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

NICK WINTERMANTEL

July 1, 2019

NMPRC CASE NO. 19-_____-UT
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NICK WINTERMANTEL

WITNESS FOR
PUBLIC SERVICE COMPANY OF NEW MEXICO

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I. INTRODUCTION AND PURPOSE

Q. PLEASE STATE YOUR NAME AND BUSINESS ADDRESS.

A. My name is Nick Wintermantel, and my business address is 1935 Hoover Court, Hoover, AL, 35226.

Q. WHAT IS THE PURPOSE OF YOUR TESTIMONY?

A. My testimony summarizes the evaluation process Astrapé Consulting ("Astrapé") used to determine generation resource recommendations to replace San Juan Generating Station ("SJGS") Units 1 and 4 and the results of that evaluation process. I am including PNM Exhibit NW-2 with my testimony which is a full report of the evaluation performed by Astrapé.

Q. PROVIDE A BRIEF OVERVIEW OF WHAT YOUR TESTIMONY CONCLUDES.

A. My testimony concludes that the replacement resources that meet reliability targets, and when combined provide reasonable risk and costs to customers, are: seven aeroderivative gas units totaling 280 MW,[1] two combined solar battery projects including a total of 60 MW of battery and 350 MW of solar, and two stand-alone battery projects of 40 MW and 30 MW shown in PNM Table NW-1. This combination of resources is the recommended plan submitted by Public Service Company of New Mexico ("PNM" or "Company") and is discussed as

[1] The 280 MW represents nameplate capacity. The net capability results in 269 MW for modeling purposes.

Scenario 1. This set of resources takes advantage of the "best in class" offers, as discussed in PNM Witness Nagel's testimony, across several technologies including solar, battery, and natural gas resources while alleviating technology risk for customers as discussed in PNM Witness Kemp's testimony. The selected resources combine supplier-owned purchased power agreements ("PPAs") and utility-owned Engineer Procure Construct ("EPC") projects. These replacement resources, combined with the recent Renewable Portfolio Standard ("RPS") wind resource of 140 MW[2] and the recent 50 MW PNM Solar Direct project, provide great diversity to PNM's generation fleet.

PNM Table NM-1 – Replacement Resources in Scenario 1

Name	Resource Type	Nameplate Capacity	Ownership	Location
Jicarilla	Solar	50 MW	PPA	Rio Arriba
Arroyo	Solar	300 MW	PPA	McKinley
Jicarilla	Battery	20 MW	PPA	Rio Arriba
Arroyo	Battery	40 MW	PPA	McKinley
Sandia	Battery	40 MW	EPC	Bernalillo
Zamora	Battery	30 MW	EPC	Bernalillo
San Juan Gas	Natural Gas	280 MW	EPC	San Juan

Q. BY WHOM ARE YOU EMPLOYED AND WHAT IS YOUR POSITION?

A. I am a Principal Consultant and Partner at Astrapé, which is a consulting firm that provides expertise in resource planning and resource adequacy to utilities across the United States and internationally.

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[2] See New Mexico Public Regulation Commission Docket No. 19-00159-UT.

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Q. PLEASE BRIEFLY SUMMARIZE YOUR EDUCATIONAL BACKGROUND.

A. I graduated summa cum laude with a Bachelor of Science in Mechanical Engineering from the University of Alabama in 2003 and a Master's degree in Business Administration from the University of Alabama at Birmingham in 2007. A copy of my resume is attached as PNM Exhibit NW-1.

Q. PLEASE DESCRIBE YOUR CONSULTING BACKGROUND AND EXPERIENCE.

A. I have worked in the utility industry for over 19 years. I started my career at Southern Company where I worked in various roles within Southern Power, the competitive arm of the company, and on the retail side of the company within Southern Company Services. In my various roles, I was responsible for performing production cost simulations, financial modeling on wholesale power contracts, general integrated resource planning, and asset management. In 2009, I joined Astrapé as a Principal Consultant and have been responsible for resource adequacy, resource planning, and renewable integration studies across the U.S. and internationally.

Q. HAVE YOU PREVIOUSLY TESTIFIED IN UTILITY-RELATED PROCEEDINGS?

A. I have testified in Georgia and provided written testimony in South Carolina and North Carolina in utility-related proceedings. This is the first time I have presented testimony before the New Mexico Public Regulation Commission ("NMPRC" or "Commission").

Q. PLEASE PROVIDE AN OVERVIEW OF YOUR EXPERTISE PERFORMING RESOURCE ADEQUACY AND PLANNING STUDIES.

A. Since being employed by Astrapé in 2009, I have managed target reserve margin studies; capacity value studies of wind, solar, storage, and demand response resources; resource selection decisions; and ancillary service studies for integrating renewables. I performed these studies using Astrapé's proprietary Strategic Energy Risk Valuation Model ("SERVM") used by utilities and system operators across the U.S. and internationally. More recently, I performed studies for companies seeking to increase their renewable penetrations, similar to PNM, and have worked with our Astrapé team to develop a modeling framework within SERVM to capture reliability, flexibility, and economics of varying resource mixes.

Q. CAN YOU PLEASE EXPAND ON THE BUSINESS OF ASTRAPÉ?

A. Astrapé is the exclusive licensor of the SERVM model which is used by utilities, system operators, and regulators to perform resource adequacy and planning studies. Astrapé has managed SERVM licenses or performed studies for utilities and regulatory organizations such as the Tennessee Valley Authority, Southern Company, Duke Energy, Entergy, Pacific Gas & Electric, Louisville Gas & Electric, and the California Public Utilities Commission. The SERVM model is also used for resource adequacy by large independent operators such as the Electric Reliability Council of Texas, the Southwest Power Pool, the Alberta Electric System Operator, and the Midwest Independent System Operator.

Q. HAVE YOU PERFORMED CONSULTING SERVICES FOR PNM BEFORE?

A. Yes. I have performed resource adequacy and resource planning studies for PNM since 2013 using the SERVM model. A significant portion of Astrapé's work was included in the Company's 2017 Integrated Resource Plan ("IRP"), which included reliability and flexibility analysis for the PNM system. PNM now licenses the SERVM model from Astrapé.

II. ASTRAPÉ'S ROLE AND THE SERVM MODELING FRAMEWORK USED IN PNM'S RFP EVALUATION

Q. BRIEFLY DESCRIBE ASTRAPÉ'S ROLE IN THE RFP EVALUATION.

A. After HDR Engineering, Inc. ("HDR") performed its screening evaluation to develop its "best in class" RFP offers, as discussed in the testimonies of PNM Witnesses Fallgren and Nagel, Astrapé was engaged to evaluate combinations of these offers and recommend a set of low-cost replacement resources for PNM that meet reliability targets.

Q. EXPLAIN WHY SYSTEM PRODUCTION COST AND RELIABILITY MODELING IS REQUIRED TO EVALUATE DIFFERENT REPLACEMENT RESOURCE COMBINATIONS.

A. The screening analysis performed by HDR analyzed each offer independently and determined the low-cost offer by technology or "best in class," but did not provide analysis of how the offers performed together or provide insight on how much capacity to take of each technology. Production cost modeling is necessary in order to understand how the range of different technologies perform within the existing PNM generation fleet and with each other over the next 20-year period. More importantly, the SERVM model assesses system reliability to help ensure there is sufficient capacity and flexibility in each replacement resource combination evaluated. For replacement resource combinations that meet reliability requirements, the total system costs, including all production costs to serve load and the fixed capital and O&M costs of the replacement resources (or offers), are calculated to determine the net present value ("NPV") of expected costs for each combination over the 20-year period. The costs of each replacement resource combination can then be compared on a NPV basis.

Q. BRIEFLY DESCRIBE THE MODELING CHARACTERISTICS REQUIRED TO PERFORM PRODUCTION COST AND RELIABILITY MODELING ON PNM'S SYSTEM.

A. As the PNM system changes due to the retirement of base load resources and higher renewable penetrations, future resource decisions must not only take into account customer economics and reliability during peak demand, but also system flexibility needs. This includes the capability of the system to meet unforeseen net load ramps on an hourly and intra-hour basis. Typical planning studies utilize load shapes and renewable profiles from a single weather year and only simulate average unit performance characteristics. Since flexibility and reliability issues are high impact, low-probability events, many scenarios of load, renewable output, and conventional generator performance should be considered to adequately capture their expected impact. In addition to considering many scenarios to capture the reliability of the system, the production cost model should also commit and dispatch resources chronologically, taking into account resource characteristics such as startup times, ramp rates, minimum up times, and minimum down times. By taking into account these resource characteristics, the flexibility of the system can be assessed.

Q. BRIEFLY DESCRIBE THE SERVM MODEL.

A. As discussed in PNM Exhibit NW-2, the SERVM model is a chronological production costing model and reliability model that takes into account the uncertainty of weather, load forecast, generator outages, and intra-hour volatility of intermittent resources. Thousands of yearly simulations are performed at 5-minute time steps for each replacement resource combination, which allows the model to calculate both reliability metrics and costs. SERVM respects all unit characteristics including ramp rates, startup times, and minimum up and down times. SERVM does not have perfect knowledge of net load[3] when it makes its commitment and dispatch decisions. This is important since it mimics the uncertainty faced by utility operators.

Q. IN SIMPLE TERMS, PLEASE EXPLAIN THE RELIABILITY ANALYZED AS PART OF THE EVALUATION.

A. While reliability metrics and terms can come across as complex topics, it is actually very simple. A Balancing Authority ("BA") such as the PNM BA must plan to have enough capacity to serve its peak demand and have enough flexibility or ramping capability in its generation fleet to meet its net load in real time. As more intermittent resources are added to the system, the net load ramps become larger requiring additional generation flexibility. To resolve generation capacity shortages during peak demand periods, new generation capacity must be installed or purchased. To resolve flexibility or system ramping problems, additional online operating reserves are committed. Having additional reserves available allows the system to mitigate the intra-hour and hourly ramps caused by unforeseen solar, wind, and load ramps. Adding more flexible resources can also be used to resolve flexibility problems.

[3] Net load is defined as gross load minus renewable resources and reflects the load the conventional fleet must serve on a minute to minute basis.

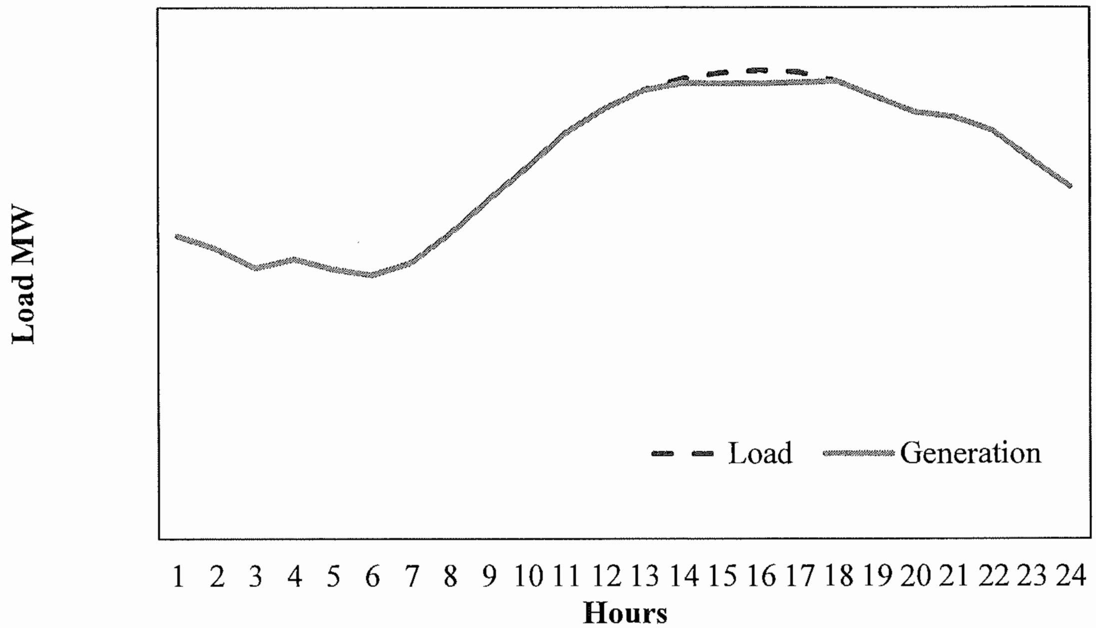
Q. HOW DOES SERVM MEASURE THE RELIABILITY OF THE PNM SYSTEM FROM A CAPACITY AND FLEXIBILITY NEED STANDPOINT?

A. SERVM calculates two reliability metrics for the PNM BA. Both of these metrics use LOLE ("Loss of Load Expectation"), which is a count of the expected number of days per year that load could not be met over the thousands of yearly simulations performed. The first metric ("$LOLE_{CAP}$") measures capacity shortfalls, while the second metric ("$LOLE_{FLEX}$") measures flexibility shortfalls.

Q. PLEASE FURTHER DESCRIBE $LOLE_{CAP}$.

A. The $LOLE_{CAP}$ metric represents the number of loss of load events due to capacity shortages, calculated in events per year. Traditional LOLE calculations only calculate $LOLE_{CAP}$. PNM Figure NW-2 shows an example of a capacity shortfall which typically occurs across the peak of a day. In this example, all available installed capacity was fully utilized but the load was greater than the generating capacity causing a capacity shortfall. For these events, additional capacity must be added to the system in order to reduce $LOLE_{CAP}$.

PNM Figure NW-2
$LOLE_{CAP}$ Example

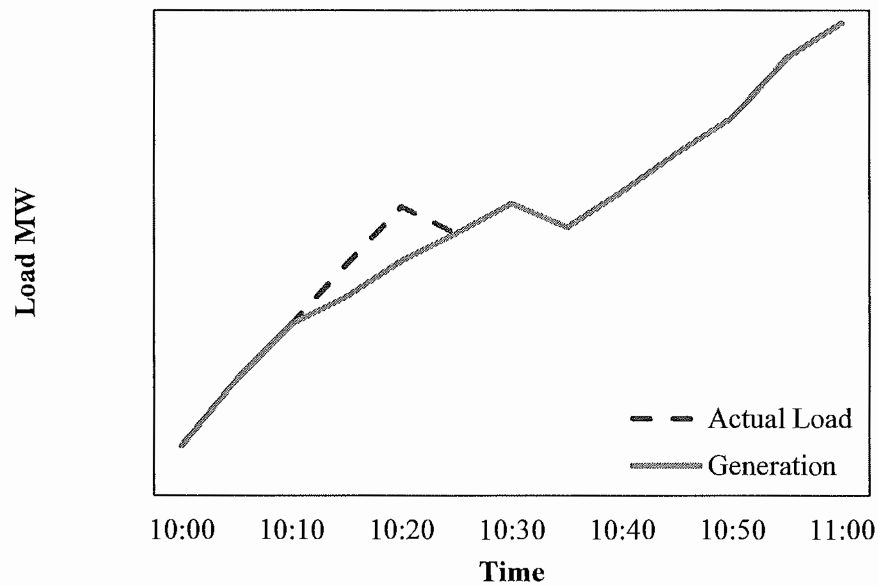


Q. PLEASE FURTHER EXPLAIN $LOLE_{FLEX}$.

A. The $LOLE_{FLEX}$ metric is the number of loss of load events due to system flexibility problems, calculated in events per year. In these events, there was enough capacity installed but not enough flexibility to meet the net load ramps, or startup times prevented a unit coming online fast enough to meet the unanticipated ramps.

PNM Figure NW-3 shows an $LOLE_{FLEX}$ example occurring intra-hour. These $LOLE_{FLEX}$ events are typically very short in duration and are caused by a rapid drop in solar or wind resource output over a short time interval. Increasing online spinning reserves or adding fast ramping capability resources can help resolve these issues.

PNM Figure NW-3
Intra-hour $LOLE_{FLEX}$



Q. HOW DID YOU ENSURE RELIABILITY METRICS WERE MET FOR THE VARIOUS RESOURCE COMBINATIONS?

A. Each replacement resource combination modeled was developed to meet or be below the $LOLE_{CAP}$ and $LOLE_{FLEX}$ criteria of 0.2 events per year. If a combination of replacement resources did not meet these criteria, either additional capacity was added or additional online reserves were input into the model. This allows each replacement resource combination to be comparable rather than allowing one combination to provide significantly lower reliability than another.

Q. WHY WAS 0.2 EVENTS PER YEAR CHOSEN AS THE RELIABILITY CRITERIA FOR $LOLE_{CAP}$ AND $LOLE_{FLEX}$?

A. Based on the size of PNM's system, Astrapé recommended as part of the 2017 IRP that PNM target a 0.2 LOLE (two events in ten years) standard at a minimum. The industry-standard reliability threshold is one firm load shed event in ten years. This is known as the '0.1 LOLE' or '1-in-10 LOLE' standard. For small systems with limited interconnections, this level of reliability is difficult and costly to achieve. The simultaneous forced outage of two larger units during peak conditions puts significant risk on smaller systems such as PNM's, compared to a larger system with more than 50 generators.

Q. DESCRIBE THE RELATIONSHIP BETWEEN RELIABILITY UNDER A LOLE STANDARD AND RENEWABLE CURTAILMENT.

A. LOLE events are times when generation cannot meet net load requirements; renewable curtailment occurs when resources are greater than net load causing over-generation periods. During these periods, the system cannot ramp down fast enough to meet net load or all online generators are dispatched at minimum but are still producing more than system net load needs. Renewable curtailment is expected in systems with large renewable penetration and impacts the economics of each replacement resource combination evaluated. In general, as renewable penetration increases, renewable curtailment will increase. For modeling purposes, there was no additional penalty included for renewable curtailment other than the cost associated with generation that was not used to serve load.

Q. WHAT ARE THE IMPLICATIONS OF CAPTURING 5-MINUTE INTRA-HOUR VOLATILITY OF LOAD, WIND, AND SOLAR IN THE MODEL?

A. By modeling the system on a 5-minute basis and capturing the volatility or unexpected movement of load, wind, and solar, the dispatchable generation fleet is forced to follow net load and absorb this volatility to maintain reliability. This modeling framework quantifies the savings that flexible resources such as battery or fast-start gas resources provide to the system, as compared to slower-starting resources with poor ramping capability. This modeling also captures the additional costs that inflexible resources such as solar and wind have on the system since these resources cause the dispatchable fleet to ramp up and start up more frequently in order to maintain reliability.

Q. OVER WHAT TIME HORIZON WERE THE REPLACEMENT RESOURCE COMBINATIONS SIMULATED?

A. Consistent with PNM's 2017 IRP, the SERVM analysis was performed over a period of 20 years. Due to the number of iterations required in reliability modeling, study years 2023, 2028, and 2033 were simulated and production costs were interpolated to produce 20-year production costs. Fixed costs, including capital costs, O&M, transmission costs, and fixed gas transportation if applicable, of the replacement portfolio were included over the 20 year period. The expansion plan beyond the replacement resources was held constant across each replacement resource combination analyzed.

Q. WHAT IS INCLUDED IN TOTAL SYSTEM NET PRESENT VALUE COSTS WITHIN THE MODELING?

A. The results are the NPV over 20 years of the annualized production costs, net purchase costs, and fixed costs of the replacement resources. Production costs include all fuel burned, variable O&M costs, startup costs, and CO_2 costs for the entire PNM Balancing Area. To calculate the NPV, Astrapé used PNM's most recent weighted average cost of capital (7.2%) that was approved in the last rate case.

III. SERVM MODELING INPUTS AND PARAMETERS

Q. DID THE COMPANY USE OTHER RESOURCE PLANNING MODELING SOFTWARE?

A. Yes. PNM also performed simulations with Encompass and PowerSimm.

Q. WERE THE MODELING INPUTS USED IN SERVM THE SAME INPUTS USED IN THE ENCOMPASS MODELING PERFORMED BY THE COMPANY?

A. Yes, as shown in detail in PNM Exhibit NW-2, the inputs were aligned to match loads, resources, and fuel forecasts included in the Company's Encompass modeling. As discussed previously, the SERVM model was simulated for the 2023, 2028, and 2033 study years. The Company provided an expansion plan beyond the replacement resources which consisted of solar, wind, and battery resources to meet future RPS and carbon targets. In order to ensure the reliability of PNM's system in 2028 and 2033, the magnitude of solar, wind, and battery was adjusted accordingly.

Q. WHAT FUEL FORECAST AND CO2 FORECASTS WERE USED?

A. See Table 9 in PNM Exhibit NW-2. The natural gas prices are based on a blend of forward pricing and gas pricing forecasts provided by Pace Global ("Pace") for PNM. Gas forwards from April 26, 2019 were utilized for the first 10 years; thereafter, forward pricing was scaled to the Pace forecast curve to project pricing for the next 10 years. CO_2 pricing was derived from Pace Global to reflect a 20-year forecast of national costs per ton of CO_2 emitted.

Q. WHAT LOAD FORECAST WAS USED IN THE MODELING?

A. See Table 5 in PNM Exhibit NW-2. These load forecasts reflect an update from the 2017 IRP and the Company's latest peak demand and energy forecasts.

Q. WHAT NEIGHBORING REGIONS WERE MODELED WITHIN SERVM?

A. Neighboring regions adjacent to the PNM BA were modeled. From a capacity standpoint, it is important that the modeling recognizes market assistance during extreme scenarios for PNM. For instance, when PNM's load is higher than expected and several generators are on outage, PNM will make hourly purchases if surrounding neighboring regions have excess capacity and transmission is available. Also, during renewable curtailment hours, there is potential for PNM to sell to these neighbors assuming they are not curtailing renewable resources as well. From discussions with the Company and analysis of historical data, purchases were limited to 150 MW of day ahead purchases and up to 150 MW of non-firm purchases.

IV. SUMMARY OF OFFERS EVALUATED IN ASTRAPÉ'S MODELING

Q. PLEASE PROVIDE A LIST OF THE RFP RESOURCES THAT HDR PROVIDED TO YOU FOR MODELING PURPOSES.

A. The following Table NW-4 shows the resources that were considered for modeling and provided by HDR. These offers are summarized in Tables 2 – 4 from PNM Exhibit NW-2. The offers were the "best in class" offers by technology and were further split into Tier 1 and Tier 2 based on initial rankings performed by HDR. The Tier 1 offers were used to create combinations of replacement resources that would meet an $LOLE_{CAP}$ and $LOLE_{FLEX}$ of approximately 0.2 events per year to ensure system reliability. Capacity was added or removed to achieve the $LOLE_{CAP}$ target and operating reserve assumptions were increased or decreased to achieve $LOLE_{FLEX}$ targets. Tier 2 offers, which were ranked further down in HDR's screening evaluation, were used to stress test the least cost combinations resources found in the Tier 1 Modeling to understand if more optimal combinations existed. Note that the Tier 1 wind resource was already selected as the 2019 RPS resource by PNM due to the early availability of this wind resource in 2020 and the changes in the RPS standard requirements as part of the Energy Transition Act. Therefore this 140 MW is included in all replacement resource combinations.

PNM Table NW-4. Summary of Tier 1 and Tier 2 Offers

Technology	Tier 1/Tier 2	Capacity per Unit MW*
Solar	Tier 1	300
Solar	Tier 1	50
Solar	Tier 1	150
Solar	Tier 1	150
Solar	Tier 1	50
Wind	Tier 1	140**
Solar/Battery	Tier 1	300/150
Battery	Tier 1	200
Battery	Tier 1	100
Battery	Tier 1	40
Battery	Tier 1	40
Gas: 4-10 Aero-derivatives	Tier 1	38.44
Gas: Frame	Tier 1	196.1
Gas: 10-20 Recips	Tier 1	16.91
Gas: 1 Aero-derivative	Tier 1	38.44
Wind	Tier 2	400
Wind	Tier 2	200
Solar/Battery	Tier 2	50/20
Solar/Battery	Tier 2	150/40
Battery	Tier 2	40
Battery	Tier 2	100

***Represents solar/battery MW for combined solar/battery technologies**

****Selected as the 2019 RPS Resource and included in all replacement resource combinations**

V. REPLACEMENT RESOURCE EVALUATION AND RESULTS

Q. HOW DID ASTRAPÉ DEVELOP REPLACEMENT RESOURCE COMBINATIONS WITH THE SHORTLISTED OFFERS FOR THE MODELING?

A. As discussed in PNM Exhibit NW-2, resource combinations including only renewable options (wind and solar offers) were explored first but were found to not meet reliability requirements unless capacity resources were also added.

Next, using the Tier 1 offers as discussed above, replacement resource combinations were designed to analyze varying amounts of solar (0 MW to 700 MW) with capacity resources including battery and gas technology to capture the full range of possible combinations that could meet reliability. As discussed previously, only the single wind offer selected as the 2019 RPS resource was included in the Tier 1 modeling because the next best wind offers were significantly more costly. These next best wind offers were analyzed as part of the Tier 2 Modeling to understand if those offers were economic. The possible combinations within the Tier 1 Modeling included "bookends" that ran from all gas scenarios to all battery/renewable makeups. Table 23 in Exhibit NW-2 shows all the combinations that were modeled as part of the Tier 1 Modeling. The magnitude of the capacity resource included in each combination was the amount needed to meet reliability thresholds. As noted earlier, "only renewables" scenarios failed system reliability parameters. Each of the capacity resources (gas and battery offers) were similarly analyzed with the varying solar offers (0 to 700 MW) to determine reliability and costs of each combination. Combinations of battery options and combinations of gas options were also analyzed such as stand-alone batteries with combined solar/battery and aero-derivatives with reciprocating engines. A total of 81 different replacement resource combinations were simulated as part of the Tier 1 Modeling. If reliability was not met, and there were no more Tier 1 resources for that technology being simulated then Tier 2 resources were added. For example, in a few of the all battery/renewable combinations, the Tier 2 battery options had to be added for reliability.

Q. WHY WAS IT NECESSARY TO ANALYZE COMBINATIONS OF RESOURCES IN THIS MANNER?

A. This analysis of potential combinations showed which capacity resource proposals optimally integrated the different amounts of renewable generation amounts while maintaining system reliability. The analysis ultimately indicated a range of how much capacity of each technology should be built. In the initial Tier 1 and Tier 2 Modeling, there was no constraint put on capacity for a given technology or capacity size on a single project and therefore the most optimal combination of replacement resources is represented from this modeling.

Q. WHAT WAS THE OPTIMAL UNCONSTRAINED REPLACEMENT RESOURCE COMBINATION FROM THE TIER 1 MODELING MATRIX THAT MET RELIABILITY METRICS?

A. The best performing replacement resource combination consisted of 350 MW of solar, 150 MW of battery, and 269 MW of aeroderivative capacity shown in PNM Table NW-5. The combination is represented by the least cost gas, solar, and battery options. There was a substantial increase in energy price for the next cheapest solar option which explains why only 350 MW of solar was selected.

PNM Table NW-5. Tier 1 Modeling Optimal Cost Replacement Resources

	Aeroderivatives MW	Recips MW	Frame MW	Battery MW	Solar MW
Tier 1 Optimal Replacement Resource Combination	269	-	-	150	350

Q. HOW DID THE ALL RENEWABLE AND STORAGE (NO GAS) COMBINATIONS PERFORM WITHIN THE TIER 1 MODELING?

A. The results did not show that an all energy storage and battery combination was the best performing option. While battery is included in the unconstrained best performing option, the costs of battery bids to fill the entire capacity need was more expensive than other low cost gas alternatives.

Q. DESCRIBE THE DIFFERENCES IN THE GAS OPTIONS AND WHY THE AERODERIVATIVES RESOURCES WERE SELECTED OVER OTHER OPTIONS.

A. The aeroderivatives and frame offers had similar fixed costs but the aeroderivatives provide more flexibility, especially given their low minimum capacity levels. The reciprocating engines provide more flexibility and slightly cheaper energy costs, but those benefits do not overcome the fixed cost premium on these offers. Across the entire Tier 1 combinations, the aeroderivatives outperformed the frame and reciprocating engine offers.

Q. HOW WERE TIER 2 REPLACEMENT RESOURCE COMBINATIONS DEVELOPED?

A. Tier 2 offers were included in the optimal replacement resource combination found in the Tier 1 Modeling to understand if the economics improved. Additional Tier 2 wind offers were added first which did not improve the economics due to the higher costs of those incremental wind resources. Then, additional hybrid battery/solar and stand-alone battery projects were added. The batteries were allowed to replace both the aeroderivatives and 150 MW battery project. Table 25 in Exhibit NW-2 shows all the combinations that were modeled as part of the Tier 2 Modeling.

Q. WHAT WAS THE OPTIMAL UNCONSTRAINED REPLACEMENT RESOURCE COMBINATION FROM THE TIER 2 MODELING MATRIX THAT MET RELIABILITY METRICS?

A. The Tier 2 Modeling produced a combination that improved upon the Tier 1 Modeling which is shown in Table NW-6 below. This combination of resources removed a single aeroderivative and added 20 MW of battery which better optimized the capacity need and maintained flexibility on the system. This combination included two combined solar plus battery projects. The first included 300 MW of solar and 150 MW of battery and the second included 50 MW of solar and 20 MW of battery.

PNM Table NW-6 Tier 2 Modeling Optimal Cost Replacement Resources

	Aeroderivatives MW	Recips MW	Frame MW	Battery MW	Solar MW
Tier 1 Optimal Unconstrained 2023 Replacement Resources	269	-	-	150	350
Tier 2 Optimal Unconstrained 2023 Replacement Resources	231	-	-	170	350

Q. WERE ADDITIONAL OWNERSHIP BATTERY OFFERS CONSIDERED AS PART OF THIS ANALYSIS?

A. Yes. While the original set of bids in the Tier 1 and Tier 2 Modeling included a large number of PPA bids, the utility owned bids were limited due to a lack of bidders having NM state contractor licenses. Because some original bidders were automatically rejected for that reason, PNM solicited additional utility owned battery proposals through a supplement to the original RFP in order to ensure a range of ownership battery options would be evaluated.

Q. DESCRIBE THE ANALYSIS PERFORMED BY ASTRAPÉ TO INCORPORATE THE STORAGE OWNERSHIP PROPOSALS PROVIDED IN MAY OF 2019.

A. The unconstrained optimal combination of resources found in the Tier 2 modeling was modeled with the low cost storage ownership proposals. This was done in multiple combinations by removing gas resources and the battery resources included in Tier 2 least cost combination of resources.

Q. HOW DID THE STORAGE OWNERSHIP OPTIONS PERFORM?

A. In comparison to the optimal unconstrained replacement resource combination, the battery ownership options did not improve the economics. The large 300 MW solar plus 150 MW battery PPA offer was less expensive than the battery ownership options due to the low cost of these options as a result of qualifying for the Investment Tax Credits.

Q. WHAT RISKS WERE IDENTIFIED IN THE UNCONSTRAINED OPTIMAL SET OF REPLACEMENT RESOURCES?

A. As part of the Company's review, PNM asked Enovation Partners to review this least cost set of replacement resources with a focus on energy storage since it included a 150 MW battery. Enovation Partners as expressed in Witness Kemp's testimony recommended that initial energy storage implementation by PNM should not be beyond 2% - 5% of the system peak load and that individual projects should be between 10 MW and no more than 40 MW. PNM accepted this recommendation and asked Astrapé for further modeling with this constraint.

Q. AS A MODELER THAT LOOKS AT SYSTEM RELIABILITY AND RISKS WHAT IS YOUR OPINION OF THAT APPROACH TO LIMITING BATTERY SIZES AND OVERALL RESOURCES?

A. I support this approach. While the model is an excellent tool to compare reliability and costs, there are attributes and factors that must be considered that don't automatically translate in the model results and must be separately incorporated. One of these is the risk associated with development and deployment of new technology.

Q. HOW DID ASTRAPÉ INCORPORATE THIS CONSTRAINT?

A. The unconstrained optimal set of resources was modified to maintain smaller energy storage options and limit the energy storage to 130 MW. The Tier 1 and Tier 2 modeling approach demonstrated that the aeroderivative resources were the best capacity resource other than battery capacity and that 350 MW of solar was economic. Next, permutations with the least cost smaller battery offers (both PPA and ownership options) were simulated similar to the Tier 2 Modeling approach.

Q. WHAT WERE THE RESULTS OF THIS CONSTRAINED MODELING?

A. The results of this analysis are shown in PNM Table NW-7which sorts the replacement resource combinations that were simulated with these constraints. The top 5 combinations are separated by an NPV of 2 million meaning they are essentially equal from an economics basis. Given the other battery ownership benefits discussed by PNM Witness Kemp and the fact that the differences in economics are negligible, the Company proposes the third replacement resource combination on the list. With battery ownership, PNM will have more flexibility in the operation of those resources as more is learned about the operations through the 20 year period. This proposed plan includes 269 MW of aeroderivatives, 350 MW of solar, and 130 MW of battery. The 130 MW of battery consists of a 40 MW PPA, 20 MW PPA, 40 MW ownership option, and 30 MW ownership option. This combination is discussed by the Company as Scenario 1.

PNM Table NW-7 Constrained Replacement Resource Combinations Sorted by Least Cost

Resource Replacement Combination	LM6000	PPA Battery	Ownership Battery	Solar	Total NPV	NPV Fixed Costs	NPV Production Costs
	MW	MW	MW	MW	M$	M$	M$
Constrained – 1	269	140	0	350	$4,677	$470	$4,207
Constrained – 2	307	100	0	350	$4,678	$461	$4,217
Constrained - 3 (Proposed Plan)	269	60	70	350	$4,678	$472	$4,206
Constrained – 4	345	40	0	350	$4,678	$430	$4,248
Constrained – 5	307	60	40	350	$4,679	$469	$4,210
Constrained – 6	269	140	0	370	$4,679	$482	$4,198
Constrained – 7	269	60	70	370	$4,679	$483	$4,196
Constrained – 8	269	100	40	350	$4,683	$476	$4,207
Constrained – 9	231	140	30	350	$4,693	$485	$4,208
Constrained – 10	345	60	0	350	$4,696	$456	$4,240
Constrained – 11	231	100	70	350	$4,698	$491	$4,207
Constrained – 12	269	140	0	500	$4,702	$449	$4,253
Constrained – 13	307	100	0	500	$4,708	$442	$4,266
Constrained – 14	345	0	40	350	$4,711	$457	$4,254
Constrained – 15	345	40	0	500	$4,718	$430	$4,288
Constrained – 16	345	60	0	350	$4,724	$474	$4,250
Constrained – 17	383	20	0	350	$4,726	$470	$4,256
Constrained – 18	345	60	0	500	$4,735	$456	$4,280
Constrained – 19	383	40	0	350	$4,758	$503	$4,255

Q. IS SERVM ABLE TO MODEL ALL OF THE UNIQUE BATTERY VALUES?

A. SERVM is able to capture the capacity, energy, and ancillary service benefits of battery but is not able to determine transmission and distribution locational benefits. These must then be addressed beyond the model outputs. Not included in my analysis, the Company determined that there was an additional transmission benefit of the ownership options of approximately $11/kW-yr which would further support the Company's decision to move forward with the combination of replacement resources that included the ownership battery options. These additional benefits were not included in PNM Table NW-7 above.

Q. WHAT ADDITIONAL RESOURCE COMBINATIONS DID PNM HAVE YOU SIMULATE?

A. The Company requested Astrapé run 3 additional scenarios to compare against the proposed plan. These were developed by PNM's resource planning department and respect the 40 MW battery size project limit. These included the following:

Scenario 1 – This scenario is the proposed plan discussed above. It includes seven aeroderivatives consisting of 269 MW, a combined solar/battery project consisting of 300 MW of solar and 40 MW of battery, a combined solar/battery project consisting of 50 MW of solar and 20 MW of battery, and two standalone battery ownership projects consisting of 40 MW and 30 MW.

Scenario 2 - San Juan Location Preference Alternative Scenario – This scenario included the least cost resources in the San Juan Location which included 7 aeroderivatives and 1 Frame machine.

Scenario 3 - No New Fossil Fuel Alternative Scenario – This scenario included the least cost battery projects that were less than 40 MW and renewable resources. It included 500 MW of solar and 11 battery projects summing to 410 MW. The 11 different battery projects included 7 PPA options and 4 ownership options.

Scenario 4 - All Renewable Replacement Scenario – This scenario includes all renewable capacity. This scenario includes all wind and solar PPA projects consisting of 1,200 MW of wind and 975 MW of solar.

Q. PLEASE SUMMARIZE THESE ADDITIONAL SCENARIOS AND THEIR COSTS COMPARED TO THE RECOMMENDED COMBINATION.

A. These scenarios were treated in the same manner as all the other combinations that were simulated as part of the Tier 1 and Tier 2 Modeling and battery constrained approach. The results are shown in PNM Table NW-8 below. Of the 4 replacement resource scenarios put forth by the Company, the proposed plan is the most economic. Scenario 2 has an NPV of $54 million more than Scenario 1 while Scenario 3 has an NPV of $156 million higher than Scenario 1. Scenario 4 is even more expensive due to all the renewable curtailment caused in that case but still does not meet reliability criteria. Scenario 3 is unreliable as well and would require additional capacity making the costs in the below table for that scenario lower than what they would be if they were forced to be reliable.

PNM Table NW-8 Additional Scenarios Provided by the Company

Resource Replacement Combination	LM6000	Frame	PPA Battery	Owned Battery	Solar	Wind	Total NPV
	MW	MW	MW	MW	MW	MW	M$
Scenario 1 – Proposed Plan	269	0	60	70	350	140	$4,678
Scenario 2 – SJ preferred	269	196	0	0	0	140	$4,732
Scenario 3 – No Gas	0	0	260	150	500	140	$4,834
Scenario 4 – All renewable	0	0	0	0	975	1,199	$5,452

VI. ADDITIONAL CASE SUPPORT

Q. OUTSIDE OF THE REPLACEMENT RESOURCE EVALUATION, ARE YOU SUPPORTING ANY OTHER ANALYSIS AS PART OF THE OVERALL CASE?

A. Yes, Astrapé provided fuel outputs from the SERVM runs in the evaluation to PNM Witness Monroy for 2023. This 2023 data was provided for Scenarios 1 – 4 discussed above as well as the San Juan coal plant continues scenario.

Q. WITNESS MECHENBIER DESCRIBES ADDITIONAL ANALYSIS YOU PERFORMED ON SCENARIO 1 IN RELATION TO THE 650 MW EXPORT LIMIT. PLEASE EXPLAIN.

A. Within the SERVM simulations, Astrapé performed analysis on a few of the 8,760 hourly runs to see what percentage of hours the output of the 269 MW for the gas turbine facility; 50 MW associated with Jicarilla Solar 1 (which includes a 20 MW battery energy storage facility but will be limited to 50 MW export capability); 300 MW associated with Arroyo Solar (which includes a 40 MW battery energy storage facility but will be limited to 300 MW export capability); and 50 MW associated with Jicarilla Solar 2 for the PNM Solar Direct Project, was above 649 MW. That analysis demonstrated that 0.03% of the hours (less than 3 hours out of 8,760 hours) would have a simultaneous output above 649 MW. This is due to the intermittent nature of the 400 MW of solar and the fact that the small aeroderivatives are usually serving some level of ancillary services and not operating at full output. Based on these factors, any curtailment due to transmission is estimated to be minimal.

VII. CONCLUSIONS

Q. BASED ON THE MODELING, WHAT IS ASTRAPÉ'S CONCLUSION?

A. Based on the evaluation performed by Astrapé, the proposed plan of replacement resources including 350 MW of solar, 130 MW of battery, and 269 MW of gas meets reliability criteria and provides reasonable costs given the technology constraints imposed. These replacement resources provide a diverse set of resources and take advantage of the lowest cost renewable, battery, and gas offers submitted into the RFP

Q. DOES THIS CONCLUDE YOUR TESTIMONY?

A. Yes, it does.

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