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,	)	**19-______-UT**
FINANCING, AND RESOURCE REPLACEMENT	)	
FOR SAN JUAN GENERATING STATION	)	
PURSUANT TO THE ENERGY TRANSITION ACT	)	

DIRECT TESTIMONY

OF

GARY W. DORRIS

July 1, 2019

NMPRC CASE NO. 19-_____-UT
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GARY W. DORRIS

WITNESS FOR
PUBLIC SERVICE COMPANY OF NEW MEXICO

DIRECT TESTIMONY
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NMPRC CASE NO. 19-_____-UT

I. SUMMARY

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

A. My name is Gary W. Dorris. I am the Chief Executive Officer (CEO) of Ascend Analytics, LLC ("Ascend"). Our headquarters is located at 1877 Broadway Street, Suite 706, Boulder, CO 80302.

Q. ON WHOSE BEHALF ARE YOU TESTIFYING IN THIS PROCEEDING?

A. I am testifying on behalf of Public Service New Mexico ("PNM" or "the Company").

Q. PLEASE SUMMARIZE YOUR TESTIMONY

A. My testimony supports the prudency and cost-effectiveness of PNM's preferred portfolio of resources for the replacement of San Juan coal plant. PNM is replacing a single large inflexible resource with a clean and diverse mix of resources. This portfolio will provide PNM system operators improved flexibility to integrate the increasing amount of renewable energy envisaged by the Energy Transition Act (ETA). The preferred portfolio of 280[1] MW of aeroderivative natural gas turbines, 350 MW of solar, 140 MW of wind, and 130 MW of 2- and 4-hour lithium-ion batteries, represents the most economic and rational transition toward a 100% renewable plan. The thermal investments can operate on

[1] Net summer capacity of 269 MW.

hydrogen or biofuel, and thus offer the option of carbon-free backup capacity, to meet the 2045 ETA goal.

The selected *Scenario 1* portfolio utilizes wind and solar projects to provide low-cost energy to PNM customers with physical firming of these renewable resources through a diverse and distributed battery capacity. The two and four-hour duration batteries will provide several important services for PNM, including maximizing the use of renewable resources, managing resource intermittency by providing frequency regulation services, grid-hardening benefits for the transmission and distribution system, and providing a physical hedge to protect the rate payer from real-time price spikes associated with operations in the highly volatile Western Energy Imbalance Market (EIM). Ascend's modeling of sub-hourly market dynamics clearly indicates that batteries will provide a valuable service to PNM rate payers in the EIM. I endorse PNM's strategy to contract with several battery vendors on smaller projects versus one or two vendors on large projects to manage the risk that accompanies adoption of new technologies. Utility ownership of Sandia and Zamora 2-hour batteries will provide PNM with the maximum operational flexibility to serve multiple power products of regulation services and incremental energy related to the EIM. The level of control through ownership not only enhances the expected value across multiple power products, but also provides PNM the opportunity to gain experience in maximizing the value of batteries.

In this proceeding, PNM is taking appropriate and cost-effective steps to transition from a coal and gas-based energy supply to a renewable and clean supply supported by the proposed bank of LM 6000 aeroderivative engines located at San Juan. These aeroderivative engines are completely congruent with the objectives of New Mexico's 100% clean energy goals because:

1) they serve as a critical flexible capacity resource to integrate renewables and costs less than half of energy storage
2) they are the least-cost capacity resource
3) they can be utilized as zero carbon back-up capacity beyond their expected life burning either hydrogen or biofuel
4) they will serve as a necessary back-up capacity resources in a 100% carbon-free future when unfavorable meteorologies, such as extreme load conditions combined with a short-term wind-drought, depress renewable generation, and leave the batteries drained.

Ascend independently evaluated PNM's four core *Scenarios 1-4.* All four reasonably represent the range of available options. Ascend also constructed two additional no-gas portfolios to further examine, with more advanced storage modeling, that PNM's selected storage and renewable resources were the least cost and best fit.

We find that *Scenario 1*, the preferred portfolio, is the most cost-effective supply portfolio to transition to a carbon free energy supply and meet reliability requirements. *Scenario 2*, while reliable, is significantly more costly. *Scenario 3* is both more costly and less reliable than *Scenario 1. Scenario 4* is simply not reliable and would put PNM customers at risk of supply interruptions and thus the potential for blackouts. One of our no gas scenarios satisfied the loss of load reliability criteria and the other failed this criteria, but both were more costly than *Scenario 1* (Preferred) and *Scenario 3* (no gas).

II. QUALIFICATIONS INTRODUCTION

Q. PLEASE SUMMARIZE YOUR EDUCATIONAL AND PROFESSIONAL BACKGROUND.

A. I am founder and CEO of Ascend. Ascend is an energy analytics software and consulting company that provides economic, financial, and technology solutions for the electric power industry, particularly in the area of long-term resource planning, energy supply procurement, asset valuation, portfolio risk management, quantitative modeling, and complex litigation.

I have been involved in the energy industry for over 25 years and have extensive experience in advising corporations in complex decision analysis, energy asset valuation, and risk management. I have also provided independent expert reports to support the valuation and financing of over $10 billion in electric generating assets. I have written and delivered expert testimony regarding risk management, energy procurement, trading practices, asset valuation, market power, and emissions trading. I have also led the analytic architecture of over ten analytic software products used by 30 of the top 100 energy companies.

Before founding Ascend, I served as CEO and Chief Model Architect for e-Acumen, a 60-person energy consultancy and software analytics firm, which was sold to Ventyx, an ABB subsidiary. I have also directed the development of the analytic infrastructure and risk management policies for the launching of the trading floors of Entergy Solutions, Duke Solutions, The Energy Authority, and Consolidated Edison, and led the development of the analytic infrastructure solutions for portfolio and risk management solutions at over a dozen other utilities.

I was also a faculty member at Cornell University in 1996, where I taught a doctoral-level course in modeling competitive energy markets and have been adjunct faculty at University of Colorado's Leeds Business School from 1997 to 2007. I have published papers on energy trading and risk management in peer-reviewed scholarly journals and have spoken at over 100 conferences on resource planning, battery storage economics, portfolio management, risk analysis, and modeling of competitive energy markets. I hold a PhD in applied economics and finance from Cornell University and both a BS in mechanical engineering and a BA in economics with Magna Cum Laude distinction from Cornell University. My Curriculum Vitae is attached as PNM Exhibit GWD-1.

I reserve the right to update and supplement my expert testimony as may be necessary.

Q. PLEASE SUMMARIZE ASCEND ANALYTIC'S EXPERIENCE IN RESOURCE PLANNING AND SELECTION.

A. Ascend actively works with utilities across the United States supporting resource planning activities with our advanced analytical tools including: Ameren, Austin Energy, Burbank Water & Power, City of San Francisco, Dayton Power & Light, Duke, Glendale Water and Power, Hawaiian Electric Utilities, Indianapolis Power and Light, Los Angeles Department of Water and Power, Monterey Bay Clean Energy, New York Power Authority, NorthWestern Energy, Peninsula Clean Energy, Puget Sound Energy, Redding Utilities, Riverside Public Utilities, Salt River Project, Silicon Valley Clean Energy, and Turlock Irrigation District.

We specialize in resource planning for high renewables systems and have recently developed integrated resource plans for Hawaiian Electric (100% renewable by 2045), Burbank Water and Power, Glendale Water and Power, and Reading (all 60% renewable by 2030 and 100% carbon free by 2045), and NorthWestern Energy. We excel in planning for high renewables systems because of our ability to accurately model the energy system conditions that emerge from adding large amounts of weather-driven intermittent power resources and the hourly/sub-hourly market and system dynamics relevant to balancing high renewable systems. We find that prudent decisions regarding the resources of the future can only be made when modeling captures the increasingly volatile system dynamics we expect to see as we transition towards a renewables-based energy system. This new approach to resource planning with a strong focus on weather driving the volatility of supply and inclusion of sub-hourly operations is what we call Resource Planning 2.0.[2]

Q. WHAT IS THE PURPOSE OF YOUR TESTIMONY?

A. My testimony is intended to provide my view on the economics and reliability of the portfolios developed to replace San Juan coal plant. PNM provided Ascend with a set of portfolios and resource bids for independent evaluation. Ascend developed fundamental forecasts regarding market conditions and evaluated the recommended and other potential portfolios using Ascend's resource planning model PowerSimm. PowerSimm adds a powerful new element to the analysis of resource value by capturing:

1) sub-hourly nodal interactions (5 and 15-minute market conditions) with the EIM,
2) new system and power market dynamics of a more volatile energy landscape with weather as a fundamental driver of renewable energy production, load, and market prices, and
3) battery storage economics including detailed value stacking and physical state-of-charge controls.

[2] Additional details of select project activities are contained in PNM Exhibit GWD-2.

By adding these critical analytic elements, Ascend evaluated the relative benefits of candidate portfolios and I will communicate our view of what is the best portfolio for PNM rate payers given a rapidly changing energy environment in the Western Energy Coordinating Council (WECC) grid.

Q. HOW IS YOUR TESTIMONY ORGANIZED?

A. Section II describes the credentials of myself and my firm Ascend Analytics in resource planning for high renewables systems. Section III describes the impact of WECC transitioning to near carbon free energy and its bearing on resource selection. In Section IV, I present the valuation and reliability analysis of the final four PNM selected energy supply portfolios plus two additional thermal free portfolios. The valuation uniquely includes a sub-hourly credit for operations to the EIM real-time prices and examines the utilization of the aeroderivative turbines as back-up capacity in 2045 with a no-carbon fuel. PNM Exhibit GWD-1 contains my Curriculum Vitae. PNM Exhibit GWD-2 describes Ascend's recent experience performing resource planning. PNM Exhibit GWD-3 provides a more detailed discussion of the evolving power market dynamics in the WECC and fundamental modeling performed in support of the analysis.

III. CHANGING MARKET DYNAMICS AND IMPLICATIONS FOR PNM RESOURCE DECISION MAKING

Q. WHAT CHANGES ARE OCCURRING IN THE WESTERN GRID WITH REGARDS TO RENEWABLE EXPANSION AND HOW SHOULD THAT AFFECT PNM'S RESOURCE DECISION MAKING WITH RESPECT TO SAN JUAN COAL PLANT REPLACEMENT?

A. To summarize, we believe that the WECC in 2045 will include a diversified mix of renewables, storage, and flexible thermal generation, powered by a mixture of hydrogen, bio-gas, and natural gas.[3] These thermal resources will serve as critical back up when meteorological regimes conspire to provide low renewable energy production in conjunction with high loads that drain energy storage. As I explain later, PNM's replacement portfolio for San Juan coal plant perfectly fits this blueprint of a supply portfolio to transition to a carbon free future. The portfolio physically and economically combines to provide a pathway toward a least cost future of carbon free energy.

Q. HOW DO CHANGES IN WESTERN ENERGY MARKET STRUCTURES AFFECT PNM'S RESOURCE DECISION MAKING WITH RESPECT TO SAN JUAN COAL PLANT REPLACEMENT?

A. The Western Energy Imbalance Market (EIM) is a rapidly expanding program that allows vertically integrated balancing authorities like PNM to purchase and

[3] Please see PNM Exhibit GWD-3 for a detailed discussion of changes in the western energy landscape.

sell energy in 15 and 5-minute (aka "real-time") energy markets. PNM has indicated that it will join the EIM in April 2021. The EIM is a computerized dispatch of participating resources and loads run by the California Independent System Operator (CAISO). The purpose of the real-time markets is to efficiently solve imbalances between generation and load between the day-ahead forecast and the realized system conditions. PNM can benefit from the EIM by allowing the CAISO to pay PNM's resources to ramp up or down. PNM can also benefit by purchasing energy to make up a short position between day-ahead and real-time instead of ramping up a more costly PNM resource.

Participants in the EIM settle load and resources to nodal specific real-time market prices. The EIM construct adds a critical dimension to resource planning for PNM by providing a transparent market price for the calculation of the cost to serve load on a 5-minute basis and an opportunity cost to realize revenue in response to the 5-minute prices. EIM stakeholders are actively discussing broadening the EIM to include the day-ahead market, where about 95 percent of California's energy is scheduled and traded. The extension of EIM to a day-ahead market provides gains in economic efficiency for the day-ahead market transactions relative to the current "over-the-counter" system. These efficiency gains in economic power transactions will help integrate increasing penetrations of renewable energy across a large geographic footprint. Our expectation is that within the next five years, this opening up of EIM to the day-ahead will be enacted. We may even see the adoption of a west-wide Regional Transmission

Organization (RTO), which would completely centralize the optimization of all western loads and resources under a single organization.

Because of the new market dynamic imposed through the EIM, PNM's decision-making with respect to replacement resources for the San Juan coal plant should move to reflect two critical aspects:

1) Resource Economics: Participation in the EIM means PNM's resources should include economic valuation in terms of the 15 and 5 minute market prices of power. For a replacement portfolio to be successful, it should account for EIM price levels and volatility, today and forecast into the foreseeable future.
2) Reliability: Participation in the EIM still requires PNM to control enough capacity that it can maintain its resource self-sufficiency in the absence of the market. In other words, the EIM does not relieve PNM from its responsibility to control enough variable and dispatchable generation to supply its own native load.

Evaluation of these two aspects, (1) resource economics and (2) reliability, along with PNM's goal for 100% clean energy production should also subsume the November 16, 2018 National Association of Regulatory Commissioners (NARUC) resolution for "Resolution on Modeling Energy Storage and Other Flexible Resources".[4] This resolution states the need for models to incorporate sub-hourly

[4] https://pubs.naruc.org/pub/2BC7B6ED-C11C-31C9-21FC-EAF8B38A6EBF

dynamics for evaluation of resource economics and renewable integration by stating:

"*Planning frameworks and modeling tools that are publicly and commercially available should model the full spectrum of services that energy storage and flexible resources are capable of providing, including subhourly services. Utilities should analyze a range of flexible resource options, such as energy storage, and current cost assumptions in their modelling, due to the diverse characteristics and resource lives of different technologies, with the goal of identifying and pursuing the most cost-effective opportunities that best meet the needs of the utilities' systems*".

Q. HOW DOES THE COMBINATION OF CHANGING MARKET DYNAMICS IN THE WECC AND THE INCORPORATION OF PNM IN ENERGY MARKETS AFFECT RESOURCE SELECTION FOR SAN JUAN COAL PLANT REPLACEMENT?

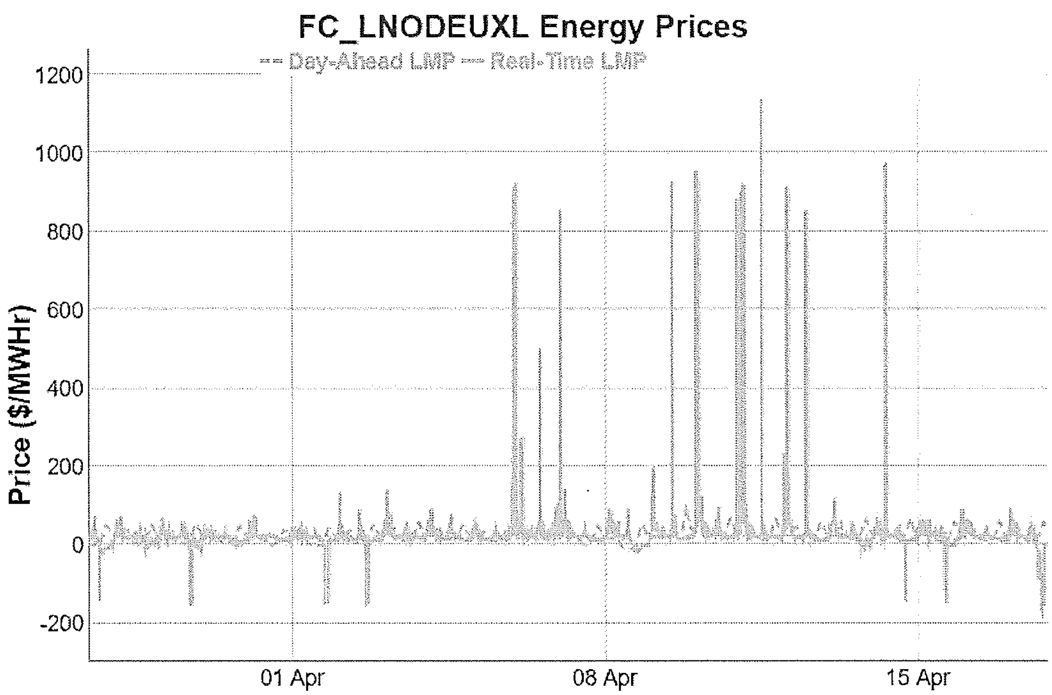
A. Renewables are rapidly becoming the principal energy supply resource of the west. The structural change in power supply realized through increasing renewables impacts the dynamics of power market prices, which in turn, impacts market prices. Regional power market prices exhibit a precipitous and continuous rise in volatility as a direct function of increasing renewables. We have observed a consistent annual increase in price volatility, with grid connected renewable penetration increasing from 8% in 2014 to 19% in 2018 and volatility in prices nearly tripling in the day-ahead market and a one and a half fold increase in the real-time market as shown in PNM Table GWD-1.[5] This increase in volatility is a direct result of increasing amounts of intermittent renewable generation.

PNM Table GWD-1: Renewable Penetration vs Price Volatility

Year	Renewable Penetration	Standard Deviation in DA Prices ($/MWh)	Standard Deviation in RT Prices ($/MWh)
2014	8%	12	53
2018	19%	38	72

PNM Figure GWD-1 shows a typical time series of real-time and day-ahead prices for the Four Corners node in northwestern New Mexico.

PNM Figure GWD-1: Typical Price Spike Behavior in the EIM



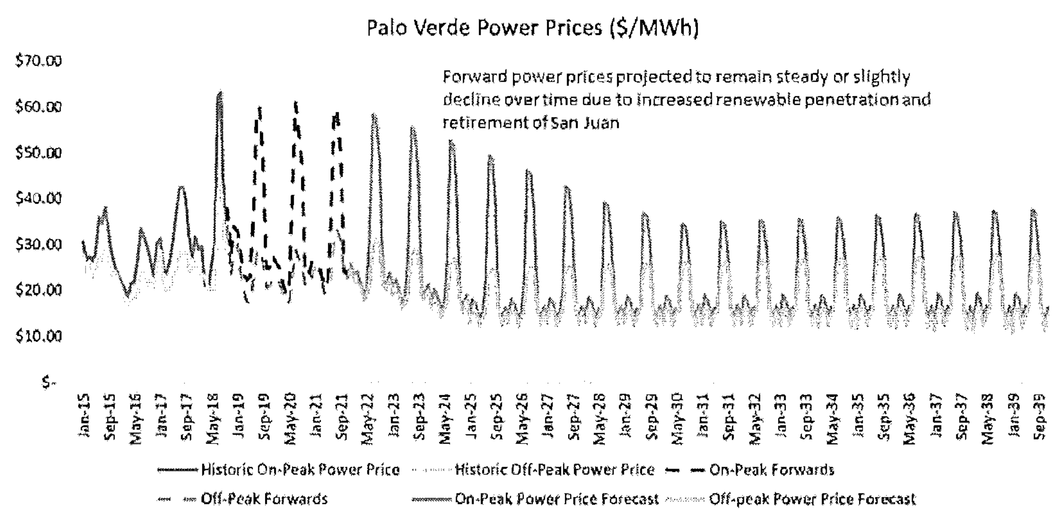
[5]Volatility is measured in terms of standard deviation of prices in $/MWh.

As more renewables are added to the system over time, we expect the frequency of positive and negative price spikes to increase concomitantly. Within this context of increased volatility, the resources best suited to dispatch and provide value for PNM ratepayers are highly flexible and dispatchable. Flexible generation can be called to capture the full value of price spikes by turning on and off quickly and economically and ramping up to full power quickly and efficiently. These resources include batteries, reciprocating engines, and aeroderivative engines. Resources that fare poorly in terms of flexibility include large frame style turbines, combined cycles and coal plants. PNM Exhibit GWD-3 includes further discussion of Ascend's outlook on hourly and sub-hourly price dynamics for the EIM.

Q. WHAT WERE YOUR INPUTS REGARDING POWER PRICES AND IMPLIED HEAT RATES IN THE FUTURE?

A. Ascend's forward price forecast is shown in PNM Figure GWD-2:

PNM Figure GWD-2: Palo Verde Power Price Forecast



Ascend forecasts power prices through a blending of forward market prices through the end of 2021 and a fundamentals-based forecast from 2022 through 2040. As described above and in PNM Exhibit GWD-3, prices remain relatively flat in real dollar terms as low-cost renewables flood the system. We forecast gas prices to increase at inflation after the forward curve for gas ends in 2023, which results in a market declining implied market heat rates.[6]

Ascend forecasts declining implied heat rates from an average of 11 to 7.5 MMBTU/MWh between today and 2030. On the other hand, we assume increased price volatility driven by renewable intermittency, until the time batteries become substantially deployed onto the grid.

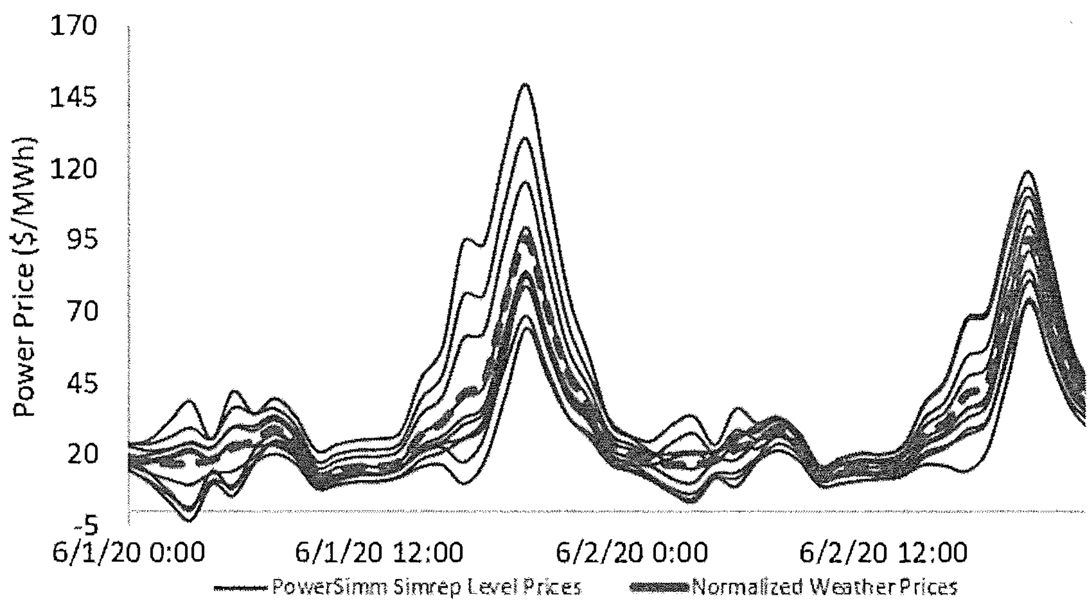
Q. HOW DOES POWERSIMM DIFFER FROM TRADITIONAL RESOURCE PLANNING MODELS AND WHY IS THAT IMPORTANT GIVEN THE CHANGES IN ENERGY MARKET DYNAMICS DESCRIBED ABOVE?

A. PowerSimm is a power system optimization/production cost modeling tool with deep roots in quantifying uncertainty and risk, making it a perfect fit for evaluation of high renewable energy portfolios. PowerSimm addresses this inherent uncertainty in supply and market conditions by creating a coherent and validated construct that generates renewable output, load, and energy prices as a function of simulated weather, the shared core driver. Instead of a single

[6] Implied heat rates are determined by dividing the price of power in $/MWh by the price of natural gas $/MBtu, realizing an average system conversion efficiency of gas to power in units of MBtu/MWh.

deterministic and weather-normalized run, PowerSimm simulates hundreds of hourly and sub-hourly system conditions rigorously benchmarked to current and evolving system fundamentals. Dispatch and market interactions are optimized to respond to the increasingly volatile simulated price conditions, thereby revealing the true value of flexible generation.

PNM Figure GWD-3: PowerSimm Simulated Prices vs Weather Normalized Prices



We are also able to run PowerSimm at a sub-hourly time increment and therefore simulate the behavior and economics of resources in the EIM and specifically reveal the value of flexible resources to benefit from volatility.

By creating conditions favorable to energy storage reflected through the highly volatile EIM market, PowerSimm provides a solid framework to remove traditional biases in resource selection. PowerSimm realizes the full economic value of battery storage through co-optimization between system ancillary services and the 5-minute energy market. The optimization engine of PowerSimm provides realistic values for storage by limiting foresight of future system conditions and actively managing the state of charge inclusive of degradation and depth of discharge constraints. The physical and economic modeling constructs have traditionally proven to select battery storage as a supply resource in the WECC, when other modeling frameworks realize less economic and reliability value.

IV. EVALUATION OF REPLACEMENT RESOURCES FOR SAN JUAN COAL PLANT

Q. HOW DID YOU EVALUATE THE REPLACEMENT OPTIONS FOR SAN JUAN COAL PLANT?

A. Ascend modeled PNM's power system in PowerSimm, including the transmission system, access to regional markets, and EIM market value through sub-hourly analysis. All assumptions were independently developed by Ascend, including PNM's renewable portfolio[7] needed over time to meet the requirements of the Energy Transition Act.

For the replacement portfolio analysis, PNM provided Ascend with its top four portfolios as shown in PNM Table GWD-2 below.

[7] See Figure C-7 in PNM Exhibit GWD-3

PNM Table GWD-2: Portfolios Analyzed for San Juan Coal Plant Replacement

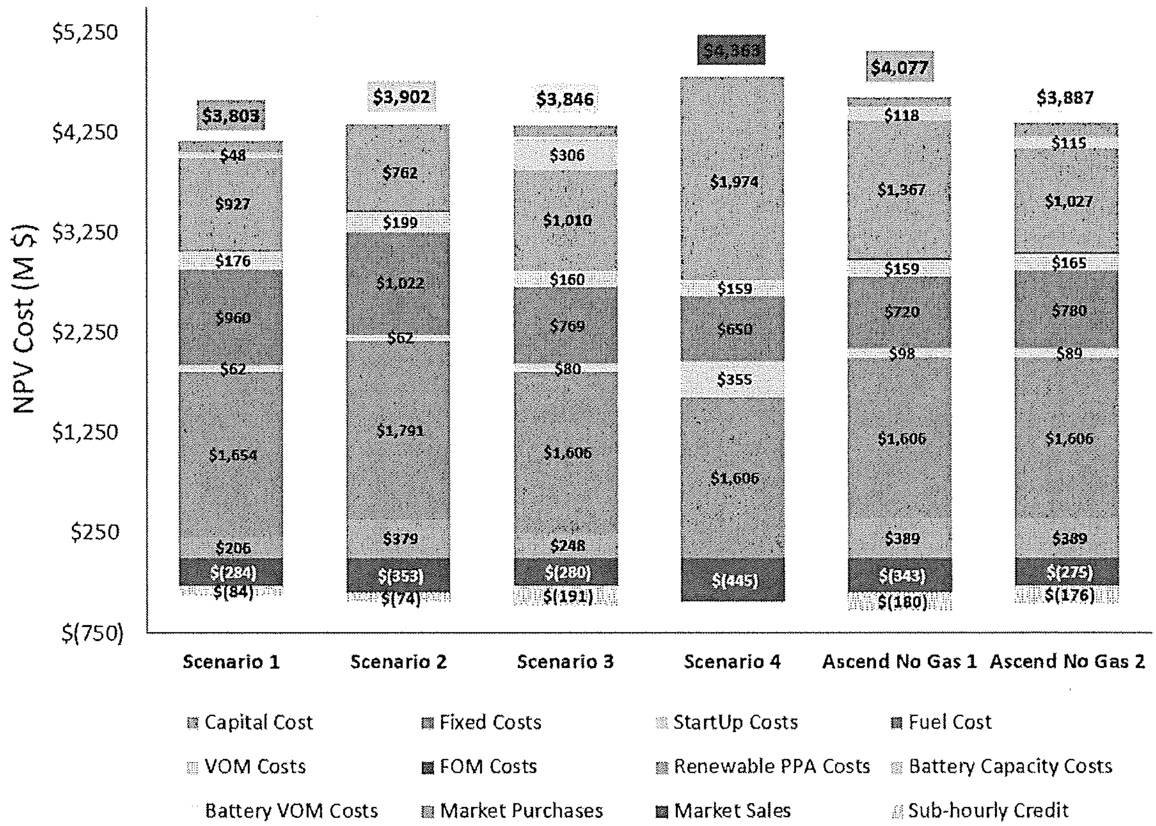
Portfolio Name	Thermal (MW)	Batteries (MW-Duration)	Solar (MW)	Wind (MW)
Scenario 1	7 aeroderivatives (268 MW)	60 MW – 4 hr 70 MW– 2 hr	350	140
Scenario 2	1 Frame (196 MW) 7 aeroderivatives (268 MW)	None	-	140
Scenario 3	None	260 MW – 4 hr 160 MW – 2 hr	500	140
Scenario 4	None	None	975	1199
Ascend No Gas 1	-	100 – 4 hour 300 – 2 hour	500	540
Ascend No Gas 2	-	150 – 4 hour 300 – 2 hour	200	140

Ascend modeled these portfolios for cost and reliability impacts. Ascend also developed two additional no gas portfolios to determine whether a completely carbon free portfolio would be economic and reliable.

Q. WHAT IS YOUR ECONOMIC ASSESSMENT OF THE SAN JUAN COAL PLANT PORTFOLIOS?

A. PNM Figure GWD-4 below shows Ascend's assessment of the four PNM scenarios and Ascend's additional sensitivities with additional details presented in PNM Table GWD-3.

1 **PNM Figure GWD-4: Comparison of Net Present Value Portfolio Costs**



2 **PNM Table GWD-3: Economic Analysis with PowerSimm**

Portfolio Name	Capital Cost	Production Cost	PPA Cost	Hourly Market Value	EIM Benefit	Total NPV
Scenario 1	206	2,911	927	-157	-84	3,803
Scenario 2	379	3,091	762	-256	-74	3,902
Scenario 3	248	2,939	1,010	-160	-191	3,846
Scenario 4	0	2,773	1,974	-383	0	4,363
Ascend No Gas 1	389	2,752	1,367	-251	-180	4,077
Ascend No Gas 2	389	2,790	1,027	-143	-176	3,887

The bar charts show the breakdown of system costs[8] to serve load plus the market benefits from interactions with hourly markets and the Energy Imbalance Market (shown as "EIM benefit" in gray cross hatch pattern).

Q. IS PNM'S PREFERRED PORTFOLIO RELIABLE WITH RESPECT TO PEAK CAPACITY?

A. Yes, Ascend's LOLH (Loss of Load Hours) analysis shows that PNM's preferred portfolio can reliably serve demand. LOLH determines the number of hours that PNM's capacity is insufficient to serve load and a shortfall will be observed. Ascend's model considers hourly dispatch results and determines whether PNM had enough capacity to serve load during each hour. The accepted criterion for this metric is 2.4 hours per year.[9] PNM Table GWD-4 shows the LOLH results for different portfolios.

PNM Table GWD-4: LOLH for Candidate Portfolios

Portfolio Name	LOLH 2023	LOLH 2030	LOLH 2038	Pass/Fail
Scenario 1	0	2.1	0.8	Pass
Scenario 2	0	1.1	0.5	Pass
Scenario 3	1.3	3.3	2.3	Fail
Scenario 4	181	255	205	Fail
Ascend No Gas 1	.4	2.3	1.9	Pass
Ascend No Gas 2	1.3	5.5	6.7	Fail

[8] These include fuel costs, variable operations and maintenance costs, startup costs, fixed operations and maintenance costs, other fixed costs, and PPA costs for energy (in green) and battery capacity (in yellow).
[9] Loss of load expectation (LOLE) is a similar metric to loss of load hours (LOLH). The comparable LOLE is 0.2, which is used by Astrape in its reliability analysis.

We find that *Scenario 1*, the preferred portfolio, is the most cost-effective supply portfolio to transition to a carbon free energy supply and meet reliability requirements. *Scenario 2*, while reliable, is significantly more costly. Scenario 3 is both more costly and less reliable than *Scenario 1. Scenario 4* is simply not reliable and would put PNM customers at risk of supply interruptions and thus the potential for blackouts. Our no gas scenarios were reliable but were more costly than *Scenario 1*.

Q. IS PNM'S PREFERRED PORTFOLIO RELIABLE WITH RESPECT TO FLEXIBLE CAPACITY FOR RENEWABLE INTEGRATION?

A. Yes, PNM's preferred portfolio adds 130 MW of highly flexible batteries and 280 MW of flexible aeroderivative gas turbines. According to an analysis Ascend has performed on PNM's system assuming 50 percent renewable by 2030 and 100% clean by 2045, PNM requires the amounts of flexible generation shown in PNM Table GWD-5.

PNM Table GWD-5: Estimated Flexible Capacity Need to Meet ETA Goals

Year	Regulation Reserves (MW)	15-minute Ramping Capability (INC/DEC)	Total Requirement
2020	66	246	430
2025	104	374	604
2030	117	427	678
2035	149	508	803

We separate flexible capacity requirements into two primary categories: regulation and 15-minute "INC". Regulation is the ability for a generator to move up or down at a 1-minute time scale. This is best used to smooth out short duration perturbations in generation and load. Batteries do an excellent job of providing this service economically and the 130 MW of batteries proposed in this plan cover this need through 2030. INC (or its opposite "DEC") are 15-minute ramps that smooth out renewables that have their production reduced by sudden drops in wind or transient cloudiness. These fast ramps are needed to maintain WECC standards for energy load balance across a 30-minute rolling time horizon. Batteries and the aeroderivatives can provide this service along with purchases or sales in the EIM. Between the batteries, aeroderivatives, and the EIM, PNM should not have a shortage of resources to cover INC/DEC requirements in the foreseeable future.

Q. HOW DOES PARTICIPATION IN THE EIM AFFECT THE VALUE OF PNM'S PREFERRED PORTFOLIO?

A. Ascend assumed new batteries and the aeroderivative turbines would be nominated as EIM participating resources. In Ascend's modeling construct, these resources provide both ancillary services such as regulating reserves and respond to price signals in the 15- and 5-minute energy markets. Ascend based its sub-hourly modeling on the prices at the nearby EIM node: DGAP-PNM-APND. To avoid overvaluing the resources through the use of "perfect foresight" into the prices, Ascend set fixed hours for resources to either perform ancillary services for PNM's system or bid into the EIM based on historical price patterns. Typically, real time price spikes that are advantaged for energy bids occur in the mid-day to late afternoon, therefore we schedule the resources to bid into energy markets during these times and provide regulation and spin at night.

Accordingly, the model calculates a reasonable value estimate for the additional value that can be generated from flexible resources in the EIM. This value is called the "EIM benefit" which is appended onto the results of the hourly production cost runs for final decision analysis. The forecast of the sub-hourly benefit related to the volatility forecast shown above, since price volatility is a direct driver of sub-hourly resource value. PNM Table GWD-6 shows Ascend's estimate for EIM benefit by resource type including power purchase agreement (PPA) and utility-owned generation (UOG):

PNM Table GWD-6: EIM Benefit in $/kw-year

Year	PPA – 4 hour battery	UOG – 4 hour battery	UOG – 2 hour battery	UOG – 1 hour battery	LM 6000
2022	100	105	101	92	44
2023	117	123	118	107	51
2024	100	105	101	92	44
2025	83	88	85	77	37
2026	67	70	68	61	29
2027	67	70	68	61	29

The EIM benefit reflects increases from 2022 to 2023 and then declines thereafter until an equilibrium is reached in 2026. The first-year increase in benefit reflects a perpetuation of current market dynamics of increasing volatility and value of flexible generation with increasing storage. However, new unit entry forecasts have these conditions of "super-normal" returns for flexible generation migrating to toward "normal returns" by 2026.[10]

Q. PNM PROPOSES A PORTFOLIO OF FOUR-HOUR DURATION BATTERIES TIED TO SOLAR FACILITIES UNDER POWER PURCHASE AGREEMENTS AND TWO-HOUR DURATION UTILITY OWNED STAND-ALONE BATTERIES. IS THIS A PRUDENT STRATEGY GIVEN THE STATE OF THE BATTERY MARKET TODAY?

A. Yes. Batteries are a critical technology to enable the transition to a reliable clean energy electricity system, but as with any new technology in the power sector, there are some technology risks as discussed in William Kemp's testimony. PNM has decided to limit any one storage project to 40 MW or less and contract with several vendors instead of just one or two. This diverse risk-managed portfolio approach is reasonable given PNM's growing reliance on battery technology to meet peak demand.

I also recommend PNM's strategy to purchase two two-hour battery projects under utility ownership because of the greater economic value and operational flexibility. There is only a 14% gain in energy value going from a one-hour to a four-hour battery system, but the cost increases by 300%. PNM Table GWD-5

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[10] Normal returns reflect an 8% expected return.

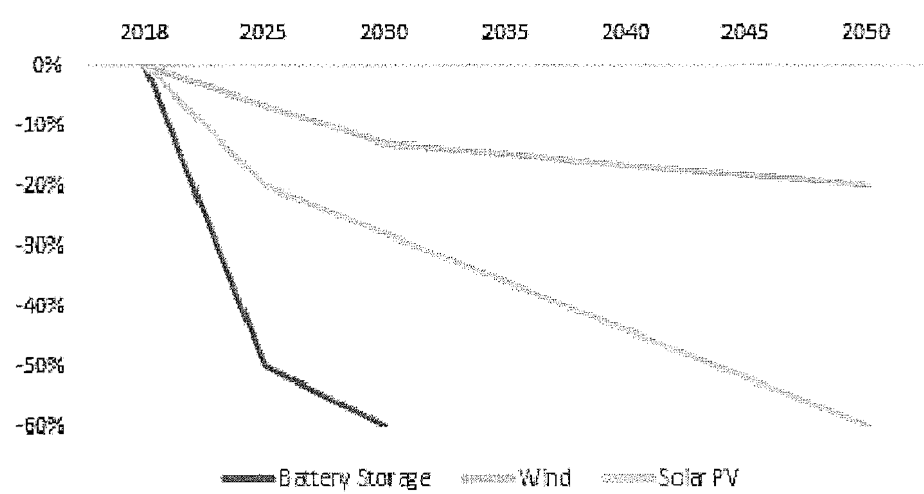
shows that the value of the battery in the EIM lies in the maximum power, not the duration, thus a 4-hour battery can earn $105/kw-year while a 1-hour battery can earn $92/kw-year. The corresponding capital costs are approximately $1,350/kW for the 4-hour and $450/kW for a 1-hour battery, making clear the concept that without the benefit of the ITC, shorter duration batteries are more cost-effective today for utility ownership. The choice of two-hour duration battery is also prudent because the majority of cost declines will be in the cost of the battery packs (i.e. the storage part) rather than the balance of plant (including inverters, racks, cooling equipment, etc.). As the cost of battery packs decline, PNM can add storage capacity later when it is more cost-effective.

PNM system operators will have complete flexibility to maximize battery storage across several value streams, including ancillary services, minimizing renewable curtailment, and capturing the value of price volatility in the EIM. Ownership will also allow the important benefit of providing PNM system operators with the organizational learning needed to take on increasing amounts of battery capacity onto the system over time. We also evaluated several PPA solar and storage projects that capture the full value of the Investment Tax Credit (ITC). These projects tend to have more physical restrictions such as cycle and state of charge limits, since the operator maximizes the value of the ITC by only charging from the solar during the first five years of operation. A standalone battery cannot take advantage of the ITC, but it provides more operational flexibility and capacity contribution with full grid charging and no stranded state of charge limitations during events where the battery would be needed for reliability to provide energy.

Q. IF PNM HAS AN OBLIGATION TO ACHIEVE 80 PERCENT RENEWABLE ENERGY AND 100 PERCENT CARBON FREE ELECTRICITY BY 2045, DOES IT MAKE SENSE TO ADD NEW GAS NOW?

A. Yes. At first this seems counter intuitive, but it makes perfect sense from an economic and reliability perspective. To track towards 100 percent clean energy, PNM must retire legacy coal and gas units and replace the capacity with flexible and ultimately non-emitting capacity resources. Batteries today can serve as capacity resources primarily charged by renewables, but from an economic perspective, it benefits PNM rate payers to wait until the industry matures and prices drop dramatically between now and the mid-2020s as shown in PNM Figure GWD-5 below.

PNM Figure GWD-5: NREL cumulative projected declines in technology cost



The National Renewable Energy Lab[11], Bloomberg New Energy Finance,[12] among others are projecting steep declines in battery storage costs through 2025 and continued moderate declines through 2030. In this environment, limiting battery procurement to 60 MW of 4-hour duration battery and 70 MW of 2-hour duration batteries strikes a reasonable balance between the desire to avoid out-of-the-money investments in a declining cost technology while still taking a substantial step towards building the clean energy system of the future.

If it pays to wait until storage technology matures, it follows that PNM should secure low cost flexible capacity today as part of the solution to replace San Juan coal plant's retiring capacity. Aero derivative turbines are a mature technology and these units are grey market and thus extremely attractive from a cost standpoint. These units will play an important role for PNM's clean energy transition.

The role of the aeroderivatives is to enable the retirement of less flexible coal and gas resources by providing *critical back-up power* when meteorological conditions are unfavorable for reliable self-supply of electricity. Critical back up power means the units capacity factors will be low and decline over time. Their role is not to provide energy; the renewables fulfill that purpose, but only to start

[11] Values taken from the NREL Annual Technology Baseline: https://atb.nrel.gov/electricity/data.html
[12] https://about.bnef.com/blog/behind-scenes-take-lithium-ion-battery-prices/

up and deliver capacity when the system needs short bursts of energy. According to our modeling, the capacity factor of the aeroderivatives would be as follows:

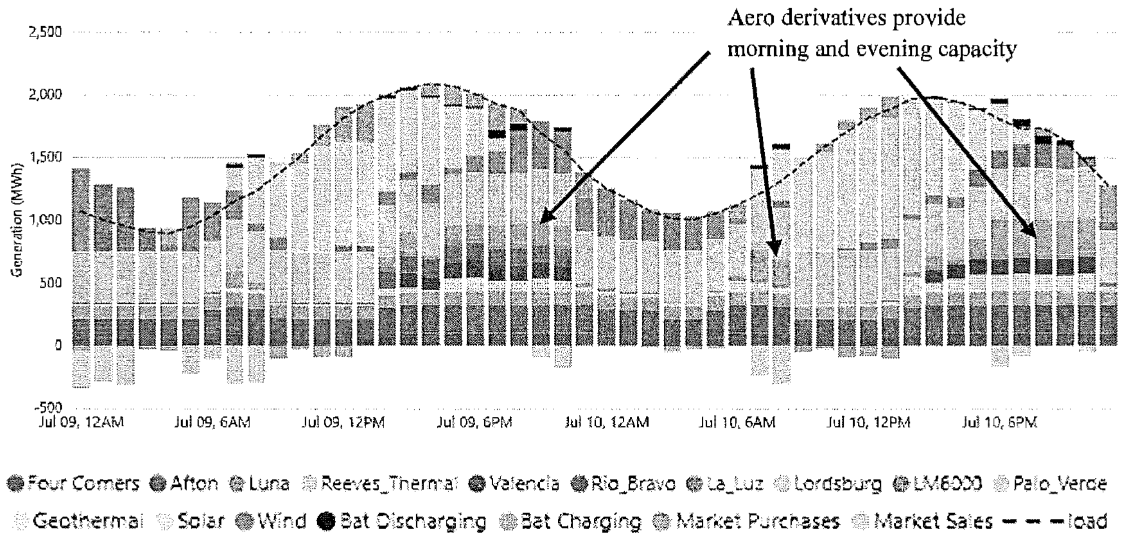
PNM Table GWD-7: Simulated Average Annual Capacity Factors for Aero Derivatives

	2022	2025	2030	2035	2040
Capacity Factor	18%	9%	7%	6%	5%

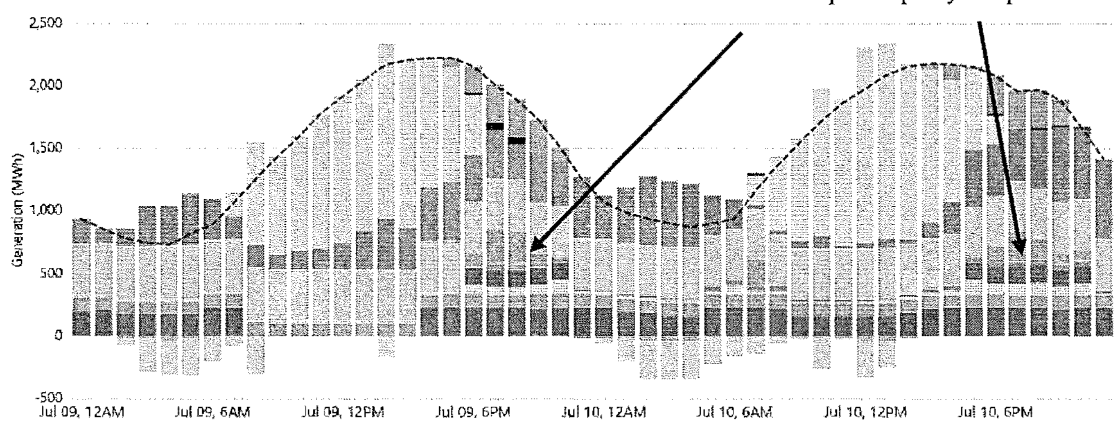
From the traditional Resource Planning 1.0 perspective, these units could be considered underutilized. However, in the new energy paradigm under Resource Planning 2.0, we find these units performing exactly the job we want and expect: to provide peaking capacity with a high level of flexibility while letting renewables provide the vast amount of system energy. PNM Figure GWD-6a-d shows this concept graphically.

PNM Figure GWD-6a-d: Hourly Dispatch of PNM System: Scenario 1

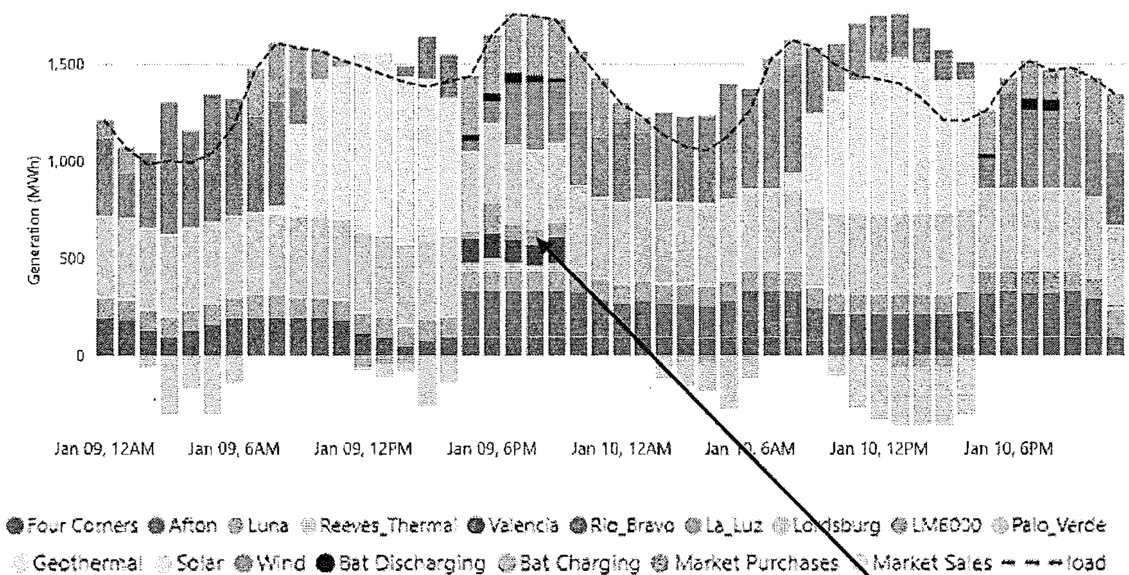
Figure 6a: Summer 2025



PNM Figure GWD 6b: Summer Nearly all energy provided by renewables and nuclear. Aeros provide less peak capacity compared with 2025



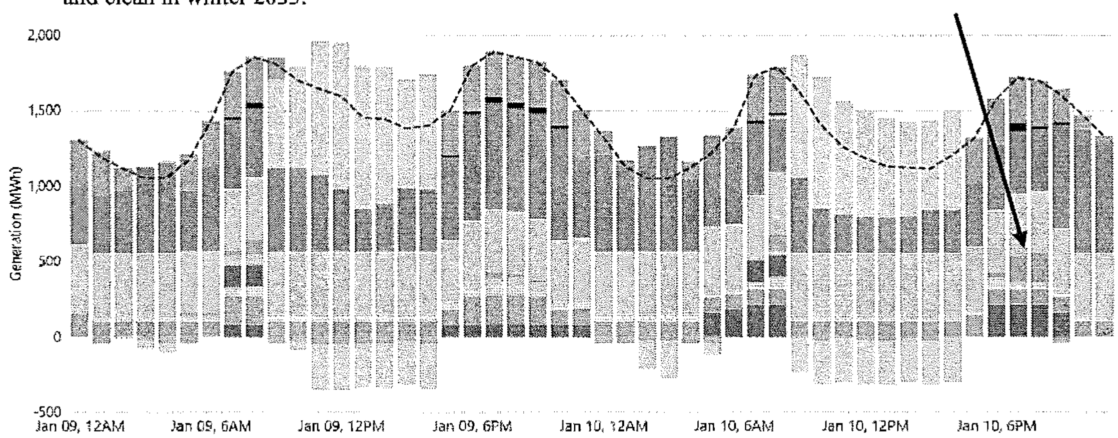
PNM Figure GWD-6c: Winter 2025



PNM Figure GWD-6d: Winter 2(

In winter, aeros only needed occasionally for peak capacity and reliability

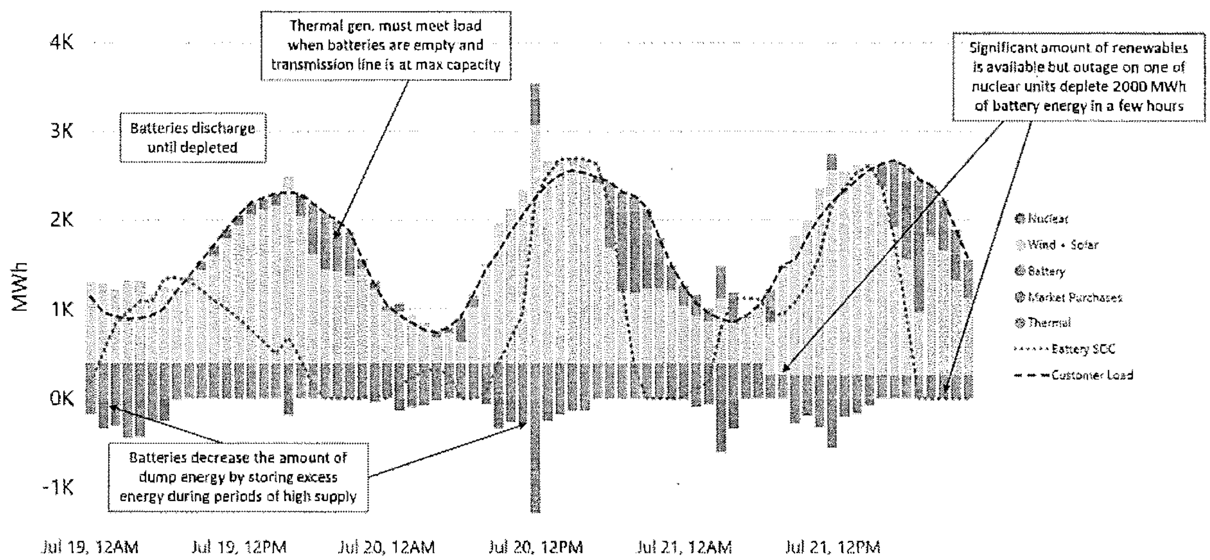
System is almost always renewable and clean in winter 2035.



Q. COULD PNM UTILIZE THE AERODERIVATIVE TURBINES AS PART OF A 100% CARBON FREE PORTFOLIO?

A. Yes. To test our hypothesis that these gas plants provide material benefit to PNM in a carbon free portfolio, we ran a simulation of 2045, assuming that these seven aero-derivatives become the sole thermal plants left on PNM's system. We added a balanced portfolio of renewables to cover 80% of PNM's energy needs, maintained Palo Verde providing of carbon free energy of 402 MW, and the addition of 2,560 MW of 4-hour duration batteries (10,240 MWh of storage) to cover the expected peak demand four hours.

PNM Figure GWD-7: Role of thermal in high-renewables system



PNM Figure GWD-7 shows that even with enough battery capacity to meet peak demand and enough renewables to provide 80% of system energy, there are still adverse meteorologies where thermal generation provides critical backup power. In the simulation above, the batteries charge as renewables generate and discharge to serve load when the renewable generation is inadequate. The afternoon of July 19th had an unusual decline in solar, perhaps due to a thunderstorm. The batteries are drained in the evening hours and the thermal generation must come online to augment the system. On the 20th, you see a sudden spike in renewable output, probably a short-lived high wind pattern, and the batteries quickly charge to absorb the excess generation and avoid renewable curtailment. Again, there is insufficient renewable generation to meet the evening load and thermal kicks on to supply the difference. Finally, on the 21st we simulate a partial outage at Palo Verde[13]. In this scenario, the batteries drain again and thermal turns on to provide system energy.

While the aeroderivative turbines are forecast to operate relatively infrequently, with a capacity factor in the low single digits, they provide a critical and cost-effective component to a 100% carbon free portfolio. The sustained value contribution of the aeroderivative turbines beyond their projected book life of 18 years adds to the economic rationale include flexible thermal generation as the most economic investment today to realize a carbon free portfolio in the future. To summarize, the role of thermal in a high-renewables system:

1) they serve as a critical flexible capacity resource to integrate renewables and costs less than half of energy storage
2) they are the least-cost capacity resource
3) they can be utilized as zero carbon back-up capacity beyond their expected life burning either hydrogen or biofuel
4) they serve as a necessary back-up capacity resources in a 100% carbon-free future when unfavorable meteorologies, such as extreme

[13] Each unit (of three) has a 5% forced outage rate, so the likelihood of this occurrence is not insignificant.

load conditions combined with a short-term wind-drought, depress renewable generation, and leave the batteries drained.

Q. IN YOUR PROFESSIONAL OPINION, IS PNM'S PREFERRED PORTFOLIO REASONABLE, DURABLE, AND IN THE INTEREST OF PNM'S RATE PAYERS?

A. Yes, PNM has developed a diverse, cost-effective, flexible, and reliable portfolio that will benefit PNM's rate payers for many years to come. The portfolio is well balanced, gaining most of its energy from low-cost solar and wind while also assuring enough flexible capacity to integrate the renewables and provide operators with the resources to assure continued supply during the peak load hours of the year. The seven aeroderivative engines at San Juan will allow PNM to modernize its generation fleet and retire older inflexible thermal generation without sacrificing reliability. This portfolio puts PNM on a path towards a clean energy future with that aligns with the targets of the Energy Transition Act.

Q. DOES THIS CONCLUDE YOUR TESTIMONY?

A. Yes it does.

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