BEFORE THE PUBLIC UTILITIES COMMISSION
OF THE STATE OF COLORADO

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IN THE MATTER OF THE APPLICATION OF PUBLIC SERVICE COMPANY OF COLORADO FOR APPROVAL OF ITS 2011 ELECTRIC RESOURCE PLAN	))))	DOCKET NO. 11A-869E

ANSWER TESTIMONY OF

RANDALL J. FALKENBERG

ON BEHALF OF

THE INTERWEST ENERGY ALLIANCE

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June 4, 2012

Q. PLEASE STATE YOUR NAME AND BUSINESS ADDRESS.

A. Randall J. Falkenberg, PMB 362, 8343 Roswell Road, Sandy Springs, Georgia 30350.

Q. PLEASE STATE YOUR OCCUPATION, EMPLOYMENT, AND ON WHOSE BEHALF YOU ARE TESTIFYING.

A. I am a utility regulatory consultant and President of RFI Consulting, Inc. ("RFI"). I am appearing on behalf of the Interwest Energy Alliance ("Interwest").

Q. WHAT CONSULTING SERVICES ARE PROVIDED BY RFI?

A. RFI provides consulting services related to electric utility system planning, energy cost recovery issues, revenue requirements, and other regulatory matters.

Q. PLEASE SUMMARIZE YOUR QUALIFICATIONS AND APPEARANCES.

A. My qualifications and appearances are provided in Interwest Exhibit RJF-1.

I. INTRODUCTION AND SUMMARY

Q. WHAT IS THE PURPOSE OF YOUR TESTIMONY?

A. My testimony addresses technical aspects and implementation issues concerning the Public Service Company of Colorado ("PSCo" or "the Company") Coal Cycling Study. Interwest witness Mr. Craig Cox addresses policy matters concerning this issue.

Q. PLEASE SUMMARIZE YOUR TESTIMONY.

A. I recommend against utilization of the results of the Coal Cycling Study in the Company's resource selection and bid evaluation process. There are a variety of technical issues and implementation problems which argue strongly that utilization of the study results will not improve the Company's resource selection process. Below is a list of my major points:

1. **PSCo's proposal to apply the Coal Cycling Study results to penalize wind resources in the bid evaluation process appears one-sided. All resources, including new thermal plants will contribute some amount to coal cycling costs. Consequently, it is inappropriate to apply a coal cycling cost only to wind resources in the acquisition process. If used at all, the study results should also be applied in the evaluation of thermal plant acquisition and retirement as well as the review of wholesale contracts in future studies.**

2. **The PSCo study deals primarily with "load following" rather than on and off cycling costs. The Company assumes such costs occur whenever output of a coal plant is reduced from its maximum dependable capacity. Load following occurs routinely in system operation due to load variations, generator outages and is not attributable only to wind generation. Consequently, if load following costs occur they are not solely attributable to wind.**

3. **The Company's concept of load following costs suggests that decreasing plant output increases costs. This runs counter to the standard industry practice of modeling Variable O&M for thermal plants – a cost that increases with output. PSCo itself has modeled Variable O&M costs in its Strategist model studies. If load following costs are as substantial as the Company assumes, the Company should make wholesale sales at price below the cost of fuel. The Company acknowledges it does not do so, suggesting that load following costs are not factored into its operational procedures.**

4. **The Company modeling assumes load following costs do not depend on the length (in time) or depth (in MW) of a load following event. In the Company modeling, load following costs are the same whether a unit has its output reduced by 1 MW for one hour or 100 MW for an entire day.[1] These assumptions are questionable and unsupported.**

5. **The Company assumes no effort will be made to mitigate coal cycling costs. The most obvious mitigation strategy is to arrange off system sales to eliminate surplus generation. This is standard industry practice. It would be imprudent if the Company failed to avail itself of such opportunities.**

6. **Other potential mitigation strategies include offering surplus energy to large customers on a real time pricing basis to avoid cycling costs, changing the thermal plant outage schedules or seeking greater geographic diversity in its wind portfolio.**

7. **The load following cost data used in the Coal Cycling Study is outdated and subject to considerable estimation uncertainty. The data used for the [redacted] current PSCO**

[1] The Company models two types of load following events – a shallow and deep cycle event, depending in whether a coal unit is backdown to its minimum economic or emergency rating. While costs do differ for these types of cycles, within a shallow cycle the Company assumes the cycle depth or length does not matter.

generators is based on data for [redacted].

8. **The Company modeling considers only variability in load and wind generator output, but ignores the equally important variability of thermal plant output. Outages of large units greatly reduce the coal cycling costs in the Company model. The Company's modeling actually overstates the maximum available capacity of coal generators more than [redacted]**

9. **The PSCO study does not attempt to minimize load following costs by determining the optimal coal backdown sequence. This overstates coal cycling costs. There are no workpapers supporting the Company's assumed backdown sequence. A proper modeling of cycling costs cannot be performed without an analysis that determines the optimal sequencing of coal backdowns.**

10. **The PSCO study does not accurately model the PacifiCorp Foote Creek Storage Agreement. For example, the Company assumes the Foote Creek energy is delivered at a rate of [redacted]. For PSCo's 25.2 MW share for Foote Creek this would amount to a [redacted]. The contract also limits deliveries to occur between 1AM and 7AM. Finally, the Company assumes the Foote Creek deliveries continue until [redacted] even though the contract terminates in 2015. These errors overstate cycling costs.**

11. **The Company models only the receipt of [redacted] of capacity around the clock from the PacifiCorp Exchange contract, but not the return of energy to PacifiCorp. The Company states that it purchases rather than generates the return energy. However, this is little more than an arbitrary choice made by the Company, which would make little sense if the Company has surplus generation available. This overstates cycling costs.**

12. **The Company has incorrectly modeled the receipt of energy from the PacifiCorp Long Term Power Supply Agreement by assuming the contract deliveries continue until 2022. However PSCo invoked an option to terminate the contract at the end of 2011. This overstates cycling costs.**

13. **The Company did not accurately model its obligation to provide Holy Cross and Intermountain backup capacity when Comanche 3 is offline. While the Company modeled the impact on planned outages, it failed to accurately assess the impact of providing backup capacity during unplanned outages. This overstates cycling costs.**

14. The Company assumes a number other contracts are fixed energy requirements operating at [redacted] load factor. The Company objected to providing actual data to enable review of contract deliveries to validate their assumptions. Consequently, they have not justified these important inputs.

15. The formula used to reflect outage rates of thermal plants produces inconsistent and counter-intuitive results. For example, decreasing the outage rate for pumped storage (which should reduce cycling costs) actually increases cycling costs.

16. The Company acknowledges that the Cabin Creek upgrades would reduce cycling costs, but has not reflected them in its model.

17. The Company has also failed to accurately reflect the gas conversion of Cherokee 4 in its coal cycling model. The Company assumed that the unit continues to operate on a must run basis, while the ERP indicates that may no longer be necessary. This substantially reduces cycling costs after 2017.

18. The Company failed to include outage rates for two combined cycle plants in the study, thus overstating cycling costs by a material amount. Further, the Company did not model an outage rate for Cherokee 4 gas operation.

19. The coal cycling model itself is a simple spreadsheet analysis which fails to account for many practical aspects of utility operation. If a proper coal-cycling study is to be performed, it should be performed within the context of a detailed production simulation model which captures the logic of unit commitment and dispatch, reserve requirements and operating constraints. A spreadsheet model cannot capture all such impacts in a realistic manner.

20. Due to the large number and wide variety of problems in the Coal Cycling Study, I recommend it not be used any further in the resource acquisition process or this ERP. PSCo should be directed to develop a better analysis for future IRP's if it believes cycling costs are important enough to include in its process. If so, the Company should also perform new study of cycling and load following costs for all of its coal plants rather than rely on the highly uncertain and outdated information from a limited sample of units reported in the APTECH study.

II. REVIEW AND CRITIQUE OF THE PSCO COAL CYCLING STUDY

Application of Cycling Costs and the PSCo Study

Q. WHAT IS THE COAL CYCLING STUDY?

A. The Coal Cycling Study is a report entitled *"Wind Induced Coal Plant Cycling Costs and the Implications of Wind Curtailment for Public Service Company of Colorado"* (called hereinafter "the Report or the Coal Cycling Study") filed by the Company in this proceeding. According to the Report:

> The purpose of this study is to define and quantify the integration costs directly associated with 1) cycling baseload coal generator output as a result of wind generation levels 2) curtailing wind generation at times to avoid certain excessive system bottoming events. PSCo intends to incorporate all wind integration costs into its resource planning and selection processes to ensure that wind generation is compared equitably with the other resource technologies. (Report, Page 6, internal footnote omitted.)

Q. WHAT ARE COAL CYCLING COSTS AND HOW DO THEY DIFFER FROM TRADITIONAL WIND INTEGATION COSTS?

Wind integration costs are intended to reflect the added costs (if any) imposed on a power system due to inclusion of naturally variable wind energy. This generally concerns the increase in responsive reserve requirements accompanying wind generators. Exhibit RJF-2, includes excerpts from a report by the National Renewable Energy Lab ("NREL")[2] which explains various factors that impact wind integration costs.

It is my understanding that the Company has performed a wind integration study for use in this ERP. However, the Company believes there are additional costs, not considered in its wind integration study, called coal cycling costs. The Company

[2] **Cost-Causation and Integration Cost Analysis for Variable Generation,** Michael Milligan, Erik Ela, Bri-Mathias Hodge, Brendan Kirby (Consultant), and Debra Lew *National Renewable Energy Laboratory* Charlton Clark, Jennifer DeCesaro, and Kevin Lynn *U.S. Department of Energy, June, 2011 http://www.nrel.gov/docs/fy11osti/51860.pdf.*

believes that if additional wind resources are added to its system, then there will be times when the amount of wind capacity on line will force output reductions ("backdowns") from its coal plants.[3] The Company believes this will cause increased O&M expenses and capital expenditures which (it argues) are not factored into its planning process in any other way. The Company also includes costs related to curtailment of wind generation as part of the wind induced cycling costs in its modeling.

Q. IS WIND GENERATION THE ONLY CAUSE OF COAL CYCLING COSTS?

A. No. Coal plants are cycled routinely to respond to changes in system load, output levels of other plants, transmission constraints or for reserve purposes. There is nothing unique about wind generation that causes cycling costs to occur. The Company recognizes this fact in the way in which it developed its study, by attempting to compute the cycling costs associated with wind as well as those resulting from the other system resources.

Application of Study Results

Q. HOW DOES THE COMPANY PROPOSE TO APPLY THE COAL-CYCLING STUDY RESULTS?

A. The Company clarified the ultimate purpose of the Coal Cycling Study in its response to CPUC 11-1 as follows:

> Coal plant cycling costs will be added to wind bids and other must-take type resources as discussed in Section 5 of Attachment 3.2-2 and illustrated (with numbers) on the second "LEC Tab" of Attachment 3.2-2 the Renewable RFP Forms. As described for CPUC Staff in Discovery Request No. CPUC7-10, both the cycling and curtailment components from the Coal Plant Cycling study will be applied to wind resources (and other must-take type resources) during initial economic screening of bids.

[3] The use of the term "coal cycling costs" is really a bit of a misnomer. The study really concerns what it calls "load following costs", which are costs related to reducing the output of a coal unit, rather than cycling costs which result from taking it offline. In the discussion that follows, however, we will focus on load following costs, though they may be referred to generically as coal cycling costs as did the Company.

In effect, the Coal Cycling Study results are used to "handicap" bids from wind generators and other "must-take" resources in the Company's bid evaluation process.

Q. DO YOU BELIEVE THIS IS AN APPROPRIATE APPLICATION OF THE STUDY RESULTS?

A. No. If used at all, the coal cycling cost adders should be done in a more even handed manner than proposed by the Company. No resources class should be singled out for a cost penalty while the contribution other resource classes to the same problem is ignored. If the supporting analysis is sound, accurately implemented and based on reliable data it should be applied to all resource classes in future planning activities based on cost adders specific to each resource class. In the case of coal cycling costs, the Company's own model shows that nearly any type of resource acquired, whether a new thermal plants or a wind project will increase coal cycling costs. Consequently, application of the study results to wind (or other "must take") projects alone would be inappropriate.

Further, all resources give rise to a unique set of integration problems. While combined cycle gas plants have become the "default" option for many utilities, even these plants engender their own set of unique problems. For example, combined cycle plants may have to run at minimum loadings overnight or during low demand hours when they are otherwise not needed. Typically combined cycle plants have a six to eight hour minimum down time, and thus may not be shut down on demand if load drops or market prices dip for a few hours. This increases the likelihood of coal cycling and should be considered in planning as well. Further, gas plants frequently give rise to hedging costs and mismatches between the quantity of gas acquired, and the amount actually used. Finally, coal plants require a coal inventory be maintained, the cost of which would

probably be reduced as wind energy increases on the system. The resulting costs and benefits of such issues are frequently ignored in the planning process. There is nothing to suggest that these issues are of less importance than coal cycling costs.

Q. WOULD THE ADDITION OF A NEW COAL PLANT ALSO INCREASE COAL CYCLING COSTS, OR CONVERSELY, WOULD RETIREMENT OF AN EXISTING COAL PLANT REDUCE CYCLING COSTS?

A. Yes. A model run removing Pawnee from the PSCO mix in 2011 decreased the coal cycling costs attributed to wind by nearly 60% in the 2 GW curtailment scenario. Whether coal capacity were increased or decreased it would make a substantial difference in the overall level of cycling costs. This occurs because the addition of more capacity to the system means that there are more times when the existing coal plants have to be backed down. Consequently, it would be inappropriate to apply coal cycling costs to only wind resources in the Company's future resource acquisition process.

Q. THE COMPANY REACENTLY COMPLETED A VERY LARGE COAL UNIT, COMMANCHE 3. DOES THIS HIGHLIGHT ANY PROBLEMS WITH THE COAL CYCLING STUDY FRAMEWORK?

A. Yes. As noted above, addition (or removal) of a large coal generator makes a substantial difference in the overall level of coal cycling costs. PSCo has had wind resources on its system for many years. The addition of a Comanche 3 in 2010 clearly exacerbated any problems related to coal cycling.

Q. IS IT REASONABLE TO ATTRIBUTE COAL CYCLING COSTS TO EXISTING WIND RESOURCES WHEN IN LARGE MEASURE THEY WERE CREATED BY RECENT COAL PLANT ADDITIONS?

A Mr. Cox addresses the policy implications of this issue. In any case, if coal cycling costs are applied in the evaluation of bids for wind projects in future studies, they should also be examined in the context of all new generation resource decisions, regardless of generation technology, whether they are considering new resource additions or plant retirements.

Q. DOES THE COMPANY ACKNOWLEDGE THAT OTHER TYPES OF RESOURCE IMPACT CYCLING COSTS?

A. Yes and I believe this validates the comments above. The Report states as follows:

> New low cost resources or baseload resources can increase cycling costs for the existing coal fleet as well. For example, a low cost flat power purchase schedule can displace the current baseload generation fleet, forcing it to cycle more. While this report only addresses costs associated with wind induced coal cycling and wind curtailments, this modeling approach may be used to evaluate similar costs of other energy resources. (Report, page 11.)

Q. SUMMARIZE THIS POINT.

A. *If* (and this is a big if) the Company is using a sound analysis coal cycling costs, the results should be applied in a manner consistent with cost causation for all resources.[4] Different resources will likely have a different cost profile, and some will have a larger effect than others. However, if coal cycling costs are used, each class of resource should have cycling costs reflected in the evaluation process.

<u>Underlying Data Quality Concerns</u>

[4] If the modeling or data is not sound, there is little point in using the results for any resource class. This will be discussed in more detail later.

Q. HOW IMPORTANT IS THE UNDERLYING DATA IN THIS SORT OF ANALYSIS?

A. The PSCo model results are generally proportional to the assumed level of overall cycling costs.[5] For example, increasing the 2011 load following costs inputs by 100% produces approximately an 80% increase on the coal cycling costs in the 2GW curtailment scenario. Clearly, the data underlying the load following cost assumptions are very critical. There is no basis for assuming that use of inaccurate or questionable data applied to a subset of resources will improve the resource selection process.

Q. ARE THERE CONCERNS ABOUT THE UNDERLYING DATA USED IN THE REPORT?

A. Yes. The data is quite dated, and it was acknowledged from the start to be subject to substantial, and unavoidable, estimation error. Coal plant cycling costs are not directly observable, but rather, must be estimated from historical data in a complex analysis. PSCo retained APTECH, an engineering consulting firm to estimate the coal cycling costs around 1996. APTECH provided a report called "*Coal Cycling Estimates for Representative Public Service Company of Colorado Fossil Generation Units*" in December 1996 ("the 1996 Study"). While the 1996 Study examined results for ten generating units, results for only six coal generators were applied in the Report.[6] In 2008 APTECH was retained again to update the study, but did so for only one unit, Pawnee.[7]

[5] There are also some additional costs related to curtailment of wind generation that are factored into the analysis.
[6] Two of the original ten units were pumped storage and one was a CT. It appears one of the fossil plants was retired.
[7] This will be called "the 2008 Study".

The results for Pawnee were developed for a baseline year 2000, which was selected because that was prior to the growth of wind generation on the PSCo system.

Q. BEFORE GOING ANY FURTHER, ARE YOU MAKING ANY SPECIFIC CRITICISMS OF THE WORK PERFORMED BY APTECH?

A. No. APTECH documented their work, and provided an analysis that provides their "Best Estimate" of coal cycling and load following costs. APTECH also was quite candid in revealing how uncertain its estimates were by providing a "High" and "Low" estimate as well. APTECH itself stated in the 2008 Study:

> Cost-of-cycling estimates are, by their nature not precise. This is because the cycling damage mechanisms leading to component failures are complex and usually involve multi-year time lagging. (2008 Study, I-3.)

I do have concerns that PSCo may have not applied the APTECH analysis in a manner consistent with its intended use, and it did not fully consider the implications of the estimation range of data supplied by APTECH. I am also concerned that most of the data provided by APTECH to the Company is quite outdated.

Q. THE COMPANY INCLUDED 17 COAL PLANTS IN THE COAL CYCLING MODEL. HOW WAS THE APTECH DATA APPLIED TO DEVELOP THE DATA FOR PLANTS NOT INCLUDED IN EITHER THE ORIGINAL OR UPDATED APTECH STUDIES?

A. It was assumed larger units would have higher cycling costs than smaller ones. Based on the 1996 APTECH data for six units, the Company developed a regression model, shown in the Highly Confidential figure below which relates plant size to cycling costs. As the figure shows, the regression equation does not fit the actual data very well. Two units of nearly identical capacity have load following costs which differ by more than [redacted].

This renders use of the curve-fit model of questionable value in developing cost estimates for the many units not sampled in the 1996 or 2008 studies.

--HIGHLY CONFIDENTIAL FIGURE DELETED--

Q. PLEASE EXPLAIN THE CONCEPTUAL PROBLEMS ASSOCIATED WITH THIS ANALYSIS.

A. The APTECH study presented regression results which were interpreted as the start up or load following costs. In effect, the Company performed a regression on regression model results. In such cases, the dependent variables themselves are subject to substantial measurement error. This means that all conventional statistics (such as r-squared, significance, etc) are not accurately determined using standard statistical formulae. It is virtually meaningless to try to determine the validity of the resulting model.

The chart above shows only the "Best" estimate of the load following costs per cycle. However, the APTECH study also provided a High and Low estimate for each of the six data points. These reveal a substantially larger range of possible results. On

average, the "High" estimates were more [redacted] of the Low estimates. The figure below compares the Best, High and Low estimates for the six units studied in 1996.

--HIGHLY CONFIDENTIAL FIGURE DELETED--

Q. WHAT DOES THIS IMPLY FOR THE REGRESSION MODEL RESULTS?

A. If the Low, Best and High estimates are combined into a single equation, in order to gain an appreciation of the true validity of the regression results, the resulting equation would have an R-Squared on only [redacted] A simple way of viewing this is that the "Noise to Signal" ratio is more than [redacted]. Further, the standard error of the resulting regression is approximately [redacted] Even these results are quite likely to overstate the significance of the final equation because the process used was to perform a "regression on a regression" as discussed above. No matter what, the modeling based on the Company study is very unlikely to do a good job of predicting actual 2011-2025 cycling costs for 17 units, based on a limited sample of data from a 1996 study.

At this point, it would be fair to ask whether application of the coal cycling data is of any value at all, given the fact that a very detailed and complex analysis performed by expert engineering consultants provides such a broad range of possible results.

Q. EARLIER YOU MENTIONED THAT THE 1996 STUDY WAS UPDATED IN 2008. DOES THE UPDATE PROVIDE INFORMATION THE WOULD REDUCE THE UNCERTAINTY IN THE CYCLING COST ESTIMATES?

A. No. [redacted][8]

The Pawnee data was then used to scale the curve fit model discussed above. Consequently, the uncertainty in the 2000 Pawnee data was compounded with the uncertainties in the 1996 Study data. This clearly compromises any benefit from reflecting the study results in the planning process.

In this regard, the 1996 study makes a rather interesting comment. It is stated that if the cycling cost data were applied in the system dispatch[9] process reduced cycling costs of $[redacted] might be obtained. (1996 Study, page 6). Consequently, the potential benefit of using the cycling data is only known within [redacted].

[8] 2008$ escalated from the 2000 baseline data.

[9] The original purpose of the 1996 Study appears to have been primarily directed at dispatch and commitment issues. It is quite significant that the Company apparently does not actually use the APTECH study results in actual operations for purposes of pricing off-system sales or for determination of the dispatch sequence. These issues will be discussed shortly.

This clearly implies the authors of the study recognized that the study results could not be used as precise figures. This casts serious doubt on the benefits one can obtain from including the results of the Coal Cycling Study in the planning process. It seems quite possible that the damage done by using the wrong estimates will outweigh any potential gain in efficiency resulting from including these costs. When coupled with the fact that all resource classes contribute to coal cycling costs (no matter how large or small they may be), I believe the benefit of applying the study result are dubious, at the very best.

Q. WHAT CONCLUSION DO YOU DRAW FROM THIS ANALYSIS?

A. The load following cost data is crucial to the Company's analysis. Given the tremendous uncertainty present in the data used, and the fact that the results are extrapolated from a very limited and outdated sample of units the value of the cycling study results within the context of a bid evaluation process must be called into question.

Conceptual Problems

Q. DO ANY CONCEPTUAL PROBLEMS ARISE FROM THE COMPANY'S APPROACH TO COAL CYCLING COSTS?

A. Yes. Typically in system planning studies, power plant costs include a Variable O&M component. These are costs which are assumed to increase with plant output. One example would be chemicals or other consumables. It is frequently thought that plant O&M costs *increases* with output, which is why Variable O&M is included in models. There is no particular formula for determination of Variable O&M in use within the industry for planning purposes. In every planning study I have ever recall examining the Variable O&M component used in planning studies is a positive number, if included at

all. PSCO data responses do shows the Company assumes positive Variable O&M values being used in its ERP studies.

This conventional view of power plant cost analysis seems completely contrary to the assumption used in the Coal Cycling Study, that as plant output is reduced, costs increase. The load following costs developed for PSCo indicate that power plant costs increase when output is reduced, rather than increase with increasing output as is conventionally assumed.

Q. ARE THERE IMPLICATIONS BEYOND THE PSCO BID EVALUATION PROCESS THAT ARISE FROM CONSIDERATION OF LOAD FOLLOWING COSTS?

A. Yes. If costs increase whenever the output of a coal plant dips below the maximum capacity rating, PSCo should enter into sales transactions below the actual variable cost of fuel to prevent the coal plant backdowns. This point was raised with the Company in discovery, and the Company responded as follows:

> We understand this data request as asking whether from an operational perspective to minimize additional O&M costs we make it a standard practice to sell energy at a price below the variable cost of generation to avoid having to back plants down to minimum loading levels. With that understanding, the answer to the data request is no. (Response to Interwest 4-20.)

Consequently, the Company does not appear to use the coal cycling costs in its operational practices.

Q. DO YOU HAVE ANY OTHER CONCERNS REGARDING THE WAY IN WHICH THE LOAD FOLLOWING COSTS WERE APPLIED BY THE COMPANY?

A. Yes. I have two, interrelated, concerns. In its modeling the Company counts the projected number of incidents of load following for each of the coal units in its fleet. The

model tracks the *maximum daily* "backdown" required as the difference between the derated maximum net dependable coal capacity less the load net of wind during the day. It then determines (based on a pre-determined order) which coal plants should be backed down to either their minimum economic rating, or their minimum emergency rating (the so called "shallow cycle" and "deep cycle" curtailment scenarios.) The cycling costs are then computed for each unit that is required to have a backdown of one hour or more for each day. It does not make any difference in the Company methodology if the backdown is for one hour, or ten hours – the same load following cost is assumed to occur. Further, the amount of the backdown, whether one MW or 100 MW is also not considered in the analysis. As long as a unit is required to backdown at all, even for a single hour, it is assumed the full cost of a complete load following cycle from maximum to minimum is incurred. This appears to be a "worst case scenario" for the modeling of load following costs.

This raises the question of whether the application of the data by the Company is consistent with the derivation of the data by APTECH. APTECH used quarterly data to develop regressions analyzing the cost of cold starts, warm starts, hot starts and load following. For a complete shutdown and start up the length of time between shut down and start up allowed for differentiation between cold, warm or hot starts. These are defined based on temperature readings for the boiler and turbine at the time of the restart. For load following, a cycle is not as easy to define. Load following could be considered a minor dip in output for an hour, or a complete backdown to minimum loading for an entire night or day. The 2008 Study examined what it called "significant load follows":

[redacted] (2008 Study, page iii)

It is not completely clear how a "significant load following cycle were defined,[10] but no matter how defined, I question whether a regression performed using quarterly data can applied to discern the impact of a load following event that may differ substantially in length and depth. If nothing else, this clearly explains the enormous uncertainty in the cost estimates provided by APTECH. In any case, a minor load following event should not be included in the analysis. As noted above, PSCo includes any load following event projected to occur, no matter it duration or how large the backdown would be.

I believe a much more reasonable approach to both estimation of the load following costs and modeling it in the Coal Cycling Study would have used a per MWH cost rather than a per cycle cost. Given that load following costs are supposed to represent the additional costs that ensue when a plants' output is reduced, it would stand to reason that the amount of the reduction and the length of time it occurred would provide a better measure of the effect.

Q. DID YOU ASK THE COMPANY ABOUT ITS UNDERSTANDING OF THE LOAD FOLLOWING COSTS DERIVED BY APTECH?

A. Yes. In Interwest 6-9 I asked about this specific issue and received the following response:

a) Explain how the regression analysis APTECH performed to develop the load following costs addressed the length (in hours) and depth (in MW) of coal plant load following cycles. For example, how does the APTECH regression differentiate between a backdown of 5 MW for one hour, as compared to a 100 MW backdown for 8 hours for

[10] Table 2-3 in the 2008 Study suggests it a load following event was limited to [redacted] maximum capacity. If this definition was used for all units, then load cycle less than this amount should be excluded in from the model.

the same plant. b) Explain how the quarterly data developed by APTECH can be used to draw inferences about load following events that last for only a number of hours.

RESPONSE:

a) Public Service relied on APTECH's expertise and proprietary analysis methods to define load following costs. **Any methods used by APTECH to define load following costs, in terms of length and/or depth of load following cycles, were not provided to Public Service and therefore, Public Service does not know specifics of the APTECH regression analysis as requested above.**

b) Public Service relied on APTECH's expertise and proprietary analysis methods to define quarterly load following data in their report. Any methods used by APTECH to define or interpret load following durations, were not provided to Public Service and therefore, **Public Service does not know specifics of the APTECH quarterly data as requested above. (Emphasis added.)**

This response clearly indicates the Company simply does not know how APTECH defined the load following cycles or whether it has been correctly applied. This seriously compromises the value of their study.

Q. PLEASE SUMMARIZE YOUR CONCLUSIONS REGARDING THE QUALITY OF THE DATA USED AND THE WAY IN WHICH IT HAS BEEN APPLIED.

A. The data underlying the Coal Cycling Study is quite outdated, and even when originally developed it was recognized as being subject to substantial estimation error. Further, the original sample was quite limited, covering only 6 of the current 17 coal units. The methodology used to scale the 1996 data to current levels interjects even more dispersion into the analysis. The regression model used did not fit the data very well and that curve was scaled based on results for a single units' cost for the year 2000. The way in which this data was applied in the model also gives rise to concerns that it models a worst case scenario. The Company admits it really doesn't know how APTECH defined a load following cycle, so its application of the APTECH data to its study is highly

problematical. In the end, the amount of noise in the Company's underlying data greatly exceeds the useful information. This compromises the validity of the study results.

Study Design Issues

Q. PUTTING ASIDE YOUR CONCERNS WITH THE DATA, DO YOU SEE ANY SERIOUS PROBLEMS WITH THE OVERALL STUDY DESIGN?

A. Yes. A fundamental problem is that the cycling study assumes the Company does nothing to mitigate cycling costs during the study horizon. This further compromises any remaining value of the study. Utilities have always faced periods of surplus generation, and their first response is to arrange sales to dispose of the surplus. This is the ordinary, prudent, operating practice for any utility. I know of no utility that would simply ignore the option to sell surplus generation. I seriously doubt that PSCo has done so in the past, or would do so in the future. In effect, the Coal Cycling Study models imprudent, rather than prudent, system operations.

Q. ARE THERE OTHER MITIGATION MEASURES THE COMPANY COULD PURSUE ASIDE FROM OFF-SYSTEM SALES?

A. Yes. Implementation of real-time pricing could allow large consumers to take advantage of low cost surplus power on an as available basis. Large customers in Georgia, for example, have used real time pricing tariffs for a number of years. There is no reason why PSCo could not explore such options.

Further, varying the schedule for coal plant outages and shutting down inefficient coal plants may be economical as well. Further, the resource portfolio could change to reflect mitigation of cycling costs. Finally, if the geographic distribution of wind resources were increased, the wind generation pattern would likely be flatter and less

problematic vis-à-vis coal cycling. This suggests that if cycling costs are applied in the bid evaluation process the Company should consider the location of the project, and adjust the cycling penalty depending on how correlated each projects output is with the existing wind projects.

Q. DOES THE COMPANY ACKNOWELDGE IT FAILED TO CONSIDER MITIGATION?

A. Yes. The Company states it did not consider mitigation strategies in its study.

> The results in this study are dependent on both the existing generation portfolio as well as assumptions about how that portfolio might change over time. The study does not account for cycling cost mitigation opportunities that might be available as a result of modifications to the resource portfolio such as additional coal unit retirements, baseload unit modifications or the addition of more flexible power supply resources. The study is based on a fixed generation mix including known changes over time. Cycling costs and curtailment costs should be considered when evaluating future portfolio modifications. (Report, page 23.)

Q. ARE THERE OTHER CONCERNS REGARDING THE STUDY DESIGN?

A. Yes. The Company's model examines the variability of load and wind generation based on an hourly profile for a historical period of one year. The Company model considers scheduled retirements, summer and winter capacity ratings, new capacity additions and planned outages. However, forced outages are modeled as a constant capacity deration rather than as a stochastic variable. This has a substantial impact on the study results.

For example, if the Company has 3000 MW of installed coal capacity, and a 10% average outage rate, the Company would assume 2700 MW (3000-300) of installed capacity is always available. The Company has several large coal plants. Outage of a single plant, say 500 MW, would produce a greater reduction in capacity (and therefore lower load following costs) than the hypothetical 300 MW average deration. In fact, in

2011, the Company has [redacted] whose capacity exceeds the average capacity deration for all units in the study (less than [redacted]). The combined outage rates for these units exceeds [redacted], meaning [redacted] of the time, at least one of these plants would be on outage. Scenarios without only one of these units, Pawnee, reduce 2011 cycling costs by nearly [redacted]. Of course, some of the time all plants are available which, when it occurs, results in higher cycling costs. However, there will be other times when two or more units are on outage. The confidential figure below compares the actual generation available in 2011 (Source Interwest, 4-10) to the values being used in the model for 2011. The results show that more than 80% of the time, the model is assuming there is more capacity online than actually occurred. This may be due to other problems such as failure to model partial outages correctly and failure to model station service requirements. While there are times when the actual exceeds the model capacity, overall the model capacity exceeds the 2011 actual by [redacted].

--HIGHLY CONFIDENTIAL FIGURE DELETED--

Consequently, cycling costs should not be computed based on a constant derated capacity assumption but rather should simulate an actual or simulated pattern of available capacity taking account of full forced outages. To do so, could require a complete redevelopment of the Company model. In any case, it is not appropriate to treat coal generation as largely fixed and constant, while wind generation and load are modeled as being subject to hourly variations. This really amounts to perpetuating an assumption that wind generation is responsible for cycling costs, but coal plants are not.

Implementation Problems

Q. IF ONE ACCEPTS THE UNDERLYING DATA AND STUDY DESIGN, HAS COAL CYCLING STUDY BEEN IMPLEMENTED IN A REALISTIC MANNER?

A. No. There are a number of concerns that I have identified. First, it appears the Company does not model any attempt to optimize the sequence of coal backdowns to minimize cost. Referring back to Figures 1 and 2, one can see a wide variation in the cost of load following for individual units. What is not as apparent is the fact that the amount of capacity available from of a backdown varies widely among units, and more than the assumed load following costs. The amount of capacity available for backdown is the difference between the maximum and minimum operating levels. These differences should be considered in the costing of coal backdowns. Highly Confidential Table 1 below illustrates this problem.

--HIGHLY CONFIDENTIAL TABLE DELETED--

In the Company simulations, Cherokee Unit 4 is the first unit to backdown for load following followed by Cherokee 3, and then Cherokee 1. For Unit 4, the difference between the maximum and minimum capacity is only [redacted]. If Cherokee units 1 and 3-4 are backed down, it would reduce generation by [redacted], at a cost of [redacted]. However, a backdown of Pawnee would provide [redacted] and would cost only [redacted] Consequently, for a [redacted] MW backdown, it would be far more economical to use the Pawnee unit rather than the 3 smaller Cherokee units. In fact, Pawnee is one of the last

units cycled down by the Company model, instead of being one of the first ones. Unless there is a rather large difference in fuel costs, these modeling assumptions are not appropriate. The Company seems to have acknowledged this issue in the following statement:

> It is important to note that the study attempts to quantify the costs associated with cycling coal plants for a specific system configuration. The methodology presented in this paper is not a cost optimization methodology. This study does not attempt to minimize costs while considering potential changes to the system that could mitigate coal cycling and curtailment costs such as unit modifications to increase flexibility or unit retirements. (Report, page 15.)

Q. WOULD IT MAKE A SUBSTANTIAL DIFFERNCE IF THE SCHEDULE FOR BACKDOWNS WERE ALTERED TO CONSIDER RECOGNIZE THIS ISSUE?

A. Yes. For example, in 2011, it would reduce the coal cycling cost in the 2 GW scenario by more than 20% if a more optimal schedule of backdowns were simulated.

Q. HOW SHOULD THE MODELING BE PERFORMED?

A. The backdown sequence should be developed in the context of other variables such as fuel costs, outage rates, etc. In other words, an optimization *is* required to perform a fair analysis. It would not be prudent for the Company to ignore economics in deciding which units on the system should be used for load following.

Q. DID YOU ATTEMPT TO DETERMINE HOW THE COMPANY ACTUALLY DEVELOPED THE BACKDOWN SEQUENCE?

A. Yes. I asked for workpapers showing the development of the backdown sequence. The Company provided no workpapers and stated:

> The load follow order was based on verbal discussions between the coal cycling study team members and Public Service operations. The order was based on

factors including unit dispatch cost, cycling capability, unit age and unit ownership.[11]

It is noteworthy that the Company did not include cycling costs as part of the determination of the backdown sequence. If this is representative of actual operations then the Company has tacitly admitted that it does not consider cycling costs in system dispatch. This again, was the original purpose of the 1996 APTECH study. In any case, the backdown sequence used in the study is seriously flawed for this reason.

Contract Modeling

Q. HOW DO WHOLESALE CONTRACTS IMPACT THE COAL CYCLING STUDY RESULTS?

A. In the coal cycling model, contracts are treated as fixed additions to the capacity available from coal resources. Aside from any summer/winter differentials, the contracts are treated as flat energy deliveries around the clock. Contract energy is derated by the average thermal availability factor of the PSCo units.

Q. IS THIS MODELING REALISTIC?

A. That depends entirely on the contract. If a contract is truly a fixed energy purchase with a flat profile, then modeling the contract in that manner would be adequate. Otherwise, it would not be appropriate.

Q. IS THE FIXED AND FLAT DELIVERY PATTERN REALISTIC FOR ALL CONTRACTS MODELED BY THE COMPANY?

A. No. The Company models the Foote Creek Storage Agreement with PacifiCorp as a fixed delivery of [redacted] MW around the clock. This is a very unrealistic delivery pattern. First of all, the PSCo share of the Foote Creek project is only 25.2 MW. The assumed

[11] Interwest 4-13.

delivery pattern would be equivalent to an annual capacity factor of [redacted]%. The actual capacity factor for the Foote Creek project deliveries has been only 34.4%[12] for the past five years. Second, under the terms of the contract, PacifiCorp is required to deliver the Foote Creek energy from the hour ended 1 AM to the hour ended 7AM, within two months after the energy is generated by PSCo's 25.2 MW share of the project. Finally, the Company assumes that the deliveries from Foote Creek will continue until [redacted], while the contract actually terminates in July 2014.

Q. HOW WOULD ONE MODEL A PROPER DELIVERY PATTERN FOR THE FOOTE CREEK STORAGE AGREEMENT?

A. It could be modeled as a flat delivery pattern from 1AM to 7AM, only, at a level sufficient to providing the actual amount of energy produced by the PSCo turbines, lagged by two months. There should be no deliveries modeled any other time. Under such an approach, most of the time, these off-peak deliveries would be well below the [redacted] assumed by the Company. The actual off peak delivery rate for the last five years has averaged 29.7 MW. Further, the contract should be removed after July, 2014. Removal of the Foote Creek project in 2019 would reduce the cycling costs by 9% in the 3 GW curtailment scenario.

Q. WHY DID THE COMPANY ASSUME THE FOOTE CREEK CONTRACT WOULD BE EXTENDED BEYOND ITS TERMINATION DATE?

A. In the response to Interwest 6-5 the Company stated "*The coal cycling study made the assumption that Foote Creek would be successful in winning a new 5-year PPA with Public Service.*" I see no basis for this assumption. It seems tantamount to showing

[12] See Interewest 4-9 Non Confidential Data Response

favoritism to the Foote Creek contract in a bid evaluation process by penalizing other wind project bids by including Foote Creek in its analysis.

Q THE COMPANY MODELS THE PACIFICORP LONG TERM POWER SUPPLY AGREEMENT ("LTPSA") IN THE COAL CYCLING STUDY. DID IT CORRECTLY MODEL THE CONTRACT?

A. No. The Company modeled the contract as requiring a purchase of [redacted] However, the LTPSA allowed PSCo to reduce its required purchases from PacifiCorp and terminate the contract at the end of 2011. According to PacifiCorp's public record testimony and exhibits from Utah Docket No. 10-035-124 (a 2010 general rate case) PSCo did, in fact, invoke this option, apparently due to the high contract price. See Exhibit RJF-3, for copies of the PacifiCorp public record documents. Consequently, the Company modeled the LTPSA in the Coal Cycling Study long after the contract was terminated. This overstates the coal cycling costs by approximately 20% in 2019.

Q. HAS THE COMPANY OTHERWISE MODELED THE PACIFICORP EXCHANGE CONTRACT CORRECTLY?

A. No. The Company models only the deliveries of energy under the exchange agreement ([redacted] MW) but not the return of that power to PacifiCorp.

Q. HOW SHOULD THE EXCHANGE AGREEMENT BE MODELED?

A. Since deliveries and purchases offset, it should probably be excluded completely. Doing so would reduce cycling costs by 19% in 2011.

Q. WHAT IS THE COMPANY'S JUSTIFICATION FOR IGNORING THE RETURN ENERGY FOR THE EXCHANGE AGREEMENT?

A. The Company stated as follows:

> The Company did not model the return energy provided to PacifiCorp because that energy is not supplied by the Public Service power supply system; rather, it is purchased by Public Service at one of three market trading hubs, Palo Verde, Four Corners, and Mona.[13]

Q. IS THIS A REASONABLE EXPLANATION?

A. No. Again, the Company merely chose to follow a pattern that fails to mitigate cycling costs. One explanation is that they simple do not believe cycling costs are important. If so, then, they should not be used for planning purposes. In any case, the Company could make deliveries to Four Corners from its system or purchase transmission to make deliveries at other locations. As the Company has the choice of delivery points, there is nothing to prevent delivery to Four Corners. It could well be imprudent for the Company to purchase energy at Four Corners than back down coal plants at times when there was surplus generation.

Q. IN THE CONFIDENTIAL RESPONSE TO INTERWEST 6-6, THE COMPANY DISCUSSED ITS APPLICATION FOR APPROVAL OF AN EXTENSION OF THE PACIFICORP EXCHANGE AGREEMENT. IT IS POSSIBLE THAT THE COMPANY WILL EXTEND THIS OR OTHER CONTRACTS. DOES THAT IMPLY THEY SHOULD BE INCLUDED IN THE STUDY?

A. No. There is no reason these contracts should be assumed to have precedence over any other potential resource. At a minimum, the impact of the cycling costs due to these contracts should be considered in the renewal evaluation process (assuming cycling costs are included in the evaluation of wind projects.) Further, until regulatory approval is obtained it is speculative to assume contract extensions.

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[13] Interwest 4-4.

In the case of the PacifiCorp exchange the agreement resulted from a dispute over transmission obligations. If the Company did renegotiate the contract, it could end up in a transmission, agreement rather than an exchange agreement. Further, such legacy contracts frequently become unfavorable to one party or the other. In 2010, PacifiCorp greatly increased its wind integration cost estimates. These costs may be considered by the Company in evaluating renewal of the Foote Creek contract. Parties in PacifiCorp proceedings are quite active in reviewing the prudence of new contracts and could be expected to object if the Company was to renew an unfavorable contract.

Q. HAS THE COMPANY PROPERLY MODELED THE IREA AND HOLY CROSS CONTRACT FOR COMMANCHE 3 BACKUP ENERGY?

A. No. This contract is listed in the "Other loads" category, and has a minor impact on the outage rate calculation and impacts requirements during planned outages of Comanche 3.[14] However, forced outages of Comanche 3 are not properly considered. Review of the contracts[15] shows that the Company is obligated to provide 250 MW of capacity to these counterparties when Comanche 3 is offline due to planned or forced outages. As a result, during forced outages, the Company not only loses the 546 MW capacity of the unit, it also has an additional load obligation of 250 MW. The outage rate of the unit is [redacted] meaning [redacted] of the time the Company is "down" nearly 800 MW. Factoring in the forced outages of the Comanche 3 unit, would reduce the amount of capacity included in the model by more than [redacted].

[14] Interwest 4-6.
[15] Interwest 4.6A1 and A2.

Q. DO YOU HAVE CONCERNS ABOUT THE MODELING OF OTHER CONTRACTS?

A. Yes. The Basin and Tri-State contracts are unit contingent purchases. Consequently, outage would reduce the amount of capacity available from these resources. Further, the development of the inputs for these and other contract should be verified by comparison to actual contract deliveries. However, the Company objected to providing this data on the basis the contract data was used to develop the inputs, and actual data was irrelevant.[16] This is not a reasonable basis for an objection, however, because, at least in the case of the unit contingent contracts, the deliveries can be disrupted, by plant outages. Further as shown above, the Company did not correctly model many other contracts. Again, comparison to actual is the only reasonable method to validate the contract inputs. The Company's refusal to provide this data further compromises the validity of the Coal Cycling Study.

Pumped Storage Modeling

Q. DO YOU HAVE ANY CONCERNS REGARDING THE MODELING OF THE PUMPED STORAGE PLANTS IN THE COAL CYLING MODEL?

A. Yes. The modeling of pumped storage is important because it provides a means of limiting the amount coal cycling costs. However, the Company's modeling produces counter-intuitive results. For example, a scenario that set the outage rate for pumped storage to zero actually increased cycling costs. Reducing pumped storage plant outages should reduce cycling costs because that would mean that pumped storage is available more often to reduce the need for coal cycling. This problem stems from application of

[16] Interwest 4-1.

the average availability factor to determine the minimum loading levels of all generation resources. A more proper analysis would use the sum of the derated capacities taking outages into account.

A further concern regarding pumped storage is that it appears the planned upgrades for the project have not been reflected in the simulation. The Company has acknowledged than the upgrade would reduce coal cycling costs.[17]

Q. ARE THERE ANY OTHER PROBLEMS IN THE COAL CYCLING MODEL?

A. The Company acknowledges an error in the input because it did not include outage rates for two combined cycle units. Though the Company views these errors as immaterial, in 2019 they overstate the study results.

TRC Review of the Coal Cycling Study

Q. THE COMPANY OBJECTED TO INTERWEST'S INQUIRIES (INTERWEST 2.2 (A) AND (C) RELATED TO ITS INTERACTIONS WITH THE TECHINICAL REVIEW COMMITTEE ("TRC"). THE TRC CONSIDERED THE STUDY "COMPETENT." YOU HAVE RAISED VARIOUS CONCERNS WITH THE STUDY. PLEASE COMMENT ON WHY YOUR CONCLUSIONS DIFFER FROM THE TRC'S.

A. Though the Company objected to some of Interwest's inquiries into this area, (in response to Interwest Set 6, Question 1) the Company did eventually provide documents supplied to the TRC related to the Coal Cycling Study. It is not clear what the charge of the TRC was with regards to the Coal Cycling Study, however, the TRC review appears to have been quite limited. Despite the importance of the actual spreadsheet model itself, the TRC either did not request or was not provided the actual spreadsheet model.[18] Further, the APTECH studies were of crucial importance to the Coal Cycling Study and

[17] Interwest 4-16, Note that the storage capacity of the unit is being increased which would increase pumping load.
[18] Response to Interwest 6-3.c and 6-3.d

they were not provided to the TRC either.[19] There were only two documents actually provided to the TRC, a summary presentation and a brief word document which summarized the study assumptions and methodology.[20] The TRC may have been more concerned with the "big picture" rather than the details, and in my review of the documents provided the TRC there was not enough detail provided to raise many of the troubling issues I have dealt with in this testimony. For example, many of the details, such as the modeling of wholesale transactions, the outage rate errors, the pumped storage issues, etc would not be apparent from the information provided to the TRC. Further, there was no indication of the uncertainty in the coal cycling cost estimated as determined by APTECH, provided to the TRC. To support my analysis, Interwest undertook six rounds of data requests to obtain detailed workpapers, supporting documents and has identified the problems which I have discussed herein. I leave it to the Commission to decide how much weight to assign to the TRC's findings. However, the criticisms I have made are supported by the discovery responses I have reviewed.

Q. DO YOU HAVE ANY FINAL COMMENTS?

A. The Coal Cycling Study represents a substantial effort by the Company to address a very difficult problem. However, the complexity of this problem, the lack of unambiguous data, conceptual missteps in the study design, implementation errors and oversights suggests that the results will not meaningfully improve the PSCo resource selection process if applied as intended by the Company. I recommend the Coal Cycling Study not be used in the resource selection process until a more proper analysis has been

[19] Id.
[20] Response to Interwest 6.1.

performed. The first step in such a study would be to update the APTECH cost estimates and to determine whether the uncertainty inherent in these estimates can be reduced enough to provide useful results for application to planning, system dispatch and outage scheduling. If so, then the other problems in the coal cycling model must be addressed, preferably in a production cost model that optimizes total system cost including cycling costs and mitigation strategies are carefully considered.

Q. DOES THIS CONCLUDE YOUR TESTIMONY?

A. Yes.