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IN THE MATTER OF: **LIBERTY UTILITIES (GRANITE STATE ELECTRIC) CORP. D/B/A LIBERTY UTILITIES**

Distribution Service Rate Case

DIRECT TESTIMONY

OF

AGUSTIN J. ROS

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I. INTRODUCTION

Q. Please state your name, address, employer, position, and professional qualifications

A. My name is Agustin J. Ros, and I am a Principal at the Brattle Group. My expertise is in public utility economics including electricity cost of service and performance-based ratemaking, competition and market power analysis, demand studies and econometric modelling. I teach a class at the annual Edison Electric Institute ("EEI") Advanced Rate Course in Madison, Wisconsin, on embedded and marginal cost of service as well as efficient rate design principles and practices. I am an Adjunct Professor at the International Business School at Brandeis University where I teach a course on regulation and antitrust economics with a focus on public utilities. My research on public utility and competition issues has been published in *Public Utilities Fortnightly*, *The Electricity Journal*, *The Energy Journal*, *The Journal of Regulatory Economics*, *The Review of Industrial Organization*, *The Review of Network Economics*, T*elecommunications Policy* and *Info*. I have a B.A. in economics from Rutgers University and an M.S. and Ph.D. in economics from the University of Illinois at Champaign-Urbana. I attach my CV as an Attachment, AJR-1.

Q. Please describe the scope of your testimony.

A. The Staff of the New Hampshire Public Utility Commission asked me to review and comment on the marginal cost of service ("MCOS") study that Liberty Utilities (also known as Granite State Electric) submitted in this proceeding. Liberty witness Melissa

F. Bartos prepared the Liberty MCOS study ("the Liberty Study") and described the methods and approach in her direct testimony. I provide a brief summary of those methods below.

II. BACKGROUND ON ELECTRICITY MCOS STUDIES

Q. Please define marginal costs.

A. Marginal cost is the change in the total costs of providing a unit change in the output of a good or service. Marginal cost is a forward-looking concept, examining and estimating the economic resources that society will likely incur when producing an additional unit of a good or service. The marginal cost concept is different from the embedded cost concept, the main objectives of which are to assign and allocate the historically incurred costs of providing a good or service.

The precise definition of marginal costs involves estimating the present value of the cash flows caused by a permanent increase in production.[1] Specifically, marginal cost is the difference between two incremental system costs where incremental system cost is the change in the cost of providing an increment of service and not just one additional unit. The first incremental system cost is the change in the present value of the flow of costs caused by a permanent increase in production. The second incremental system cost reflects the same increase in production deferred by one year. The difference in

[1] *See* Ralph Turvey, "Marginal Costs," *The Economic Journal*, June 1969, for one of the earliest discussions on calculating marginal costs.

the two incremental cost flows is the first-year marginal cost. This calculation is known as the deferral approach to calculating first-year marginal costs.

Q. What are the different categories of marginal costs for electricity production?

A. Electric utility marginal costs consist of three main categories: marginal capacity costs—also referred to as marginal demand costs—marginal energy costs and marginal customer costs. Marginal capacity costs are the change in total electricity costs resulting from an increase in customers' peak-period (instantaneous) demands. In the production of electricity, there are marginal generation, transmission and distribution capacity costs. Marginal energy costs are the change in total electricity costs resulting from an increase in the demand for energy during a particular interval in time. Marginal energy costs consist of the fuel costs and the variable operations and maintenance ("O&M") expense required to produce the energy as well as the energy losses associated with increased usage—*i.e.*, transmitting electricity from the generation source to the load source necessarily entails energy losses that needs to be made up through additional generation to meet demand. Marginal customer costs consist of the change in total electricity costs resulting from an increase in the number of customers.

Q. What are the relevant marginal costs for this proceeding?

A. Liberty is an electricity distribution provider. Electricity distribution gives rise to all three marginal costs concepts in theory—marginal capacity costs, marginal energy cost and marginal customer costs—although in practice, the two main categories in an electricity distribution MCOS study are marginal capacity costs and marginal customer costs. Marginal energy costs in an MCOS distribution study are accounted for in the loss factors. In the Liberty MCOS study, the two main categories of distribution marginal cost analysis are the marginal capacity costs and the marginal customer costs with loss factors to account for energy losses applied as a step within the MCOS study.

Q. What are marginal costs used for in the regulation of the electricity sector?

A. Marginal costs play an important role in the regulation of the electricity sector as they can be used for pricing and rate design objectives such as establishing economically efficient dynamic pricing and time of use/time of day rates and for setting appropriate price floors to customers for competitive and economic development purposes. Marginal costs are also used for internal resource planning, for company decision-making, and for wholesale transactions. Marginal costs can also be used for cost allocation purposes in a rate case proceeding.

Q. What are the different types of methodologies that exist for calculating marginal distribution costs?

A. There are two methodologies for calculating marginal distribution investment costs in theory. The first is the system planning approach and the second is the use of statistical/regression analysis ("regression analysis").

The system planning approach follows in the spirit of the marginal cost definition that I discussed previously. Under the system planning approach, electricity engineers and system planners determine the amount of distribution investment that is required in the short- to medium-term due to an increase in peak demand and the cost analyst uses this information to calculate marginal costs. Depending on the availability of the data, the cost analyst performs the analysis for different parts of the distribution system, such as the primary and secondary level. The result of this analysis is a marginal investment per unit of demand, such as per MW or per kW. The cost analyst then annualizes the investment using an economic carrying charge and accounts for additional shared investments and expenses such as general plant, materials and services and administrative and general services. Finally, the cost analyst estimates marginal O&M expenses associated with the marginal investment and includes them in the MCOS calculation.

Q. What is regression analysis?

A. At a high level, regression analysis is the use of statistical methods for estimating relationships between different variables. In this proceeding, we are interested in quantifying the relationship between peak-period demand and distribution investment, with peak-period demand being the independent variable—also known as the “control”, “predictor” or the “regressor” variable—and distribution investment being the dependent variable—also known as the “explained”, the “response” or the “regressand” variable. Regression analysis uses the underlying data to estimate a regression model that provides a quantitative relationship between the dependent variable and the independent variable. As an example, the results of a regression model may indicate that for every one percent increase in the inflation-adjusted price of electricity services, residential electricity demand decreases by one half of one percent. The magnitude of the quantitative relationship between the independent and dependent variable as well as different measures of strength of that relationship and the overall quality of the regression model provides the researcher with information regarding the researcher’s hypothesis and overall research objectives.

There are different regression model specifications and estimation techniques that the researcher can use that can affect the magnitude and strength of the relationships and the overall quality of the regression model. As a result, regression analysis contains a fair amount of “specification testing” to examine the “goodness”—*i.e.*, quality—of different regression models and an analysis of how robust are the results of the regression model to different model specifications and estimation techniques.

Q. Please describe the regression analysis approach in an MCOS study.

A. Under the regression analysis approach for MCOS studies, the cost analyst uses historical data and if data are available a forecast of investment to estimate a regression model that provides a quantitative relationship between peak-period demand and distribution investment costs, in inflation-adjusted terms. An important assumption when using regression analysis is that the historical relationship between peak-period demand and investment is a good estimate of the forward-looking relationship that is expected, given that marginal cost is a forward-looking concept. If, for example, technology or planning criteria have significantly changed over the historical period or expected to change significantly going forward, then use of regression analysis should be avoided and instead the cost analyst should use the system planning approach if these data are available.

The regression model provides an estimate of the marginal investment costs per unit of demand—a key element of an MCOS study. Specifically, the cost analyst obtains a time series of data on peak demand and different plant-related distribution investment costs. Since investment in distribution assets can be lumpy, cumulative plant-related investment is typically used as the dependent variable in order to smooth out the data series and ease the regression modelling process.[2] Using regression analysis, the cost analyst estimates an investment cost per unit of demand and follows the general approach above to arrive at marginal costs.

Q. How are marginal distribution O&M costs typically calculated in marginal cost of service studies?

A. A standard approach is to calculate O&M costs on a per-unit of output basis—*i.e.*, calculate average per-unit O&M expenses—and to utilize that statistic as the value for marginal O&M costs.[3] Specifically, the standard approach begins with historical data on O&M costs for the different investment categories and converts those expenses into an inflation-adjusted series, similar to the conversion that the cost analyst makes for calculating marginal distribution investment. The next step is to convert the O&M

[2] While the smoothing out of the data assists in the estimation of regression models, by eliminating the lumpy nature of capital additions it can distort marginal cost estimates. The fact that capital additions tend to be lumpy in capital-intensive industries like electricity means that the timing of such investments is an important element of marginal costs. In general, marginal costs of investments tend to be higher when the size of the investment is larger or the investment occurs immediately. By contrast, marginal costs of investments tend to be lower when the size of the investment is smaller or likely occurs further out in the future. The nature of a cumulative investment series to a certain extent masks these important facts of marginal costs.

[3] *See* National Association of Regulatory Utility Commissioners, *Electric Utility Cost Allocation Manual*, January, 1992, ("*NARUC Manual*") Chapter 10, p. 131 for a discussion on calculating marginal O&M expenses for transmission capacity costs, an approach that is applicable to O&M expenses for distribution capacity costs.

expenses to a per-unit level of peak demand—for plant-related O&M expenses—or a per-unit level of customer demand—for customer-related O&M expenses—and examine some basic statistics of that data series. The resultant statistics from the data series—*i.e.*, the mean value for the series or the mean value for more recent years or the use of a simple linear extrapolation—provides the O&M expenses that are added to the annualized marginal investments discussed above.

Use of more formal and complex regression models for O&M is, in my opinion, an approach used less often in practice, although it does have some support in the literature as well. An important consideration in the use of more complex regression models for O&M is the characteristic of the underlying data—*e.g.*, how "noisy" are the data, overall variability of the data, and the amount of "outliers" and "anomalies" in the data and explanation for them. When O&M data exhibit these types of characteristics, it is important to examine and compare the O&M regression results with the more standard and parsimonious method that I described in the previous paragraph.

III. LIBERTY MCOS STUDY

Q. Please provide a summary of the methodology of Liberty's MCOS study.

A. The Liberty Study primarily utilizes the regression analysis approach for calculating marginal investment and marginal O&M costs. Specifically, the Liberty Study estimates fourteen different regression models producing fifteen marginal cost inputs into the Liberty MCOS study.[4] For marginal distribution investments for the three main categories of Liberty's plant-related network—the primary system, the secondary system and line transformer—the Liberty Study estimates three different regression models, one for each plant-related network and uses the results of the three regression models for the marginal investment costs in the MCOS study. It then applies an economic carrying charge rate to develop an annualized cost of the investment.

For the O&M expenses for the three plant-related marginal investment costs, the Liberty Study estimates six different regression models, two for each of the three plant-related marginal investment costs. Specifically, the Liberty Study estimates one regression model for operations expenses for the primary network and one regression model for maintenance expenses for the primary network. It does the same for the secondary network and for line transformers for a total of six regression models.

In addition to these nine regression models, the Liberty Study estimates five additional regression models. One regression model for O&M expenses that are customer related—dealing with the O&M expenses associated with the meters and the service drop. One regression model for expenses that are customer account related—these are customer accounting expenses, excluding bad debt—and three separate regression models used as "loaders" in the Liberty Study to account for shared expenses such as

[4] For one of the regression models—the Marginal Administrative and General Expense regression model—Liberty derives two separate loaders, the O&M loader and the Plant loader.

marginal administrative and general expenses, marginal materials and supplies expenses, and marginal general plant.

Q. How does the Liberty Study calculate marginal customer investment costs?

A. The marginal customer investment costs consist of the costs of the customer meters and the cost of the service line connecting the customer to the distribution network. For these two components, the Liberty Study does not utilize regression analysis. Instead, it relies on an analysis performed by Liberty that provided the installed cost of a meter and installed cost of a service drop that is typical for each rate class. Similar to the marginal distribution investment costs, the Liberty Study then applies an economic carrying charge rate to develop an annual cost of the investment.

Q. What are some additional features of the Liberty MCOS study?

A. While there are many additional features and nuances of the study, two additional features involve the marginal costs for street lighting and the loss factors. With respect to street lighting, the Liberty Study uses an approach similar to the marginal customer investment costs. Liberty performed an analysis to provide the installed costs of the different types of street lighting. With respect to the loss factors, Liberty performed an analysis to determine the losses at different levels of the distribution network and developed loss factors to use in the study.

Q. Please summarize the results of Liberty's MCOS study.

A. Liberty witness Ms. Bartos provides the results of the Liberty MCOS study in her direct testimony in Attachments MFB-1 through MFB-11. The results of the fourteen regression models and the fifteen inputs are contained in different attachments. For convenience, I created a table in Attachment AJR-2 that provides the fifteen MCOS inputs used in the Liberty Study that were the result from the regression results. In addition, in the same attachment I provide my recommended changes to some of those fifteen inputs, based upon my discussion and analysis in the next Section of my testimony.

IV. ECONOMIC ANALYSIS

Q. Please describe and summarize the economic analysis you performed in evaluating the Liberty MCOS study and in providing your recommendations.

A. There are several analyses that I performed. First, I utilized the regression data in the Liberty Study and replicated the regression models. Specifically, I used the same model specification and the same estimation technique that the Liberty Study used for the fourteen regression models and replicated the parameter values in the regression models and the overall summary statistics of the models.

Second, I estimated additional regression models for each of the fourteen regression models that the Liberty Study estimated in order to examine the impact on the results from different model specifications and different estimation techniques. My objective in this analysis was to examine how robust were the regression results from the Liberty Study.

Regarding the six O&M regression models that the Liberty Study estimated for the three plant-related investments, in addition to replicating and performing the sensitivity analysis, I combined the O&M data into a single variable for each of the three plant categories and estimated three regression models, rather than the six regression models.

Q. Was there additional economic analysis that you performed with respect to the eight O&M related variables?

A. Yes. For each of the eight O&M expenses in the Liberty Study that use regression analysis—the six plant-related O&M for primary, secondary, line transformer and the two customer-related O&M—I calculated marginal O&M expenses using the standard approach that I discussed in Section II. Specifically, for the plant-related O&M variables, I created a new variable: O&M dollar expenses divided by the peak demand. For the customer-related O&M variables, the new variable I created was the O&M dollar expense divided by the number of customers. These new variables are the average per-unit O&M expenses for the different plant categories and for the customer category.

Q. Please explain why you created this new O&M variable and the analysis that you performed.

A. As discussed previously, a standard approach for determining the marginal O&M expenses in a marginal cost of service study is to utilize the most recent per unit O&M expense—or a simple average of the more recent period—or to extrapolate the per unit O&M forward over several years using the historical data. It is reasonable to compare the results from the Liberty Study to results using the standard approach. This is especially required if the underlying O&M data are particularly “noisy” with high variability and with data observations that appear to be outliers or anomalies. Data with these characteristics makes regression analysis more difficult, complex, and potentially less robust. After reviewing the O&M data, I believe there is sufficient evidence to conclude that the O&M data meet these characteristics and believe it is reasonable and necessary to compare the marginal O&M estimates from the regression models to the estimates from the more standard approach. I find significant differences between the two approaches and recommend the use of the standard approach for the marginal O&M estimates.

Q. Please explain the O&M analysis you performed in more detail.

A. For the six O&M expenses associated with the three plant-related investments and for the two expenses associated with the customer category—eight in total—I calculated the per unit O&M expense as described above. This results in eight per unit O&M time series data. For each of the eight data series I calculated the mean value of the data series over the entire period as well as the mean value of the data series over the most recent 5 years. In addition, I also used the entire data series to extrapolate three years forward using a simple linear trend of historical values.

Q. How do the marginal O&M expenses under the standard approach compare to the Liberty MCOS marginal O&M?

A. I have created Attachment AJR-3 where I compare Liberty’s eight marginal O&M expenses from the MCOS study to the marginal O&M cost results using the standard approach. For each of the eight O&M expenses from the MCOS study I calculated the mean value of the per unit O&M data series over the entire period, the mean value over the most recent five years and a simple linear extrapolation using the entire period.

Q. What are your main observations and conclusions from Attachment AJR-3?

A. Compared to the marginal O&M costs using the standard approach, the Liberty Study's marginal O&M costs are systematically and significantly higher. For example, for primary operations expense, the Liberty Study is $35,927 per MW while the mean value of the entire period and the most recent five-year period are $5,633 per MW and $9,659 per MW, respectively. The extrapolated 2019 value is $9,887. Another way of comparing the results is that the Liberty Study's estimate for primary operations expense is approximately 3.7 times the mean value of the most recent five-year period.

With only one exception involving secondary operations expenses, using the most recent five-year period in Attachment AJR-3 the marginal O&M estimates from the Liberty Study are significantly higher than the standard approach, with the difference ranging from around 1.9 times higher for customer account expenses to 3.7 times higher for primary operations expenses. Compared to the 2019 extrapolated values the differences range from 1.8 times higher for line transformer maintenance expenses to 3.6 times higher for primary operations expenses.

For the exception where the Liberty results are lower than the standard approach, which involves the secondary operations expenses, the Liberty Study's estimate of $3,410 per MW is practically identical to the simple five-year mean value of $3,516 per MW.

Q. What is your recommendation with respect to O&M?

A. I recommend that the Liberty MCOS study use the 5-year average results for the O&M marginal costs as summarized in Attachment AJR-2. I base this upon the fact that there are significant and systematic differences in the marginal O&M estimates from the Liberty Study compared to the standard approach as well as the data issues that I discussed above that make regression analysis more challenging, complex and less robust.[5] In general, in the absence of evidence and support I do not believe that the marginal O&M costs predicted by the regression model would be so much greater than the company's recent average unit O&M expenses. The Liberty Study does not provide evidence to justify such large differences.

Q. Why do you recommend the 5-year average instead of the average over the historical period or the projected O&M expenses?

A. The historical period begins in early 2000s and using the entire series puts equal weight on older O&M data and more recent O&M data and can compromise the goal of estimating forward-looking O&M expenses. Use of more recent years for developing O&M "adders" is a standard practice in a marginal cost study. Projected expenses are more consistent with the forward-looking goal of marginal cost analysis but in this particular case, I do not recommend using the projected expenses. A simple linear extrapolation using the entire historical period confronts the same data issues as discussed above. Using fewer years of data to estimate a linear trend makes the estimate

[5] The latter is reflected, in part, by the lower explanatory power of the O&M regression equations compared to the plant additions regression equations, pointing to increased difficulty of the regression method to satisfactorily estimate marginal O&M costs.

more forward looking but comes with the cost of having a lower sample size and less precise estimates. Quantitatively, the differences between use of the 5-year average O&M expenses and the 2019 projected O&M expenses are relatively modest and are not systematic; that is, in 5 instances projected 2019 O&M expenses are higher in 2 instances lower and in one case unchanged.

Q. In Liberty's previous case involving marginal costs the Staff raised concerns with Liberty not utilizing regression analysis for most of the components and instead relying too much on average unit costs. What were the concerns that Staff raised?

A. I have read the testimony of Staff witness Leszek Stachow in Docket DE 16-383.[6] In that proceeding, Liberty utilized the average unit cost approach not just for the operations and maintenance components but also for the primary, secondary and transformer *investment* components. Staff's overall concern appeared to be that relying too much on the average unit costs approach would result in deviating too much from standard marginal cost based methodology and importantly distort class revenue signals. Staff also objected to the lack of explanation on the company's part for using the average unit cost approach, especially for the investment components.

Q. Does your recommendation to use the average unit cost approach for O&M expenses result in deviating too much from a standard marginal cost based methodology?

[6] *See In the Matter of Liberty Utilities (Granite State Electric) Corp. d/b/a Liberty Utilities Request For Change in Rates*, Direct Testimony of Leszek Stachow, December 16, 2016.

A. No, it does not and I believe Staff's concern was properly more related to the investment components and less so related to the O&M components. With respect to the investment component of the marginal cost study, my recommendation is to utilize the Liberty Study results and not use average unit investment costs.

Q. Please explain.

A. Using average unit costs for O&M from a recent historical period can be a good approximation of the forward-looking O&M expenses that the company is likely to incur—*i.e.*, the marginal costs.[7] Significant differences between the average unit cost approach for O&M and other approaches for calculating marginal O&M expenses require a reasoned analysis, an examination of whether the results are plausible and evidence to justify why O&M expenses in the immediate future will be so different than in recent years.

The use of the average unit cost approach for O&M costs in a marginal cost of service study is standard practice and recognized as an acceptable method in the *NARUC Manual*. Based upon my experience with marginal cost studies in electricity and telecommunications the average unit O&M cost approach is widely used as a proxy for marginal O&M costs. While there can be more sophisticated and costly methodologies employed to adjust average unit O&M costs and forecast them—such as conducting surveys of future O&M processes and procedures—using such methodologies occur less frequently and may not result in much greater precision to justify the added costs.

[7] See *NARUC Manual*, *op. cit.* 3 at 131.

In contrast, the use of an average unit cost approach for investment as a proxy for forward-looking marginal *investment* costs is not standard practice in electricity and would likely result is significant deviations from forward-looking marginal investment calculations. In its discussion of different methodologies for calculating marginal investment (capacity) costs, the *NARUC Manual* identifies the Projected Embedded Analysis, a variation of the type of regression performed in the Liberty Study only that it also includes forward-looking data in the regression. It also discusses the System Planning Approach, which I discussed above as being one way of implementing the methodology that arises from the definition of marginal costs. The average unit cost approach for investment is not an option identified in the *NARUC Manual*. My experience in marginal cost of service is that using the average unit cost for investment as a proxy for marginal investment costs is rare.

Q. Regarding the Liberty Study's fourteen regression analyses, where you able to replicate all of them?

A. Yes. I was able to replicate all aspects of the fourteen regression models in the Liberty Study.

Q. Please describe in more detail the additional regression models that you estimated using different specifications and estimation techniques.

A. For each of the fourteen regression models, I estimated many different regression models. I began by estimating regression models where there was a contemporaneous relationship between the independent variable—*e.g.*, peak demand or number of customers—and the dependent variable. Within this category of regression models, I experimented with a number of different model specifications, such as including a linear time trend by itself and with a quadratic element, as well as experimenting with other forms of non-linear time trends.[8] For some of the regression models I included year dummy variables for specific data observations that seemed to be data outliers by visual inspection, with these models being the models involving the O&M models and the shared expense (loader) models. In terms of estimation techniques, I utilized both ordinary least squares ("OLS") estimators as well as feasible generalized least squares estimators ("FGLS") that correct for autocorrelation and heteroscedasticity.

In addition to the regression models just described, I experimented with three additional regression methodologies. First, I used the same model specifications described above but transformed the data by "first differencing" the data. First differencing the data means creating a new variable that is the difference in the data for two adjacent periods. First differencing the data is another way to deal with autocorrelation and to make the data stationary, an important statistical property needed for regression analysis. The second additional methodology that I used was to estimate "dynamic" regression models using similar model specifications and the OLS and FGLS estimators. Specifically, I included the lagged value of the dependent variable in the model specification. A dynamic regression model—also known as an autoregressive model or in this case a geometric distributed lag model—recognizes that past values of the

[8] A regression model with a linear time trend and with a quadratic time trend means the regression model has a time trend variable as a coefficient and the square of the time trend as an additional coefficient. A quadratic is included to account for the possibility that the effect of time on the dependent variable may not be constant throughout the period and may be changing at an increasing or decreasing rate.

dependent variable may be important in explaining the current value of the dependent variable. The Liberty Study utilizes autoregressive models as well. The third additional methodology that I use is to estimate a particular type of dynamic model by including, in addition to the lagged value of the dependent variable, the lagged value of the explanatory value, in this case the lagged value of peak demand or lagged value of customer. This type of model is known as the rational distributed lag model.

Q. Please summarize your main findings from your regression analyses involving the three plant-related investment categories.

A. With respect to the regressions involving plant-related investment categories, I found one instance where a different model specification provided plausible results compared to the Liberty Study's regressions. For all other specifications, I did not find regression models that were superior to the Liberty Study's regression models.

Q. For which regression model did you find an alternate specification that you believe provides plausible results?

A. The model was the regression where the dependent variable was the primary plant additions and the independent variables were contemporaneous peak demand and its lagged value, the lagged value of primary plant additions and a simple time trend. This is a specification of the rational distributed lag model. The coefficient estimates of the contemporaneous peak demand and its lagged value were jointly significant at the 8.8 percent level of statistical significance and implied a marginal investment cost of approximately $155,000 per MW under both OLS and FGLS estimators. This compares to $115,690 per MW in the Liberty MCOS study for primary plant additions. Attachment AJR-4 provides the results for this model.

Q. What do you recommend concerning the marginal cost of primary plant additions?

A. The Liberty Study regression model for primary plant additions is a better model than what I found, based upon the precision of the coefficient estimates. To assess further the Liberty model I took the Liberty Study regression model for primary plant additions, the model that results in a marginal cost estimate of $115,690 per MW, and I experimented with different specifications. This analysis led me to conclude that the $115,690 per MW is a reasonable estimate. Specifically, the Liberty Study regression model for primary plant includes a specification with an autoregressive lag order 4. I kept the same specification but instead of including an autoregressive lag order 4, I included different lag orders from 1 through 5. I found that models with lag order 2 and lag order 3 resulted in marginal cost estimates of $100,224 per MW and $93,518 per MW, and both statistically significant. The Liberty Study marginal cost estimate of $115,690 per MW is reasonably close to the midpoint range consisting at the low end of $93,518 per MW and the high end of $155,690 per MW and so I recommend keeping the $115,690 per MW estimate.

Q. Please summarize your main findings from your regression analyses involving the eight operations and maintenance related expenses.

A. With respect to the eight operations and maintenance related expenses, I was not able to find model specifications that produced plausible results and where the quality of the regression model was good. As discussed previously, if the underlying O&M data are particularly “noisy” with high variability and with data observations that appear to be outliers or anomalies regression analysis becomes more difficult, complex, and potentially less robust.

Q. Did you perform any other regression analyses involving the operations and maintenance data?

A. Yes. For the six regression analyses involving operations and maintenance for the three plant-related categories—primary system, secondary system and line transformer—I combined the data into one O&M variable for each plant-related category. I estimated three additional regression model using the same set of model specifications and estimators described above.

Q. Why did you combine the O&M data?

A. Given the data issues with the O&M data discussed above, combining the O&M expenses helps smooth out the data and minimizes the effects of data outliers/anomalies in the individual data series. In general, costing theory does not require that operations and maintenance be treated separately in a cost analysis.

Q. What were your main findings?

A. I found two instances where the regression models provided plausible statistical results involving the combined operations and maintenance expenses for primary plant additions. The two models where I found plausible results were the geometric distributed lag model and the rational distributed lag model. For the two other plant categories, I did not find regressions models that produced plausible results and where the quality of the regression model was good.

Q. Please describe your findings from these two models.

A. For the geometric distributed lag model, the independent variables were contemporaneous peak demand, contemporaneous SAIFI, 3 separate year dummies for 2005, 2010 and 2014, a time trend and the lagged value of primary O&M expenses with the model estimated using FGLS. The coefficient estimate on the contemporaneous peak demand implies a marginal primary plant O&M cost of approximately $16,000 per MW. For the rational distributed lag model, the independent variables were contemporaneous peak demand and its lagged value, contemporaneous SAIFI, 3 separate year dummies for 2005, 2010 and 2014, a time trend and the lagged value of primary O&M expenses all estimated using FGLS. The coefficient estimates of the contemporaneous peak demand and its lagged value were jointly significant at the 6.5 percent level of statistical significance and the coefficient implied a marginal primary plant O&M cost of approximately $16,000 per MW. Attachment AJR-5 provides the results for this model.

I note that the $16,000 per MW estimate for primary plant O&M costs using these two models are very close to the estimates from the standard approach discussed above. Specifically, for the combined primary plant O&M costs, the mean value of the most recent five-year period is approximately $17,000 per MW while the 2019 extrapolated value is approximately $18,000 per MW.

Q. Do you have any recommended changes to the Liberty Study as it pertains to the share expense loader?

A. No, I do not. I did not find regression models that were plausible or superior to the models estimated in the Liberty Study. In addition, a comparison of the loaders estimated in the Liberty Study to the standard approach discussed above leads me to conclude that the Liberty Results are reasonable.

V. RECOMMENDATIONS

Q. Based upon the economic analysis that you performed and described in your testimony what are your MCOS recommendations?

A. Attachment AJR-2 provides a summary of my recommendations involving the fifteen marginal cost inputs that make up the Liberty Study. For seven of the marginal cost inputs I recommend no change. For eight of the marginal cost inputs I recommend that the changes in Attachment AJR-2 be inputted into the Liberty Study.

Q. Did you input these values into the Liberty Study and what were the results?

A. Yes. The only change I made to the Liberty Study was to input the values for the eight recommended marginal cost inputs in Attachment AJR-2 into the Liberty MCOS model. A good way to summarize and compare the results is to replicate Table 1 in Liberty witness Bartos testimony. Attachment AJR-6 summarizes the results. My recommended changes results in lower overall marginal capacity and customer cost estimates for all customer classes (except outdoor lighting, which remains unchanged).

In terms of the relative distribution of the marginal cost revenue requirement among the rate classes, my recommendations affect the relative overall cost obligation of the different rate classes. The domestic class D goes from 50.60% in the Liberty Study to 51.76% based upon my recommendations. The changes for the other classes are: class D-10, from 0.74% to 0.78%; class G-1, from 19.16% to 17.17%, class G-2, from 12.29% to 11.81%, class G-3, from 14.20% to 14.68%, class M, from 1.40% to 2.16%, class T from 1.56% to 1.60%, and class V, remains practically unchanged.

Q. Does this conclude your testimony?

A. Yes.

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Dr. Agustin J. Ros is a Principal of the Brattle Group whose expertise is in public utility economics and antitrust in network industries—airlines, energy, postal, telecommunications and water—and is an Adjunct Professor at the International Business School at Brandeis University where he teaches a course on public utilities and antitrust economics. He has more than 20 years of consulting and agency experience and specializes in cost of service and performance-based ratemaking, competition and market power in network industries, damages, and econometric modelling. He teaches at the annual Edison Electric Institute ("EEI") Advanced Rate Course in Madison, Wisconsin on embedded and marginal cost of service as well as efficient rate design principles and practices. At the EEI Electric Rate Course he has taught industry professionals all aspects of embedded cost of service including the theory and practice of functionalization, classification, allocation and rate design.

Dr. Ros worked at the Illinois Commerce Commission where he reviewed dozens of cost of service studies and advised the Chairman on all matters before the Commission. His consulting and research interest includes examining the workings of retail electricity competition and his econometric and statistical investigation of competition in retail and wholesale electricity markets in the U.S. was recently published in the *Energy Journal*. In addition, he has published his research in the *Journal of Regulatory Economics*, *Review of Industrial Organization*, *Review of Network Economics*, T*elecommunications Policy* and *Info*.

AREAS OF EXPERTISE

- Cost of Service, Demand and Pricing in Network Industries
- Regulated Industry Policy and Restructuring
- Competition and Performance Based Ratemaking

EDUCATION

Ph.D. Economics, University of Illinois-Urbana Champaign 1994

M.S. Economics, University of Illinois-Urbana Champaign 1991

B.A. Economics, Rutgers University-Newark 1989

TEACHING POSITIONS

Brandeis University, International Business School, *Adjunct Professor* 2016-present

University of Anahuac, Mexico City, *Guest Lecturer* 2010

Northeastern University, *Adjunct Instructor* 2000

EXPERT REPORTS, TESTIMONY AND AFFIDAVITS

Expert report on behalf of the Newfoundland and Labrador Board of Commissioners of Public Utilities: Review of Existing and Proposed Network Additions Policies for Newfoundland and Labrador Hydro, with Philip Hanser and Peal Donohoo-Vallet, November 19, 2019.

Expert report on behalf of Bragg Communications Inc. (c.o.b. Eastlink), Cogeco Communications Inc., Rogers Communications Canada Inc., Shaw Cablesystems G.P., and Videotron Ltd., Analysis of CRTC's Final Rates for Aggregated Wholesale High-Speed Access Services: Impact on Broadband Network Investment and Innovation, with Renée M. Duplantis, Dimitri Dimitropoulos and Ian Cass, November 13, 2019.

Direct Testimony on behalf of the Virginia Electric Power Company on cost allocation of utility scale solar projects, before the Virginia Corporation Commission, July 1, 2019.

Expert report on behalf of the Newfoundland and Labrador Board of Commissioners of Public Utilities: Embedded and Marginal Cost of Service Review, with Phil Hanser, T. Bruce Tschusida, Pearl Donohoo-Vallet, and Lynn Zang, May 3, 2019.

Expert report on behalf of Shaw Communications before the Canadian Legislative Review Panel of the Broadcasting and Telecommunications: Analysis of BDU Contributions, ISP Taxes and Regulations in the Canadian Broadcasting and Telecommunications Industries: Economic Efficiency, Investment and Innovation, with Coleman Bazelon and Renée Duplantis, January 11, 2019.

Expert opinion on behalf of CFE International LLC before the U.S. Citizenship and Immigration Services and Department of Homeland Security: An Overview of the Mexican Energy Markets and Reforms, October 25, 2018.

Expert report on behalf of Shaw Communications before the Canadian Competition Bureau: An Analysis of Broadband Services in Canada, Competition, Regulation and Investment with Coleman Bazelon and Renée Duplantis, August 30, 2018.

Affidavit on behalf of CFE International LLC before the Federal Energy Regulatory Commission: market-based rate authority application on vertical and horizontal market power issues in U.S. electricity markets, with Judy Chang, June 13, 2018.

Expert report on behalf of the Australian Competition and Consumer Commission (ACCC), before the ACCC: International experiences in retail electricity markets, with Toby Brown, Neil Lessem, Serena Hesmondhalgh, James D. Reitzes and Haruna Fujita, June 2018

Expert report on behalf of Transportadora de Gas Natural de la Huasteca, S. de R.I. de C.V. before the Mexican Energy Regulatory Commission: expert opinion on issues related to the appropriate allowed rate of return for the TGNH pipeline, with Paul Carpenter and Bente Villadsen, May 23, 2018.

Expert report on behalf of Infraestructura Marina del Golfo, before the Mexican Energy Regulatory Commission: expert opinion on issues related to the appropriate allowed rate of return for the IMG pipeline, with Paul Carpenter and Bente Villadsen, May 23, 2018.

Expert report on behalf of GCI Communications before the Federal Communications Commission: rate of return, cost of service and cross-subsidy analysis of GCI's Satellite-Based Services, with William Zarakas and Nicolas E. Powers, May 2018.

Expert report on behalf of GCI Communications before the Federal Communications Commission, In the Matter of Connect America Fund and Universal Service Reform, WC Docket No. 10-90 and WT Docket No. 10-208A: analysis of the FCC's Rural Health Care Program Funding and Recipients, with William Zarakas, David Kwok, and M. Elaine Cunha, September 2017.

Expert report on behalf of Teléfonos de Mexico before the Mexican Telecommunications Authority: measurement of total factor productivity for Teléfonos de Mexico, July, 2014.

Expert report on behalf of Citibank, before the Honduran Competition Commission: expert report on the competitive effects of the FICHOSA – Citibank merger, April, 2014.

Expert report on behalf of America Móvil before the Mexican Competition Commission: correcting the OECD's erroneous assessment of competition in the Mexican telecommunications sector, May 2013. With Professor Jerry A. Hausman.

Expert report on behalf of Leyde and LACTHOSA before the Honduran Competition Commission: expert report on the competitive effects of a joint venture between Leyde and LACTHOSA in the Honduran dairy sector, April 2013.

Expert report on behalf of Lowe's Mexico before the Mexican Competition Commission: economic analysis on market definition, market power and monopolistic practices in the market for home improvement products sold through superstores, October 2012.

Expert report on behalf of Comcel before the Regulatory Commission of Communications in Colombia: expert report on economic analysis of Resolution CRC 3139 2011 regarding on-net and off-net pricing and termination rates, November 9, 2011.

Expert report on behalf of ESSOSA and Puma before the El Salvador Competition Commission: expert report on the competition implications of assets sales in El Salvador, (with Ramsey Shehadeh) October 5, 2011.

Expert report on behalf of ESSOSA and Puma before the Honduran Commission for the Defense and Promotion of Competition: expert report on the competition implications of assets sales in Honduras, (with Ramsey Shehadeh) July 19, 2011.

Testimony before the state of Illinois on behalf of Northern Illinois Gas Company, Docket No. 11-0046, surrebuttal testimony regarding market definition, market power and public interest considerations, filed April 22, 2011.

Testimony before the Alberta Public Utility Commission, Proceeding 566 Electricity Rate Regulation Initiative, update, reply and PBR review study, filed February 22, 2011.

Testimony before the Alberta Public Utility Commission, Proceeding 566 Electricity Rate Regulation Initiative, total factor productivity study, filed December 30, 2010.

Testimony before the state of Illinois on behalf of Northern Illinois Gas Company, Docket No. 09-0310, rebuttal testimony regarding market definition, market power and public interest considerations, filed August 6, 2010.

Expert report before the Commission for the Supervision of Business Competition of the Republic of Indonesia on behalf of Singapore Telecommunications Limited and Singapore Telecom Mobile, "Competitive Assessment of the Indonesian Mobile Sector," (with William E. Taylor, Nigel Attenborough and Christian Dippon), filed October 15, 2007, rebuttal report filed January 11, 2008.

Expert report before the Ministry of Economic Affairs and Development on behalf of Cable and Wireless Barbados, "An Economic Assessment of Mandating Indirect Access in Barbados," (with Michael Khyefets and Loren Adler), November 14, 2007.

Expert report before the Supervising Agency for Private Investment in Telecommunications in Peru (OSITPEL) on behalf of Telefonica de Peru, expert report on economic efficiency considerations with respect to termination rates and the impact of capacity-based charges, (with Jose Maria Rodriguez), filed October 17, 2007.

Expert report before the Canadian Radio and Telecommunications Commission (Telecom Public Notice CRTC 2006-14) on behalf of Bell Aliant Regional Communications, "Telecommunications Competition in the US: An Assessment of Wholesale Regulation Policy," (with William E. Taylor), filed March 15, 2007.

Expert report before the New York Public Service Commission (Case 06-C-0897) on behalf of Verizon New York, "Report on Competition for Retail Business Services," (with William E. Taylor and Harold Ware), filed report August 31, 2006. Supplemental Report filed October 2, 2006.

Expert report before the Telecommunications Authority of Trinidad and Tobago on behalf of Telecommunications Services of Trinidad and Tobago, response to Digicel's economic analysis of Interconnections costs and rates, filed May 12, 2006 (with Timothy Tardiff).

Expert report before the Telecommunications Authority of Trinidad and Tobago on behalf of Telecommunications Services of Trinidad and Tobago, expert report on interconnections costs in Trinidad and Tobago, filed May 4, 2006 (with Timothy Tardiff).

Expert report before the Telecommunications Authority of Trinidad and Tobago on behalf of Telecommunications Services of Trinidad and Tobago, expert report on Benchmark Mobile Termination Rates, Evaluation of the .Econ Report, filed February 10, 2006 (with Timothy Tardiff).

Expert report before the Supervising Agency for Private Investment in Telecommunications in Peru (OSITPEL) on behalf of Telefonica de Peru, expert report on OSIPTEL's imputation methodology, filed February 7, 2006 (with Jose Maria Rodriguez and Eduardo Prieto Kessler).

Expert report before the Comisión Federal de Telecomunicaciones de México, on behalf of Telcel, S.A., expert report measuring the cost Telcel incurs when providing interconnection services to operators, filed 22 June 2005.

Expert report before the Supervising Agency for Private Investment in Telecommunications in Peru (OSIPTEL) on behalf of Telefonica de Peru, final report regarding the estimation of Telefonica de Peru's total factor productivity for application in the 2004-2007 price cap regime (with José María Rodríguez Ovejero and Juan Hernández García), 21 June 2004.

Expert report before the Bahamas Public Utilities Commission, on behalf of the Bahamas Telecommunications Company, "Public Consultation on the Universal Service Obligation in The Bahamas," Comments filed 24 March 2004; Reply Comments filed 10 June 2004.

Expert report before the Canadian Radio-television and Telecommunications Commission on behalf of Aliant Telecom Inc., Bell Canada, MTS Communications Inc., Saskatchewan Telecommunications and Télébec, société en commandite, Public Notice 2003-10, "A Review of Rules and Regulations Governing Bundled Telecommunications Services." filed 12 March 2004, updated report filed 26 March 2004.

Expert report before the Bahamas Public Utilities Commission, on behalf of the Bahamas Telecommunications Company, "Public Consultation on Price Control of Bahamas Telecommunications Company," 19 September 2003.

Expert report before the Comisión Federal de Telecomunicaciones de México, on behalf of the Commission, "Telmex's 2003-2006 Price Cap Tariff Proposal," expert report in arbitration regarding the renewal of the price cap plan for Telmex (with William Taylor, Georgina Martinez, and Aniruddha Banerjee), 13 December 2002.

Expert report before the Honorable Arbitration Tribunal of Fairness in Guatemala, Case No. CENAC-A-01-2002, final report in arbitration regarding call termination costs in fixed and wireless networks (with José María Rodríguez Ovejero, Laurent Bensancon, and Juan Hernández García), September 2002.

Expert report before the Federal Communications Commission on behalf of BellSouth Corporation Docket Nos. 01-338, 96-98, 98-47 Reply Declaration (with William Taylor, Aniruddha Banerjee, and Charles Zarkadas) regarding unbundling obligations of local exchange carriers. Filed 17 July 2002.

Expert report before the Federal Communications Commission on behalf of Verizon Communications, Docket Nos. 01-339, 01-337, 02-33, Statement of 43 Economists on the Proper Regulatory Treatment of Broadband Internet Access Service, 3 May 2002.

Expert report before the New Zealand Commerce Commission on behalf of Telecom New Zealand, "Review of CostQuests' Associates Benchmarking Survey" (with William Taylor, Greg Houston, Tom Hird, Jaime D'Almeida, and Carol Osborne), May 2002.

Testimony before the State of Illinois on behalf of Verizon North Inc. and Verizon South Inc., Docket No. 98-0195, surrebuttal testimony regarding investigation into certain payphone issues as directed in Docket 97-0225, 16 July 2001.

Expert report before the Supervising Agency for Private Investment in Telecommunications in Peru (OSIPTEL) on behalf of Telefonica de Peru, final report regarding the estimation of Telefonica de Peru's total factor productivity for application in the 2001-2003 price cap regime (with Timothy Tardiff, José María Rodríguez Ovejero, and Juan Hernández García), 22 June 2001.

Testimony before the State of Illinois on behalf of Verizon North Inc. and Verizon South Inc., Docket No. 98-0195, rebuttal testimony regarding investigation into certain payphone issues as directed in Docket 97-0225, 20 April 2001.

Expert report before the New Zealand Commerce Commission, on behalf of Telecom New Zealand, "Costs of Telecommunications Competition Policies," final report exploring the indirect economic costs of changing competition policy to a more regulatory approach (with Harold Ware, Timothy Tardiff, and Nigel Attenborough), May 2000.

Testimony before the State of Illinois on behalf of GTE North Incorporated and GTE South Incorporated, Docket No. 98-0195, direct testimony regarding investigation into certain payphone issues as directed in Docket No. 97-0225, 21 December 1999.

Expert report before the Federal Communications Commission on behalf of US West, An Economic and Policy Analysis of Efficient Inter-Carrier Compensation Mechanisms for ISP-Bound Traffic, 12 November 1999.

Expert report before the Pennsylvania Public Utility Commission on behalf of Bell Atlantic Pennsylvania, Promised Fulfilled: Bell Atlantic-Pennsylvania's Infrastructure Development (with William Taylor, Charles Zarkadas, and Jaime D'Almeida), 15 January 1999.

Testimony before the State of Illinois on behalf of Illinois Gas Transmission Company, Docket No 98-0510, rebuttal testimony regarding certification of Illinois Gas Transmission Company as a Common Carrier by Pipeline and approval of rates and accounting, and for cancellation of the Certificate of Illini Carrier, LP, 11 January 1999.

Expert report before the Spanish Regulatory Commission on behalf of Telefónica, final report "Assessment of the methodology used by Telefónica in the calculation of the prices included in the interconnection reference offer and comparison with BT's interconnection prices" (with Nigel Attenborough, David Robinson, Yogesh Sharma, and José María Rodríguez Ovejero), October 1998.

Expert report before the Italian Regulatory Commission on behalf of Telecom Italia, final report "Volume Discounts: A Report for Telecom Italia" (with Nigel Attenborough, Andrea Coscelli, and Andrea Lofaro), October 1998.

Expert report before the Federal Communications Commission on behalf of Bell Atlantic, Docket Nos. 96-262, 94-1, 91-213, 96-263, "An Analysis of the Effects of Exchange Access Reform on Demand Stimulation" (with Charles Zarkadas), 27 April 1997.

RECENT CONSULTING ENGAGEMENTS

Consulting work on behalf of a major electricity distribution company in the U.S.: cost study and competitive pricing principles of advanced metering services. 2018.

Consulting work on behalf of a Canadian electricity provider: benchmarking analysis of generation utilities in transmission and regulatory practices with respective to generation procurement practices, distributed energy resources and customer-specific pricing practices, 2018.

Consulting work on behalf of a U.S. generation and transmission electricity cooperative: embedded and marginal cost of service studies to support rate reform initiative, 2018.

Consulting work on behalf of a major electricity distribution provider in the U.S.: develop a locational distribution marginal cost-based cost of service study to support the value of distributed energy resource proceedings, 2017 - 2018.

Consulting report on behalf of major foreign electricity and gas distribution company: Rules and regulations applicable to the competitive U.S. retail electricity providers in the U.S. and Canada: A regulatory assessment. November 2017.

Consulting report on behalf of major foreign electricity and gas distribution company: Rules and regulations applicable to the competitive U.S. retail natural gas providers in the U.S. and Canada: A regulatory assessment. November 2017.

Consulting work on behalf of the Cities of Garland, Mesquite, Plano, and Richardson appealing the decision by North Texas Municipal Water District affecting wholesale water rates, Texas PUC Docket No. 46662 and SOAH Docket No. 473-17-4964.WS: economic analysis of whether wholesale water rate charged by the District adversely affects the public interest and rate design issues.

Consulting work on behalf of a major electricity distribution company in the U.S.: cost study and competitive pricing principles of advanced metering services. 2015 - 2016.

Consulting report for the Mexican National Center for the Control of Natural Gas: Electricity demand forecast for the National Mexican Electricity System for the period 2017-2030. December 2016. With Veronica Irastorza and Elvira Creel.

Consulting report for the Mexican Secretariat of Communications and Transport: “Econometric demand study of fixed and mobile broadband and telephony services and Pay-TV services using discrete choice analysis.” January 2016. With Kenneth Train and Douglas Umaña.

Consulting report for the Mexican Secretariat of Energy, CFE horizontal generation split analysis: recommended number of CFE gencos. September 2015. With Hamish Fraser and Willis Geffert.

Consulting report for the Mexican Secretariat of Energy, CFE horizontal generation split analysis: Recommended optimal portfolio mix for the CFE gencos. September 2015. With Hamish Fraser and Willis Geffert.

Consulting report for the Mexican Secretariat of Energy, CFE horizontal generation split analysis: Identification of relevant markets within the Mexican wholesale electricity markets. August 2015. With Hamish Fraser and Willis Geffert.

Consulting report for the Mexican Secretariat of Energy: Vesting contract criteria and methodology report. July 2015. With Hamish Fraser, Gene Meehan and Kurt Strunk.

RECENT PRESENTATIONS

Presentation before Rutgers University’s Center for Research in Regulated Industries, Advanced Workshop: “Residential Electricity Competition at a Crossroads,” January 2019.

Presentation before the EEI Electric Rates Advanced Course, “Introduction to Embedded Cost of Service,” with Phil Q Hanser, July 2018.

Presentation before the EEI Electric Rates Advanced Course, "Introduction to Marginal Cost of Service," with Phil Q Hanser, July 2018.

Presentation before the Public Collaborative for the Puerto Rico Electricity System, "Introduction to Utility Regulation," with Karl McDermott, July 19, 2018.

Presentations before the Public Collaborative for the Puerto Rico Electricity System, "Introduction to Electricity System Planning," with Karl McDermott, July 19, 2018.

Presentation before the Public Collaborative for the Puerto Rico Electricity System, "Ownership Structure, Contracting Process and Wholesale Markets," with Karl McDermott, July 19, 2018.

Presentation before Rutgers University Center for Research in Regulated Industries Eastern Conference: "Marginal cost of service: electricity distribution locational marginal costs, with Phillip Q Hanser and T. Bruce Tsuchida, June 8, 2018.

Presentation before the World Forum on Energy Regulation, Cancun Mexico: "Rate design helping facilitate change in electricity markets," March 2018.

Presentation before Rutgers University's Center for Research in Regulated Industries, Advanced Workshop: "Utility of the future and cost of service: challenges and opportunities," January 2018.

Presentation before Rutgers University's Center for Research in Regulated Industries, 36th Annual Eastern Conference: "The evolving electricity distribution network – technological, competitive and regulatory implications." May 2017.

Presentation before Rutgers University's Center for Research in Regulated Industries, Advanced Workshop: "Costing and pricing of electricity smart grid service offerings and competitive implications." January 2017.

Presentation before Rutgers University's Center for Research in Regulated Industries, 35th Annual Eastern Conference: "Determinants of total factor productivity in the U.S. electricity sector and the effects of performance-based regulation." May 2016.

Presentation before Rutgers University's Center for Research in Regulated Industries, Advanced Workshop: "merger theory and practice in the U.S. electricity sector." January 2016.

PUBLICATIONS

"Economic framework for compensating distributed energy resources: Theory and practice." (with Romkaew Broehm and Philip Hanser), *The Electricity Journal* 31(8): 14-22 (2018).

"The future of the electric grid and its regulation: Some considerations," *The Electricity Journal* 31(2): 18-25 (2018).

"An Econometric Assessment of Electricity Demand in the United States using Utility-Specific Panel Data and the Impact of Retail Competition on Prices." *The Energy Journal* 38(4): 73-99 (2017).

"An Econometric Assessment of Telecommunications Prices and Consumer Surplus in Mexico using Panel Data." (with Jerry A. Hausman), *Journal of Regulatory Economics*, vol. 43:284-304 (2013).

"Corrección de la Evaluación Errónea de la OCDE Acerca de la Competencia en el Sector de las telecomunicaciones en México." (con Jerry Hausman), *El Trimestre Economico* (2013).

"The Impact of Asymmetric Mobile Regulation in Colombia." (with Douglas Umana), *Info*, vol. 15 No. 3:54-65 (2013).

"Correcting the OECD's Erroneous Assessment of Telecommunications Competition in Mexico." (with Jerry A. Hausman), *CPI Antitrust Chronicle* June 2012.

"North American Performance-Base Regulation for the 21st Century." (with Jeff D. Makholm and Stephen Collins), *Electricity Journal* vol. 25, Issue 4, May 2012.

"The Determinants of Pricing in the Mexican Domestic Airline Sector: The Impact of Competition and Airport Congestion." *Review of Industrial Organization* vol. 38:1 (2011), pp 43-60.

"Anticipating Merger Guidelines from Mexico's Commission on Competition." (with Elizabeth M. Bailey), *International Antitrust Bulletin* vol. 4, (2010).

"X-factor Updating and Total Factor Productivity Growth: The Case of Peruvian Telecommunications, 1996-2003." (with Jeffrey I. Bernstein, Juan Hernandez and Jose Maria Rodriguez), *Journal of Regulatory Economics*, vol. 30:3 (2006), pp 316-342.

"Crecimiento de la demanda por servicios de comunicación móviles. Mitos y realidades (International Mobile Demand Growth: Myths and Reality)" (with Aniruddha Banerjee), *AHCIET Móvil* (September 2005).

"Concepto de costes básicos para la modelización entelecomunicaciones (Basic Economic Cost Concepts for Telecommunications Cost Modeling), Perspectivas en Telecomunicaciones (Perspectives in Telecommunications) (July 2005).

"Drivers of Demand Growth for Mobile Telecommunications Services: Evidence from International Panel Data." (with Aniruddha Banerjee), in Global Economy and Digital Society, Elsevier (2004).

"Patterns in Global Fixed and Mobile Telecommunications Development: A Cluster Analysis." (with Aniruddha Banerjee), *Telecommunications Policy*, vol. 28 (2004), pp. 107-132.

"The Impact of the Regulatory Process and Price Cap Regulation in Latin American Telecommunications Markets." *Review of Network Economics*, vol. 2 (2003), pp. 270-286.

"Does Employee Ownership Motivate Workers? Worker Effort, Shirking and Horizontal Monitoring in ESOP." The Determinants of the Incidence and the Effects of Participatory Organizations, Advances in the Economic Analysis of Participatory and Labor Management, edited by Takao Kato and Jeffrey Pliskin, Elsevier Science, vol. 7 (2003).

"The Internet: Market Characteristics and Regulatory Conundrums." (with Aniruddha Banerjee), Forecasting the Internet: Understanding the Explosive Growth of Data Communications, edited by David G. Loomis and Lester D. Taylor, Kluwer Academic Publishers (2002), pp. 187-216.

Profits for All? The Costs and Benefits of Employee Ownership, Nova Science Publishers, (2001).

"Are Residential Local Exchange Prices Too Low? Drivers to Competition in the Local Exchange Market and the Impact of Inefficient Prices." (with Karl McDermott), in Expanding Competition in Regulated Industries, edited by Michael Crew, Kluwer Academic Publishers (2000), pp. 149-168.

"Telecommunications Privatization and Tariff Rebalancing: Evidence from Latin America." (with Aniruddha Banerjee), *Telecommunications Policy*, vol. 24 (2000), 233-252.

"Utility Regulation in Latin America." (with Leonardo Giacchino, Cesar Herrera, Siôn Jones, Phillip Maggs, and Kristina Sepetys), Privatisation International, edited by Mark Baker, vol. 2 (2000).

"Essential Facilities, Economic Efficiency, and a Mandate to Share: A Policy Primer." (with Karl McDermott, Kenneth Gordon, and William Taylor), Edison Electric Institute (January 2000).

"Does Ownership or Competition Matter? The Effects of Telecommunications Reform on Network Expansion and Efficiency." *Journal of Regulatory Economics*, vol.15 (1999), pp. 65-92.

"Telecommunication Restructuring in Brazil: Issues and Options (A Report Based on the Proceedings of the U.S./Brazil Aspen Global Forum)." International Center for Public Administration and Policy Institute for Policy Research and Implementation, Graduate School of Public Affairs, University of Colorado at Denver (December 1997).

"When, Where and How? Implementing Effective Telecommunications Competition & Regulatory Policy." *Journal of Project Finance* (Winter 1997).

"Telecommunications in Brazil: Restructuring and Privatization" (et. al.), A Report Based on the Proceedings of the Brazil/U.S. Aspen Global Forum, International Center for Public Administration and Policy Institute for Policy Research and Implementation, Graduate School of Public Affairs, University of Colorado at Denver, August (1997).

"Another Look at What's Driving Utility Stock Prices." (with John L. Damagalski and Philip R. O'Connor), *Public Utilities Fortnightly* (January 1997).

"Regulatory Change and the Dismantling of the Bottleneck." Tenth NARUC Biennial Regulatory Information Proceedings (October 1996).

"Stranded Costs: Is the Market Paying Attention? A Look at Market-to-Book Ratios." (with John L. Damagalski and Philip R. O'Connor), *Public Utilities Fortnightly* (May 1996).

"The Gas Storage Market: What Does it Tell Us?" (with Ruth Kretschmer), *Public Utilities Fortnightly* (April 1996).

"Incentive Ratemaking in Illinois: The Transition to Competitive Markets" (with Terry S. Harvill), *Public Utilities Fortnightly* (July 1995).

AJR-2: Summary of Recommendations

System	Variable	Unit		Marginal Cost Estimate*	Recommended Marginal Cost Estimate†	Recommendation
Primary	Plant Additions	*($/MW)*	[1]	$115,690	No change recommended	
Secondary	Plant Additions	*($/MW)*	[2]	$82,116	No change recommended	
Line Transformers	Plant Additions	*($/MW)*	[3]	$84,022	No change recommended	
Primary	Operations	*($/MW)*	[4]	$35,927	$9,659	Five year average
	Maintenance	*($/MW)*	[5]	$16,349	$7,451	Five year average
	O&M Combined	*($/MW)*	[6]	$52,276	$17,110	Five year average
Secondary	Operations	*($/MW)*	[7]	$3,410	$3,516	Five year average
	Maintenance	*($/MW)*	[8]	$9,625	$2,756	Five year average
	O&M Combined	*($/MW)*	[9]	$13,035	$6,272	Five year average
Line Transformers	Operations	*($/MW)*	[10]	$1,458	$689	Five year average
	Maintenance	*($/MW)*	[11]	$2,846	$1,344	Five year average
	O&M Combined	*($/MW)*	[12]	$4,304	$2,033	Five year average
Customer Related	O&M Expenses	*($/customer)*	[13]	$132.4	$70.4	Five year average
Customer Related	Customer Accounts	*($/customer)*	[14]	$109.6	$58.9	Five year average
Marginal Loading Factors	Admin & General	*($/$ of O&M)*	[15]	$0.0373	No change recommended	
	Admin & General	*($/$ of Util Plt)*	[16]	$0.0353	No change recommended	
	Materials and Supplies	*($/$ of Util Plt)*	[17]	$0.0207	No change recommended	
	General Plant	*($/$ of Util Plt)*	[18]	$0.1016	No change recommended	

Sources:
*Marginal cost estimates are obtained from exhibits MFB-1, MFB-4, MFB-5 and MFB-6 provided in the direct testimony of Melissa F. Bartos.
† Own analysis.
Notes:
1. [1] - [12]: Recommended marginal cost estimates are caclulated with respect to contemporaneous normalized peak demand.
2. [13] - [14]: Recommended marginal cost estimates are caclulated with respect to contemporaneous number of total customers.
3. For the marginal cost estimate, the O&M combined expenses are a simple sum and are not obtained from the regression analysis:
[6] = [4] + [5]
[9] = [7] + [8]
[12] = [10] + [11]

AJR-3: Operations and Maintenance Expenses - Plant and Customer-Related

System	Variable	Unit		Marginal Cost Estimate*		Average Expenses (per unit)†				Projected Expenses (per unit)†		
						Entire Period		Past 5 Years				
				Coefficient**	Std. Error***	Mean	Std. Dev.	Mean	Std. Dev.	2019	2020	2021
Primary	Operations	($/MW)	[1]	$35,927	$5,834	$5,397	$3,317	$9,659	$2,020	$9,887	$10,329	$10,767
	Maintenance	($/MW)	[2]	$16,349	$5,293	$8,260	$2,175	$7,451	$1,302	$8,062	$8,042	$8,022
	O&M Combined	($/MW)	[3]	$52,276	$7,877	$13,657	$3,429	$17,110	$1,224	$17,949	$18,371	$18,790
Secondary	Operations	($/MW)	[4]	$3,410	$1,609	$1,726	$1,480	$3,516	$979	$3,711	$3,921	$4,129
	Maintenance	($/MW)	[5]	$9,625	$2,207	$3,177	$986	$2,756	$550	$3,105	$3,097	$3,089
	O&M Combined	($/MW)	[6]	$13,035	$2,731	$4,903	$1,538	$6,272	$737	$6,816	$7,018	$7,218
Line Transformers	Operations	($/MW)	[7]	$1,458	$641	$374	$366	$689	$390	$689	$722	$755
	Maintenance	($/MW)	[8]	$2,846	$1,342	$1,546	$458	$1,344	$272	$1,542	$1,541	$1,540
	O&M Combined	($/MW)	[9]	$4,304	$1,487	$1,920	$455	$2,033	$350	$2,231	$2,263	$2,295
Customer Related	O&M Expenses	($/customer)	[10]	$132.4	$69.5	$57.0	$13.0	$70.4	$10.5	$64.6	$65.4	$66.1
Customer Related	Customer Accounts	($/customer)	[11]	$109.6	$33.1	$48.1	$10.4	$58.9	$9.6	$55.9	$56.8	$57.7

Sources:
* Marginal cost estimates are obtained from exhibits MFB-4 and MFB-5 provided in the direct testimony of Melissa F. Bartos.
** Coefficient estimates from the regression analysis in exhibits MFB-4 and MFB-5.
*** Standard error of the regression coefficient.
† Own Analysis

Notes:
1. Projected expenses are calculated based on a simple forecast assuming a linear trend of historical values.
2. For the marginal cost estimate, the O&M combined expenses are a simple sum and are not obtained from the regression analysis:
[3] = [1] + [2]
[6] = [4] + [5]
[9] = [7] + [8]

AJR-4: Marginal Distribution Plant-Related Costs: Primary System

Dependent Variable: Primary Distribution Plant Additions 2018$

Regression Variable		RationalDistributed Lag Model - OLS	RationalDistributed Lag Model - FGLS
		[1]	[2]
Constant	[A]	-8,953,243	-8,951,116
		(0.140)	(0.140)
Contemporaneous Normalized Peak	[B]	37,515	37,427
		(0.324)	(0.326)
Primary Plant Additions - 1 Year Lag	[C]	0.442	0.444
		(0.088)	(0.087)
Normalized Peak Demand - 1 Year Lag	[D]	49,048	49,050
		(0.237)	(0.238)
Linear Trend	[E]	1,144,328*	1,140,175*
		(0.043)	(0.043)
Marginal Investment Cost	[F]	155,130	155,535
Observations	[G]	16	16
R-Squared	[H]	0.995	0.996
Adj. R-Squared	[I]	0.994	0.994
RMSE	[J]	820,102	820,095
F-Statistic	[K]	1,036	1,042
Prob > F	[L]	0.000	0.000
Durbin Watson (Original)	[M]	1.975	1.975
Durbin Watson (Transformed)	[N]	-	1.967
Breusch Godfrey Test (Prob > chi2)	[O]	0.984	-
F test to test joint significance of the normalized peak and its lagged term:			
F-Statistic	[P]	3.05	3.05
Prob > F	[Q]	0.0884	0.0881

Source: Own Analysis
Notes:
p-values in parentheses
* p<0.05 ** p<0.01 *** p<0.001
[F] = ([B] + [D]) / (1-[C])

AJR-5: Marginal Operations & Maintenance Expenses: Primary System

Dependent Variable: Primary Distribution Non-Customer O&M Expenses 2018$

Regression Variable		Geometric Distributed Lag Model - FGLS	RationalDistributed Lag Model - FGLS
		[1]	[2]
Constant	[A]	-1,637,649	-1,613,456
		(0.058)	(0.074)
Contemporaneous Normalized Peak	[B]	13,998*	14,216
		(0.020)	(0.066)
Contemporaneous SAIFI	[C]	378,888**	382,411**
		(0.007)	(0.003)
Primary Plant O&M - 1 Year Lag	[D]	0.147*	0.148*
		(0.023)	(0.036)
Normalized Peak Demand - 1 Year Lag	[E]	-	-415
		-	(0.937)
Dummy: 2005	[F]	-1,618,112***	-1,619,760***
		(0.000)	(0.000)
Dummy: 2010	[G]	-1,101,464***	-1,099,090***
		(0.000)	(0.000)
Dummy: 2014	[H]	675,178***	674,997***
		(0.000)	(0.000)
Linear Trend	[I]	76,694***	77,071***
		(0.000)	(0.001)
Marginal Investment Cost	[J]	16,410	16,198
Observations	[K]	17	17
R-Squared	[L]	0.996	0.996
Adj. R-Squared	[M]	0.992	0.991
RMSE	[N]	137,505	145,788
F-Statistic	[O]	526.9	380.3
Prob > F	[P]	0.000	0.000
Durbin Watson (Original)	[Q]	2.817	2.817
Durbin Watson (Transformed)	[R]	2.610	2.633
F test to test joint significance of the normalized peak and its lagged term:			
F-Statistic	[S]	-	3.91
Prob > F	[T]	-	0.0655

Source: Own Analysis
Notes:
p-values in parentheses
* p<0.05 ** p<0.01 *** p<0.001
For model [1]: [J] = [B] / (1-[D])
For model [2]: [J] = ([B] + [E]) / (1-[D])

AJR-6: Total Marginal Costs by Rate Class ($000) - Recommended Estimates

	Domestic D	Domestic-Opt. Peak D-10	General TOU G-1	General Long Hour G-2	General Service G-3	Outdoor Lighting M	Limited All Electric T	Ltd Comm Space V	Total Company
Customer	$9,480	$149	$105	$486	$2,337	$0	$280	$6	$12,844
Capacity	$5,114	$70	$4,737	$2,843	$1,802	$0	$172	$6	$14,743
Lighting	$0	$0	$0	$0	$0	$609	$0	$0	$609
Total	$14,595	$219	$4,842	$3,329	$4,139	$609	$452	$12	$28,196
	51.76%	0.78%	17.17%	11.81%	14.68%	2.16%	1.60%	0.04%	100.00%

Source: Own Analysis

AJR-6: Total Marginal Costs by Rate Class ($000) - Original Estimates

	Domestic D	Domestic-Opt. Peak D-10	General TOU G-1	General Long Hour G-2	General Service G-3	Outdoor Lighting M	Limited All Electric T	Ltd Comm Space V	Total Company
Customer	$13,596	$209	$145	$674	$3,215	$0	$397	$8	$18,246
Capacity	$8,385	$114	$8,180	$4,663	$2,954	$0	$281	$10	$24,588
Lighting	$0	$0	$0	$0	$0	$609	$0	$0	$609
Total	$21,981	$323	$8,326	$5,338	$6,169	$609	$679	$18	$43,443
	50.60%	0.74%	19.16%	12.29%	14.20%	1.40%	1.56%	0.04%	100.00%

Source: Table 1 provided in the direct testimony of Melissa F. Bartos