Before the Public Service Commission of Utah

Docket No. 17-057-20

IN THE MATTER OF THE PASS-THROUGH APPLICATION OF DOMINION ENERGY UTAH FOR AN ADJUSTMENT IN RATES AND CHARGES FOR NATURAL GAS SERVICE IN UTAH

Prepared Direct Testimony of

Kenneth H. Ditzel

DPU Exhibit 4.0 DIR

On Behalf of the

Utah Division of Public Utilities

CONFIDENTIAL VERSION

April 22, 2018

Introduction and Background

Q. Please state your name and business address.

A. My name is Kenneth H. Ditzel. I am with FTI Consulting, Inc. (FTI), and my business address is 8251 Greensboro Dr. – Suite 1111, McLean, VA 22102.

Q. Please state your current position with FTI Consulting.

A. I am a Managing Director in the Economic and Financial Consulting segment at FTI.

Q. Would you please briefly state your background and qualifications as it relates to demand forecasting for natural gas markets?

A. I currently lead FTI's North American energy markets forecasting team, which focuses on providing short and long-term outlooks for supply, demand, and prices for electricity, natural gas, and coal markets. My team and I employ a wide range of models to develop our forecasts, such as linear programming models, valuation models, multivariate regression models, and general spreadsheet models. Prior to joining FTI in 2014, I led the long-term price, supply, and demand modeling for electricity and natural gas markets at Charles River Associates (CRA). Before CRA, I was an Associate at Booz Allen Hamilton and was a production engineer in two natural gas co-generation plants for the Dow Chemical Company in Freeport, TX.

In the natural gas demand modeling that I have conducted, I typically focus on the drivers and variables that impact the major natural gas demand sectors – residential and commercial, industrial, electricity, and transportation – at the state, regional electricity market, or national levels. My analysis typically employs fundamental modeling of natural gas supply, pipeline networks, and price elasticity of natural gas demand using linear programming models. At times, I use regression analysis to help provide additional insights into demand forecasts. I have consulted on natural gas supply, demand, and prices for electric utilities, electricity consumers, manufacturers, coal producers, freight rail companies, natural gas developers, natural gas pipeline companies, and trade associations.

I am a graduate of the University of Virginia with a Bachelor of Science in Mechanical Engineering and Georgetown University with a Master of Business Administration.

A copy of my resume is attached to this testimony as DPU Exhibit KHD-1.

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

A. My testimony provides a comprehensive review of the multivariate regression model used by DEU to forecast Design-Peak-Day firm sales demand, including model assumptions and inputs, model specification, model validation, and model results. In addition, my testimony also provides a brief review of the unsteady-state model, which determines the Peak-Hour demand. My review of the unsteady-state model is limited because the model requires a license to operate and cannot be easily replicated like the model used for the Design-Peak-Day firm sales demand as it is a highly complex engineering model.

Q. What material did you rely upon as the basis for your review and analysis?

A. I generally relied upon the following materials:

- The direct testimony of Mr. David C. Landward filed on January 31, 2018
- The direct testimony of Mr. Michael L. Platt filed on January 31, 2018
- “OCS 1.03 Attachment.xlsx”
- “OCS 1.06 Attachment.xlsx”
- “DPU 8.04 Attachment.xlsx”
- Reponses to Discovery

Peak-day Model Overview, Assumptions, and 2016/2017 Peak-Day Forecast

Q. How would you describe the type of model that DEU uses to calculate Design Peak-Day firm sales demand?

A. DEU uses a multivariate ordinary least squares regression model to estimate Design-Peak-Day firm sales demand. The dependent variable of the regression is historical firm sales, and the independent variables include heating degree days, mean wind speed, maximum wind gust speed, day of the week, winter holiday indication, and prior day firm sales.[1]

[1] Docket No. 17-057-09; Direct Testimony of David C. Landward for Dominion Energy Utah, “In the Matter of the Passthrough Application of Dominion Energy Utah for an Adjustment in Rates and Charges for Natural Gas Service in Utah”, lines 32-35

Q. What data are used to calibrate the model?

A. According to Mr. Landward, the daily data used to calibrate the Design-Peak-Day model are contained within “OCS 1.03 Attachment.xlsx”.[2] The file contains DEU’s historical firm demand, heating degree days (HDDs), maximum wind speed, and mean wind speed, and dummy variables to indicate which days fall on a Friday, “Weekend”, and/or “Holiday”. The dataset in “OCS 1.03 Attachment.xlsx” covers the period of January 1, 2004, through January 31, 2018. The OCS 1.03 Attachment.xlsx file does not indicate the sources of the data. Mr. Landward states in DPU 2.03 that the source of the temperatures used in the data are from the Salt Lake City Airport. However, when translating HDDs in the file to temperature[3], I was unable to match these values against data obtained from the National Oceanic and Atmospheric Administration (NOAA) for the Salt Lake City International Airport.[4]

Q. What assumptions were used in the model to determine Design-Peak-Day firm demand for the 2016-2017 heating season?

A. The Design-Peak-Day assumptions are shown below.[5]

Table 1-Design Peak Day Assumptions

	Design-Peak-Day Assumptions
Mean Temperature	-5 degrees F
Mean Wind Speed	26 mph
Maximum Wind Speed	47mph
Day of week	Mon-Thur, No Holiday
Prior day usage	882,609 Dth

[2] Response to OCS 1.03
[3] Response to Discovery DPU 2.03
[4] Data for Station USW00024127, “SALT LAKE CITY INTERNATIONAL AIRPORT, UT US”, obtained from National Centers for Environmental Information, National Oceanic and Atmospheric Administration
[5] Docket No. 17-057-09; Direct Testimony of David C. Landward for Dominion Energy Utah, “In the Matter of the Passthrough Application of Dominion Energy Utah for an Adjustment in Rates and Charges for Natural Gas Service in Utah”, line 98

Q. What Design-Peak-Day firm sales were forecasted by DEU when using the Design-Peak-Day assumptions for the 2016-2017 heating season?

A. DEU forecasted the Design-Peak-Day firm sales for the 2016-2017 heating season to be 1,316,588 Dth.[6] Mr. Lawrence did not provide any information about uncertainty regarding this point estimate, such as a standard confidence interval.

Quality of Peak-day Model Assumptions and Inputs

Q. Is the type of methodology that DEU uses for computing Design-Peak-Day firm sales an appropriate methodology?

A. Multivariate regression is a common and appropriate methodology to estimate Design-Peak-Day demand. The 2009 American Gas Association Survey[7] found that nearly all 21 respondents use regression analysis in analyzing and predicting peak demand, and many use a similar amount of data to calibrate those models. However, there are some obvious differences between the model constructed and applied by DEU and the models described by the survey respondents. First, out of 21 respondents, two respondents explicitly include wind and a third respondent implicitly includes wind as an independent variable in their regression equations. DEU used two different wind variables in its model. Second, only two of the 21 respondents mentioned using lagged variables in their regression equation, with one using prior day send out, and one using prior day HDD count. DEU used prior day sendout as the single, lagged variable in its model. While I note that the multivariate regression methodology is common and appropriate to use for computing Design-Peak-Day firm sales, I do not believe DEU applied this methodology correctly, both in assumption choices and construction of the multivariate regression model, as I explain in the rest of my testimony.

[6] Docket No. 17-057-09; Direct Testimony of David C. Landward for Dominion Energy Utah, "In the Matter of the Passthrough Application of Dominion Energy Utah for an Adjustment in Rates and Charges for Natural Gas Service in Utah", line 98
[7] OCS 1.06 Attachment.xlsx

Q. What is your assessment of DEU's assumption of a Design-Peak-Day temperature of minus 5 degrees F?

A. In DPU 2.46, DEU points to the mean temperature in the Salt Lake Region being at or below minus 5 degrees F on seven occasions. It should be noted that two of these occasions fall outside of the Monday to Thursday specification of what qualifies as a Design-Peak-Day as shown in Table 1 above. In the table below, I replicate the table in DPU 2.46, but I add the day of the week.

Table 2 – Salt Lake Region Days with Temperature at or below minus 5 degrees F

Observation	**Date**	**Temperature (degrees F)**	**Day of the Week**
1	Dec 12, 1932	-6	Monday
2	Dec 13, 1932	-5	Tuesday
3	Feb 9, 1933	-11	Thursday
4	Feb 10, 1933	-8	Friday
5	Jan 21, 1937	-7	Thursday
6	Jan 25, 1949	-7	Tuesday
7	Jan 12, 1963	-7	Saturday

The last occurrence when the mean temperature was at or below minus 5 degrees F, excluding Friday through Sunday, was January 25, 1949, which was 69 years ago. Since then, DEU has not experienced a weather event where temperatures were at or below minus 5 degrees F. In fact, the lowest temperature recorded on a Monday to Thursday and not a holiday since January 25, 1949 was minus 2 degrees F on January 23, 1962.[8] In the last 30 years, the lowest mean daily temperature recorded for the Salt Lake Region between Monday to Thursday was 1.5 degrees Fahrenheit or 6.5 degrees above the Design-Peak-Day temperature assumption.[9] In the last 20 years, the lowest mean daily temperature recorded for the Salt Lake Region between Monday to Thursday was 6 degrees Fahrenheit or 11 degrees above DEU's Design-Peak-Day temperature

[8] DPU 8.04 Attachment
[9] DPU 8.04 Attachment

assumption.[10] In DPU 8.03, DEU was asked whether any trends in the lowest mean daily temperature since 1932 have been factored into DEU's analysis of a design peak day. The DEU response was "No trend assumptions are incorporated in the analysis."[11] Given the last occurrence of the mean daily temperature being at or below minus 5 degrees between Monday to Thursday was 69 years ago and that the lowest mean daily temperatures have been above 0 degrees F in the last 30 years, I believe that DEU should more closely examine temperature trends and re-evaluate the likelihood of not only its Design-Peak-Day temperature but also the joint likelihood of the Design-Peak-Day assumptions occurring simultaneously. This latter point is explored further in the next question in my testimony.

Q. What is the likelihood of the Design-Peak-Day input assumptions occurring simultaneously?

A. In DPU 2.47, DEU was asked to provide an analysis of the likelihood of the peak-day assumptions (mean temperature of -5 degrees, mean wind speed of 26 mph, maximum wind speed of 47 mph, and day of week of Monday through Thursday and no Holiday, and prior day usage of 882,609 Dth) occurring simultaneously. The response indicated that the Company did not have the data needed to assess this probability, as wind speed data for days where temperatures were less than or equal to -5 degrees Fahrenheit was not complete. The inability of the Company to assess the joint probability of these events alone should raise concerns about the usefulness of the model for system planning purposes.

Exploration of the data reveals that temperature, maximum wind speed, and average wind speed are correlated with one another. Therefore, independent selection of variable maximums, such as DEU chose to do, may not be appropriate, and may lead to a set of assumptions that describe conditions that occur much more infrequently than once per 20, 30, or even 100 years. A significantly decreased probability of occurrence can materially alter the cost benefit analysis of avoiding peak day shortfalls. To this notion, I examined the top 10 maximums observed in the "OCS 1.03 Attachment.xlsx" workbook for maximum wind speed, mean wind speed, and HDD over the months of November-March. As illustrated in the table below, for the top 10

[10] DPU 8.04 Attachment
[11] DPU 8.03

observations of maximum wind speed, ranging from 36 to 47 mph, the average HDD was only 21, compared to 70 assumed in the Design-Peak-Day, and the average mean wind speed was 16 mph, compared to the Design-Peak-Day assumed 26 mph. Even the maximum values for HDD and mean wind speed over these observations fell far short of the Design-Peak-Day assumptions, at only 41 HDDs and 22 mph respectively.

Table 3 – Top 10 Observations on Highest Maximum Wind Speed Days, January 1, 2004 to January 31, 2018[12]

Observation	MAX WIND (mph)	HDD	MEAN WIND (mph)	DATE
1	47	23	21	2/16/2011
2	38	25	12	1/29/2014
3	38	17	17	12/30/2011
4	38	16	18	12/2/2012
5	37	9	15	11/1/2014
6	37	21	16	3/17/2014
7	37	23	22	3/5/2017
8	36	41	11	12/19/2008
9	36	13	15	2/17/2016
10	36	25	15	2/18/2016
Mean:	**38**	**21**	**16**	

Examining maximum observed HDD counts, ranging from 54 to 61, the mean maximum wind speed was only 10 mph compared to 47 mph in the Design-Peak-Day, and the average mean wind speed was only 5 mph, compared to an assumed 26 mph. The maximum wind speed observed was 16 mph, 31 mph below the value assumed for the Design-Peak-Day, and the maximum mean wind speed was only 7 mph, compared to an assumed 26 mph.

Table 4 – Top 10 Observations on Highest HDD Days, January 1, 2004 to January 31, 2018[13]

Observation	HDD	MAX WIND (mph)	MEAN WIND (mph)	DATE
1	61	9	5	1/6/2017
2	59	9	4	1/13/2013

[12] OCS 1.03 Attachment.xlsx
[13] OCS 1.03 Attachment.xlsx

3	57	16	6	1/5/2017
4	56	8	5	1/13/2007
5	55	10	6	1/14/2007
6	55	10	6	1/14/2013
7	55	8	4	1/23/2008
8	55	12	7	1/15/2007
9	54	13	5	1/12/2013
10	54	9	4	1/22/2013
Mean:	**56**	**10**	**5**	

Finally, the HDD count among the top 10 highest mean wind speed observations was 15, with a maximum of 26 (44 short of the Design-Peak-Day assumption), and the mean maximum wind speed was 35 mph, with a maximum of 47mph.

Table 5 – Top 10 Observations on Highest Mean Wind Speed Days, January 1, 2004 to January 31, 2018[14]

Observation	MEAN WIND (mph)	HDD	MAX WIND (mph)	DATE
1	26	23	36	1/27/2008
2	25	13	32	2/20/2017
3	24	10	35	3/4/2017
4	23	0	35	3/31/2012
5	23	27	33	1/1/2004
6	22	21	29	12/30/2004
7	22	23	37	3/5/2017
8	22	11	30	11/19/2010
9	21	3	32	11/8/2012
10	21	23	47	2/16/2011
Mean:	**23**	**15**	**35**	

To look at the problem in a different manner, I conducted an analysis of the reasonableness of the assumed maximum wind speed of 47mph[15] and mean wind speed of 26 mph.[16]. Three models were estimated using ordinary least squares regression, on the data provided in "OCS

[14] OCS 1.03 Attachment.xlsx
[15] Docket No. 17-057-09; Direct Testimony of David C. Landward for Dominion Energy Utah, "In the Matter of the Passthrough Application of Dominion Energy Utah for an Adjustment in Rates and Charges for Natural Gas Service in Utah", line 98
[16] Docket No. 17-057-09; Direct Testimony of David C. Landward for Dominion Energy Utah, "In the Matter of the Passthrough Application of Dominion Energy Utah for an Adjustment in Rates and Charges for Natural Gas Service in Utah", line 98

1.03 Attachment.xlsx", with maximum wind speed as the dependent variable, and a combination of mean wind speed, HDD, and HDD-squared terms as independent variables. The independent variable used in the three models, and the adjusted R-squared value for each model, is shown in the table below.

Table 6: Max Wind Speed Models

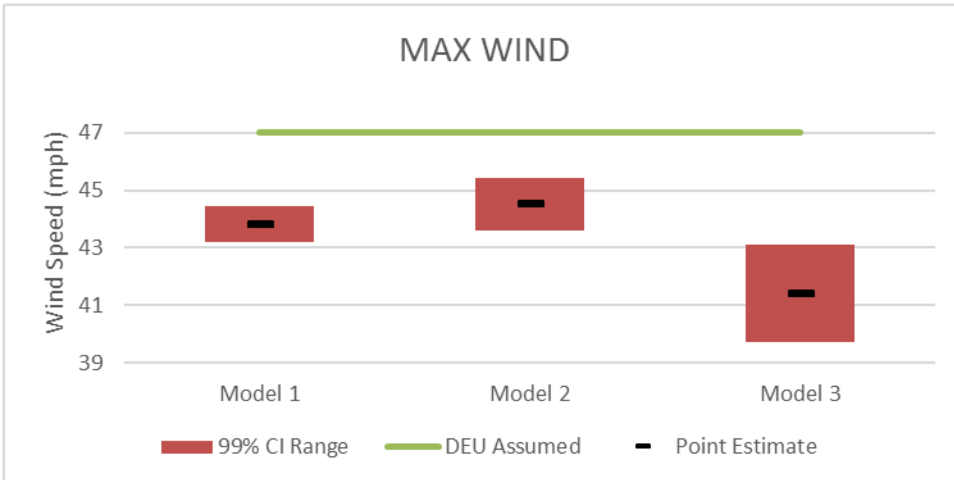
Max Wind Speed Model	Mean Wind Speed	HDD	HDD^2	Adjusted R-squared
1	X	NA	NA	0.73
2	X	X	NA	0.73
3	X	X	X	0.74

X = used as a variable; NA = Not Applicable

The estimated model parameters were then used to predict maximum wind speed, given 70 HDDs[17], and a mean wind speed of 26 mph. In each of the three models, the statistical significance of each independent variable's partial effect on the dependent variable was found to be statistically significant at the 1% level, or below. The models generated point estimates for maximum wind speed ranging from 41.4 to 44.5 mph. The point estimates, and 99% confidence interval around the estimates, are shown below. Notably, none of the 99% confidence intervals contain the 47 mph Design-Peak-Day assumption used in Mr. Landward's testimony. In other words, the models suggest 99% confidence that the true maximum wind speed, given the conditions for the independent variables imposed, lies below the value assumed by DEU. It should be noted that these models likely suffer from some of the same flaws as those used by DEU, including the risks associated with extrapolation, due to limitations of the dataset provided in OCS 1.03 Attachment.xlsx.

[17] Response to Discovery DEU 2.03

<u>Figure 1 - Max Wind</u>



I conducted a similar analysis to examine the Design-Peak-Day mean wind speed assumption of 26 mph used in Mr. Landward's testimony. Three models were estimated using ordinary least squares regression, on the data provided in "OCS 1.03 Attachment.xlsx", with mean wind speed as the dependent variable, and a combination of maximum wind speed, HDD, and HDD-squared terms as independent variables.

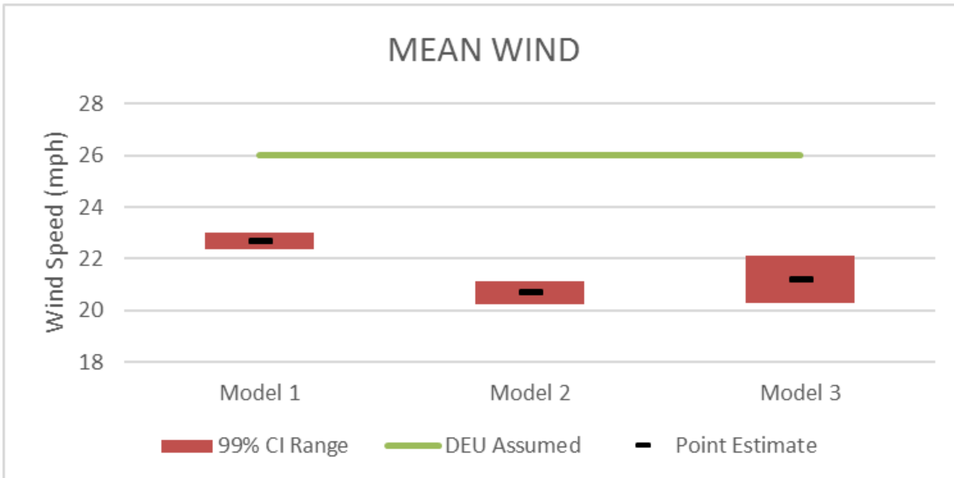
Table 7: Mean Wind Speed Models

Mean Wind Speed Model	**Max Wind Speed**	**HDD**	**HDD^2**	**Adjusted R-squared**
1	X	NA	NA	0.73
2	X	X	NA	0.75
3	X	X	X	0.75

X = used as a variable; NA = Not Applicable

The estimated parameters were then used to predict mean wind speed, given 70 HDDs and a maximum wind speed of 47 mph. The models provided point estimates ranging from 20.7 to 22.7 mph. The point estimates, and a 99% confidence interval around the estimates, are shown below. Notably, none of the 99% confidence intervals contain the 26 mph Design-Peak-Day assumption used in Mr. Landward's testimony.

Figure 2 - Mean Wind



This analysis suggests that independently picking the peak historical values for both maximum wind speed and maximum mean wind speed over winter months[18] is not appropriate, given the interdependence of maximum wind speed, mean wind speed, and temperature. In addition, this analysis suggests that, given an assumed historical maximum wind speed of 47 mph and 70 HDDs, the mean wind speed assumption is likely too high, and would lead to an overestimation of peak demand given the Company's parameter estimates. Conversely, given an assumed mean wind speed of 26 mph, and 70 HDDs, the assumed maximum wind speed of 47 mph is likely too high, and would lead to an overestimation of peak demand given the Company's parameter estimates.

Q. Is Mr. Landward's assessment of the probability of a Design-Peak-Day event occurring at any point in the next ten years reasonable?

A. The assessment of the probability of Design-Peak-Day event conditions occurring over the next 10-year period, as shown on line 267 of Mr. Landward's testimony is not reasonable, given the

[18] Docket No. 17-057-09; Direct Testimony of David C. Landward for Dominion Energy Utah, "In the Matter of the Passthrough Application of Dominion Energy Utah for an Adjustment in Rates and Charges for Natural Gas Service in Utah", lines 178 - 190

concerns raised in the previous question and answer. Mr. Landward assumes a Design-Peak-Day occurrence rate of 5%, however, there is absolutely no evidence to suggest that the joint probability of these events occurring on any given day is 5%. When asked to calculate the joint probability of these conditions occurring simultaneously, Mr. Landward states that "without a complete set of data on all variables at those points in time, a reliable computation is not possible."[19] Mr. Landward seems to have conflated the historical probability of temperatures falling to negative 5 degrees Fahrenheit or below, which he asserts is 5%[20], with the joint-probability that 1) the temperature is negative 5 degrees Fahrenheit, 2) the maximum wind speed is 47 mph, 3) the mean wind speed is 26 mph, 4) the day is not a holiday, 5) the day is Monday, Tuesday, Wednesday, or Thursday and 6) prior day demand was 882,609 Mcf. It is my belief that the true joint probability of these conditions occurring simultaneously, given the probability of the temperature falling to or below negative 5 degrees Fahrenheit is 5%, and the very low probability of maximum wind speed and mean wind speeds of 47 mph and 26 mph occurring simultaneous is extremely low, as demonstrated earlier, to be much lower than 5%.

Q. Is the Company's application of prior day firm sales demand to estimate Design-Peak-Day reasonable?

A. The use of prior day firm sales demand is not necessarily reasonable. Mr. Landward's opinion that "the approach used to estimate demand on the day prior to a Design-Peak-Day is sound and produces a reasonable result"[21] is not founded on any evidence provided by DEU. The methodology provided in Mr. Landward's testimony indicates that the prior day demand assumption was derived by "identifying the maximum value of the temperature and wind variables each year and computing the prior day's portion of that maximum value. The average portion across all years in the data is calculated for each variable and then applied to Design-Peak-Day conditions to derive prior day conditions."[22] First, these averages are based upon only 15 observations (assuming data from 2004 through 2018 were used). Second, Mr. Landward's

[19] Response to Discovery DPU 2.47
[20] Docket No. 17-057-09; Direct Testimony of David C. Landward for Dominion Energy Utah, "In the Matter of the Passthrough Application of Dominion Energy Utah for an Adjustment in Rates and Charges for Natural Gas Service in Utah", lines 247-251
[21] Docket No. 17-057-09; Direct Testimony of David C. Landward for Dominion Energy Utah, "In the Matter of the Passthrough Application of Dominion Energy Utah for an Adjustment in Rates and Charges for Natural Gas Service in Utah", lines 228-229
[22] Docket No. 17-057-09; Direct Testimony of David C. Landward for Dominion Energy Utah, "In the Matter of the Passthrough Application of Dominion Energy Utah for an Adjustment in Rates and Charges for Natural Gas Service in Utah", lines 74-77

statement implies that there is some correlation between "today's" observed values for temperature and wind, and the previous day's values. While there is a strong correlation between temperature and its one-day-lagged value (my analysis indicates correlation of 0.95, using raw temperature data[23], instead of HDDs), there is weak correlation between maximum wind speed, and its one-day-lagged value (0.40) and average wind speed, and its one-day-lagged value (0.41). Attempting to reconstruct DEU's methodology for defining the prior day maximum wind speed produced the following data:

Table 8 - DEU's Methodology for Defining the prior day maximum wind speed

	Highest Max Wind (mph)	Highest Max Wind Date	Prior Day Max Wind (mph)	Proportion (Prior Max / Max)
2004	43	5/10/2004	16	37%
2005	37	6/22/2005	29	78%
2006	36	4/5/2006	26	72%
2007	37	4/18/2007	25	68%
2008	43	7/27/2008	20	47%
2009	39	8/6/2009	25	64%
2010	36	8/28/2010	21	58%
2011	47	2/16/2011	24	51%
2012	38	12/2/2012	23	61%
2013	38	8/9/2013	24	63%
2014	38	1/29/2014	9	24%
2015	40	4/14/2015	23	58%
2016	36	2/17/2016	14	39%
2017	37	3/5/2017	35	95%
2018	28	1/24/2018	14	50%
			Mean:	58%

The average proportion of prior day maximum wind speed to "day of" wind speed was 58% using this data. However, the proportions from each year show a high degree of variability, ranging from a low of 24%, to a high of 95%. If you were to use the % proportion to predict the

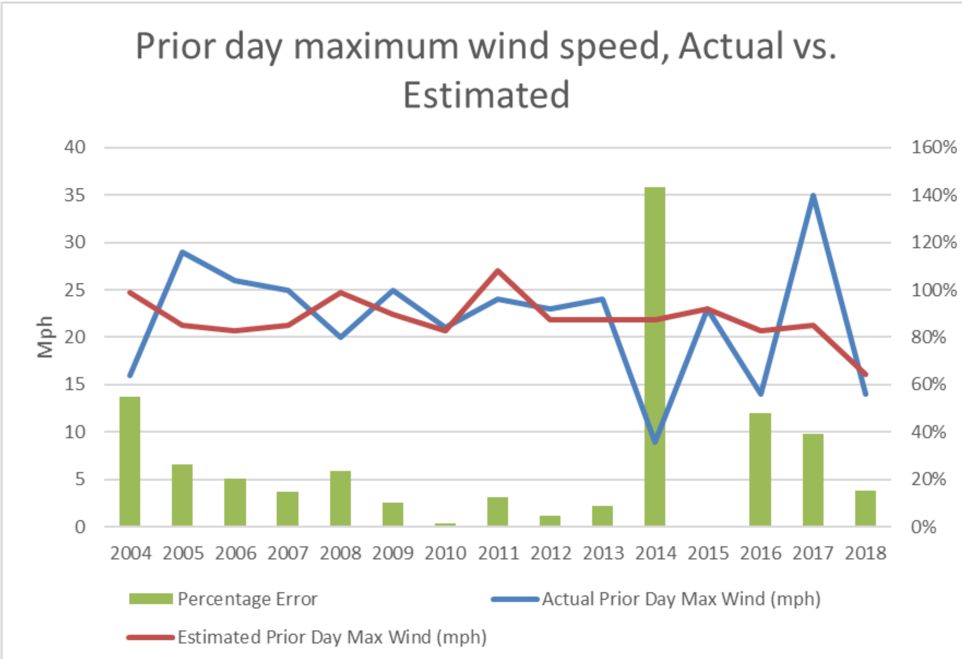
[23] Data for Station USW00024127, "SALT LAKE CITY INTERNATIONAL AIRPORT, UT US", obtained from National Centers for Environmental Information, National Oceanic and Atmospheric Administration

prior day maximum wind speed on the same 15 days shown in the table above, the mean absolute error of the estimates is around 5 mph, while the average percentage error compared to the actual values is 28%, as shown in the table, and chart below.

Table 9 - Average Proportion of Prior Day Maximum Wind Speed

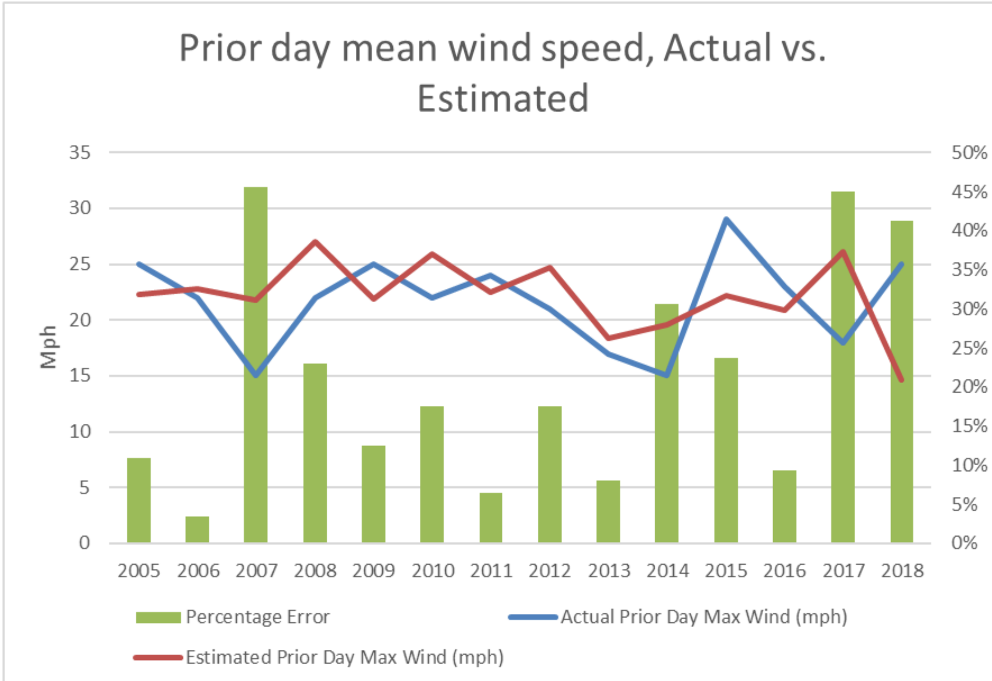
	Actual Prior Day Max Wind (mph)	Estimated Prior Day Max Wind (mph)	Absolute Error (mph)	Percentage Error
2004	16	25	9	55%
2005	29	21	8	27%
2006	26	21	5	20%
2007	25	21	4	15%
2008	20	25	5	24%
2009	25	22	3	10%
2010	21	21	0	1%
2011	24	27	3	13%
2012	23	22	1	5%
2013	24	22	2	9%
2014	9	22	13	143%
2015	23	23	0	0%
2016	14	21	7	48%
2017	35	21	14	39%
2018	14	16	2	15%
		Mean:	5	28%

Figure 3 - Prior Day Maximum Wind Speed, Actual vs. Estimated



An average estimated error of 28% of the maximum wind speed is not acceptable. However, DEU uses this methodology to predict the prior day conditions for the maximum and average wind speeds for the Design-Peak-Day. Errors can easily propagate from the calculation of variables such as wind speed, throughout the model for prior day firm sales, into the model for Design-Peak-Day firm sales, ultimately affecting the estimate for Design-Peak-Day demand. The same methodology was carried out on the mean wind speed variable. The results are displayed below in Table 6. Because the maximum mean wind speed for 2004 was observed on January 1, 2004, which is the first record in OCS 1.03 Attachment.xlsx, data for the prior day was not available, and as such, 2004 was omitted from the chart. The average absolute error for the prior-day mean wind speed estimated was 4 mph, or about 21%.

<u>Figure 4- Prior Day Mean Wind Speed, Actual vs. Estimated</u>



Overall, the methodology used for calculating prior day demand is too inaccurate, overly complex, and requires significant modification, or complete replacement, if it is to be used. It is another question entirely, but worth considering, if prior day demand should be used in the peak demand model at all.

One can point to a high correlation between firm sales, and prior day firm sales, and suggest that the latter needs to be included in a model to predict the former. Because firm sales in general are highly correlated with HDDs, and yesterday's HDD count is highly correlated with today's HDD count, it would of course make sense that yesterday's firm sales would be correlated with today's firm sales, but it is not something inherently "special" about yesterday's sales that drive this correlation with today's sales, but rather, I would suggest, similarity in weather. Due to the previously expressed concerns about DEU's methodology used to estimate prior day demand, it would be reasonable to explore replacing the prior day firm sales variable with a simpler measure, such as prior day HDD count, which can be predicted with higher accuracy than wind, and is a fundamental driver of gas demand, unlike prior day sales.

Multivariate Regression Model Calibration and Validation

Q. What records in "OCS 1.03 Attachment.xlsx" were used to calibrate the model, and which records were excluded from the calibration for use in validating the model.

A. It is standard practice to partition a dataset into at least two sets, one on which the model will be calibrated, and one on which the resulting model will be tested. There is not clear evidence that DEU did so in their analysis. It is not enough to say that the calibrated model performs well on the same data that was used to calibrate it (such as the adjusted R-squared)– the model must be tested on data that is has never "seen" before, if the goal is to forecast values (such as for a Design-Peak-Day). It is often difficult to model the past, and hard to know whether a model from the past can be used to accurately predict the future. However, there are generally accepted standards that can and should be used to estimate both historical fit, and predictive accuracy.

Q. Does a high adjusted R-squared value indicate that the model is a good fit for determining Design-Peak-Day firm sales demand?

A. Mr. Landward states that the adjusted R-Squared for the DEU multivariate regression model is 0.9893.[24] Adjusted R-squared is a statistical measure of how well a regression model's equations "fits" with the data. An adjusted R-squared of zero means that the model explains none of the variability of the response data around its mean while an adjusted R-squared of one indicates that the model explains all of the variability of the response data around its mean. A high adjusted- R-squared value, like the value DEU obtained for its model, does not indicate how well a model performs on data that is outside of the sample data (such as the Design-Peak-Day conditions). The model only explains how well it can predict conditions within the calibrated dataset. In fact, one can construct a model that has an extremely high adjusted R-squared but has little predictive power when given new data that was not used for calibration. The testimony of Mr. Landward provides no discussion of out-of-sample forecast error. As such, there can be no expectation as to how this model will perform on predicting demand under the Design-Peak-Day conditions.

Q. Is there sufficient evidence to suggest that the DEU model predicts demand accurately at extreme values of the independent variables?

[24] Docket No. 17-057-09; Direct Testimony of David C. Landward for Dominion Energy Utah, "In the Matter of the Passthrough Application of Dominion Energy Utah for an Adjustment in Rates and Charges for Natural Gas Service in Utah", line 217.

A. I reviewed the DEU dataset used for calibration and found that the dataset does not contain data that are even remotely close to Design-Peak-Day conditions. The highest HDD in the dataset is 60.54, which occurred on January 6, 2014.[25] This HDD value translates to 4.46 degrees F as compared to minus 5 degrees F for the assume Design-Peak-Day conditions. Furthermore, the maximum and mean wind speeds on January 6, 2014 were 9 mph and 4.58 mph[26], respectively, as compared to 47 mph and 26 mph for assumed Design-Peak-Day maximum and mean wind speed conditions, respectively. Because the DEU model was constructed with data that excludes conditions at or near Design-Peak-Day, it is unclear whether it has adequate predictive power for Design-Peak-Day firm demand sales. Predictions derived from extrapolation beyond the range of the data used to calibrate the model must be treated very skeptically as they depend upon the assumption that the relationships observed in the calibration data extend beyond what is able to be tested.

Q. What is the rationale behind the use of four HDD terms as independent variables in the regression model?

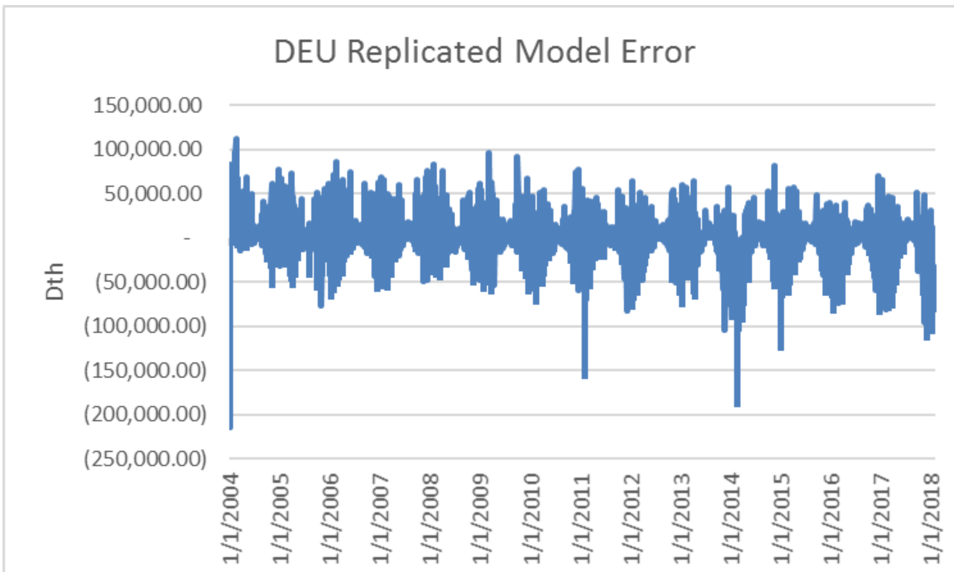
A. Mr. Landward's testimony does not provide a justification for the use of HDD, HDD^2, HDD^3, and HDD^4 as independent variables in the multivariate regression model. While it is accepted in industry that energy demand responses to changes in temperature can be non-linear, this can be approximated with simply the HDD and HDD^2 terms. Though the additional HDD^3 and HDD^4 terms are statistically significant, and increase the overall fit of the model, they do so at the expense of a higher probability of overfitting. Overfitting can lead to very high measures of fit, as the model becomes tailored to the calibration dataset, but the goal of regression analysis is to build a model for the entire population. When models become too complex (and more tailored to the calibration dataset) they may become less generalizable and perform poorly when presented with a new dataset on which to make predictions. The symptoms of overfitting are often a larger problem with small sample sizes, however, which is not applicable to this analysis. Unfortunately, Mr. Landward's testimony provides no discussion of the model's forecast accuracy, so it is impossible to say if overfitting is an issue in this case. The use of cross-validation would alleviate most of this concern.

[25] OCS 1.03 Attachment
[26] OCS 1.03 Attachment

Q. Does the model described in Mr. Landward's testimony seem to be correctly specified?

A. The DEU model does not appear to be correctly specified. I attempted to replicate the DEU model using the model coefficients from Mr. Landward's testimony[27] and the data provided in "OCS 1.03 Attachment.xlsx". A plot of the error terms, calculated as measured firm sales demand minus estimated firm demand sales, from the DEU Replicated Model are concerning. Below is a graph of the error terms from my replication of the DEU model.

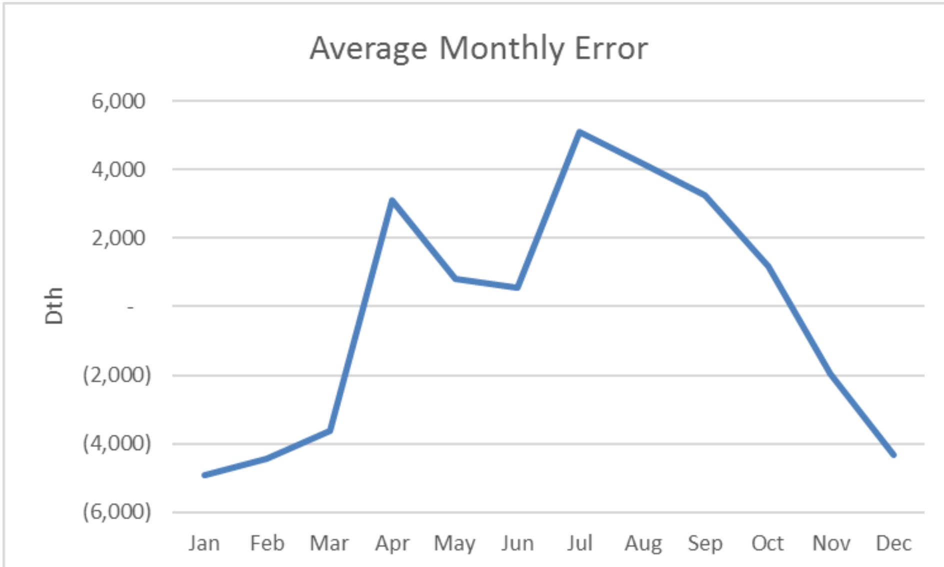
Figure 5 - DEU Replicated Model Error



As you can see, there is a clearly defined pattern to these error terms, they are decidedly not randomly distributed. The pattern is even more evident when viewed on a monthly average basis, as shown below.

Figure 6 - Average Monthly Error

[27] Docket No. 17-057-09; Direct Testimony of David C. Landward for Dominion Energy Utah, "In the Matter of the Passthrough Application of Dominion Energy Utah for an Adjustment in Rates and Charges for Natural Gas Service in Utah", line 217

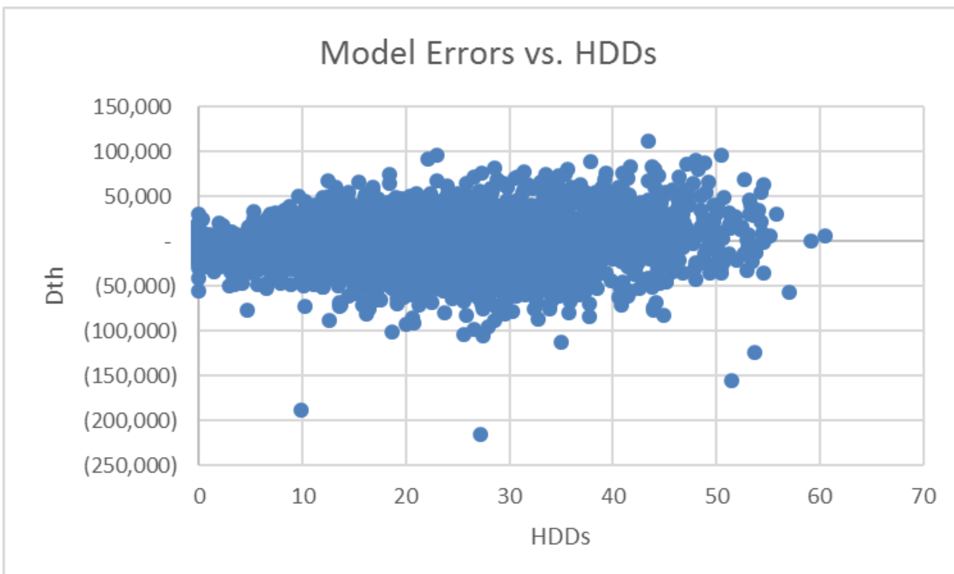


The errors from my DEU Replicated Model are highly correlated with one another and exhibit a strong seasonality. This phenomenon is known as autocorrelation. Autocorrelation of the errors violates the assumptions of the Gauss-Markov theorem, meaning that the ordinary least squares regressor is no longer the Best Linear Unbiased Estimator (BLUE). A quantitative test for autocorrelation, using the Durbin Watson statistic, confirms autocorrelation of these errors. Autocorrelation does not bias the coefficient estimates of the model, or, consequently, the model estimates. However, it will often lead to biased standard error estimates, often to the low side when autocorrelation is positive, which may make some independent variables appear to have a statistically significant relationship with the dependent variable, when they otherwise may not. This makes variable selection and model specification more difficult. While Mr. Landward does show come concern about autocorrelation, stating, "Prior-day usage shows a strong positive correlation with contemporaneous usage. This means that when other factors are accounted for, an increase in usage on a given day generally precedes an increase in usage on the following day. This statistical relationship is referred to as first-order autocorrelation and must be accounted for in this type of analysis."[28] Mr. Landward did not mention that autocorrelation was present in his chosen model errors. There are several potential remedies to eliminate the autocorrelation of the errors, though the seasonal pattern suggests that it may be

[28] Docket No. 17-057-09; Direct Testimony of David C. Landward for Dominion Energy Utah, "In the Matter of the Passthrough Application of Dominion Energy Utah for an Adjustment in Rates and Charges for Natural Gas Service in Utah", lines 135-138

related to omitted variable bias caused by the use of HDDs as the only temperature measurement in the model, discussed below. Further examination of the errors, and confirmed by use of the Breusch-Pagan test, suggest that heteroskedasticity is also present. Heteroskedasticity is a phenomenon that describes the variance of error terms changing, as the values of an independent variable change. Heteroskedasticity also violates the assumptions of the Gauss-Marvov theorem, and similar to autocorrelation, will invalidate standard error estimates, with the same negative consequences as before. Plotting the error terms from this model against HDDs, shows a clear "fanning" of residuals, with residual variance increasing as HDDs increase, associated with the presence of heteroskedasticity. This graph is shown below.

<u>Figure 7 - Model Errors vs. HDDs</u>



Both of these previously explored issues assume that the model presented by Mr. Landward was calibrated using all the data provided in "OCS 1.03 Attachment.xlsx". It is unclear whether or not this is the case from my review of DEU's responses. If observations across the summer months, where temperatures routinely exceed 65 degrees Fahrenheit, were used in the calibration of the model, the model is likely to be mis-specified. The model detailed in Mr. Landward's testimony does not allow for the effects of temperatures above 65 degrees F to be estimated, as it only includes HDD terms, and not CDD terms (or raw temperature and temperature-squared). If CDDs are a statistically significant driver of natural gas demand on the system, which my preliminary analysis suggests, then leaving them out of the regression equation will result in omitted variable bias. The symptoms of omitted variable bias include inaccurate parameter estimates for independent variables, with over/under-estimation of the individual coefficients depending upon their correlation to the omitted variable. This could render statements regarding the individual effects of independent variables on firm sales, such as "If, on January 6, 2017, temperatures had been -5 degrees rather than 4.5 degrees, the demand would have increased by 104,880 Dth to 1,048,291 Dth."[29] inaccurate. It can also cause autocorrelation, as was mentioned previously.

Given the concerns regarding autocorrelation, heteroskedasticity, and potential omitted variable bias, I cannot trust the t-statistics or parameter estimates reported by Mr. Landward in his testimony[30], and also conclude that the model is not correctly specified.

<u>Multivariate Regression Model Results</u>

Q. Is the accuracy of the prior day forecast for January 5, 2017, presented in the testimony acceptable?

A. Mr. Landward's example in lines 83-93 of his testimony, in which he predicts January 5, 2017 demand using January 6, 2017 conditions, and the average proportion of temperature and wind derived using his methodology is materially flawed.

First, January 6, 2017 was the coldest day of 2017, according to the HDD data provided in "OCS 1.03 Attachment.xlsx". This, by definition of the methodology described by Mr. Landward, means that the proportion of January 5 temperatures to January 6 temperatures was used in the very calculation that determined the average proportion for prior-day temperatures used to predict the temperature for January 5. With a sample size of only 15 observations, this single observation had a significant effect on the calculated proportion value itself.

Second, January 5th data appears to have been used in the calibration of the model. Therefore, this comparison is not detailing the forecast accuracy of the model using new, out-of-sample

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[29] Docket No. 17-057-09; Direct Testimony of David C. Landward for Dominion Energy Utah, "In the Matter of the Passthrough Application of Dominion Energy Utah for an Adjustment in Rates and Charges for Natural Gas Service in Utah", lines 104-105

[30] Docket No. 17-057-09; Direct Testimony of David C. Landward for Dominion Energy Utah, "In the Matter of the Passthrough Application of Dominion Energy Utah for an Adjustment in Rates and Charges for Natural Gas Service in Utah", line 217

data, but data that was used to determine the model parameters. This example, therefore, should not be used to assert the validity of the methodology for calculating prior day demand.

Q. Upon consideration of the available data and analysis, do you believe the Design-Peak-Day demand estimate of 1,316,588 Dth to be reasonable?

A. There are too many potential problems across the areas of data assumptions and model inputs, the likelihood of Design-Peak-Day conditions occurring simultaneously, and the validation of model specification and accuracy, to put any confidence behind the 1,315,588 Dth peak demand estimate provided in Mr. Landward's testimony. The potential for omitted variable bias resulting from the exclusion of CDD or raw temperature terms draws into question the individual regression parameters. The unknown joint probability of Design-Peak-Demand conditions occurring simultaneously draws into question the assumptions used in generating the forecast. The Company's approach to estimating prior day demand for the Design-Peak-Demand scenario seems to be inappropriate, and not supported empirically. Finally, the lack of information on out-of-sample model performance (as opposed to fit) prevent any conclusions from being made as to the model's ability to predict Design-Peak-Day firm sales demand, even if the assumptions and methodology for the other sections were proper. As such, I have no confidence in the 1,316,588 Dth demand forecast provided in Mr. Landward's testimony.

Peak-hour Model Overview, Assumptions, and 2016/2017 Peak-Hour Forecast

Q. How would you describe the type of model that DEU uses to calculate Design-Peak-Hour demand?

A. DEU uses the Design-Peak-Day forecast from the multivariate regression model, which has been the focus of my testimony, as an input into an unsteady-state model, which analyzes the peak-day demand discretely, hour by hour, for the Company's high-pressure system.[31] The unsteady-state model, "Synergi"[32], is a complex technical/engineering model, which is tailored to the

[31] Docket No. 17-057-20; Direct Testimony of Michael A. Platt for Dominion Energy Utah, "In the Matter of the Passthrough Application of Dominion Energy Utah for an Adjustment in Rates and Charges for Natural Gas Service in Utah", lines 34-37
[32] Response to Discovery DPU 2.62

physical infrastructure describing the Company's transmission system. Synergi is a product of DNV-GL[33], and is a licensed product. As such, I was unable to examine many aspects of the model, and its underlying assumptions/inputs.

Q. **What assumptions were used in the model to determine Design-Peak-Hour firm demand for the 2016 heating season?**

A. The Design-Peak-Hour model incorporates engineering data to describe the physical system. In addition, the Design-Peak-Hour model assumes that the peak-hour demand of the peak demand day is equal to 117% of the average hourly demand.[34] The 17% increase in peak-hour demand over that of average hourly demand was calculated by Mr. Platt by taking 979[35] observations from August 2010 to August 2017, finding the peak hourly demand for a given day, and dividing that value by the hourly average demand.[36] Raw data was not provided by Mr. Platt in 17-057-20 DEU Exhibit 2.2, but instead, 979 observations of the hour of peak demand , and the peak hour demand divided by the average hourly demand. Because full hourly data, including 24 observations per day, the date of occurrence, and firm demand, was not provided – I am unable to replicate Mr. Platt's methodology and verify his results. The model also seems to have an assumed set of initial conditions regarding operating pressures, it is unclear how this set of initial conditions was defined. The model assumes that the peak-demand hour occurs from 8:00 a.m. to 9:00 a.m.[37]

Q. **What were the results of the Design=Peak-Hour analysis?**

A. Mr. Platt simulated Design-Peak-Hour pipeline system pressures based upon the Design-Peak-Day estimate of Mr. Lawrence. He concluded that a significant loss of pressure would occur on the system given current firm supply and simulated Design-Peak-Hour demand.[38] Mr. Platt

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[33] DPU 2.62 Attachment 1 – Synergi Help File.pdf

[34] Docket No. 17-057-20; Direct Testimony of Michael A. Platt for Dominion Energy Utah, "In the Matter of the Passthrough Application of Dominion Energy Utah for an Adjustment in Rates and Charges for Natural Gas Service in Utah", lines 47-49

[35] 17-057-20 DEU Exhibit 2.2

[36] Response to Discovery DPU 2.66

[37] Docket No. 17-057-20; Direct Testimony of Michael A. Platt for Dominion Energy Utah, "In the Matter of the Passthrough Application of Dominion Energy Utah for an Adjustment in Rates and Charges for Natural Gas Service in Utah", lines 102-109

[38] [38] Docket No. 17-057-20; Direct Testimony of Michael A. Platt for Dominion Energy Utah, "In the Matter of the Passthrough Application of Dominion Energy Utah for an Adjustment in Rates and Charges for Natural Gas Service in Utah", lines 61-64

concluded that additional firm peak hour supply is necessary to maintain system reliability on a Design-Peak-Day based on the results of his analysis.[39]

Q. **Do you find the conclusion that additional firm supply is needed to meet Design-Peak-Hour demand reasonable?**

A. Unfortunately, the flaws in the Design-Peak-Day analysis mean I am unable to assess the reasonableness of Mr. Platt's Design-Peak-Hour analysis, as the modeled Design-Peak-Day estimate is a direct, if not the most important, input into the Design-Peak-Hour analysis. Over/under-estimation of Design-Peak-Day demand will directly lead to over/under-estimation of Design-Peak-Hour demand.

<u>Conclusions</u>

Q. **What are your conclusions on the reasonableness of the analysis and estimates for both Design-Peak-Day demand and Design-Peak-Hour demand?**

A. I am unable to verify the reasonableness of both the Design-Peak-Day and Design-Peak-Hour analyses. First, DEU is unable to assess the likelihood of Design-Peak-Day conditions occurring. This fact alone should raise serious doubt about the Design-Peak-Day analysis' usefulness in system planning. Peak-demand planning should involve planning for a high-impact, low-probability event, where both elements should be quantifiable in order to be informative and actionable. Second, setting aside the concern that the probability of Design-Peak-Day conditions occurring simultaneously has not been evaluated by DEU, the assumed conditions for the Design-Peak Day may be unreasonable. DEU disregarded the correlation between the independent variables used in their model when selecting conditions for a peak demand day. The failure to account for these correlations, and the choice to independently pick maximum values for HDD count, maximum wind speed, and mean wind speed, suggests that these assumptions may not be reasonable. Third, even if the Design-Peak-Day assumptions were valid, and we knew their likelihood to occur, the multivariate regression model itself suffers from

[39] [39] Docket No. 17-057-20; Direct Testimony of Michael A. Platt for Dominion Energy Utah, "In the Matter of the Passthrough Application of Dominion Energy Utah for an Adjustment in Rates and Charges for Natural Gas Service in Utah", lines 66-67

several potential statistical problems. There are grounds to reasonably suspect that DEU's exclusion of temperature-related effects on gas demand above 65 degrees F may lead to omitted variable bias, the effects of which include the misestimation of individual independent variable coefficients in the multivariate regression model. This means that references to the individual effects of the independent variables on gas demand may be biased, and not representative of the true relationship between the variables. Additionally, DEU's methodology for selecting "prior-day" conditions, which effect Design-Peak-Day estimates, does not seem reasonable, and is based on unfounded and inaccurate assumptions. Furthermore, there is evidence to suggest that both autocorrelation and heteroskedasticity are present in the error terms produced by this multivariate regression model. Both of these conditions could independently lead to the standard error estimates of the independent variable effects on gas demand to be misestimated. This suggests that the usual ordinary least squares t-statistics and confidence intervals are no longer valid. The joint consideration of omitted variable bias, autocorrelation in errors, and heteroskedasticity in errors suggest that the ordinary least squares estimator is no longer an unbiased, or the minimum variance, estimator. While considerations of the likelihood of occurrence and selection of conditions for the Design-Peak-Day, along with the potential flaws with the model employed themselves make it impossible to say if the resulting estimates are reasonable, DEU also neglected to provide an adequate assessment of the model's predictive accuracy based on historical records that were not used for calibrating the model. This means that even if the Design-Peak-Day assumptions, and the underlying multivariate regression model were valid, there would still be insufficient evidence to suggest that DEU's estimate for Design-Peak-Day demand is a reasonable one. For all of these reasons, the Design-Peak-Hour estimate also cannot be shown to be reasonable, as the flawed Design-Peak-Day estimate is its most important input.

My testimony is based on the information available at the time it was prepared. I reserve the right to amend my testimony should new information become available.