BEFORE THE NEW MEXICO PUBLIC REGULATION COMMISSION

IN THE MATTER OF PUBLIC SERVICE COMPANY OF NEW MEXICO'S CONSOLIDATED APPLICATION FOR APPROVALS FOR THE ABANDONMENT, FINANCING, AND RESOURCE REPLACEMENT FOR SAN JUAN GENERATING STATION PURSUANT TO THE ENERGY TRANSITION ACT	)	**19-______-UT**

DIRECT TESTIMONY

OF

WILLIAM KEMP

July 1, 2019

NMPRC CASE NO. 19-_____-UT
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WILLIAM KEMP

WITNESS FOR
PUBLIC SERVICE COMPANY OF NEW MEXICO

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I. INTRODUCTION

Q. PLEASE STATE YOUR NAME, POSITION AND BUSINESS ADDRESS.

A. My name is William J. Kemp. I am a co-founder and Senior Managing Director of Enovation Partners, LLC ("Enovation"), which is a management consultancy focused on strategic and financial issues in the electricity and natural gas industries. My business address is 18 South Michigan Avenue, Suite 1200, Chicago, Illinois 60603.

Q. WHAT IS THE PURPOSE OF YOUR TESTIMONY IN THIS PROCEEDING?

A. My testimony is intended to provide a broader perspective for the members of the New Mexico Public Regulation Commission ("Commission") and interested parties on electricity storage technology, economics, value and procurement, especially with respect to the nascent storage program of Public Service Company of New Mexico ("PNM"). My testimony also outlines how that broader industry perspective should inform PNM's initial introduction of battery storage on its system.

To boil down my advice after considering the relevance of national experience on battery storage for New Mexico, the most important lessons are:

1. Location is important. Batteries add more value in strongly interconnected sites like major substations.

2. Avoid crash programs. Expand capacity incrementally as needed.
3. Minimize daylight between operations and ownership. Lean toward utility ownership for the storage projects with the tightest system integration.
4. Build the required skills. Ensure that the utility gains the experience and knowledge to leverage future cost decreases and technology advances.

Because storage is still a fairly new topic before the Commission, I have included a number of citations and exhibits that provide useful background information on the topic, as well as supporting particular statements in my testimony.

Q. WHAT ARE YOUR RESPONSIBILITIES AT ENOVATION PARTNERS?

A. My responsibilities include leadership of Enovation's regulatory, sustainability, and strategy implementation practice areas. This includes consulting services in areas such as strategic planning, business planning, resource planning, regulatory strategy, transaction support, commercial due diligence, merger integration, financial analysis, financing strategies, operations improvement, and litigation support.

Q. PLEASE BRIEFLY SUMMARIZE YOUR RELEVANT EDUCATION AND WORK EXPERIENCE.

A. My educational background includes a Bachelor of Arts *magna cum laude* in Anthropology and Physics from Harvard University and a Master of Public Policy from the Goldman School of Public Policy at the University of California at Berkeley, with a focus on energy policy.

Prior to co-founding Enovation Partners, LLC in 2013, I served as Vice President for Black & Veatch from 2005 to 2012, leading their strategic consulting services. Before that, I co-founded and served as a Managing Director of Economists.com, a management consultancy focusing on financial and technology issues in the power, gas, and water industries. My previous consulting experience was primarily with Deloitte Consulting. From 1986 to 1999, I held positions of increasing responsibility in that firm's management consulting practice in the energy industry, ultimately serving as one of three managing partners for the worldwide practice. I was energy industry leader for the Asia-Pacific-Africa region, based in Sydney, Australia and before that for the western U.S. region, based in Portland, Oregon. I have directed over 300 consulting projects over my career.

Earlier in my career, I held positions as Senior Wholesale Rate Engineer for Pacific Gas & Electric Company, Regulatory Cost Analyst for Southern California Edison Company, Research Specialist for Lawrence Berkeley Laboratory in the U.S. Department of Energy, and Regulatory Economist for the President's Council on Environmental Quality, Office of the White House.

I have testified personally or developed testimony for my clients on utility ratemaking and resource planning issues in many regulatory proceedings, and also on energy economics issues in a number of civil suits. My resume and testimony experience are provided in PNM Exhibit WK-1.

Q. PLEASE BRIEFLY SUMMARIZE THE RELEVANT EXPERIENCE AND EXPERTISE OF ENOVATION PARTNERS, LLC.

A. Enovation's professionals have served many of the leading companies throughout the energy value chain. We have earned a reputation as experts in electricity storage economics and strategy. Our team takes a global energy perspective, supported by our experience in more than 30 countries during more than 600 engagements with utilities, governments, developers, suppliers, investors, and private equity interests. We have offices in Chicago, San Francisco, New York, Washington, DC, and London.

Enovation Partners has a long track record with regard to understanding the costs, performance and utilization of energy storage technologies in restructured[1] and vertically integrated electric markets.

In addition to the present matter, Enovation's more recent experience includes:

- For a large Northeastern wires utility:

[1] Refers to energy storage deployed in organized wholesale power markets, including PJM Interconnection, ISO-NE, NYISO, MISO, ERCOT, CAISO and SPP.

    - Assessed economic viability and system benefits of energy storage by use case and under increasing market saturation to determine the "optimal" amount, location and timing of storage that should be deployed by 2030.
    - Designed and assisting in executing a large storage procurement process.
- For San Diego Gas and Electric:
    - Provided a storage revenue assessment in support of San Diego Gas and Electric's 2018 Energy Storage Procurement and Investment Plan.[2]
- For Lazard Freres
    - Continued management and execution of Lazard's annual Levelized Cost of Storage study, which is a respected industry benchmark.

Enovation's experience and expertise, especially on storage issues, is more fully described in the attached PNM Exhibit WK–2.

Q. WHAT ARE THE KEY ISSUES THAT YOU WILL ADDRESS?

A. My testimony will focus on these issues:

- Are the size and pace of PNM's storage program consistent with prevailing utility industry practices?

[2] CPUC Docket A.18-02-016

- How can PNM use the results of its energy storage RFP to assemble a storage portfolio that represents the best long-term value for PNM's customers?

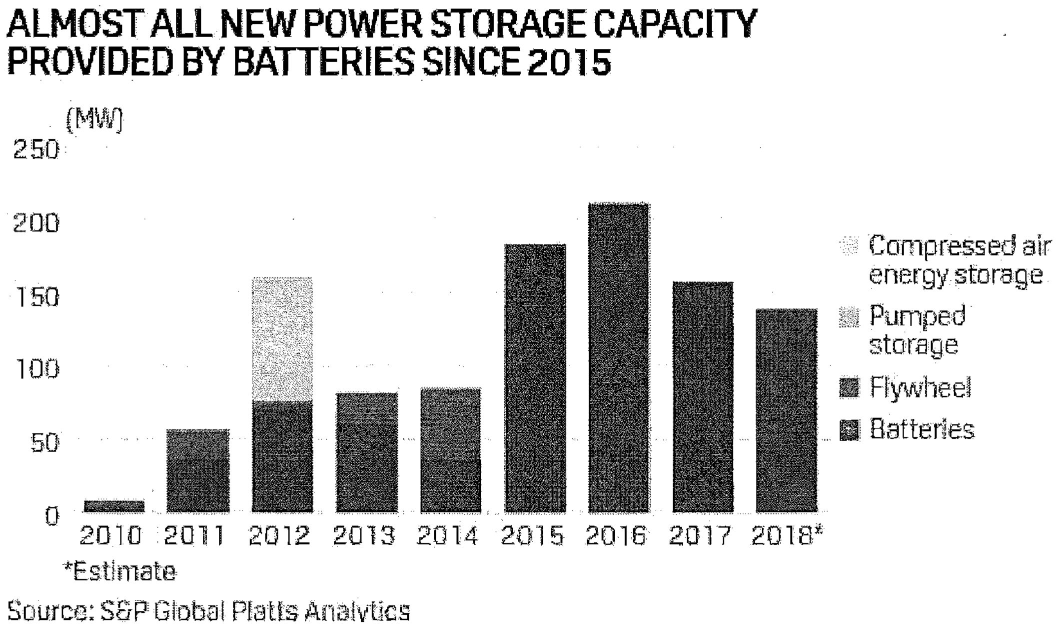
II. HISTORY OF BATTERY STORAGE IN THE UTILITY INDUSTRY

Q. HOW MUCH BATTERY STORAGE CAPACITY HAS BEEN INSTALLED TO DATE IN U.S. ELECTRICITY GRIDS?

A. S&P estimates that as of early 2019 the United States has approximately 1 gigawatt (GW) of grid-connected battery energy storage capacity installed, and expects that amount to increase seven-fold by 2022. Numerous announcements around significant increases in the pipeline of planned projects provide a preview to the industry of trends over the next five years in technology choice and pricing. Since 2015, almost all of new electricity storage capacity has been provided by battery energy storage systems, according to S&P Analytics.[3] Please see PNM Figure WK-1 for a graphic depiction of the deployment of energy storage by utilities in the United States.

[3] https://blogs.platts.com/2019/03/28/us-expansion-power-battery-storage/

PNM Figure WK-1



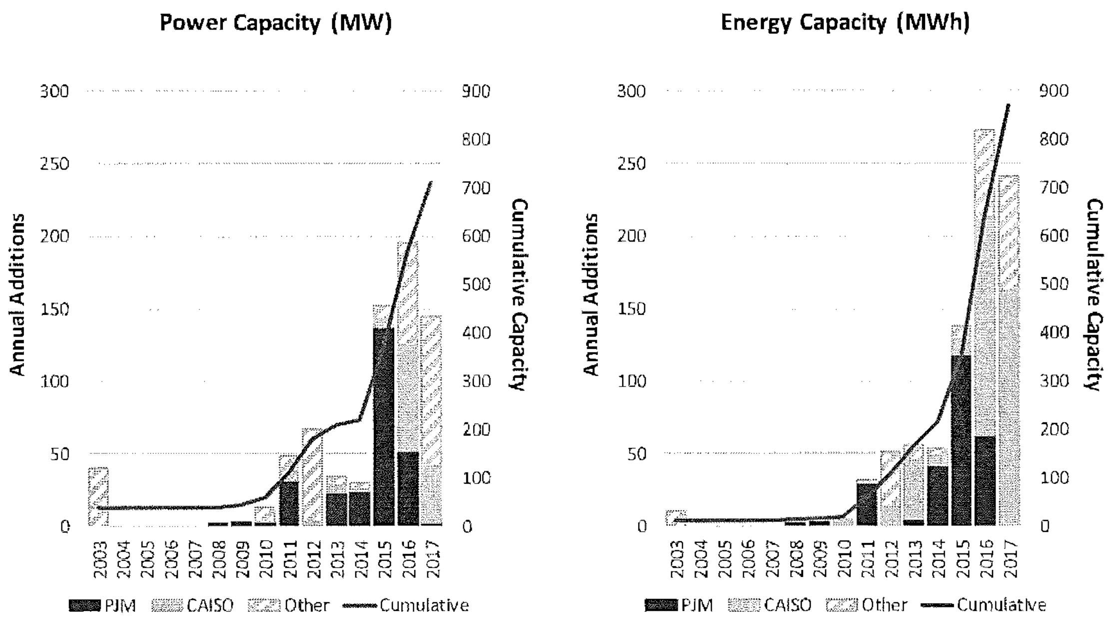
Q. WHERE HAVE LARGE BATTERY ENERGY STORAGE SYSTEMS BEEN INSTALLED?

A. In the United States, the bulk of utility-scale battery energy storage systems have been installed in two primary regions: California and within the PJM Interconnection footprint.[4] As illustrated in the below table from the Energy Information Administration, battery energy storage systems have also been installed elsewhere in the U.S., but not at significant scale. Of the current deployments, about 90% of utility-scale battery energy storage systems have been developed in regions covered by five of the seven organized regional transmission

[4] A broad area including all or parts of Delaware, Illinois, Indiana, Kentucky, Maryland, Michigan, New Jersey, North Carolina, Ohio, Pennsylvania, Tennessee, Virginia, West Virginia and the District of Columbia.

organizations, along with Alaska and Hawaii. California and PJM account for 75% of battery storage energy capacity installed through 2017.[5]

PNM Figure WK-2[6]



Q. HOW DO UTILITIES TYPICALLY USE BATTERY ENERGY STORAGE SYSTEMS ("BESS")?

A. Utilities use battery energy storage systems for a variety of reasons. The three broad categories of economic drivers for storage include deferral of transmission and/or distribution investment, generation firming[7] (including time arbitrage and

[5] https://www.eia.gov/analysis/studies/electricity/batterystorage/pdf/battery_storage.pdf
[6] See 4. Other includes ISO-NE, MISO, ERCOT, Alaska and Hawaii
[7] Largely generation firming of variable output from renewable resources

various ancillary services), and microgrid/islanding[8] and pilots. Of the existing utility-owned energy storage capacity, 34% is used for T&D deferral, 27% for generation firming, 22% for microgrids, with the rest used as pilots.[9]

Q. WHAT KIND OF TECHNOLOGY IS TYPICALLY USED FOR BATTERY ENERGY STORAGE SYSTEMS?

A. Over 80% of utility-scale battery storage system capacity is provided by batteries utilizing lithium-ion chemistries.[10] Other electrochemical[11] technologies exist (e.g., flow batteries) but have not gained significant traction yet in the marketplace.

Q. WHAT ARE SOME OF THE OPERATIONAL RISKS OF LITHIUM-ION CHEMISTRIES?

A. The most significant risk of lithium-ion battery chemistries is thermal runaway. Manufacturing defects or internal failures due to structural or operational stress can cause an internal short circuit that suddenly releases the energy stored in one or more battery cells. The temperature rises rapidly (within fractions of a second), creating temperatures of around 400°C. The battery cell becomes gaseous, and a fire erupts. If not isolated, this fire can spread quickly to adjacent

[8] A small network of electricity users with a local source of supply that is usually attached to a centralized grid but is also able to function independently
[9] Based on an Enovation Partners analysis
[10] See footnote 3
[11] I use the terms "electrochemical storage" and "battery storage" as basically synonymous in current market conditions, although strictly speaking, battery storage is a subset of electrochemical storage.

cells, initiating a cascading chain reaction. Lithium-ion fires are difficult to extinguish by conventional means. (This is one reason why airlines have banned lithium-ion computer batteries from the cargo holds of their airplanes.) The battery and utility industries have recognized the importance of preventing the failure of one cell from progressing into the runaway failure and combustion of a large pack of cells.[12]

Q. HAVE THERE BEEN BATTERY FIRES AT U.S.-BASED BATTERY ENERGY STORAGE SYSTEMS?

A. Yes. There have been at least two well-publicized fires at utility-scale battery energy storage systems in the United States. In August 2012, a 15 Megawatt (MW) battery installed by Xtreme Power on the Hawaiian island of Oahu burned for seven hours before firefighters could extinguish it.[13] More recently, a battery fire at a 2 MW Phoenix-area project owned by Arizona Public Service sent several emergency responders to the hospital after suffering chemical burns.[14]

[12] https://www.osti.gov/servlets/purl/1249044
[13] https://www.hawaiinewsnow.com/story/19173811/hfd-battling-kahuku-wind-farm-blaze/
[14] https://www.greentechmedia.com/articles/read/aps-and-fluence-investigating-explosion-at-arizona-energy-storage-facility#gs.kzezgp

Q. HAVE THERE BEEN BATTERY FIRES OUTSIDE THE UNITED STATES?

A. Yes. There have been at least 15 fires in battery energy storage systems in Korea so far in 2019,[15] and there was a fire at a lithium-ion battery energy storage system in Belgium in November 2018.[16]

Q. HAVE THERE BEEN OTHER OPERATIONAL ISSUES WITH U.S.-BASED BATTERY ENERGY STORAGE SYSTEMS?

A. Yes. Several battery energy storage systems installed in the PJM Interconnection footprint suffered operational problems during early 2017 when PJM operators increased the intensity of a frequency regulation dispatch signal. In some cases, battery temperatures and cycling caused premature degradation and voided manufacturer warranties.[17]

Q BY PROVIDING THESE EXAMPLES OF BATTERY FIRES ARE YOU SAYING THAT BATTERY TECHNOLOGY IS UNSAFE?

A. No, but battery technology should be deployed and managed in a manner that reduces risks and ensures PNM customers see the full benefits that battery storage offers. As the industry matures, risks from deficiencies in design and manufacturing will be reduced, operations and maintenance performance will be

[15] http://m.koreatimes.co.kr/pagso es/article.asp?newsIdx=260560
[16] http://www.energystoragejournal.com/2018/01/11/belgiums-li-ion-ess-fire-cause-still-unknown-two-months-later
[17] See FERC dockets EL-17-64-000 and EL 17-65-000.

honed, and optimal strategies for placement locations and dispatch will be perfected.

Q. GIVEN THE ABOVE ISSUES, WHAT RECOMMENDATIONS WOULD YOU HAVE FOR PNM?

A. Battery storage is obviously an important part of the future of the energy systems. We recommend, however, that PNM enter this market on a measured basis to allow the company to understand better the technology risks and how to manage them, and to take advantage of the expected advancements in the storage technology's safety and dependability rather than lock in existing technology that rapidly becomes obsolete.

Q. WHAT IS THE OUTLOOK FOR DEVELOPMENT OF ADDITIONAL BATTERY ENERGY STORAGE SYSTEMS IN THE UNITED STATES?

A. As stated earlier, analysts are projecting that the amount of electrochemical storage installed on the grid to increase significantly. This is due to expectations that system costs will continue to decline[18], performance will improve, and market rules will evolve to reduce barriers to full participation of battery energy storage systems in wholesale electric markets.[19]

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[18] https://www.lazard.com/media/450774/lazards-levelized-cost-of-storage-version-40-vfinal.pdf, pages 14 and 15

[19] FERC Order 841 (https://www.ferc.gov/whats-new/comm-meet/2018/021518/E-1.pdf)

Q. HOW MUCH STORAGE HAVE EARLY ADOPTING UTILITIES PROCURED IN RELATION TO THE SIZE OF THEIR SYSTEMS?

A. As mentioned earlier, the battery storage industry is in the very early stages of growth in the industry and has not yet reached maturity. PNM Table WK-1 below details the battery storage penetration as a percentage of 2018 peak load for the 10 utility operating companies with the highest battery penetration. At 2.6% PG&E Corporation is the national leader in battery storage penetration on its grid.

PNM Table WK-1

Utility Operating Company	Battery Storage Operating or In Development (MW)	2018 Peak Load (MW)	% Penetration
Pacific Gas and Electric Company	449.5	17,263	2.60%
San Diego Gas & Electric Company	81.0	4,377	1.85%
Monongahela Power Company	31.5	2,090	1.51%
Southern California Edison Company	332.5	23,460	1.42%
Jersey Central Power & Light Company	39.8	5,977	0.67%
New York State Electric & Gas Corporation	20.0	3,061	0.65%
Commonwealth Edison Company	115.4	21,349	0.54%
Duke Energy Ohio, Inc.	4.0	1,062	0.38%
Arizona Public Service Company	10.0	7,253	0.14%
Portland General Electric Company	5.0	3,816	0.13%

Q. HAVE SOME UTILITIES SET BATTERY PENETRATION GOALS THAT EXCEED THESE PENETRATION RATES?

A. Yes. Arizona Public Service, for example has stated a goal of 850 MW by 2025 or approximately 10% of its peak load. NV Energy recently announced intention to build 560 MW by 2023 or approximately 7.5% of its load. PNM is approximately one third the size of these utilities. Enovation Partners recommends that PNM adopt a target penetration rate for its introductory storage program phase that would place its system at the higher end of the above percentages for current in-service capacity. Near-term penetration rates above that level could foreclose the future opportunities discussed in this testimony. A target battery storage penetration rate in the range of 2% - 5% of peak load for this introductory phase of PNM's storage program would set a vigorous but prudent pace. PNM will have significant opportunities with the next ten years to add much more battery storage with improved technology and reduced pricing, providing higher benefits to PNM's customers.

III. EVOLUTION OF STORAGE USES

Q. HOW HAS THE USE OF ELECTROCHEMICAL STORAGE EVOLVED IN THE UNITED STATES?

A. Some utility systems have used pumped hydro storage for decades to store large amounts of energy. However, that storage technology is very difficult to site and has limited potential for most utilities. As the volume of renewable energy production grew rapidly in the U.S. in the 2000-2010 period, attention turned to other, more easily developed types of energy storage. Two policy actions early in the current decade catalyzed development of the initial sizable battery energy storage systems. In 2010, the state of California approved AB 2514[20], which was the nation's first mandate for electric utilities to procure storage resources on the grid. Two years later, the Federal Energy Regulatory Commission (FERC) approved Order 755. Order 755 required that wholesale market operators implement a "Pay for Performance" model that compensated owners of fast-responding energy storage technologies such as batteries for providing frequency regulation service.[21]

Shortly after that, a seminal 2015 study by the Rocky Mountain Institute (RMI) raised the prospect that battery energy storage projects could provide a multitude of services to the grid depending on where they were installed and how they were operated. This led to the idea that energy storage resources could "stack" values and improve the cost-effectiveness of the grid by reducing the need for single-use assets.[22]

Q. PLEASE SUMMARIZE THE RANGE OF SERVICES THAT BATTERY STORAGE CAN PROVIDE.

A. PNM Table WK-2 below summarizes the potential services or use cases electrochemical energy storage can provide at the utility level.

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[20] https://www.renewableenergyworld.com/articles/2016/11/at-the-halfway-point-the-effect-of-california-s-energy-storage-mandate.html
[21] https://www.ferc.gov/whats-new/comm-meet/2011/102011/E-28.pdf
[22] https://rmi.org/wp-content/uploads/2017/03/RMI-TheEconomicsOfBatteryEnergyStorage-FullReport-FINAL.pdf

PNM Table WK-2 – Electrochemical Storage Grid Services / Use Cases

Bulk Power	Network
Time Shifting Energy (Energy Arbitrage)	Resource Adequacy
Spinning / Non-Spinning Reserves	Transmission System Investment Deferral
Frequency Regulation / Voltage Support	Transmission Congestion Relief
Black Start	Distribution System Deferral

Q. PLEASE DEFINE THE BULK POWER USES OF STORAGE IDENTIFIED IN PNM TABLE WK-2.

A. **Time Shifting Energy**: storing electricity when it is lower cost and injecting it into the grid when prices are higher.

Spinning Reserves: the extra generation capacity that is available by increasing the power output of generators that are already connected to the power system.

Non-Spinning Reserves: extra generating capacity that is not currently connected to the system but can be brought online after a short delay.

Frequency Regulation: When system operators instruct generators to increase or decrease output in order to maintain a 60 Hz on the grid.

Black Start: the process of restoring an electric power station or a part of an electric grid to operation without relying on the external electric power.

Q. PLEASE DEFINE THE NETWORK SERVICES USES OF STORAGE IDENTIFIED IN PNM TABLE WK-2.

A. **Resource Adequacy**: Ensuring that utilities have acquired enough generation plus a reserve margin to satisfy peak load or demand.

Transmission System Investment Deferral: Using energy storage to avoid transmission investment, such as high voltage lines or substations.

Transmission Congestion Relief: Using storage to reduce transmission constraints.

Distribution Investment Deferral: Using energy storage to avoid distribution investments, such as feeders or substations.

Q. PLEASE EXPLAIN THE CONCEPT OF STORAGE USE CASES.

A. The ways in which utilities or energy consumers can use storage are now referred to as energy storage use cases. Since particular energy storage technologies may be better suited to serve the needs of particular use cases, Enovation Partners recognized that comparisons of energy storage technology costs and performance are more relevant when conducted within broad use cases. With the sponsorship and participation of Lazard Freres, the well-known investment bank, Enovation Partners now produces annually the Lazard Levelized Cost of Storage (LCOS) study. This study incorporates data collected from over 300 interviews with storage manufacturers, engineering companies and storage buyers. It is recognized as the industry benchmark for current information on storage costs and performance. The fourth and most recent LCOS study, from November 2018, is attached as PNM Exhibit WK-3.

Q. DID EARLY DEVELOPERS OF ELECTROCHEMICAL STORAGE TECHNOLOGIES HAVE ALL THESE USE CASES IN MIND?

A. No. As is the case with many new technologies, or existing technologies used for very different new purposes, the electricity industry's understanding of uses of electrochemical storage technologies expanded as more experience was gained. Similar broadening of application scope happened with other fundamental technologies such as lasers, semiconductors, the Internet and many others. The electricity industry is figuring out new ways to add value through this very flexible, modular resource.

Q. TO WHAT EXTENT CAN ENERGY STORAGE OWNERS HARVEST THE VALUE OF THE USE CASES IDENTIFIED IN PNM TABLE WK-2?

A. The ability of energy storage owners to monetize the use cases (i.e., to earn revenue from them) identified in PNM Table WK-2 is uneven, depending on whether the asset is located in a restructured or vertically integrated market. While this is expected to change in the near future[23], battery energy storage resources as of today cannot participate independently in restructured markets for wholesale energy and capacity markets, with the exception of the Resource

[23] FERC Order 841 requires regulated regional transmission organizations and independent system operators to develop an energy storage participation model that will enable those technologies to participate in energy and capacity markets.

Adequacy product in the CAISO market. Moreover, utility-owned energy storage resources today in many cases are prevented from providing storage services at market-based prices in restructured electricity markets.[24]

Q. IS IT EASIER FOR UTILITIES IN VERTICALLY INTEGRATED MARKETS TO REALIZE THE VALUE OF THE USE CASES OUTLINED IN PNM TABLE WK-2?

A. Yes. It is much easier for utilities in vertically-integrated markets to harvest the value of the range of utility-scale energy storage use cases outlined in PNM Table WK-2. Vertically integrated utilities do not face restrictions on generation ownership, nor do they require complicated solutions to calculate market values for transmission and distribution services. Under vertically integrated utility ownership, the resource can be dispatched as necessary for the specific service that is needed. So long as the utility maintains a safe and reliable grid, the storage resources under its control can provide generation, transmission, or distribution services, and need not participate in bidding and dispatch of discrete storage-related services as defined ISOs or RTOs.

[24] See CPUC rulemaking 15-03-011 on multiple use applications for energy storage. NYISO Market Issues Working Group: https://www.nyiso.com/documents/20142/5256593/DER+Energy+Market+Design+Dual+Participation+022819.pdf/cfaf3647-4b77-a706-b86d-24129d460ecf?version=1.2&download=true

IV. RISKS FROM EARLY TECHNOLOGY ADOPTION

Q. WHAT HAS THE ELECTRICTY INDUSTRY'S EXPERIENCE BEEN WITH EARLY STAGE GENERATION TECHNOLOGIES?

A. The industry has a great deal of experience with new technologies as well as major innovations of existing technologies. History has demonstrated that prudence is the best course of action when adopting a new generation technology. Experience with first generation nuclear plants bears this out. The Fermi 1 plant demonstrated a new nuclear technology: liquid metal cooled fast breeder reactor. It was constructed in 1963 and was expected to operate for 30 or more years. Due to several operational issues, the plant was forced to close prematurely in 1972.

Q. ARE THERE EXAMPLES OF OPERATIONAL DIFFICULTIES EVEN IN ADVANCED DESIGNS OF EXISTING GENERATION TECHNOLOGY?

A. Yes. In the 1990's gas turbine manufacturers responding to market conditions introduced new large frame type machines, generically designated as F & G type turbines. Swift load growth and cheap natural gas prices created demand for these turbines. After going into commercial operation these turbines experienced a number of problems including turbine blade failures, compressor disk cracking, and other serious problems. PNM Exhibit WK-4, a 2003 article from Power Engineering entitled "Gas Turbines: Breaking Through the Barriers to Higher Reliability," details the issues these turbine designs had from every major turbine manufacturer. In the course of a decade, the turbine manufacturers fixed the problems with the initial designs and eventually improved their efficiency and operating cost.

Another example is wind generation. Early wind turbines for electricity production had inefficient designs (e.g., the egg-beater) and were prone to metal fatigue in the blades.

Q. WHAT IS THE OUTLOOK FOR THE COST OF BATTERY STORAGE SYSTEMS?

A. As mentioned above, in the course of developing the annual LCOS studies for Lazard Freres and the industry, Enovation Partners interviews hundreds of industry participants including OEM's, developers, utilities, and financiers. Our Analytics division performs all of the LCOS calculations and market value snapshots. The 4.0 version of the study from November 2018 showed that the industry expects lithium-ion battery storage system costs to decline at a rate of 8% per year through 2022.

Q. HAVE WE SEEN COST DECLINES LIKE THIS WITH OTHER GENERATION TECHNOLOGIES?

A. Yes. The PV solar industry experienced a similar rapid drop in cost from approximately 2010 through today. Early adopters of PV solar power were saddled with what are currently massively over-priced power contracts or expensive utility owned generation. Lazard's Levelized Cost of Energy report from November 2018, version 12 of this benchmark series that I helped start in 2007, found that the median levelized cost of utility scale solar PPAs in the U.S. plummeted 88 percent from 2009 to 2018, from $358/MWh in 2009 to $43/MWh in 2018.[25] That downward price trajectory has continued, as witnessed by the levelized cost of solar of less than $20/MWh that PNM recently received. Wind energy has also experienced a significant cost decline in the U.S. Since 2010, wind energy has declined from $50-70/MWh to less than $20/MWh owing to significantly increased size and efficiency of individual wind turbines[26]. Lithium-ion battery storage will likely follow a similar downward cost curve in the coming years, although the slope may not be quite as steep as with PV.

V. CONSIDERATIONS IN ASSEMBLING PNM'S INITIAL STORAGE PORTFOLIO

Q. WHAT ARE THE ADVANTAGES OF DEVELOPERS CO-LOCATING BATTERY STORAGE WITH SOLAR FACILITIES?

A. Co-locating with solar farms allows developers to take immediate advantage of the Investment Tax Credit of up to 30% of the total capital cost as well as accelerated depreciation.

[25] Lazard's Levelized Cost of Energy Analysis – Version 12.0, November 2018. https://www.lazard.com/media/450784/lazards-levelized-cost-of-energy-version-120-vfinal.pdf

[26] U.S. DOE 2017 Wind Technologies Market Report; https://www.energy.gov/eere/wind/downloads/2017-wind-technologies-market-report

Q. WHAT DISADVANTAGES DO THESE DEVELOPER CO-LOCATED BIDS PRESENT TO PNM?

A. The primary disadvantages are location and limited control and operational ability. Since the batteries are being co-located with solar facilities, they are located in areas with lower land costs away from the Albuquerque load center and will provide limited reliability and system benefits. Another disadvantage is the fact that they are co-located with solar and will rely on upon solar charging for the first five years in order to qualify for the Investment Tax Credit. While solar charging has a cost advantage, these solar plus storage facilities will be prevented by the Investment Tax Credit rules from recharging with cheap excess wind energy from the grid at night and will therefore be unable to support the morning load ramp.

As discussed by PNM Witness Fallgren, the Brattle Group conducted a study that estimated the reductions in benefits from PPA storage bids due to less valuable locations and operational restrictions[27].

Q. WHAT OTHER CONCERNS ARE RAISED BY THE PPA BIDS RECEIVED FROM STORAGE DEVELOPERS?

A. The sizes of the proposed storage facilities raise several issues. The lowest cost bid received was for a battery storage project with a capacity of 150 MW, to be

[27] Brattle Locational Study, PNM Exhibit TGF-3.

co-located with a 300 MW solar facility in northwest New Mexico, the Arroyo project. The largest battery storage facility operating in the U.S. right now is the 40 MW Vista Energy Storage facility connected to the SDG&E grid in California. Clenera, the bidder on the 150 MW Arroyo storage facility, has never constructed a battery energy storage facility before, much less what would currently be the largest in the U.S by over a factor of three.

As mentioned above on page 9, a 2 MW BESS developed by Fluence in the Arizona Public Service territory experienced a catastrophic thermal runaway and fire in April 2019[28]. Fluence is a joint venture between AES Corporation and Siemens, two of the largest and most experienced players in electricity generation, and has developed 766 MW of storage globally. Yet Fluence still had this failure. The technology risk and risk of non-performance are real and deserve serious consideration.

Q. ARE THERE ADDITIONAL CONCERNS ASSOCIATED WITH THE SIZE OF THE PROPOSED ARROYO BATTERY STORAGE FACILITY?

A. Yes, such a large facility constructed far from the Albuquerque load center would lock PNM into existing technology in a disadvantageous location for well over 5% of its balancing area peak capacity. PNM would be less able to take advantage of projected declines is battery storage prices as well as inevitable

[28] See footnote 14 above

future technological innovations. Lastly, PNM would likely be forgoing other advantages of ownership.

Q. WHAT ARE THE ADVANTAGES OF UTILITY OWNERSHIP OF STORAGE FACILITIES?

A. Even though the PPA contract template in the recent storage RFP specifies that PNM will have operational control of storage facilities, PNM would not be responsible for maintaining the facility. Such a divorce of operational knowledge and its impacts on maintenance requirements is sub-optimal for such a new technology. Of course, since utility ownership would not require co-location with solar facilities, PNM would be free to take advantage of the operational learnings from optimizing location for grid and reliability benefits.

Q. HOW SHOULD PNM APPROACH DEVELOPING ITS STORAGE PROGRAM?

A. PNM would be prudent to exercise some caution in the size of each location and the overall storage build-out as a percentage of its peak load. An approach characterized by taking on smaller facilities in multiple locations over a reasonable period of time will allow PNM to gain the valuable knowledge and experience related to both the operating control and maintenance of battery facilities as well as their locational value to the grid and to system reliability.

Q. DO YOU HAVE ANY SPECIFIC RECOMMENDATIONS FOR PNM'S INITIAL IMPLEMENTATION OF ITS BATTERY STORAGE PROGRAM?

A. Yes, in addition to our previous recommendation of limiting the penetration of this initial implementation to between 2% and 5% of system peak, we strongly recommend limiting the size of individual facilities to between 10 MW and no more than 40 MW. We acknowledge that PNM wants to make a material move into increased integration of battery storage resources, a move that will bring significant benefits to the grid and to customers, but it should do so in a prudent manner.

Q. HOW SHOULD PNM POSITION ITSELF FOR FUTURE BATTERY INSTALLATIONS EITHER THROUGH A PPA OR UTILITY OWNERSHIP?

A. One of the key integration aspects for introducing batteries on the PNM system is the control systems that both protect the battery systems and allow for the maximum value of battery system to be realized across the PNM system. Our contacts in the storage and utility industries consistently expect that significant technology advances will be achieved in both control areas in the future. Utility ownership of some battery storage facilities will be critical for PNM to understand and gain experience in these areas to better inform future PPA or EPC contracts.

VI. MAXIMIZING STORAGE VALUE FOR CUSTOMERS

Q. WHAT MAJOR LESSONS FOR THE DESIGN OF PNM'S STORAGE PROGRAM CAN BE DRAWN FROM THE INDUSTRY'S PAST EXPERIENCE AND EXPECTED FUTURE TRENDS IN STORAGE?

A. My short list of major lessons learned includes:

1. Location is important. As the electricity industry has become more sophisticated in its understanding of how the speed of response and flexibility of electrochemical storage can be used, locational optimization has become more important. Storage can deliver much more value than merely the arbitrage gains of shifting energy delivery by a few hours. Costs of new T&D facilities can be deferred. A host of valuable ancillary services can be provided: spinning reserves, voltage support, fast/faster/fastest frequency regulation, black start, congestion relief, resource adequacy and others as shown in PNM Table WK-2 above. These services can improve customers' experience of power quality and reliability. But to harvest fully these types of value, storage facilities should be located close to major load centers – ideally adjacent to transmission substations with multiple distribution interconnections.
2. Avoid crash programs. Since storage costs are expected to decline substantially through the mid-2020s, utilities should proceed judiciously with their storage installations, and not build too far in

advance of need. A "just in time" approach to storage development will reduce the NPV of storage program costs, leverage future improvements in technology performance and safety, and increase the long-term value for customers. It will also allow utilities to use the experience they accumulate in their initial storage projects.

3. Minimize daylight between operations and ownership. The ownership structure should not get in the way of system operator using the full range of storage capabilities. The proportion of storage value derived from short duration, fast reaction services is increasing. To harvest that value, the electric system operator (or balancing authority in organized markets) must have full automated control over storage dispatch. Dispatch through manual, discrete transactions is too slow. Furthermore, the operation and maintenance of storage assets should be aligned fully with their optimal pattern of use. Restrictions in PPAs on frequency and depth of discharge due to developer concerns about warranties, or inadequate attention to maintenance or cell replacement where needed, can erode the value delivered by storage assets.

4. Build the required skills. Utility ownership of some battery storage facilities will be critical for PNM gaining valuable knowledge and experience related to not only the operating control and maintenance but also the locational value to the grid and system reliability, to better inform it future storage program expansion.

In a nutshell, utility-scale storage delivers highest value to the host utility system when it can be tightly integrated in both location and dispatch.

Q. WHAT ARE THE IMPLICATIONS OF THESE LESSONS LEARNED FOR PNM'S INITIAL STORAGE PROCUREMENTS?

A. Given the results of PNM's storage RFP, the following implications from industry lessons learned deserve consideration:

- PNM's system currently has a limited need for utility-scale storage. It should not "overbuild" now to meet later long term needs with its initial procurement. A smaller first bite would be wise.
- It does not make sense to locate a large portion of the long-term storage capacity needs in a far corner of system at the end of long radial line, as proposed in the Arroyo project. It will be less valuable in that location.
- While storage procured through the PPA model could in concept be sited and dispatched with utility direction, the cost savings in the PPA model (vs. the EPC model) are small could be outweighed by the reduced benefits caused by transaction inefficiency in dispatch and misalignment of asset management priorities.
- The best solution for customers is to allow PNM to own a substantial portion of the ultimate storage asset portfolio - while requiring price-competitive storage development costs. This would provide PNM with a better opportunity to learn how to optimize the use of storage assets,

achieve full value from real-time dispatch of a variety of storage services, and ensure safe and reliable operation.

VII. CONCLUSIONS

Q. PLEASE SUMMARIZE YOUR CONCLUSIONS.

A. My conclusions on the key issue I address are as follows:

- *Are the size and pace of PNM's storage program consistent with prevailing utility industry practices?*

  Yes. PNM's proposal in this filing for the first phase of its battery storage program is consistent the direction of its peers in states with heavy renewables penetration. Achieving cumulative storage capacity by 2022 that is in the range of two to five percent of its peak load sets a vigorous but prudent pace.

- *How can PNM use the results of its energy storage RFP to assemble a storage portfolio that represents the best long-term value for PNM's customers?*

  PNM should incorporate in its selection of proposed energy storage projects an approach characterized by taking on smaller facilities in multiple locations over a reasonable period of time. In addition to the target capacity range, PNM should limit the size of individual facilities to between 10 MW and no more than 40 MW. Finally, PNM should have the opportunity to gain valuable operations and maintenance experience with storage assets.

Q. DOES THIS CONCLUDE YOUR TESTIMONY?

A. Yes, it does.

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