100 x 30:

Enabling the Clean Power Transformation

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Energy Storage Association

Contents

About the U.S. Energy Storage Association

The U.S. Energy Storage Association (ESA) is the national trade association dedicated to energy storage, working toward a more resilient, efficient, sustainable and affordable electricity grid – as is uniquely enabled by energy storage. With more than 190 members, ESA represents a diverse group of companies, including independent power producers, electric utilities, energy service companies, financiers, insurers, law firms, installers, manufacturers, component suppliers and integrators involved in deploying energy storage systems around the globe.

A Historic Transformation is Underway

Over the past decade, the U.S. electric power system has changed in ways that few predicted or expected, driven primarily by changes in fuel prices, technology advancements and cost declines, and policies at the federal, wholesale and state levels that favored renewable generation. Ten years ago, coal generated about 45 percent of our electricity, while wind power and utility scale solar power accounted for 2.3 percent and 0.03 percent of generation, respectively. Carbon emissions from electric power were expected to rise for decades. By 2019, coal generation had fallen to 23 percent of total generation, natural gas resources rose from 24 percent to 38 percent, and wind and solar power accounted for 7.3 percent and 1.8 percent of generation, respectively. Between 2010 and 2019, carbon emissions from electric power generation fell by 29 percent.[1]

As profound and historic as these changes are, they will be dwarfed by the changes anticipated over the coming decade, both in how we generate electricity and how we manage the grid. The ongoing transformation of the grid from fossil fuels to renewable generation will continue regardless of any headwinds encountered from current policy or economic downturns, and the deployment of energy storage systems will accelerate. Energy storage applications and uses are multiplying, including integration of variable renewable generation, reducing renewable generation curtailments, enhancing reliability and resilience, deferring costly transmission and distribution grid expansion and upgrading, increasing customer control over energy consumption, enabling significant local penetration of electric vehicle charging, and many more uses. Storage comes in many forms, and while Lithium-ion (Li-ion) batteries currently dominate new investment, the U.S. Energy Storage Association (ESA) anticipates significant contributions from other storage technologies such as flow batteries, thermal storage, mechanical storage and pumped storage hydro. Rapidly increasing investment will occur as markets respond to the increased cost-effectiveness of energy storage technologies, and as supportive legislative and regulatory policies play an important role in setting the pace of grid transformation.

The role energy storage can and will play in enabling the transition of electricity generation from fossil to renewable sources has come into focus. Reflecting on recent market dynamics and projecting a continuation of the clean energy revolution, ESA has extended its vision for energy storage deployment to 2030, adopting a goal of 100 gigawatts (GW) of new energy storage installed by the end of this decade. This vision builds upon the first ESA 35x25 Vision report issued in November 2017, and incorporates recent developments in both the energy storage and renewable energy markets, as the role of energy storage will inevitably expand to maintain and enhance the reliability, resilience, stability and affordability of clean energy in the U.S. over the coming decade. This report explains how the 100 GW goal will be realized and what 100 GW of new storage will mean to the U.S. economy.

[1] All figures from Energy Information Administration (EIA) Generation Data Browser and Environmental Data Browser.

Beyond the 2025 Vision

In 2017, ESA released *35x25: A Vision for Energy Storage* that described how supportive policies and a vibrant market could achieve 35 GW of new energy storage in the United States by 2025. The 35 GW target included a range of storage technologies – batteries, thermal, mechanical, pumped hydro and others. The report highlighted the expected benefits of 35 GW of new storage, such as:

- $4 billion in cumulative operational cost savings;
- Customer engagement to help modernize the grid;
- Improved reliability and resilience, potentially saving customers about $30 billion in cumulative outage avoidance costs;
- Reduced emissions; and
- The creation of more than 167,000 new jobs in manufacturing and R&D, construction, project development, operations and maintenance, construction, sales, marketing, management, administrative, and other positions.

The estimates of expected benefits from deploying 35 GW of new storage were developed in partnership with Navigant, Inc., based on an analysis of the U.S. electricity system and a projection of how the grid was expected to evolve. The analysis focused on the ability of storage to reduce the potential disruption from outages and to decrease emissions by reducing the curtailment of renewable electricity generation and enhancing the efficiency of energy use.

In the 2025 Vision report, we laid out an actionable pathway to achieve 35 GW of storage by 2025, with a series of policy levers necessary to meet that goal. Since then, significant progress has been made in policy developments by legislators, regulators, and utilities:

For Legislators, we recommended:

- *Conduct energy storage impact studies*. 10 states have completed these studies, and more are underway.

- *Enact deployment targets*. 7 states have enacted deployment targets totaling approximately 11 GW of new storage by 2035.

- *Establish incentive programs*. Over $1 billion in incentives specifically for energy storage have been made available in 6 states, with an additional several states piloting storage incentives.

- *Set clean energy standards*. Massachusetts established a Clean Peak Standard that can serve as an example of market-based clean energy programs that incorporate storage. A total of 8 states have established 100% clean energy futures by law—for which energy storage will be a critical component.

For Regulators:

- *Establish clear rules for storage*. The Federal Energy Regulatory Commission (FERC) Order 841 has created a foundation for market participation of storage at varying levels of interconnection.
- *Use updated modeling in proceedings*. 7 states now have specific laws or regulations on including storage in integrated resource planning. The National Association of Regulatory Utility Commissioners (NARUC) adopted a resolution calling for system planning that reflects "the full spectrum of services that energy storage and flexible resources are capable of providing."
- *Streamline interconnection standards*. 6 states have updated their interconnection rules to specifically improve treatment of storage, with several other states in progress. FERC's Order 845 facilitates co-location of storage with existing generation.

For Utilities:

- *Expand integrated resource planning (IRP) to include storage*. There is immense progress to report here. Over 80% of 2018-2019 utility IRPs examined storage in their models, and over 20 GW of storage has been economically selected in IRPs out to 2040.
- *Explore new ownership and business models*. Across the entire U.S., utilities and policymakers are exploring ways to drive innovative business models. Innovative "Bring Your Own Device" (BYOD) storage programs have been set up in 3 states, with more considering them. Maryland is implementing a program to test innovative ownership and operation business models, and California, New York, and Massachusetts have updated regulations to enable multiple-use distributed storage.

Even with this progress, recent data on storage deployment has slightly lagged the pace that Navigant projected, although the expectation for the next few years from experts is consistent with meeting the 35 GW target. In part that gap reflects the fact that available projections tend to include only grid-connected batteries, which is the dominant form of storage, but exclude other technologies such as thermal storage which was included in the 2025 Vision report. Even accounting for those omissions, BloombergNEF (BNEF) projects 32 GW of battery storage by 2025 and Wood Mackenzie projects about 28 GW of battery energy storage in 2025. Under both projections, the growth in storage deployments is accelerating through 2025, making the precise timing of attaining the 35 GW target difficult to pinpoint. In the case of the Wood Mackenzie projection, for example, extrapolating the 2023-2025 growth rate in battery deployments to 2026 yields about 36 GW.

Just as polices can support the acceleration of energy storage deployments, policies can also produce headwinds. Current storage deployments lag the (then) projected 2025 Vision scenario level for several reasons: the pace of supportive policy development, uncertainty caused by tariffs on Chinese goods, the White House Executive Order on the Bulk Power System, and the unanticipated coronavirus pandemic and resulting economic slowdown. However, the emergence of supportive federal policy such as the Federal Energy Regulatory Commission (FERC) Order 841 in 2018 and subsequent proceedings in

Regional Transmission Organization and Independent System Operator (RTO/ISO) wholesale markets, along with the quickening pace of supportive storage policy at the state level has boosted storage deployments and poised energy storage for accelerated growth in the coming years. The primary question regarding the next decade is the policy and market context in which storage operates.

Recent projections of energy storage deployments to 2025 or 2030 under current market trends and policies point to a continued acceleration of energy storage deployment.[2] These projections include:

- **2017 Navigant Vision 2025 Analysis**. The underlying Navigant analysis that formed the basis for the 35 GW by 2025 Vision extended through 2026, when Navigant estimated 10.4 GW of energy storage would be installed annually. Simply extending an assumed 10.4 GW of storage installed each year between 2026 and 2030 yields about 88 GW in 2030, ignoring completely the growth rate in deployments embedded in the projections out to 2025.
- **Wood Mackenzie Energy Storage Monitor**. The most recent U.S. Energy Storage Monitor (ESM) report from Wood Mackenzie projects about 27.5 GW of *battery* energy storage installed by 2025, with almost 7 GW of battery storage installed annually by 2025. In this projection, the average annual growth rate for battery storage deployments between 2022 and 2023 is about 23 percent. If that growth rate were extrapolated through 2030, about 95 GW of battery storage would be installed, excluding all other forms of energy storage (thermal, mechanical, pumped storage hydro).
- **Bloomberg New Energy Finance (BNEF) Projections**. BNEF projects 69 GW of battery energy storage by 2030, which is a little more than double the 32 GW of battery storage they projected for 2025. Between 2025 and 2030, BNEF projects annual average battery storage deployments of about 7.4 GW per year, a slight increase over the annual average battery storage deployments of about 6.0 GW per year that BNEF projects between 2020 and 2025. If the annual average growth rate of 17 percent between 2025 and 2030 were increased by five percentage points to 22 percent, the 2030 battery storage projection would be over 85 GW.

All projections of energy storage deployments point to unprecedented growth in the next decade. Differences in energy storage market and policy outlooks are certainly evident among these projections, but those variables are themselves dependent on the overall scenario for grid evolution. Because storage plays a critical role in enabling increased penetration of renewables such as wind and solar in decarbonization scenarios, future energy storage deployments would be far higher than the above projections suggest if clean energy policies boosted the penetration of wind and solar generation beyond the forecasted levels. A combination of strengthened policy support – such as the investment tax credit (ITC) for stand-alone storage facilities – operating alongside a significant commitment to expanding wind and solar generation and decarbonizing the grid certainly would propel storage deployments. A supportive policy framework and a vibrant clean energy economy would drive energy storage growth and set a trajectory to attain the 100 GW storage goal by 2030.

[2] Other projections include those that are not publicly available. For example, in July 2020 Rethink Energy released a forecast for 78 GW of energy storage in the U.S. by 2030, according to that company's description of their analysis.

Decarbonizing the Grid: 50 Percent Renewables by 2030

In June 2020, the leaders of four clean energy associations – the American Wind Energy Association (AWEA), the National Hydropower Association (NHA), the Solar Energy Industries Association (SEIA) and the U.S. Energy Storage Association (ESA) adopted a shared vision for 2030 that projected that solar, wind and hydroelectric generation would comprise 50 percent of U.S. electricity generation.[3] This majority renewable generation target was derived from a 2019 baseline of approximately 7 percent hydro, 7 percent wind, 3 percent solar and 2 percent other renewable generation (about 19 percent renewable total). Alongside this ambitious clean energy goal, ESA unveiled a new vision of 100 GW of new energy storage by the year 2030, which incorporated the NHA vision of 16 GW of new pumped storage hydro by 2030.[4]

A key application of energy storage is helping to maintain grid reliability and stability when increasing the contribution of variable generation such as solar and wind. Energy storage can:

- Reduce wasted solar and wind generation from curtailments that arise from mismatches in the timing of generation and consumption, or from inverter or transmission limitations. Solar photovoltaic (PV) generation that otherwise would be "clipped" by an inverter limit can be stored for use later, and "storage as transmission" can utilize wind generation that might otherwise be bottled up and curtailed behind a transmission constraint.
- When installed in conjunction with solar and wind generation, storage can significantly enhance the capacity credit that solar and wind generators obtain to recognize their contribution to reliability. Including storage in hybrid facilities has become commonplace with large PV installations, meaning that continued large-scale PV growth will automatically increase storage deployment going forward.
- Storage helps provide frequency regulation and operating reserves to maintain a reliable grid in times when renewable energy contributes a significant portion of overall generation, and storage enhances the overall flexibility for grid operators to balance generation and load when managing fluctuations in variable generation or demand.

In this way, storage is a natural complement to renewable energy investment, i.e., the more wind and solar on the grid, the more valuable storage services become. This linkage between renewables and storage increasingly takes a more direct form in the emergence of hybrid facilities (where generation and storage are either integrated or co-located) that share an interconnection point. Simply put, the more renewables that appear on the grid, the more storage will be deployed in order to keep the grid operating. This is especially true in decarbonization scenarios, since storage can assume the role that gas turbines traditionally played in providing capacity, reserves and peaking power. Recently, energy

[3] Abigail Ross Hopper, Tom Kiernan, Kelly Speakes-Backman & Malcolm Woolf, "The U.S. Electric Grid of the Future Powers a Stronger Economy and Environment," Morning Consult, June 26, 2020.
[4] The NHA vision was based on the scenarios found in *Hydropower Vision: A New Chapter for America's 1st Renewable Electricity*, U.S. Department of Energy, July 26, 2016.

storage has been used to replace older gas peaking plants, particularly in urban areas with poor air quality.[5]

The ability of storage to enhance grid reliability and resilience has always been a key source of value, as evidenced by the 2017 Navigant analysis focus. Earlier analyses of clean energy scenarios traditionally focused on integration of renewables (particularly the need for gas peaking capacity), the need to expand transmission networks, and the implications of nuclear retirements as key considerations. As storage costs have declined precipitously in the past few years, more recent analyses of the clean energy transformation and decarbonization of the grid have revealed a critical relationship between clean energy expansion and energy storage deployment; namely, these analyses point to a huge demand for energy storage systems in the coming years as a direct function of increased penetration of wind and solar generation.

Analyses from the National Renewable Energy Laboratory (NREL) have addressed the potential for energy storage to provide peaking capacity in scenarios of high renewable generation penetration.[6] For example, a study released in 2019 found that 28 GW of 4-hour storage could effectively provide peaking capacity in the U.S., *i.e.*, substitute for retiring peaking capacity or displacing the need for new peaking capacity. That same study found that roughly 70 GW of a mix of 4-, 6- and 8- hour storage could serve as reliable peaking capacity in the U.S., before considering potential additions of variable generation in the grid systems analyzed. However, in scenarios where solar PV penetration reached 20%, the researchers found that about 85 GW of 4-hour energy storage could provide peaking capability and that almost 130 GW of 4-, 6- and 8- hour storage could provide reliable peak load service.

Recent studies of decarbonization and clean energy scenarios have focused on how increased solar PV and wind generation increases the cost-effective market for energy storage. For example, researchers at the University of California at Berkeley Goldman School of Public Policy analyzed a scenario that attains 90 percent clean energy generation (including nuclear) by 2035.[7] In the 90 percent clean generation scenario in 2035, wind provides 45 percent of total generation and solar contributes another 25 percent, while nuclear and hydro combined add up to 20 percent of supply, with natural gas providing the remaining 10 percent. In this scenario about 150 GW of (4-hour) battery storage is deployed by 2035 as an economic and emission-free way to maintain the reliability and resilience of the grid in the presence of 70 percent variable generation.

Finally, while energy storage deployments are certainly not limited to batteries, a recent multiple-value analysis from researchers at Massachusetts Institute of Technology and Princeton confirm that under conditions where battery prices continue to fall and wind and solar penetration rises to between 40 to 60 percent, the cost-effective demand for storage soars. The researchers found that 4-hour battery energy storage demand rose from 0-4 percent of peak load to 8-16 percent of peak load when battery

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[5] See "Giant electric battery set will curb Ravenswood plant pollution in Queens, state says" New York Daily News Oct 17, 2019 and "PG&E Proposes Two Energy Storage Projects for Oakland Clean Energy Initiative to CPUC" PG&E Press Release, April 15, 2020.

[6] See Paul Denholm, Jacob Nunemaker, Pieter Gagnon, and Wesley Cole, *The Potential for Battery Energy Storage to Provide Peaking Capacity in the United States*. National Renewable Energy Laboratory, June 2019.

[7] See Amol Phadke, et. al., Goldman School of Public Policy, University of California Berkeley, *2035 The Report: Plummeting Solar, Wind, and Battery Costs can Accelerate our Clean Electricity Future*, June, 2020.

storage costs fell by half and variable renewable energy (VRE) generation rose into the 40 to 60 percent range. (By way of reference, 2019 U.S. noncoincident peak load was roughly 870 GW, so 10 percent would be about 87 GW). This study demonstrated the value of storage arising from reduced investments in VRE capacity through limiting curtailment (i.e., less VRE capacity is needed to deliver a given amount of generation to the grid), as well as storage substituting for peaking resources and transmission capacity.[8]

These studies, combined with other analyses and projections, show the strong relationship between a commitment to clean energy and the demand for energy storage. In addition to these energy storage studies, the National Hydropower Association has a goal of about 16 GW of new pumped storage hydro installed by the 2030 timeframe, based on the HydroVision document produced by DOE.[9] The ESA target of 100 GW by 2030 incorporates pumped storage hydro, and supports efforts to encourage its deployment.

There are storage applications beyond the clean energy scenarios that will continue to encourage storage deployment, both behind the meter (BTM) and in front of the meter (FTM). Residential and commercial retail customers, especially those with on-site solar generation, are increasingly utilizing BTM storage to help manage overall energy usage and to maximize solar generation utilization that might otherwise be lost due to inverter or interconnection limits. Utilities increasingly find that FTM storage can defer costly transmission and distribution grid upgrades that otherwise would be necessary to alleviate congestion-related constraints. The rise in electric vehicle demand, especially medium- and heavy-duty vehicle fleets, will increase the need to control loads for both consumers and utilities operating the grid system. These applications, along with others, continue to provide a growing demand for energy storage development in addition to the storage development required to support the clean energy transformation of the grid. In the 50% renewable goal by 2030 adopted by the clean energy trade associations, 100 GW of energy storage appears not only likely, *but necessary* to ensure the continued operation of a reliable and affordable electricity grid. When combined with the other flourishing applications for energy storage, the 100 GW by 2030 goal is even closer to reach.

Jobs and the Environment with 100 GW of Storage

The construction and operation of 100 GW of new energy storage by 2030 will create jobs and enable a substantial reduction in emissions from electricity generation. Employment in the energy storage industry includes jobs in storage equipment and component manufacturing, R&D, engineering and construction (project development), operations and maintenance, sales, marketing, management, and administrative positions. The 2017 Navigant analysis assumed that industry jobs per new MW of storage capacity installed would decline from 50 per MW in 2021 to 34 per MW by 2025. The attainment of 100 GW by 2030 would involve rapidly growing annual installations between 2025 and 2030, but a continued

[8] See Dharik S. Mallapragada, Nestor A. Sepulveda, and Jesse D. Jenkins, "Long-run system value of battery energy storage in future grids with increasing wind and solar generation," Applied Energy 275 (2020) 115390.
[9] See *Hydropower Vision: A New Chapter for America's 1st Renewable Electricity*, U.S. Department of Energy, July 26, 2016, Table F-2, pp. 103-104 .

decline in jobs/MW as the industry continues to refine construction techniques and management. In the 100 GW by 2030 scenario, annual installation figures for 2030 would likely be in the range of 15 GW to 20 GW per year; if these levels of construction account for 10 jobs per MW installed, employment in the energy storage industry would be between 150,000 to 200,000 from new construction. Combined with ongoing O&M and other support for existing installations, ESA anticipates that at least 200,000 jobs would be directly associated with the expanding energy storage market, roughly a threefold increase from current levels.

Some storage applications, such as replacing old peaking units, directly reduce emissions. But by far the bigger emission impact of storage arises as a function of storage enabling greater amounts of clean generation to reliably displace fossil generation. There are several ways to estimate the emission reduction attributable to storage, although none perfectly capture or isolate the emissions reductions from storage alone. For example, one could estimate the amount of natural gas combustion turbine capacity that otherwise would be needed to ensure grid reliability in the absence of storage, although this would not capture the emission reductions provided by renewable generation displacing existing fossil generation that are enabled by storage. Alternatively, one could attribute all emission reductions under clean energy scenarios to storage, although that would overstate the role of storage insofar as it implies that clean generation plays no identifiable role in emission reductions.

Instead of attempting to allocate the emission reductions between storage and clean generation, it is more illuminating to quantify the overall emission reductions that would occur under a majority renewables vision scenario enable by expanding storage, relative to a business-as-usual (BAU) or base case projection. For example, the Berkeley study that examined a 90% clean generation scenario by 2035 projected that wind, solar and hydro would provide slightly more than half of generation in 2030.[10] Under this scenario, the Berkeley researchers found that CO_2 emissions from electricity generation were reduced by about half in 2030 relative to BAU projections (falling about 800 million tons per year), while SO_2 and NO_x emissions fell by more than two-thirds from BAU levels (each declining roughly 700,000 tons per year).[11] While it is not possible to fully isolate the role of storage in producing these emission reductions, it is reasonable to assess that a significant portion of these emission reductions are attributable to storage, enabling the introduction of more clean energy to the grid while maintaining reliability that customers demand.

The Path to 100 GW

While well on our way, the policy work initiated in 2017 is not yet complete. Additional policy initiatives beyond what was laid out in the 2025 Vision report will be needed to attain 100 GW of storage deployments by 2030. ESA continues its work to reform federal and state regulatory frameworks on the treatment of storage, such as:

[10] See Amol Phadke, et. al., Goldman School of Public Policy, University of California Berkeley, *2035 The Report: Plummeting Solar, Wind, and Battery Costs can Accelerate our Clean Electricity Future*, June, 2020, Figure ES-1, p. 4.
[11] *Ibid*, Figure ES-3, p. 6

- expanding valuation as a flexible asset beyond today's siloed classifications of generation, transmission OR distribution;
- ensuring that storage receives appropriate credit for contributing to resource adequacy;
- updating modeling efforts to include multiple value streams and sub-hourly impacts; and
- changing interconnection standards.

In addition, legislative actions are also key policy tools. Chief among these at the federal level would be the enactment by the U.S. Congress of an investment tax credit (ITC) for stand-alone storage facilities. This would create an investment signal and facilitate a rush of capital into storage development that would match the demand for storage arising from the clean energy transformation and electrification over the coming decade. At the state level, energy storage targets commensurate with renewable portfolio standards and beyond will be important tools to ready the grid for increased renewable penetrations.

Conclusion

The U.S. power sector is in the midst of profound transformation to a cleaner, more modern infrastructure. The role of cost-effective storage in enabling the clean energy transformation of the electricity grid is becoming a central tenet in electricity planning and policy across the United States but will require further policy advancements and regulatory reforms. The current momentum of both energy storage investments and the clean energy transformation suggest that the next decade will usher in a burgeoning era of energy storage deployments. From our current vantage point, ESA has determined that it is possible, desirable and increasingly likely that by the end of the decade we will witness 100 GW of new energy storage deployed in the U.S.

This new vision of 100 GW by 2030 provides a focus for our industry to continue to develop, improve, innovate, and deploy energy storage to enable the clean energy system for a more resilient, efficient, sustainable and affordable future.