Portland General Electric Company
Legal Department
121 SW Salmon Street • Portland, Oregon 97204
503-464-7611 • Facsimile 503- 464-2200

Richard George
Assistant General Counsel

June 27, 2018

Via Electronic Filing

Oregon Public Utility Commission
Attention: Filing Center
PO Box 1088
Salem OR 97308-1088

Re: UM 1912 – PGE's December 4, 2017 Testimony of Brett Sims – Errata Exhibit 301

Enclosed for filing please find an errata to Portland General Electric Company's ("PGE") December 4, 2017 Testimony of Brett Sims, Exhibit 301. This exhibit contains an article titled "How Big Is the Risk Premium in an Electricity Forward Price?". PGE wishes to resubmit this article in its entirety, unchanged, but redacting the artwork that appears at the end of article as filler, is not part of the article, and does not reflect PGE's values.

In light of this, PGE requests that the enclosed five pages be substituted for pages 72-76 to Exhibit 301 to the Testimony of Brett Sims.

If you have any questions regarding this filing, please contact me at (503)464-7611. Thank you for your assistance in this matter.

Sincerely,

James Richard George, OSB No. 974691
Assistant General Counsel
Portland General Electric Company
121 SW Salmon Street, 1WTC1301
Portland, Oregon 97204
(503) 464-7611 phone
(503) 464-2200 fax
richard.george@pgn.com

JRG/al

Andrew DeBenedictis *is a Consultant at Energy and Environmental Economics, Inc. (E3), an economics and engineering consulting firm in San Francisco. He has prepared testimony for use in regulatory proceedings and performed analyses of bill impacts and costs of service that involve large billing and load data files. He holds a B.A. in Physics from Bowdoin College.*

David Miller *is a Consultant at E3. He has performed cost effectiveness analyses of various energy technologies for use in California public regulatory proceedings and has created dispatch simulation models. He holds a B.A. in Economics from Stanford University.*

Jack Moore *is a Senior Consultant at E3, specializing in resource planning and distributed resources. He has conducted research and analysis for the California ISO, the Environmental Protection Agency, Electric Power Research Institute, Pacific Northwest Generating Cooperative, and the State Of Idaho. He holds an M.Sc. in Management Science and Engineering from Stanford University.*

Arne Olson *is a Partner at E3. With 15 years in the electric power sector, he specializes in integrated resource planning and renewable energy policy. He holds an M.Sc. in International Energy Management and Policy from the University of Pennsylvania.*

C.K. Woo *is a Senior Partner at E3 and an affiliate of the Hong Kong Energy Studies Centre of Hong Kong Baptist University. With 25 years of experience in the electricity industry and over 90 refereed publications, he is an Associate Editor of* Energy *and a member of the editorial board of* The Energy Journal. *He holds a Ph.D. in Economics from UC Davis.*

How Big Is the Risk Premium in an Electricity Forward Price? Evidence from the Pacific Northwest

The numerous benefits of electricity forward trading come at a cost to consumers when a forward price contains a risk premium. An analysis based on the theory of cross hedging suggests that there is a risk premium of about 5 percent in the forward price for delivery at the Mid-Columbia hub of the Pacific Northwest. The existence of a relatively large risk premium suggests that forward contract buyers are more risk-averse than sellers.

Andrew DeBenedictis, David Miller, Jack Moore, Arne Olson and C.K. Woo

I. Introduction

Wholesale spot market prices for electricity generation are inherently volatile, chiefly due to daily fuel cost variations, fluctuating weather-sensitive demands that must be met in real time by capacity already in place, and planned and unexpected facility outages.[1] Unmitigated spot price volatility can be very costly to electricity consumers, as dramatically demonstrated by the California energy crisis a decade ago.[2] To mitigate the spot price volatility, an electricity consumer may buy a forward contract which sets a fixed price for future delivery.[3]

Electricity forward trading offers several benefits to electricity consumers, including

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price discovery, hedge against spot price risk, and market power mitigation.[4] However, these benefits come at a cost to consumers when the forward price contains a risk premium, measured by the percentage above an unbiased spot price forecast. This raises a substantive question: how big is this premium?

Using the theory of cross hedging,[5] this article estimates the risk premium in a forward price based on a sample of daily data for the seven-year period of 2003–09. It shows that there is a risk premium of about 5 percent in the forward price for delivery at the Mid-Columbia (Mid-C) hub of the Pacific Northwest that is rich in hydro generation.[6] Corroborating the empirical evidence for a wholesale market dominated by thermal generation (e.g., PJM), the existence of a relatively large risk premium suggests that forward contract buyers are more risk averse than sellers.[7]

II. Model

A. Cross hedging

Consider P_t, the daily Mid-C price for delivery on day t during the high-load-hours of 06:00–22:00, Monday–Saturday. We assume the data generating process (DGP) for P_t is the following regression:

$$P_t = \alpha + \beta G_t + \varepsilon_t; \qquad (1)$$

where G_t = daily spot natural gas price for Henry Hub delivery; ε_t = random error; and (α, β) = coefficients to be estimated.

Our DGP assumption is based on: (1) natural gas is the likely fuel for marginal generation; (2) the Mid-C market price tends to track the short-run marginal cost of generation; and (3) NYMEX natural gas futures are actively traded which enables cross hedging. Eq. (1) does not have weather or hydro conditions as drivers for the Mid-C price because such conditions cannot be accurately forecasted months ahead when making a Mid-C price forecast, say, in early 2010 for the 12-month delivery in 2011.

Using the theory of cross hedging, this article estimates the risk premium in a forward price based on a sample of daily data for a seven-year period.

Given suitable data, one can apply ordinary least squares (OLS) to estimate Eq. (1), yielding its estimated version:

$$P_t = a + bG_t + e_t$$

The slope estimate b is the optimal hedge ratio for procuring the MMBTU of natural gas that minimizes the spot price variance.[8]

B. Spot price forecast

Suppose an electricity buyer (e.g., a load-serving entity transacting in the wholesale market) buys b MMBTU of natural gas futures at $\$H_n$/MMBTU for future delivery on day n. Further suppose the buyer takes natural gas delivery and resells the same in the natural gas spot market, realizing a cash flow of $b(G_n - H_n)$. Thus, the buyer's net spot electricity price for day n is:

$$\begin{aligned} P_n &= a + bG_n - b(G_n - H_n) + e_n, \\ &= a + bH_n + e_n \qquad (2) \end{aligned}$$

Based on Eq. (2), an unbiased forecast of P_n is

$$\mu_n = a + bH_n,$$

whose variance is

$$\sigma_n^2 = \mathrm{var}(a) + 2\,\mathrm{cov}(a,b)H_n + \mathrm{var}(b)H_n^2 + \mathrm{var}(e_n). \qquad (3)$$

Since μ_n and σ_n can be generated by a standard statistical package (e.g., PROC REG in SAS), their computation is fast and straightforward.

If the buyer's forecast period has N days (e.g., $N \approx 26$ for January), the period's average forecast price is

$$\mu = \sum_n \frac{\mu_n}{N},$$

whose variance is

$$\sigma^2 = \sum_n \frac{\sigma_n^2}{N^2}.$$

C. Forward pricing and risk premium

Based on the Central Limit Theorem, μ is normally distributed.[9] Hence, a 90 percent confidence interval for the average forecast price has an upper bound of $U = \mu + 1.65\sigma$, and a lower bound of $L = \mu - 1.65\sigma$. Consistent with the notion of value-at-risk, L (U) is the price floor (ceiling) under normal circumstances for the actual average price in the forecast period.[10]

When a forward price F is at or below L, the contract is profitable, with a 95 percent probability, from a contract buyer's perspective when compared to the spot market purchase alternative. If F is at or above U, the contract is profitable, with a 95 percent probability, from a contract seller's perspective when compared to the spot market sale alternative. If $F = \mu$, the forward price does not advantage the buyer or seller.

Suppose an observed F is close to U. This suggests that the contract buyer is more risk-averse than the seller, willing to pay a risk premium of

$$\rho = \frac{F - \mu}{\mu}$$

above the average forecast price to eliminate the spot price volatility in the forecast period.

III. Results

A. Monthly spot price regressions

Table 1 presents the descriptive statistics for the daily data used in our regression analysis, showing that Mid-C and Henry Hub prices can be high and volatile. The Phillips–Perron unit-root test statistics indicate that the Mid-C series is stationary at the 1 percent level ($\alpha = 0.01$), and that the Henry Hub price series is stationary at $\alpha = 0.05$.[11] Thus, the regression results reported below are not "spurious."[12]

Recognizing that the hedge ratio may vary substantially across months, we estimate Eq. (1) for each month in our seven-year data sample. That is, the January regression is based on the daily data for January in the seven-year period.

Table 2 shows the regression results by month, yielding the following findings:

- The Mid-C monthly mean prices are relatively low at around \$40/MWh in the spring months of March–June and relatively high at above \$55/MWh in the summer months of July and August and the winter month of December.
- The mean squared error, which is var(e_t) in Eq. (3), indicates large unexplained price variances for the months of April–July. This is because spring runoff in these months, instead of natural gas price, is the main driver of Mid-C prices.
- Measured by the adjusted R^2, the regression goodness-of-fit varies substantially across months. It is likely to be low for the low-price months (e.g., 0.05 for June) and high for the high-price months (e.g., 0.86 for September). This is because the high-price months are those likely with natural gas price as marginal generation fuel.
- The optimal hedge ratio given by the slope coefficient estimate b varies substantially across months (e.g., 1.51 for June vs. 9.61 for April), suggesting that

Table 1: Descriptive Statistics for the 2003–2009 Sample of 2,256 Daily Observations

Variable	Mean	Standard Deviation	Minimum	Maximum	Correlation with Mid-C Price	Phillips–Perron Unit Root τ Test Statistics (lags): Singe Mean	Phillips–Perron Unit Root τ Test Statistics (lags): Trend
Mid-C high-load-hour price (\$/MWH)	50.6	18.7	4.0	197.4	1.0	–7.80 (9)	–7.82 (9)
Natural gas price at Henry Hub (\$/MMBTU)	6.64	2.29	1.83	18.4	0.65	–3.35 (9)	–3.37 (9)

Data source: Intercontinental Exchange.

1040-6190/\$–see front matter , doi:/10.1016/j.tej.2011.02.011

Table 2: Monthly OLS Regression Results for the Period January 2003–December 2009, Standard Errors in (), and "*" = "significant at the 1 percent level".

Variable	January	February	March	April	May	June
Panel A: January–June						
Sample size	187	177	194	187	177	188
Mean Mid-C price	51.5	51.8	46.5	44.7	41.5	36.4
Mean squared error	79.9	37.2	73.7	180.3	185.6	256.8
Adj. R^2	0.54	0.75	0.70	0.65	0.39	0.05
Intercept estimate: *a*	1.295 (3.40)	10.74* (1.83)	-3.15 (2.41)	-16.03* (3.39)	7.96 (3.20)	25.72* (3.34)
Slope estimate: *b*	7.68* (0.510)	6.08* (0.262)	7.59* (0.356)	9.16* (0.489)	4.95* (0.448)	1.51* (0.443)

Variable	July	August	September	October	November	December
Panel B: July–December						
Sample size	186	194	182	195	185	193
Mean Mid-C price	56.8	56.8	51.7	54.2	52.0	63.1
Mean squared error	391.2	56.1	29.3	41.8	52.1	165.6
Adj. R^2	0.23	0.74	0.86	0.83	0.72	0.69
Intercept estimate: *a*	27.96* (4.12)	18.39* (1.74)	22.87* (0.936	21.33* (1.14)	15.92* (1.71)	7.07* (2.81)
Slope estimate: *b*	4.44* (0.594	6.03* (0.259)	4.65* (0.136)	4.90* (0.156)	5.61* (0.254)	7.79* (0.369)

using a single hedge ratio for the entire year may result in sub-optimal cross-hedging effectiveness.

B. Price forecast and risk premium

We use the spot price regressions in Table 2 to make a Mid-C forecast based on the natural gas futures prices from Mar. 26, 2010, the trading day for the delivery months of January through December 2011. **Figure 1** shows the forecast of the monthly average of daily high-load-hour Mid-C prices and the 90 percent confidence intervals for the monthly forecast results. It also shows the quarterly forward prices published in Platts *MegaWatt Daily* on Mar. 26, 2010 for the 12 delivery months in 2011.

Despite the unavailability of monthly forward prices, this figure yields two important observations. First, the quarterly forward prices track but are above the upper bound of the 90 percent confidence interval. Thus, these forward prices imply almost certain *ex ante* profitability for a forward seller who may meet its delivery obligation using spot-market

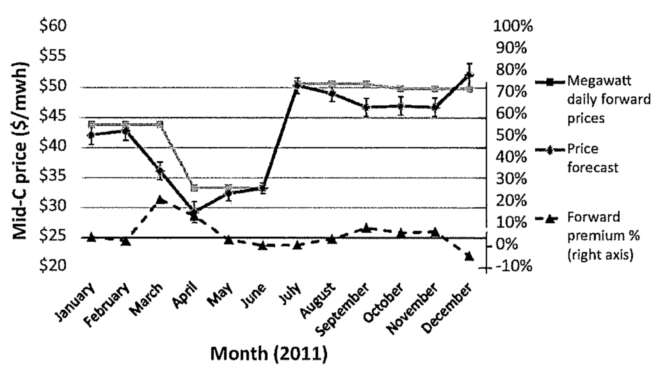

Figure 1: Forecast of Monthly Average of Daily On-Peak Mid-C Prices with 90 percent Confidence Interval and Premium Percentage of MegaWatt Daily's Quarterly Forward PricesBoth the Henry Hub Natural Gas Futures and the Quarterly Forward Prices are Taken from Mar. 26, 2010. The Average Forward-Price Premium is 5.4 Percent

purchases. Second, these forward prices contain an average premium of 5.4 percent above the price forecast.

IV. Conclusion

Dealing with electricity spot-price risk presents electricity buyers with a considerable challenge, one that can be overcome by procuring forward contracts. However, a forward contract is likely to contain a risk premium. Thus, when making a forward purchase, a buyer must necessarily ask: how big is this premium?

To help answer this question, this article provides a readily implementable means for determining if a forward transaction is likely to be profitable from a buyer's (or seller's) perspective when compared to the spot market alternative. It demonstrates that the forward price for Mid-C contains a 5.4 percent risk premium, suggesting that forward-contract buyers are more risk-averse than sellers.■

Endnotes:

1. Asher Tishler, Irena Milstein and Chi-Keung Woo, *Capacity Commitment and Price Volatility in a Competitive Electricity Market*, 30 Energy Econ. 1625–1647 (2008); Ying Li and Peter C. Flynn, *Electricity Deregulation, Spot Price Patterns and Demand-Side Management*, 31 Energy 908–922 (2006); Chi-Keung Woo, Ira Horowitz, Nate Toyama, Arne Olson, Aaron Lai and Raymond Wan, *Fundamental Drivers of Electricity Prices in the Pacific Northwest*, 5 Advances in Quantitative Anal. of Fin. & Acctg. 299–323 (2007).

2. Chi-Keung Woo, Debra Lloyd D and Asher Tishler, *Electricity Market Reform Failures: UK, Norway, Alberta and California*, 31 Energy Policy 1103–1115 (2003); Chi-Keung Woo, Michael King, Asher Tishler and Larry C.H. Chow, *Costs of Electricity Deregulation*, 31 Energy 747–768 (2006).

3. Chi-Keung Woo, Ira Horowitz and Khoa Hoang, *Cross Hedging and Forward-Contract Pricing of Electricity*, 23 Energy Econ. 1–15 (2001).

4. Shijie Deng and Shmuel S. Oren, *Electricity Derivatives and Risk Management*, 31 Energy 940–953 (2006); Frank A. Wolak, *An Empirical Analysis of the Impact of Hedge Contracts on Bidding Behavior in a Competitive Electricity Market*, 14 Int'l. Econ. J. 1–39 (2000).

5. Ronald W. Anderson and Jean-Pierre Danthine, *Cross Hedging*, 89 J. Political Econ. 1182–1196 (1981).

6. For a description of the Mid-C market, see Woo, Horowitz, *et al., supra note* 1.

7. Hendrik Bessembinder and Michael L. Lemmon, *Equilibrium Pricing and Optimal Hedging in Electricity Forward Markets*, 57 J. Finance 1347–1382 (2002); Francis A. Longstaff and Ashley W. Wang, *Electricity Forward Prices: A High-Frequency Empirical Analysis*, 59 J. Finance 1877–1900 (2004).

8. Sheng-Syan Chen, Cheng-Few Lee and Keshab Shrestha, *Futures Hedge Ratios: A Review*, 43 Q. Rev. Econ. & Finance 433–465 (2003).

9. Robert V. Hogg and Allen T. Craig, Introduction to Mathematical Statistics (Macmillan, 1970) at 182.

10. Chi-Keung Woo, Ira Horowitz and Khoa Hoang, *Cross Hedging and Value at Risk: Wholesale Electricity Forward Contracts*, 8 Advances in Investment Analysis & Portfolio Mgmt. 283–301 (2001).

11. The test is implemented through the AUTOREG procedure of SAS, which automatically determines the optimal number of lags.

12. Russell Davidson and James G. MacKinnon, Estimation and Inference in Econometrics (Oxford Univ. Press, 1993) at 669.

Artwork Omitted

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