Implied Market Heat Rate and Electric Cost Overcharge in 2018

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Overview of Analysis

- Objective – Perform two analyses:
  - Assess market efficiency before and after the Aliso event and pipeline outages using the implied market heat rate (IMHR) approach.
  - Estimate excess electricity costs caused by the Aliso event and pipeline outages.
- Staff concluded that the increase in market inefficiency (IMHR) in 2018 can be explained by the volatility and higher price of natural gas at SoCal Citygate, related to pipeline outages that occurred while there was still lack of storage at Aliso, and not one or the other conditions in isolation.
- Staff estimated that electric customers paid about $916 million excess in costs in 2018 due to outages on pipelines and the Aliso event.

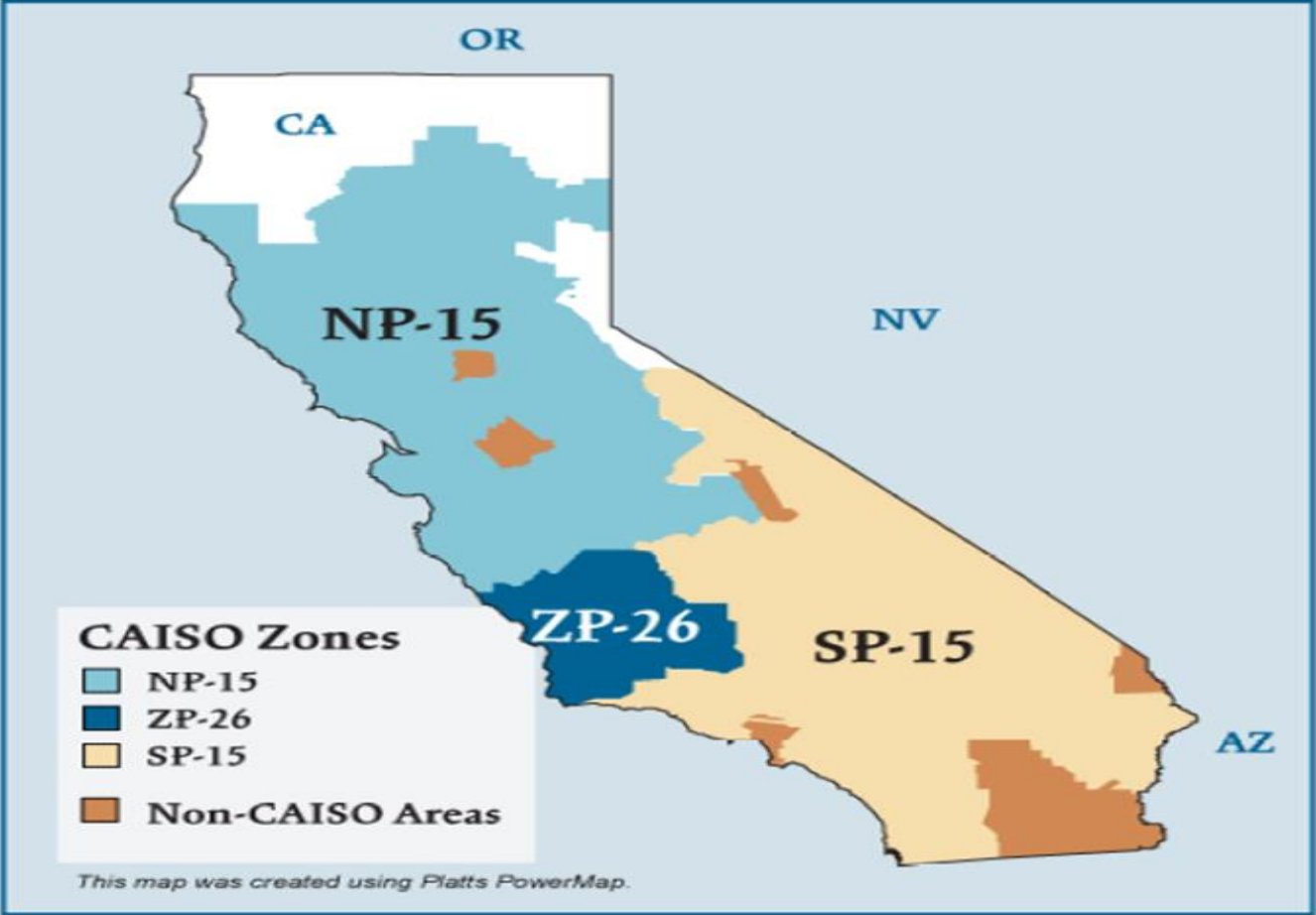# Part 1 - Implied Market Heat Rate (IMHR) Assessment of Market Efficiency

- Staff calculated IMHR for both the northern (NP15) and southern (SP15) sections of CAISO as described in the Final Scenarios Framework.

- IMHR is used to estimate market efficiency by comparing actual electricity prices in the market to the estimated heat rate (amount of fuel burned to generate one MWh of electricity) that electricity price would equate to. A lower IMHR means a more efficient market, and a higher IMHR translates to a less efficient market.

- Staff calculated IMHR during peak hours of the day, Hour Ending 6 am to Hour Ending 10 pm every day except Sunday.

Calculation:

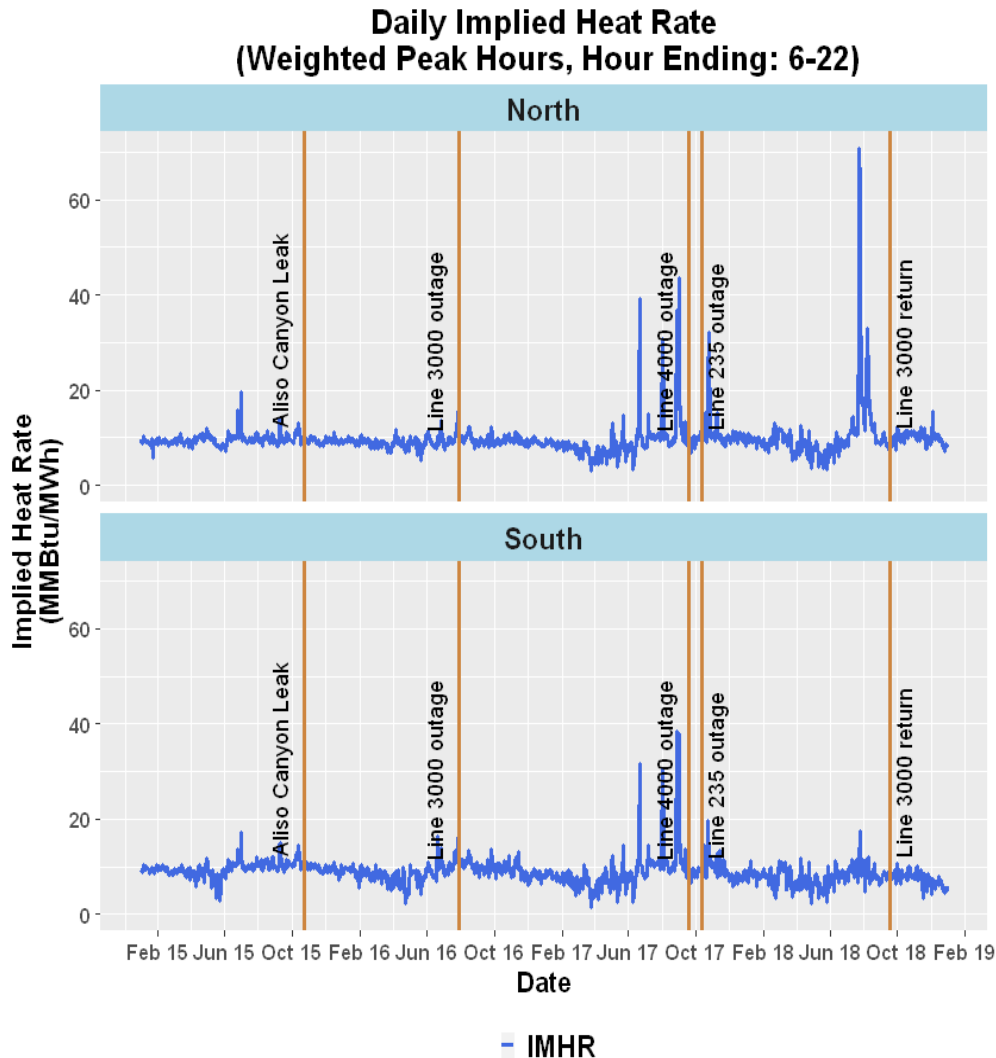$$NP15\ IMHR = \frac{Weighted\ day\ ahead\ hourly\ NP15\ price}{Daily\ PG\&E\ Citygate\ price}$$

$$SP15\ IMHR = \frac{Weighted\ day\ ahead\ hourly\ SP15\ price}{Daily\ SoCal\ Citygate\ price}$$

Map of CAISO Electricity Price Zones

https://www.ferc.gov/market-oversight/mkt-electric/california/2012/02-2012-elec-ca-archive.pdf

Low IMHR in SP15, High IMHR in NP15 in 2018

Daily Implied Heat Rate
(Weighted Peak Hours, Hour Ending: 6-22)

- Stable and low IMHR and correlation between IMHR in NP15 and SP15 is consistent until mid 2017.

- Significant increase in IMHR in NP15 when SoCal Citygate price starts to increase beyond its historical range.

- The large spikes in IMHR before Line 4000 and Line 235 outage are likely due to high electricity use and demand; IMHR is symmetrical in NP15 and SP15 until late 2017.

- Electric prices are the same across CAISO. High IMHR in NP15 is due to low gas prices and higher than normal electric prices in NP15. Gas prices increase after Line 4000 and 235 outages.

Mean and Standard Deviation of Daily IMHR – electricity prices are adjusted for the GHG cost component of the LMP

Year	Mean_NP15	StdDev_NP15	Mean_SP15	StdDev_SP15
2015	9.7	1.3	9.7	1.5
2016	9.3	1.2	9.1	1.9
2017	9.7	4.7	9.1	4.1
2018	10.4	5.9	7.8	1.9

# SoCal Citygate Price Drives Rise in IMHR in NP15

Implied Heat Rate
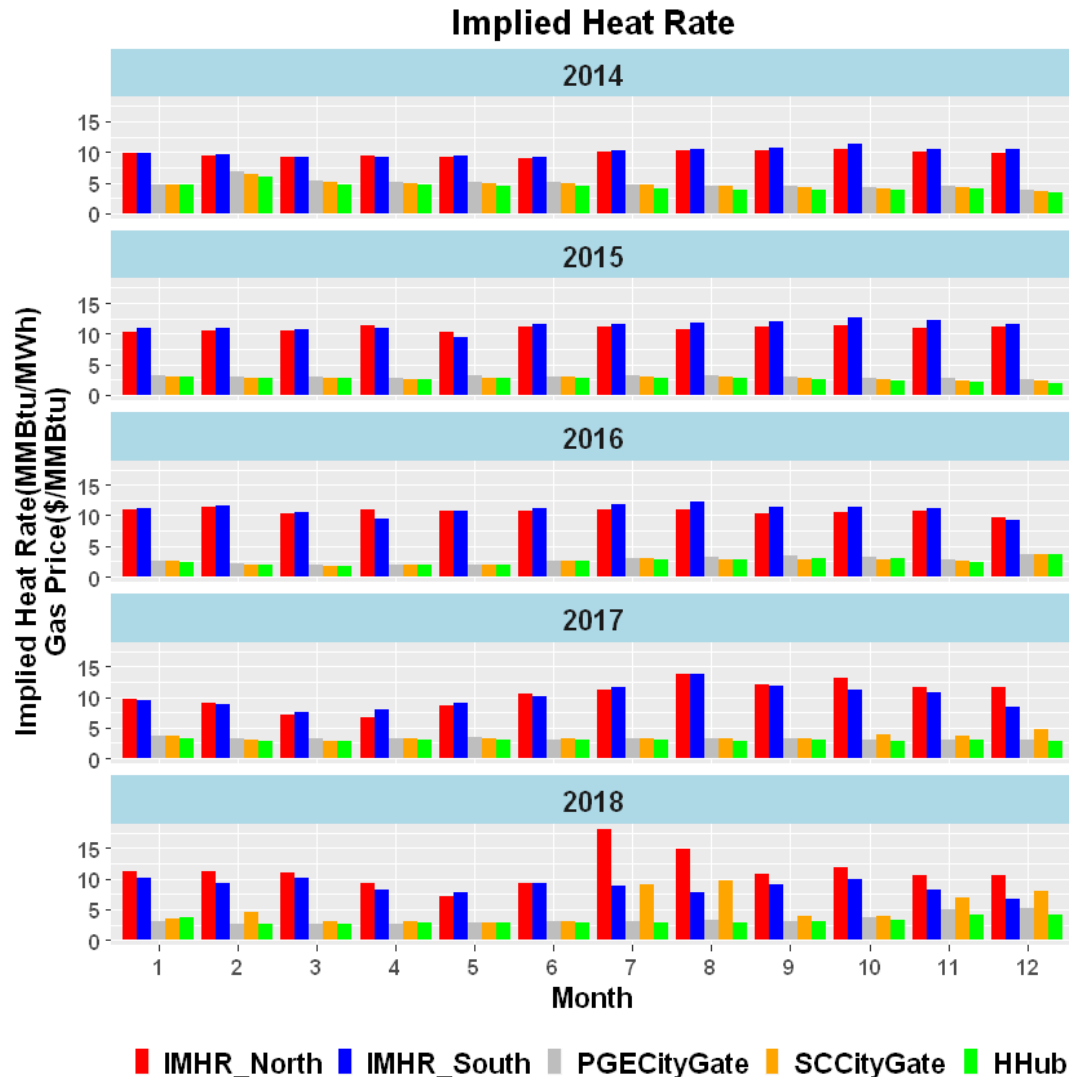
- IMHR increased in NP15 when SoCal Citygate prices increased relative to PG&E Citygate. This increase was significant in August and July 2018.

- IMHR in NP15 increases when SoCal Citygate prices increases.

- Gas prices in SoCal Citygate is a major contributor to IMHR.

- Gas prices in SoCal Citygate have higher impact on hourly IMHR.

Increase in IMHR is highest in a small number of hours (Top 100 hours of year)

- IMHR in each year, 2014-2018, ranked from highest IMHR to lowest – all years show stable and low IMHR until 2017 and 2018.

- IMHR increases substantially in 2017 and 2018 despite other significant factors that drive electric prices lower, such as increased renewable generation, more hydro generation, and transitioning to more efficient thermal generation.

- High IMHR in top 100 hours of 2018 correspond to higher price of natural gas at SoCal Citygate and the embedded gas price effects of expected OFO penalties on the SoCal system.
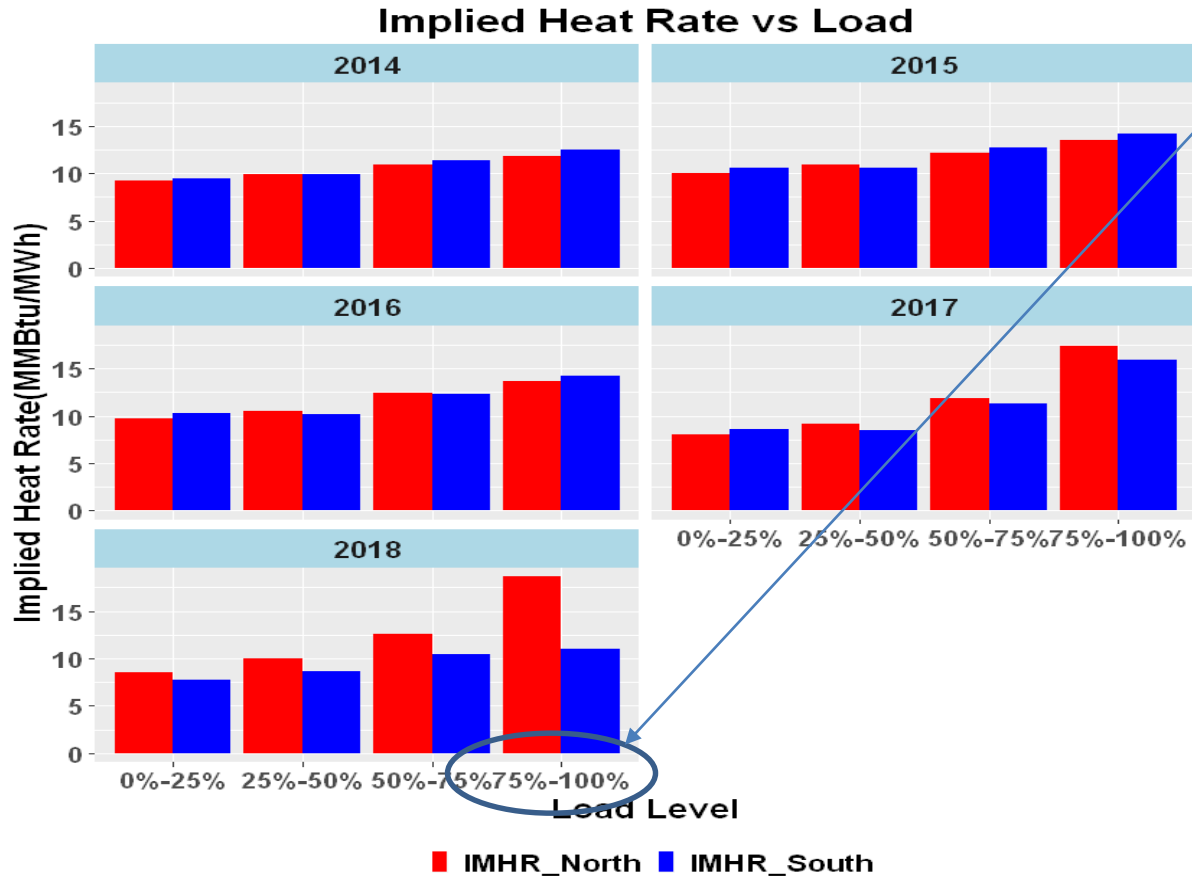

Duration Implied Heat Rate Curve

Hours with highest IMHR in 2017 and 2018
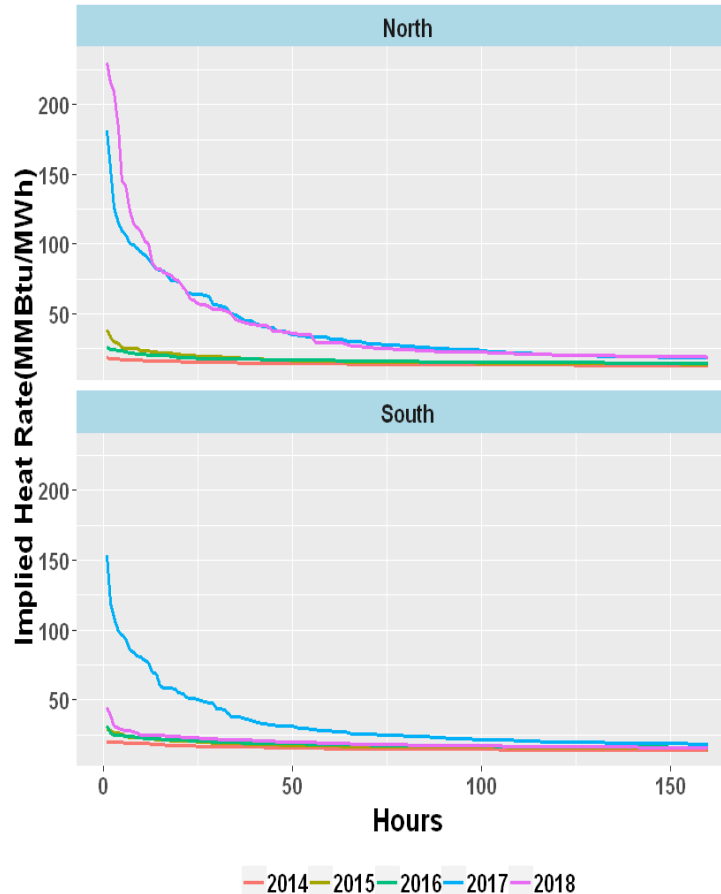
Date	Hour	IMHR NP15
7/24/2018	20	230.2
7/24/2018	19	215.7
7/25/2018	20	209.6
7/25/2018	19	182.5
9/1/2017	19	181.0

Date	Hour	IMHR SP15
7/9/2017	19	153.2
6/21/2017	20	119.9
8/28/2017	19	108.5
8/28/2017	20	98.9
9/1/2017	20	96.3

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IMHR increase in highest quartile of electric demand

Implied Heat Rate vs Load

Y-axis: Implied Heat Rate(MMBtu/MWh)
X-axis: Load Level (0%-25%, 25%-50%, 50%-75%, 75%-100%)

Panels: 2014, 2015, 2016, 2017, 2018

Legend: ■ IMHR_North ■ IMHR_South

- Gas generation is marginal, particularly at high demand.

- Normally IMHR is expected to increase at high demand (75%-100% quartile) but effect is much more pronounced in 2018.

- Normally IMHR is higher in SP15, but after 2017 NP15 IMHR is higher.

- IMHR increases even as overall demand and generation decreases and renewable energy increases in penetration.

Increase in IMHR even though decrease in overall generation and demand from 2014-2018 (MWh)

Year	Gen_NP15	Load_NP15	Gen_SP15	Load_SP15
2014	62,685,609	66,090,217	52,834,786	83,144,559
2015	62,953,130	66,388,093	55,683,578	82,102,337
2016	60,101,115	65,593,854	47,802,058	81,861,354
2017	60,893,390	64,808,895	51,170,408	82,539,875
2018	59,279,306	61,964,336	47,435,718	81,229,788

- This data is total across all peak hours (HE 6 to HE 22 all days except Sunday)
- In 2018, NP15 electric demand decreased while the electric generation remained roughly the same when gas generation is on the margin.
- In SP15, the electric demand remained roughly the same but the generation decreased (not all the generation is necessarily from gas).
- Ratio of generation to electricity demand is lower in NP15 – higher overall electricity clearing prices driving lower market efficiency, not necessarily operating less efficient power plants.

Key points from the IMHR Analysis

- Staff used IMHR analysis to assess implied market efficiency in NP15 and SP15.

- The IMHR is higher in NP15 compared with SP15 especially after outage to Line 4000 and 235 in October 2017.

- Significant increase in implied market inefficiency in NP15 compared to SP15 in 2018 even with the decrease of electric demand and overall generation in 2018.

Conclusions –

- Staff concluded that the increase in market inefficiency (IMHR) in 2018 can be explained by the volatility and higher price of natural gas at SoCal Citygate, related to pipeline outages that occurred while there was still lack of storage at Aliso, and not one or the other conditions in isolation.

- Also, in times of high gas use/ gas scarcity, electric generators can price in the expectation of OFO penalties into their electric generation bids **even when OFOs are not called**.

Part 2 - Electricity Cost Analysis in SP15 and NP15

- Staff estimated the total excess cost customers paid for electricity in the SP15 and NP15 regions of the CAISO.
  - For SP15 area, staff used regression to estimate SoCal Citygate price in the absence of Aliso incident and pipelines outages then estimate total excess cost for electricity with gas prices and the heat rate.
  - For NP15 area, staff used regression analysis to predict the electricity prices in the absence of Aliso incident and pipelines outages then use spark spread analysis to estimate total excess cost for electricity.
  - Spark spread is defined as the difference between the revenue received for selling power and the cost of gas used to generate power i.e. the cost per MWh.

- Two different analyses were used to quantify two different dynamics.
  - NP15 had low gas prices (from PG&E Citygate) and high electricity prices (from CAISO clearing market). Counterfactual was electricity prices
  - SP15 had high gas and high electricity prices. Counterfactual was the gas price.

Regression Analysis Overview

- Regression analysis seeks to describe the impact of one or more independent explanatory variables on the dependent variable.

- A regression model can be Linear or Non-Linear.

- Regression can be used for prediction like we did in this analysis, or forecasting and causality quantification.

- Staff took the following regression modeling steps: estimation of unknown parameters, fitted model evaluation and use of the model for prediction.

- R^2 is a measure of how well the model explains the interaction between the variables.

- According to the definition of R^2, adding extra explanatory variables will inflate the R^2.

- In order to not overestimate the effect of the extra variables, we consider the adjusted R^2.

SP15 Estimating Excess Costs for Electricity

- Staff used regression analysis to quantify the relationship of Henry Hub and SoCal Citygate prices before the Aliso event (fitted model with 2010-2015 historical data).

- Staff applied regression to calculate gas prices after Aliso event (2016-2018).

SP15 Estimate of Excess Electricity Cost due to High SoCal Citygate Prices

- Staff used regression analysis to predict SoCal Citygate gas prices from 2010-2015 historical trend ($/MMBtu) then predict prices for 2016-2018.

- From analysis of trends before the Aliso event, staff discovered that SoCal Citygate prices trended closely with Henry Hub prices (Better than Permian and San Juan Basins).

- The heat rate assumed to be 8 MMBtu/MWh, which is a reasonable number based on the settlement data and based on CEC table: QFER CEC-1304 Power Plant Data Reporting 1.

- Calculate electricity prices by multiplying actual gas prices by the assumed heat rate and total actual generation from thermal electric plants (based on CAISO settlement data).

Example of the calculation

- Assume the actual gas price is $4/MMBtu and the predicted prices is $3/MMBtu.

- Electricity cost $(\frac{\$32}{MWh})$= Gas Price $(\frac{\$4}{MMBtu})$* Heat Rate $(\frac{8\ MMBtu}{MWh})$

- Electricity cost $(\frac{\$24}{MWh})$= Gas Price $(\frac{\$3}{MMBtu})$* Heat Rate $(\frac{8\ MMBtu}{MWh})$

- The excess $ paid per MWh is: $32-$24 = $8/MWh

- The Total excess $ paid is $8 for each MWh of total generation by gas-fired power plants.

SP15 Regression results in good prediction of SoCal CityGate price from Henry Hub price

- SoCal Citygate = $\beta 0 + \beta 1 *$ Henry Hub + Error Term

Coefficients:

     Estimate Std. Error t value Pr(>|t|)

(Intercept) 0.442317 0.024100 18.35 <2e-16 ***

HH   0.924572 0.006464 143.03 <2e-16 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.2659 on 2185 degrees of freedom

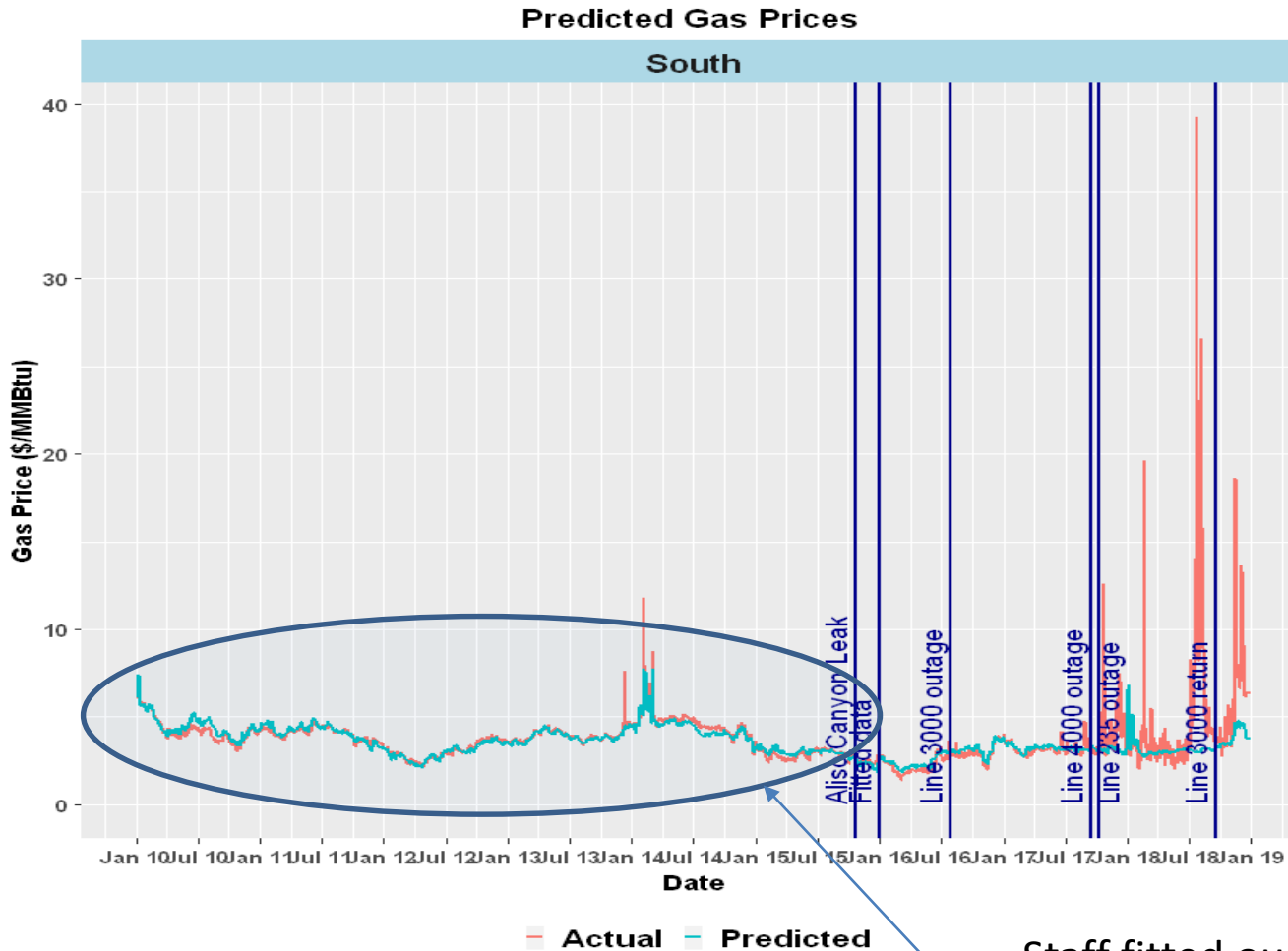Multiple **R-squared: 0.9035,   Adjusted R-squared: 0.9035**

F-statistic: 2.046e+04 on 1 and 2185 DF, p-value: < 2.2e-16

One dollar change in Henry Hub price makes about 93 cents change to SoCal Citygate Price.

The **p-value** tests the null hypothesis that there is no relationship between the Henry Hub price and SoCal Citygate price. A low **p-value** indicates that you can reject the null hypothesis.

Henry Hub explains 90% of the variation in SoCal Citygate price.

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SP15 Predicted Gas Prices vs Historical Gas Prices

Predicted Gas Prices

South

Gas Price ($/MMBtu)

Alis Canyon Leak Fitted data

Line 3000 outage

Line 4000 outage

Line 235 outage

Line 3000 return

Actual — Predicted

- Predicted SoCal Citygate prices were very different than historical prices after Line 235 outage.

Staff fitted our model with 2010-2015 gas price data, then applied that prediction to 2016-2018 data.

SP15 Total Monthly Electricity Cost
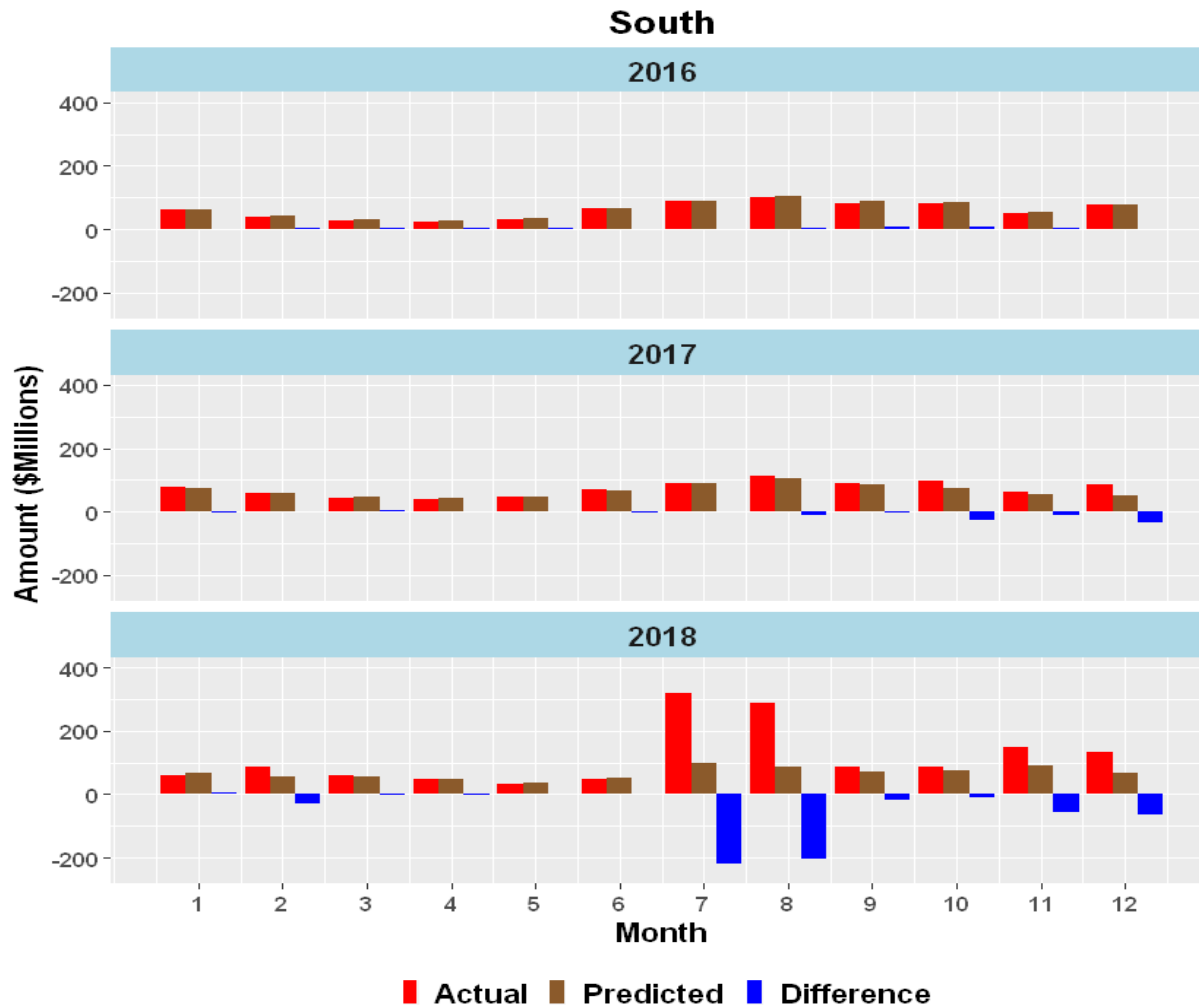
- After Line 235 outage in October 2017, the difference between predicted and actual electricity cost starts to become significant.

SP15 Annual Total Electricity Cost ($)

Year	Actual_SP15	Predicted_SP15	Estimated Excess Cost
2016	$728,834,671	$769,304,598	-$40,469,928
2017	$878,319,298	$802,260,110	$76,059,188
2018	$1,399,384,680	$800,536,934	$598,847,746

- Thermal generation estimates include CC, CT, Cogen, ICE and Steam power plants.
- Caveat: this calculation is likely an underestimate of the excess dollar amount paid by the electric rate payers in the south since it doesn't account for any increase in imported power caused by gas curtailments or other electric costs other than gas prices.

NP15 - Use Spark Spreads to calculate the excess electricity cost in NP15

- Spark spread is defined as the difference between the revenue received for selling power and the cost of gas used to generate power i.e. the cost per MWh.

- Spread $(\frac{\$}{MWh})$= LMP $(\frac{\$}{MWH})$ – Gas Price $(\frac{\$}{MMBtu})$* Heat Rate $(\frac{MMBtu}{MWh})$

- The spread is a measure of the approximate difference between revenues and marginal costs and is an indicator of profitability.

- The spread analysis assumes that the gas prices is the only marginal cost.

NP15 Spark Spreads-cont

- The spark spreads for NP15 use day-ahead electricity prices at NP15 and the gas price at PG&E Citygate.

- The predicted spark spreads use predicted energy price and gas prices at PG&E Citygate.

- The heat rate assumed to be 8 MMBtu/MWh, which is a reasonable number based on the settlement data and based on CEC table: QFER CEC-1304 Power Plant Data Reporting1.

NP15 Power Price Prediction Model

- Log(electric prices)= electric demand +log(Henry Hub)+ dummy (Mon)+ dummy(Tue)+ dummy(Wed) +dummy(Thu) + dummy(Fri) + dummy(Sat) +dummy(Jan) + dummy(Feb) + dummy(Mar) + dummy(Apr) + dummy(May)+dummy(Jun) + dummy(Jul)+ dummy(Aug) +dummy(Sep)+ dummy(Oct)+ dummy(Nov)+ error term

- Staff used the price for day-ahead at NP15.

- Can't include all months or all days of week – doing so would cause multicollinearity.

NP15 Electricity Price Regression Output

```
Coefficients:
                Estimate Std. Error t value Pr(>|t|)
(Intercept)    1.865e+00  5.937e-02   31.420  < 2e-16 ***
load           9.064e-05  5.592e-06   16.208  < 2e-16 ***
log_HH         7.081e-01  1.113e-02   63.621  < 2e-16 ***

Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.08019 on 710 degrees of freedom
Multiple R-squared:  0.8713,    Adjusted R-squared:  0.8679
F-statistic:   253 on 19 and 710 DF,  p-value: < 2.2e-16
```

If we change Henry Hub prices by one percent, we expect the electricity prices to change by 0.71%.

The **p-value** tests the null hypothesis that the coefficient has no effect. A low **p-value** indicates that we can reject the null hypothesis.

The included variables in the regression explain 87 percent of the variation in NP15 Citygate prices.

NP15 - Increase in Divergence – Predicted MWh price versus Historical MWh price
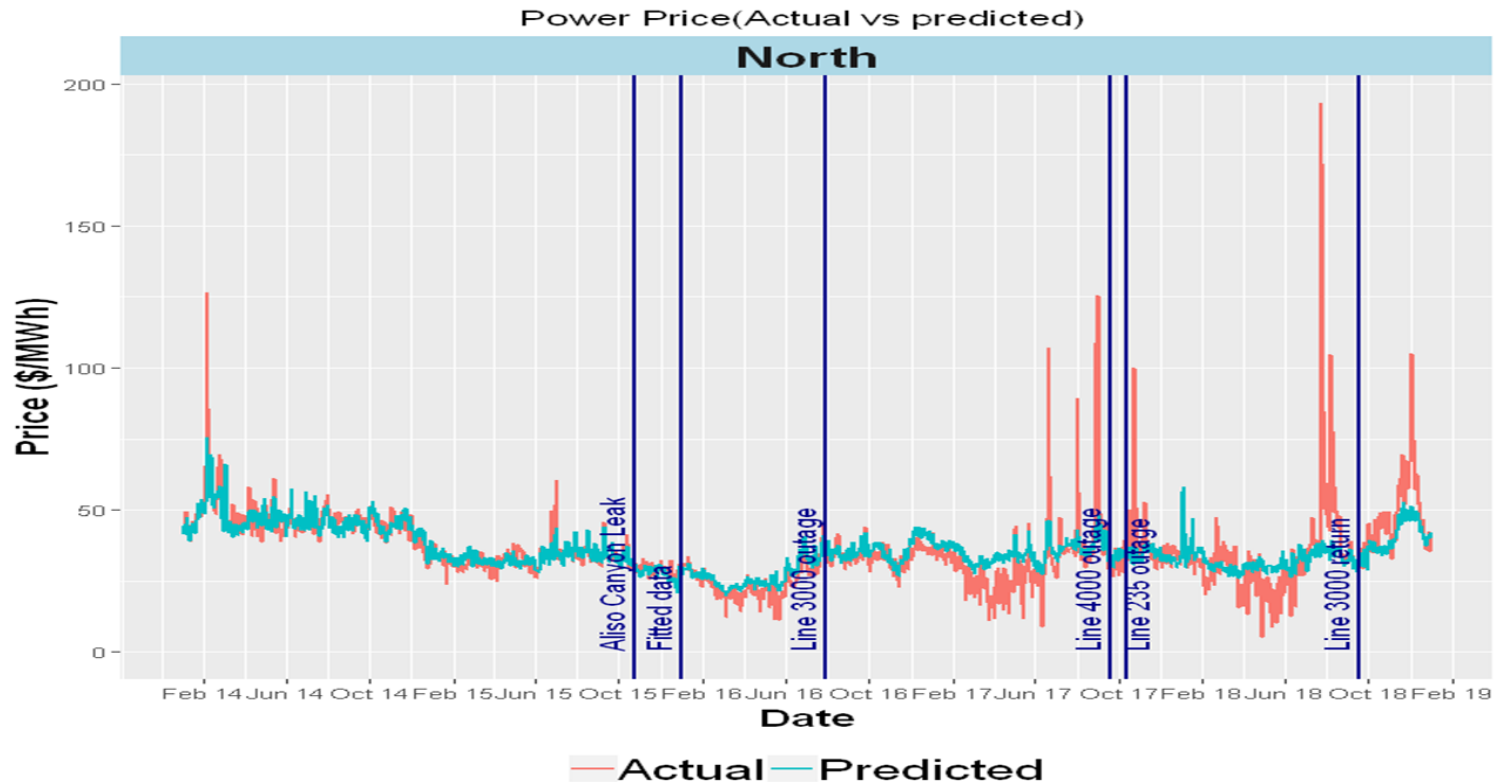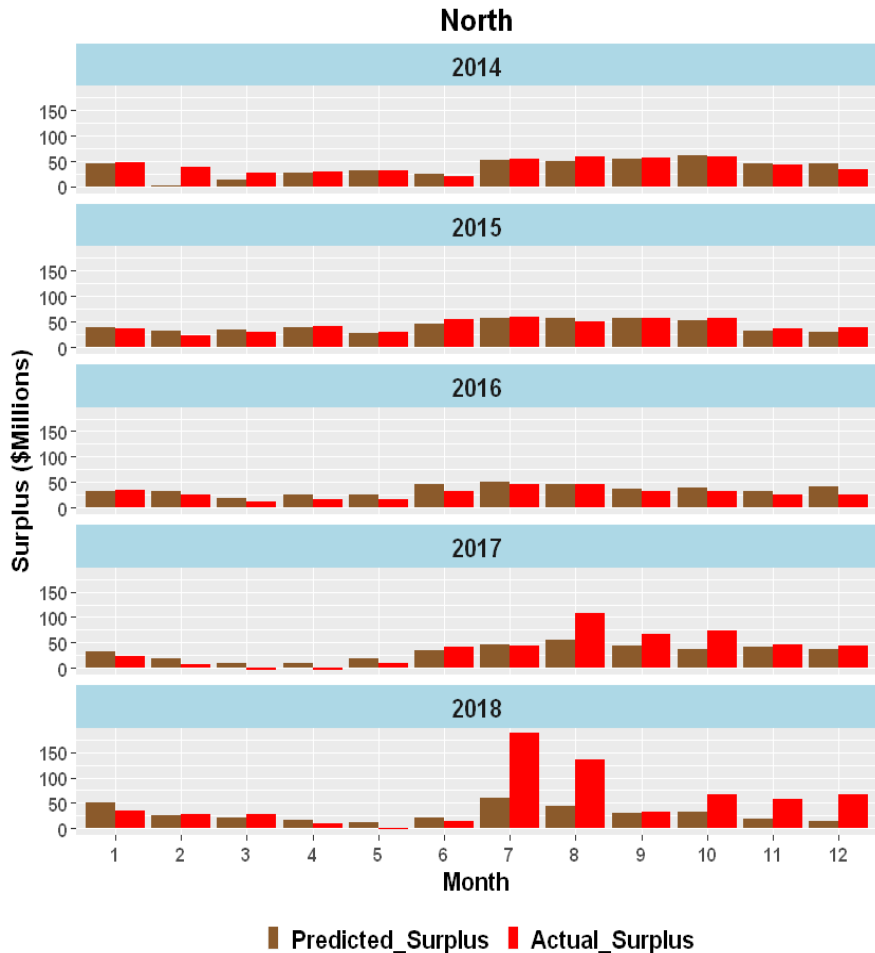

Prediction based on data from 2014 and 2015. Prediction becomes worse as renewable energy increases in penetration, there is more hydro generation, and as pipeline outages cause volatile gas prices.

NP15 Historical vs Predicted Spark Spread

Spark Spread for North
Actual vs Predicted
Heat Rate equal=8
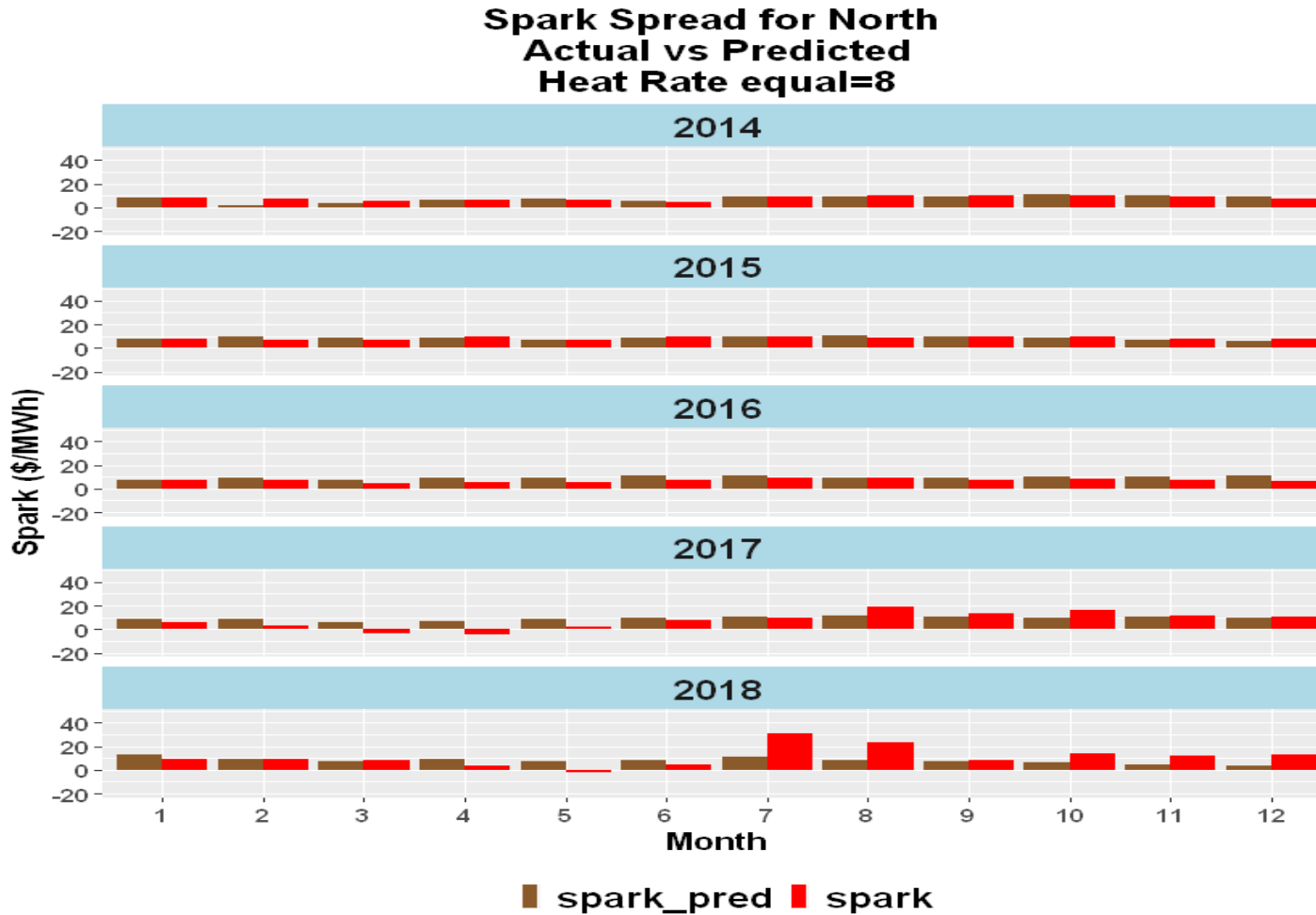
NP15 - Total Monthly Surplus Cost in $

- As illustrated in the previous slide , the gas prices in SoCal Citygate were trending similar to PG&E and Henry Hub until July 2017; the increase in the cost of electricity prior to these months was consistent with predictions, meaning heat waves and high electric demand.

- In October, November and December 2017 (after Line 235 outage), the gas prices rise and contribute to this increase.

- In 2018 the increase of excess electricity cost in NP15 was due to high gas prices of SoCal Citygate.

NP15 Annual Electricity Cost Predicted vs. Historical ($)

Year	Actual_Surplus	Predicted_Surplus	Excess Electricity Cost
2016	$346,527,375	$425,059,109	-$78,531,735
2017	$457,072,018	$382,084,780	$74,987,238
2018	$660,501,274	$343,471,435	$317,029,839

Key points from the Electricity Cost Analysis

- Staff predicted the gas prices for SoCal Citygate from 2016 to 2018.

- Staff calculated the electricity cost using the actual and predicted gas prices and heat rate of 8 MMBtu/MWh. SP15 and NP15 total electric cost was calculated from CAISO settlement data (historical hourly generation) from thermal generators.

- Electricity cost in SP15 begins to increase in October 2017, concurrent with the outage of Line 235. Staff estimated that electric customers paid about $599 million excess in costs in 2018 due to outages on pipelines and the Aliso event.

- This estimate does not include other electricity costs such as administration costs or purchases of imported electricity, so it is likely an underestimate.

- There were excess costs in NP15 also. Staff estimated overcharges based on PG&E Citygate prices compared to predicted electricity prices versus PG&E Citygate prices and actual electricity prices. Overcharges totaled about $317 million.

Wrap Up/Questions