Analysis of Forward Net Energy & Ancillary Services Offset Calculation Methods

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Purpose

This work assesses several methods for calculating a forward-looking Net Energy & Ancillary Services Offset (Net E&AS Offset). Methods encompass both traditional, simulation-based and novel, revenue-scaling approaches to incorporate forward-looking elements into the Net E&AS Offset revenue assumption.

Executive Summary

Historic methods for computing the revenue component of PJM's Net E&AS Offset were compared with alternatives that incorporate forward-looking elements – namely, forward electricity and fuel prices – into the calculation. Each method was assessed as follows:

- Results were benchmarked against those of simulations receiving actual delivery year inputs.
- Methods were executed across delivery years to develop an understanding of variance.
- Dispatch simulations were duplicated across two Reference Resource models to gauge each method's model sensitivity.

This assessment serves to illustrate the performance of these methods on various fronts and to inform ongoing discussions regarding a forward-looking energy and ancillary services revenue offset.

Background

The Net E&AS Offset is one of several components in PJM's Reliability Pricing Model (RPM). This study examines its role as an input in the Variable Resource Requirement (VRR) curve, which establishes demand expectations in the model's procurement process. VRR curve methodologies are re-examined periodically under the (formerly Triennial) Quadrennial Review process,[1] in which an outside consultant assesses RPM market design and recommends changes intended to maintain VRR curve integrity.

The Net E&AS Offset is designed to model net revenue that a "representative resource" would earn during its first year of commercial operation. A "representative resource" in this case is the Reference Resource, a fictitious generator with parameters characteristic of a typical market entrant at the time of the delivery year. Determinations of what is "characteristic" occur during the PJM Quadrennial Review – since 2010, the external consultant has posed, and PJM has implemented, at least three iterations of the Reference Resource:

- **Pre-2014 GE Frame Model 7FA CT** which was not explored in this report.
- **Post-2014 GE Frame Model 7FA CT** which was implemented following the 2014 Review.
- **GE Frame Model 7HA CT** which was approved following the 2018 Quadrennial Review.

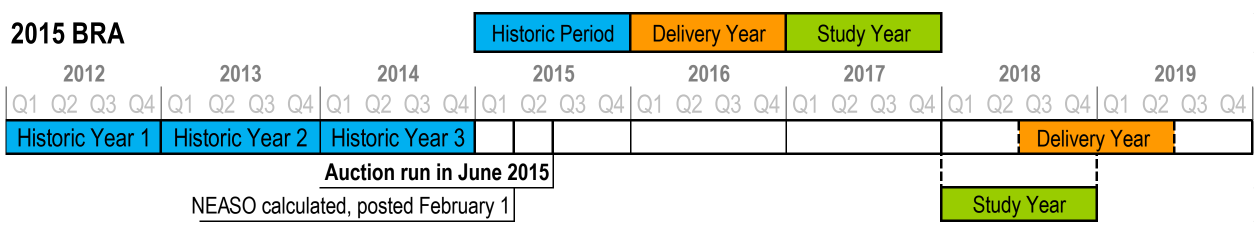
The latter two are captured in this study, from here on referenced as "7F" and "7H" models. Net revenues are all revenues earned in PJM wholesale energy and ancillary services markets (balancing/Real-Time, Day-Ahead and ancillary services), less the resource's production costs. This report focuses on energy market revenues, given the ancillary services revenues are administratively determined and set forth in the Tariff.

[1] Most recent QR report available on PJM website: https://www.pjm.com/-/media/library/reports-notices/special-reports/2018/20180420-pjm-2018-variable-resource-requirement-curve-study.ashx?la=en

Methods Overview

This report seeks to assess select "forward-looking" approaches by comparing various revenue calculation methods. Stakeholders and process advisors have suggested forward-looking methods in the past, expressing concern over the use of historic data to approximate delivery conditions three years in the future. An illustration of this gap in the timeline is provided in Figure 1.

Figure 1. Example Net E&AS Offset Calculation Timeline for 2015 Base Residual Auction



Visible here are foundations of the traditional "Status Quo" calculation method, which estimates revenues for each of the three Historic Years preceding an auction. These three historic revenue outputs are averaged and used to represent the revenue assumption for the Base Residual Auction (BRA). However, the offset's purpose is to model a theoretical resource's revenues generated during the *Delivery Year*[2], which is three years *following* the auction year. Note the use of "**Study Year"** in Figure 1.

Traditional Offsets in This Study

Only one traditional method was explored in this study: the status quo three-year historic calculation.

Status Quo Method (Historic Inputs, Three-Year Average)

Status quo represents the existing method, averaging the estimated historic annual revenues for each of the three-years prior to the auction. No forward contracts are used or incorporated in these values.

Forward-Looking Offsets in This Study

A variety of approaches exist by which a forward-looking Net E&AS Offset might be generated. The effort here captures two methods that incorporate forward elements (e.g., futures contract prices for LMP and fuel) into either the *input* (e.g., the Input Scalar Method) or the *output* (e.g., the Spark Spread Output Scaling Method) of PJM's existing Reference Resource CT dispatch simulation.

[2] For simplicity's sake "actual" revenues were calculated using inputs from the first *calendar year*, rather than the traditional 2Q–2Q *Delivery* Year (i.e., for the 2015 BRA, the calendar year 2018 was used instead of mid-year 2018 through mid-year 2019). Note **Figure 1** and its use of "Study Year" – this is assumed to be a proxy for "Delivery Year."

Forward contract prices are determined by market forces and, with sufficient liquidity, reflect current knowledge about the likely value of a future product; here, they serve as the primary tool for incorporating forward-looking elements into the revenue estimation. **Each forward-looking method was run using two sets of forward contract prices:**

- **Hub Forwards –** Forward prices from LMP and fuel contracts traded at the PJM Western and Henry Hub, respectively. For each BRA, a unique set of forwards was used. Trade dates in each case were set to May 1, or approximately one-month prior to the BRA. Both real-time and day-ahead, on-peak and off-peak LMP contracts were collected.
- **Synthetic Zonal Forwards –** Forward prices calculated by projecting Hub Forward prices to each of the 17 studied zones using LMP and fuel-basis differentials. Calculation of this set of forwards followed procedures outlined in the long-term methodology of PJM Manual 15.[3]

Duplicating methods with both inputs intends to address concerns about zonal granularity.

Input Scalar Method (Manual 15, Opportunity Cost Calculator)

The Input Scalar Method uses techniques inspired by the Manual 15 Opportunity Cost Calculator to scale otherwise historic inputs using factors derived from forward contract prices.

Hourly scaling factors are calculated using historic LMP and fuel prices over the three historic years. These scalars represent hourly (LMP) or daily (natural gas) price volatility against the monthly average. Once produced, scalars are applied to monthly forward prices to produce hourly (LMP) or daily (natural gas) prices, preserving historic price fluctuations while scaling the magnitude to levels projected by the forward contracts. These adjusted prices are used in the dispatch simulation to estimate energy revenues.

This method was executed twice, as described above. In the first iteration, the **Hub Input Scalar Method,** the creation of a basis differential[4] was bypassed, and hub contract prices were used directly when scaling forward price inputs. In the second iteration, the **Zonal Input Scalar Method,** zonal contract prices were generated by projecting hub contracts to zonal buses and used as dispatch simulation inputs.

[3] See Manual 15, 12.5 Long Term Methodology, 12.5.1 Step 1 through 12.5.5 Step 5 https://www.pjm.com/~/media/documents/manuals/m15.ashx

[4] Manual 15, 12.5.1 through 12.5.5.

Spark Ratio Output Scaling Method (2014 PJM Recommendation)

This method differs from the Input Scalar approach in that it uses forward prices to scale the Reference Resource dispatch simulation *output* in order to project future revenue. Here, outputs of the traditional Net E&AS Offset estimation are scaled using a ratio representing projected Resource performance. This scaling ratio compares a historic market-based spark ratio with a forward market-based spark ratio, illustrated below, to make its projection.

Historic spark ratios are generated using historic monthly Henry Hub natural gas prices and PJM Western Hub power prices. They are compared to future spark ratios, generated from monthly futures contracts for power and natural gas. This comparison creates the scaling ratio, which is applied to the traditional dispatch simulation (monthly) outputs as described.

$$\mathrm{HMHR} = \frac{Monthly\ On\text{-}Peak\ Average\ LMP}{Monthly\ Average\ Fuel}$$

$$\mathrm{FMHR} = \frac{Future\ Monthly\ On\text{-}Peak\ Average\ LMP}{Future\ Monthly\ Average\ Fuel}$$

$$\text{Forward E\&AS Offset} = \sum_{y=1}^{3}\left(\sum_{m=1}^{12}\left(\text{Historic E\&AS Offset}_{m,y} * \frac{\mathrm{FMHR}_{m,y}}{\mathrm{HMHR}_{m,y}}\right)\right)$$

Note that, as with the Input Scalar Method, this method was performed twice and produced two sets of revenues: **Hub Spark Ratio Output Scaling** and **Zonal Spark Ratio Output Scaling** revenues. There is no difference in the calculation between these runs, only in the prices used in FMHR calculation.

Benchmarking the Offset

For this study, benchmarking method performance involved comparing each methods' results to those produced by the Actual Revenue Method.

Actual Revenue Method

The Actual Revenue estimation was used as the benchmark for other methods explored. Actual Revenue results represent a scenario in which PJM has perfect insight into conditions during the Reference Resource's first delivery year. The method uses real input data (LMP, fuel prices, weather) from the first delivery year associated with each auction under investigation (2016, 2017, 2018) to approximate realistic energy market revenues – rather than relying on inputs reflecting or derivative of historic data.

Study Design and Assumptions

Methods of Net E&AS Offset calculation described above were compared as though they had been applied during the 2013, 2014 and 2015 BRA. Scenarios for both traditional and forward-looking offsets were executed as **in Table 1.**

Table 1. Basic Scenario Matrix

Method	Forward Prices Used
Status Quo	None
Spark Ratio Output Scaling	Hub
Spark Ratio Output Scaling	Synthetic Zonal
Input Scalar	Hub
Input Scalar	Synthetic Zonal
Actual Revenue	None

Each scenario was executed for both 7F and 7H CT technologies, for each studied BRA.

Dispatch Simulation Mechanics

No change was made to the mechanics of the dispatch simulation from method to method – only inputs and model parameters were adjusted per the scenarios described above. Each dispatch simulation computes daily revenue for various services and calculates an annual Net Revenue UCAP as follows:

$$Net\ Revenue_{RR} = Net\ Revenue_{DA} + Net\ Revenue_{RT} + Operating\ Reserves_{DA} + Operating\ Reserves_{RT}$$

$$\boldsymbol{Net\ Revenue\ UCAP} = \frac{Net\ Revenue_{RR} * (1 - EFORd)}{ICAP}$$

EFORd changes year to year in each BRA but does not differ between models.

Study Areas and Zonal Granularity

Dispatch simulations were run at a zonal level – each program executes simulations in a loop, running a CT model in each of the 17 areas under study. The 17 areas included:

Areas Under Study								
AECO	AEP	APS	BGE	COMED	DAY	DOM	DPL	RECO
DUQ	JCPL	METED	PECO	PENELEC	PEPCO	PPL	PSEG	-

Note that these study areas are a subset of areas currently active in PJM. The study restricted the zonal scope to areas with full historic data – excluding three areas integrated between the years 2010–2019 (i.e., DEOK, ATSI and EKPC). RTO-level revenue assumptions were drawn from zonal results by averaging zonal simulation outputs – impacts of this decision are discussed in **Assumptions**.

Assumptions Regarding an RTO Offset

One of the major assumptions taken that distinguishes this report's revenues from the revenue values used at the time of the auction has to do with how revenues are brought to the "RTO-level."

In current practice, inputs are averaged *prior* to the simulation and fed into a single RTO Reference Resource. In this report, the decision was made to instead operate Reference Resources zonally and average the 17 simulation outputs to produce RTO revenue. This difference makes a direct comparison between this report's "Status Quo" and published Net E&AS Offsets difficult, as illustrated below.

A comparison using publicly posted zonal and RTO offset values[5] capturing annual energy revenues used for each year from 2009–2015 is shown in **Table 2**. Posted RTO offsets use average inputs for the single simulation, and Average Posted Zonal offsets take an average of posted zonal outputs.

Table 2. Comparing RTO-level offsets (posted) versus average of zonal offsets (posted)

	2009	2010	2011	2012	2013	2014	2015
Posted RTO Offsets ($/Year)	$5,838	$24,756	$25,439	$20,049	$15,184	$41,217	$31,012
Average Posted Zonal Offsets ($/Year)	**$9,098**	**$33,283**	**$32,026**	**$23,895**	**$18,758**	**$55,839**	**$39,255**

Values produced by averaging zonal revenue outputs appear *consistently larger* (typically 29 percent greater) than those produced by averaging zonal price inputs. Applying this to the current study, the Status Quo Method (averaged outputs) shows similar divergence from posted offsets (averaged inputs). See **Table 3**.

Table 3. Each auction's posted RTO offset versus offsets generated during this project using Status Quo methods

	2013 BRA	2014 BRA	2015 BRA
Posted Auction RTO Offset	$23,415	$20,224	$25,484
Status Quo RTO Offset **7F**	$30,009	$25,348	$33,354
Status Quo RTO Offset **7H**	$24,935	$20,748	$26,613

The underlying cause of these differences could come from any number of sources – particularly the chosen model.[6] Ultimately this drives home the caveat that revenue offsets in this report should be examined only within the context of the report and not against values used in prior auctions.

[5] PJM RPM webpage found here; historic Net E&AS Offset spreadsheet downloadable here.
[6] Particularly given the 7H Status Quo Method outputs seem not to diverge from Posted outputs – despite using different approaches for translating zonal conditions to RTO conclusions.

Net Energy Revenue Results

Scenarios executed in this study produced the following results, presented **Figure 1** and **Figure 2** in terms of energy market revenue generated from Reference Resource UCAP MW.

7F Model

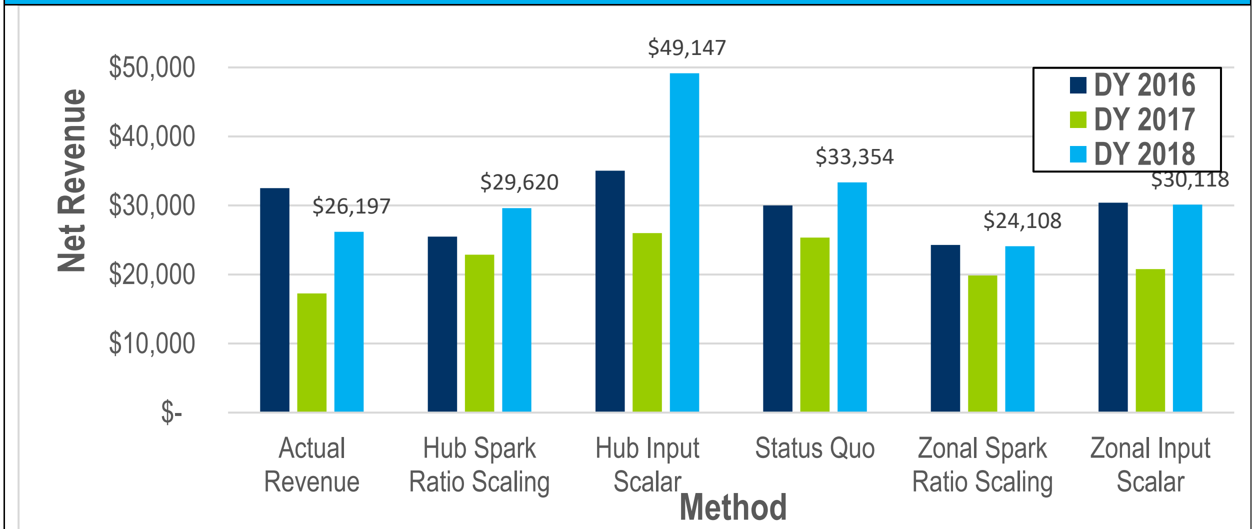


Figure 1. Revenues generated by 7F Reference Resources, by method and BRA

7H Model

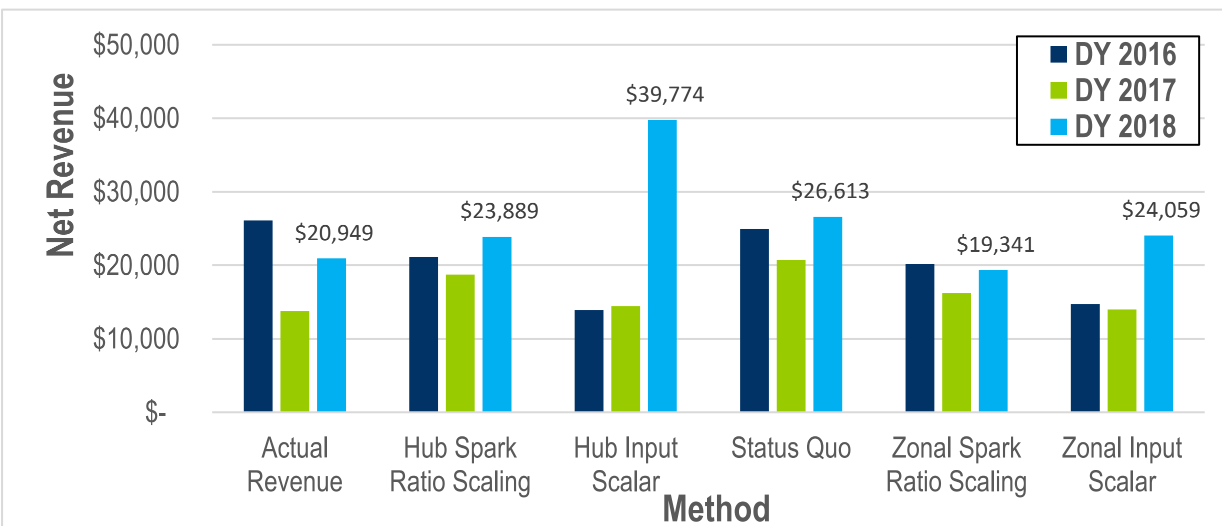


Figure 2. . Revenues generated by 7H Reference Resources, by method and BRA

Traditional and Forward-Looking Method Performance

Performance is assessed on three fronts:

- Results were benchmarked against those of dispatch simulations receiving actual delivery year inputs to assess similarity with “real” entry revenues.
- Methods were executed across delivery years to develop an understanding of year-over-year variation.
- Dispatch simulations were duplicated across two Reference Resource models to gauge each method’s model sensitivity.

1. Benchmarking to Actual Revenues

Examining net revenues produced for Delivery Years 2016, 2017 and 2018 provides insight into the general long-term performance of each simulation method. These summed net revenues are provided below, sorted by magnitude total net revenue:

Table 4. Long-term accuracy of offset calculation methods using the 7F Model

7F Model	
Method	Net Revenues, Summed Across 2016–2018 Delivery Years
Hub Input Scalar	$110,199.98
Status Quo	$88,710.98
Zonal Input Scalar	$81,322.02
Hub Spark Ratio Scaling	$77,980.50
Zonal Spark Ratio Scaling	$68,269.85
Actual Method	**$75,962.42**

Takeaways from **Table 4**:

- Using the 7F CT, the Hub Input Scalar Method produces the greatest revenue over three auctions.
- Hub Spark Ratio Output Scaling produces revenues nearest the Actual Revenues.

Table 5. Long-term accuracy of offset calculation methods using the 7H Model

7H Model	
Method	Net Revenues, Summed Across 2016–2018 Delivery Years
Status Quo	$72,296.33
Hub Input Scalar	$68,149.60
Hub Spark Ratio Scaling	$63,791.43
Zonal Spark Ratio Scaling	$55,739.21
Zonal Input Scalar	$52,777.48
Actual Revenue	**$60,854.47**

Takeaways from **Table 5**:

- It appears the Status Quo Method produced values most unlike the Actual Revenues.

- The unusual magnitude of Hub Input Scalar revenues seen in 7F long-term revenue is not seen when modeling with 7H.
- Hub Spark Ratio Output Scaling produces revenues nearest the Actual Revenues.
- All methods see a reduction in long-term revenues under this performance metric when implementing the 7H over 7F Model.

2. Revenue Volatility

Auction-to-auction output volatility was assessed by taking the range[7] of revenue results for each of the three study years. Range was selected as a proxy for variance, given the sample size of BRAs (n = 3) is too small to justify using standard deviation. Methods are sorted below by magnitude of variation.

Table 6. Range of revenues generated by each method, representing volatility (7F Model)

7F Model			
Method		**Revenue Range**	**Variation**
Hub Input Scalar	$	23,143.59	Most
Actual Revenue	**$**	**15,257.28**	
Zonal Input Scalar	$	9,619.29	
Status Quo	$	8,006.86	
Hub Spark Ratio Scaling	$	6,753.51	
Zonal Spark Ratio Scaling	$	4,432.73	Least

Takeaways from Error! Reference source not found.:

- Actual Revenue under 7F modeling shows significant volatility, greater than many alternative methods explored.
- Both Spark Ratio Output Scaling methods show low volatility.

Table 7. Range of revenues generated by each method, representing volatility (7H Model)

7H Model			
Method		**Revenue Range**	**Variation**
Hub Input Scalar	$	25,833.68	Most
Actual Revenue	**$**	**12,326.41**	
Zonal Input Scalar	$	10,069.96	
Status Quo	$	5,864.45	
Hub Spark Ratio Scaling	$	5,152.25	
Zonal Spark Ratio Scaling	$	3,935.04	Least

[7] Note that given a larger sample size of delivery years, the preferred metric for understanding variance would have been standard deviation. Range serves as a compromise in this study given the sample size of three years.

Takeaways from Error! Reference source not found.:

- The 7H Model produces a nearly identical ranking of greatest-to-least revenue variation, compared to 7F variation. Actual Revenue shows significant variation.
- It appears that under 7H modeling, the overall range of revenues produced increases ($23,000 to $4,400 versus $25,800 to $3,900).
- As with 7F results, 7H results show Spark Ratio Output Scaling as the least volatile methods.

3. Reference Resource Modeling Impacts

Comparing results by Reference Resource configuration highlights modeling's impact on revenues.

Comparisons by method of 7F and 7H results are provided in graphic and table formats below:

Figure 3. Method-to-method revenue differences across CT models (2016 DY)

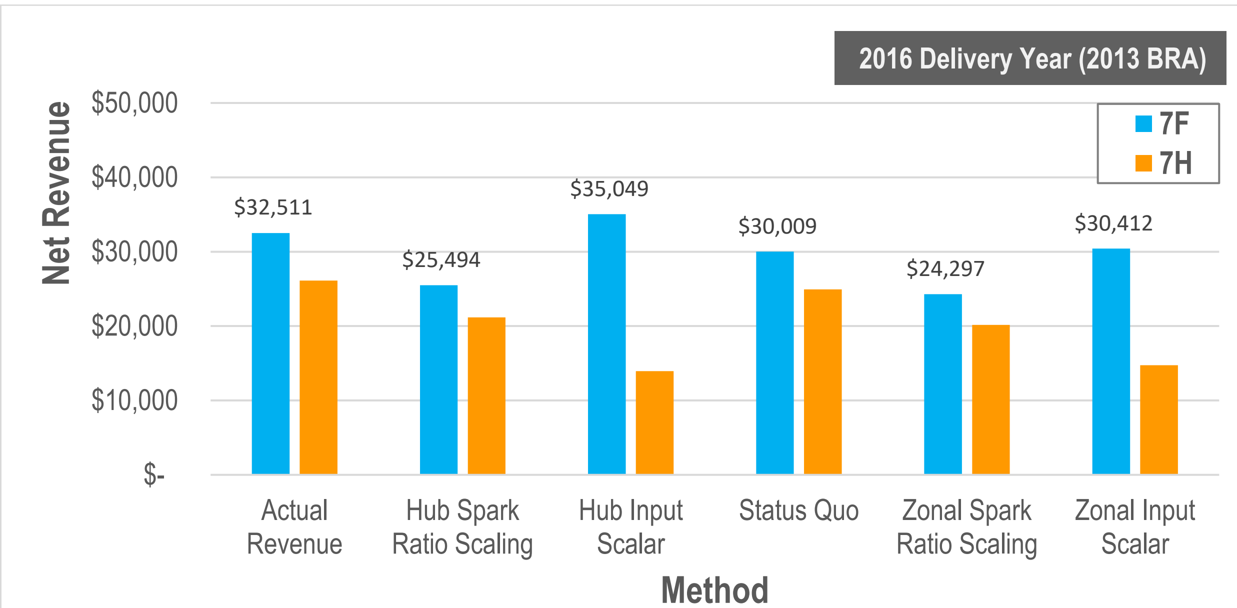


Figure 4. Method-to-method revenue differences across CT models (2017 DY)

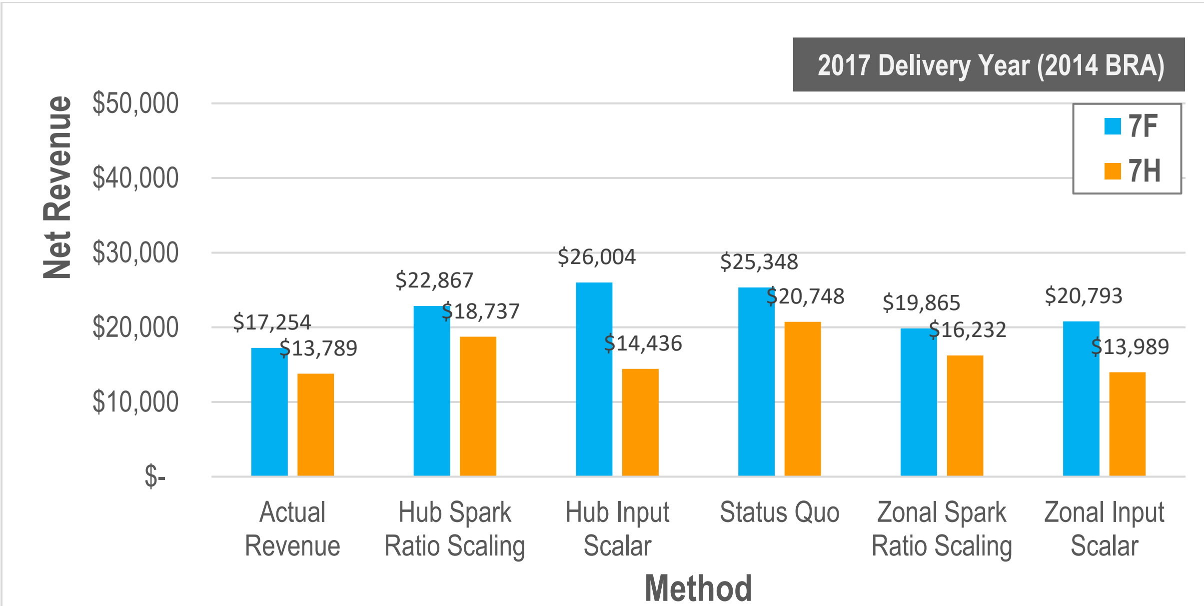
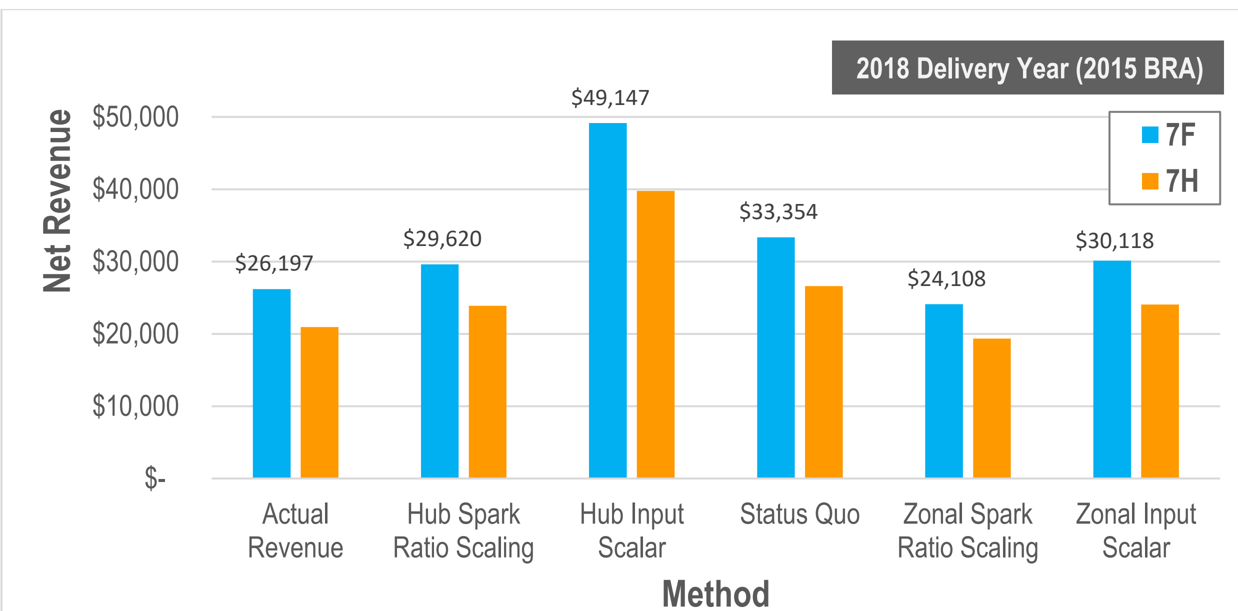


Figure 5. Method-to-method revenue differences across CT models (2018 DY)



Numbers underlying these graphs are provided in Error! Reference source not found., Error! Reference source not found. and Error! Reference source not found.. Differences between 7H and 7F values are called out in the final column of each.

Table 8. Delivery Year 2016 (2013 BRA) revenue differences between CT models

Delivery Year	Method	7F Model Offset UCAP	7H Model Offset UCAP	7H Offset Divergence from 7F Offset
2016	Hub Input Scalar	$35,049.29	$13,940.09	($21,109.20)
	Zonal Input Scalar	$30,411.80	$14,728.53	($15,683.27)
	Actual Revenue	**$32,511.34**	**$26,115.75**	**($6,395.59)**
	Status Quo	$30,008.97	$24,935.15	($5,073.81)
	Hub Spark Ratio Scaling	$25,493.91	$21,165.48	($4,328.44)
	Zonal Spark Ratio Scaling	$24,297.39	$20,166.78	($4,130.61)

Table 9. Delivery Year 2017 (2014 BRA) revenue differences between CT models

Delivery Year	Method	7F Model Offset UCAP	7H Model Offset UCAP	7H Offset Divergence from 7F Offset
2017	Hub Input Scalar	$26,003.55	$14,435.75	($11,567.80)
	Zonal Input Scalar	$20,792.51	$13,989.49	($6,803.02)
	Status Quo	$25,347.57	$20,748.36	($4,599.21)
	Hub Spark Ratio Scaling	$22,866.54	$18,736.85	($4,129.69)
	Zonal Spark Ratio Scaling	$19,864.66	$16,231.74	($3,632.92)
	Actual Revenue	**$17,254.06**	**$13,789.34**	**($3,464.72)**

Table 10. Delivery Year 2018 (2015 BRA) revenue differences between CT models

Delivery Year	Method	7F Model Offset UCAP	7H Model Offset UCAP	7H Offset Divergence from 7F Offset
2018	Hub Input Scalar	$49,147.14	$39,773.77	($9,373.37)
	Status Quo	$33,354.44	$26,612.82	($6,741.62)
	Zonal Input Scalar	$30,117.71	$24,059.46	($6,058.25)
	Hub Spark Ratio Scaling	$29,620.05	$23,889.10	($5,730.95)
	Actual Revenue	**$26,197.02**	**$20,949.39**	**($5,247.64)**
	Zonal Spark Ratio Scaling	$24,107.81	$19,340.69	($4,767.12)

Takeaways here include:

- As the delivery years progress, it appears that the divergence between the 7H and 7F models decreases.
- The Hub Input Scalar Method appears to be unusually impacted by this shift, in comparison to same-auction results for other methods.
- Zonal and Hub Spark Ratio Output Scaling seem to generate revenue in a manner that produces the least divergence between 7F and 7H models, consistently across delivery years.

These comparisons are indicative of the sensitivity of each method to CT parameter shifts (or, change in CT cost metrics – see the 7H cost adder).