Grid Modernization Advisory Group

Whitepaper Series
#11: Storage

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STORAGE – THE ESSENTIAL PIECE

1- DESCRIPTION OF ACTION

The Grid Modernization Advisory Group (GMAG) recommends that New Mexico **strategically deploy battery and other energy storage on the New Mexico grid.**

DRIVERS AND OBJECTIVES

The New Mexico Energy Transition Act requires, with some qualifications, "(c) a target of achieving the zero-carbon resource standard by January 1, 2050, composed of at least eighty percent renewable energy…", and also addresses storage deployment,[1] essentially targeting decarbonization of electricity production by 2050. The National Academies' report "America's Energy Future: Technology and Transformation: Summary Edition (2009)"[2] provides a good perspective on greenhouse gas (GHG) emission reduction, grid modernization, and potential technologies for achieving both, as perceived over a decade ago. It is still true today that decarbonization involves the replacement of fossil generation used today by non-carbon energy sources, including renewables and nuclear, although renewables are the leading near-term (ten-year) candidate. There continues to be role for carbon-neutral sources such as fuel from algae, biomass, etc., and at least a transitional role for natural gas. We emphasize that while the replacement of energy produced by fossil fuels is a primary challenge, it is also necessary to provision essential grid services for grid reliability that the existing fossil fuel generation plants naturally provide. Both transitional and ultimate solutions to maintaining an affordable, reliable and resilient 'modern' grid will likely be location-specific, and will be deployed in conjunction with synergistic technologies, including storage, enhanced transmission that allows regional energy transfers, agile distribution, and demand response.

This white paper focuses on *Energy Storage* and its role in achieving decarbonization goals. We emphasize near-term (ten-year) opportunities within the broader context of the thirty-year target in ETA. Today, the path to decarbonizing involves withdrawing large fossil fuel generation plants from the grid and replacing the energy using renewable resources. Given the variability of renewable resources such as wind and solar, energy storage is attractive in terms of providing firm energy as well as its ability to respond rapidly to disturbances. As discussed in this paper, several energy storage approaches are sufficiently mature to be deployed in the near-term in a cost-effective manner[3,4].

Strategically deployed energy storage, with a well-defined purpose, contributes to all the objectives in the grid modernization vision – affordability, DER Integration reliability, resilience, customer choice, markets and asset optimization. A commitment to deploying storage also empowers economic development in New Mexico. If we strongly promote storage and commit to its implementation, we will encourage research, development, and demonstration (RD & D), can attract battery companies to locate in New Mexico, and make New Mexico attractive to other industries as well.

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[1] https://www.nmlegis.gov/Sessions/19%20Regular/bills/senate/SB0489.pdf

[2] https://www.nap.edu/download/12710

[3] https://www.energy.gov/sites/prod/files/2020/07/f76/ESGC%20Draft%20Roadmap_2.pdf

[4] https://www.sandia.gov/ess-ssl/wp-content/uploads/2020/11/EnergyStorageAccomplishments_2020_FINAL.pdf

Today's power system, aka 'the grid', is a just-in-time system – power and energy are produced when demanded, because we do not always have an effective way to store energy for future use. Today, energy needs are largely met with natural gas, coal and nuclear plants.[5]

These power plants are 'firm' resources, available at will, and have traditionally acted as a cushion with respect to disturbances over a vast range of time scales, geographical spread and severity. As these power plants are retired[6] and replaced with renewable generation, action is required to maintain a dependable electricity generation supply. Decreasing costs[7] and a desire to decarbonize has driven a rapid increase of solar and wind renewable generation.[8] Wind and solar are intermittent generation resources; solar is only available during sunlight hours and both wind and solar energy production can change rapidly due to weather. Solar generation can be reduced by extreme wildfires[9] which are growing more prevalent.[10] At times, these resources may not be available at all. As more and more fossil generation is replaced by renewables, these risks have been managed by adding gas turbines.[11] Although a necessary transitional alternative that also supports some reduction in emissions, these plants delay decarbonization. Energy storage is essential to mitigating these problems. Storage can be used as a firming energy resource for a defined period of time, while also providing the needed cushion with respect to disturbances.[12] Additionally, storage can provide grid support and allow economical use of resources through energy arbitrage.

ENERGY STORAGE APPLICATIONS

Energy storage technologies have a wide variety of applications, and various technologies have strengths and weaknesses for accomplishing each. These applications fall into broad categories of bulk power, infrastructure, and behind-the-meter, as summarized in Table 1.

Table 1: Some Use Cases for Storage Systems

Bulk Power	Infrastructure	Behind-the-meter
Load shifting	Transmission capacity	Peak demand reduction
Supply capacity	Congestion relief	Back-up power
Renewables integration	Distribution capacity	Time-varying rate management
Curtailment avoidance	VAR support	
Ancillary services	Hosting capacity	

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[5] https://www.eia.gov/energyexplained/electricity/electricity-in-the-us.php
[6] https://www.nwcouncil.org/news/coal-retirements
[7] https://www.eia.gov/todayinenergy/detail.php?id=45136
[8] https://www.eia.gov/todayinenergy/detail.php?id=42655
[9] https://www.eenews.net/stories/1063713459
[10] https://www.eia.gov/todayinenergy/detail.php?id=45336
[11] https://www.spglobal.com/marketintelligence/en/news-insights/latest-news-headlines/natural-gas-bridge-now-looks-shorter-and-narrower-60626417
[12] https://resourcecenter.ieee-pes.org/publications/white-papers/PES_TP_WP_ESORN_063020.html

OVERVIEW OF STORAGE TECHNOLOGIES [13, 14, 15]

Storage comes in many forms, sizes, and capabilities. The suitability of a specific technology depends on site- and system-specific needs. Key metrics for storage applications include:

- how much energy (MWH) can be stored (how long will the energy last)?
- how quickly can the energy be released or absorbed (MW)? I.e., what is the ability to supply demand, and support the grid during disturbances and variability?
- the cost (measured as an annualized cost ($/KW-year) and levelized cost of energy ($/KWH)
- lifetime of the technology (ultimately, annualized cost versus competing cost of alternatives)

Examples of storage technologies to consider include:

- Batteries, 'behind the meter', grid-scale and distributed grid-scale battery-based storage
- Solar-thermal storage
- Virtual thermal storage (in buildings)
- Pumped Hydro
- Compressed air storage (may involve oil and gas in New Mexico)
- Electric vehicle to grid (V2G)
- Flywheel
- Other (e.g., Hydrogen)

Table 2 summarizes these characteristics for a number of storage options. The information in this table is adapted from a report from Pacific Northwest Laboratories[13] and a USDOE peer review presentation from Sandia National Laboratories.[14] The indicators in the title row are explained below:

Technology – Indicates type of storage.

Domain – Indicates where this type of storage is typically applied (including transmission sub-transmission and distribution; behind the meter including commercial (institutional) and residential).

Time frame – Indicates the amount of time that the storage can supply demand at full power.

Response – Indicates how quickly the technology can change power level. Note that switching from charging to discharging usually involves additional delay.

Current Status – Indicates typical MW capacities that have been recently implemented or are planned and the time frame for implementation.

Cost $/KW(PNNL) and Spread – The PNNL report provides cost in $/KW and $/KWH, assuming four hours of operation per day. The report also provides the spread in these costs. The SNL report also provides cost in $/KW for a 4-hr discharge.

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[13] https://www.sandia.gov/ess-ssl/lab-pubs/doeepri-electricity-storage-handbook/

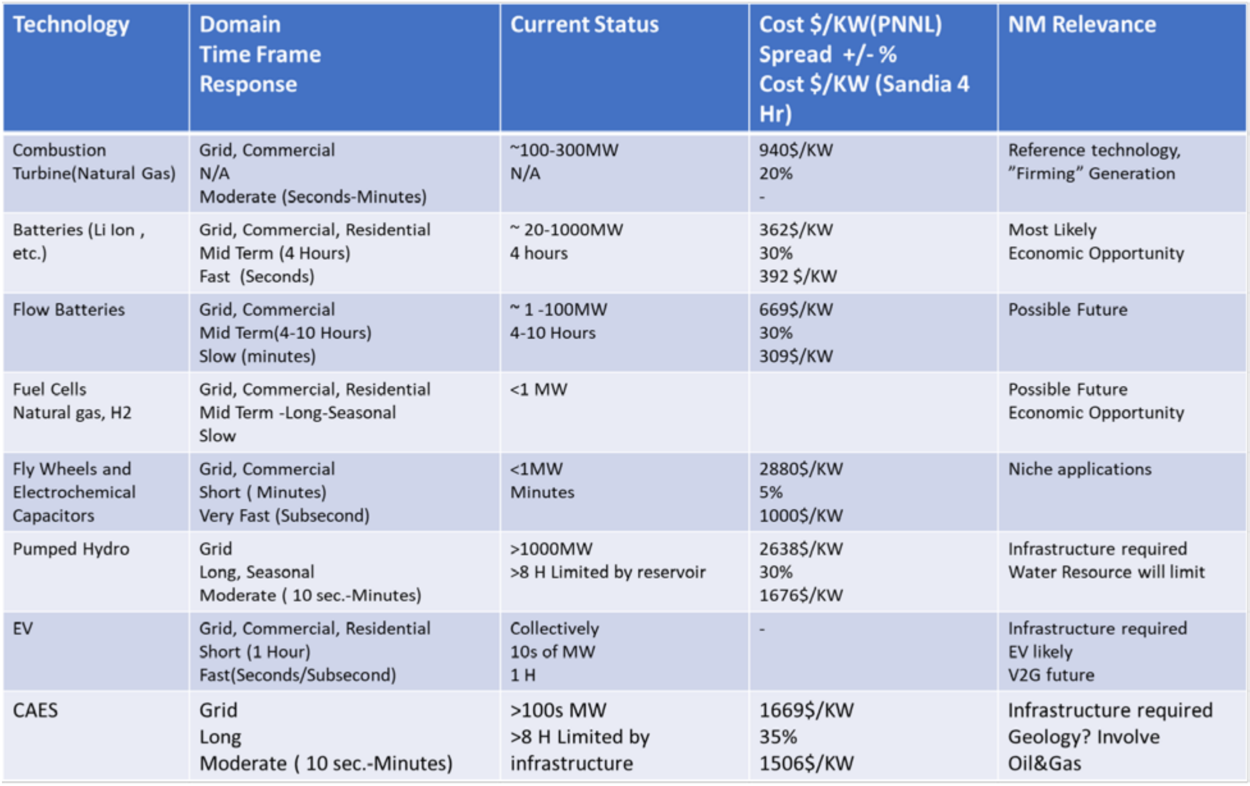
[14] https://www.sandia.gov/energystoragesafety-ssl/wp-content/uploads/2017/08/ESS-Fundamentals-Presentation.pdf

[15] https://www.osti.gov/biblio/1573487-energy-storage-technology-cost-characterization-report

It should be noted that the costs listed have a large variance (spread). The costs of grid-scale deployments involve incentives, subsidies, and special rates and demonstration/pilot projects are often partially funded from federal and state sources. The costs are expressed in $/KW – the total capital cost, typically assuming 4-hour operation. For these reasons, the value of this data is in comparing technologies. Since the firming of renewable integration currently relies to a large extent on gas-fired, combustion turbines, the cost of gas-turbines provides a baseline for comparisons.

Table 2 suggests that Li-Ion battery-based systems are a front runner, with the caveat that their use for long-term (>10-hour) storage may have a prohibitive cost. Pumped-hydro costs seem to be prohibitive, it is a good candidate for long term storage, and, as noted in the PNNL report, retrofits of existing reservoirs and hydroelectric facilities may reduce cost by as much as 70%. Recent proposals for closed pumped hydro also appear to show promise. We conclude that although battery-based storage has immediate promise, all potential storage solutions should be considered.

Table 2: Energy Storage Technology Characteristics



Technology	Domain Time Frame Response	Current Status	Cost $/KW(PNNL) Spread +/- % Cost $/KW (Sandia 4 Hr)	NM Relevance
Combustion Turbine(Natural Gas)	Grid, Commercial N/A Moderate (Seconds-Minutes)	~100-300MW N/A	940$/KW 20% -	Reference technology, "Firming" Generation
Batteries (Li Ion , etc.)	Grid, Commercial, Residential Mid Term (4 Hours) Fast (Seconds)	~ 20-1000MW 4 hours	362$/KW 30% 392 $/KW	Most Likely Economic Opportunity
Flow Batteries	Grid, Commercial Mid Term(4-10 Hours) Slow (minutes)	~ 1 -100MW 4-10 Hours	669$/KW 30% 309$/KW	Possible Future
Fuel Cells Natural gas, H2	Grid, Commercial, Residential Mid Term -Long-Seasonal Slow	<1 MW		Possible Future Economic Opportunity
Fly Wheels and Electrochemical Capacitors	Grid, Commercial Short (Minutes) Very Fast (Subsecond)	<1MW Minutes	2880$/KW 5% 1000$/KW	Niche applications
Pumped Hydro	Grid Long, Seasonal Moderate (10 sec.-Minutes)	>1000MW >8 H Limited by reservoir	2638$/KW 30% 1676$/KW	Infrastructure required Water Resource will limit
EV	Grid, Commercial, Residential Short (1 Hour) Fast(Seconds/Subsecond)	Collectively 10s of MW 1 H	-	Infrastructure required EV likely V2G future
CAES	Grid Long Moderate (10 sec.-Minutes)	>100s MW >8 H Limited by infrastructure	1669$/KW 35% 1506$/KW	Infrastructure required Geology? Involve Oil&Gas

Historically, the majority of grid scale storage has been pumped-hydro (PH), which can provide quick response as well as long-term energy storage. Pumped-hydro systems can be 'retrofitted' into existing hydro- or water-system resources and are often called 'open' systems. They can also be constructed at 'closed' systems purely for pumped-hydro storage,[16] and have been deployed as such in urban water supply systems.[17] Compressed air storage (CAES) can also provide long-term storage. These systems are often designed to utilize existing geological formations and, particularly relevant to New

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[16] https://permalink.lanl.gov/object/tr?what=info:lanl-repo/lareport/LA-UR-17-28923
[17] https://www.sdcwa.org/san-vicente-energy-storage-facility

Mexico, may be able to utilize spent oil and gas infrastructure. PH and CAES can supply (or store) energy over time periods ranging from hours to days. PH may involve reservoirs that may have multiple uses (recreation, irrigation) which create short-term and seasonal constraints on storage and utilization. Both PH and CAES involve a conversion of potential energy to electrical via a rotating generator and have response characteristic similar to conventional generation. They can be deployed by a utility or an independent supplier, but their location is dictated by availability of land and water resources.

Battery-based systems can provide quick response and are being designed today to supply energy for four hours, based on the value of supplying energy during peak demand hours. Battery based systems are being deployed at grid scale, while behind-the-meter technologies are essentially ‘off-the-shelf’ items today. While Li-Ion technology leads the way, substantial research is being directed to finding chemistries that utilize more readily available materials. Flywheels and electrochemical capacitors (also called ‘supercapacitors), have limited energy storage but extremely quick response. Batteries, flywheels and supercapacitor-based systems are scalable and can be distributed across the grid or applied ‘behind-the-meter’ where they are naturally a distributed deployment. The former can be utility owned or deployed by an independent energy supplier, while the latter provide the customer-owner an ability to participate in markets as an individual or as a member of an aggregated resource. It should be noted that thermal storage is available in the built environment (e.g., building HVAC) and is being used to some extent in the context of demand response. In fact, demand response is a form of ‘virtual’ storage. Initial concerns with the safety of battery-based systems, Li-Ion in particular, have spurred efforts in safety assurance and standards development. At this time adequate safety standards are in place to guide the installation and operation of such systems.[18]

Fuel cells, whether supplied by natural gas or hydrogen, are a nascent technology with potential grid-scale and BTM applications. We note that the ability to produce and store hydrogen, perhaps using nuclear and renewable energy, is a technology path with vast implications. Hydrogen can be stored but also transported with existing infrastructures and directly utilized in industrial processes without conversion to electricity.

Batteries, flywheels, supercapacitors and demand response are currently being deployed as short-term storage with capabilities ranging from minutes to a few hours. Several current trends in the evolution of the electric grid – increasing renewables, more inverter-based DER, and the need for greater fuel flexibility and system resilience – call for an increasing need for long-duration energy storage, on the order of days to months. Today’s battery-based systems are cost prohibitive and simply do not offer the economies of scale needed to provide long-term storage on a regional basis. The best current example of long-duration storage is the proliferation of pumped hydro systems that were mostly developed to provide constant loads for nuclear plants during low-load periods, such as at night.

Without long-duration energy storage, transitioning the electric grid to fossil free generation will be extremely difficult.[19] In addition, long-duration energy storage will be needed to maintain reserve margins and to maintain the reliability and resilience of the electric grid. For large capacity, long-duration storage options, pumped hydro storage, hydrogen, compressed air energy storage, and thermal storage using sensible, latent, or thermochemical methods are seen to be most promising. Commercial

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[18] https://www.sandia.gov/energystoragesafety-ssl/wp-content/uploads/2017/08/ESS-Fundamentals-Presentation.pdf

[19] https://www.sandia.gov/ess-ssl/wp-content/uploads/2020/11/EnergyStorageAccomplishments_2020_FINAL.pdf

concentrating solar power (CSP) has demonstrated the ability to provide on the order of 100 MW of power capacity over 10 hours (~1 GWh) for both grid support and bulk power management. Companies are also exploring raising and lowering weights on towers for potential energy storage solutions. It is likely longer duration storage with capacity to handle days and weeks will be needed within a decade. This is an area where there are virtually no readily available grid-level technologies that can address potential needs. While hydrogen, thermal energy storage and liquid fuels can potentially provide longer duration storage, so far, there have not been any commercial demonstrations of these technologies in the grid.

STORAGE DEPLOYMENT IN NM

New Mexico appears ripe for grid-scale storage deployment, should renewables development continue to grow – the only question is when. However, a recent transmission study evaluating New Mexico assumed that the significant advancements needed in storage technology would not be available by 2030.[20] There is currently one battery-based storage demonstration at grid-scale operating in New Mexico, with several projects tied to renewable generation in development; implementation is anticipated in the next few years. New Mexico could consider storage deployment incentives similar to those established in a few other states. The status of storage technology is summarized further in Section 2, Context and Current Situation.

SUMMARY RECOMMENDATION

It will be important to consider all technologies with respect to their relevance to New Mexico. It is critical to realize that firm, fossil-based, energy resource is being replaced by the renewable resources that are so abundant in NM. Storage provides a non-fossil, firming, resource. Strategically located, storage can be a non-wires alternative and add local resilience. Storage technologies, batteries in particular, are a developing industry – NM can leverage its need for and investment in grid modernization, its abundant renewable resources and its expertise with National Laboratories and universities, to incubate economic development and leadership in manufacturing and deployment.

Battery based storage, both grid- and customer-scale, appears, at least for now, to be the most feasible storage option for grid modernization in New Mexico. This is because of limited water resource for pumped hydro and limited geologically suitable sites for compressed air storage. Utility-scale battery-based storage costs are decreasing[21] and are projected to continue falling.[22] Solar thermal storage as well as hydrogen fuel cells may mature in the next two decades. Battery based storage systems, via their electronically based interfaces, are capable of behaving like conventional generators and providing grid support services (ancillary services). Batteries can be connected at the transmission level, distributed through sub-transmission systems, or used 'behind-the-meter'. This potential for truly distributed application can provide improve asset optimization, customer choice, reliability, and most importantly,

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[20] ICF Resources and NM RETA (2020). New Mexico Renewable Energy Transmission and Storage Study, Executive Summary. NM RETA. Retrieved from https://nmreta.com/wp-content/uploads/2020/07/072220-RETA-Executive-Summary-FINAL-APPROVED_online.pdf

[21] https://www.eia.gov/todayinenergy/detail.php?id=45596

[22] https://www.energy.gov/sites/prod/files/2019/07/f65/Storage%20Cost%20and%20Performance%20Characterization%20Report_Final.pdf

resilience. To the extent of piggybacking on electric vehicle (EV) battery markets, batteries may have an initial edge. Sharing BES systems and O&M costs across New Mexico has the potential to optimize the cost/benefit value. For example, a BES at the balancing authority level can benefit most areas across New Mexico, with a smaller (hence lower cost) BES serving more customers than may be the case for an alternative where independently managed BES systems serve smaller areas. Possible cost benefits from BES systems under central management stem from reduced overhead and increased energy imbalance market (EIM) participating resource opportunities.

It should be noted that developments in battery technology and systems are continuing. Although there is rapidly growing experience with both grid-scale and BTM storage, the experience with comprehensive, system level, management (dispatch) and control of these systems under high penetration is limited. A second challenging aspect relates to lifetime of batteries and systems. Battery systems require battery replacement to meet the desired lifetime of twenty-five years or more. Managing these replacements could be challenging because of changing technology including packaging. These concerns, of course, also represent areas of opportunity in terms of economic development.

For the reasons above we recommend that New Mexico plan for and enable wide-spread deployment of energy storage in its modernized grid. Although all technologies should be considered, battery-based storage should be the initial focus. We recommend that New Mexico commit to adding 100MW/800 MWH of storage each year to achieve adequate capacity to decarbonize by 2050.

Widespread deployment of storage will put New Mexico in a position to fully develop its renewable resource to serve both local demand as well as external markets, thereby providing revenue to the state. Behind the meter, customer owned storage, enables the customers to participate in energy market. Finally, distributed storage allows local resilience.

2 – CONTEXT AND CURRENT SITUATION

From 2009 - 2015, Los Alamos County partnered with Japan's New Energy and Industrial Technology Development Organization (NEDO), the State of New Mexico, and the Los Alamos National Laboratory (LANL) on the U.S.-Japan Demonstration Smart Grid Project in New Mexico. It was the first smart grid project to demonstrate how high penetration of renewable energy on a microgrid to meet a residential community's needs. Utilizing a one-megawatt solar array and utility-scale lead acid and sodium-sulfur batteries, NEDO, DPU and LANL demonstrated photovoltaic penetration levels ranging from 25 to 50 percent on a residential neighborhood of 1,600 homes.[23] Figures 1 and 2 illustrate grid-scale deployments.

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[23] https://www.losalamosnm.us/government/departments/utilities/energy_resources/smartgrid

Figure 1. PNM Prosperity Energy Storage Project and Solar Field, Mesa del Sol (left) and Tesla's 80-MW PowerPack Substation in Mira Loma, CA (right).

Figure 2. LS Power's 250-MW Gateway Energy Storage Project in San Diego County, CA

There have been promising advances in storage technology in New Mexico, the U.S., and the world in the last several years. It is anticipated that the various storage technologies will become key components of the modern grid. However, as of this writing, the ability to implement storage in New Mexico is constrained by technology costs, siting, policy, incentives, and performance limitations. In the early going of planning for the ETA targets in 2025 and 2030, electric utilities are faced with the reality that upgrading flexibility of transmission networks is cost-effectively achieved by adding more transmission lines, not dedicated storage. There are some exceptions to this.

Upgraded flexibility in New Mexico's transmission network can be achieved by infrastructure improvements of new segments, uprating existing segments, or deploying storage. This provides more options for grid managers to avoid thermal overloads. Transmission components will be relied on more in moving forward to a modern grid, in the management of increasingly variable loads and variable generation, with daily profiles that are becoming more challenging to match.

A current look at storage deployment in our own state, nationally, and globally, yields a picture of what is possible, and what is emerging, in battery-based storage. Table 3 provides a high-level summary of Battery-based storage systems development; consider this to be a short list of international activity in this area. On a national scale there are significant battery-based storage projects being implemented and yet more in mature development stages. Researching online accounts of battery-based storage development yields an acceleration in utility-scale projects, with announcements or approvals of higher performance ratings coming in on an almost monthly basis. For example, California started off 2020 with 136 MW of operating Battery-based Storage; 3rd quarter reports were projecting 923 MW to be in place by the end of the year. More recent projects include the AES Alamitos,[24] the Moss Landing project,[25] and AES APS.[26]

For comprehensive information on the U.S. energy storage industry and projects, policies, and incentives, see these two sources:

- Energy Storage Association;
- Database of State Incentives for Renewables & Efficiency.

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[24] http://www.renewaesalamitos.com/projectUpdate.php

[25] https://www.energy-storage.news/news/california-utility-pge-breaks-ground-on-730mwh-moss-landing-battery-project

[26] https://www.businesswire.com/news/home/20190221005246/en/AES-to-Help-APS-Customers-Get-Solar-After-Sunset-with-New-100-MW-Energy-Storage-System

Table 3. Selected Battery Energy Storage Systems--New Mexico, Nationally, and Globally

Location/Project	Developer/ Utility	Operation Start	Generation Capacity (MW)	Storage Performance (MWh)
New Mexico				
Prosperity Energy Storage Project, Mesa del Sol NM	PNM[27]	2011	0.5	1
Casa Mesa Wind Battery Energy Storage, House NM	PNM[28]	2018	1	1.8
Jicarilla Storage	PNM[29]	2021	20	--
Sandia Storage	PNM	2022	40	--
Zamora Storage	PNM	2022	30	--
Arroyo Storage	PNM	2022	40	--
NMSU Solar and Energy Storage Project, Las Cruces	EPE[30]	2021	4	--
Nationally				
Gateway Energy Storage, San Diego CA	LS Power Group[31]	2020	250	250
Ravenwood Energy Storage, Queens NY	Ravenwood Development[32]	2021	316	2,528
Vistra Moss Landing	Vistra Corp.	2021	1,500	6,000
FPL Manatee Energy Storage Center	Florida Power and Light[33]	2021	409	900
Globally				
Hornsdale Power, Australia	Tesla	2018	150	193.5
Jardelund, Germany	EnspireME	2018	48	50
Bashkortostan, Russia	Liotech/RUSNANO[34]	2020	10	8
Stocking Pelham, UK	British Solar	2017	50	--

Another emerging trend is the inclusion of battery-based storage as a component of utility-scale solar developments. Three such developments are planned in New Mexico, going operational in the next few years. Two PRC-approved projects are planned as a part of the San Juan Generating Station replacements by PNM, a northwest New Mexico location in the WECC zone; one is planned to serve El

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[27] https://www.pnm.com/documents/396023/396157/Prosperity+Project+Fact+Sheet.pdf/fddfe81b-cfb3-484a-af3c-18cf414c1a44

[28] https://eciusa.com/project/casa-mesa-wind-substation-expansion

[29] https://www.pnm.com/solarstorage

[30] https://www.epelectric.com/company/request-for-proposals/nmsu-solar-and-energy-storage-project

[31] https://www.pv-magazine.com/2020/08/20/worlds-largest-battery-storage-system-now-operational/

[32] https://pv-magazine-usa.com/2019/10/18/new-york-city-trading-gas-plants-for-worlds-largest-battery/

[33] https://pv-magazine-usa.com/2019/03/28/florida-power-and-light-enters-the-race-for-the-worlds-largest-battery/

[34] https://en.rusnano.com/press-centre/news/20200226-rusnano-largest-ppp-with-energy-storage-facility-built-based-on-three-technologies

Paso Electric in southeast New Mexico, also in the WECC. This may signal that bundling battery-based storage with utility-scale solar is now a cost-effective approach.

With New Mexico's world-class solar and wind resources, battery-based storage vendors are watching development of renewables and transmission in New Mexico. These vendors with global name recognition have impressive resumes of projects around the world. It appears that they are looking for implementation opportunities, but system packaging has not achieved the cost-effectiveness or delivery efficiency to make merchant storage development worthwhile, for storage as a dedicated transmission component. Battery-based storage facilities are integrated with substations, which are critical nodes in the transmission network. There may be transmission nodes on the New Mexico grid that would benefit greatly from the addition of battery-based storage, but these opportunities have not been identified in comprehensive fashion.

A review of energy storage reporting built into state regulatory processes provides the current status of how New Mexico IOUs and the PRC look at storage. The IOUs evaluate storage as a part of the current Integrated Resource Planning process, for submittal to the PRC on a three-year cycle. The New Mexico Administrative Code (NMAC) includes a PRC-administered regulation, Integrated Resource Plans for Electric Utilities [17-7-3 NMAC]. Provisions pertaining to planning for energy storage are shown in Table 4.

Table 4. New Mexico Regulatory Provisions for Energy Storage in Integrated Resource Plans

NMAC Citation	Subsection	Provision
17.7.3.7E	Definitions	**energy storage resource** means a commercially available technology that is capable of absorbing energy, storing it for a period of time, and thereafter delivering the energy…
17-7-3-9C(10)	Description of existing resources	description of each existing and approved **energy storage resources**, to include, at a minimum, the expected remaining useful life of the resource, its maximum capacity and dispatch characteristics, and operating costs…
17-7-3-9E(2)	Load and resources table	The load and resources table, to the extent practical, shall contain the appropriate components from the load forecast. Resources shall include…**energy storage resources**…
17-7-3-9F(1)	Identification of resource options	In identifying additional resource options, the utility shall consider all feasible supply-side, **energy storage**, and demand-side resources. The utility shall describe in its plan those resources it evaluated for selection to its portfolio and the assumptions and methodologies used in evaluating its resource options, including, as applicable: life expectancy of the resources, the recognition of whether the resource is replacing/adding capacity or energy, dispatchability, lead-time requirements, flexibility and efficiency of the resource.
17-7-3-9G(1)	Determination of the most cost-effective resource portfolio and alternative portfolios	To identify the most cost-effective resource portfolio, utilities shall evaluate all feasible supply, **energy storage**, and demand-side resource options on a consistent and comparable basis and take into consideration risk and uncertainty (including but not limited to financial, competitive, reliability, operational, fuel supply, price volatility and anticipated environmental regulation). The utility shall evaluate the cost of each resource through its projected life with a life-cycle or similar analysis. The utility shall also consider and describe ways to mitigate ratepayer risk.

3 – IMPACTS OF THE ACTION

As discussed in this white paper, investment in storage is an important, even critical, component of any decarbonization plan. The path to decarbonizing involves withdrawing large fossil plants and replacing the energy using renewable sources. Given the variability of renewable resources such as wind and solar, storage becomes essential to provide firm energy as well as well as to provide an ability to respond rapidly to disturbances by providing regulation and frequency control along with spinning reserves on a limited times scale in the Energy Imbalance Market (EIM). All storage options deserve consideration, with battery-based storage providing near-term opportunities.

Storage supports all the objectives in the grid modernization vision.

- **Affordability and DER Integration.** At least anecdotally, storage-plus-solar deployments are often cost competitive with other technologies for firming variable renewable generation. Storage can also be installed strategically in transmission systems as a ‘non-wires’ alternative for grid support. In this regard storage can support moving energy from renewable resource locations to the entire state as well as to regional markets, generating revenue for the state. The recent FERC Order 2222 may expand opportunities for participating in regional markets, both for utilities and customers.

- **Reliability and resilience.** Renewable integration is challenging because of its variability. The storage solution mitigates this variability while at the same time allowing for grid support services. Utility implementation of distributed storage, and behind-the-meter storage, which is naturally distributed throughout the system, significantly increase local resilience. We note that the state of NM hosts a number of DOD and National Laboratory facilities for whom resilient electric supply is critical.

- **Customer Enablement**. Markets and asset optimization-storage technologies are ‘dispatchable’ and dramatically increase the ability to increase demand (charge) or produce energy (discharge). This ability allows for further optimization in operating economics while allowing both utilities and customers to participate in markets for economic gain.

In addition, a commitment to deploying storage can be exploited towards significant economic development in New Mexico.

Investment in storage is not devoid of concerns and risks. Technologies such as pumped hydro and CAES must be carefully evaluated with respect to environmental impacts related to land and water use. Battery technologies have shorter lifetime as compared to conventional utility plant. Thus, components may have to be replaced several times in order to achieve a lifetime of 30 years commonly used in planning scenarios. Small (tens of KWH), behind-the-meter battery-based storage is now an ‘off the shelf product’, but grid-scale storage must be carefully examined as to primary purpose and secondary benefits, and applied in a manner that meets ‘least-cost’ thresholds. These applications, in the near term, will continue to be site- and purpose-specific. As an example, in New Mexico, a pumped hydro solution may be cost-prohibitive, but a retrofit at existing hydroelectric facility may be quite feasible.

4 – PREREQUISITES, RISKS, ROADBLOCKS, AND ENABLERS

PREREQUISITES

As discussed in Section 2, storage deployment is increasing in New Mexico, both through utility plans and customer investments behind the meter. There is every reason to believe that this trend will gain momentum as stakeholders evaluate the storage option.

New Mexico stakeholders have the choice of letting this trend evolve on its own or enable and accelerate deployment with emphasis on economic development potential. This can be accomplished by:

- regulatory policy that encourages storage, by itself or in conjunction with renewables;
- legislative and PRC support to approve pilot projects and end-user programs to utilize the full spectrum of services that storage can provide;
- policies that encourage and incentivize utilities (cost recovery) and private enterprise (market entry, incentives) and customers (incentives for grid support) to deploy storage grid scale and behind the meter.

RISKS AND ROADBLOCKS

Anecdotally, there are examples where solar-plus-storage solutions have been found to be cost effective. However, storage systems by themselves remain expensive even with a consideration of multiple value streams and incentives. The ‘least cost threshold’ may be perceived as a roadblock, but storage costs are decreasing. Storage deployment may, initially, increase costs (decrease affordability) in the next 10 years, but there is a cost to decarbonization. The challenge is to keep things ‘affordable’.

Behind-the-meter, customer-owned storage is essentially an off the shelf technology which is increasingly of interest to small businesses and homeowners as a hedge against outages caused by extreme events. It is also of interest to customers who wish to disconnect from the grid. Nevertheless, the obvious roadblock to the development of grid-scale storage is the ‘least-cost threshold.’ Storage must compete with other technologies, primarily gas. It is critically important to identify the key purpose and its financial competitiveness rather than justify a project using multiple, uncertain, value streams. A second risk is related to acceptance. The public is used to the robustness of conventional electricity infrastructure and expects similar performance from a technology that is maturing in large scale application.

ENABLERS

As discussed in Section 5, the stakeholders in storage deployment include the State, Utilities, investors, and customers seeking affordable, reliable and resilient supply.

5 – STEPS TO IMPLEMENTATION

Steps:

1. Document as precisely as possible which value streams are most relevant, to storage deployment in NM and the associated cost-benefit in sufficient detail to guide stakeholders.
    - Firming and thereby supporting renewable development and integration
    - Energy arbitrage for NM native demand
    - Energy arbitrage on a reginal basis (will there be regional needs to support long-term contracts?)
    - Frequency regulation and control and participation in EIM
    - Other grid support services.

2. Document NM resources that are suitable for pumped-hydro and CAES (i.e., similar to work done by RETA in the transmission area).

3. Document impact of grid- and BTM- storage on transmission and distribution planning and need for transmission and distribution enhancement (and system operation).
    - Integrating Renewables
    - Improving transmission capacity and hosting capacity
    - Creating transmission paths for regional markets
    - Building resilience
    - Transmission and distribution grid services

4. Document regulatory policy recommendations to further incentivize storage implementation.
    - Additional incentives for solar plus storage
    - Incentive design and financing for storage, not tied to renewables
    - Incentive design for BTM storage for participating in grid support
    - Incentive design for NM-based consortia to develop storage manufacturing and deployment

5. Create roadmap for supporting public-private partnerships for aggressive implementation and associated economic development. Put in place necessary legislative and policy (PRC) mechanisms that encourage storage pilots.

6. Establish incentive programs that encourage customers to purchase, lease, or contract behind-the-meter energy storage; and compensation programs to provide payment for operation attributes such as capacity, demand response, load shifting, locational value, voltage support, and other ancillary and grid services that encourages customers to purchase, lease, or contract energy storage systems

As milestones, we suggest that stakeholders set a goal, e.g., adding 100 MW storage per year with appropriate metrics to track progress:

- 2025 500 MW
- 2030 1500MW
- 2040 2000+MW

6 – UTILITY COMMENTS/QUESTIONS/CONCERNS

This section explores two main discussions offered by PNM that shed some light on related issues.

1. Control systems

While we agree that energy storage is potentially the most flexible asset on the grid, we cannot say today that we know of a software application that can sit in a control center and is able to balance all of these capabilities (i.e., we just don't ramp a 40 MW gas plant 40 MW in the negative direction). Complexities emerge where we are trying to utilize these assets for regulation activities and energy dispatch for peak, arbitrage, skipping the downramp in the morning for charging so we don't exacerbate the Duck Curve, etc. – all while being mindful of the state of charge of the battery in order to ensure that we are not creating undue cycling and battery degradation on an asset that already has cost concerns in the near term. This is not a complete summary of control center concerns, but it gives an idea of all of the "smarts" necessary for battery optimization which will need to be built in to both the on-site battery controllers and in the control center systems. PNM's current Energy Management System (EMS) in our transmission control center is unlikely to be able to spin all of those plates and optimize the various resources that would need to work in concert – and that is for a scenario where PNM controls the battery resource directly and it is not provided through a power purchase agreement (PPA). The ability to control a PPA-provided research will be as good as the thought that goes into the contract and the incentives for the nature of dispatch. An example of bad contract design might be incentivizing having high availability at system peak. While that sounds optimal (and it may be for some systems), that would also not only incentivize peak dispatch but possibly incentivize charging at times of low load in the morning and exacerbating the Duck Curve down ramp we see in the mornings when all the solar panels are coming on and we are ramping down other generation resources to compensate.

2. The unknowns of the long-term maintenance on energy storage systems

As battery cell technology improves, we may end up with cells with different form factors (e.g., do we then have to re-rack batteries or are they containerized, and we need to move a whole container out for another?). A larger issue would be different energy densities in different battery generations, which might create a need for changes to battery management system parameters for both operation and safety. Many of the energy storage systems in the nation now are fairly new, so it will be interesting to see what happens as we get to the end of cell life on enough of the systems to get a good-sized data set of how these maintenance activities go.