THE MONDAY PRICE QUESTION

A focus paper on the volatility of the price difference between real-time and day-ahead power markets in the Pacific Northwest

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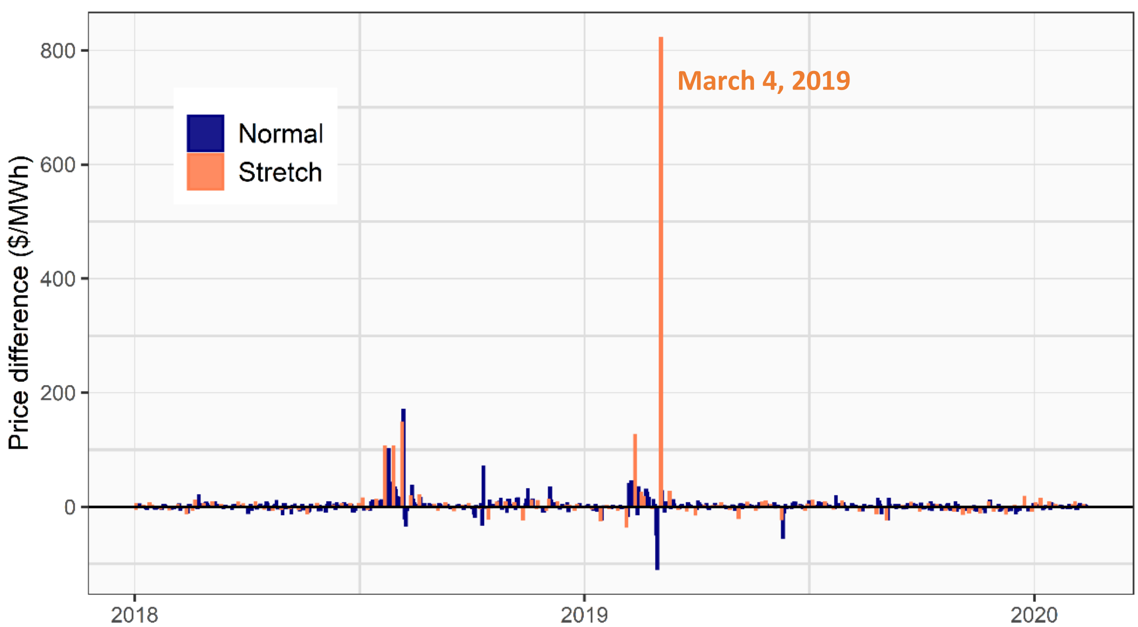
This report was developed by members of the PNUCC System Planning Committee

EXECUTIVE SUMMARY

On Friday, March 1, 2019, electric power traded on the day-ahead market in the Northwest for the upcoming Monday (March 4). The region was in the midst of an extended period of cold temperatures, coping with reduced natural gas availability due to a pipeline rupture and problems at underground storage facilities, and water conditions were suboptimal for hydroelectric generation. Day-ahead market prices for Monday, March 4, reached $1,000/MWh and averaged just under $900/MWh. But when March 4 arrived the fears of resources scarcity had passed. Real-time power prices reached above $100/MWh for a few hours, but ultimately averaged under $100/MWh for the heavy-load-hour block, around $800/MWh less than the average day-ahead price.

Multiple groups have studied the factors leading to the high 2019 March prices. During a February 2020 PNUCC System Planning Committee meeting a question related to the March event was raised – what role did March 4 being a Monday play in creating the large day-ahead to real-time market price difference?

Figure 1 – Day-ahead to real-time price differences (Mid-C HLH), January 2018 to early 2020



The goal of this analysis is to explore the historical price differences between the day-ahead and real-time power markets in the Northwest (at Mid-Columbia, heavy-load-hour only). See Figure 1 for an example of the differences between 2018 and early 2020. The study focuses on the volatility of the price difference, and how different lengths of time between power trading and delivery impacts volatility. **The analysis finds that the difference in day-ahead to real-time market prices is more volatile when there is an extended number of days between the time power is traded and delivered.** The analysis is narrow in focus and does not explore other explanatory factors.[1]

[1] WECC wrote a report exploring factors that contributed to the high power prices experienced in winter 2019. It can be found here: https://www.wecc.org/Reliability/PricingEvent_Paper_Final.pdf

Most days, the heavy-load-hour day-ahead market in the Northwest is traded day-ahead. Power traded on Monday is delivered Tuesday, power traded on Tuesday is delivered Wednesday, power traded on Wednesday is delivered Thursday, and power traded Thursday is delivered over Friday and Saturday.[2] These days, when power is traded the day before delivery, are classified as normal days in the analysis.

However, heavy-load-hour power traded on Friday is delivered on Monday. This adds extra days between the trading and delivery of power as compared to the normal days. This extended gap also occurs over some holidays (for example if July 4 is a Wednesday, power traded on July 3 is delivered on July 5), and during other occasions. These days, with a multiday gap between trading and delivery, are classified as stretch days in the analysis.

The real-time market trades on an hourly basis (e.g. in real-time or hour ahead). This analysis examines power prices differences between the day-ahead market and the real-time market, with a focus on the volatility of that difference. As noted earlier, the primary finding is the price difference is more volatile when the day-ahead market is on a stretch day (as opposed to a normal day).

The study also concludes that day-ahead market prices are, on average, higher than real-time prices (this analysis compares both normal and stretch days, together, to the real-time market). These findings are specific to heavy-load-hour power blocks and the late 2003 to early 2020 period. A third finding is that the average price difference between the day-ahead and real-time markets on normal versus stretch days is statically insignificant.[3]

The analysis raised additional questions that could become future work. For example, some report contributors theorized that more volatile price difference between the day-ahead and real-time markets may result in higher options prices or power prices (potentially most acutely during extreme conditions).[4] Contributors also wondered if price volatility between the day-ahead to real-time markets contributes to adequacy concerns. For example, would the March 4, 2019, $890/MWh day-ahead price event been different had it landed on a normal day rather than a stretch day (Monday)? This analysis does not answer these questions, nor does it examine methods for reducing price volatility between the day-ahead and real-time markets – although trading seven days a week was brought up as a way to reduce volatility on the stretch days. These questions are further discussed on page 8 of this report (Discussion).

[2] This report examines the heavy-load-hour time period, which excludes Sundays and holidays.
[3] The data is insignificant for the full dataset, but in some sensitivities, it became significant. These findings are for the average price difference –see Appendix B for an examination of the absolute price differences.
[4] Day-ahead prices in the full dataset are higher, on average, on stretch days as opposed to normal days by $1.77/MWh. However, this difference is not statistically significant (Welch 2-sample t-test, p value = 0.11).

DATASET CONSTRUCTION

The analysis uses two datasets. The first is a publicly available Mid-Columbia day-ahead-market heavy-load-hour price dataset from the US Energy Information Administration (EIA). The EIA receives the data from the Intercontinental Exchange (ICE). The dataset comes with the daily price information averaged into heavy-load-hour blocks (16 hour).

The second dataset (provided by a PNUCC member utility) is an hourly tabulation of Mid-C real-time market prices. To match the heavy-load hour blocks of the EIA/ICE data, the hourly data are averaged into 16-hour heavy load blocks. Fridays/Saturdays are averaged together on most dates to match the Friday/Saturday day-ahead trading package. The datasets are joined by the power-delivery start date (from the EIA/ICE dataset). This process also screens out any light load hour days (Sundays, holidays, etc.) since the EIA/ICE dataset is heavy-load-hour only.

The majority of the dataset manipulation and analysis is done in R. Some additional dataset manipulation is done in Excel due to irregularities in the trading calendar (e.g. schedulers meetings that create a mid-week 2-day trading package). Fewer than 20 available days are discarded due to dataset errors.

The final dataset runs from late 2003 through early 2020, and includes 4,043 days. The days are grouped into two categories: normal days and stretch days. Normal days do not have a gap between trading and delivery on the day-ahead-market. For example, a Tuesday where power trades the Monday prior is categorized as a normal day. The Friday/Saturday package (traded on Thursday) is also a normal day for this analysis. There are 2,953 normal days in the dataset.

The other group, with 1,090 days, are the stretch days. These days have a gap between trading and delivery. Mondays, where power is typically traded the Friday prior, are the bulk of the stretch day group. Days following holidays, and long multipackage days, are also stretch days (for example if power traded on Monday and delivers over Tuesday, Wednesday, and Thursday, it is classified as a stretch day).

The focus of the analysis is the difference between the day-ahead and real-time prices. A positive difference indicates the day-ahead price are higher than the real-time prices, a negative value indicates real-time price are higher. This difference is examined in aggregate (all days combined), and also broken out by the normal and stretch day groups.

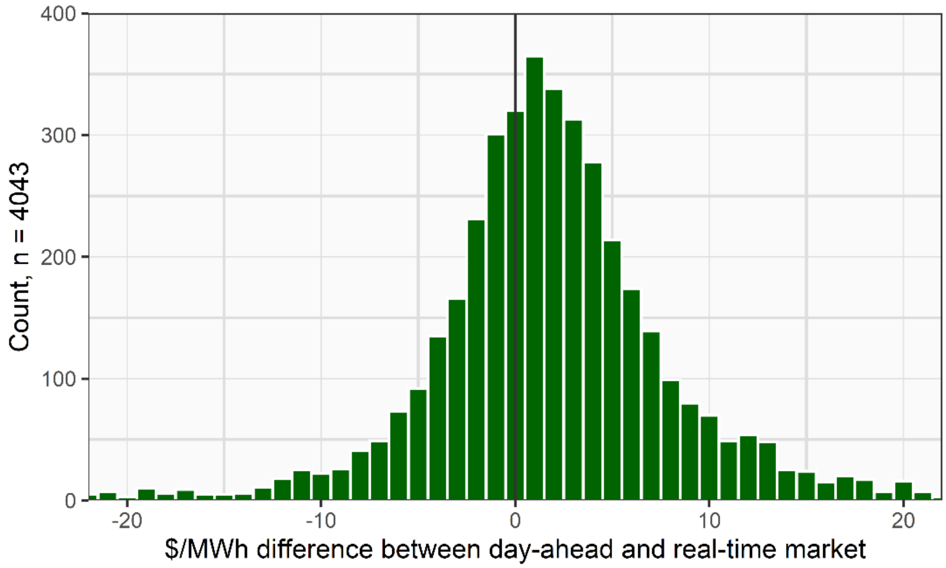
ANALYSIS

The main analysis consists of three steps:

1. Using a t-test to determine if, on average, day-ahead and real-time prices differ.
2. Using a Welch two-sample t-test to determine if, on average, the difference between day-ahead and real-time power prices is different between normal and stretch days.
3. Using a Fligner-Killeen and Levene test to determine if the variance of the price difference between the day-ahead and real-time market is different between normal and stretch days.

The histogram in Figure 2 shows the difference in price between the day-ahead and real-time markets. Each bin is $1/MWh wide. The tails extend out past -$200 and $800 due to large deviation events (not shown).

Figure 2 – Histogram of difference between day-ahead and real-time prices



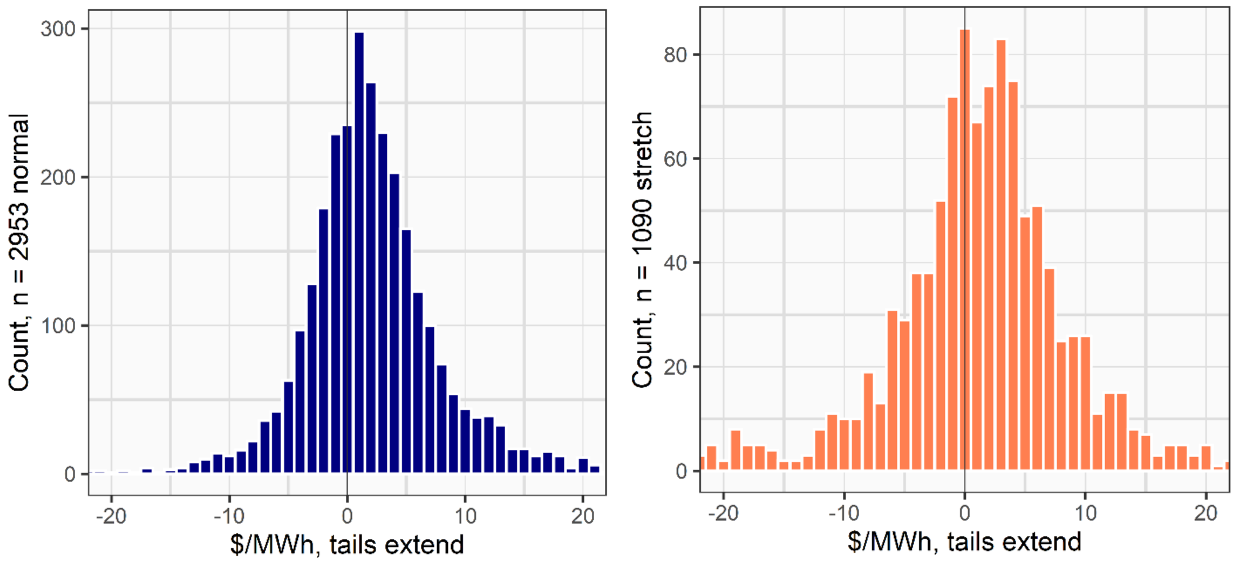
On average (mean), the price difference is $2.60. The median (50th percentile) difference is smaller at $1.68/MWh. The mean is statistically greater than zero, indicating that on average, day-ahead prices are higher than real-time prices (see Table 1).

Table 1 – Full sample t-test

Test type	1 sample t-test	
Data and hypothesis	Difference between day-ahead & real-time prices; alternative hypothesis: true mean is not equal to 0	
t = 9.60	df = 4042	p-value < 2.2e-16
95% conf. interval	2.07 to 3.13	
mean of x	2.60	

The histograms in Figure 3 show the day-ahead to real-time price difference grouped by normal days (left) and stretch days (right). The y-axis scales are different since there are more normal days than stretch days.

Figure 3 - Histogram of difference between day-ahead and real-time prices, normal v. stretch



On average (mean), the prices difference between the two groups is statistically insignificant. This finding can switch to significant if examining a subset of the data or when removing extreme price deviation events (see Appendix A). These price differences are also explored using absolute values in Appendix B.

Table 2 – Testing the difference in means of the normal and stretch days

Test type	Welch 2 sample t-test	
Data and hypothesis	Normal & stretch day difference between day-ahead and real-time prices; alt. hypothesis: true difference in means is not equal to 0	
t = 0.42	df = 1194.3	p-value = 0.68
95% conf. interval	-1.37 to 2.1	
mean of x & y	2.70 (normal) & 2.33 (stretch)	

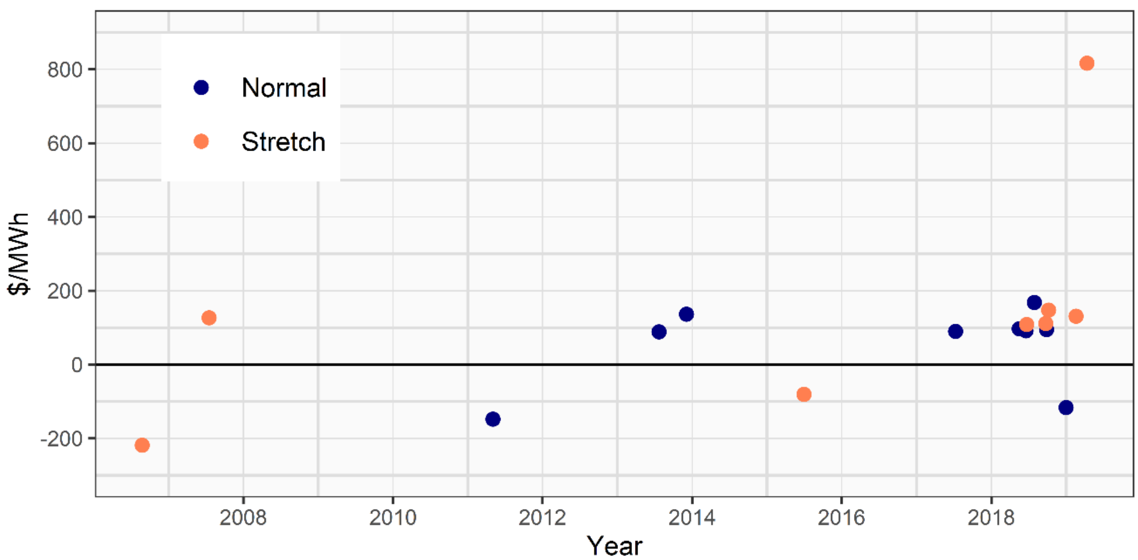
The variance (and thus standard deviation) of the difference between day-ahead and real-time prices is greater on the stretch days than normal days.[5] A variance test confirms that the difference is statistically significant. This finding holds up well in sensitivity testing (see Appendix A). Due to data non-normality, the Fligner-Killeen test establishes the difference in variance (see Table 3). The Levene test also confirms the results (not shown).

Table 3 – Testing if variances are equal or different between normal and stretch days

Test type	Fligner-Killeen test of homogeneity of variances	
Data and hypothesis	Normal & stretch day difference between day-ahead and real-time prices; alt. hypothesis, groups have different variances	
med chi-squared: 42.43	df = 1	p-value = 7.33e-11

Figure 4 shows seventeen days where the price difference between the day-ahead and real-time market is greater than $85 in either direction (negative values indicate the real-time prices are higher). The graph uses $85 as this is a natural breakpoint in the data.[6]

Figure 4 – High day-ahead to real-time price deviation events, Mid-C



14 of the 17 days in the graph occur in the summer, and the majority of events occur in 2018 and 2019. Additionally, 8 days are stretch days and 9 are normal days. The analysis did not test if these observations are significant.

[5] Standard deviation for normal days is 10.27, 28.57 for stretch. This is sensitive to high difference days, but stretch days have a higher standard deviation when high difference days are removed (see sensitivity appendix).
[6] Points in the graph have been jittered vertically and horizontally to prevent them from overlapping – prices may vary by up to $10/MWh and dates may vary by over a month. Graph excludes earlier dates (no >$85 days).

DISCUSSION

The focus of the analysis is to see if the difference between day-ahead prices and real-time prices is more or less volatile on stretch days as compared to normal days (stretch days have an extended period between day-ahead trading and power delivery). The study finds stretch days have a more volatile price difference than normal days. This conclusion leads to some interesting questions for future analysis that are discussed below:

a) Is there value in reducing the day-ahead to real-time market price difference volatility on stretch days? Increased volatility may result in higher options prices or power prices (potentially most acutely during extreme conditions).[7] This hypothesis is not tested in this analysis. And given that power trading is a zero-sum game, any potential benefits to reduced volatility may be asymmetrical (some parties would benefit, others may see losses) and/or balance out in the long run.

b) If there is value in reducing the volatility in the day-ahead to real-time price differences, what is the best way to reduce the volatility? One suggestion is trading day-ahead power seven days per week. For example, Monday power would be traded on Sunday rather than Friday as it is today. There are costs to implementing more frequent trading, and potentially other benefits – the cost/benefit of this is not examined in this analysis.

c) Has day-ahead to real-time price difference volatility been increasing or decreasing in the past decade, and if so, why? There are many anecdotal thoughts on this. One thought is volatility is increasing due to increased variable energy resource penetration. Another thought is volatility is decreasing due to improved forecasting methods and more efficient markets (e.g. EIM). This was not tested in the analysis, in part due to the difficulty in isolating what factors affect price differences.

d) How does day-ahead to real-time price volatility impact resource adequacy perceptions? Adequacy concerns are growing in the Northwest due to recent high price events (i.e. high prices in summer 2018, winter 2019, and summer 2020). Report contributors wondered if the March 4, 2019, $890/MWh day-ahead price event would have been different had it landed on a normal day (it occurred on a Monday, a stretch day).

[7] Day-ahead prices in the full dataset are higher, on average, on stretch days as opposed to normal days by $1.77/MWh. However, this difference is not statistically significant (Welch 2-sample t-test, p value = 0.11).

APPENDIX A – SENSITIVITY STUDIES

Various sensitivity studies test if the findings hold up under different subsets of the data. The sensitivities are combinations of dataset length and screening out higher deviation days. The higher deviations days screened out are the March 4, 2019, $890 day-ahead-market price day, and days with a day-ahead to real-time price difference greater than $85.

In all sensitivities, day-ahead prices are statistically greater than real-time prices at the mean. Additionally, in all sensitivities the price differences between day-ahead prices and real-time prices have statistically greater variance on stretch days as opposed to normal days. The mean difference in day-ahead to real-time prices in the normal versus stretch groups was at times insignificant and at times significant.

Table 4 – Sensitivity analysis

p value - report uses p < 0.05 for significance

Question	Test	Full dataset (2003 - 2020)*	Full dataset, no $890 DAM day	Full dataset, no > $85 days
Is the mean difference between day-ahead and real-time prices significant	t-test	p-value < 0.01, mean 2.6	p-value < 0.01, mean 2.4	p-value < 0.01, mean 2.2
Is the mean difference in prices significantly different in normal v. stretch days	Welch 2 sample t-test	p-value .68	p-value = 0.02, norm. mean larger	p-value < 0.01, norm. mean larger
Do the difference in prices have significantly different variances in normal v. stretch days	Fligner Killeen & Levene test	p-values < 0.01 for both	p-values < 0.01 for both	p-values < 0.01 for both

Question	Test	2009 - 2020 dataset	2009 - 20 dataset, no $890 DAM day	2009 - 20 dataset, no > $85 days
Is the mean difference between day-ahead and real-time prices significant	t-test	p-value < 0.01, mean 2.8	p-value < 0.01, mean 2.5	p-value < 0.01, mean 2.1
Is the mean difference in prices significantly different in normal v. stretch days	Welch 2 sample t-test	p-value = 0.63	p-value = 0.30	p-value = 0.01, norm. mean larger
Do the difference in prices have significantly different variances in normal v. stretch days	Fligner Killeen & Levene test	p-values < 0.01 for both	p-values < 0.01 for both	p-values < 0.01 for both

Question	Test	2015 - 2020 dataset	2015-2020 dataset no $890 DAM day	2015 - 20 dataset, no > $85 days
Is the mean difference between day-ahead and real-time prices significant	t-test	p-value < 0.01, mean 2.5	p-value < 0.01, mean 1.9	p-value < 0.01, mean 1.2
Is the mean difference in prices significantly different in normal v. stretch days	Welch 2 sample t-test	p-value = 0.47	p-value = 0.59	p-value = 0.02, norm. mean larger
Do the difference in prices have significantly different variances in normal v. stretch days	Fligner Killeen & Levene test	p-values < 0.01 for both	p-value < 0.01 (FK), p-value = 0.01 (L)	p-value < 0.01 (FK), p-value = 0.03 (L)

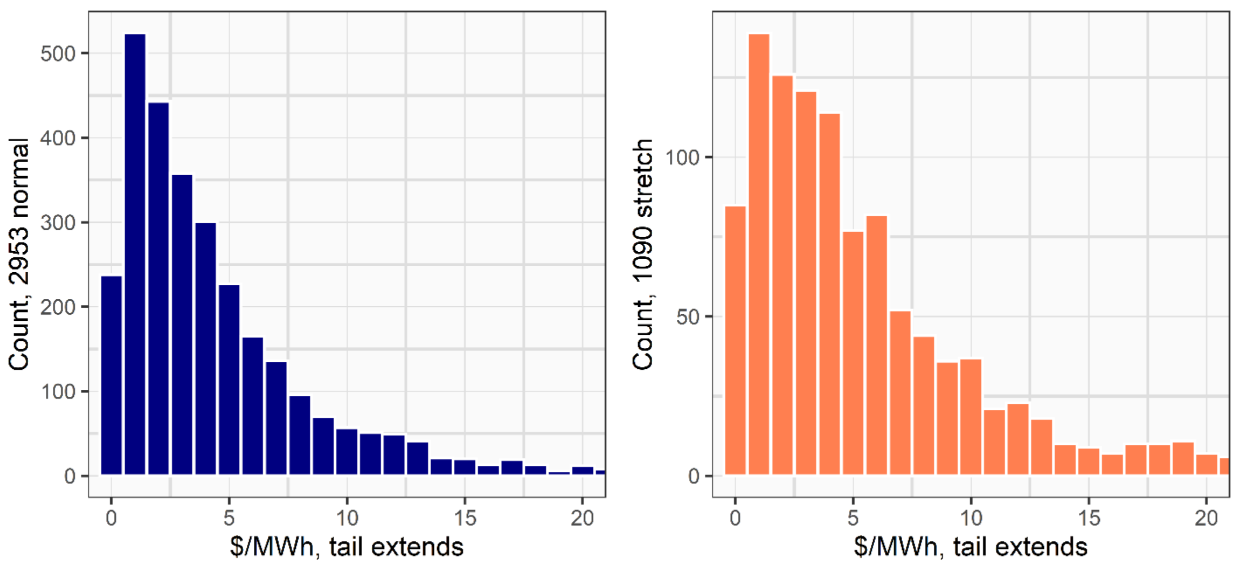
** September 2003 through mid-February 2020*

APPENDIX B – ABSOLUTE VALUE ANALYSIS

One interesting part of the analysis is the mean price difference between day-ahead and real-time markets is \$2.70/MWh for normal days and \$2.33/MWh for stretch days. Although this difference is insignificant in the full dataset, it is significant under certain sensitivities.

To further examine this, an absolute-value investigation is performed to examine the total distance from zero and prevent high and low deviations from averaging out (for example, if the day-ahead to real-time price difference is -\$20 one day, and +\$20 the next, this would average out to zero normally, but average to \$20 when looking at absolute value). Figure 5 shows two histograms – the one on the left is the absolute value of the difference between day-ahead and real-time price difference on normal days, the one on the right is the same but for stretch days.

Figure 5 – Absolute value of the difference between day-ahead and real-time market prices



The absolute mean value for the normal days is \$5.44/MWh, and \$7.61/MWh for the stretch days, in the full dataset. A Welch 2 sample t-test shows that this difference is statistically significant (p-value = 0.01). This indicates that the mean absolute difference between day-ahead and real-time prices is further from zero on stretch days than normal days.