers of electric storage resources that participate as Energy Limited Resources may set the price for capacity, energy, and ancillary services; Limited Energy Storage Resources may set the price for regulation service.

Proposed reforms:
It is proposed that the RTOs/ISOs accept wholesale bids from electric storage resources to buy energy so that the economic preferences of the electric storage resources are fully integrated into the market, the electric storage resource can set the price as a load resource where market rules allow, and the electric storage resource can be available to the RTO/ISO as a dispatchable demand asset. These requirements must not prohibit as price takers, consistent with the existing rules for self-scheduled load resources.

The RTOs/ISOs must to be able to symmetrically utilize the capabilities of electric storage resources to both receive electricity from the grid and inject it back to the grid, meaning they must be able to dispatch these resources as supply when the market clearing price exceeds their offers to sell and to dispatch them as demand when their bids to buy exceed the market clearing price.

To participate as a supply and demand resource simultaneously, i.e., submit bids to buy and offers to sell during the same market interval, is necessary to maximize the value that electric storage resources can provide in the organized wholesale electric markets, allowing the markets to identify whether it is more economic to dispatch an electric storage resource as supply or demand during a given market interval.

d. Minimum size requirement

RTO/ISO market rules may restrict electric storage resources from participating in the organized wholesale electric markets based on minimum size requirements designed for different types of resources. Such restrictions can limit these resources' ability to employ their full operational range because they are prohibited from injecting electricity into the grid in excess of their host load and preclude them from providing services such as reserves.

Current rules:
Under existing market rules, minimum capacity, and minimum offer and bid requirements for electric storage resources to participate in the organized wholesale electric markets vary across the RTOs/ISOs, with minimum size requirements ranging from 100 kW to 5 MW.

PJM and **SPP** have minimum offer requirements of 100 kW for all resources, with other RTO/ISO minimum size requirements varying across participation models and markets.

CAISO states that the minimum capacity requirement for demand response resources is 100 kW and that all resources other than demand response have minimum capacity requirements of 500 kW.

ISO-NE minimum capacity requirements range from 100 kW for demand response resources, to 1 MW for Alternative Technology Regulation Resources, to 5 MW for generators seeking to provide demand response in the regulation market.

MISO minimum capacity requirements vary from 100 kW for Load Modifying Resources, to 1 MW for demand response resources, to 5 MW for generators.

In **NYISO**, the minimum size requirement is 100 kW for demand response resources and 1 MW for Energy Limited Resources and Limited Energy Storage Resources.

Proposed reforms:
As large minimum size requirements create a barrier to the participation of smaller electric storage resources, it is proposed that the minimum size requirement to participate in the organized wholesale electric markets must not exceed 100 kW. This would include any minimum capacity requirements, minimum offer requirements, and minimum bid requirements for resources participating in these markets under the electric storage resource participation model.

e. Energy Used to Charge Electric Storage Resources

Electric storage resources must absorb electricity to sell that electricity, net of losses, back to an RTO/ISO as energy or ancillary services. The manner in which an electric storage resource charges (consumes) energy and discharges (produces) energy will determine whether the electric storage resource is engaging in a sale for resale subject to our jurisdiction.

Current rules:

CAISO states that all electric storage resources participating in its wholesale markets pay LMP for their charging energy.

ISO-NE states that electric storage resources purchasing energy directly from the wholesale market pay the LMP for the electricity they receive

MISO states that any resources eligible to participate in MISO's capacity, energy, and ancillary service markets pay LMP for the electricity they receive.

NYISO states that Energy Limited Resources using electric storage resource technology and Limited Energy Storage Resources will pay the wholesale price for the electricity they consume to meet a regulation service schedule or to charge the resource if the resource is either in front-of-the-meter (a generator) or a direct **NYISO** customer (a load-serving entity). **NYISO** notes that, if the resource is behind-the-meter and served by a separate load-serving entity, then it would pay the load-serving entity's retail rate.

PJM states that an electric storage resource would pay wholesale LMP if the resource is taking power off the system solely to inject into the energy or ancillary service markets at a later time. **SPP** states that, in its real-time market, electric storage resources pay the real-time LMP for their load consumption, although they may also be subject to retail rules for electric consumption.

Proposed reforms:

The Commission has found that the sale of energy from the grid that is used to charge electric storage resources for later resale into the energy or ancillary service markets constitutes a sale for resale. Therefore, the reasonable rate for that wholesale sale of energy used to charge the electric storage resource is the RTO/ISO market's wholesale price for energy or LMP. It is proposed to require each RTO/ISO to revise its tariff to specify that the sale of energy from the organized wholesale electric markets to an electric storage resource that the resource then resells back to those markets must be at the wholesale LMP.

The proposed reform also provides developers and operators of electric storage resources certainty about the price that they will be charged for purchasing charging electricity in the organized wholesale electric markets when they will use that electricity to provide wholesale services.

2. Participation of Distributed Energy Resource Aggregators in the Organized Wholesale Electric Markets

Generally, distributed energy resources tend to be too small to participate directly in the organized wholesale electric markets on a stand-alone basis. First, they often do not meet the minimum size requirements to participate in these markets under existing participation models. Second, they may have difficulty satisfying all of the operational performance requirements of the various participation models due to their small size. Allowing these resources to participate in the organized wholesale electric markets through distributed energy resource aggregations can help to remove these barriers to their participation, providing a means for these resources to, in the aggregate, satisfy minimum size and performance requirements that they could not meet on a stand-alone basis.

The majority of distribution-connected electric storage and other distributed energy resources that seek to access the organized wholesale electric markets must do so by participating as behind- the-meter demand response. While these demand response programs have helped reduce barriers to load curtailment resources, they often limit the operations of other types of distributed energy resources, such as electric storage or distributed generation, as well as the services that they are eligible to provide.

Current rules:
The RTOs/ISOs describe the opportunities for electric storage resources connected to the distribution system and electric storage resource aggregations to participate in their capacity, energy, and ancillary service markets.

CAISO supports the aggregation of distributed energy resources, including storage, seeking to participate in the **CAISO** markets. In addition, **CAISO** states that electric storage resources that wish to aggregate into a resource that can participate in the wholesale markets can participate by providing load curtailment as Proxy Demand Resources or Reliability Demand Response Resources.

ISO-NE explains that a single resource may be composed of multiple resources if those resources are either physically in the same location or require coordinated control.

ISO-NE states that electric storage resources that meet its definition of Distributed Generation (i.e., behind-the-meter resources with an aggregate nameplate capacity of less than 5 MW or the demand of the end-use customer, whichever is greater) may qualify as

Real-Time Demand Response Assets, which allows for participation in the forward capacity market, the transitional price-responsive demand program, and the regulation market if it is also registered as an Alternative Technology Regulation Resource.

MISO states that Stored Energy Resources and Demand Response Resources – Type II are allowed to aggregate under a single elemental pricing node. **MISO** adds that Demand Response Resources – Type I and Load Modifying Resources are allowed to aggregate within one local balancing authority.

NYISO states that aggregated resources can participate in the Emergency Demand Response Program, Day-Ahead Demand Response Program, Demand Side Ancillary Services Program, and Special Case Resource Programs.

PJM states that aggregated electric storage resources can participate in the capacity, energy, and ancillary service markets. In the capacity market, PJM states that demand-side resources can be aggregated to provide load reductions.

SPP states that resources at the same point of injection may register at the unit or plant level and electric storage resources may be aggregated if the resources are electrically equivalent from the transmission system perspective (i.e., use the same point of injection)

Proposed reforms:
Each RTO/ISO is required to revise its tariff as necessary to allow distributed energy resource aggregators to offer to sell capacity, energy, and ancillary services in the organized wholesale electric markets.

Distributed energy resources are generally smaller than other resources connected to the grid and therefore may be unable to meet all of the qualification or performance requirements for participation in the organized wholesale electric markets. If these distributed energy resources were permitted to aggregate with other distributed energy resources to participate in the organized wholesale electric markets, they may be able to, in the aggregate, meet any minimum size and performance requirements.

Distributed energy resource aggregations will also help to address the commercial and transactional barriers to distributed energy resource participation in the organized wholesale electric markets.

It is also proposed to expand the types of distributed energy resources that are eligible to participate in the organized wholesale electric markets through aggregators and require RTOs/ISOs to remove any unnecessary limitations on how the distributed energy resources that participate in such aggregations must be operated.

The proposal requires the RTOs/ISOs to define distributed energy resource aggregators as a type of market participant that can participate in the organized wholesale electric markets under the participation model that best accommodates the physical and operational characteristics of its distributed energy resource aggregation.

The costs of distributed energy resources have decreased significantly, which when paired with alternative revenue streams and innovative financing solutions, is increasing these resources' potential to compete in and deliver value to the organized wholesale electric markets.

It is also proposed to require each RTO/ISO to revise its tariff to allow distributed energy resource aggregators to participate directly in the organized wholesale electric markets and to establish market rules to accommodate the participation of distributed energy resource aggregations, consistent with the following:

a) Eligibility to participate in the organized wholesale electric markets through a distributed energy resource aggregator;
b) Locational requirements for distributed energy resource aggregations;
c) Distribution factors and bidding parameters for distributed energy resource aggregations;
d) Information and data requirements for distributed energy resource aggregations;
e) Modifications to the list of resources in a distributed energy resource aggregation;
f) Metering and telemetry system requirements for distributed energy resource aggregations;
g) Coordination between the RTO/ISO, the distributed energy resource aggregator, and the distribution utility; and
h) Market participation agreements for distributed energy resource aggregators.

B. US Select States Energy Indictors

The following tables provide some selected statistics and indicators of energy estimates of the US states reviewed.

B1. **California**

Tables 3-5 present the latest energy estimates including energy indicators, prices and generation values for the State of California obtained from the US Energy Information Administration database [47].

Table 4 – Energy Indicators - California State Profile and Energy Estimates by the US Energy Information Administration [47].

Energy Indicators			
Demography	**California**	**Share of U.S.**	**Period**
Population	38.8 million	12.2%	2014
Civilian Labor Force	19.1 million	12.0%	2016-June
Economy	**California**	**U.S. Rank**	**Period**
Gross Domestic Product	$2,311.6 billion	1	2014
Per Capita Personal Income	$49,985	12	2014
Vehicle Miles Traveled	329,534 million	1	2013
Land in Farms	25.6 million acres	16	2012
Climate	**California**	**U.S. Rank**	**Period**
Ave. Temperature	60.8 degrees F.	11	2015
Precipitation	15.0 inches	47	2015

Table 5 – Energy Prices - California State Profile and Energy Estimates by the US Energy Information Administration [47].

Prices			
Petroleum	**California**	**U.S. Average**	**Period**
Domestic Crude Oil	$41.31/barrel	$41.02/barrel	2016-May
Natural Gas	**California**	**U.S. Average**	**Period**
City Gate	$2.49/thousand cu ft	$3.43/thousand cu ft	2016-May
Residential	$10.53/thousand cu ft	$11.51/thousand cu ft	2016-May
Coal	**California**	**U.S. Average**	**Period**
Ave. Sales Price	---	$34.83/short ton	2014
Delivered to Power Sector	---	$2.16 million Btu	2016-May
Electricity	**California**	**U.S. Average**	**Period**
Residential	17.74 ¢/kWh	12.80 ¢/kWh	2016-May
Commercial	14.58 ¢/kWh	10.25 ¢/kWh	2016-May
Industrial	11.66 ¢/kWh	6.54 ¢/kWh	2016-May

Table 6 – Energy Generations - California State Profile and Energy Estimates by the US Energy Information Administration [47].

Energy Generation			
Total Utility-Scale Net	**California**	**Share of U.S.**	**Period**
Total Net Generation	15,649 GWh	4.9%	2016-May
Utility-Scale Net (share)	**California**	**U.S. Average**	**Period**
Petroleum-Fired	0.1 %	0.3 %	2016-May
Natural Gas-Fired	39.3 %	35.0 %	2016-May
Coal-Fired	0.2 %	25.8 %	2016-May
Nuclear	5.4 %	20.9 %	2016-May
Renewables	52.9 %	17.1 %	2016-May

B2. **New York**

Tables 6-8 present the latest energy estimates including energy indicators, prices and generation values for the State of New York obtained from the US Energy Information Administration database [48].

Table 7 – Energy Indicators – New York State Profile and Energy Estimates by the US Energy Information Administration [48].

Energy Indicators			
Demography	**New York**	**Share of U.S.**	**Period**
Population	19.8 million	6.2%	2015
Civilian Labor Force	9.6 million	6.0%	2016-Dec
Economy	**New York**	**U.S. Rank**	**Period**
Gross Domestic Product	$1,441.0 billion	3	2015
Per Capita Personal Income	$57,705	5	2015
Vehicle Miles Traveled	129,263 million	4	2014
Land in Farms	7.2 million acres	36	2012
Climate	**New York**	**U.S. Rank**	**Period**
Ave. Temperature	47.6 degrees F.	37	2016
Precipitation	38.6 inches	25	2016

Table 8 – Energy Prices – New York State Profile and Energy Estimates by the US Energy Information Administration [48].

Prices			
Petroleum	**New York**	**U.S. Average**	**Period**
Domestic Crude Oil	Withheld	$41.65/barrel	2016-Nov
Natural Gas	**New York**	**U.S. Average**	**Period**
City Gate	$3.40/thousand cu ft	$3.88/thousand cu ft	2016-Nov
Residential	$10.91/thousand cu ft	$10.76/thousand cu ft	2016-Nov
Coal	**New York**	**U.S. Average**	**Period**
Ave. Sales Price	---	$31.83/short ton	2015
Delivered to Power Sector	Withheld	$2.08 million Btu	2016-Nov
Electricity	**New York**	**U.S. Average**	**Period**
Residential	17.75 ¢/kWh	12.75 ¢/kWh	2016-Nov
Commercial	13.99 ¢/kWh	10.25 ¢/kWh	2016-Nov
Industrial	5.87 ¢/kWh	6.64 ¢/kWh	2016-Nov

Table 9 – Energy Generation – New York State Profile and Energy Estimates by the US Energy Information Administration [48].

Energy Generation			
Total Utility-Scale Net	**New York**	**Share of U.S.**	**Period**
Total Net Generation	9,892 GWh	3.3%	2016-Nov
Utility-Scale Net (share)	**New York**	**U.S. Average**	**Period**
Petroleum-Fired	NM	0.4 %	2016-Nov
Natural Gas-Fired	37.1 %	31.8 %	2016-Nov
Coal-Fired	0.2 %	29.3 %	2016-Nov
Nuclear	34.8 %	21.9 %	2016-Nov
Renewables	27.2 %	15.9 %	2016-Nov

B3. **Massachusetts**

Tables 10-12 present the latest energy estimates including energy indicators, prices and generation values for the State of Massachusetts obtained from the US Energy Information Administration database [49].

Table 10 – Energy Indicators – Massachusetts State Profile and Energy Estimates by the US Energy Information Administration [49].

Energy Indicators			
Demography	**Massachusetts**	**Share of U.S.**	**Period**
Population	6.8 million	2.1%	2015
Civilian Labor Force	3.6 million	2.3%	2016-Dec
Economy	**Massachusetts**	**U.S. Rank**	**Period**
Gross Domestic Product	$476.7 billion	12	2015
Per Capita Personal Income	$61,032	3	2015
Vehicle Miles Traveled	57,552 million	20	2014
Land in Farms	0.5 million acres	46	2012
Climate	**Massachusetts**	**U.S. Rank**	**Period**
Ave. Temperature	50.3 degrees F.	32	2016
Precipitation	37.0 inches	29	2016

Table 11 – Energy Prices – Massachusetts State Profile and Energy Estimates by the US Energy Information Administration [49].

Prices			
Petroleum	**Massachusetts**	**U.S. Average**	**Period**
Domestic Crude Oil	----	$41.65/barrel	2016-Nov
Natural Gas	**Massachusetts**	**U.S. Average**	**Period**
City Gate	$4.16/thousand cu ft	$3.88/thousand cu ft	2016-Nov
Residential	$13.38/thousand cu ft	$10.76/thousand cu ft	2016-Nov
Coal	**Massachusetts**	**U.S. Average**	**Period**
Ave. Sales Price	---	$31.83/short ton	2015
Delivered to Power Sector	Withheld	$2.08 million Btu	2016-Nov
Electricity	**Massachusetts**	**U.S. Average**	**Period**
Residential	19.15 ¢/kWh	12.75 ¢/kWh	2016-Nov
Commercial	14.89 ¢/kWh	10.25 ¢/kWh	2016-Nov
Industrial	12.89 ¢/kWh	6.64 ¢/kWh	2016-Nov

Table 12 – Energy Generation – Massachusetts State Profile and Energy Estimates by the US Energy Information Administration [49].

Energy Generation			
Total Utility-Scale Net	**Massachusetts**	**Share of U.S.**	**Period**
Total Net Generation	1,915 GWh	0.6 %	2016-Nov
Utility-Scale Net (share)	**Massachusetts**	**U.S. Average**	**Period**
Petroleum-Fired	8.2 %	0.4 %	2016-Nov
Natural Gas-Fired	51.5 %	31.8 %	2016-Nov
Coal-Fired	2.7 %	29.3 %	2016-Nov
Nuclear	25.5 %	21.9 %	2016-Nov
Renewables	10.5 %	15.9 %	2016-Nov

B4. **Texas**

Tables 13-15 present the latest energy estimates including energy indicators, prices and generation values for the State of Texas obtained from the US Energy Information Administration database [50].

Table 13 – Energy Indicators – Texas State Profile and Energy Estimates by the US Energy Information Administration [50].

Energy Indicators			
Demography	**Texas**	**Share of U.S.**	**Period**
Population	27.5 million	8.5 %	2015
Civilian Labor Force	13.4 million	8.4 %	2016-Dec
Economy	**Texas**	**U.S. Rank**	**Period**
Gross Domestic Product	$1,586.5 billion	12	2015
Per Capita Personal Income	$46,745	3	2015
Vehicle Miles Traveled	243,076 million	20	2014
Land in Farms	130.2 million acres	46	2012
Climate	**Texas**	**U.S. Rank**	**Period**
Ave. Temperature	67.1 degrees F.	3	2016
Precipitation	32.5 inches	34	2016

Table 14 – Energy Prices – Texas State Profile and Energy Estimates by the US Energy Information Administration [50].

Prices			
Petroleum	**Texas**	**U.S. Average**	**Period**
Domestic Crude Oil	$42.49/barrel	$41.65/barrel	2016-Nov
Natural Gas	**Texas**	**U.S. Average**	**Period**
City Gate	$5.10/thousand cu ft	$3.88/thousand cu ft	2016-Nov
Residential	$18.47/thousand cu ft	$10.76/thousand cu ft	2016-Nov
Coal	**Texas**	**U.S. Average**	**Period**
Ave. Sales Price	$22.69/short ton	$31.83/short ton	2015
Delivered to Power Sector	$1.87 million Btu	$2.08 million Btu	2016-Nov
Electricity	**Texas**	**U.S. Average**	**Period**
Residential	11.11 ¢/kWh	12.75 ¢/kWh	2016-Nov
Commercial	7.62 ¢/kWh	10.25 ¢/kWh	2016-Nov
Industrial	5.29 ¢/kWh	6.64 ¢/kWh	2016-Nov

Table 15 – Energy Generation – Texas State Profile and Energy Estimates by the US Energy Information Administration [50].

Energy Generation			
Total Utility-Scale Net	**Texas**	**Share of U.S.**	**Period**
Total Net Generation	32,813 GWh	11.0 %	2016-Nov
Utility-Scale Net (share)	**Texas**	**U.S. Average**	**Period**
Petroleum-Fired	Too small	0.4 %	2016-Nov
Natural Gas-Fired	46.4 %	31.8 %	2016-Nov
Coal-Fired	28.1 %	29.3 %	2016-Nov
Nuclear	10.1 %	21.9 %	2016-Nov
Renewables	14.5 %	15.9 %	2016-Nov

B5. **Hawaii**

Tables 16-18 present the latest energy estimates including energy indicators, prices and generation values for the State of Hawaii obtained from the US Energy Information Administration database [51].

Table 16 – Energy Indicators – Hawaii State Profile and Energy Estimates by the US Energy Information Administration [51].

Energy Indicators			
Demography	**Hawaii**	**Share of U.S.**	**Period**
Population	1.4 million	0.4%	2015
Civilian Labor Force	0.7 million	0.4%	2016-Dec
Economy	**Hawaii**	**U.S. Rank**	**Period**
Gross Domestic Product	$79.7 billion	39	2015
Per Capita Personal Income	$47,753	21	2015
Vehicle Miles Traveled	10.174 million	44	2014
Land in Farms	1.2 million acres	43	2012
Climate	**Hawaii**	**U.S. Rank**	**Period**
Ave. Temperature	NA	NA	2016
Precipitation	NA	NA	2016

Table 17 – Energy Prices – Hawaii State Profile and Energy Estimates by the US Energy Information Administration [51].

Prices			
Petroleum	**Hawaii**	**U.S. Average**	**Period**
Domestic Crude Oil	----	$41.65/barrel	2016-Nov
Natural Gas	**Hawaii**	**U.S. Average**	**Period**
City Gate	$12.93/thousand cu ft	$3.88/thousand cu ft	2016-Nov
Residential	$34.09/thousand cu ft	$10.76/thousand cu ft	2016-Nov
Coal	**Hawaii**	**U.S. Average**	**Period**
Ave. Sales Price	---	$31.83/short ton	2015
Delivered to Power Sector	Withheld	$2.08 million Btu	2016-Nov
Electricity	**Hawaii**	**U.S. Average**	**Period**
Residential	28.48 ¢/kWh	12.75 ¢/kWh	2016-Nov
Commercial	25.90 ¢/kWh	10.25 ¢/kWh	2016-Nov
Industrial	21.89 ¢/kWh	6.64 ¢/kWh	2016-Nov

Table 18 – Energy Generation – Hawaii State Profile and Energy Estimates by the US Energy Information Administration [51].

Energy Generation			
Total Utility-Scale Net	**Hawaii**	**Share of U.S.**	**Period**
Total Net Generation	796 GWh	0.3 %	2016-Nov
Utility-Scale Net (share)	**Hawaii**	**U.S. Average**	**Period**
Petroleum-Fired	64.7 %	0.4 %	2016-Nov
Natural Gas-Fired	0.0 %	31.8 %	2016-Nov
Coal-Fired	16.1 %	29.3 %	2016-Nov
Nuclear	0.0 %	21.9 %	2016-Nov
Renewables	15.4 %	15.9 %	2016-Nov

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