Energy
Storage
Association

# 35x25

## A Vision for Energy Storage

The United States power sector is in the midst of profound transformation. Energy demands and the role of the consumer are shifting, bringing new stresses and strains to an aging grid. Energy sources are also in transition, as the economics of natural gas and electricity continue to disfavor coal, and renewables increasingly prove to be a least-cost option in markets. Recently, advancements in energy storage technologies are improving the economics of accommodating these changes, while improving reliability and resilience, and enhancing electric system performance.

These trends necessitate an electricity network that is flexible and adaptable to the rapidly changing needs of the grid and consumers. Dramatic and recent decreases in pricing, advances in technology, and attention to improving resilience are all factors contributing to an exponential growth in energy storage markets over the next several years. This confluence of forces will create an opportunity to innovate and drive the deployment of more than 35 gigawatts (GW) of new energy storage systems in the U.S. by 2025.

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# A VISION FOR 2025

## 1.1. AN ACCELERATING INDUSTRY

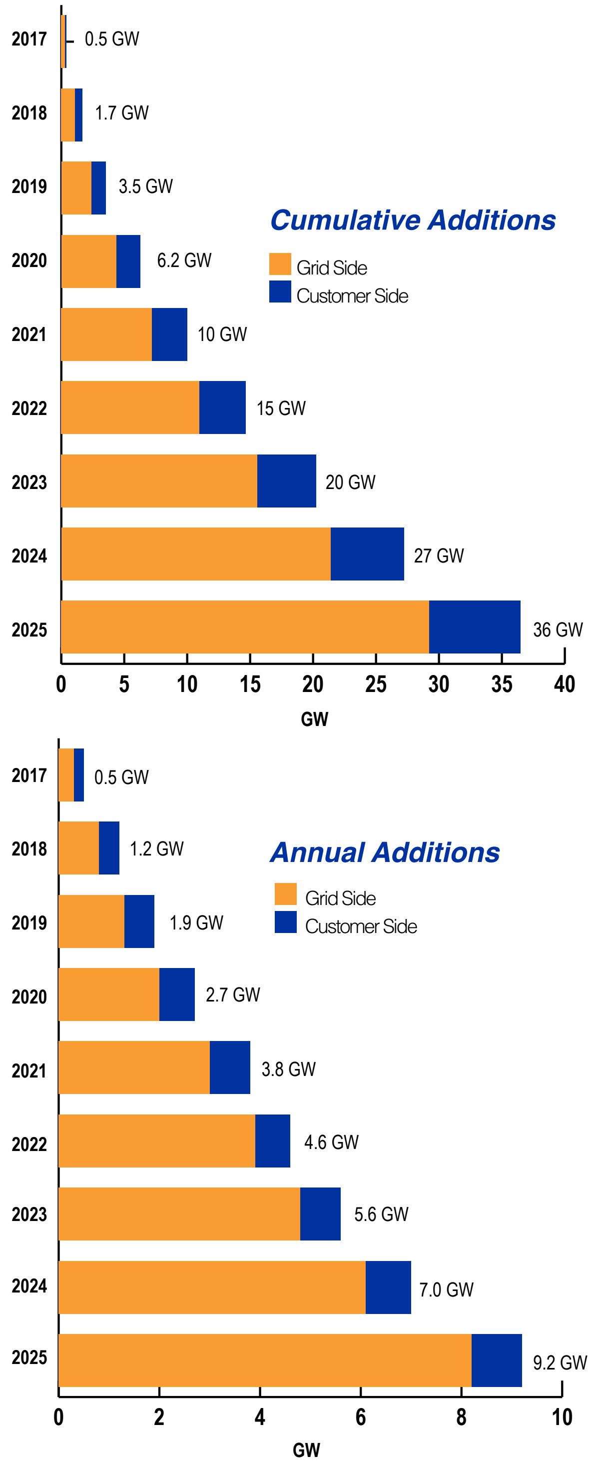
The current U.S. grid infrastructure is a marvel of engineering, designed to be safe, reliable, and cost-effective. For the past century, it has operated without widespread capability to store its end product, which is vital to the efficient function of any market, supply chain, or network. Advances in technology, changes in consumer behavior and market dynamics have facilitated deployment of large amounts of cost-effective energy storage at different scales throughout the system. This will dramatically change the way we generate, deliver, and use energy.

> *The paradigm is changing. We now have cost-effective energy storage systems proven as modular, scalable, adaptable, safe, and reliable grid resources. In effect, rather than systems, these are energy storage power plants delivering commercial services equivalent to thermal resources.*

Over the past decade, the advanced energy storage industry has grown rapidly. Dramatic cost declines, increasing manufacturing capacity, and market and regulatory reforms have all contributed to this growth. Most importantly, the value of storing energy on the grid, in all its forms, is increasingly recognized.

This white paper describes how a confluence of forces and continued advancement in grid planning and operations will drive the deployment of more than 35 GW of new, cost-effective advanced energy storage systems in the U.S. by 2025, as depicted in Chart 1.1. With this industry acceleration will come billions of dollars in market efficiencies, improved grid performance and tens of thousands of jobs across the country in manufacturing, installation, and operations.

***Chart 1.1 Cumulative and Annual U.S. Energy Storage Power Capacity Additions, Vision Case (2017-2025)***



*(Source: Navigant Research)*

*More than 35 GW of energy storage by 2025 will affect all stakeholders on the grid, enabling a more resilient, efficient, sustainable and affordable energy network.*

## 1.2. THE ENERGY STORAGE ASSOCIATION

The Energy Storage Association (ESA) is the national trade association and the leading voice for the energy storage industry. ESA represents electric utilities, independent power producers, project developers, manufacturers, integrators, component, suppliers, and system support service companies, to accelerate the widespread use of competitive and reliable energy storage systems.

ESA sees a clear and actionable pathway to achieving 35 GW of new energy storage deployed in the U.S. by 2025. This is undoubtedly ambitious, and will require fundamental changes in how the grid is planned and engineered, including a reform of U.S. energy markets and regulations. The exact nature and timing of this transformation is debatable, but all stakeholders agree that the inherent ability to safely and affordably store energy will produce significant, measurable benefits across the U.S. economy and vastly expand the value of the electric grid.

This white paper, created in conjunction with Navigant Research, describes the evolving needs of the electric grid and the market drivers that are powering rapid storage industry growth. It also quantifies some of the considerable economic benefits and system impacts of widespread energy storage deployment.

Markets and regulations will require reform to unlock the potential of energy storage, and ESA provides recommendations in this document for grid stakeholders and policymakers as they consider how best to improve the grid and properly integrate advanced energy storage systems.

*(Photo credit: RES*

# MARKET DRIVERS FOR GROWTH

## 2.1 TODAY'S GRID: A DISRUPTED NETWORK

The U.S. electric grid and the work of its utilities, municipals, and cooperatives are the engineering achievement of the 20th century. It is fundamental to society, and transforms the lives of every consumer.

Although planning and investment in the electric power sector have evolved over the last century, the U.S. continues to rely almost entirely on large, centralized power plants and a one-way power flow. Until recently, the services provided by available grid assets were largely similar. This meant that decision-making could be entirely based on least-cost planning, as every choice had essentially the same value and outcome.

Planning today favors longer time horizons, since assets typically take several years to build and are constructed to last for decades. Once put in the ground and interconnected to the grid, these large, centralized assets have a limited ability to adapt to changing needs. Also, because electricity is instantaneous and a perishable good, the entire energy network is scaled up to address predictable and infrequent peaks in demand.

This system design is vulnerable to disruptions of all types, and is ineffective at adapting to any rapid change in network conditions. This means ratepayers are obligated to pay for a system that is overbuilt and overburdened with underutilized assets that will take decades to pay off.

These inefficiencies and vulnerabilities are inherent to any real-time, centralized network that lacks meaningful flexibility and storage capacity. In contrast, every other network critical to our daily lives, whether it be transportation, natural gas, food supply, or data, is underpinned by robust supplies and significant capacity to store the end product.

Critical networks typically have storage capacity on the order of at least 10% of daily demand[1]. However, it is estimated that North America's power grid has capacity equal to about 20 minutes of of daily demand[2]. Compared to other networks, this is insufficient to meet today's needs, and is woefully unprepared for the evolving demands of the future such as increased demand for reliability and resilience, electrification of our economy, and a changing mix of generation resources.

Electrification puts the grid at the nexus of these networks. The electrification of transportation, data centers, HVAC, communications, industry, and manufacturing means each of these interconnected networks will become more reliant on the electricity grid to function properly. This significant uptick in demand will underpin the role of the centralized grid, but it will also expose these segments of our economy to increasingly expensive disruptions to the grid.

Today's inflexible electric grid requires consistency in supply and demand to be efficient and reliable, and any disruption—from a minor variation in frequency or spike in demand to a system-wide blackout—comes with a significant and escalating cost. This fundamental weakness is a problem for today's system needs, and is entirely untenable for future demands.

The most common type of system disruption on the grid is supply and demand imbalance largely driven by seasonal and daily weather. The resulting variations in demand are addressed by mediating supply by ramping a sluggish power plant up or down, or by deploying faster responding peaking plants. Ramping a thermal power plant means lower economic, fuel, and emissions efficiency and shortens the lifespan of the asset. In particular, peaking plants can have utilization as low as 5%-7% of their capacity[3], resulting in millions of dollars of stranded capacity and value.

Over building power plants causes added costs. Because it is easier to ramp down than turn on a new fossil power plant, the grid is consistently over-generating from all sources to ensure that demand is met. Increasing solar penetration depresses mid-day power prices, shrinking the value of baseload power plants. Stronger wind energy production at night often outpaces system demands, leading to negative wholesale energy prices in competitive markets.

Tens of thousands of megawatt-hours of renewable energy from solar, wind, and hydro are curtailed every year, wasting this emissions-free local energy. These oversupply issues exist because the grid is incapable of storing electricity or dynamically adapting to align supply and demand.

Even with abundant energy supplies, the grid is still straining to meet peak demands, disrupting both planning and operations. Demand peaks represent the largest inefficiency in our system planning today, and each transmission line, distribution wire, and substation must be sized and ready for the peak at any time. The top 10% of demand can account for more than 40% of the total system costs[4].

Every disruption, oversupply incident, and rise in peak demand increases the cost of delivering power for consumers, whether caused by an imbalance in supply and demand, extreme weather a physical disruption, or a cyber threat.

Energy storage is critical to addressing these vulnerabilities, and is the building block of a disruption-proof grid.

## 2.2 THE CLIMBING COST OF DISRUPTIONS

Disruptions impact the electricity network every day, but most small deviations can be mitigated quickly. Each of those disruptions comes with a cost though, and in total, across all sectors, the impact resulting from power outages, surges, and spikes on the grid is estimated to already cost more than $150 billion to the U.S. economy every year and rising[5].

One of the drivers of this increasing expense is a technology-driven concentration of value happening throughout our economy. A computer that used to fill a room now fits in a pocket, and similarly the value and capability of that pocket-sized computer has grown exponentially. Data and electricity networks are already inextricably linked, and this concentration of value contributes significant cost to any disruptions.

Grid outages impose costs to generators, operators and consumers. To understand the impact of grid outages, analysts calculate the value of lost load (VOLL); in effect, how much it costs to go without power for a period of time. For a homeowner, the economic cost may seem minimal, but the cost to quality of life is high: medication and food refrigeration, shelter and access to water are among those critical losses. For commercial and industrial (C&I) buildings, the VOLL is more quantifiable on an economic basis: estimated to be as much as $20,000 per megawatt-hour on average[6].

For data centers and server farms in particular— the backbone of the Internet and fundamental to modern banking, communications, and transportation networks— that cost is even higher, and continues to increase year over year. A recent report by Talari Networks surveyed more than 400 IT professionals. They combined this research with a separate cost-of-downtime study by IHS Markit and put the current cost of loss of power at a data center at more than $9,000 a minute ($540,000 per hour) and rising, with larger installations losing millions of dollars an hour[7].

Businesses and individuals are more and more reliant on these data centers, moving immense amounts of data to remote servers. As enhanced connectivity drives increases in computing capability and economic value in the same footprint, every server that loses power will only have a greater economic cost to it—rippling even further throughout society.

The higher VOLL extends to almost all commercial enterprises. Grocers lose perishable products, stores are unable to sell their wares, and credit card systems lose capability to process payments at data centers and points of sale.

Automated smart buildings, the high-power requirements of ultra-high definition video, virtual reality interfaces, and fully-enabled cloud computing—all of these advances will further concentrate financial risk as a corollary to increases in computing power.

The same escalation can also be observed in the electrification and digitization of industrial and transportation networks. A fully automated and electrified manufacturing hub brings with it exacting power standards and a fleet of high-tech robots dependent upon a stable and reliable source of power. The expansion in electrified mass transit and increasing adoption of electric vehicles (EVs) means that a system outage in any part of the transportation network will impact more individuals than ever before.

The value of every kilowatt-hour delivered is steadily rising, and with it, the cost of disruption. As the electric grid increasingly plays a critical role at the center of multiple electrified networks, the cost, impact, and frequency of power disruptions will play a critical role across the entire U.S. economy.

## 2.3 THE BREADTH AND IMPACT OF NEW ENERGY NETWORKS

Transportation, data centers, HVAC, communications, industry and manufacturing are all becoming increasingly interconnected and reliant on electricity. Even as consumers become more efficient in how they use energy, electrification is steadily changing the nature of the U.S. grid, introducing our economy to new constraints, disruptions, and dynamic demand changes faster; and supply is increasingly bi-directional, more distributed and non-dispatchable.

The electrification of transportation and buildings will add more than 3,500 TWh of new system demands as electricity reaches ubiquity across these networks in 2050[8] (the U.S. currently consumes roughly 4,200 TWh of electricity each year[9]). With the grid at the nexus of these networks, disruptions to the grid will ripple throughout the economy even more, reinforcing the need for a disruption-proof grid.

Electrified transportation will likely provide the largest source of new system load, and also some of the most dynamic requirements of grid performance. The most significant challenges facing this network today are variable demand (having the right transport in the right place at the right time), fuel security, and system congestion (overcrowding and traffic jams).

Interconnectivity and data will serve to address the first challenge by employing on-demand automated vehicles and better coordinated mass transit systems. Electrification will mitigate fuel security risks. The diverse needs of the electric transportation network will likely have a leveling effect on load overall, but it will also introduce new demands and disruptions to the grid.

Electricity demands vary widely between transportation, building, industrial, and data networks. Each sector will introduce its own load profiles, its own challenges and vulnerabilities, and its own potential to disrupt the normal operation of the electric grid. Without flexibility, the grid is unable to adapt to the needs of these sectors' networks. Unpredictable disruptions will throw load projections and energy markets into disarray. Without the flexibility afforded by energy storage, significantly more generation capacity is needed to sit idling to meet changing demands—further increasing the costly differential between base load and peak demand. Servicing these dynamic new sectoral network needs with traditional inflexible grid resources will quickly become cost prohibitive, making new electrified networks untenable.

The key to integrating these networks into the grid lies in increasing system flexibility and efficiency, building more buffer into the system in the form of on-demand capacity and responsive balancing capability. Stationary energy storage systems will enable the effective integration of these new network demands into the grid and mitigate the costly impacts of network disruptions.

Without vastly improved flexibility, today's grid cannot service the needs of these dynamic sectors. The ability of energy storage to instantly adapt to changing network conditions, smooth out load curves, reduce peak demand, and ensure system capacity when and where it is needed is essential to the electrification of transportation, communications, manufacturing, data and buildings.

The introduction of these new disruptive demands calls for a flexible and responsive network that is able to address real-time localized operations of a vastly expanded network, creating a disruption-proof grid.

## 2.4 CREATING A DISRUPTION-PROOF GRID

The need for a disruption-proof grid is clear. Grid disruptors are being introduced at a pace unmatched in recent history, and the increasing concentration of value and interconnectivity means that even a local disruption can have systemic impacts costing millions of dollars, affecting millions of people. The electric network is already inherently vulnerable to disruption, and continued electrification of the economy is only one factor increasing the frequency, cost, and risk of outages. This will exacerbate the fundamental weakness of the grid until stakeholders intervene. Energy storage is the foundation of a disruption-proof grid.

Fast responding energy storage addresses second-to-second fluctuations to match supply and demand without the need for idling and inefficient fossil fuel power plants waiting on standby. Transmission- and distribution-scale energy storage systems improve market efficiency and operations, can provide backup power for entire communities, and enable further integration of dynamic demands and intermittent resources. Distributed energy storage systems improve system resiliency, prevent blackouts and surges, and increase overall reliability for the end user, while also saving them money.

Storage systems can shift large quantities of energy across time, ensuring that there is capacity when and where it is needed to meet unpredictable demands and dynamic loads. Providing backup power for a single building or an entire community also means grid disruptions can be isolated and mitigated in real-time, and the grid is able to heal itself faster when there are widespread outages.

### Moving Austin through the Lincoln Tunnel

*Today's EV batteries require nearly three times as much energy to be fully charged as a typical household uses in a day. The Lincoln Tunnel in New York sees 120,000 commuters a day pass through it, meaning a slowdown in the tunnel could impact the daily load equivalent of 360,000 households – an entire city's worth of electricity demand that may reconnect to the grid in 20 minutes, or two hours.*

*The average coal power plant is about 125 MW and capable of serving about 100,000 homes. That means a traffic jam intersecting with an inflexible grid would result in the equivalent of three or four traditional power plants or more to be sitting on the system, idling and waiting for an 'electric city' larger than Austin to get home from work.*

Energy storage scales easily. Large systems provide hundreds of megawatt-hours to ensure flexibility can improve the utilization of large generating assets. Distribution-scale systems can provide constant balancing and peak demand reductions, enhancing performance of the entire system.

Just as the scale and location of energy storage varies, so do the technologies. Pumped storage, compressed air, thermal storage, electrochemical and flow batteries, flywheels, ultracapacitors, and other forms of energy storage will all contribute to achieving more than 35 GW of new energy storage by 2025. While each of these systems may have different applications, they all share a similar performance trait: to decouple generation and load from the element of time, and to power a disruption-proof grid.

Storing energy enables a more resilient, efficient, sustainable and affordable grid. This is true whether the U.S. produces electricity from fossil fuel, nuclear, or renewables, either in a regulated or deregulated market.

To realize this more flexible grid, policies and regulations must keep pace with the advancement of technology and consumer demands. Creating a disruption-proof grid will require not only a technology transformation, but also revising to the traditional methods of planning and operating the grid.

## 2.5 A VISION FOR ENERGY STORAGE IN 2025

ESA sees a clear and actionable path to add 35 GW of energy storage to the U.S. grid by 2025. And ESA sees a less than optimal outcome for the reliability, resilience and flexibility of the grid without energy storage.

The physical limitations of the grid and the continued electrification of the economy will intensify the economic punch of increasingly frequent and impactful disruptions. Over the next several years, utilities and grid operators will invest billions of dollars in grid infrastructure, working to repair aging assets and modernize system capabilities under the direction of regulators.

There is a choice to be made: either rebuild the grid with today's infrastructure and assets with incremental improvements, or invest in new technologies and strategies that can deliver better outcomes at a lower cost. Today's model of a grid driven solely by cost, predicated on balancing and infrequent peaks, is quickly becoming outdated.

The U.S. needs a grid that is prepared for the future; a disruption-proof grid will ensure that the limitations of the electricity network do not unduly hinder progress across the entire economy. Electrification of the economy underpins the important role of the utility as a cornerstone. At the same time, electrification of networks and the widespread use of energy storage will enhance the value of grid hardware for the utilities and third parties that own it.

Built around the vision of 35 GW of energy storage deployed by 2025, planners will embrace new ideas and employ new strategies for grid planning and operation. Utilities and regulators will engage in holistic integrated resource planning (IRP), incorporating the multi-faceted value of advanced energy systems. Companies and building owners will collaborate with grid operators, third party service providers and utilities to monetize distributed energy systems at competitive prices.

The result is a robust and resilient energy network that addresses today's challenges and is prepared for the dynamic demands of tomorrow. Energy storage is critical to this transformation. Understanding and recognizing the value and capabilities of these systems is of the utmost importance for all grid stakeholders, to realize a future grid that is more resilient, efficient, sustainable and affordable.

# VALUING A DISRUPTION-PROOF GRID

There is little doubt that the addition of energy storage can provide significant benefits to the grid. However, calculating the total value of energy storage is different from the methods used for traditional grid assets, especially considering the differences in regulations and market dynamics between jurisdictions.

The following sections explore the benefits of energy storage deployments in the U.S., focusing on four main categories that can be quantified and modeled today: (1) market contributions to grid services, (2) enhanced grid reliability and resiliency, (3) jobs growth, and (4) emissions reductions. These four categories represent a selection of the benefits of energy storage.

It is important that stakeholders understand all the benefits that increased storage deployments will provide to the U.S. market, and simultaneously consider what opportunities will be lost if the U.S. does not adequately support the growth of energy storage deployments. To quantify these storage values, Navigant Research developed a framework to evaluate the costs and benefits based on the various services and applications storage systems will provide. This framework was incorporated into an analytical platform: Navigant Research's Valuation of Energy Storage Tool (NVEST). The primary purpose of NVEST is to analyze operational deployments, but it can also analyze proposed projects in a given market.

## 3.1 FASTER, MORE ACCURATE RESOURCES

One of the most readily accessible benefits of energy storage systems is their vastly superior flexibility over traditional grid assets. This has significant impacts on overall market performance and efficiency by introducing a technology that can better balance dynamic demands with supply, and can be utilized to address a range of applications.

A traditional fossil fuel generator responds to a grid signal in a few minutes or hours, and must be on and idling to ramp up or down as needed. An energy storage system is always on and can respond in seconds instead of minutes, with improved accuracy and no need to inefficiently ramp to achieve the right output.

These inherent performance characteristics provide benefits across a wide range of grid applications and services, enabling regulators, grid operators and utilities to lower costs and better stabilize market pricing in the face of system peaks or variability. These market improvements and cost savings can be achieved by storage systems alone, or by pairing directly with another generation or transmission and distribution (T&D) asset on the grid—augmenting the value and utilization of the current infrastructure, while introducing new benefits and capabilities.

Overall, energy storage is able to improve outcomes and lower costs in markets and competitive procurements, savings that can be passed on to ratepayers' bills.

The Mid-Atlantic and Midwestern regions of the U.S. have seen significant energy storage deployments in the past several years. One of the most notable drivers for growth has been PJM's competitive ancillary service market. PJM was the first regional transmission organization (RTO) in the country to implement an economical market for energy storage based on premium payments that recognize the value of accurate and fast responding frequency regulation resources. Additional regulatory reforms at the federal, RTO and state levels are likely to provide even more opportunities for storage to compete in ancillary service markets throughout the country.

### 3.1.1. 35 GW Impact: Operational Cost Savings

The analysis presented in this section focuses on operational cost savings from the use of storage. For example, this analysis reflects the ability of storage to reduce the cost to provide frequency regulation and spinning reserve services, and on the operational cost savings to homes and businesses.

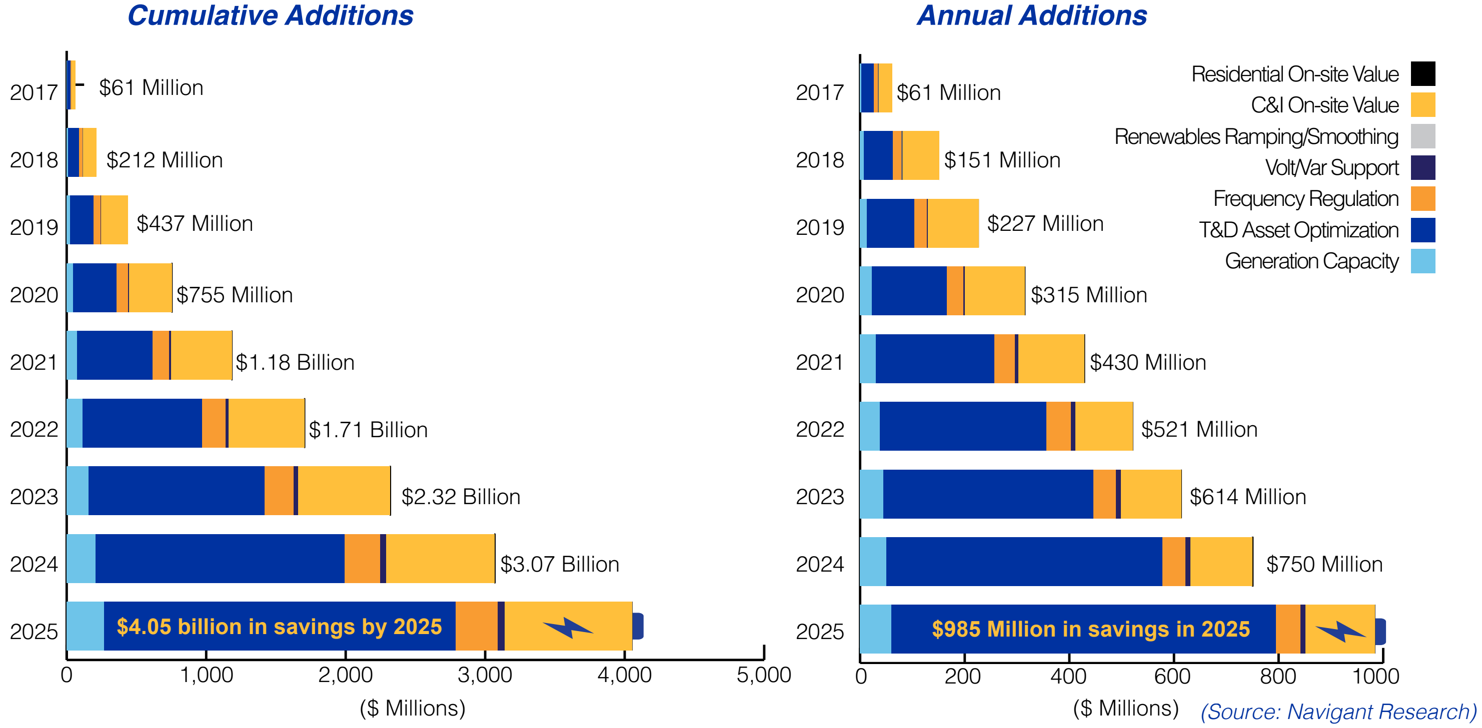
However, this analysis does not capture numerous systemic benefits of adding storage to the grid. As a result, the values provided in this study reflect only the currently quantifiable benefits of storage from a grid operator's perspective.

There are two important factors that were not fully accounted in this analysis, but merit consideration and more precise quantification. The first reflects the systemic value of enhanced grid flexibility that can reduce the costs to integrate distributed generation and other new resources. Secondly, while T&D asset optimization is included for storage's ability to defer upgrades in T&D capacity, the deferral or avoidance of investments in other grid infrastructure such as adding new conventional generating plants or substation upgrades, and other T&D infrastructure is not included. For example, while the analysis will show the value storage provides in terms of reduced operating costs for providing spinning reserves, it does not account for the additional peak capacity plant that will no longer need to be built, or the reduced costs to accommodate new distributed solar PV.

Chart 3.1 reflects the operational savings value of 35 GW of storage by 2025 and serves as a starting point for estimating grid cost savings as new revenue streams are recognized.

- *Residential On-Site Value:* This analysis is based solely on the ability to arbitrage between on- and off-peak electricity rates, and use the entire capacity of energy storage for this arbitrage.
- *C&I On-Site Value:* The value of C&I energy storage assumes standard, national averages for on-peak versus off-peak energy and demand charges. This analysis does not consider storage used in demand response (DR) programs or to provide other grid services, which are captured in other categories of value.

***Chart 3.1 Estimated Cumulative and Annual Grid Operational Cost Savings from U.S. Energy Storage Deployment by Application, Vision Scenario (2017-2025)***



*(Source: Navigant Research)*

- *Ramping/Smoothing:* Currently there are no specific revenue streams associated with ramping or absorption of over-generation from inflexible or non-dispatchable resources such as “baseload” or renewables.
- *Volt/Volt-ampere Reactive (Volt/VAR) Support:* The value of Volt/VAR support is calculated based on the ability to defer investments in other grid systems, specifically capacitor bank upgrades. It does not account for the fast availability for VAR support to avoid broader impacts to service.
- *Frequency Regulation:* The value of frequency regulation is based on a straightforward calculation of the number of hours a system would provide regulation services (estimated at 90%) and the average price for regulation service. For this analysis, Navigant Research used payment data from the New York Independent System Operator, which is the most representative of overall national averages.
- *T&D Asset Optimization:* The value T&D asset optimization is based on the deferral of conventional equipment upgrades. It is assumed that the addition of storage can defer these grid upgrades for a period of 5 years.
- *Generation Capacity:* The generation capacity application is made up of both traditional grid reserves (spinning and non-spinning) and renewable energy shifting applications.

## 3.2 RELIABILITY, RESILIENCE AND FLEXIBILITY

In considering the role of energy storage systems on the grid, the most readily apparent benefit is the ability to provide backup power during disruptions. While this concept is most familiar as it applies to backup power for an individual device (e.g., a smoke alarm that plugs into a home but also has battery backup), this same capability and value can be scaled up to an entire building or section of the grid.

Energy storage provides flexibility for the grid, to ensure uninterrupted power to consumers, whenever and wherever they need it. This flexibility is critical to both reliability and resilience, which have important but subtle distinctions. Reliability is the ability to maintain service every moment of every day, and to do so in the face of variable, unpredictable, and sometimes extreme system conditions. Resilience, on the other hand, is the ability to maintain or restore power following a disruptive external event. Today’s grid is designed to be reliable, but it lacks resilience.

Individual generation assets do not necessarily require coupled storage to enhance reliability and resilience. Strategic planning and operation of microgrids or a fleet of energy storage systems spread across the grid will vastly improve the grid’s resilience. And as the cost of these outages continues to rise, the value of enhanced reliability and improvements in resilience will increase as well.

**Puget Sound Energy Improves Reliability**

*Several utilities have partnered with vendors in microgrid projects. For example, Puget Sound Energy (PSE) of Washington has worked to improve the reliability of its electric service for customers. In 2016, the company installed its Glacier Battery Storage Project, capable of providing backup power during extended outages. The system can also reduce load during peaks of high demand and balance intermittent loads to integrate more renewables within PSE’s service territory.*

### 3.2.1 35 GW Impact: Enhanced Resilience and Reduced Outages

Recent natural disasters have highlighted the fragility of a centralized grid architecture. Communities are opting for local generation and microgrids to provide community centers of refuge, or to ensure their power stays on during a disaster. Per a 2014 report from the International Energy Agency, the grid in the U.S. alone will require $2.1 trillion in investments by 2035 to modernize and ensure continued reliability.[10] Energy storage will play a key role in these investments by optimizing new and existing hardware, as well as by hardening the grid to handle external threats including natural disasters, physical attacks, and cybersecurity threats.

This analysis considers the VOLL against the cumulative value of reliability and resilience investments in energy storage. Key assumptions used in this analysis include:

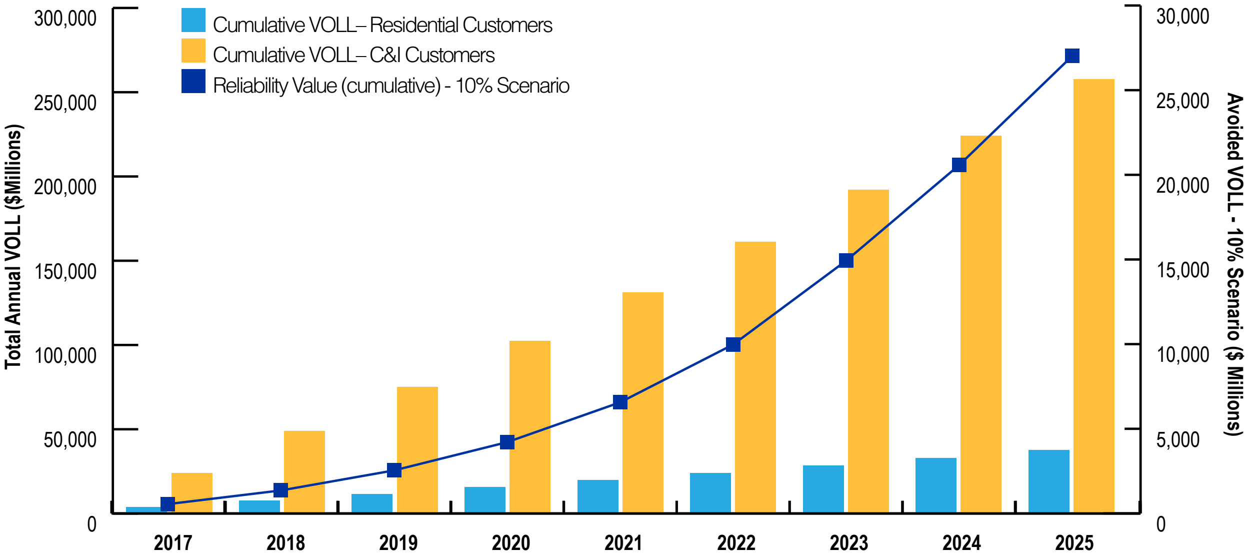
- Overall growth in energy consumption is relatively flat, based in part on energy efficiency improvements concurrent with population and economic growth;
- The number of customers is predicted to increase by 5.7%, while average residential electricity demand per is forecast to grow only by 0.4%, and average C&I electricity demand is forecast to grow only 0.8%;
- Annual lost load for residential customers decreases 2% for residential customers and 1.6% for C&I customers;
- Costs decline across all applications and technologies from $2.05 million per MW in 2017 to $1.15 million per MW in 2025, and average $1.38 million per MW over the period; and
- 35 GW of energy storage by 2025 will require $48.7 billion of investment.

The outcome of this analysis demonstrates the increased impact of power outages, and the additional value that energy storage systems can provide - on top of day-to-day power and energy applications to mitigate potential losses.

- Thanks to the concentration of value over time, the megawatt-hour VOLL for residential grows 26.7% and the megawatt-hour VOLL for C&I grows 42.2%;
- C&I outages are more valuable than residential outages, even though resident energy consumption is 87% of total electricity consumption in the U.S.;
- Cumulative VOLL between 2017 and 2025 is $295 billion; and
- Capturing 10% of the cumulative VOLL would be $29.5 billion.

Chart 3.2 illustrates the cumulative value of all load lost due to outages for both residential and C&I customers through 2025 along with the expected reliability and resilience value resulting from energy storage deployments, assuming a 10% improvement in reliability.

**Chart 3.2 Cumulative VOLL for Residential and C&I Customers and the Value of U.S. Energy Storage to Improve Reliability (2017-2025)**



*(Source: Navigant Research)*

## 3.3 NON-ENERGY BENEFITS

The benefits of energy storage also extend well beyond any one system on the grid, and provide a host of non-energy benefits. Some of these benefits, like job creation and emissions reduction, can be directly quantified. Projections of these outcomes have been included in the following sections.

Other systemic benefits are apparent but more difficult to quantify simply with any one metric. Improving systemic efficiency and raising utilization and capacity factors of other assets is a direct result of storage deployment, but is much more difficult to articulate in dollars per kilowatt installed. The ability to more easily integrate large amounts of intermittent generation and distributed generation will enable continued growth in renewable energy, but little of that value is, under the current regulatory framework, easily transferred back to a storage system owner.

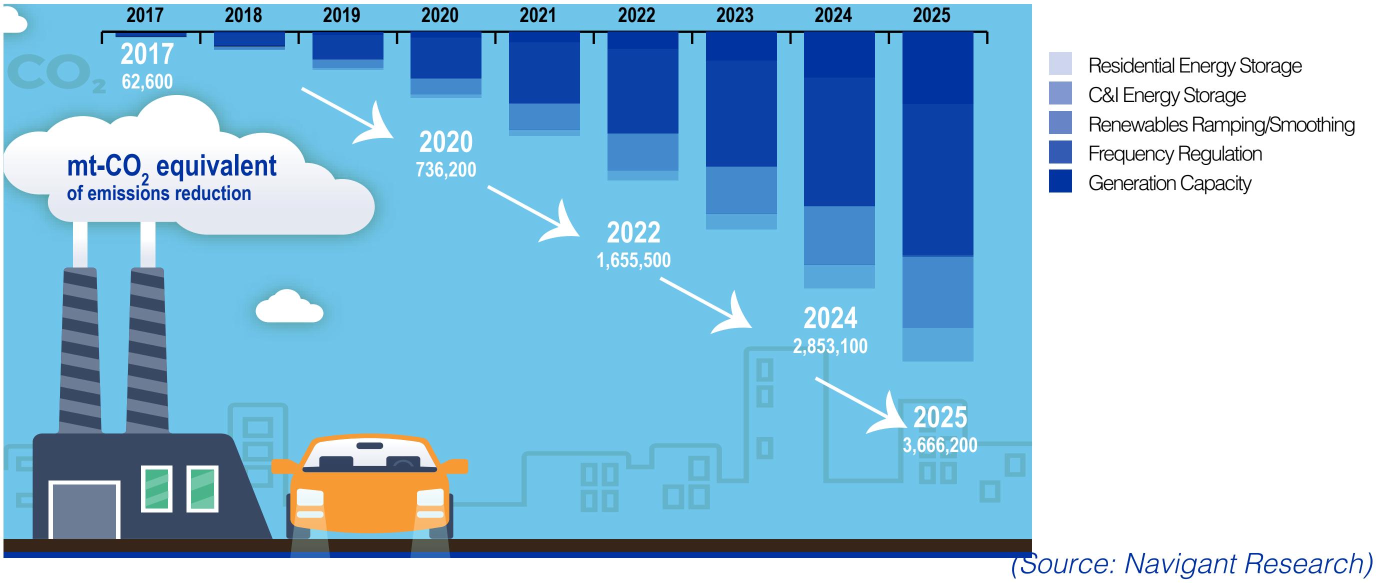
Efforts to value and incorporate societal impact into the evaluation of planning and operation of the grid is challenging, but nonetheless are present and tangible. Over time, non-energy benefits will become increasingly quantified in analyses, and the electrification of society will contribute to accelerating that transition.

### 3.3.1 35 GW Impact: Reducing Emissions

The specific reductions in carbon emissions that can be achieved with greater amounts of energy storage on the grid has been the subject of many studies in the past several years. While energy storage has a unique ability to improve the overall efficiency of the grid, the actual reduction in emissions depends on the original fuel mix. Navigant Research's NVEST tool calculates the emissions savings expected from the new capacity of energy storage, anticipated to be installed over the next 10 years. Chart 3.3 illustrates the estimated emissions $CO_2$ reductions resulting from the deployment of 35 GW of energy storage in the U.S. by 2025.

There are two ways the energy storage can reduce emissions from the power sector: by maximizing the utilization of renewable energy, and by improving the efficiency of conventional grid generation. For several storage applications, including residential, C&I plant emissions due to higher efficiency and reduced idling of generator and renewable energy shifting, the ability to maximize consumption of emissions-free renewable energy is key.

***Chart 3.3 Cumulative Estimated $CO_2$ Emissions Reductions from U.S. Energy Storage Deployment, Vision Scenario (2017-2025)***



*(Source: Navigant Research)*

When integrated into the grid with increasing amounts of variable wind or solar generation, storage is used to shift excess production to align with greater demand and higher electricity costs – decoupling the element of time from generation and end use. This results in costs savings for customers and reduced emissions for everyone, as traditional on-peak generation is replaced with stored carbon-free renewable energy. Energy storage systems are also used to improve the overall efficiency of the grid and conventional power plants through reduced cycling and changes in output, resulting in lower emissions. For applications such as frequency regulation, reserve capacity, and renewables ramping/smoothing, energy storage is used to cover short-term fluctuations in generator output, leading to improved power plant efficiency and reduced emissions.

Navigant Research has modeled the expected emission reductions possible from storage deployments from three pollutants in addition to carbon dioxide ($CO_2$), nitrogen oxides ($NO_x$), sulfur oxides ($SO_x$), and particulate matter (PM). The inputs used in this analysis are sourced from the U.S. Environmental Protection Agency's Emissions & Generation Resource Integrated Database, and range on average from 0.0251 lb/MWh for $SO_x$ to 0.1946 lb/MWh for $NO_x$.

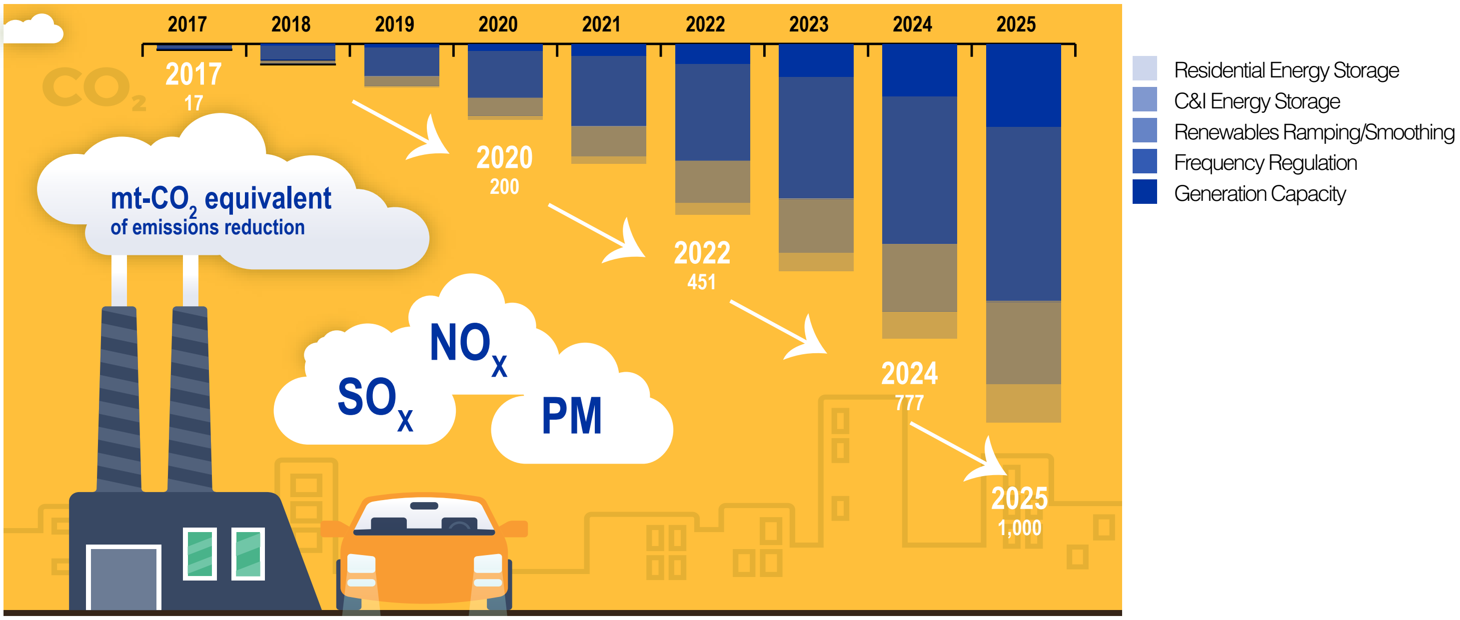
Utilizing these values and the methodology outlined above, Navigant Research analysis illustrates in Chart 3.4 the forecast for emissions savings from $NO_X$, $SO_x$ and PM. The resulting use of energy storage on the grid; translates to a 20% reduction in thermal inefficiency.

For ease of understanding, Chart 3.4 utilizes an equivalency ratio that quantifies the climate impact of various power plant emissions equivalent to the global warming potential of $CO_2$ emissions.[11]

### 3.3.2 Job Creation

The impact of the energy storage industry on employment in the U.S. is expected to grow substantially over the coming ten years. In January 2017, the U.S. Department of Energy published its U.S. Energy and Employment Report, which calculated the total employment across various sectors of the energy industry including storage. The findings in this report provided key data inputs for determining total employment across the storage industry in 2017 and over the coming decade.

**Chart 3.4** *Cumulative Estimated $NO_x$, $SO_x$, and PM Emissions Reductions from U.S. Energy Storage Deployment, Vision Scenario (2017-2025)*



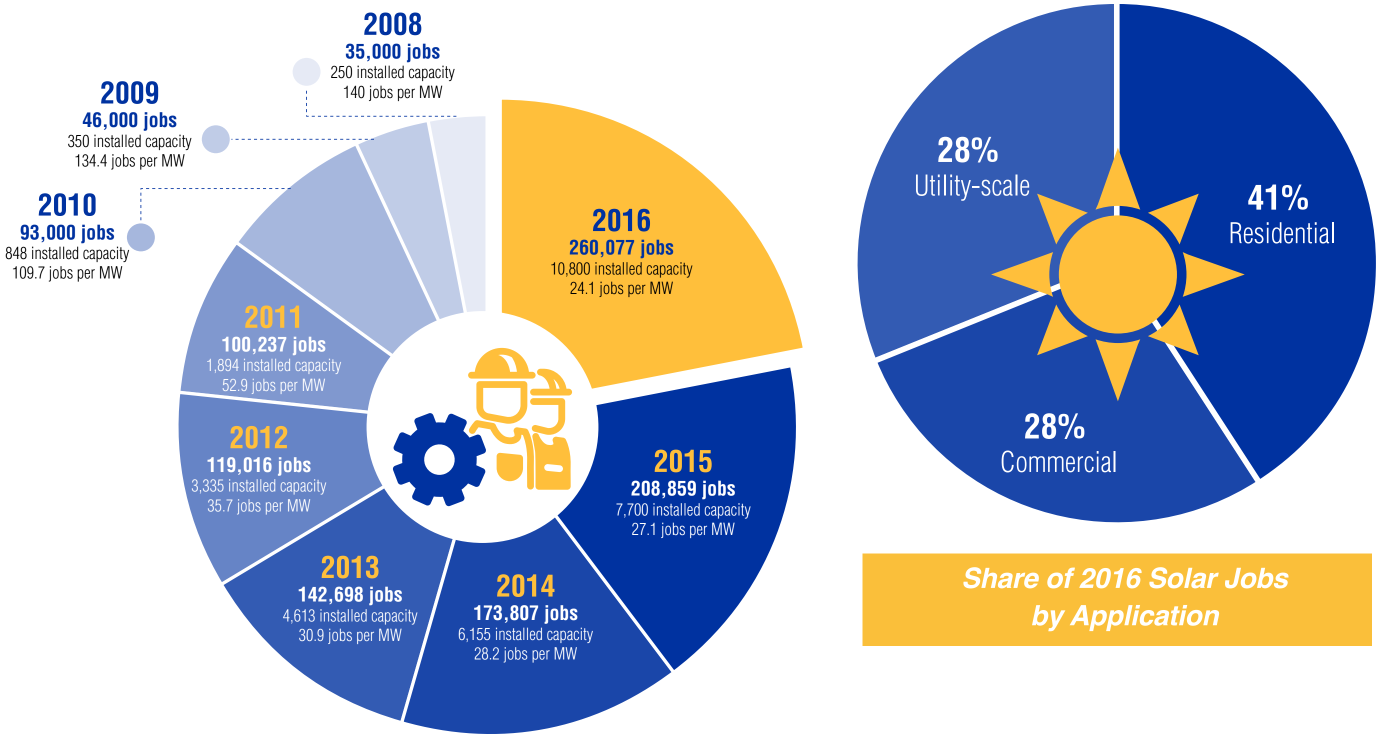
*(Source: Navigant Research)*

According to the U.S. Energy and Employment Report, there were a total of 90,831 individuals directly employed in the U.S. energy storage industry in 2016. These direct jobs include battery and component manufacturing, R&D, engineering and construction (project development), operations and maintenance, sales, marketing, management, administrative, and other positions. As the storage market grows, employment will scale accordingly.

To understand the impact of market growth on the total number of industry jobs per unit of new capacity, data from the solar PV industry over the past decade provides a template for estimating job creation in the storage industry over the next ten years. Chart 3.5 illustrates the relationship between solar market growth and the number of jobs per megawatt of new capacity, broken down by residential, commercial, and utility-scale installations. As the market scales up over time, each incremental megawatt requires fewer jobs to deploy an additional megawatt of capacity. This reflects front-loading of key hires, industry learning, and optimization of resources. In addition, the number of solar jobs required for residential installation jobs per MW is higher than that for utility-scale.

Navigant Research expects that over the coming ten years the energy storage industry will see a similar trend in the number of industry jobs per megawatt of new capacity as the market matures, with residential solar installations serving as a proxy for residential and C&I. Given the current maturity of the storage industry, it is expected that the number of industry jobs per megawatt of new capacity will soon decrease. This is a result of the improved efficiency in developing projects, and the fact that companies have been expanding their teams over the last two years in preparation for expected growth,

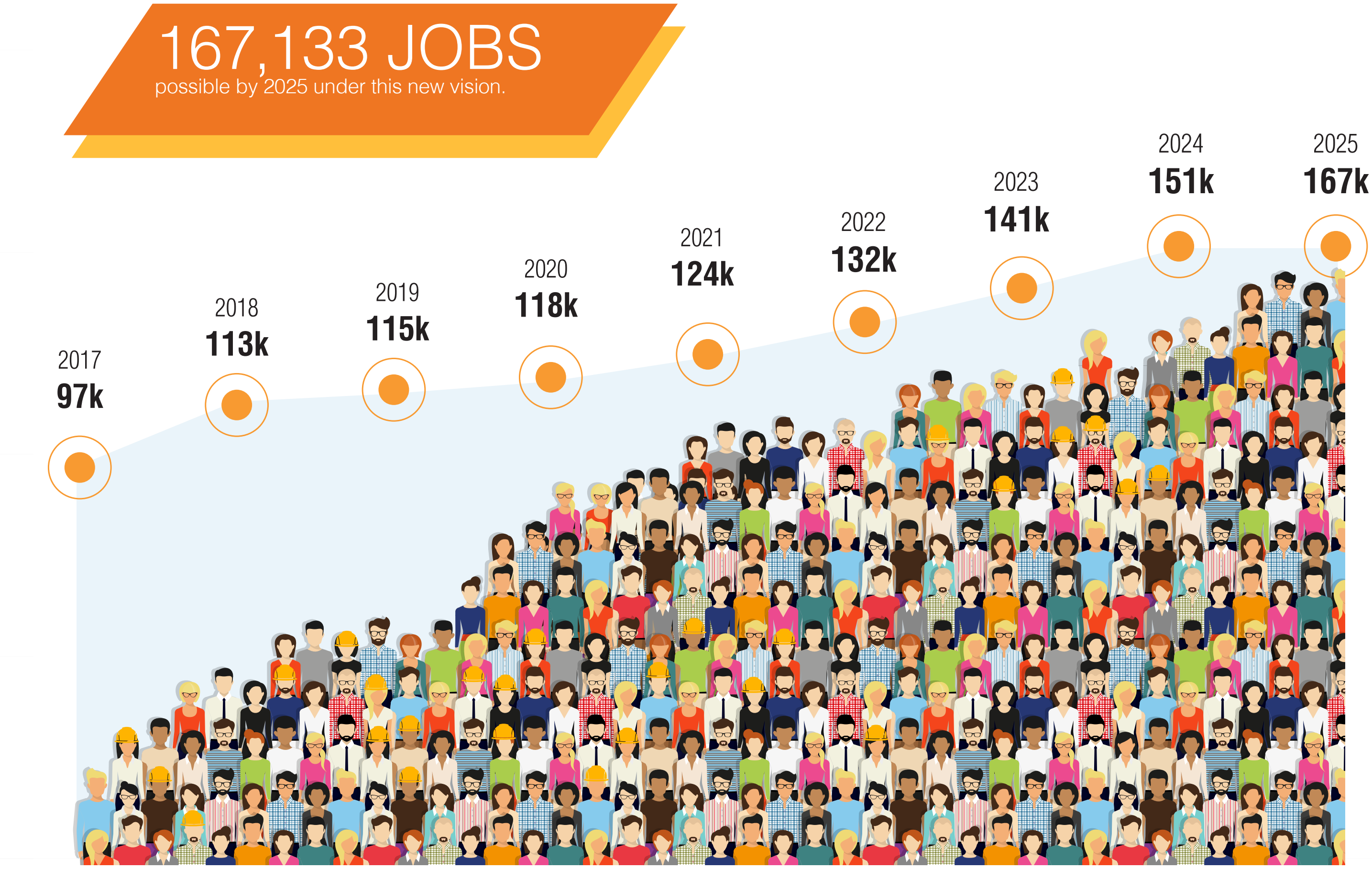
**Chart 3.5 Annual U.S. Solar Energy Capacity Additions, Solar Jobs, and Industry Jobs per MW of New Capacity (2008-2016)**



*(Source: The National Solar Foundation and Solar Energy Industries Association)*

as seen in the solar industry from 2009 to 2012. Based on this trend and the current number of energy storage jobs per megawatt of new capacity, Navigant Research estimates that the number of jobs per megawatt in the storage industry will decrease from 404 in 2016 to 50 in 2021, and 34 jobs per megawatt in 2025.

**Chart 3.6** ***Cumulative U.S. Energy Storage Industry Jobs, Vision Scenario (2017-2025)***



*(Source: Navigant Research)*

# FROM HERE TO 2025: MAPPING 35 GW

## 4.1 REGIONAL GROWTH BY THE NUMBERS

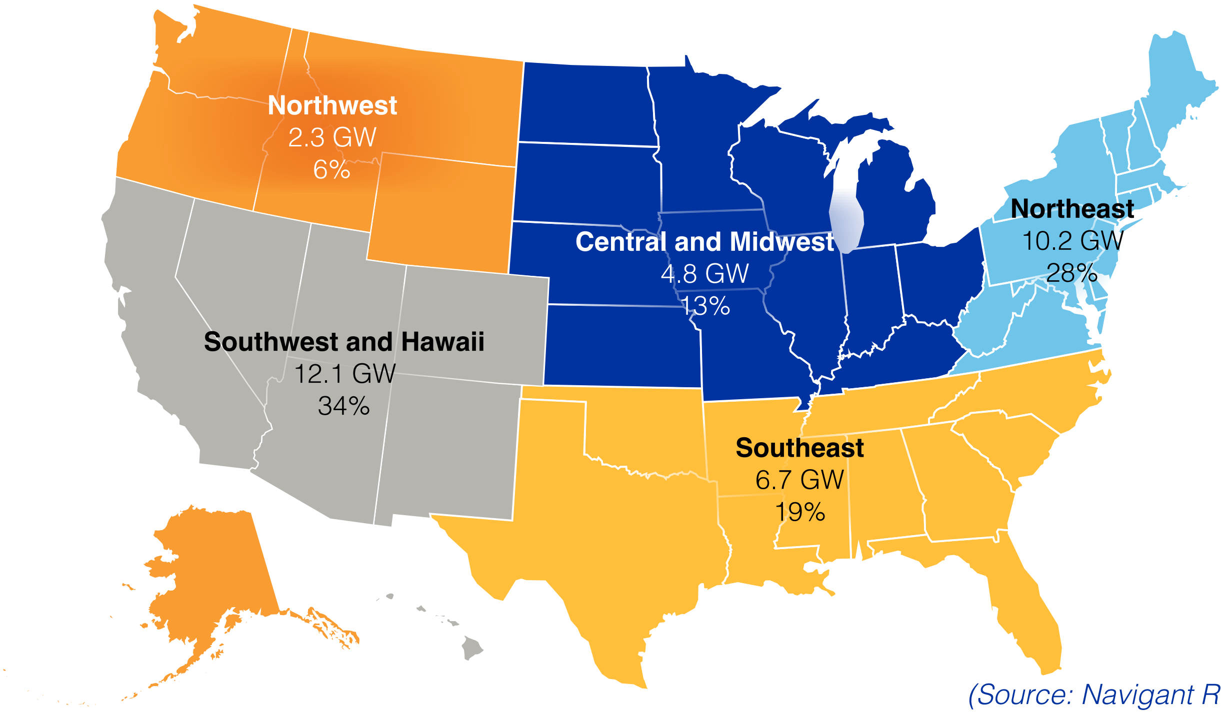
To date, the U.S. energy storage market has been highly concentrated in select areas where market and regulatory conditions are supportive. However, over the coming years, energy storage deployments will accelerate around the country with different factors influencing the overall size and dynamics of the market. The following sections explore the specific drivers and trends influencing energy storage markets in regions around the U.S.

The Southwest and Hawaii will account for a little over one-third of the storage market between 2017 and 2025. The Northeast will account for slightly over one- quarter of capacity installed, and the remaining capacity will be split between the Central and Midwest region, the Southeast and the Northwest. Not coincidentally, the top regions for storage correspond to population centers, congested grids, high renewable penetration, and strong policies supporting distributed energy resources (DER).

### 4.1.1. Central And Midwest

Wind integration is a major driver for storage in the Central and Midwest region. With more than 8 GW of U.S. wind energy added in 2016 alone, much of it concentrated in Midwest states and Texas, the high penetration of intermittent renewables has increased the need for frequency regulation to manage power fluctuations. Additionally, demand for resilience in rural communities has created a new market for storage resources. These communities are often served at the end of long T&D lines that are frequently damaged by tornados or other severe weather events throughout the region. Currently, there are 294 MW of non-hydro storage deployed or in the region's pipeline, with about 90% providing frequency regulation in either the Midcontinent Independent System Organizer (MISO) or PJM markets.

***Figure 4.1 Cumulative U.S. Energy Storage Energy Capacity Additions by Region, Vision Case, (2017-2025)***



*(Source: Navigant Research)*

### 4.1.2. Northeast

Key drivers in the Northeast include aggressive greenhouse gas (GHG) reduction policies or renewable deployment targets implemented by states in the region, including the Regional Greenhouse Gas Initiative (RGGI).

New York has been a pioneer in efforts to modernize both the physical architecture of the grid and utility business models—most notably through its Reforming the Energy Vision (REV) initiative. REV has given rise to pilot programs like Consolidated Edison's virtual power plant (VPP). Massachusetts, another state seeing significant energy storage market growth also benefits from supportive regulatory policies. At the end of 2016 the state's Department of Energy Resources decided to set an official energy storage mandate. Following stakeholder input and engagement, the state has set a target of 200 MWh of new energy storage system capacity by 2020. There are currently 385 MW of non-hydro energy storage deployed in the Northeast.

#### Reforming the Energy Vision

*REV aims for major reforms to both utility business models and market regulations to enable a transformation to a grid built around DER.*

#### Virtual Power Plant

*The VPP model generally employs an energy aggregator to own and operate a portfolio of smaller generators and synchronize them as a larger, unified, and flexible generation resource. This resource can sell power on the energy market or as a system reserve.*

### 4.1.3 Northwest

Hydropower in the region's energy mix keeps wholesale and retail prices low, and also provide for a low emission energy mix compared to most of the country. Nonetheless, the region's populous coastal states of Oregon and Washington have adopted aggressive GHG reduction and renewables adoption targets. Government and regulatory support for storage in the region is likely to be an important driver to enable more renewables. The state government in Oregon has already implemented a mandate for the state's largest utilities to deploy storage,[12] and in Washington State, the Commission issued a policy statement directing investor-owned utilities that for their planning processes to be considered prudent, they must include energy storage in their analyses.[13] Currently, there are 19 MW of non-hydro storage deployed or in the pipeline in the region with over 3,200 MW of new pumped hydro storage planned throughout the region.

*The mandate in Oregon requires two utilities, Portland General Electric and PacifiCorp to deploy 5 MWh of energy storage each by 2020.*

### 4.1.4 Southeast

Low electricity prices in the Southeast, a regulatory structure that doesn't account for the flexibility values of storage, and limited deployments of renewable energy have influenced the development of the storage market in the Southeast. However, North Carolina and Georgia are leading the region in solar photovoltaic (PV) deployments. Several of the largest utilities in the region, and the U.S. for that matter, have evaluated the benefits of adding energy storage to the grid, primarily for T&D deferral and optimization and peak demand reduction. Currently there is 16 MW of non-hydro energy storage deployed or in the pipeline in the southeastern U.S.

### 4.1.5 Southwest And Hawaii

The Southwest region of the U.S. has been by far the leading market for energy storage to date. California accounts for a majority of new storage development in the country over the past five years. The market in California has been driven by a combination of aggressive renewable energy goals and development, high and volatile retail electricity prices, utility support, and regulatory mandates. The efforts by regulators to integrate energy storage onto the grid is likely the most significant single driver, specifically Assembly Bill 2514 passed by the state government in 2013. California's three major investor-owned utilities (IOUs) have procured or signed contracts for more energy storage than is required under the law, highlighting the value and increasing cost- effectiveness of storage on the grid.

*The Assembly Bill 2514 passed in 2013 is now a California law calling for 1.3 GW of energy storage to be procured and built in the state of California by its three major IOUs by 2024.*

This region also has the most distributed and grid-scale solar PV in the country. This results in growing demand from both customers and grid operators for energy storage to maximize the value of new solar resources and minimize negative impacts to the grid. Anticipated changes in net-metering programs for solar and new retail rate structures including time-of-use rates will impact the economics of energy storage in coming years.

Hawaii is experiencing challenges brought on by the rapid penetration of renewable energy on a physically constrained grid, and is expected to be an early test-bed for residential storage and other DER business models, including distributed generation (DG). Due to high electricity rates, federal incentives, and the state's net-metering policy, solar PV has been installed at a rapid rate in Hawaii, growing ten-fold, from 56 GWh total in 2010 to over 559 GWh in 2014[14]. These factors—combined with the natural resource of abundant sunshine—make PV an attractive investment for utilities, businesses, and homeowners, and have resulted in distributed PV supplying over 100% of load on some distribution circuits during the day.

There are currently over 4,200 MW of non-hydro storage deployed or in the pipeline in the region, by far the most in the U.S. Notably, proposed compressed air projects account for 2,300 MW of this capacity, and 454 MW comes from molten salt/thermal storage tied to concentrated solar power projects in the region.[14]

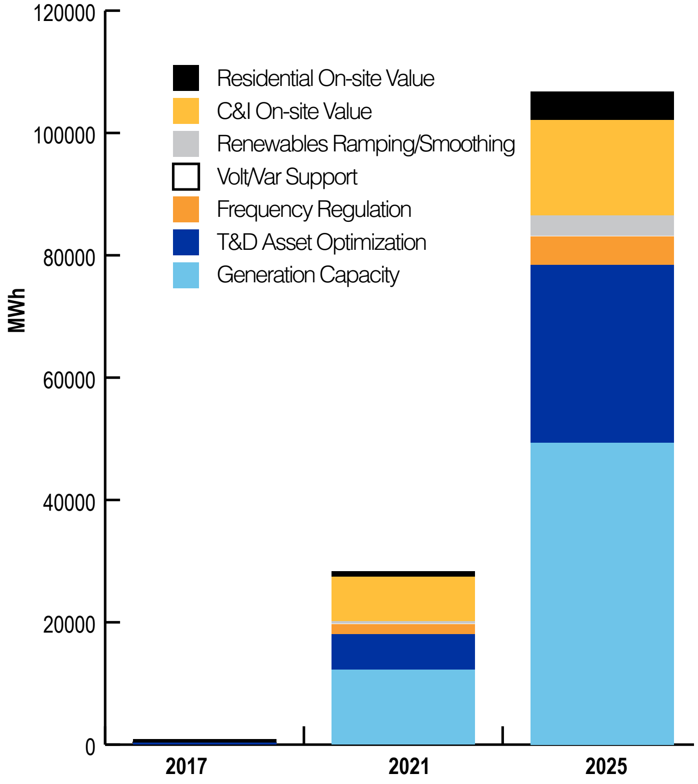
### Aliso Canyon: Rapid Storage Deployment

*In October of 2015, a catastrophic natural gas leak was detected at the Aliso Canyon storage facility in California which caused the evacuation of 8,000 nearby families. Under direction of the California Public Utilities Commission (CPUC), three companies collectively brought online more than 70 MW of advanced energy storage systems in less than 6 months – a record-breaking speed for energy assets. These systems were installed to prevent anticipated peak demand shortfalls in the coming summer. This rapid procurement of energy storage assets demonstrates the just-in-time capacity that has a transformative effect on response to the grid's biggest challenges.*

## 4.2. Looking Ahead To 2025: Storage Applications

ESA envisions 35 GW of new energy storage capacity by 2025. This corresponds to the Navigant Research forecast 106 GWh in the same time frame.

**Chart 4.1** ***Cumulative U.S Energy Storage Energy Capacity Additions by Application, Vision Case (2017, 2021, 2025)***



*(Source: Navigant Research)*

## 4.2.1 Utility Storage

In this future state of electrification and digitization, transactional energy will be more prevalent and utilities will enable this transactional energy. Supported by VPPs and aggregation, the transactional energy concept is based on ongoing communication of offers and transactions among market players. Buyers and sellers can include generators, storage with metered delivery, loads, and even traders with no actual delivery or metering. In this environment, a seller can include a load that is selling back from a contracted position, and a buyer can include a generator that is buying back from a contracted position.

Within the transactional energy environment there is no hierarchy of players - only bids and offers, simplifying business for all parties, including generators and independent system operators. In a transactional energy environment, retail and wholesale customers coordinate in real-time with transactions executed automatically by smart agents. This offsets the risk of complex centralized optimization.

The only required information in this environment are offers for energy transactions and the actual contracts. The procedures and required information are the same for all market participants, both large and small, and for all types, including large generators, DER, renewable resources, large industrial customers, homes, electric vehicles (EVs), microgrids, energy traders, aggregators, or system operators. Transactions can occur between retail and wholesale markets and within wholesale markets. Ultimately, the environment created with transactional energy levelizes market opportunities for all technologies and all participants on the grid.

## 4.2.2 Community Storage

Community energy storage refers to utility-owned or third-party owned energy storage at the distribution transformer or on downstream feeders. These systems deliver services such as load shifting frequency regulation, and voltage support. Commonwealth Edison (ComEd) recently announced the first of several pilot projects that use batteries to improve electric reliability and resilience for communities. ComEd is focusing on areas prone to power outages from harsh weather. Storage assets are located near existing utility facilities that provide power to customers selected for the pilot. Community storage will play an important role in electric water heating, residential solar, and EV proliferation.

## 4.2.3 C&I Storage

By 2025, C&I energy storage will be delivering grid services at a significant scale. Approximately one-third of the C&I energy storage systems will be delivering local services, while the remaining two-thirds are forecast to deliver grid services. The latter capacity is allocated into frequency regulation, T&D asset optimization, and capacity services.

Virtual Power Plants will be a common platform for C&I storage to monetize distributed storage. VPPs integrate several types of DER to provide a more reliable overall power supply (such as micro combined heat and power, wind turbines, small hydro, solar PV, backup generator sets and storage batteries). Controlled by a central entity, these power resources are designed to optimize value for both the end user and the distribution utility by leveraging sophisticated, software- based control systems. These dynamic systems can react in real-time to changing customer load conditions in ways that the traditional hub-and-spoke model simply cannot achieve.

The VPP model generally employs an energy aggregator to own and operate a portfolio of smaller resources and synchronize them as a larger, unified, and flexible resource. This resource can sell power on the energy market or as a system reserve. VPPs serve multiple goals: they balance the grid while also maximizing the asset owners' profits. These systems can address load fluctuations through advance metering, forecasting, and computerized control while optimizing generation assets in real-time. The technology represents an "Internet of Energy" by tapping existing grid networks to tailor electricity supply and demand services for a customer. The VPP market is expected to grow significantly with flexibility and demand response (DR) becoming more crucial as the number of variable renewables on the grid continue to increase.

### 4.2.4 Residential Storage

With the development of advanced, smarter technology, consumers are able to be more selective about their energy consumption decisions. Furthermore, the technology is available for consumers to produce energy and become prosumers, ultimately steering the one-way power flow model into a two-way directional flow. This new interaction with the grid can be aggregated into a VPP, similarly to C&I VPPs.

In the prosumer model of the future, energy customers will be able to choose their energy source. Furthermore, deployment of renewable sources will reach levels able to supply a significant portion of demand. Finally, in this prosumer model, the grid will significantly improve reliability and resilience, due to distributed power and storage capabilities.

### 4.2.5 Microgrids

Smart grid technologies (i.e., smart inverters, energy storage, and smart switches) enable safe operations like islanding, which can provide system benefits such as resilience, DR, and renewables integration. Microgrids can serve the larger distribution grid as well as the economic and resiliency needs of third parties.

Microgrids are on the forefront of the emerging DER ecosystem that challenges the traditional power market. In the future, utilities will continue to forge partnerships with energy storage companies and other vendors active in the microgrid space. These companies will understand the technical control platforms required to provide interoperability, the ability to stack value, and manage DER as well as legacy assets across an entire enterprise. A network of utilities and vendors will securely share data and insight to identify policy reforms needed to accelerate microgrid deployments, improving reliability and resilience.

# A CALL TO ACTION FOR STAKEHOLDERS

The energy storage market is growing fast, based on sharply declining system costs, electrification of the economy, consumers' demands for increased reliability and resilience, and the significant economic savings that energy storage provides. Creating a disruption-proof grid, however, will require continued evolution of the way policymakers, operators and other stakeholders think about the grid. It will require more open, performance-based policies and strategies that include a path to ESA's vision: 35 GW of new storage by 2025.

We must shift thinking about the grid as a singular-direction, centralized system purely based on cost of service, infrequent peaks and balancing, to a new paradigm driven by value, performance and outcomes. This will take the efforts of a diverse group of stakeholders to adapt and prepare for electrification and digitization of the power, transportation, data centers, HVAC, communications, manufacturing, and building sectors.

There are many resources available that can provide guidance on the specifics of the recommendations provided in this white paper. Herein, ESA highlights the high-level strategies for stakeholders to consider.

## 5.1 LEGISLATOR CONSIDERATIONS

It is impossible to capture all the exciting and innovative policies being enacted by U.S. legislators and policymakers today that advance the adoption of safe, reliable energy storage systems. States are taking action for many different reasons, and they are creating a number of diverse marketplaces for storage to provide varied competitive services to achieve state policy objectives.

The following sections include categories of energy storage legislation already adopted or being considered in states today.

### 5.1.1 Energy Storage Impact Studies

Policymakers should first consider legislation or regulation to study their energy networks, to better understand the benefits and long-term impacts of widespread energy storage deployment on their grid. Regional energy needs, generation profiles, and system reliability performance standards, as well as individual state sustainable energy policies and objectives will shape the scope and objectives of these studies.

The resulting study can provide guidance and insight for regulators and utilities into the most impactful applications and locations for cost savings. Massachusetts notably commissioned the "State of Charge" report in 2016 that articulated $2.3 billion in total benefits to ratepayers from widespread deployment of more than 1.7 GW of energy storage. The study also estimated the significant economic benefits and potential for job creation that come from taking a leading role in the energy storage industry.

> *"Through this modeling effort, it was found there is a potential for a large cost-effective deployment of advanced energy storage in Massachusetts. The modelling results show that up to 1,766 MW of new advanced energy storage would maximize Massachusetts ratepayer benefits. The results show that this amount of storage, at appropriate locations with sizes defined by system requirements and dispatched to maximize capability, would result in up to $2.3 billion in benefits."*
>
> \- Massachusetts State of Charge Report 2016

### 5.1.2 Procurement Targets or Mandates

Some states have passed laws that enforce competitive energy storage procurement targets—most notably California—that set minimum requirements for utilities to adopt storage systems. Oregon and Massachusetts are also in the process of implementing their own storage targets, and recently the New York Public Service Commission ordered the utilities to each have at least two storage projects operational at two substations or feeders on their distribution systems by the end of 2018.

Procurement targets can serve a number of beneficial functions: clarifying long-term policy objectives for the storage industry to invest, spurring action from utilities, and providing operational experience for grid stakeholders. Targets are not intended to be the ultimate goal for a state or utility, in the way the renewable portfolio standards might aim for 100% renewables, but instead serve as a way to modernize and enable more flexibility, guide and enhance grid planning and procurement.

As more states take this step to establish targets or mandates, there are now many more resources, examples, and experience that other utilities and regulators can reference. Several states are also considering their own procurement target strategies in upcoming legislative cycles. This is not limited to states as a whole: New York City recently announced a target of 100 MWh of energy storage to be installed in the city by 2020.[15]

### 5.1.3 Incentive Programs

States have also implemented incentives, subsidies, and rebate programs for energy storage. Maryland was the first in the nation to create a dedicated energy storage tax credit program;[16] many other states have incentives for peak load reduction, renewables, and energy efficiency for which energy storage systems may qualify. These types of programs lower costs of the projects themselves which spurs faster adoption and accelerates market growth, and they also lower system costs for all consumers.

Other incentive programs include investments in pilot or demonstration projects. Over the past 15 years, pilot projects of various sizes and technologies have been demonstrated in the field. The success of these projects, and the wealth of experience gained from these real-world deployments and operation, have opened up competitive U.S. commercial markets. Information and resources relating to these projects are widely available for states to include in their considerations.

### 5.1.4 Clean Energy Standards

A Clean Energy Standard, or Clean Portfolio Standard, is similar to a Renewable Portfolio Standard. It is a legistlative or regulatory mandate to increase renewable generation, energy efficiency and other energy technologies to a specific level, to achieve emissions reductions targets and promote new technologies in states. This provides another way for energy storage to be considered competitively alongside other energy solutions. Connecticut put forth a clean energy procurement standard that seeks to compare renewable energy, efficiency, and energy storage side-by-side in a resource procurement process. Vermont amended their standard in 2015, now requiring 2% of each retail electricity providers' annual sales come from energy transformation projects that provide energy services other than generation.

Other states are considering what is called a Clean Peak Standard, which seeks to merge the benefits of renewable generation and energy storage to service peak capacity needs with emissions-free energy. This provides both economic savings and pollution reduction in states, fueling efforts to achieve more sustainable electricity networks.

## 5.2 REGULATOR CONSIDERATIONS

Regulators are critical to the advancement of markets and facilitating the adoption of advanced energy systems of many types. In their obligation to protect ratepayers and oversee utility investments, regulators increasingly must work collaboratively with all stakeholder groups to facilitate constructive dialogue around the deployment and integration of energy storage systems.

While federal and state regulators operate in different jurisdictions under different authorities, ESA makes these recommendations to enable greater deployments of energy storage, leading to a more efficient, resilient, sustainable and affordable grid.

### 5.2.1 Clear Rules Regarding Storage

The first step for any regulator is investigation and evidence gathering: do current regulations adequately account for energy storage participation and a better outcome for ratepayers? If not, what steps can be taken to ensure market access and competitive procurement of energy storage technologies in different applications?

Where not currently clarified, regulators can initiate stakeholder processes to better define participation mechanisms and strategies, and the elements of prudent investments for energy storage. Working with utilities, industry, and nonpartisan research organizations in an open, public process can set a clear path forward.

### 5.2.2 Updated Modeling in Proceedings

Whether to ensure cost-effective implementation of policies, or to ensure that long-term planning and IRPs are meeting the projected needs of customers, regulators play an important role in ensuring that modeling approaches and strategies are current and expanded to include advanced energy systems.

Many of the modeling tools used by commissions in integrated resource planning proceedings today lack granularity and an evaluation methodology that properly incorporate energy storage. It is important to note that there are several validated and commercially available planning models today that commissions, utilities and stakeholders can use to evaluate all resources, inclusive of energy storage. Several validated commercial models are available that can examine economic resource options including intra-hourly dynamics, such as PLEXOS, PSO, and FESTIV.[17]

In general, models that consider the value of storage incorporate more specific inputs than models used for other resources. For example, because load profiles and system needs differ by location, the precise location of storage assets is critical to accurately understanding its value on the grid. In addition, models for storage should assess activity over sub-hourly time intervals, to reflect the contributions to ancillary services that storage provides, including rapid charging and discharging.

### 5.2.3 Streamlined Interconnection Standards

Regulators and electric utilities have the difficult task of establishing fair and efficient interconnection standards and processes, while ensuring safe, reliable service. Despite efforts, current interconnection procedures often pose a significant barrier to new entrants. Streamlining interconnection processes is critical to enable innovative grid strategies.

In 2013, the Federal Energy Regulatory Commission put forth recommendations for Small Generator Interconnection Procedure, and many states have adopted similar approaches. Some states have affirmed that existing rules can and do apply to storage systems in different applications (though often limited to a generator class), while some states have taken the additional step of defining the net output (exported power) of energy storage systems. The remaining states should follow the pioneering steps made by these states.

### 5.2.4 The Effects of Rate Design

Current rules regarding net energy metering (NEM) also effect the deployment of energy storage. Some jurisdictions have developed ways to include energy storage in net energy metering, yet many others are already considering successor programs that account for continuing technology advancement and improvements in modeling when valuing distributed energy resources (DER).

Beyond net energy metering, rate design that reflects cost and value of energy storage can encourage the use of more energy storage systems, which enables more efficient use of energy. When rates better reflect the actual cost of delivering energy at a specific time (time-of-use rates), it can unlock the potential to better value the energy that is produced by distributed resources like solar and wind (time-of-delivery pricing).

When regulators determine the appropriate cost of service and design for base rates, accounting for the capabilities of all available technologies will help keep fair rates at their lowest levels. Pricing structures can encourage consumers to adapt their behavior, or invest in solutions to better regulate their consumption. Dynamic rates also ensure that customers are paying their fair share for energy usage, and getting fair compensation for excess generation based on time and location.

Regulators will likely have a role in the adoption of transactive energy markets as well. These innovative market-driven structures can be enabled by energy storage system capabilities, and are only possible on a flexible grid with two-way power flows that can adapt to dynamic transactions. As regulators look to future market designs, understanding the enhanced technical capabilities of the grid and what is possible will be essential to regulating new market structures.

## 5.3 UTILITY CONSIDERATIONS

> *"As we look to the future, it is important to revisit policies and regulations to maximize the value achieved by energy storage. Furthermore, with technical improvements in design and control, the value and uses of energy storage will continue to evolve. Therefore, it is important for the nation's electric companies to continually explore the technical performance of energy storage to ensure appropriate planning and deployment of storage technologies that can best enhance the reliability and resiliency of the energy grid for the benefit of all customers."*
>
> - Edison Electric Institute

Although the U.S. electricity sector has shifted toward more distributed and decentralized generation models, ESA believes utilities will continue to play a central role in the expansion of the energy storage industry, and will be active participants in owning, operating, contracting, and interconnecting these advanced energy systems all across the grid. Navigant Research analysis shows that more than 22 GW of advanced energy storage systems deployed in grid-side applications by 2025, and estimates that utilities and third parties will finance more than 80% of energy storage systems by 2025.

Energy storage represents a significant opportunity for the utility sector as both an owner and a beneficiary. Adapting to the demands of these new electrified sectors will require a flexible, resilient, and dynamic network. To prepare for this transformation, utilities should consider the following strategies:

### 5.3.1 Updated Approach to Asset Classification

Grid assets are generally categorized into basic buckets when being assessed: generation, T&D infrastructure, and load. A major distinction of energy storage systems when compared to traditional grid assets is that it can provide service for one category or all three at different times during its useful life.

This siloed approach to classification can under-value the storage asset benefits, and can prevent innovative ownership and business models in certain regulatory environments. Specifically, interconnection rules are different for generation versus load, and can cause the truncation of one or the other service unnecessarily.

Another example of classifications hampering progress is technology-specific requirements, rather than performance-based, in competitive procurements and markets. Certain markets can require the use of a technology add-on (called a governor) to provide more dynamic grid services, but only fossil-turbine technologies require a governor to perform those services. An energy storage system provides a digital response to grid commands, and does not need a physical device to slow it down or speed it up to match system needs. A third example of an outdated approach to asset classification is that in restructured markets, utilities are prohibited from owning generating assets, which results in an undue restriction as it pertains to energy storage systems.

This does not necessarily mean that energy storage requires its own classification, but it does require revising and updating definitions throughout utility planning and operations to account for technologies that do not fit neatly and exclusively into these three buckets.

### 5.3.2 Expanded Integrated Resource Planning

In vertically integrated markets, utilities will invest billions in new and replacement capacity in the next several years[18]. Aging power plant retirements and growing demand from new sectors (tempered by expanded operational and asset efficiency) will be a key focus of future planning.

Utilities prepare integrated resource plans (IRPs) to determine the combination of resources that will meet annual peak demand and energy forecasts (plus some established reserve margin), over a specified future period, usually 10-20 years. Those IRPs then inform utilities' subsequent decisions on what kind of resources to build and own, or to procure from other parties through long-term contracts.

While some utilities have demonstrated interest in understanding the costs and benefits of advanced energy storage in the context of IRPs, informational barriers remain: planning models are not granular enough to capture the operations of advanced storage, and some models use inaccurate or out-of-date cost information. Utilities are thus missing the opportunity to analyze, evaluate, and procure advanced storage as a cost-effective capacity resource, putting ratepayers at risk of significant imprudent investments.

Utilities and their regulators can address these barriers. Today, advanced energy storage is now commercially contracted and procured competitively with traditional resources at project scales up to 100 MW, on par with natural gas-fired power plants and deployed in a fraction of the time. There are several validated commercial planning models available today that can capture intra-hourly operations of storage and other resource options. Storage cost estimates are available through public sources, many of which are updated annually or even quarterly. If utilities and regulators update their approach to storage in IRPs, the choice of storage as a capacity resource can be made on a least-cost economic basis today, avoiding costs for ratepayers and improving overall system outcomes.

## Work Across Utility Silos

One of the biggest challenges to utility resource planning is in the silos formed within regulated utilities that divide the decision-making processes for differing asset types. Currently, load forecasting often indicates how much generation will be needed to ensure peak capacity, from which T&D system investments are determined.

Energy storage assets, however, can perform various functions that bridge these divides and minimize investment requirements. A storage system can perform like a generator during one part of the day, and be used to support a distribution substation through peak load reduction at another. These multiple value streams that overlap different segments of a utility require upfront integrated planning methods to better assess a device's complete value to the system.

## Conduct More Granular Modeling

Typical IRP models use three inputs—forecasted demand, the capital cost of available technologies, and the technologies' operating profiles—to calculate economic long-term options for system capacity. These models adequately capture the operations of traditional generation units providing simple capacity, but are unable to incorporate dynamic or distributed asset value.

In contrast, advanced energy storage provides high value flexibility services, like frequency regulation or ramping support, in addition to capacity. A large-scale energy storage resource providing peak capacity when needed—typically a 4-hour period in the afternoon and early evening—can also provide ancillary grid services for the many hours when that peak capacity is not needed. Storage resources can do this because they are always on and available for service, in contrast to traditional generation units that must be started up and shut down to provide peak capacity or other services. To capture the multiple values storage offers, planners should use modeling tools that estimate the net cost of capacity on a more granular, sub-hourly basis.

**Net cost of capacity =**
**Total installed cost – Total operational benefits**

## Operational Benefits

*Some of the operational benefits of storage are flexibility services directly provided by the individual unit being considered.*

***Direct operational benefits include:***

- *regulation*
- *load following*
- *contingency reserves*

*When the direct operational benefits of storage are modeled, they can represent as much or more than the capacity value of storage. Other indirect operational benefits of storage accrue to the entire system as avoided costs.*

***Indirect operational benefits include:***

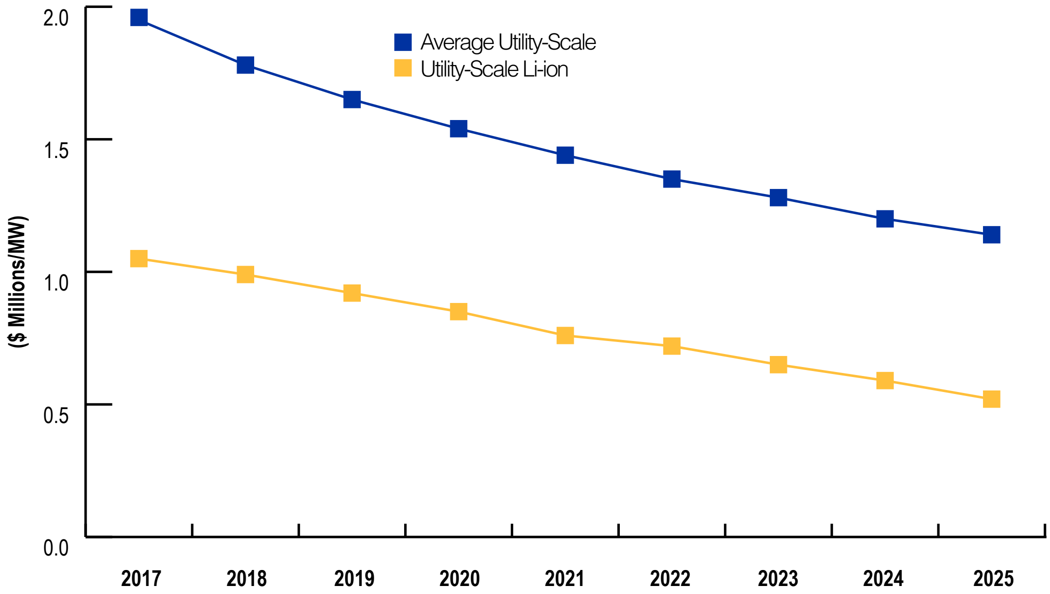
- *reduced operating reserve requirements*
- *reduced start-up and shut down costs of all generation facilities*
- *improved heat-rate of thermal plants and consequently reduced emissions*
- *reduced uneconomic dispatch decisions in the form of uplift or revenue sufficiency guarantee payments*
- *reduced curtailment of renewable resources*
- *reduced risk of exposure to fuel price volatility*
- *reduced local emissions for areas with emissions restrictions.*

## Use Current Cost Data

The installed cost of advanced energy storage has declined significantly in recent years, generally faster than market expectations. Battery storage technologies—primarily lithium-ion batteries—are declining rapidly in cost: dropping by 50% every three to four years and projected to continue at this rate[19]. Considering this rapid and recent technical progress, it is critical for planners to use up-to-date advanced storage cost estimates and forecasts for IRP model inputs.

While advanced energy storage technologies are diverse, lithium-ion energy storage is the most common technology being deployed today.

***Chart 5.1 Energy Storage Revenue per MW, Utility-Scale Systems, Average All Technologies vs. Lithium Ion***



*(Source: Navigant Research)*

### 5.3.3 New Ownership and Business Models

The multi-faceted capabilities of energy storage enable utilities to explore new ownership and business models. This opens the opportunity for utilities to work with third parties and consumers to improve outcomes and avoid costs, increasing the value of utility services through customer engagement.

Energy storage offers an opportunity for new and innovative business models, including VPPs and aggregation, community energy storage, transactive energy markets, ownership by utilities, as well as third-party and customer-owned systems with equal access and opportunity. Ownership solutions could also include all three participants: utility, third parties and customers - each owning and benefitting from a portion of the system's total capabilities.

## The Future at Pena Station

*One example of a system that includes three different owners and five different value streams is Xcel Colorado's Pena Station Microgrid, in collaboration with developer Younicos, and building owner Panasonic. This one energy storage system is owned by all three, providing a portfolio of benefits including renewables integration, ramping, peak demand reduction, energy arbitrage, frequency regulation, and resilience through backup power.*

*Pena Station site tour during ESA's 2017 Annual Conference in Denver.*

# CONCLUSION

The U.S. power sector is in the midst of a profound transformation. Electrification of our economy, aging infrastructure and generation, cleaner and more DER, changes in the role and demand of consumers: these are all factors contributing to increasing risk of a disrupted grid.

The entry of advanced energy storage technologies provides new capabilities to create a disruption-proof grid. But to realize 35 GW of energy storage by 2025, the current paradigm of grid planning and regulation must change.

Policymakers, regulators, utilities and other stakeholders must all act to enable energy storage. This includes opening a collaborative stakeholder dialogue around energy storage, integrating energy storage into system planning with updated data and inclusive modeling, valuing all storage contributions to the grid, and exploring the potential for new business models integrating energy storage into system planning and market operations.

A more resilient, efficient, sustainable and affordable electric system benefits everyone that interacts with it, and there are tools available today to create a disruption-proof grid.

From the humble beginnings of a single small power plant in Manhattan, today's electricity system has become a necessity of everyday life, and at the center of our broader economy. After decades of large-scale, highly centralized infrastructure based around fossil fuel power plants and long-distance transmission networks, the electrical grid is now in a state of transformation driven by concerns around air pollution, climate change and resiliency, made more feasible to address by increasingly cost-effective technologies.

Change itself is disruptive. To withstand - and indeed thrive from - the fundamental shifts taking place in the physical structure and business models of our electricity system will take flexible, dynamic solutions, as well as an openness of stakeholders to understand and correct the constraints of our current system. Energy storage can accelerate us toward that disruption-proof grid, and the deployment of 35 GW by 2025 will enable efficiency, resilience, sustainability, and affordability.

# ACRONYM AND ABBREVIATION LIST

| | |
|---|---|
| CAES | Compressed Air Energy Storage |
| $CO_2$ | Carbon Dioxide |
| ComEd | Commonwealth Edison |
| C&I | Commercial and Industrial |
| DER | Distributed Energy Resources |
| DR | Demand Response |
| EPA | Environmental Protection Agency (U.S.) |
| ESA | Energy Storage Association |
| EV | Electric Vehicle |
| GHG | Greenhouse Gas |
| GW | Gigawatt |
| GWh | Gigawatt-Hour |
| HVAC | Heating, Ventilation & Air Conditioning |
| IRP | Integrated Resource Plan |
| IT | Information Technology |
| MISO | Midcontinent Independent System Organizer |
| MW | Megawatt |
| MWh | Megawatt-Hour |
| NaS | Sodium Sulfur |
| $NO_X$ | Nitrogen Oxide |
| NVEST | Navigant Research's Valuation of Energy Storage Tool |
| PJM | PJM Interconnection LLC |
| PM | Particulate Matter |
| PSE | Puget Sound Energy |
| PV | Photovoltaic |
| REV | Reforming the Energy Vision |
| RTO | Regional Transmission Organization |
| $SO_X$ | Sulfur Oxide |
| T&D | Transmission and Distribution |
| TWh | Terawatt-Hour |
| US | United State |
| VAR | Volt-Ampere Reactive |
| VOLL | Value of Lost Load |
| Volt/VAR | Volt/volt-ampere reactive |
| VPP | Virtual Power Plant |

# TABLE OF CHARTS AND FIGURES

# SCOPE OF STUDY

This white paper examines the value of energy storage in the U.S. in terms of grid operations savings, reliability, emissions reductions and job create. This study includes a Vision case for the energy storage market in utility-scale and distributed storage market segments in the U.S. This Vision case is a more aggressive scenario based on Navigant Research's business-as-usual energy storage market forecast. The technologies included in this Vision forecast are: advanced lead-acid, CAES, flow batteries, flywheels, lithium ion, NaS Batteries, other advanced battery chemistries, power-to-gas, pumped storage and ultracapacitors. This paper draws upon Navigant Research analysis of the energy storage market in the U.S. and globally. The goal is to present an objective analysis of the value and cost of energy storage deployment in the U.S.

# SOURCES AND METHODOLOGY

Navigant Research's industry analysts utilize a variety of research sources in preparing Research Reports. The key component of Navigant Research's analysis is primary research gained from phone and in-person interviews with industry leaders including executives, engineers, and marketing professionals. Analysts are diligent in ensuring that they speak with representatives from every part of the value chain, including but not limited to technology companies, utilities and other service providers, industry associations, government agencies, and the investment community.

Additional analysis includes secondary research conducted by Navigant Research's analysts and its staff of research assistants. Where applicable, all secondary research sources are appropriately cited within this report.

These primary and secondary research sources, combined with the analyst's industry expertise, are synthesized into the qualitative and quantitative analysis presented in Navigant Research's reports. Great care is taken in making sure that all analysis is well-supported by facts, but where the facts are unknown and assumptions must be made, analysts document their assumptions and are prepared to explain their methodology, both within the body of a report and in direct conversations with clients.

Navigant Research is a market research group whose goal is to present an objective, unbiased view of market opportunities within its coverage areas. Navigant Research is not beholden to any special interests and is thus able to offer clear, actionable advice to help clients succeed in the industry, unfettered by technology hype, political agendas, or emotional factors that are inherent in cleantech markets.

# APPENDIX

## COMPARISON TO OTHER STUDIES ON THE VALUE OF STORAGE

Two recently published studies on the value of storage were reviewed to provide a comparison to the findings included here. The first study, published by The Brattle Group for Texas utility Oncor in late 2014, also analyzed the potential value and grid cost savings provided by energy storage. While this study only looked at storage added to the Texas grid, the overall findings are quite similar to Navigant Research's analysis. The Brattle/Oncor study concluded that the addition of 5,000 MW of energy storage in Texas by 2020 would result in $750 million in system-wide benefits per year, representing a value of approximately $150,000 of annual savings per megawatts of storage deployed. Per Navigant Research's analysis, 3,727 MW of new storage capacity is forecast to be installed in 2020, resulting $429.6 million in annual grid savings. This translates to $115,266 of annual savings per megawatt of storage deployed. A key difference from the Brattle/Oncor study is that the analysis includes the value of avoided distribution outages. In contrast, Navigant Research's analysis focuses only on grid operational cost savings. The value of avoided outages and improved reliability is calculated separately and discussed in Section 3, "Valuing a Disruption-Proof Grid," of this report.

A second study reviewed for this report was the *State of Charge: Massachusetts Energy Storage Initiative* study published in September 2016. While this study also examines the total value and grid cost savings from the deployment of energy storage, there are a few significant differences in methodology from both Brattle/Oncor and Navigant Research's analysis. A key finding from the *State of Charge* study is that a total of 1,766 MW of energy storage could be cost-effectively deployed in Massachusetts, resulting in nearly $2.3 billion in cumulative system benefit/cost savings. This translates to $1.3 million in benefits per megawatt of storage, a figure much higher than the cumulative value per megawatt identified in either Brattle/Oncor or Navigant Research's analysis.

> *Some studies on the value of energy storage for grid cost savings recommend certain regulatory changes, and assume storage systems will capture revenue streams that require these changes to be viable. Navigant Research's analysis for this study focuses only on currently available value streams and cost savings.*

A key difference resulting in this discrepancy is that the *State of Charge* study assumes storage systems will be able to capture revenue streams that are not currently available to storage assets and that a number of recommended market and regulatory changes would be implemented. The study indicates that, "the value of storage as determined in this study include the cost of a project, the currently monetizable value to the project owner, additional value that could be captured with market changes, and the expected system benefits." As a result of the study's optimistic view of storage's future value and revenue opportunities, the findings on the value of storage are considerably higher.

# ENDNOTES

1. IHS Markit Whitepaper "Reaching Peak Performance: What the Electric Power Sector Can Learn from Society's Other Vital Networks" March, 2017
2. Ibid
3. EIA Monthly Generator Capacity Factor Data (Jan.2011 - July 2013).
4. MA Office of Energy and Environmental Affairs.
5. Eaton. "Blackout Tracker, U.S. Annual Report 2016."
6. Ibid
7. Machowinski, Matthias. "The Cost of Server, Application & Network Downtime Survey & Calculator – 2016." IHS, Jan. 24, 2016.
8. Brattle Electrification: Emerging Opportunities for Utility Growth
9. EIA Electric Power Monthly Report (July, 2017).
10. Energy Policies of IEA Countries - The United States 2014 Review
11. Each greenhouse gas (GHG) has a different global warming potential (GWP), and persists for a different length of time in the atmosphere. References to emissions convert all greenhouse gas (GHG) emissions into $CO_2$ equivalents to be compared more readily. This equivalency is determined with the following formula.
    $CO_2$ Equivalent = (metric tons of gas) * (GWP of the gas)
12. Trabish, Herman, "Oregon Saddles Up to Implement Trailblazing Energy Storage Mandate." Utility Dive, Nov. 17, 2015
13. Washington Utilities and Trade Commission, "Energy storage key to electric utilities' efficiency and service," Oct. 11, 2017
14. Hawaii Energy Facts and Figures 2015
15. Climate Week Announcement by Mayor Bill de Blasio.
16. MD Senate Bill No. 758.
17. Burwen, Jason, "Including Advanced Energy Storage in Integrated Resource Planning: Cost Inputs and Modeling Approaches," Energy Storage Association, Nov. 2016
18. EEI Industry Capital Expenditures projections.
19. IHS, Future of Grid Connected Energy Storage, Nov. 2015

Published November 2017

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