The Value of Energy Storage to the PNM System

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I. Introduction

The purpose of this study is to summarize the potential benefits of energy storage additions to the Public Service Company of New Mexico (PNM) system. In particular, PNM is interested in understanding the advantages of a standalone utility-owned energy storage project compared to a PPA (Power Purchase Agreement) contract structure for storage that is co-located with a solar photovoltaic (PV) facility and owned by a third party.

Our assessment identifies two areas in which utility-owned storage provides incremental benefits relative to a contract for storage that is co-located with solar PV. First, PNM's knowledge of its own transmission and distribution (T&D) system would allow the company to site utility-owned storage in the most beneficial locations on the power grid, irrespective of whether that location is suitable for co-location with solar generation. We estimate this locational transmission-related value of storage to be up to $22/kW-year for a 4-hour (e.g., 1 MW / 4 MWh) battery. Second, storage ownership would give PNM greater operational capabilities, including the flexibility to mitigate off-peak wind curtailments. Specifically, a standalone energy storage system could charge during any hour of the day, rather than being constrained to charging from the output of the solar PV facility. This ability to charge and discharge any time would increase the energy value of the storage system by approximately $10 to $25/kW-yr according to our simulations (and more through the provision of ancillary services and possibly other grid services). Direct ownership would also provide PNM with options to modify the use of the storage device as operational experience is gained and market conditions change over time.

This analysis is based on a review of (1) PNM transmission and outage data and (2) energy storage market simulations using Brattle's bSTORE model.[1] The scope of our study focused specifically on the incremental value that the standalone utility-owned storage system could provide relative to the storage portion of a hybrid "solar+storage" contract. Further analysis could estimate the total value of the combined storage+solar facility and produce a holistic assessment of the costs and benefits of each storage application.

II. System Benefits of Energy Storage

Due to rapidly falling costs and its operational flexibility, energy storage can be a valuable addition to the PNM system. Possible benefits of energy storage include the following:

Reducing the production costs of generating electricity. Energy storage can be charged in off-peak periods, when the cost of providing energy is low. It can then be discharged during peak load hours, reducing the need to operate expensive peaking units. The fast ramping capabilities of storage can help system operators manage rapid changes in load or variable generation,

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[1] For more information about the bSTORE model, see https://www.brattle.com/bstore.

thereby reducing the production costs associated with the (up and down) ramping of conventional generators.

Reducing the production cost associated with providing ancillary services. The operational flexibility of storage would allow it to provide regulation and operating reserve services more cost-effectively than conventional resources.

Reducing capacity needed from traditional power generation resources. By discharging during peak load hours, storage can reduce the need for peaking capacity that would otherwise be built to maintain resource adequacy.

Avoiding customer outages. If located on the transmission or distribution system, the deployment of storage can be targeted to reduce the frequency and severity of customer outages.

Reducing transmission congestion costs. Energy storage can effectively increase transmission capacity when deployed to congested locations of the system. This reduces the cost of otherwise dispatching more expensive generators to address the transmission congestion constraints.

Reducing emissions and decreasing the curtailment of renewable generation. Storage can potentially reduce emissions either by reducing generation from high-emitting generators or by being charged with the output of wind and solar generators that would otherwise be curtailed due to system constraints. Reducing the curtailment of renewable generation will reduce system-wide production costs. The extent to which storage reduces emissions depends on the marginal emissions profile of the resource mix during the charging and discharging of the storage systems.

Deferring transmission and distribution investment costs. To the extent that storage can be used to meet local peak loads, the loading on the transmission and distribution system during those hours would be reduced. In such cases, storage can help defer certain transmission and distribution upgrades. Currently, PNM staff have not identified any opportunities for T&D investment deferral on the PNM system.

Providing additional grid services. Storage can be deployed where additional grid services (such as voltage support) may be needed, thereby deferring other investments needed to provide the same service.

III. Advantages of Utility-Owned Storage

There are two ways in which standalone utility-owned storage can capture greater potential benefits than storage that is part of a contract for a hybrid solar+storage project: (1) locational value and (2) greater operational flexibility.

Locational Value

PNM is in the best position to determine the locations in which storage would provide the greatest value to its system. Owning the storage facility would provide PNM with the control necessary to capture this value. For example, PNM can deploy energy storage to targeted, high-value locations on the grid. PNM can take advantage of unrestricted site access (e.g., by integrating the storage system into an existing substation), thereby potentially reducing maintenance costs of the storage. With a storage contract, particularly one in which storage must be co-located with solar PV, this ability to site the storage device in specific locations on the grid is diminished.

To develop an estimate of the potential locational value of energy storage, we assessed the transmission value of battery investments in two locations that appear to be the most valuable based on discussions with PNM and our review of the PNM system: The Sandia substation and the Tijeras substation, both of which are located in the Albuquerque area.

A battery storage deployment at the Sandia substation would reduce the local system's congestion management costs. The storage deployment would lessen the need to run higher-cost generation units that would otherwise be required to address transmission constraints in that location of the grid. In 2017 and 2018, congestion management costs in the Sandia area averaged $3.8 million per year.[2] Based on analysis of the timing and size of those transmission congestion events, we identified the portion of the events that could be avoided for various battery sizes and configurations.

Smaller battery deployments mitigate a lower share of the total congestion management costs than larger battery deployments would. For instance, a 100 MW battery with a 2-hour duration (i.e., 200 MWh of energy storage capacity) could mitigate approximately 14 percent of the historical congestion, whereas a 200 MW, 4-hour duration battery could mitigate approximately 34 percent of the congestion. However, the value decreases incrementally with each additional megawatt of storage capacity addition. On a dollars-per-kilowatt basis, batteries with low MW capacity but high energy storage capability provide the most congestion management value. Table 1 summarizes the congestion management value of a range of battery storage deployments.

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[2] Congestion management costs were significantly higher in 2018 than in 2017. PNM transmission planning staff have indicated that the higher value in 2018 may be an anomaly.

Table 1: Congestion Management Benefit of Sandia Storage Deployment, by Battery Size ($/kW-yr)

	2hr	4hr	6hr	8hr	10hr
50 MW	$6	$11	$15	$18	$20
100 MW	$6	$9	$12	$14	$15
150 MW	$5	$8	$10	$11	$12
200 MW	$5	$7	$8	$9	$10
250 MW	$4	$6	$7	$8	$8

Additionally, battery storage deployed at the Tijeras substation could be designed and operated to avoid downstream service interruptions. The battery's stored energy could be discharged during local reliability events to provide backup generation to customers who would otherwise experience an outage.[3] Between 2011 and 2018, customers in the Tijeras Canyon area experienced an average of 1.5 hours of outages per year. Studies of the value of lost load ("VOLL") have suggested that customers would be willing to pay about $12,000/MWh to avoid these interruptions, on average.[4]

Load at the Tijeras substation historically has ranged up to approximately 27 MW, suggesting that a maximum battery size of 30 MW would address local reliability conditions. Our assessment of the duration and frequency of the historical outages indicates that a 4-hour battery could fully mitigate these outages, with the customer value of those avoided outages being $11/kW-yr. Because Tijeras is connected into Sandia, the benefits of storage installed at Tijeras include (and thus are additive to) the congestion management benefits of a battery deployed at the Sandia substation.

Operational Flexibility

By owning a standalone energy storage system, PNM would have complete control over when and how to operate the storage system. This is particularly valuable for managing wind curtailment during overnight hours when load is low. In contrast, a battery that is co-located with solar PV would need to charge from the output of the solar PV facility in order to qualify for the federal Investment Tax Credit. This daytime charging constraint would reduce the ability to otherwise charge during low-cost hours when solar output is low. Additionally, the PPA contract structure could establish contractual requirements that would constrain the utility to a

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3 The battery would need the ability to function in islanded mode ("grid forming" capability), typically not a standard feature of such deployments.

4 Based on a review of several Value of Lost Load (VOLL) studies. Assumes a VOLL of $3,000/MWh for residential and $20,000/MWh for commercial and industrial (C&I) customers, and a weighted average based on approximate PNM customer load shares of 45% residential and 55% C&I.

specific storage use case. These contractual limitations would reduce PNM's ability to modify the operations of the storage device as experience is gained and market conditions change over time.

To assess the incremental value of charging at any time of day, we simulated the potential energy revenues of a battery storage system for both daytime-only and 24-hour charging cases.[5] The simulations used recently-observed prices in the California ISO's Energy Imbalance Market (EIM) at three locations near PNM's service territory: Arizona Public Service (APS), Nevada Energy, and PacifiCorp East (Utah). Since the EIM is not an ancillary services market, we separately assessed spinning reserves and frequency regulation revenues based on experience from the nearby CAISO, ERCOT, and SPP markets.

The ability to charge the battery during any hour increases energy revenues by between 14 and 40 percent, relative to the case where the battery can only charge during daytime hours. This amounts to between $10 and $25/kW-year in incremental value, depending on the locational prices used in the analysis. Ancillary services revenues are increased even further (between 70 and 148 percent) when the restriction on daytime charging is lifted.

It is worth noting that the pricing locations (i.e., EIM prices) that were used in the analysis have significant market penetration of solar PV. Therefore, these locations tend to have lower prices during daytime hours, making storage less valuable than at locations where off-peak prices (in the nighttime) are much lower than prices during the day. It is likely that the incremental value of unrestricted battery charging would be greater for PNM's system than our simulations indicate, because PNM is expected to experience development of significant additional wind generation on its system, which will yield more nighttime charging opportunities than offered in the more solar-dominated EIM pricing points in Arizona and Nevada. Growth in wind adoption may lead to curtailments due to the high wind generation output during off-peak hours, which could be avoided by charging a standalone battery. The need for ancillary services may also be higher during those off-peak times.

Results of the revenue analysis are summarized in Figure 1. As shown in the figure, the proxy energy and ancillary services revenues are estimated to be greater if PNM owns and operates the storage as a standalone facility. Even though PNM is a vertically integrated utility and would not "earn revenues" directly from the market, these proxy market revenue estimates represent the type of value that PNM could realize on behalf of its customers if PNM were to own the energy storage resources. At the lower end, the additional value of standalone storage could be approximately $10/kW-year greater if the storage had been contracted for from a third party that restricted the charging pattern of storage co-located with the solar PV.[6] At the high end, based

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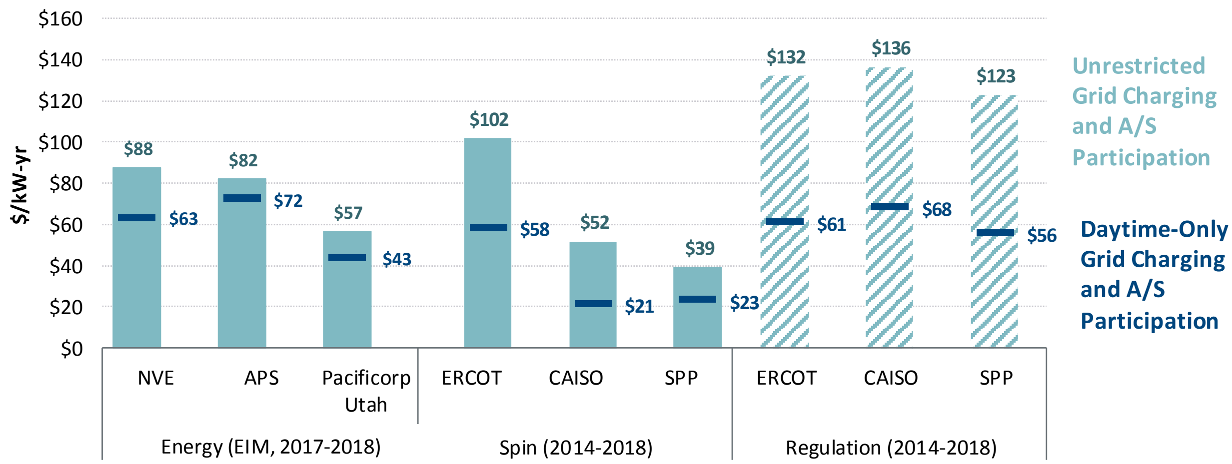
[5] Energy and ancillary services revenues for standalone battery facilities were simulated for a case where they battery can charge at any time of day, and separately for a case where the battery can only charge between the hours of 8 am and 7 pm (thus approximating a scenario where the battery can only charge from solar PV output).

[6] This is the incremental energy value at the nearby APS location in the EIM.

on the value of providing frequency regulation services under ERCOT-like market conditions, the additional value of standalone storage could be $71/kW-year. These incremental values of standalone storage systems are in addition to the transmission-related values presented earlier in this paper.

Figure 1: Simulated Energy and Ancillary Services Revenue, with and without Limits on Timing of Charging



Note: Results shown for 100 MW, 4-hour battery. Frequency regulation value is limited to a relatively low overall need for capacity (estimated at 20 to 40 MW for PNM system).

Addendum – Benefits of Projects Proposed by PNM

Following the development of this study, PNM proposed to develop two storage projects. The first project ("Sandia") is a 40 MW, 80 MWh battery located near the Sandia substation. The second project ("Zamora") is a 30 MW, 60 MWh battery located on the Tijeras radial line. For clarity, this addendum describes the annual transmission value that we identified for projects of those sizes and locations.

Sandia: As described earlier in this report, a battery located at the Sandia substation would reduce congestion-related dispatch costs. Brattle estimated the congestion cost savings associated with a range of 2-hour battery deployment capacities, ranging from 50 MW up to 250 MW. On a dollars-per-kilowatt-year basis, the 40 MW deployment proposed by PNM would provide benefits at least as high as the 50 MW deployment level simulated in our study. Based on an estimated benefit of $6/kW-year, the proposed Sandia project would produce benefits of $240,000 per year.

Zamora: Because the Tijeras substation is connected radially to the Sandia substation, a 30 MW battery with 2-hour duration located at the Tijeras radial line would reduce congestion-related dispatch costs at the same rate as the Sandia location, i.e., $6/kW-year. In addition, such a battery would also provide $6/kW-year in reliability benefits by reducing local outages.[7] The $6/kW-year reliability benefit estimate is additive to the $6/kW-year congestion relief benefit, as it accounts for the possibility that the battery would not be sufficiently charged when needed to provide reliability services due to its use for congestion management.[8] Based on estimated total benefits of $12/kW-year, the proposed Zamora project would produce benefits of $360,000 per year.

7 As noted, the battery would need the ability to function in islanded mode ("grid forming capability") in order to produce these reliability benefits.

8 Not accounting for such possibility leads to $7/kW-year reliability benefits.