Q. Please state your name, business address, and position with PacifiCorp dba Rocky Mountain Power ("RMP" or the "Company").

A. My name is Douglas L. Marx. My business address is 1407 West North Temple, Salt Lake City, UT 84095. I am director of Engineering Standards and Technical Services for RMP.

Q. Please briefly describe your educational and professional background.

A. I've worked for RMP for 33 years in various engineering, operations and management positions. I hold a bachelor's degree in electrical engineering from the University of Utah and a master's degree in business administration from Utah State University.

Q. Please describe your present duties.

A. I oversee all non-routine technical studies including distributed generation, power quality and smart grid reports. I am responsible for the development of all material and equipment specifications and standards used in the construction and maintenance of the transmission and distribution systems.

Q. What is the purpose of your rebuttal testimony?

A. The purpose of my rebuttal testimony is to respond to the direct testimony of Utah Clean Energy, The Alliance for Solar Choice, and Sierra Club ("Joint Parties") witnesses Ben Norris and Tim Woolf.

Q. What testimony do the Joint Parties offer regarding avoided distribution costs?

A. Both Mr. Norris and Mr. Woolf testify, without any basis or support, that there are avoided distribution costs associated with net metering but neither explains how or why the Company would avoid distribution costs with the addition of distributed generation systems. Specifically, Mr. Norris indicates that his colleague "has identified the following key benefits in his testimony: … avoided distribution costs."[1] Similarly, in his testimony, Mr. Woolf states, as fact, that there are avoided distribution costs and that "[m]y colleague Ben Norris provides additional information on these costs and benefits in his testimony in this docket."[2] The problem is that neither provides a basis for including avoided distribution costs as a benefit, in contravention of the following Commission guidance in this case:

> we expect a party advocating for consideration of a factor … to establish that factor's applicability, quantifiable value, and proper placement in an analytical framework or equation.[3]

Q. As the Company integrates increasing distributed generation into its distribution system, is the Company more likely to increase or decrease distribution costs?

A. As the Company integrates increasing numbers of distributed generation systems, the Company expects this will cause an overall increase in the Company's distribution costs.

Q. What are the distribution costs associated with increasing rooftop solar installations?

A. Incremental costs for distribution systems as a result of increased distributed rooftop solar can be divided into two categories: capacity and reliability.

Q. What are the costs associated with capacity?

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[1] Direct Testimony of Ben Norris, p.3/l. 54.
[2] Direct Testimony of Tim Woolf, p.17/ll. 345, 346.
[3] *In the Matter of the Investigation of the Costs and Benefits of PacifiCorp's Net Metering Program*, Notice, p. 6 (March 9, 2015).

A. Capacity defines the maximum amount of power that can safely be transferred across the system. The system includes the distribution power transformer, high voltage wires, distribution step-down transformers, secondary wires and finally the service lateral wires. The system components must be sized to handle the maximum expected power flow under all conditions, including bi-directional power flow as well as during generation outages. The maximum load generally peaks in the late afternoon and early evening hours. In Utah, the residential peak starts between 5:00 and 6:00 pm during the hot summer months and can last as late as 9:00 pm, sometimes later. This coincides with the waning hours of solar generation. It's important to note that residential consumers are incented to install their solar generation to maximize the energy production needed to lower their energy bills. The southern orientation required to maximize energy production lowers the availability of solar generation during the residential peak load hours and does not significantly offset capacity requirements.

Q. How are distribution systems designed and why is this important?

A. Distribution systems are designed starting with the end-use consumers load requirements and moving back along the system to the power transformer located within the local substation. It is important because the service lateral wires must be sized to meet the individual consumer's peak load requirements. Service laterals are based upon the size of the service entrance equipment and are available in standards sizes; they are not infinitely variable in size, much the same as pipe. For residential consumers, the service lateral will be sized for the peak load expected between the hours of 5:00 and 9:00 pm during the summer months. Any contribution from solar generation during these hours will not reduce the size of the service lateral conductors.

Q. What happens if a residential customer were to install a "right-sized" solar system to achieve net-zero energy?

A. If a residential customer installs a "right-sized" solar system to achieve annual net-zero energy, the net generation peak that occurs at solar noon during the summer months can be greater than the peak load for that customer. This may require an *increase* in the size of those facilities directly serving the customer in order to handle this peak reverse current flow.[4]

Q. What factors are important to analyze with the increasing installation of solar systems on the distribution system?

A. As the distribution system is planned and designed, the next components analyzed for adequate capacity are the secondary conductors and the distribution step-down transformer. It is known that consumers' load requirements and peak demand do not exactly align at a given times during the day. With this knowledge, a coincidence factor[5] is applied to calculate the size requirements of the secondary conductors. By applying the coincidence factor, these conductors can be sized slightly lower than the sum of the peak power requirements for the residential consumers served through that section of secondary wire. The same method applies to the sizing of the distribution step-down transformer.

[4] The average residential customer consumes 8,601 kWh of energy annually and showed a peak demand of 2.90 kW. This will require a 5.65 kWdc solar system to be considered net-zero. The resultant net generation at solar noon on a peak day would be 3.90 kW which exceeds the peak demand.

[5] The coincidence factor is the ratio expressed as a percentage, of the simultaneous maximum demand of a group of consumers to the sum of their individual maximum demands.

However, when analyzing the solar contributions the coincidence factors are so great that they have no effect. In other words, the simultaneous output of a group of solar systems is equal to the sum of their individual outputs.

Q. What does this mean?

A. It means that when considering local neighborhood distribution systems and applying the appropriate coincidence factors, the net generation peak for net-zero solar systems that occurs at solar noon during the summer months can be greater than the peak load requirement. Again, with high saturations of rooftop solar, this will require an *increase* in the size of those local neighborhood facilities serving the customers within a defined boundary. Increasing the size of these local neighborhood facilities *increases* distribution costs.

Q. Is reliability affected by distributed solar?

A. Yes.

Q. Are there costs associated with reliability?

A. Reliability defines the ability of the system to consistently deliver energy within defined parameters for voltage, power quality and outages. To the end user, reliability is manifested in for the form of blinking lights, flickering lights, interrupted processes, black-outs, etc. The Company continually seeks ways to improve the reliability of the electricity delivered through the application of capacitor banks, voltage regulation equipment and outage management techniques and equipment. All of this equipment and technology has been completed in a system that ran power in only one direction. The studies and analysis are very well defined and simple to apply by a trained and competent distribution engineer for these systems.

Q. How does the power flow with distributed generation and why is this important?

A. With distributed generation, the power flows in two directions. Thus, when the electrical system starts moving power in two directions, the analysis and studies become very complex. More time is required to run multiple iterations as you analyze numerous scenarios trying to account for variations in load consumption and solar production. Load consumption and solar production is affected largely by weather conditions. Variable cloud coverage, temperature levels and humidity will all have measureable effects.

Furthermore, dynamic changes in power flows resultant from planned and unplanned changes in power consumption and solar production require more complex equipment to respond in order to maintain a reliable distribution system and maintain stable voltage conditions.

Distribution outage mitigation is done through a series application of relays and breakers, reclosers and fusing. In a one-way power flow system, this equipment is highly suitable and cost effective and needs to manage only the downstream events. In a bi-directional power flow system, this standard equipment is no longer effective and must be replaced. All the devices in a bi-directional power flow situation must be able to respond to events in both directions and have the field level intelligence necessary to distinguish between fault current levels and normal reversal of power flows. Table 1 shows the installed costs of both standard protective devices and those required for bi-directional power flow.

Table 1

Device	Standard Equipment	Bi-directional Equipment
Overhead Fusing	$1,293	$25,232
Underground Fusing	$29,909	$43,857
Line Recloser	$24,802	$25,332

Voltage management and power quality is accomplished through the application of voltage regulators and capacitor banks. These devices actively manage the system to maintain voltage within the specified bandwidth and minimize transients that appear as flickering lights, interrupted processes, etc. In a one-way system, voltage management is sensitive to changes in power demand and can readily be controlled with these devices.

Q. What other considerations should be taken into account with distributed generation systems?

A. In systems where power flow can be readily reversed, voltage control due to increasing end of line levels becomes necessary to reduce the possibility of low voltage conditions at other points along the line. Intelligent voltage management devices will be required to manage those complexities. Table 2 below shows the installed costs of both standard voltage management equipment and those required for bi-directional power flow.

Table 2

Device	Standard Equipment	Bi-directional Equipment
Voltage Regulator - 1Ø	$9,429	$10,549
Voltage Regulator - 3Ø	$28,287	$32,714
Capacitor Bank	$5,362	$17,177

As distributed solar installations increase, the existing standard equipment will need to be replaced with more expensive and intelligent equipment capable of managing a dynamic distribution system. As distribution systems build out with distributed solar systems, the more expensive equipment will be installed in-lieu of the standard equipment. As higher levels of distributed solar and other energy sources are installed and existing rotating generation equipment is curtailed, the requirement for more complex voltage regulation will become necessary to prevent voltage stability issues across the entire electrical grid.

Q. Please summarize your testimony.

A. Contrary to the Joint Parties' testimony, in my experience as director of Engineering Standards and Technical Services for Rocky Mountain Power, responsible for the development of all material and equipment specifications and standards used in the construction and maintenance of the transmission and distribution systems, incorporating increasing distributed generation systems into our system will likely *increase*, not decrease costs to the Company and its customers. For this reason, the Commission should reject the Joint Parties' recommendation to attribute any benefit to avoided distribution costs related to the net metering program because operationally, as the Company integrates increasing numbers of distributed generation systems, the net metering program will do just the opposite – it will likely increase distribution costs to the Company and its customers.

Q. Does this conclude your rebuttal testimony?

A. Yes.