PJM Price Forecast and Battery Project Revenue Analysis

Prepared for

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OVERVIEW

EDF Renewables is looking to construct a 20MW Battery Storage project in the PJM region utilizing BYD's lithium iron phosphate battery storage technology. The project will provide fast frequency regulation service in PJM's Performance Based Regulation (PBR) market. EDF Renewables is interested in understanding the expected revenue and pricing for their storage plant, as well as a comparison between using a 6 minute versus a 12 minute duration battery.

PJM PEFORMANCE BASED FREQUENCY REGULATION MARKET

FERC ORDER 755 BACKGROUND

On October 20, 2011, FERC issued Order No. 755 "Frequency Regulation Compensation in the Organized Wholesale Power Markets" which found that current regulation market tariffs failed to compensate faster-ramping resources for the inherently greater amount of frequency regulation service they provide to the grid. Thus, FERC mandated that each grid operator change its regulation tariffs to pay resources based on the actual amount of regulation service each resource provides to the grid, i.e. "pay-for-performance." Prior to Order 755, Regulation pricing in PJM had been based solely on the amount of MWs a resource offers to be on "standby" to respond to a regulation signal and did not base payments on how much the resource is actually deployed to provide the service or how well it responded to the dispatch signal.

Specifically, FERC mandated that each ISO/RTO regulation market implement a two-part bid/two-part payment compensation structure comprising of:

1) a **capacity (capability) payment** for the amount of MWs a resource sets aside to provide regulation, which must include the marginal resource's opportunity cost (the cost associated with providing regulation instead of energy or another service); and,
2) a **performance payment** based on the actual amount of movement a resource provides in response to the ISO's regulation signal (otherwise known as "mileage") taking into account the resource's accuracy in following the signal.

Accordingly, there are two major changes to PJM's regulation market to comply with FERC Order 755. First, PJM must now provide a performance payment based on the total amount of movement (the sum of regulation up and down) that a resource accurately provides in response to PJM's dispatch signal. Second, PJM now includes the marginal unit's opportunity cost in its capacity payment.

PJM ORDER 755 MARKET DESIGN

On October 1, 2012 PJM began implementation of its Performance-Based Regulation (PBR) market. In compliance with Order 755, PJM changed its market compensation structure from a single market clearing price and payment for regulation to the use of two clearing prices for regulation, the Regulation Market Capability Clearing Price (RMCCP) and the Regulation Market Performance Clearing Price (RMPCP), with these prices then being used to determine a two-part payment for

Regulation made up of the sum of the Regulation Capability Credit and the Regulation Performance Credit. Due to debate at FERC, the specific market settlement formulas for calculating the Regulation Capability Credit and the Regulation Performance Credit were not approved until October 2, 2013, a year after the new market went into place. Thus, payments for performance began on November 1, 2013 with retroactive payments to resources back to October 1, 2012. The specific settlement formulas are discussed further below.

OPERATIONAL CHANGES TO INCORPORATE FAST STORAGE

PJM made operational changes to better utilize fast storage resources, implementing a two-signal approach for dispatching regulation resources: 1) a slow regulation signal designed for traditional resources with limited ramping capability (RegA signal), and 2) a fast energy-neutral dynamic regulation signal designed for new fast-ramping regulation technologies, such as batteries, that can respond nearly instantaneously to system imbalances (RegD signal). The philosophy underlying the regulation signals is that the flexible, fast-ramping resources following the RegD signal should be utilized first to counteract sudden Area Control Error (ACE) movements and then slowly reset to a midpoint – where they are ready to correct the next ACE movement – as the slower resources respond and the fast-following resources reset. The RegD signal has approximately 3 times the movement than the RegA signal. PJM has found that the use of fast resources will enable PJM to decrease the total regulation requirements necessary to maintain reliability requirements. Procurement has decreased approximately 20% since the implementation of PBR.

MARKET CLEARING

Resources submit to PJM a two-part offer to provide regulation that includes a bid for regulation capability (e.g. capacity) and a bid for performance (e.g. movement). PJM then calculates a performance-adjusted cost for the resource by dividing the resource's capability offer, performance offer, and cross-product opportunity cost (if any) by the resource's historic performance score and its benefits factor to the system. The historic performance score measures how accurately the resource has historically followed the regulation signal based on the average of its most recent 100 hours of performance scores. The benefits factor reflects the benefit that a resource will provide to the system based on whether it follows the fast RegD signal or the slow RegA signal. Dividing a resource's offer by its historic performance score and its benefits factor enables PJM to evaluate offers based on their overall effectiveness to the system. The higher the historic performance score and benefits factor of a resource the more attractive and less costly per MW it will appear in the clearing process.

KEY COMPONENTS OF PRICING

BENEFITS FACTOR

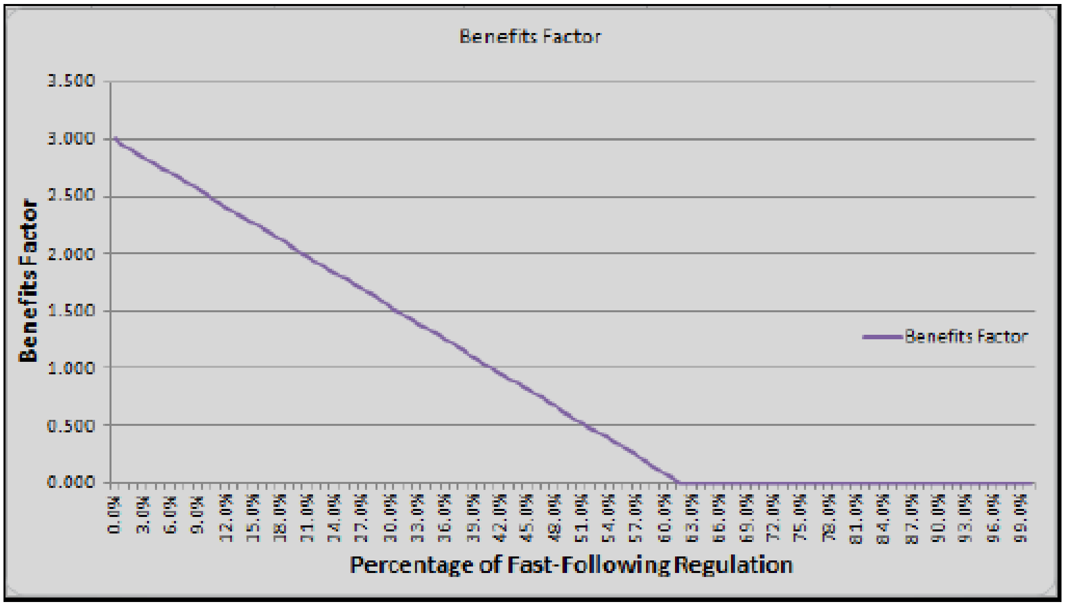
Since PJM is employing a two-signal approach for dispatching regulation resources, PJM needs a method for determining the substitution rate between resources following each signal in the market clearing process. Given that the operational characteristics of the RegA signal and the RegD signal complement one another there is an operational relationship between the percentage of resources following the two signals and how the regulation requirement is satisfied. This relationship is reflected in the market design as the benefits factor, where the benefits factor measures the amount of benefit a fast resource following the RegD signal will provide to the system as compared to the same amount of MW capacity from a slow resource following the RegA signal.

PJM conducted a study that demonstrated that the use of fast-storage resources, in conjunction with traditional resources, provided more accurate control of ACE, which will allow PJM to maintain similar reliability scores while reducing the total amount of regulation capacity required. Therefore the benefits factor is designed to reflect that a faster moving resource will provide more response to ACE for the same amount of regulating capacity and reflects the rate of substitution between resources following the two signals as the penetration of fast resources in the market increases. It represents the benefit to system control that a fast resource provides for the same megawatt capability as a traditional slow resource.

However, given that the fast signal is designed to be energy neutral and thus cannot in itself manage long durations in ACE imbalance without utilizing the traditional signal, the rate of substitution between the two signals changes as the penetration of resources following the fast signal increases. Thus, the first megawatt of resources following the fast signal provides more benefit than the second megawatt and eventually the rate of benefit decreases incrementally as more fast-following regulation resources are utilized in the PJM market. Consequently, at some percentage penetration of resources following the Reg D signal, an additional megawatt of a RegD resource and a megawatt of RegA resource will have the equivalent impact on system control and, therefore, dispatching another RegD resource has no greater benefit than using traditional regulation. The objective of the benefits factor in market clearing is to encourage the optimal selection of resources following the RegD and RegA signal.

The benefits factor curve allows PJM to translate each RegD resource into equivalent RegA megawatts. The graph below shows the benefits factor curve for resources following the fast RegD signal. The benefits factor ranges from 2.9 to 0 for fast resources. When 43% of the regulation resources are RegD the benefits factor is 1.0 which is the point when a fast RegD resource is equivalent to a RegA resource. The benefits factor curve for resources following the RegA signal is always 1.0.

Figure 1: PJM Benefits Factor Curve for Fast-following Resources



In market clearing, each resource following the RegD signal will be assigned a decreasing and unique benefits factor. The benefits factor of the offered resource, or resource specific benefits factor, is the marginal point on the benefits factor curve that aligns with the last MW that specific resource will add to the RegD resource stack. With more fast resources entering the market over time the average benefits factor used in clearing will go down.

PERFORMANCE SCORE

In market clearing PJM uses the average of the resources previous 100 hours of performance scores for its historic performance score.

PJM calculates an hourly performance score which reflects a regulation resource's accuracy in increasing or decreasing its output to provide frequency regulation service in response to PJM's dispatch signal. The performance score is used in both the market clearing and settlement. The three component score is based on the following:

1. Correlation Score: The statistical correlation between the regulation signal and a specific resource's response;
2. Delay Score: The point in time where there is maximum correlation between the regulation signal and the resource's response. For traditional resources, there is a delay on the order of minutes between when the regulation signal is sent by PJM to when a response can be seen in the output. Historically, the average hydroelectric resource operates with a one minute delay, while the average fossil resource operates with a two to three minute delay. New energy storage technologies, such as batteries, can typically provide signal matching in seconds; and,
3. Precision Score: A function of the difference in the energy provided versus the energy requested by the regulation signal. It is the "Area under the Curve" of error between the signal and the response.

For each 10 second set of calculations the performance score will be averaged over a five minute period. PJM will determine a composite Performance Score per resource as a unit-less scalar ranging from 0 to 1. The Performance Score will be a weighted average of the performance score components, with each of the component scalars being weighted equally with each at one-third (1/3).

Batteries are expected to have high performance scores in the 92% - 98% range. Technology characteristics, including ramp-rate, power rating, energy duration, and round trip efficiency, will influence a particular battery's performance score. For example, because the RegD signal is energy neutral, the more efficient a storage system is the more capable it will be in following the signal which will result in a higher performance score. Batteries can employ state-of-charge management techniques to optimize their performance score.

RMCCP AND RMPCP

The following are the clearing price formulas used to determine each resource's offer and ultimately set the RMCCP and RMPCP for each market hour. These formulas can be found in PJM Manual 11: Energy & Ancillary Services Market Operations, Section 3.2.7 Regulation Market Clearing.

For each resource, PJM will calculate an adjusted Capability Cost, as:

$$Adjusted\ Regulating\ Capability\ Cost\ (\$) = \frac{\begin{pmatrix} Capability \\ Offer\left(\frac{\$}{MW}\right) \end{pmatrix}}{\begin{pmatrix} Benefits\ Factor \\ of \\ Offered\ Resource \end{pmatrix}} * \frac{\begin{pmatrix} Capability \\ (MW) \end{pmatrix}}{\begin{pmatrix} Historic \\ Performance \\ Score \end{pmatrix}}$$

For each resource, PJM will calculate an adjusted Performance Cost, as:

$$Adjusted\ Performance\ Cost\ (\$) \\ = \frac{\begin{pmatrix} Performance \\ Offer \\ (\$/\Delta MW) \end{pmatrix} * \begin{pmatrix} Mileage\ ratio \\ of \\ Offered\ Resource\ Signal\ Type\ (\Delta MW/MW) \end{pmatrix}}{\begin{pmatrix} Benefits\ Factor \\ of \\ Offered\ Resource \end{pmatrix} * \begin{pmatrix} Historic \\ Performance \\ Score \end{pmatrix}} * \begin{pmatrix} Capability \\ (MW) \end{pmatrix}$$

The "Mileage ratio of Offered Resource Signal type" is the amount MWs-of-Movement per MW of capacity for the signal the resource is following. For the RegD signal it averages approximately 16 MWs-of-Movement per MW of capacity and for the RegA signal it is approximately 5 MWs-of-Movement per MW of capacity. Note, this is different than the mileage ratio used in settlement as described below.

For each resource with an opportunity cost, its opportunity cost is adjusted as follows:

$$\text{Adjusted Lost Opportunity Cost (\$)} = \frac{\left(\begin{matrix}\text{Estimated Lost Opportunity}\\ \left(\frac{\$}{MW}\right)\end{matrix}\right)}{\left(\begin{matrix}\text{Benefits Factor}\\ \text{of}\\ \text{Offered Resource}\end{matrix}\right)} * \frac{\left(\begin{matrix}\text{Capability}\\ (MW)\end{matrix}\right)}{\left(\begin{matrix}\text{Historic}\\ \text{Performance}\\ \text{Score}\end{matrix}\right)}$$

PJM sums the three adjusted costs for each resource to determine its Total Adjusted Offer. PJM then ranks each resource according to its Total Adjusted Offer to determine the bid stack and clear the market. The last assigned resource in the stack sets the Total Regulation Market Clearing Price (RMCP). This Total RMCP is then used by PJM to derive the clearing price for the Regulation Capability and Regulation Performance components. First, the highest adjusted performance offer in the cleared bid stack will set the RMPCP. Then the RMCCP is set by subtracting the RMPCP from the Total RMCP, i.e. RMCCP = Total RMCP – RMPCP. Thus different resources can set the capacity and performance clearing prices.

AMOUNT AND UNITS OF PROCUREMENT

In addition, with the implementation of Order 755, PJM converted its unit of procurement for regulation into "effective MWs". An effective MW takes into account the resource's historic performance score and its unit-specific benefits factor. For example, if a 10 MW RegD resource has a benefits factor of 2.0 and a performance score of 95% it is counted as 19 MW in the bid stack (10 MW * 2.0 * 95%). In general the Effective MW of a RegD resource is higher than its actual MW amount until the benefits factor becomes close to 1.0. In general the Effective MW of a RegA resource is lower than its actual MW amount because it has a performance score less than 1.0 and a benefits factor of 1.0. Thus, 1 RegD MW offsets multiple RegA MWs when the benefits factor is above 1.0.

On December 1, 2013 PJM changed its methodology for how the hourly Regulation requirement is set each hour. Instead of basing hourly regulation procurement on a percentage of daily load as had been done previously, PJM switched to the use of a fixed regulation requirement. The regulation requirement is now uniform for all on-peak hours (0500 - 2359) at 700 effective MW and all off-peak hours (0000 - 0459) at 525 effective MW.

MARKET SETTLEMENT

The following are the formulas PJM uses to calculate the Regulation Capacity Credit and the Regulation Performance Credit. These two credits are then summed together to determine overall resource compensation each hour the resource provides frequency regulation. Note that the market settlement formulas did not receive final FERC approval until October 2, 2013 a year after the market started and thus were only partially implemented during the first year of the new PBR market.

Market Settlement formulas:

- **Regulation Capability (CCP) Credit** = Hourly-integrated Regulation MW x Actual Performance Score x RMCCP
- **Regulation Performance (PCP) Credit** = Hourly-integrated Regulation MW x Actual Performance Score x Applicable Mileage Ratio x RMPCP
- **Regulation Market Clearing Price Credit = Regulation CCP Credit + Regulation PCP Credit**

These formulas can be found in section 4.2 of PJM Manual 28 *Operating Agreement Accounting*.

KEY COMPONENTS OF THE SETTLEMENT FORMULAS

HOURLY-INTEGRATED REGULATION MW

Hourly-integrated Regulation MW is the amount of MWs of Regulation the resource provides in a given hour. This is normally equal to the amount of Regulation capability MWs the resource was awarded during market clearing.

ACTUAL PERFORMANCE SCORE

In the market settlement PJM uses the resources hourly performance, calculated as shown above, in both the capability and performance payment.

APPLICABLE MILEAGE RATIO

The Applicable Mileage ratio is defined as the ratio between the requested mileage for the regulation dispatch signal assigned to the resource (RegA or RegD) and the mileage for the traditional RegA regulation signal. In other words, the Mileage Ratio is the hourly miles of the Regulation signal the resource is following (either RegD or RegA) divided by the hourly miles traveled by the RegA signal. Hourly miles equals the sum of the absolute amount of regulation up and regulation down requested by the dispatch signal as measured in MWs-of-Movement. For resources following the Fast RegD signal it is calculated each hour as follows:

RegD Mileage Ratio = RegD Miles/RegA Miles

For Resources following the RegA signal, the Mileage Ratio is always 1 because the numerator and denominator are the same.

Note, this is different than the mileage ratio used in clearing and discussed above.

On October 14th PJM issued its "Performance Based Regulation: Year One Analysis" report to FERC[1] which included data on the RegD/RegA Mileage Ratio during the first 10 months of PJM utilizing two signals. The mileage ratio averaged 3.11 during this time period, but has a fair amount of variation hour to hour. The standard deviation is 1.87. The following chart from Figure 12 in the report shows the variation in mileage from hour to hour.

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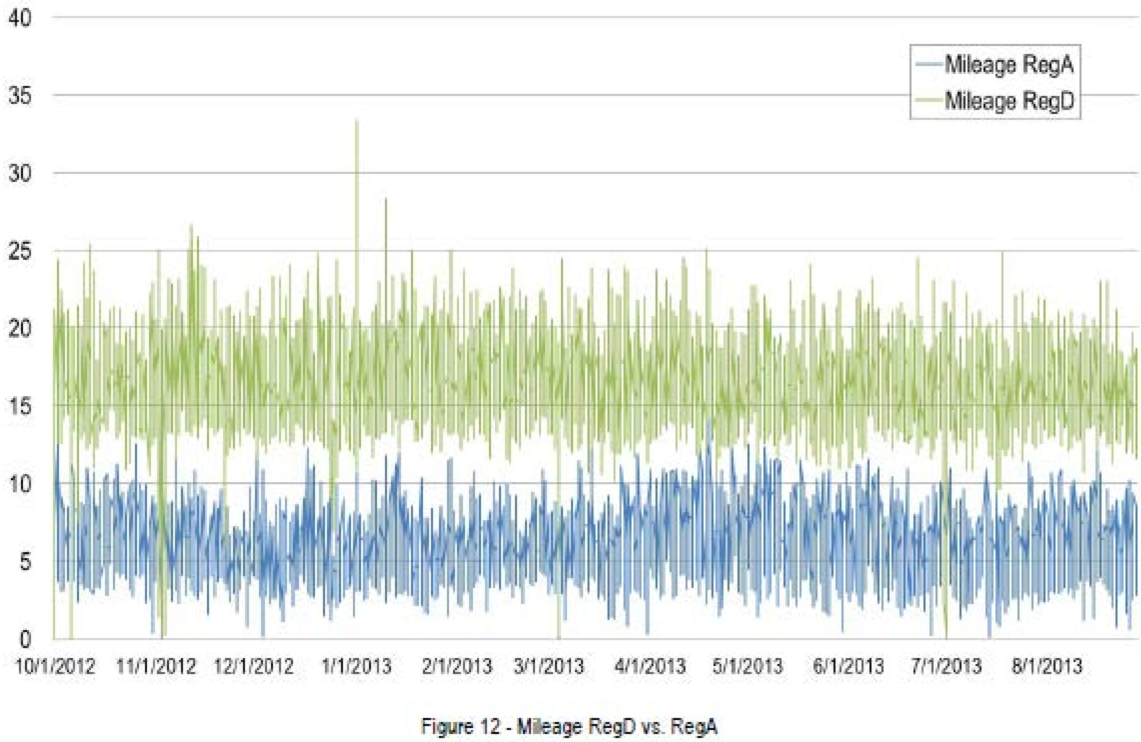
[1] PJM's Year One PBR Report can be found here.

Figure 2: RegA and RegD Signal Mileage (Source: PJM Year One Report)



PJM CURRENT PRICING

From October 1, 2012 to September 30, 2014 the RMCCP averaged $32.57/MW and the RMPCP averaged $4.57/MW, boosted by the very high prices seen this winter. The following charts show the hourly average prices for each month:

Figure 3: PJM Average Hourly Capability Prices

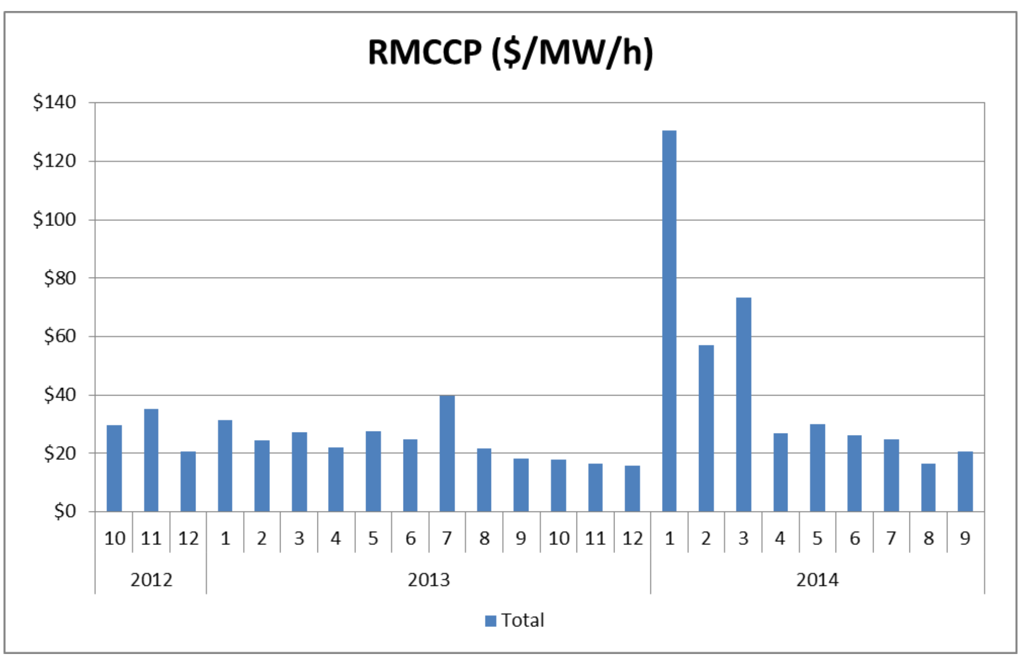
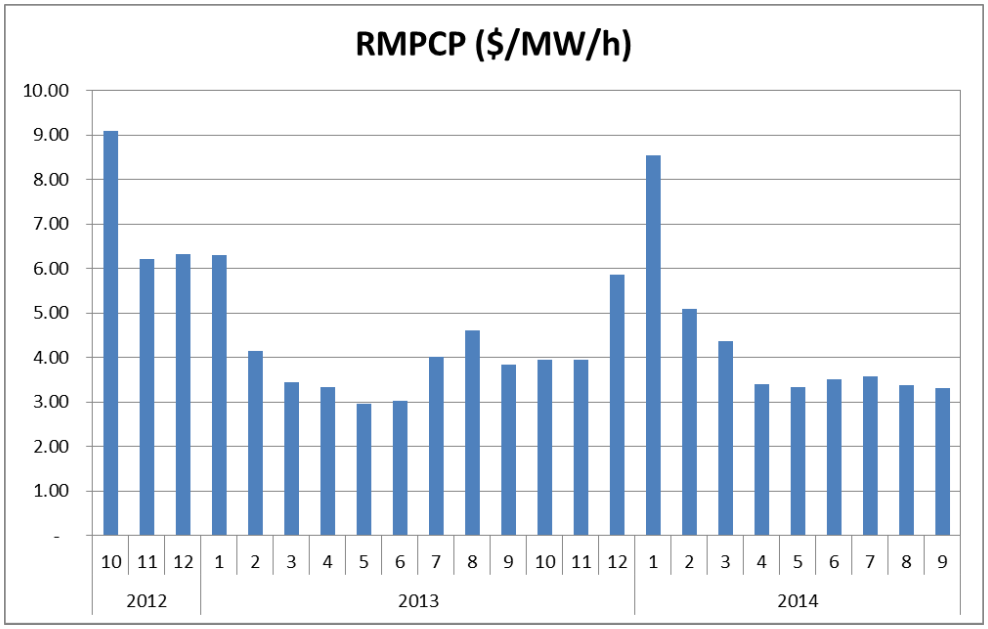


Figure 4: PJM Average Hourly Performance Prices



In Winter 2014 the regulation prices skyrocketed due to the extreme cold weather and resulting shortages of natural gas that occurred in the northeast region of the US which significantly increased energy prices. Since Order 755 requires the lost opportunity cost incurred by generators when providing regulation vs. energy to be included in the regulation clearing price, the high cost of energy in January, February and March resulted in record high regulation capacity prices during this period. As the weather warmed, regulation prices in PJM returned to more normal levels.

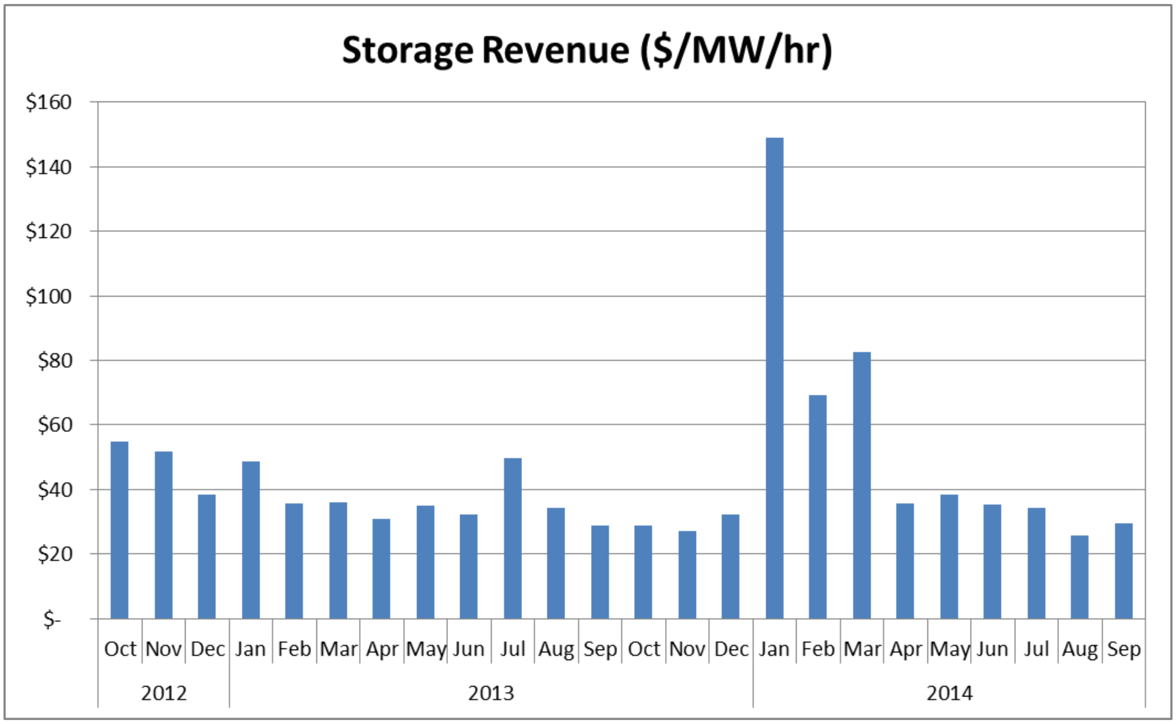
ESTIMATE OF PAYMENTS TO A BATTERY RESOURCE

A battery resource following the RegD signal with a 95% Performance score would have received an average hourly Regulation Credit of approximately $44/MW per hour over the time period from October 1, 2012 to September 30, 2014.

- Regulation Capability Credit = Hourly-integrated Regulation MW x Actual Performance Score x RMCCP = 1 MW x 95% x $32.57/MW = $30.94/MW
- Regulation Performance Credit = Hourly-integrated Regulation MW x Actual Performance Score x Mileage Ratio x RMPCP = 1 MW x 95% x 3.1 x $4.57/MW = $13.46/MW
- Regulation Market Credit = Capability Credit + Performance Credit = $30.94/MW + $13.46/MW = $44.40/MW

The following chart shows the estimated hourly revenue per MW of capacity a fast battery would have earned each month from October 2012 to September 2014. This is a 2 – 3x improvement in revenue than what a storage resource would have earned in PJM prior to Order 755.

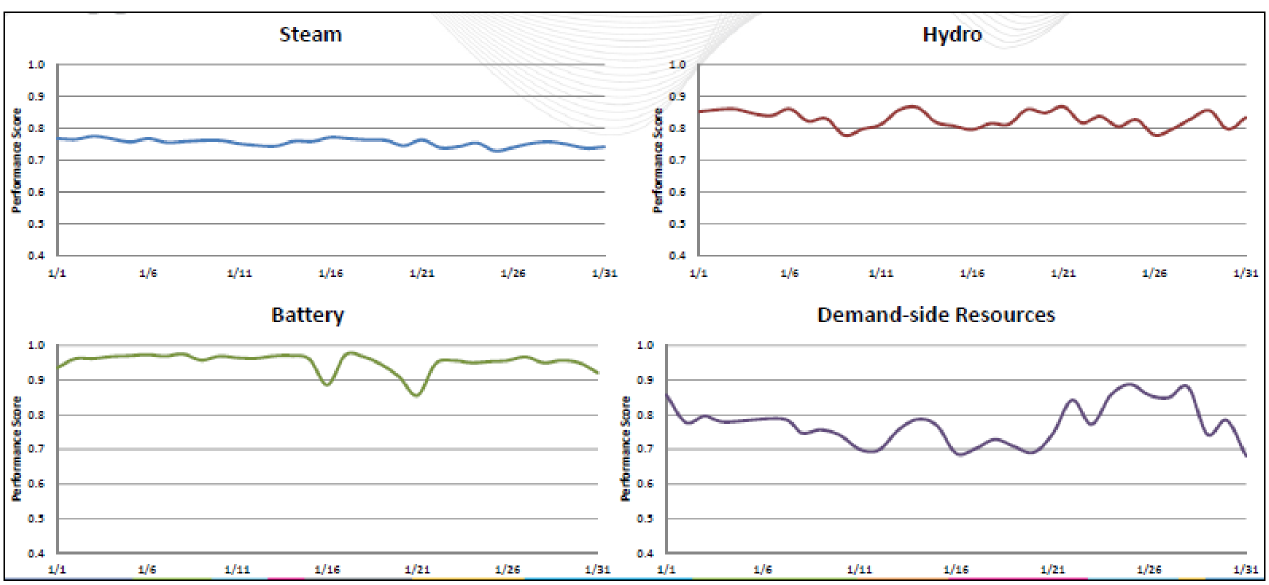
Figure 5: Estimated Fast Storage Revenue



RESOURCE PERFORMANCE DATA

The following chart shows average performance scores by major resource category:

Figure 6: PJM Resource Performance Scores (Jan 2014, Source PJM presentation)



By having higher performance scores, storage resources are not only paid more on average in settlement they also are counted as more effective (i.e. higher Effective MWs) in market clearing.

RISKS: MARKET RULE CHANGES

There have been no recent market rule changes that would impact regulation prices. However, there are always risks in any ISO/RTO market that rule changes will be proposed that impact future prices. After the very high energy and regulation prices seen this winter, PJM began considering rule changes to keep prices from spiking so high in future winters. In its May 2014 Cold Weather report, located here, PJM reviewed the market issues that occurred during the January 2014 polar vortex (January 6-8) and provided recommendations on market changes to address these issues.

PJM found that the regulation price spike seen on January 6, 7 and 8 were attributed to the inclusion of lost opportunity cost in the regulation clearing price and the use of poorer performing resources as high-performing generators were being used for energy and reserves instead of regulation. The poorer performance factor inflated the total regulation price since it is used to adjust resource offers. Thus, PJM recommended the following changes to the Regulation market:

1. Investigate whether the division by the performance score is appropriate in the market clearing.
2. Investigate whether the minimum participation requirements are adequately high enough.
3. Investigate the possibility of going short regulation during system peaks.

Recommendation #1 could lower pricing in all hours but could be offset by higher bids, while recommendation #3 would only impact peak hours with shortage conditions (the hours that drove prices so high this winter). Recommendation #2 could put upward pressure on prices.

PJM brought its recommended changes to stakeholders at the Markets Implementation Committee (MIC) on August 6th, 2014 in the form of a Problem Statement. Stakeholders did not support making changes to the Regulation market design and thus the Problem Statement was not approved. Therefore, at this time there are no pending market rule changes. However, there is always a risk of rule changes in the future.

REGULATION PRICE AND REVENUE FORECASTS

There are a number of factors that can influence the market clearing prices as well as the actual revenues to individual resources.

Factors that influence market clearing prices include:

- Overall size of the regulation market
- Supply mix changes in the regulation market:
    - Amount of RegD resources vs. RegA resources and how this changes over time
    - Mix of fossil fuel units vs. new storage and DR technologies
- Supply mix changes in the overall market:
    - Penetration of renewable resources into the market which can increase the amount of regulation that needs to be procured
- Changes in bidding behaviors from existing resources
- Energy prices and the amount of opportunity cost added to unit bids
- Natural gas prices

Factors that influence individual resource payments include:

- Ability to follow PJM's fast regulation signal (RegD) versus PJM's slow signal (RegA) – which determines the amount of mileage a resource will be paid
- Technology characteristics - including ramp-rate, power rating, energy duration, and round trip efficiency – which determine the resource's performance score

REGULATION MARKET SIZE AND CHANGES IN SUPPLY MIX

To determine future pricing Customized Energy Solutions (CES) analyzed the expected changes to the overall regulation market size, including the impact of new fast regulation resources entering the regulation market, the impact from existing traditional resources switching to the fast signal, and the expected growth in variable renewable resources into the PJM market. PJM procures an average of 664 "Effective MWs" of regulation each hour, 700 effective MW for on-peak hours (0500 - 2359) and 525 effective MW for off-peak hours (0000 – 0459). As discussed above, PJM uses each resource's benefits factor and performance score in the clearing process to convert its MW offer into Effective MWs. The Effective MWs determines how much a RegD resource can substitute for a RegA resource. For example, if a resource has a benefits factor of 2.5, 1 MW of a fast resource substitutes for 2.5 MWs of a slow resource in the bid stack. Therefore, as the amount of regulation resources following the RegD signal increases the amount of resources following the RegA signal decreases at a much faster rate. This has a large impact on the marginal unit setting the price in the market for two reasons. First, the RegD resources tend to be more efficient lower cost resources than RegA resources and second the RegD resources tend to have little to no opportunity cost as compared to the RegA resources since many of the RegD resources are not participating in the energy market. Thus as the amount of RegD MWs grows (and by accordance the less RegA MWs) the greater the downward pressure on prices.

In order to forecast the impact to prices, CES developed three scenarios of the growth of RegD resources in the market and analyzed the relationship of procurement to prices.

REGD RESOURCE PENETRATION

With the implementation of pay-for-performance pricing in PJM it is expected that new fast resources, such as storage and demand response, will enter the market and some traditional resources will switch to following the fast Reg D signal.

The market size forecast uses the latest information on the development of fast storage (and other Reg D) resources using information from the interconnection queue and CES knowledge of development in the region. In 2013 there was an average of 46 MW of new resources providing fast regulation. Resources came on-line during the course of the year and thus there was a total of 66 MW of new fast resources, made up of storage and Demand Response (DR includes behind-the-meter storage), at the end of 2013. A majority of these MWs are projects owned by AES Energy Storage, including AES's 32 MW Laurel Mountain project, 20 MW battery plant in Ohio, and 1 MW project in Pennsylvania. In 2014, through September, there has been an additional 31 MW of Storage and DR that has come on-line providing Reg D regulation, including the balance of Beacon Power's 20 MW flywheel plant (a portion was online in 2013), a 4 MW storage project developed by RES Americas and additional behind-the-meter resources. Based on knowledge of projects under construction, CES estimates an additional 36 MW will come on-line in 2014 for a cumulative total of 132 MW of new fast resources by the end of 2014 in the base case, which equates to 94 MW on average on-line during 2014.

In 2013 and 2014 there was also a certain amount of incumbent resources that switched to following the RegD signal in certain hours. Starting in March 2013, PJM eMarket data shows significant resource participation on the RegD signal during the weekday morning and evening ramp hours (approximately 5 – 7 hours a day). Based on analysis of the eMarket data it appears to be traditional incumbent resources following the fast signal. It is assumed to be approximately 50 MWs on average per hour of participation and to have a performance score of 80%. This assumption results in the calculated impact on market size and procurement to align well with actual procurement seen during these hours when taking into account the other new fast resources in the market. This has remained relatively steady since early 2013. CES anticipates that all incumbent MWs that would switch to the Reg D signal have done so by now and thus any new resources are accounted for in the addition of new fast resources in years 2015 – 2024.

For 2015 the storage interconnection queue shows 197.5 MW scheduled to come on-line, of these 62 MW are shown to be under construction. There is also 40 MW of projects in the 2014 queue remaining that will not be coming on-line in 2014, but may in future years. CES is aware that at least 100 MW of storage in the queue are still seeking partners to build out the projects and therefore may not move forward. Based on the interconnection queue in 2015, the projects shown in the 2014 queue but are not expected to come on-line in 2014, and knowledge of other projects not yet in the queue, CES estimates that approximately 270 MW of storage is being planned in PJM. Of these CES estimates that approximately 50% of these project MWs will come on-line in the base case in the next two years in 2015 and 2016. As a point of reference, on average 15% of all projects in PJM's interconnection queue actually get built so 50% is a reasonably conservative assumption. CES assumes that 40% of the projects will get built in the high case (fewer Reg D MWs translate into higher prices) and 60% of the projects will get built in the low case (higher Reg D MWs translate into lower prices). CES also includes a factor for resources that are not in the queue such as behind-the-meter storage. For 2017 and beyond, CES assumes that market penetration will decline as the benefits factor reduces to 1.0 and below. As the RegD market saturates, investment in new RegD resources will slow.

RENEWABLE RESOURCE PENETRATION

PJM expects that as renewables resources grow to meet state RPS requirements, particularly variable energy wind and solar resources, PJM will need to procure additional regulation to manage the variation. On March 3, 2014 PJM presented their PJM Renewable Integration Study (PRIS) results. It shows that more regulation will be needed under all future renewable scenarios from low levels of growth to high levels of growth in renewables. The following table provides a snap shot of the needed regulation under different scenarios. (Descriptions of the scenarios can be found in the linked presentation.) The MWs listed are in bid in MWs not effective MWs. The highest amount of regulation is associated with the high solar (HS) cases.

Table 1: Wind and Solar Penetration Scenarios and MWs of Regulation

Regulation	Load Only	2% BAU	14% RPS	20% HOBO	20% LOBO	20% LODO	20% HSBO	30% HOBO	30% LOBO	30% LODO	30% HSBO
Maximum (MW)	2,003	2,018	2,351	2,507	2,721	2,591	2,984	3,044	3,552	3,191	4,111
Minimum (MW)	745	766	919	966	1,031	1,052	976	1,188	1,103	1,299	1,069
Average (MW)	1,204	1,222	1,566	1,715	1,894	1,784	1,958	2,169	2,504	2,286	2,737
% Increase Compared to Load		1.5%	30.1%	42.4%	57.3%	48.2%	62.6%	80.2%	108.0%	89.8%	127.4%

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PJM does not have a timetable for the associated growth in renewables, but this is a forward look and is assumed to be the amount of regulation needed in year 2026. The model uses the 14% RPS scenario for the low case, the 20% RPS scenario for the base cases and the 30% RPS scenario for the high cases. Our model assumes that the growth in renewables does not start impacting the amount of regulation procurement until 2018 and then grows steadily each year until the amount shown in 2026. For the low case the growth rate in regulation procurement is 3.3%, for the base case it is 5.4% and for the high case it is 9.1% starting in 2018.

REGULATION PROCUREMENT FORECAST 2014 -2024

The following tables show the resulting amount of RegD and RegA regulation procurement for the next 10 years under the base, low and high cases, with the low case meaning that there is faster growth in RegD resources and the high case meaning there is slower growth in RegD resources (since increased RegD penetration will lower prices). This procurement analysis is used as an input to create a base, low and high case revenue forecast. It is important to note that the price forecast for 2015 – 2024 is an annual average and thus the market size forecast uses an annual average amount of new Reg D MWs that come on-line during the year and not the total number of MWs added by the end of the year. This is factored into the average of the current year as well as the cumulative average of the following years.

The market size forecasts take into account the expected impact of both increased amounts of resources following the fast RegD signal in the near term and increased renewable resources over the longer term leading to increased need for regulation. In addition, the forecasts take into account the performance score and benefits factor of the resources. Since each RegD resource is assigned a unit-specific benefits factor that aligns with the last MW that specific resource will add to the RegD resource stack, the average benefit factor of the group of RegD resources is calculated and then applied to determine the expected amount of effective MWs of fast resources to be procured. The amount of slow RegA effective MWs is determined by subtracting the effective MWs of RegD from the total required effective MWs of regulation.

The forecast assumes that when the benefits factor is at 1.0 or lower there is limited incentive for new RegD resources to enter the market until such time as the overall market size for regulation begins to grow (as expected with more renewables). As prices begin to drop, there is less of a price signal for market entry which is factored into the market growth in each scenario.

Table 2: BASE CASE: Regulation Market Size and RegD vs. RegA Procurement

Market Size - Base Case	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**
Procurement in Effective MWs	688	664	664	664	664	664	664	664	664	664	664	664
Impact of Wind and Solar on Regulation		664	664	664	664	700	738	778	820	864	911	961
Impact of Order 755				56%								
Incremental New Fast Resources		67	89	62	37	19	19	19	20	21	26	33
Average Cumulative New Fast Regulation Resources	46	94	177	252	302	330	349	368	387	407	431	461
New Fast Regulation Resources * Perf Score	43	88	166	237	284	310	328	346	364	383	405	433
Traditional Resources on Fast	7	9	9	9	9	9	9	9	9	9	9	9
Trad Fast * Performance Score	6	7	7	7	7	7	7	7	7	7	7	7
Sum of Fast Resources w/Perf Score	49	95	173	244	291	317	335	352	371	390	412	440
% Fast Resources	7.1%	14.3%	26.0%	36.8%	43.8%	45.4%	45.4%	45.3%	45.2%	45.1%	45.2%	45.8%
Marginal Benefits Factor	2.58	2.27	1.72	1.27	0.95	0.86	0.86	0.86	0.86	0.86	0.86	0.86
Average Benefits Factor	2.65	2.49	2.22	1.99	1.84	1.79	1.79	1.79	1.79	1.79	1.79	1.79
Effective MWs RegD	129	241	396	503	555	579	594	609	624	641	660	684
Effective MWs RegA	559	427	267	161	109	121	144	169	195	223	251	277
Market Size in Effective MWs	688	664	664	664	664	700	738	778	820	864	911	961
Market Size with Order 755 and Renewables (MWs)												
RegD Resources Unadjusted MW	53	103	185	261	311	339	357	376	395	416	439	469
RegA Resources Unadjusted MW	717	548	343	206	140	155	184	216	250	286	322	355
Total Market Size (MWs)	770	651	528	467	450	494	542	592	646	702	761	824

Table 3: LOW CASE: Regulation Market Size and RegD vs. RegA Procurement

Market Size - Low Case	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Procurement in Effective MWs	688	664	664	664	664	664	664	664	664	664	664	664
Impact of Wind and Solar on Regulation		664	664	664	664	686	709	732	757	782	808	835
Impact of Order 755				66%								
Incremental New Fast Resources		72	119	59	30	9	9	9	10	10	10	11
Average Cumulative New Fast Regulation Resources	46	95	196	286	330	349	358	367	377	386	396	407
New Fast Regulation Resources * Perf Score	43	90	185	268	310	328	337	345	354	363	373	382
Traditional Resources on Fast	7	9	9	9	9	9	9	9	9	9	9	9
Trad Fast * Performance Score	6	7	7	7	7	7	7	7	7	7	7	7
Sum of Fast Resources w/Perf Score	49	96	191	275	317	335	344	352	361	370	379	389
% Fast Resources	7.1%	14.5%	28.9%	41.5%	47.8%	48.9%	48.5%	48.1%	47.7%	47.3%	46.9%	46.6%
Marginal Benefits Factor	2.58	2.27	1.63	1.04	0.77	0.72	0.72	0.72	0.77	0.77	0.82	0.82
Average Benefits Factor	2.65	2.49	2.18	1.88	1.75	1.72	1.72	1.72	1.75	1.75	1.77	1.77
Effective MWs RegD	129	244	430	542	580	593	599	605	612	619	626	634
Effective MWs RegA	559	425	234	122	84	93	109	127	145	163	182	201
Market Size in Effective MWs	688	664	664	664	664	686	709	732	757	782	808	835
Market Size with Order 755 and Renewables (MWs)												
RegD Resources Unadjusted MW	53	104	205	294	339	358	367	376	385	395	405	415
RegA Resources Unadjusted MW	717	545	300	156	108	119	140	163	186	209	233	258
Total Market Size (MWs)	770	649	505	450	446	477	507	539	571	604	638	673

Table 4: HIGH CASE: Regulation Market Size and RegD vs. RegA Procurement

Market Size - High Case	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Procurement in Effective MWs	688	664	664	664	664	664	664	664	664	664	664	664
Impact of Wind and Solar on Regulation		664	664	664	664	724	790	863	942	1028	1121	1224
Impact of Order 755				44%								
Incremental New Fast Resources		62	59	59	48	38	30	33	36	40	43	47
Cumulative New Fast Regulation Resources	46	93	157	216	270	312	347	378	413	451	492	537
New Fast Regulation Resources * Perf Score	43	87	147	203	253	294	326	356	388	424	463	505
Traditional Resources on Fast	7	9	9	9	9	9	9	9	9	9	9	9
Trad Fast * Performance Score	6	7	7	7	7	7	7	7	7	7	7	7
Sum of Fast Resources w/Perf Score	49	94	154	210	260	300	333	362	395	431	470	512
% Fast Resources	7.1%	14.2%	23.2%	31.6%	39.2%	41.5%	42.1%	42.0%	42.0%	41.9%	41.9%	41.8%
Marginal Benefits Factor	2.58	2.27	1.86	1.50	1.13	1.04	1.00	1.00	1.04	1.04	1.04	1.04
Average Benefits Factor	2.65	2.49	2.29	2.11	1.93	1.88	1.86	1.86	1.88	1.88	1.88	1.88
Effective MWs RegD	129	239	363	456	522	566	599	629	662	699	739	784
Effective MWs RegA	559	430	301	207	141	158	192	234	280	329	382	440
Market Size in Effective MWs	688	664	664	664	664	724	790	863	942	1028	1121	1224
Market Size with Order 755 and Renewables (MWs)												
RegD Resources Unadjusted MW	53	101	165	225	278	321	355	387	422	459	501	546
RegA Resources Unadjusted MW	717	551	386	266	181	203	246	300	359	421	490	565
Total Market Size (MWs)	770	652	551	490	459	524	601	687	780	881	991	1111

PRICE DRIVERS

While there is still only a relatively short period of historic data for the new regulation market in PJM (and for much of 2013 the market design was still being finalized), the data shows decent correlations between the capacity and performance prices with the amount of Reg A vs. Reg D procurement, as well as very high correlation to energy prices. Using the historic data, CES has been able to develop multivariable regression formulas for use in forecasting future prices.

RELATIONSHIP OF REGULATION PRICES TO ENERGY PRICES AND MW PROCUREMENT

The inclusion of real time opportunity cost in the regulation clearing price calculation means that the real time price of energy will have an impact on prices in the Regulation market. Regulation prices – especially Regulation Capacity prices – show very high correlation with energy prices. As the amount of RegD resources increase it is expected to put downward pressure on prices. As new fast resources enter the market less and less slow Reg A resources will need to be procured. Given that traditional resources tend to be higher cost (both bid in offers and opportunity cost) than the new regulation technologies entering the market, such as storage and demand response technologies, the traditional resources will most likely continue to be the marginal unit. Thus, as less and less traditional Reg A resources are procured prices will correspondingly come down. Since slow resources will be replaced at a greater than one-for-one substitution rate, due to the benefits factor being used in the clearing process, the impact is greatest in the early years when the benefits factor is highest and the amount of new resources entering the market is expected to be high. In the outer years this impact is mitigated by the decline of the benefits factor and the likely slowdown in new resources entering the market as the market becomes saturated. Further, the expected growth in renewable resources in the outer years will increase the need for regulation putting upward pressure on prices.

In order to analyze the relationship of energy prices and changes in regulation procurement on regulation prices, we performed multivariable regression analysis. The following tables show results of regression for regulation capacity prices (RMCCP) as well as for regulation performance prices (RMPCP). High value R^2 (98%) suggests variations in LMP and effective Reg A MWs explain the variations in RMCCP very well. Results suggest that both capacity as well as performance prices increase with increase in energy prices. Capacity prices will have downward pressure due to decreasing effective Reg A MW procurement. Performance prices, although don't show very significant correlation, also will have downward pressure due to addition of more fast and efficient resources.

Table 5: Regression Statistic for RMCCP

SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.989							
R Square	0.978							
Adjusted R	0.975							
Standard Er	3.857							
Observatio	24							
ANOVA								
	df	*SS*	*MS*	*F*	*Significance F*			
Regression	2	13,642.30	6,821.15	458.59	0.00			
Residual	21	312.36	14.87					
Total	23	13,954.66						
	Coefficients	*tandard Errc*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	(42.4347)	5.475	(7.750)	0.000	(53.821)	(31.048)	(53.821)	(31.048)
RTLMP	1.3800	0.046	30.187	0.000	1.285	1.475	1.285	1.475
Total MW R	0.0311	0.009	3.479	0.002	0.012	0.050	0.012	0.050

Table 6: Regression Statistic for RMPCP

SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.7421							
R Square	0.5507							
Adjusted R	0.5008							
Standard Er	0.9382							
Observatioı	21							
ANOVA								
	df	*SS*	*MS*	*F*	*Significance F*			
Regression	2	19.4209	9.7105	11.0329	0.0007			
Residual	18	15.8425	0.8801					
Total	20	35.2634						
	Coefficients	*tandard Errc*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	2.7690	0.7819	3.5412	0.0023	1.1262	4.4119	1.1262	4.4119
RTLMP	0.0526	0.0113	4.6733	0.0002	0.0290	0.0763	0.0290	0.0763
Total MW R	(0.0052)	0.0040	(1.3031)	0.2090	(0.0135)	0.0032	(0.0135)	0.0032

Given the high correlation of regulation prices to energy prices, the underlying forecast of energy prices plays a significant role in this forecast. CES used the CME group's PJM Western Hub Peak and Off-Peak Calendar-Month Real-Time LMP Futures Quotes to forecast Average RT LMP prices for 2014 – 2019. CES used CME group's gas forecasts as the basis for forecasting RT LMP prices from 2020 – 2024. Thus, the forecast has risk if the underlying fuel costs for supplying energy deviate substantially from expectation.

RESOURCE SPECIFIC FACTORS

Each resource is paid based on its unit specific performance score and needs to be calculated based on characteristics specific to the resource. As discussed above batteries tend to have a high level of accuracy in following the signal. The average performance score of a battery tends to range from 0.92 – 0.98. Therefore, the storage revenue forecast assumes an average performance score of 0.95 in the base case, 0.92 in the low case and 0.98 in the high case. A resource specific revenue forecast for EDF's project using a 20 MW – 12 minute duration battery and 20 MW – 6 minute battery resource is also below (see signal modeling analysis results).

As described above the mileage ratio determines the amount of pay-for-performance a fast resource will receive. It is the ratio between the mileage of PJM's fast signal (RegD) and PJM's slow signal (RegA). This ratio is then used as a multiple to the RMPCP for resources following the fast signal. Since October 2012 the mileage ratio has averaged 3.06 and over the prior year has averaged 3.0. Therefore, the model uses a mileage ratio of 3.0 in the base case, 2.9 in the low case and 3.1 in the high case.

PROJECTED REVENUES FOR 2014 – 2024 FOR FAST REGD STORAGE

CES developed low, base and high case forecasts for the capacity and performance clearing prices (RMCCP and RMPCP) for the years 2014 – 2024. These prices are then used to calculate the expected revenue per MW per hour a fast, accurate battery resource following the Reg D signal would receive on average. The following figure and table show the forecasted revenue and prices:

Figure 7: PJM Regulation Revenue Forecasts for Battery Storage

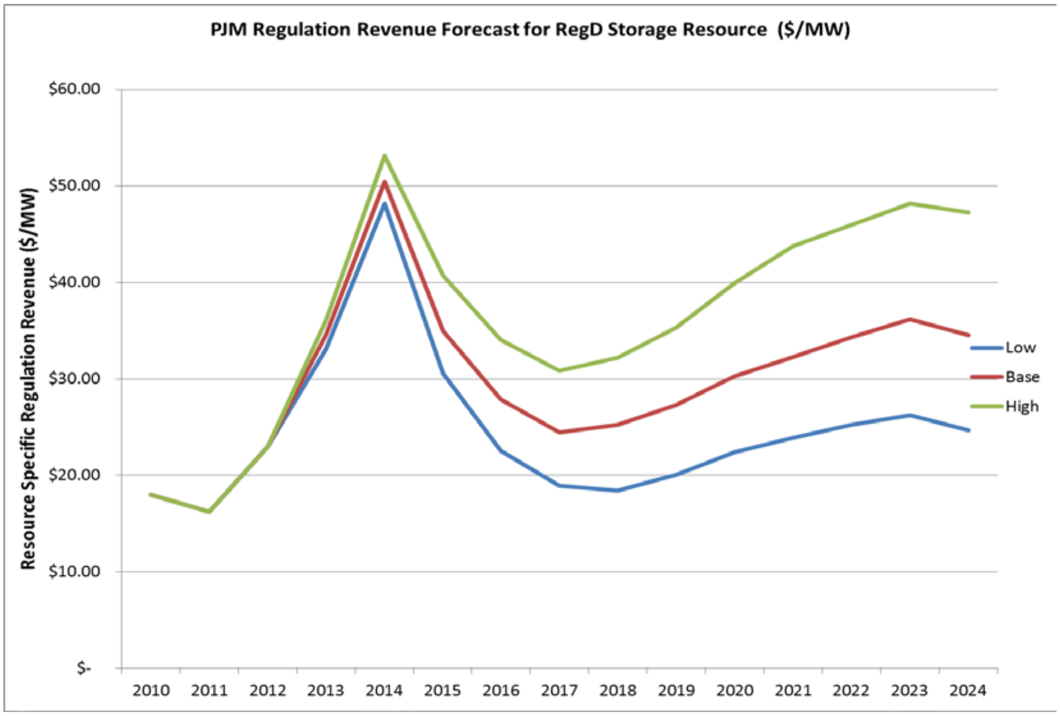


Table 7: Forecasted PJM Regulation Prices and Resource-Specific revenue for Battery Storage Resource

Regulation Revenue Resource Specific	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Low	$ 33.14	$ 48.17	$ 30.60	$ 22.58	$ 18.95	$ 18.46	$ 20.09	$ 22.44	$ 23.92	$ 25.24	$ 26.26	$ 24.66
Base	$ 34.61	$ 50.42	$ 34.93	$ 27.89	$ 24.45	$ 25.25	$ 27.29	$ 30.29	$ 32.30	$ 34.33	$ 36.15	$ 34.54
High	$ 36.11	$ 53.10	$ 40.69	$ 34.02	$ 30.82	$ 32.19	$ 35.33	$ 39.94	$ 43.73	$ 45.95	$ 48.14	$ 47.22
Performance Clearing Price (RMPCP)	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**
Low	$ 4.12	$ 4.10	$ 2.83	$ 2.13	$ 1.85	$ 1.76	$ 1.78	$ 1.82	$ 1.82	$ 1.82	$ 1.80	$ 1.69
Base	$ 4.12	$ 4.11	$ 3.06	$ 2.42	$ 2.11	$ 2.02	$ 2.00	$ 2.01	$ 1.98	$ 1.94	$ 1.89	$ 1.69
High	$ 4.12	$ 4.14	$ 3.33	$ 2.76	$ 2.42	$ 2.24	$ 2.16	$ 2.14	$ 2.07	$ 1.92	$ 1.75	$ 1.45
Capacity Clearing Price (RMCCP)	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**
Low	$ 24.07	$40.47	$ 25.05	$18.38	$15.23	$14.95	$ 16.68	$19.12	$20.71	$22.16	$23.32	$ 21.92
Base	$ 24.07	$40.74	$ 27.59	$22.08	$19.40	$20.53	$ 22.74	$25.87	$28.07	$30.31	$32.38	$ 31.28
High	$ 24.07	$41.36	$ 31.19	$26.14	$23.96	$25.89	$ 29.34	$34.12	$38.21	$40.93	$43.69	$ 43.68
Performance Revenue (Resourse Specific)	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**
Low	$ 11.00	$ 10.94	$ 7.55	$ 5.67	$ 4.95	$ 4.70	$ 4.74	$ 4.85	$ 4.86	$ 4.85	$ 4.81	$ 4.50
Base	$ 11.75	$ 11.72	$ 8.72	$ 6.91	$ 6.02	$ 5.75	$ 5.69	$ 5.72	$ 5.64	$ 5.54	$ 5.39	$ 4.83
High	$ 12.52	$ 12.57	$ 10.13	$ 8.40	$ 7.34	$ 6.81	$ 6.57	$ 6.50	$ 6.29	$ 5.84	$ 5.33	$ 4.42
Capacity Revenue (Resource Specific)	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**
Low	$ 22.14	$ 37.23	$ 23.05	$ 16.91	$ 14.01	$ 13.76	$ 15.35	$ 17.59	$ 19.06	$ 20.38	$ 21.45	$ 20.16
Base	$ 22.86	$ 38.70	$ 26.21	$ 20.98	$ 18.43	$ 19.51	$ 21.60	$ 24.58	$ 26.66	$ 28.79	$ 30.76	$ 29.71
High	$ 23.58	$ 40.53	$ 30.57	$ 25.62	$ 23.48	$ 25.38	$ 28.75	$ 33.44	$ 37.45	$ 40.11	$ 42.81	$ 42.80

ANALYSIS OF EDF RENEWABLES PROJECT SPECIFIC REVENUE

EDF Renewables is proposing a 20 MW project in PJM using either a 12 minute or 6 minute duration battery. EDF Renewables provided the following information and basic configuration for its proposed battery technology:

- Technology type: BYD lithium iron phosphate battery
- Power Rating (MW): 1.8 MW, per Container
- Energy Rating (MWh): 720 kWh, per Container (24 minutes duration)
- Upper SOC limit (%): 100%
- Lower SOC limit (%): 0%
- Ramp-rate (Charge/discharge): Ramp up from 0 to 100% output in 100ms.
- One –way energy efficiency (entire plant efficiency and not just storage): 94-95% charge, 94-95% discharge
- Standby losses (MWh/min): 2%/week when idle. 2% per month when off.
- Cycle Life (number of equivalent full DOD cycles): 6000+ 100% full cycles

Based on these specifics, CES modeled a 19.8 MW, 3.96 MWh battery plant for the 12 minute duration case and a 19.8 MW, 1.98 MWh battery plant for the 6 minute duration case.

Using our proprietary CES|CoMETS Frequency Regulation modeling tool (Competitive Market Evaluation Tools for Storage) CES simulated the response of the two battery configurations to the PJM Reg D fast signal using the operating parameters supplied by EDF Renewables as listed above. The model then calculates the key performance metrics used to drive project revenue and costs, including the resource performance score, energy losses and number of cycles.

The following table shows a comparison of performance scores as well as other metrics based on the two different battery resource configurations. Case 1 and Case 3 show the performance of the 12 minute and 6 minute battery resource, respectively, directly responding to the PJM signal without any additional operating strategies for managing state-of-charge (SOC) or communications latency. As can be seen in the table the performance score of the 12 minute resource is 93.3% and the 6 minute resource is 92.4%. However, when SOC and communications management strategies are employed the performance score of the 12 minute resource improves to 98.1% and the 6 minute resource improves to 96.9%, as shown in Case 2 and Case 4 respectively.

Table 8: Performance Comparison of Battery Configurations

		Case 1	Case 2	Case 3	Case 4
SOC Management		No	Yes	No	Yes
Power Rating	MW	19.8	19.8	19.8	19.8
Duration	Mins	12	12	6	6
Energy Rating	MWh	0.36	0.36	0.18	0.18
Round-trip Efficieny	%	89%	89%	89%	89%
Comm Delay	Seconds	-	10	-	10
Mileage*	per Hr	16.74	17.06	16.60	17.06
Performance Score	%	93.3%	98.1%	92.4%	96.9%
Correlation Score	%	98.32%	99.6%	97.11%	98.5%
Delay Score	%	99.84%	99.9%	99.69%	99.8%
Precision Score	%	81.83%	94.7%	80.49%	92.4%
Cycles	per yr/MW	171,923	171,945	171,869	171,934
Full DOD Cycles	per yr/MW	5,351	5,513	10,370	10,675
Energy Loss	MWh/yr/MW	121	125	117	121
** Up & down movement of the resource*					

Case 2 and Case 4 demonstrate how there are ways to improve this performance score and cycle life of the battery resources. The following are options to improve the performance score:

- ***Active SOC Management***: If active SOC management is done it improves performance score as well as life of the battery. Since the PJM Reg D signal is energy neutral but no battery resource is 100% efficient applying an algorithm to determine how the battery should respond to the signal based on its current SOC charge will keep the battery closer to its midpoint SOC thereby improving battery life and increasing the number of intervals the resource can precisely respond to the signal. The following two figures show the difference in SOC levels and signal response with and without active SOC management. In Figure 8 the battery is operating at a near empty most of the time, meaning the resource will run out of energy to respond to the signal. In Figure 9 a SOC management strategy is employed which improves the SOC of the battery and its ability to respond to the signal.

Figure 8: Response and SOC Histogram for 12 minute Battery without SOC management

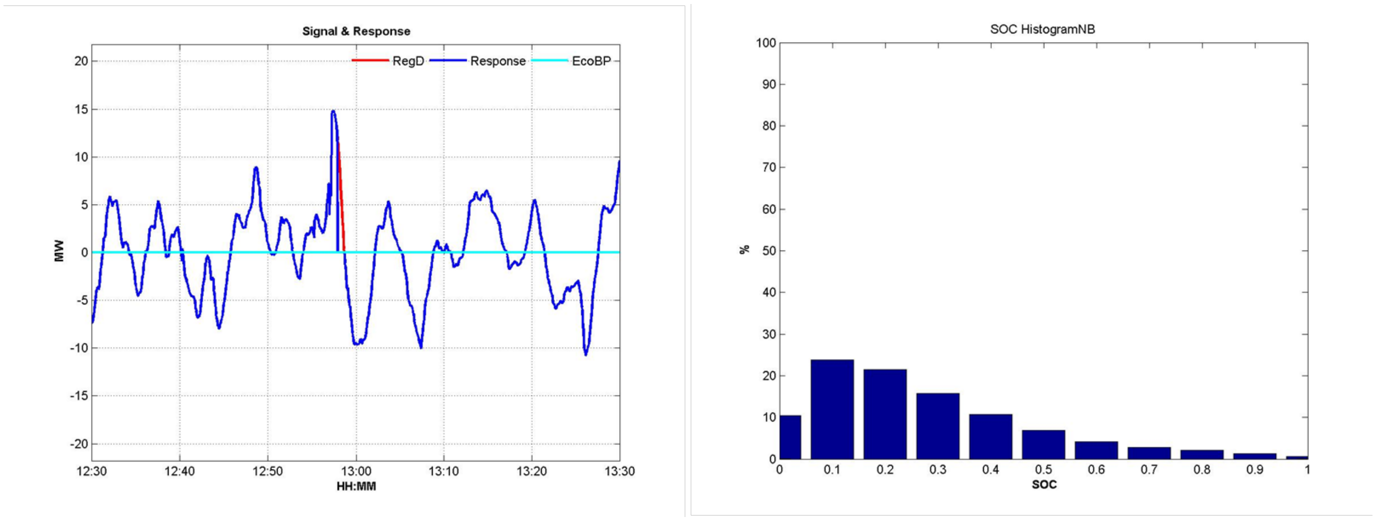
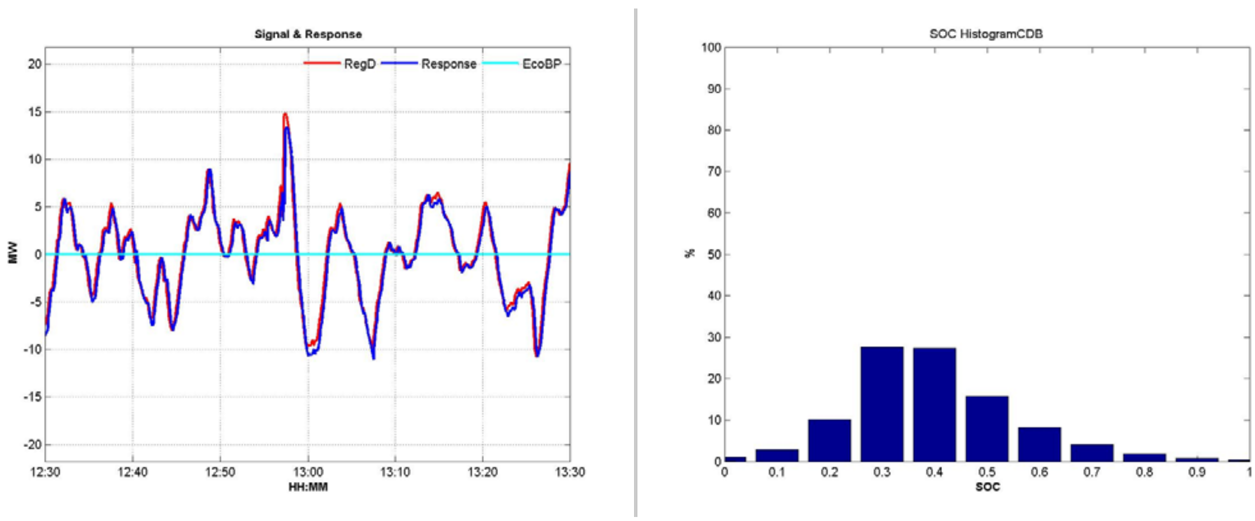


Figure 9: Response and SOC Histogram for 12 minute Battery with SOC management



- ***Signal co-ordination***: PJM measures signal response every 10th second, whereas it sends a signal every 2 seconds. Aligning the resource response to match the 10 second snapshot of performance, which requires adjusting for battery response time for signal communication latency, will improve the resource performance score. This may require slightly slowing down the battery response in order to align its response to the 10 second time period.

Additionally, further optimization can be applied through a more detailed study which could further increase the performance scores and state-of-charge. For battery projects operated by CES's operation center, CES provides resources the option to have CES provide on-going SOC and signal management.

Cycle Life

EDF Renewables supplied information that the battery Cycle Life (number of equivalent full DOD cycles) is 6000+ 100% full cycles. As can be seen in Table 8 above, the 12 minute battery provides 5000+ full DOD cycles per year and the 6 minute battery provides 10,000+ full DOD cycles per year. Shortening the duration of the battery increases the number of DOD cycles that will be performed each year. While SOC management can be used to lengthen the cycle life (operating at a higher SOC increases the number of cycles[2]), the battery resources will likely still have relatively short replacement times which should be factored into the cost of the plant. CES recommends that EDF Renewables confirm cycle life expectations with their vendor based on the expected duty cycle of the battery following the PJM RegD signal. For comparison purposes, the 24 minute battery (the base configuration supplied by BYD) has ~2,700 full DOD cycles per year.

Energy Losses

The CoMETS model also shows the expected energy losses of the battery resources. EDF Renewables can use an estimate of ~125 MWh/year per MW of Regulation supplied in its project model. For a 19.8 MW plant this equals 2,475 MWh per year.

EDF PROJECT REVENUE

The following data shows the expected revenue in $/MW/year and Total $/year for a 19.8 MW 12 minute and 6 minute battery plant in PJM following the Reg D signal. The scenarios assume that a SOC and signal management strategy is used (Case 2 and 4 above) in order to maximize performance scores. As can be seen there is a small increase in revenue for the 12 minute resource due to higher performance, however this additional revenue needs to be weighed against any added capital cost and impact to replacement cost. The annual revenue assumes the plant has a 95% availability (up time) and that the resource bids in such a way to clear in the market in all offered hours.

[2] This is known as a cycle life curve. BYD did not supply BYD's specific cycle life curve. Only a specific data point from the curve was provided, i.e. 6000+ 100% full cycles.

Table 9: EDF Renewables Project Revenue Scenarios

EDF Renewables Project Revenue											
12 minute Battery Plant											
MW	19.8										
MWh	3.96										
Performance Score	98.1%	**with SOC and Signal Management**									
Availability	95%										
$/MW	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**
Low	$ 51.34	$ 32.61	$ 24.07	$ 20.20	$ 19.67	$ 21.41	$ 23.91	$ 25.49	$ 26.90	$ 27.99	$ 26.28
Base	$ 52.05	$ 36.05	$ 28.79	$ 25.24	$ 26.07	$ 28.17	$ 31.27	$ 33.34	$ 35.44	$ 37.31	$ 35.65
High	$ 53.13	$ 40.71	$ 34.04	$ 30.84	$ 32.21	$ 35.35	$ 39.97	$ 43.76	$ 45.98	$ 48.17	$ 47.25
$/Year	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**
Low	$ 8,459,784	$ 5,373,280	$ 3,966,002	$ 3,328,535	$ 3,241,920	$ 3,528,282	$ 3,940,239	$ 4,200,796	$ 4,432,204	$ 4,611,940	$ 4,330,847
Base	$ 8,576,103	$ 5,940,840	$ 4,743,160	$ 4,158,403	$ 4,294,960	$ 4,641,042	$ 5,152,293	$ 5,493,340	$ 5,839,246	$ 6,147,957	$ 5,874,212
High	$ 8,755,195	$ 6,708,771	$ 5,608,756	$ 5,081,561	$ 5,307,365	$ 5,824,499	$ 6,585,598	$ 7,210,512	$ 7,576,237	$ 7,936,854	$ 7,785,538
6 minute Battery Plant											
MW	19.8										
MWh	1.98										
Performance Score	96.9%	**with SOC and Signal Management**									
Availability	95%										
$/MW	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**
Low	$ 50.73	$ 32.22	$ 23.78	$ 19.96	$ 19.44	$ 21.16	$ 23.63	$ 25.19	$ 26.58	$ 27.66	$ 25.97
Base	$ 51.43	$ 35.63	$ 28.44	$ 24.94	$ 25.76	$ 27.83	$ 30.90	$ 32.94	$ 35.02	$ 36.87	$ 35.23
High	$ 52.50	$ 40.23	$ 33.64	$ 30.47	$ 31.83	$ 34.93	$ 39.49	$ 43.24	$ 45.43	$ 47.60	$ 46.69
$/Year	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**
Low	$ 8,359,511	$ 5,309,591	$ 3,918,993	$ 3,289,082	$ 3,203,493	$ 3,486,462	$ 3,893,536	$ 4,151,005	$ 4,379,669	$ 4,557,275	$ 4,279,514
Base	$ 8,474,451	$ 5,870,424	$ 4,686,940	$ 4,109,114	$ 4,244,052	$ 4,586,033	$ 5,091,223	$ 5,428,228	$ 5,770,034	$ 6,075,086	$ 5,804,586
High	$ 8,651,421	$ 6,629,252	$ 5,542,276	$ 5,021,330	$ 5,244,457	$ 5,755,462	$ 6,507,539	$ 7,125,047	$ 7,486,436	$ 7,842,779	$ 7,693,257
BASE CASE											
$/Year	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**
12 minute	$ 8,576,103	$ 5,940,840	$ 4,743,160	$ 4,158,403	$ 4,294,960	$ 4,641,042	$ 5,152,293	$ 5,493,340	$ 5,839,246	$ 6,147,957	$ 5,874,212
6 minute	$ 8,474,451	$ 5,870,424	$ 4,686,940	$ 4,109,114	$ 4,244,052	$ 4,586,033	$ 5,091,223	$ 5,428,228	$ 5,770,034	$ 6,075,086	$ 5,804,586
Difference	$ 101,652	$ 70,416	$ 56,220	$ 49,289	$ 50,908	$ 55,010	$ 61,070	$ 65,112	$ 69,212	$ 72,871	$ 69,626