DIRECT TESTIMONY OF

MICHAEL S. BABINEAUX

ON BEHALF OF NORTHWESTERN ENERGY

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Witness Information

Q. Please identify yourself, your employer, and your job title.

A. My name is Michael S. Babineaux. I am a Senior Energy Supply Analyst at NorthWestern Corporation d/b/a NorthWestern Energy ("NorthWestern").

Q. Please provide a description of your relevant employment experience and other professional qualifications.

A. I have been an analyst in Energy Supply Planning at NorthWestern for eight years. I am responsible for conducting integrated supply resource planning and supply portfolio modeling, including calculations using Ascend Analytics, LLC's PowerSIMM™ model. I hold Bachelor of Science degrees in both Mathematics and Electrical Engineering.

Purpose of Testimony

Q. What is the purpose of your testimony in this proceeding?

A. I explain the modeling that NorthWestern's Supply Planning department provided to support the evaluation of the proposals submitted in response to the January 2020 Request for Proposals for long-term capacity resources

("RFP"). I also describe the calculations the Supply Planning department provided to the RFP Administrator that assess the capacity contribution of proposed weather-driven and energy-limited resources like wind, solar, storage, and hybrid projects.

Proposal Modeling – Overview

Q. Please explain the process NorthWestern's Supply Planning department used to assist the RFP Administrator in evaluating how the addition of proposed resources would affect the economic performance of NorthWestern's supply portfolio.

A. To assist the RFP Administrator in evaluating how each proposed resource would affect the costs of meeting NorthWestern's electric load, we conducted three simulation modeling exercises:

1. Individual Proposed Resources: This category of modeling included simulation studies used to assess how our supply portfolio would perform with the addition of individual proposed resources. The RFP Administrator used the results of these studies to identify a shortlist of the proposals.
2. Portfolios of Proposed Resources: This category of modeling included simulation studies to evaluate how various collections or portfolios of proposals from the shortlist would perform if added to our supply portfolio as a group. The RFP Administrator used the results of these studies to inform the evaluation of portfolios.

3. Supporting Studies: This category of modeling included studies conducted throughout the process that the RFP Administrator used to investigate certain modeling parameters. The three main items of interest in this category were cycling constraints on batteries, sub-hourly dispatch capabilities, and the number of simreps used in the simulation studies.

Q. Please explain how the simulation tool used to conduct this modeling works.

A. NorthWestern simulates the performance of our supply portfolio with a software model – PowerSIMM – that uses historical data, forecasts, and operational characteristics to determine the weather-driven conditions within each time-step. We simulate the portfolio on an hourly time-step using a 20-year evaluation time frame running from January 1, 2024 to December 31, 2043. The model begins by simulating a weather outcome over the 20-year, hourly time series or ("simrep"), for the specified number of simreps. Through historical regional correlations, the resulting weather in a given hour is used to simulate renewable generation, load, and prices. Their resulting hourly shapes are scaled to match their monthly forecasts. Dispatchable resources are economically dispatched accounting for the above conditions, operational characteristics, and randomly distributed forced outages. Excess generation is assumed to be sold to the market creating sales revenue, while market spot purchases are assumed to account for any shortages. The model iterates on each simrep as needed in order to optimize the objective function results, that is, minimize net portfolio costs while serving load and meeting ancillary service requirements.

Q. How is historical data used in the model?

A. The model uses historical data as inputs to determine the historical relationships (correlations) between weather, electric loads, market prices, and power output from weather-driven resources like wind, solar, and hydroelectric generation plants. This allows for the simulation of future values based on the relationships historically seen among the key factors that influence a supply portfolio's costs for meeting load in every hour.

Q. How are forecasts used in the model?

A. The model takes forecasts of certain values as inputs, including loads, generation output from weather-driven resources, future power and fuel prices, and outage rates for thermal generation plants. A summary list of the inputs used in the model, and their corresponding location in exhibits, is provided in Table 1 below and also in Exhibit MSB-1. The forecasts of weather-driven generation are made at the monthly level and are derived directly from historical performance data. The forecasts of power and fuel prices are based on historical data as well as expectations about relevant future conditions, such as public policy and technological changes that are expected to affect power and fuel prices. To assist the RFP Administrator in evaluating proposals, NorthWestern's Supply Planning department conducted simulations using a base-case set of price forecasts as well as eight scenarios that used alternative price forecasts or different assumptions about the supply portfolio, including sensitivities around the degree of development of future Qualifying Facilities ("QFs"), market sales revenues, and retirement date for the Colstrip generating units. These scenarios are described further below.

In addition to the exhibits described in Table 1, I provide the simulation results as Exhibit MSB-8.

Q. How were the results of the simulation studies used?

A. The results of these studies were used as inputs into the RFP Administrator's calculations of the total cost of meeting our customers' load, which is measured as the net present value ("NPV") of the total cost over the 20-year evaluation horizon. The key categories of costs that contribute to this total in each study include:

- The variable costs of operating and maintaining:
    - the existing resources in our supply portfolio, and
    - any proposed resource in the study;
- The cost of purchases from the market for power and ancillary services;
- The revenue associated with the sales of excess power to the market; and
- The fixed costs of the existing resources in our supply portfolio (which are the same in every study).

The fixed costs of proposed resources – including fixed operations and maintenance costs, capacity payments, and capital costs – were accounted for by the RFP Administrator outside of PowerSIMM. Because these costs are fixed, they do not affect resource dispatch and were therefore not necessary to include in the simulation models.

Individual Proposal Modeling

Q. Please identify the modeling inputs the RFP Administrator used in the evaluation of individual proposals.

A. The following table identifies the modeling inputs used to evaluate individual proposals and their associated exhibit number.

Table 1

Input	Description	Location
Base Generation Portfolio	NorthWestern's existing portfolio of generation resources to which proposed resources were added for simulation and evaluation	MSB-1 and MSB-4
Price Forecasts	Power, Natural Gas, and Carbon Pricing Scenarios, and Mid-C Basis Differentials. Forecast vintage is 2020 Q3.	MSB-2
Load - Forecast	NorthWestern's long-term load forecast used in RFP modeling	MSB-3
Load - Historical	Historical hourly loads	MSB-5
Generation - Forecast	Forecast monthly generation for Wind, Solar, and Hydro	MSB-6
Generation - Historical	Historical hourly generation for Wind, Solar, and Hydro	MSB-6
Ancillary Service Requirements	Ancillary service requirements for Inc and Reg by year	MSB-1

Q. What resources were included in the base supply portfolio for the simulation models?

A. Table 2 below identifies the resources in the base generation portfolio, which included NorthWestern's existing supply resources (owned by NorthWestern or under contract at that time) plus QFs that had executed power purchase agreements ("PPA"), received orders from the Montana Public Service Commission ("Commission") establishing rates and terms for a PPA, or filed a petition at the Commission to receive such an order by the time the RFP modeling was conducted.

Table 2

		Nameplate Capacity	Off-line Date*
Thermal	Colstrip	222	
	DGGS	150	
	Basin Creek	52	2036
	CELP	42	2024
	YELP	65	2028
Hydro	Thompson Falls	94	
	Madison	8	
	Hauser	17	
	Holter	52	
	Black Eagle	21	
	Rainbow	64	
	Cochrane	62	
	Ryan	68	
	Morony	49	
	Mystic	12	
	Turnbull	13	
	Tiber	8	2024
	Broadwater	10	2024
	Other Small Hydro	6	Various
Wind	Judith Gap	135	2026
	Spion Kop	40	
	Gordon Butte	10	2036
	Musselshell I	10	2036
	Musselshell II	10	2036
	Fairfield Wind	10	2033
	Two Dot Wind Farm	11	
	Greenfield	25	2041
	Big Timber	25	2043
	Stillwater	80	2043
	South Peak	80	2035
	71 Ranch	3	2043
	DA Wind	3	2043
	Oversight	3	2043
	Caithness Beaver Creek II	60	2040
	Caithness Beaver Creek III	60	2040
	ConEd Teton County Wind	19	2037
	ConEd Pondera Wind	20	2037
	ConEd Wheatland Wind	73	2037
	Black Bear Wind	80	2036
	Grizzly Wind	80	2036
	Small Wind	11	various
Solar	Green Meadow Solar	3	2042
	South Mills Solar	3	2042
	River Bend Solar	2	2042
	Great Divide Solar	3	2042
	Magpie Solar	3	2042
	Black Eagle Solar	3	2042
	MTSUN	80	2036
	Apex 1 Solar	80	2036
Total Supply		2039	

*Based on contract termination dates, or approximations thereof for QFs whose contracts are not final.

Q. What costs and operating characteristics were used for modeling each proposed resource?

A. The costs and operating characteristics used for modeling were those identified by the RFP Administrator from information provided by the bidders in the proposals. The RFP Administrator assembled templates of the characteristics and operating costs and provided these templates to the NorthWestern's Supply Planning department. These templates included only the information necessary for modeling the proposed resources; they did not include the identities of the bidders.

Q. What did the Supply Planning department do with these templates?

A. The modeling team input the data from the templates into PowerSIMM so that the performance of each proposed resource could be simulated according to the operating capabilities, costs, and constraints as indicated in the templates. After the simulations were complete, the modeling team retrieved the study outputs from PowerSIMM and put them in a standardized output file, which the team then provided to the RFP Administrator.

Q. How many simreps did NorthWestern use in the simulation process?

A. For the majority of our studies, we used 10 simreps. This means that each variable was simulated for 10 different weather outcomes across the 20-year evaluation period, from the 1^{st} hour to the $175{,}200^{th}$ hour (20 years times 8,760 hours per year equals 175,200 hours). We also created a subset of the

10-simrep studies using 100 simreps. These were used to compare with the 10-simrep studies to ensure that the results did not differ substantially between the 10- and 100-simrep studies. The results used for this comparison are contained in Exhibit MSB-7.

Q. How did the results from studies that used 10 simreps compare to those using 100 simreps?

A. The results using 10 simreps were similar to the results using 100 simreps. In general, the output values from the 10-simrep studies were within a few percentage points or less of the values in the 100-simrep studies. In the instances where the deviation was larger than 4 or 5 percentage points, the heightened deviations were often driven by the fact that the values used in the denominator when calculating the percentage difference were very small, which results in differences that might appear large when measured as percentages but whose values when expressed in non-percentage terms are actually quite close. An example of this can be seen in the annual net position of the total portfolio (total load minus total generation), which can be quite small – less than 100,000 megawatt-hours ("MWh") in some years. In instances like this, differences in the net position of 10,000 or 20,000 MWh can appear large when expressed as percentages, but are actually very small when compared to an annual load in the range of 7,000,000 MWh.

Q. Did the NorthWestern Supply Planning department conduct any additional modeling as part of assisting the RFP Administrator in the evaluation process?

A. Yes. We conducted a series of studies to ensure that the cycling patterns of battery storage systems did not exceed the cycling limits identified by the proposals in a way that would affect their evaluation.[1] We also conducted a series of studies to estimate the additional revenue that resources with a high degree of flexibility might earn via sub-hourly dispatch to sub-hourly price signals.

Q. Please describe how the NorthWestern Supply Planning department supported the RFP Administrator in evaluating the additional revenue that proposed resources might generate via dispatch to sub-hourly price signals.

A. Some resources can be dispatched in response to real-time sub-hourly price signals and thereby capture additional revenue that is not otherwise accounted for in an hourly model. NorthWestern estimated a "sub-hourly dispatch credit" for flexible resources by comparing the simulation of the dispatch of these resources in response to 5-minute price signals to their dispatch in response to hourly price signals.[2] The method used to calculate this value is the same as described in Section 5.1.2 of the 2020 Supplement

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[1] Ascend Analytics assisted NorthWestern Supply Planning with defining battery cycling constraints.

[2] Ascend Analytics performed the analysis for determining sub-hourly credits and provided values to NorthWestern Supply Planning.

to the 2019 Electricity Supply Resource Procurement Plan ("2019 Plan") in Docket No. 2019.08.052. The 5-minute price signals were based on the historical (2018) 5-minute price history at the Western Energy Imbalance Market ("EIM") node for Decker, Montana (the closest EIM node to NorthWestern's system). The volatility in the simulated 5-minute prices was scaled to match the volatility in NorthWestern's power price forecast. The difference in the revenue generated between these scenarios was used as a measure of the additional revenue that a flexible resource can generate via sub-hourly dispatch.

Portfolio Modeling

Q. How did the NorthWestern Supply Planning department assist the RFP Administrator in evaluating portfolios of proposals?

A. The NorthWestern Supply Planning department constructed the recommended portfolios in PowerSIMM, completed the simulation models, and assembled the results into a summary output file that was reviewed by the modeling team and returned to the RFP Administrator. In an iterative process based on the RFP Administrator's and NorthWestern's review of the modeling results, and in consultation with each other, the RFP Administrator subsequently constructed additional portfolios and refinements to the portfolios initially recommended. NorthWestern then modeled these portfolios and returned the results to the RFP Administrator, and the iterative process continued.

Q. Did NorthWestern conduct studies to assess the risk that a portfolio might perform differently than modeled if future conditions differ substantially from those used in the simulation studies?

A. Yes. We evaluated a "base case" scenario using our standard price forecasts and modeling configurations, and we also evaluated eight other scenarios. These included scenarios that capped the value attributed to annual sales revenues at the levels seen in our existing supply portfolio, or used alternate assumptions about future power and natural gas prices or the existence of a base or high carbon price. They also included a scenario reflecting the possibility that future generation from QFs may be less than expected, and a scenario in which Colstrip Units 3 & 4 retire at the end of 2025. Tables 3 and 4 below list the scenarios and price forecast descriptions.

Table 3

Scenario Name	Description	Scenario Number	ID in PowerSimm
Base Case	Base Generation Portfolio and Base Price Forecasts	1	S1
Constraint on High Sales Volumes	Same as Base, except: annual revenue credit given to market sales is capped at the value of sales made by the Base Portfolio (cap is applied outside of simulation model)	2	S1
Low Power Price	Same as Base, except: uses Low Power Price Forecast instead of Base Price Forecast	3	S3
High Power Price	Same as Base, except: uses High Power Price Forecast instead of Base Power Price Forecast.	4	S2
Carbon Price	Same as Base, except: uses Carbon Price Forecast from 2019 Plan	5	S5
High Carbon Price	Same as Base, except: uses High Carbon Price Forecast from 2019 Plan	6	S6
High Gas Price	Same as Base, except: uses High Natural Gas Price Forecast instead of Base Natural Gas Price Forecast	7	S4
Reduced QFs	Same as Base except only half of the QFs in the Base Portfolio are included	8	S7
Colstrip Retires 2025	NorthWestern's share of generation from Colstrip extends only through 12/31/2025. The generation is no longer included in the portfolio's dispatch.	9	S8

Table 4

Forecast Name	Description
Base Power Price	4 years of Mid-C futures prices followed by Ascend Analytics long-term price forecast for Mid-C. Futures price vintage is 2020 Q3. The transition from futures prices to Ascend forecast is a weighted average that shifts over a 3-year transition period.
Base Natural Gas Price	4 years of gas futures prices escalated thereafter by escalation rates for Henry Hub from EIA's 2020 AEO. Futures price vintage is 2020 Q3.
High Power Price	4 years of Mid-C futures prices escalated thereafter by escalation rates for Henry Hub natural gas from EIA's 2020 AEO. Futures price vintage is 2020 Q3.
Low Power Price	Average of Northwest Power and Conservation Council's price scenarios developed for the 2021 Power Plan.
Power Price with Carbon Price	Adjusts Base Power Price with the carbon price forecast from the 2019 Supply Plan. The carbon price increases the variable cost of carbon-emitting generation in NorthWestern's portfolio and prices market-wide.
Power Price with High Carbon Price	Adjusts Base Power Price with the high carbon price forecast from the 2019 Supply Plan. The carbon price increases the variable cost of carbon-emitting generation in NorthWestern's portfolio and prices market-wide.
High Natural Gas Price	Equivalent to Base Gas Price except the gas price accelerates for 10 years starting 2024 until reaching 2x of Base Gas, remaining thereafter at 2x of Base Gas

Capacity Contribution of Proposals

Q. What role did capacity contribution play in the evaluation of proposals submitted in response to the RFP?

A. As stated in Section 3.2 of the RFP, the RFP Administrator, Aion Energy LLC ("Aion") evaluated proposals based on the amount of capacity each proposed resource could be expected to contribute toward serving peak loads, which is often referred to as the resource's "capacity contribution."[3] The measurement of a resource's capacity contribution requires a probabilistic assessment of the likely amount of power that a resource will or could generate when loads peak.

Q. How did NorthWestern's Supply Planning department assist the RFP Administrator in determining the capacity contribution for weather-driven and energy-limited resources?

A. NorthWestern's Supply Planning department assessed the capacity contribution of proposals for weather-driven and energy-limited resources with a metric known as Effective Load Carrying Capability ("ELCC") and provided that assessment to the RFP Administrator. The method for calculating ELCCs is described in the Direct Testimony of Arne Olson and is also described in Section 3.3 and Appendix 1 of the 2020 Supplement to the 2019 Plan. In essence, the ELCC of a resource indicates how many megawatts ("MW") of perfect (i.e., 100% reliable) capacity the resource can effectively

[3] The concept of capacity contribution is referred to by various terms in the industry, such as Accredited Capacity or Qualifying Capacity. The concepts are similar.

replace. ELCCs are heavily influenced by expected load patterns, weather, and the other resources in a supply portfolio. NorthWestern used the ELCC metric to assess the capacity contribution from proposals with wind, solar, and storage technologies and proposals with combinations of these technologies (known as “hybrids”). The RFP Administrator determined the capacity contribution from proposals for thermal resource technologies.

Q. How did NorthWestern Supply Planning calculate the ELCCs for the proposals?

A. As part of the 2020 Supplement to the 2019 Plan, NorthWestern hired the consulting firm Energy + Environmental Economics Inc. (“E3”) to determine the ELCCs for stand-alone wind, solar, and storage resources of varying durations, as well as a range of hybrid sizes and configurations. NorthWestern used the ELCCs calculated by E3 to assess the capacity contribution from stand-alone wind, solar, and storage proposals. NorthWestern also used the ELCCs calculated by E3 for hybrids as the baseline for assessing the capacity contribution of each hybrid proposal. As described in Mr. Olson’s direct testimony, the hybrid configurations used in E3’s calculations paired a 4-hour lithium ion battery with either a 100-MW wind resource or a 100-MW solar resource. Several different battery sizes were considered, ranging from as small as 25 MW to as large as 100 MW. For RFP proposals whose hybrid configurations did not match exactly with the hybrid configurations used in E3’s calculations, NorthWestern calculated

ELCCs by using a linear interpolation based on the configurations available in the E3 study most similar to each hybrid proposal. Exhibit MSB-9 shows this linear interpolation and contains E3's ELCC values and NorthWestern's calculations. For hybrid proposals with batteries whose duration was not four hours, NorthWestern calculated the ELCCs after converting these batteries to their 4-hour equivalents, which was the duration used by E3 to determine ELCCs for hybrids.

Q. Did NorthWestern take any additional steps to validate the interpolated ELCCs?

A. Yes. To ensure that these interpolated values were based on configurations of sufficient similarity to the proposals, NorthWestern requested E3 to provide ELCC calculations for an expanded range of configurations. This expanded range was used to validate and refine the first set of ELCCs NorthWestern calculated from the initial set of ELCCs provided by E3. NorthWestern also requested a final assessment of the ELCCs for several of the most competitive proposals by providing the specific configurations of these proposals to E3 for a final calculation. The ELCCs calculated by E3 are provided as exhibits to Mr. Olson's direct testimony.

Q. Does this conclude your direct testimony?

A. Yes.

Verification

This Direct Testimony of Michael S. Babineaux is true and accurate to the best of my knowledge, information, and belief.

/s/ Michael S. Babineaux
Michael S. Babineaux