Interim Technology Performance Report

20 MW FLYWHEEL FREQUENCY REGULATION PLANT

Contract ID: DE-OE-0000200

June 1, 2015

Acknowledgement

This material is based upon work supported by the Department of Energy under Award Number DE-OE0000200.

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Hazle Spindle, LLC (Hazle), owner of a 20 megawatt (MW) flywheel-based energy storage facility located in Hazle Township, Pennsylvania (the Hazle Facility), submits this interim Technology Performance Report (the TPR) to the U.S. Department of Energy in accordance with cooperative agreement DE-OE0000200.[1]

1.1. PROJECT OVERVIEW

Hazle designed, built, commissioned, and operates a utility-scale 20 MW flywheel energy storage plant in Hazle Township, Pennsylvania (the Hazle Facility) using flywheel technology developed by its affiliate, Beacon Power, LLC (Beacon Power).[2] The Hazle Facility provides frequency regulation services to the regional transmission organization, PJM Interconnection, LLC (PJM), through its participation in PJM's Regulation Market (a market-based system for the purchase and sale of the Regulation ancillary service). The zero emission Hazle Facility is designed for a 20 year-life over which it is capable of performing at least 100,000 full depth of discharge cycles. To achieve its 20 MW capacity, the Hazle Facility is comprised of two hundred of Beacon Power's 100 kilowatt (kW)/25 kilowatt/hour (kWh) flywheels connected in parallel. The Hazle Facility can fully respond to a signal from PJM in less than 2 seconds. The Hazle facility was constructed in an economic development zone designated by the Commonwealth of Pennsylvania and its construction relied on local contractors and labor for completion.

1.2. PROJECT OBJECTIVES

In undertaking the project, Hazle identified several objectives that may be achieved through the Hazle Facility, including (i) the demonstration of the technical, cost and environmental advantages of fast response flywheel-based frequency regulation to grid operators (such as regional transmission organizations or independent system operators), which could (a) facilitate the deployment of flywheel-based energy storage technology to other transmission systems managed by such entities, and (b) stimulate the international market demand for flywheel-based energy storage; and (ii) reduce the cost of development of a 20 MW flywheel-based energy storage facility compared with that previously incurred by Beacon Power Corporation in the development of the flywheel-based energy storage facility in Stephentown, NY. Through this project, Hazle also sought to quantify and verify the broad commercial viability and scalability

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[1] The cooperative agreement was initially awarded to Beacon Power Corporation (effective as of January 1, 2010) pursuant to the U.S. Department of Energy' Smart Grid Demonstrations program. The cooperative agreement was subsequently amended, including a novation to Hazle Spindle, LLC.

[2] Beacon Power, a pioneer and global leader in the design, development and commercial deployment of fast response flywheel energy storage systems, has its headquarters and manufacturing facility in Tyngsborough, MA. Beacon Power's patented flywheels are among the most advanced energy storage technologies in operation today, and are able to respond instantly to store or deliver precise amounts of power in a broad range of high-value, high-cycle applications. Beacon Power flywheel technology is currently used in two commercial flywheel plants in two different U.S. markets and its flywheel based energy storage system has delivered almost 8 million operating hours. Each of Hazle and Beacon Power is an indirect subsidiary of Rockland Power Partners, LP, a private equity fund managed by Rockland Capital, LLC.

of this smart grid energy storage technology by providing an alternative solution to the existing methods of maintaining grid frequency (namely, relying on output movement of fossil-fuel generators).

In connection with demonstrating the advantages of the flywheel-based energy storage system to grid operators mentioned above, Hazle further defined its objective to include the demonstration that the addition of its energy storage facility would:

- Maintain better balance between network load and power generated in the PJM control area
- More efficiently maintain PJM grid frequency, thereby improving grid reliability
- Lower the amount and cost of frequency regulation procured by PJM, and thus, the costs passed through to ratepayers
- Increase regional peak power generation capacity in PJM
- Help to facility the use of intermittent renewable wind and solar power by mitigating control issues created by the frequent and relatively unpredictable changes in output
- Reduce CO_2 greenhouse gas and other air emissions from fossil fuel generation resources providing frequency regulation services in PJM
- Reduce national dependence on fossil fuel by reducing usage of traditional generation resources to provide frequency regulation services in PJM

In short, Hazle intended to produce many of the system benefits described above based on the flywheel-based energy storage system ability to quickly respond (within two [2] seconds) to a signal provided by the grid operator. This added a fast ramping and fast responding regulation resource in the PJM control area with which to procure frequency regulation capacity and service. With its fast ramping capability, Hazle allows PJM to use less regulation capacity to meet current NERC standards, thus lowering regulation costs. In addition, as fast ramping regulation resources are significantly more effective at responding to system imbalances than slower-ramping generation resources, a resource such as the Hazle Facility lowers the overall amount of frequency regulation service procured by PJM to satisfy its obligation to maintain system reliability.

Finally, this project also supports the aims of the United States Energy Storage Competitiveness Act of 2007 (42 U.S. Code § 17231) (an act to enhance the energy security of the United States by promoting various energy technologies, including energy storage) by providing a best practice example for storage-based frequency regulation that can be replicated by grid operators in other control areas of the United States, through the application of smart grid technology that improves reliability, decreases costs, and reduces CO_2 emissions.

2. DESCRIPTION OF THE HAZLE FACILITY

The Hazle Facility is a 20 MW system that is composed of 20 1 MW pods, each with 10 flywheels and related electronics and controls (see Figure 1 and Figure 2 below). The Beacon Power flywheel-based energy storage system (FESS) is designed to operate on the power grid and to run autonomously with a power command signal coming from PJM. The Hazle Facility has 24/7 offsite monitoring by a third party vendor (for major faults only) and 24/7 on-call by the Beacon Power Operations Group (all faults).

Each flywheel is controlled by a flywheel control module (FCM). The FCM monitors all of the key parameters of the flywheel, such as vibrations, temperatures, pressures, currents, and voltages. If a parameter falls out of acceptable limits, the flywheel will go into idle mode or shut down, depending on the fault. A message is sent to the Control Center (inside the electronics container), and the fault code is passed on to the Beacon Power Operations Group via text message. The Operations Group will remotely log in to the system to correct the fault. If the fault cannot be reset, the field service personnel will be dispatched to the plant to correct the problem. Similar monitoring happens with other systems on-site. Depending on the severity of the fault, PPL Energy Plus will see the fault on its 24/7 monitoring system and contact the Beacon Power Operations Group. Together, they will decide on the appropriate corrective action. The vast majority of faults can be solved and reset remotely or by dispatching a technician and the Hazle Facility has not experienced a fault that has resulted in an emergency condition.

Each of the Hazle Facility's 1MW pods has the following subcomponents:

- Main system
  - 1MW Electronics container with the main 480VAC, 1MW switchgear (1 per container)
    - Electronic Conversion Module (ECM) (10 per container)
    - Flywheel Control Modules (FCM) (10 per container)
    - Control Center (1 per container)
  - Flywheel foundations with installed flywheels (10 per container)
- Balance of Plant (BoP)
  - Process cooling system (1 per container*)*
    - Pump-house (1 per two containers*)*
    - Chillers (2 per container)
    - Dry-coolers (1 per container)
  - Vacuum system (10 per container, *one per flywheel)*
  - Dust control systems (DCS) (1 per flywheel, *partially in container and partially next to the flywheel)*
  - Power distribution wiring and data wiring (whole site)
  - 2,000 kVA pad mount transformers 13.8kV to 480VAC, (1 per two containers, *shared with two 1MW flywheel energy storage systems)*

Figure 1 - Overview of plant, in Hazle, PA, with 200 flywheels (20MW capacity)

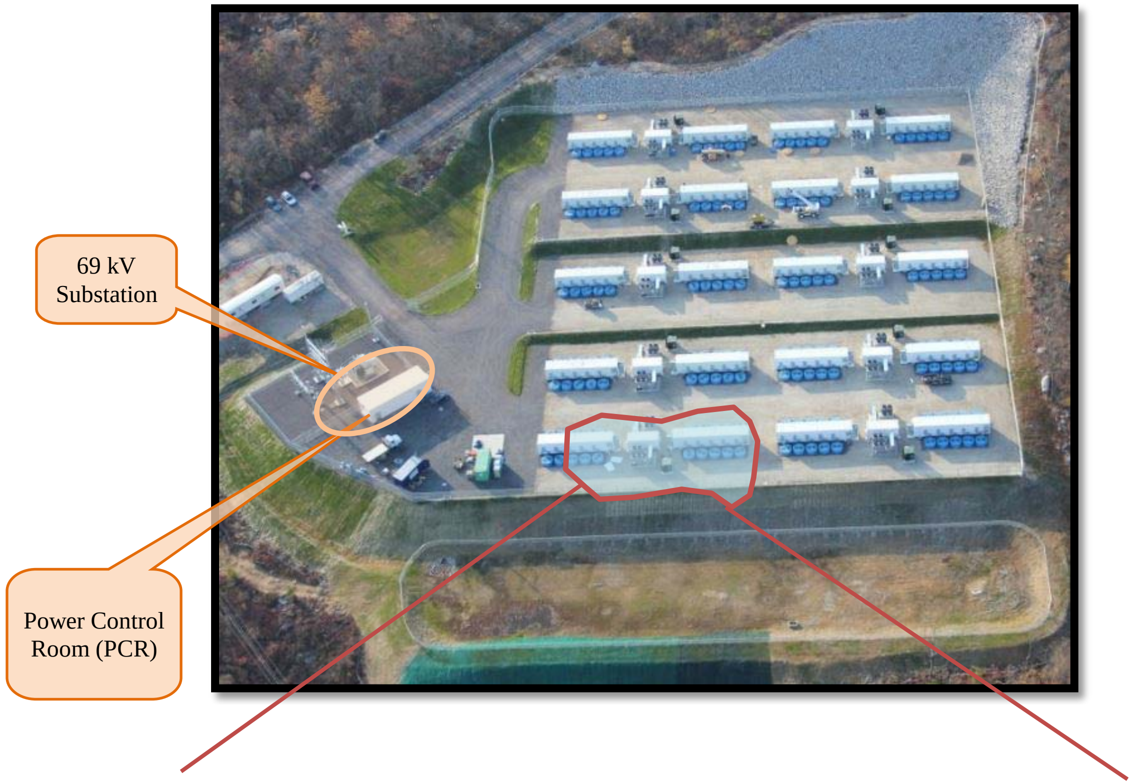
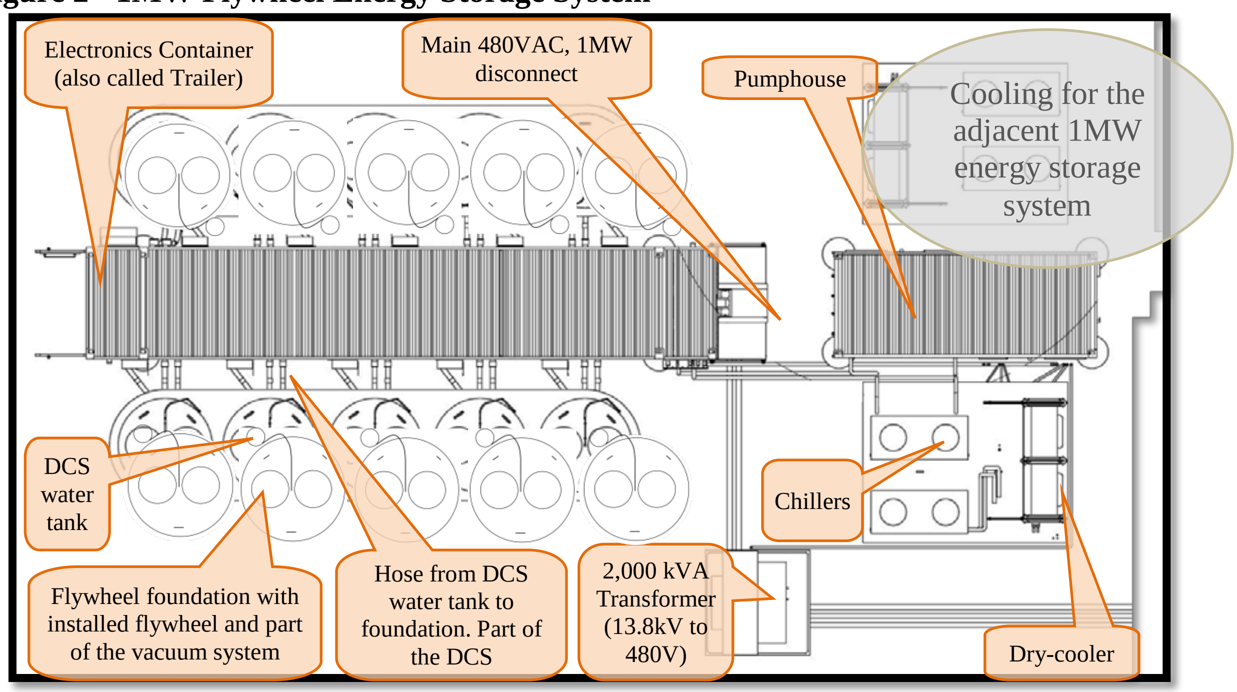


Figure 2 - 1MW Flywheel Energy Storage System



The Hazle Facility was commissioned in stages as construction of the project progressed. The key dates in the construction/commissioning of the Hazle Facility were:

• Groundbreaking – Spring 2013
• Began operation at 4 MW – September 2013
• Major site work complete – April 2014
• Last flywheel delivered – July 2014
• Full commercial operation at 20 MW – July 2014

As noted above, from groundbreaking to full commercial operation the construction of the Hazle Facility took a little more than one year. Importantly, due to the modularity of the facility's design, Hazle was able to begin commercial operation with a portion of its output within approximately six months of groundbreaking.

3. DESCRIPTION OF THE PERFORMANCE METRICS

The Hazle Facility was developed to participate in the PJM ancillary services markets through its provision of frequency regulation service. Frequency regulation is a product that PJM procures in order to balance the system generation and load at any given time to maintain system frequency at or near sixty (60) Hertz (Hz). All assets in PJM providing frequency regulation service (including the Hazle Facility) receive a signal from PJM (the Automatic Generation Control signal [AGC]) that instructs the asset to either increase or curtail its output to provide the desired balance between generation and load on its system and thus maintain system frequency. Hazle responds to the RegD signal, namely the signal that requires the fastest response from a resource providing frequency regulation service in PJM.

Recognizing that Hazle's participation in the PJM ancillary service markets is the source of information with regard to its performance, the following metrics were used to analyze the project's satisfaction of its objectives:

1. *The Hazle Facility's availability throughout the period*. The Hazle Facility's availability was demonstrated by its average availability by month, calculated by: dividing (i) (the Hazle Facility's total MW hours (MWh) of frequency regulation service; by (ii) the Hazle Facility's maximum possible MWh of frequency regulation service. This calculation accounts for any time the plant is offline or de-rated in capacity due to a plant equipment problem.

2. *The Hazle Facility's performance score in its provision frequency regulation services throughout the period*. In providing frequency regulation services in the PJM ancillary services market, PJM calculates the Hazle Facility's performance score, a measure of how accurately the facility is following the RegD signal.[3] After demonstrating the high level of accuracy with which the Hazle Facility responds to the RegD signal, the Hazle Facility's performance score provided by PJM was compared with that of: (i) traditional

[3] PJM calculates Hazle's performance score in accordance with the methodology set forth in PJM Manual 12. PJM then provided Hazle with its performance score in connection with the determination of compensation for Hazle's frequency regulation service.

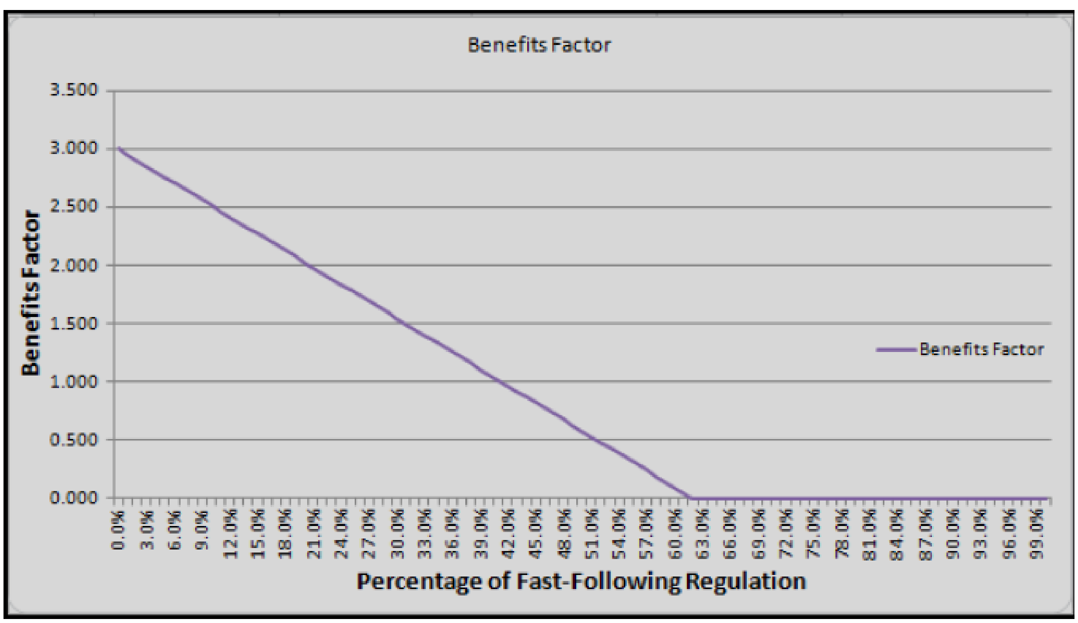
resources providing frequency regulation in PJM (e.g., fossil-fuel generation resources) and (ii) PJM's system average for all resources providing frequency regulation services.

3. *The Hazle Facility's mileage throughout the period*. "Mileage" is the term that describes the amount of work that a frequency regulation resource performs in response to the AGC signal. Specifically, mileage equals the sum of the absolute values of changes in a frequency regulation resource's output level from one AGC dispatch interval (2 seconds in PJM) to the next. As the Hazle Facility injects and absorbs energy from the PJM system, it is said to "move" up as its increases its state of charge (absorbing energy) and down as it decreases its state of charge (injecting energy). Overall, a frequency regulation resource providing a greater amount of movement for the PJM system is providing a greater amount of balancing of generation and load for the system.

   In the subsequent section, the Hazle Facility's mileage was compared with the average mileage provided by resources responding to the RegA signal (which does not require a resource to respond as quickly as the RegD signal).

4. *The Hazle Facility's Benefits Factor throughout the period.* PJM assigns each fast-responding frequency regulation resource that is following the RegD signal a unique Benefits Factor that impacts the amount of capacity each resource contributes towards meeting PJM's total frequency regulation market procurement. The Benefits Factor is determined on a sliding scale based on the penetration of RegD resources in the market as shown in Figure 3 below. As part of the presentation on market impacts we report on Hazle's Benefits Factor.

Figure 3 – Benefits Factor



5. *The total PJM Regulation Market Payments*. The total PJM Regulation Market Payments with the Hazle Facility was compared with the estimated PJM Regulation Market

Payments without the Hazle Facility. The PJM Regulation Market Payments for each resource are determined on an hourly basis and reflect the following factors:

- PJM Assigned Regulation MW – determined through PJM's commitment process
- Regulation Market Capability Clearing Price in $/MW/hr – published by PJM
- Regulation Market Performance Clearing Price in $/MW/hr – published by PJM
- Performance score – calculated by PJM for each resource
- Mileage Ratio – calculated by PJM for RegD resources; 1.00 for RegA resources
- Lost Opportunity Cost Credit – calculated by PJM for each resource

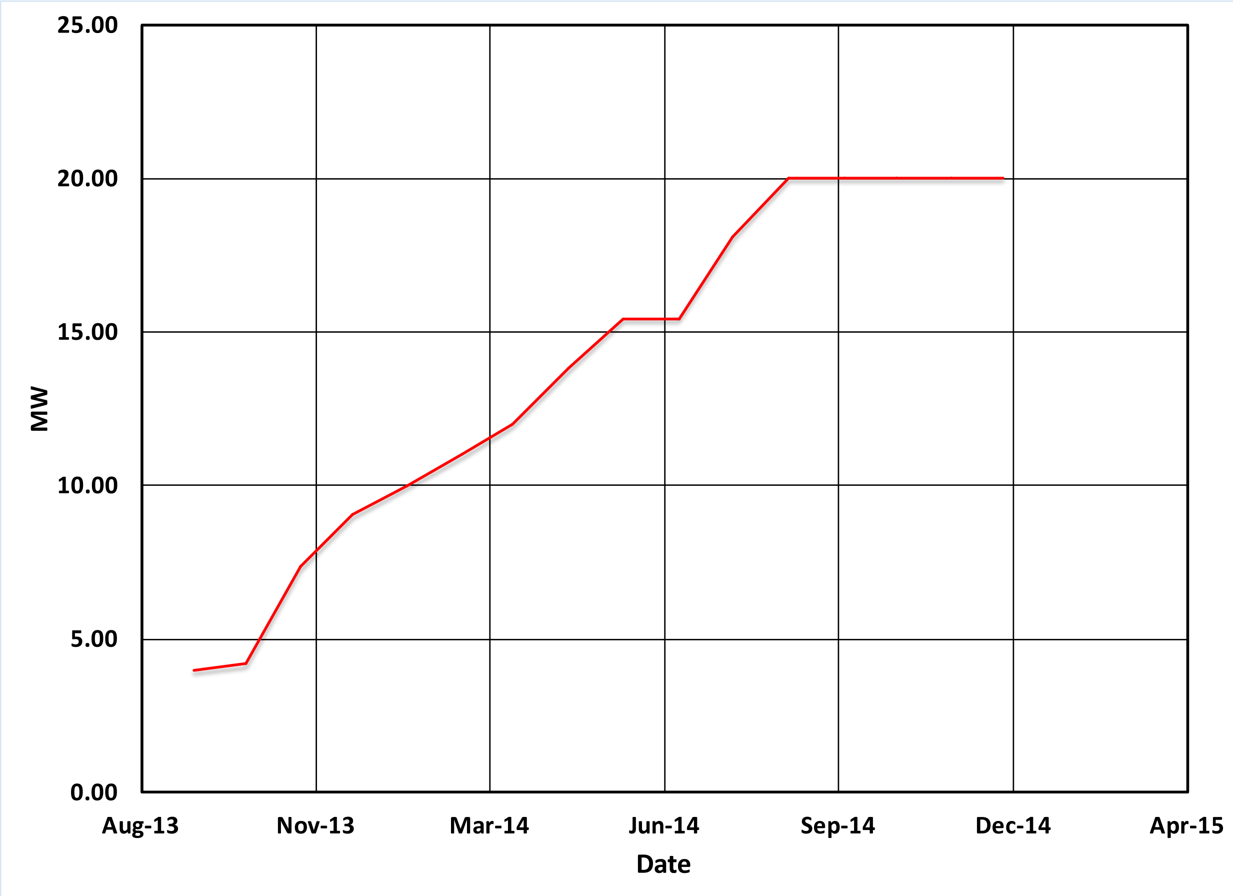
The total PJM Regulation Market Payments without the Hazle Facility was estimated based on the incremental RegA Regulation Market Payments that would have been required without the Hazle Facility plus the overall Regulation Market price impact of having to procure additional Regulation Market resources at a higher price.

6. *The amount of CO_2 and other air emissions.* The total reduction of CO_2 and other air emissions were estimated on a theoretical basis to demonstrate the potential reduction resulting from the introduction of the Hazle Facility to the PJM Regulation Market. This calculation recognizes that a reduction in the need for traditional fossil-fuel generation resources to move to provide frequency regulation service allows operation of these facilities at more efficient set points than achievable with constant set point fluctuation.

4. TECHNOLOGY PERFORMANCE RESULTS

The Hazle Facility began commercial operation on September 11, 2013 with an initial capacity of 4 MW. As noted above, the Hazle Facility is comprise of twenty 1 MW pods, which allowed Hazle to augment its capacity in commercial operations by subsequent 2 MW increments. Figure 4 below shows specifically the increase in capacity over time.

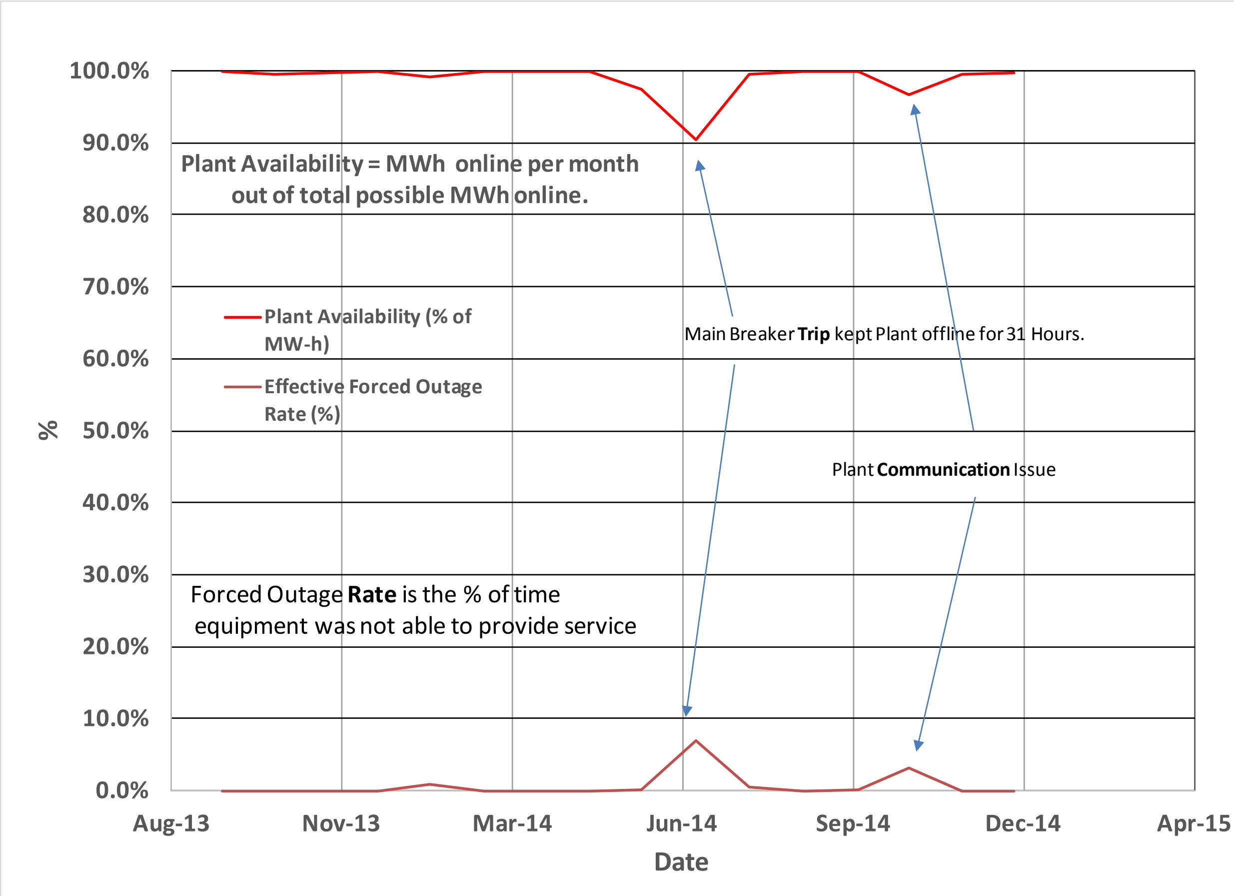
Figure 4 - MW Capacity



AVAILABILITY

Figure 5 demonstrates the availability of the Hazle Facility from its initial commissioning through the present. The red line at the top of the graph represents the plant's availability in a percentage basis. The lighter red line at the bottom of Figure 5 shows the plant's forced outage rate, the percentage of time that the Hazle Facility's equipment was not able to provide frequency regulation service. As demonstrated on Figure 5, the Hazle Facility had only two events in which significant frequency regulation service time was lost. The first such event occurred in June 2014 when the facility's main breaker tripped due to an improper setting and had to be reset. The second such event occurred in September 2014 when one of the plant computers experienced a communication problem. Overall, the plant has had an availability of almost 98% since it began commercial operation in September 2013.

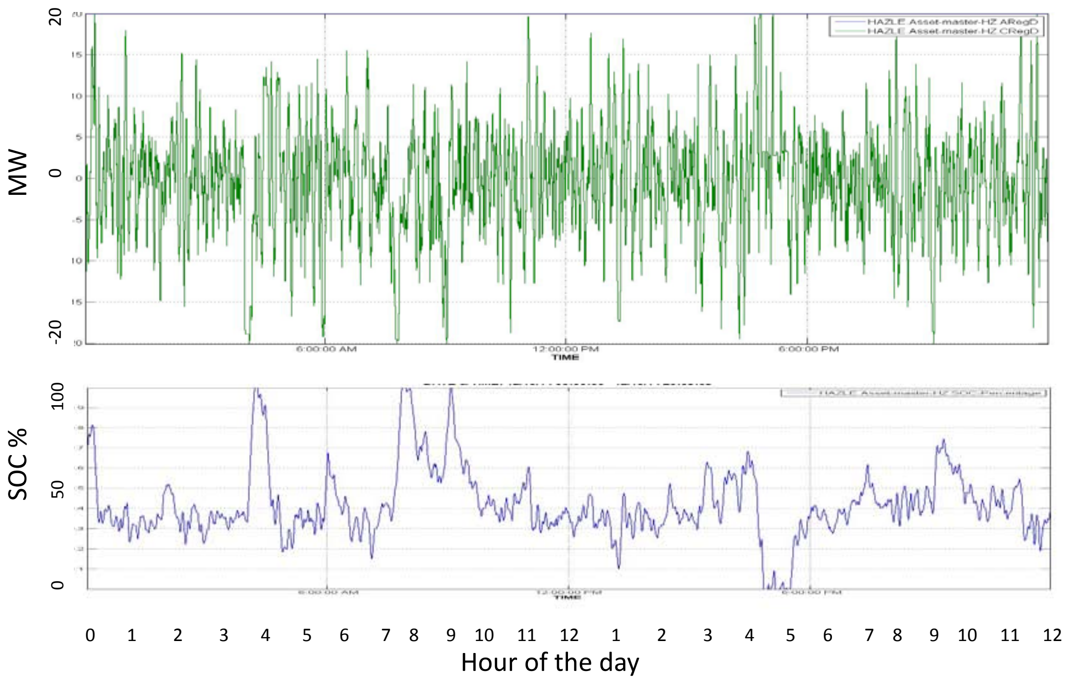
Figure 5 - Plant Availability and Forced Outage Rate



PERFORMANCE SCORE

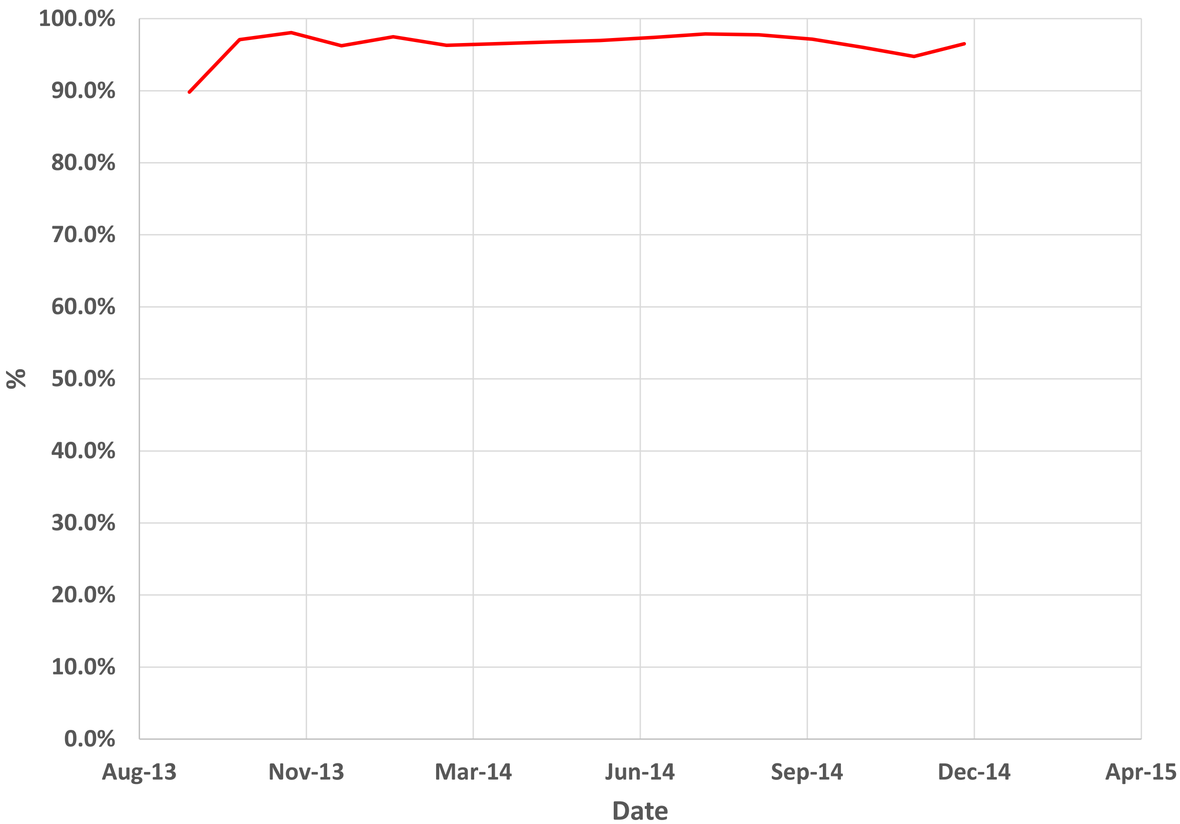
Figure 6 below shows a typical day of a “PJM RegD” dispatch signal and the state of charge for the Hazle Facility (December 15, 2014). As can be seen, the Hazle Facility experiences many power cycles in which it is initially required to absorb 20 MW of energy from the PJM system and then directed to inject 20 MW of energy into the PJM system. With only a few exceptions, the Hazle Facility is online 24 hours a day/7 days a week, receiving a signal requiring movement such as that set forth in Figure 6. The response of the Hazle Facility to such a signal is not visible on this plot as the Hazle Facility follows the signal so accurately that the lines are on top of each other.

Figure 6 – Typical Regulation Signal and SOC for a 24 Hour Period – December 15, 2014



The accuracy with which the Hazle Facility responds to the RegD signal greatly enhances its performance score from PJM. In fact, Figure 7 below shows the average PJM performance score for the Hazle Facility since commercial operation began in September 2013. As can be seen, since the first few weeks when Hazle optimized its control software, the Hazle Facility has been tracking to signal with over 97% accuracy. These performance scores are based on the point of connection plant revenue meter, as calculated by PJM as part of the settlement process.

Figure 7 - Performance Score



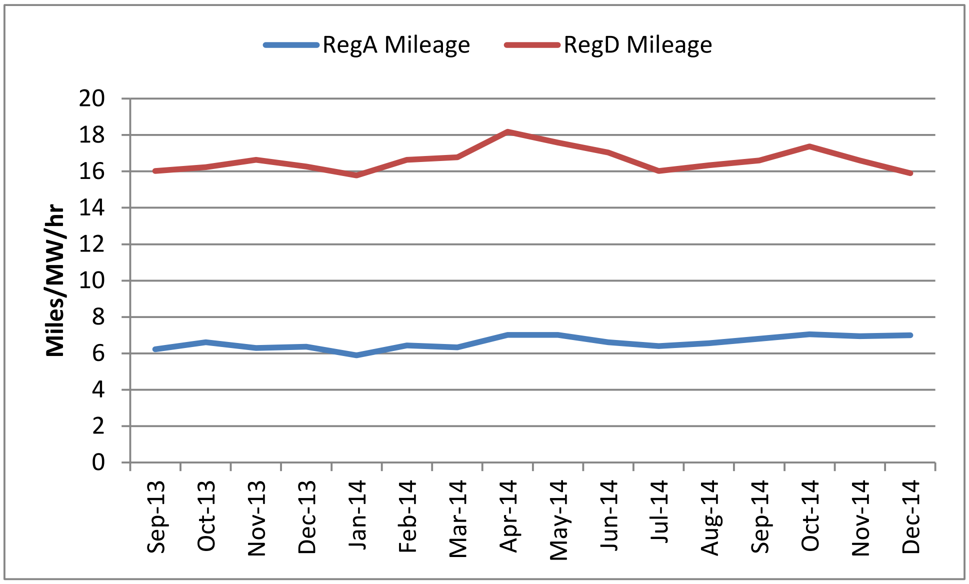
The Hazle's Facility performance score is particularly impressive when compared to the average performance score of all resources performing regulation in PJM (per data on the PJM eMKT system[4]), which was 80% for 2014. In the fourth quarter of 2012, the average performance score of all resources performing regulation in PJM was 74%, which is more representative of traditional, thermal units given the lower penetration of RegD resources in the early days of the market.

MILEAGE

As shown in Figure 7 below, during its commercial operation the Hazle Facility has performed approximately 16 to 18 miles/MW/hour, resulting in approximately 250,000 miles a month. By comparison, RegA resources have performed an average of 6.6 miles/MW/hour over this period. Thus, over this period the Hazle Facility has provided approximately 2.5 times the mileage of a RegA resource and thus, has been significantly more effective at correcting frequency deviations quickly and effectively.

[4] PJM's "eMKT system" allows resources to submit and obtain data that is necessary for participation in the PJM frequency regulation market. Importantly, the PJM eMKT allows market participant to review public and private ancillary services market results.

Figure 8 - Mileage



5. GRID IMPACTS AND BENEFITS

BENEFITS FACTOR

By participating in the PJM Regulation Market under the RegD signal, each MW of the Hazle Facility displaced approximately 2.3 MW of RegA resources in 2014 based on the resource-specific Benefits Factor assigned to the Hazle Facility by PJM on an hourly basis. The Hazle Facility's hourly Benefits Factors ranged from 0.7 to 2.8 during 2014 as reported in the Hazle Facility's hourly PJM settlement data. Table 1 below summarizes the average Benefits Factor for the Hazle Facility by month, as well as the average equivalent MW/hr of RegA resources avoided in the market, which is calculated on an hourly basis and reflects the Hazle Facility's hourly performance score as well as the Benefits Factor. The average of 34.9 MW/hr of RegA resources avoided results in a significant overall benefit in total PJM Regulation Market costs as illustrated in the next section.

Table 1 – Monthly Hazle Benefits Factor Impacts

Month	Average Hazle Benefits Factor	Average Hazle Assigned Reg MW	Average Hazle RegA MW Avoided
Jan-14	2.44	9.9	23.5
Feb-14	2.40	10.9	24.2
Mar-14	2.36	12.0	27.2
Apr-14	2.29	13.7	29.4
May-14	2.16	15.2	31.2
Jun-14	2.31	15.4	31.4
Jul-14	2.25	17.9	37.9
Aug-14	2.30	20.0	43.7
Sep-14	2.25	19.7	40.1
Oct-14	2.24	20.0	41.9
Nov-14	2.28	20.0	43.1
Dec-14	2.31	20.0	44.4
2014	**2.30**	**16.2**	**34.9**

PJM REGULATION MARKET PAYMENTS

Based on PJM settlement data, total Regulation Market payments to the Hazle Facility were approximately $6.0 million in 2014. On an hourly basis, the estimated increase in PJM Regulation Market payments without the Hazle Facility was calculated based on the amount of RegA MW avoided by the Hazle Facility times the Regulation Market prices for capability and performance in the hour. Table 2 below illustrates the Hazle Facility Regulation Market payments by month, as well as the average monthly Regulation Market prices and the Regulation Market payments avoided by the Hazle Facility. During 2014, it is estimated that the Hazle Facility reduced the overall PJM Regulation Market payments by approximately $5.9 million due to the application of the Benefits Factor by PJM, which recognizes the greater effectiveness of the fast-responding Regulation Market resources.

Table 2 – Impact on PJM Regulation Payments

Month	Hazle Regulation Payments ($mil)	Average Hazle RegA MW Avoided	Average Regulation Capability Price ($/MW/hr)	Average Regulation Performance Price ($/MW/hr)	RegA Payments Avoided ($mil)	Hazle PJM Reg Payment Impact ($mil)
Jan-14	$1.1	23.5	$130.45	$8.54	$2.3	$1.3
Feb-14	$0.5	24.2	$57.06	$5.09	$1.0	$0.5
Mar-14	$0.7	27.2	$73.44	$4.37	$1.6	$0.9
Apr-14	$0.3	29.4	$26.88	$3.41	$0.7	$0.3
May-14	$0.4	31.2	$30.21	$3.34	$0.8	$0.4
Jun-14	$0.4	31.4	$26.17	$3.50	$0.7	$0.3
Jul-14	$0.4	37.9	$25.02	$3.57	$0.8	$0.4
Aug-14	$0.4	43.7	$16.50	$3.38	$0.7	$0.3
Sep-14	$0.4	40.1	$20.69	$3.32	$0.7	$0.3
Oct-14	$0.5	41.9	$27.73	$4.12	$1.0	$0.5
Nov-14	$0.4	43.1	$23.32	$3.43	$0.8	$0.4
Dec-14	$0.4	44.4	$17.90	$2.73	$0.7	$0.3
2014	**$6.0**	**34.9**	**$39.63**	**$4.07**	**$11.9**	**$5.9**

In addition to the direct PJM Regulation Market benefits estimated due to the Benefits Factor, the Regulation Market prices paid to all resources were also likely lowered by the need to procure fewer MW of regulation resources in the market. A regression analysis was developed to determine a relationship between the total price of Regulation (capability plus performance) and two significant factors – the price of energy (based on Western Hub LMP) and the MW quantity of RegA resources procured in the market. Both factors were based on hourly values as published by PJM. The MW quantity of RegA resources procured in the market tends to be the most common regulation price-setting capacity, as self-scheduled capacity and RegD procured capacity tend to have price offers in the market at or near $0/MW/hr. The regression analysis showed a strong correlation between the total regulation price and these two variables (0.81 adjusted R-sq) and a coefficient for the RegA procured MW that estimates a total regulation price impact of $0.069/MW/hr for each MW increase in RegA capacity procured.

The total PJM Regulation Market payments with the Hazle Facility were taken from Table 10-37 of the 2014 State of the Market Report for PJM published by Market Analytics, PJM's Independent Market Monitor (IMM). In order to estimate the impact on total PJM Regulation Market payments without the Hazle Facility, a percentage increase in total Regulation Market price was estimated on a monthly basis based on the average RegA MW avoided by the Hazle Facility and the price impact coefficient of $0.069/MW/hr from the regression analysis. This percentage was then multiplied by the actual PJM Regulation Market payments by month to get the estimated PJM Regulation Market impact of the Hazle Facility due to price reductions, which is estimated at $14.2 million in 2014 as shown in Table 3 below.

Table 3 – Estimated PJM Regulation Market Price Impact

Month	Total PJM Regulation Market Payments ($mil)	Avg. PJM Regulation Market Price ($/MW/hr)	Average Hazle RegA MW Avoided	Average Regulation Price Impact ($/MW/hr)	Average Regulation Price Impact %	Average Regulation Payment Benefit ($mil)
Jan-14	$65.7	$138.99	23.5	$1.63	1.17%	$0.8
Feb-14	$27.3	$62.14	24.2	$1.68	2.70%	$0.7
Mar-14	$40.1	$77.82	27.2	$1.88	2.42%	$1.0
Apr-14	$15.2	$30.29	29.4	$2.03	6.71%	$1.0
May-14	$17.0	$33.55	31.2	$2.16	6.44%	$1.1
Jun-14	$14.3	$29.68	31.4	$2.18	7.33%	$1.0
Jul-14	$14.5	$28.59	37.9	$2.62	9.17%	$1.3
Aug-14	$10.0	$19.88	43.7	$3.02	15.21%	$1.5
Sep-14	$11.9	$24.01	40.1	$2.78	11.56%	$1.4
Oct-14	$15.5	$31.85	41.9	$2.90	9.10%	$1.4
Nov-14	$12.6	$26.75	43.1	$2.98	11.15%	$1.4
Dec-14	$9.9	$20.63	44.4	$3.07	14.90%	$1.5
2014	**$254.0**	**$43.70**	**34.9**			**$14.2**

A further PJM market benefit of the Hazle Facility could be estimated through price impacts in the PJM energy market. By displacing an average of 34.9 MW of RegA resources in the Regulation Market, this capacity was then available to participate in the PJM energy market and thus, likely resulted in slightly lower energy prices paid to all resources in the PJM market. However, due to the size of the PJM energy market (91,701 MW average in 2014) relative to the amount of incremental capacity displaced in the Regulation Market by the Hazle Facility, we did not attempt to quantify the potential PJM energy market impact associated with the Hazle Facility. However, the other two market factors suggest that the PJM market benefit associated with Hazle Facility was approximately $20 million in 2014.

CO_2 AND OTHER AIR EMISSIONS

Through its participation in the PJM Regulation Market, the Hazle Facility reduces the amount of CO_2 and other air emission produced by the generators in the PJM control area, but its precise calculation cannot be determined based on market data (*e.g.,* it is not known which specific resources are displaced by the Hazle Facility and the exact benefits from such displacement). However, to demonstrate the theoretical reduction, the following analysis is instructive.

At its full capacity of 20 MW/hour, the Hazle Facility would displace an average of approximately 45 MW/hour of traditional thermal generation, based on the Hazle Facility's average Benefits Factor of 2.30 and average performance score of 97%. This displaced generation capacity would then be able to participate in the PJM energy market. Since the 45

MW/hour reflects effective capacity (in other words, it takes into account the performance scores of the resources), if we assume a 74% average performance score for the thermal units (based on the market average performance score for all resources in PJM for the fourth quarter of 2012), then the amount of incremental thermal capacity that is displaced and thus allowed to now participate in the energy market would be closer to an average of approximately 60 MW.

Moreover, the displaced thermal capacity has the added benefits of (i) not being required to constantly change set-points based on the AGC signal, and thus, (ii) not operating at a suboptimal set-points. These benefits allow the displaced thermal capacity to operate at more efficient set-points, thus lowering heat rates and emissions rates. In addition, because it is likely that the displaced thermal capacity is not all coming from the marginal system resources, it is likely that the incremental heat rates and emissions rates for the units that can be operated more efficiently are likely to be significantly less than the marginal system heat rate and emissions rate that can be avoided.

The following example (based on a few market assumptions noted below) attempts to better demonstrate the benefits of the Hazle Facility's displacement of thermal resources (assumed to be Combined Cycle Gas Turbines [CCGT]) that provide frequency regulation.

Assumptions:

- CCGT unit maximum capacity = 250 MW/unit
- CCGT unit capacity providing frequency regulation = 15 MW/unit
- CCGT average performance score = 75%
- CCGT effective regulation capacity = 11.25 MW/unit
- Full load average CCGT heat rate = 7,000 Btu/kWh
- Heat rate penalty while providing frequency regulation = 3% of full load average
- Marginal system (peaker) heat rate = 10,500 Btu/kWh
- Average CO_2 emissions rate = 120 lbs/MMBtu (based on natural gas)

Table 4 – Sample Reduction in CO_2 Emissions

	Max MW	Effective Reg MW	Dispatch MW	Average Btu/kWh	Fuel MMBtu	CO2 tons
Without Hazle						
Hazle	0	0	0	0	0	0
CCGT1	250	11	235	7,210	1,694	102
CCGT2	250	11	235	7,210	1,694	102
CCGT3	250	11	235	7,210	1,694	102
CCGT4	250	11	235	7,210	1,694	102
Peaker	60	0	60	10,500	630	38
		45	**1,000**		**7,407**	**444**
With Hazle						
Hazle	20	45	0	0	0	0
CCGT1	250	0	250	7,000	1,750	105
CCGT2	250	0	250	7,000	1,750	105
CCGT3	250	0	250	7,000	1,750	105
CCGT4	250	0	250	7,000	1,750	105
Peaker	60	0	0	10,500	0	0
		45	**1,000**		**7,000**	**420**
				CO2 reduction - tons/hr		**24**
				CO2 reduction - tons/yr		**214,129**

Per the example above, without the Hazle Facility 45 MW of frequency regulation is provided by the CCGT units, which must back down by a total of 60 MW and are replaced for energy by a peaking unit at an average heat rate of 10,500 Btu/kWh. The units are also assumed to incur a 3% average heat rate penalty when providing frequency regulation, thus increasing their average heat rate from 7,000 Btu/kWh to 7,210 Btu/kWh. In this example, the total hourly CO_2 emissions of these units are 444 tons/hour.

With Hazle, the 45 MW of frequency regulation service provided by the CCGT units can be provided by the 20 MW Hazle Facility after taking into account the Benefits Factor (2.30) and performance score (97%). Now the CCGT units can all operate at their full capacity and most efficient heat rate, and the marginal peaking unit is no longer needed to supply energy. In this case, the total hourly CO_2 emissions of these units are reduced to 420 tons/hour, a reduction of 24 tons/hour due to the Hazle Facility.

Over the course of a year, this reduction would amount to a reduction of over 210,000 tons of CO_2 due to the Hazle Facility. Actual emissions reductions will vary based on the actual resources displaced by the Hazle Facility, the heat rate inefficiency introduced by using these thermal resources to provide frequency regulation, and the actual marginal heat rate of additional thermal resources that are required to provide energy. However, under a wide range of actual results it is anticipated that the Hazle Facility would result in significant reductions in CO_2 and other emissions.

6. MAJOR FINDINGS AND CONCLUSIONS

The Hazle Facility is fully commissioned and in service 24 hours a day, 7 days a week, providing frequency regulation services to PJM with an average performance score of 97% and average availability of 98%. The introduction of the Hazle Facility has provided PJM with numerous benefits, including a reduction in: (i) the total amount of frequency regulation required; (ii) the total cost of frequency regulation procured; and (iii) the amount of CO_2 and other air emissions produced by generators in the PJM control area. Thus, the Hazle Facility has successfully demonstrated its technical, cost and environmental benefits to the PJM grid.

In addition, in its development of a 20 MW flywheel-based energy storage facility using Beacon Power, LLC flywheel technology, Hazle was able to significantly reduce the cost from that experienced by a previous development of a similar facility. Specifically, the cost of developing the Hazle Facility (approximately $53 million) was approximately 38% less than the cost of developing a 20 MW flywheel-based energy storage facility using Beacon Power, LLC flywheel technology in Stephentown, NY (approximately $69 million). Moreover, the development and operation of the Hazle Facility has led to a further reduction in the cost of future flywheel-based energy storage facilities. Specifically, unlike the Hazle Facility which houses power electronics for flywheels in 10 flywheel (or 1 MW) pods, current projects are based on a more modular design with the power electronics for each flywheel in its own individual housing. This allows for greater flexibility in scaling projects and reduces the footprint of any future project.

Unfortunately, the Hazle Facility did not provide adequate data to demonstrate that the Hazle Facility "stimulate[d] the international market demand for flywheel-based energy storage" or "reduce[d] national dependence on fossil fuel". While the Hazle Facility did reduce the usage of traditional generation resources to provide frequency regulation services in PJM, there is no market data that would allow anything but an inference of the effect of such reduction on national dependence. Any additional findings with respect to these matters will be included in the Final Technical Report.

7. FUTURE PLANS

The plant is designed for 20-year life and is expected to stay online as long as maintained according to recommended maintenance procedures. Currently, Beacon Power LLC is contracted by Hazle Spindle LLC to operate and maintain the facility according to the approved plans. O&M and Administrative Services Agreements are in place between the entities. Beacon will continue to monitor performance (primarily maximum capacity, availability and performance scores, which affect revenues) as well as maintenance cost to assure maximum profitability. In addition Hazle Spindle/Beacon will remain active in the PJM stakeholder process to stay up to date and influence, where possible, tariff changes that may affect plant performance and economics.

Appendix A – Quarterly Build Metrics

Project	DE-OE000020C Beacon Power (20 MW Flywheel Frequency Regulation Plant)		
Filing	build_quarterly	Build Metrics Quarterly Report Quarter 3, 2013	
Period	Start: Jul 1, 2013	End: Sep 30, 2013	Submission Due Date: December 06, 2013

Distributed Energy Resources - Build Metrics

All data should be cumulative. Project data pertains to the assets or programs that are funded by the ARRA and Recipient Cost Share. System data should include both project data and any like assets or programs that are deployed in the entire service territory. The system value should be equal to or greater than the project value.

Distributed Energy Resources	Units	Project	System
Distributed generation: number of units	#	0	0
Distributed generation: installed capacity	kW	0.0	0.0
Distributed generation: total energy delivered	* kWh	0	0
Energy storage: number of units	#	57	57
Energy storage: installed capacity	kW	4,000	4,000
Energy storage: total energy delivered	* kWh	155,790	155,790
Plug-in electric vehicles charging points: number of units	#	0	0
Plug-in electric vehicles charging points: installed capacity	kW	0.0	0.0
Plug-in electric vehicles charging points: total energy delivered	* kWh	0.0	0.0
DER/DG interconnection equipment: number of units	#		

* *Energy delivered should be reported just for the quarter being reported, not cumulative for the project to-date.*

Distributed Energy Resource Descriptions	Project	System
Distributed Generation Interface Description	In this application, the flywheel plant is not considered distributed generation. It is providing the regulation ancillary service to PJM.	

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Additional Project Descriptions

The site configuration starts at the existing 69kV line and proceeds to the 12/16/20 69kV to 13.8kV power transformer and then to the 15kV class Substation Switch Gear. The switch gear is split into two separate circuits with 10MW on each circuit which are loop fed into five 13.8kV to 480V pad mounted distribution transformers. Connected to each pad mount transformers are two 1MW groupings of Flywheels. Each 1MW grouping consists of ten 100kW flywheels.

Distributed Energy Resources' Installed Costs	Units	Project Funded	Cost Share
DER Interface Control Systems	$		
Communications Equipment	$		
DER/DG Interconnection Equipment	$		
Renewable DER	$	0	0
Distributed Generation Equipment	$	0	0
Stationary Electric Storage Equipment	$	5,052,390	5,952,598
PEVs and Charging Stations	$	0	0
Other Costs	$		

Other Cost Description

Project	DE-OE000020C Beacon Power (20 MW Flywheel Frequency Regulation Plant)		
Filing	build_quarterly	Build Metrics Quarterly Report Quarter 4, 2013	
Period	Start: Oct 1, 2013	End: Dec 31, 2013	Submission Due Date: January 31, 2014

Distributed Energy Resources - Build Metrics

All data should be cumulative. Project data pertains to the assets or programs that are funded by the ARRA and Recipient Cost Share. System data should include both project data and any like assets or programs that are deployed in the entire service territory. The system value should be equal to or greater than the project value.

Distributed Energy Resources	Units	Project	System
Distributed generation: number of units	#	0	0
Distributed generation: installed capacity	kW	0.0	0.0
Distributed generation: total energy delivered	* kWh	0	0
Energy storage: number of units	#	109	109
Energy storage: installed capacity	kW	10,000	10,000
Energy storage: total energy delivered	* kWh	1,577,990	1,577,990
Plug-in electric vehicles charging points: number of units	#	0	0
Plug-in electric vehicles charging points: installed capacity	kW	0.0	0.0
Plug-in electric vehicles charging points: total energy delivered	* kWh	0.0	0.0
DER/DG interconnection equipment: number of units	#		

* *Energy delivered should be reported just for the quarter being reported, not cumulative for the project to-date.*

Distributed Energy Resource Descriptions	Project	System
Distributed Generation Interface Description	In this application, the flywheel plant is not considered distributed generation. It is providing the regulation ancillary service to PJM.	

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Project	DE-OE000020C Beacon Power (20 MW Flywheel Frequency Regulation Plant)		
Filing	build_quarterly	Build Metrics Quarterly Report Quarter 4, 2013	
Period	Start: Oct 1, 2013	End: Dec 31, 2013	Submission Due Date: January 31, 2014

Additional Project Descriptions

The site configuration starts at the existing 69kV line and proceeds to the 12/16/20 69kV to 13.8kV power transformer and then to the 15kV class Substation Switch Gear. The switch gear is split into two separate circuits with 10MW on each circuit which are loop fed into five 13.8kV to 480V pad mounted distribution transformers. Connected to each pad mount transformers are two 1MW groupings of Flywheels. Each 1MW grouping consists of ten 100kW flywheels.

Distributed Energy Resources' Installed Costs	Units	Project Funded	Cost Share
DER Interface Control Systems	$		
Communications Equipment	$		
DER/DG Interconnection Equipment	$		
Renewable DER	$	0	0
Distributed Generation Equipment	$	0	0
Stationary Electric Storage Equipment	$	6,016,810	7,088,853
PEVs and Charging Stations	$	0	0
Other Costs	$		

Other Cost Description

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Project	DE-OE000020C Beacon Power (20 MW Flywheel Frequency Regulation Plant)					
Filing	build_quarterly	Build Metrics Quarterly Report Quarter 4, 2013				
Period	Start:	Oct 1, 2013	End:	Dec 31, 2013	Submission Due Date:	January 31, 2014

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Project	DE-OE000020C Beacon Power (20 MW Flywheel Frequency Regulation Plant)				
Filing	build_quarterly	Build Metrics Quarterly Report Quarter 1, 2014			
Period	Start: Jan 1, 2014	End: Mar 31, 2014		Submission Due Date:	April 30, 2014

Distributed Energy Resources - Build Metrics

All data should be cumulative. Project data pertains to the assets or programs that are funded by the ARRA and Recipient Cost Share. System data should include both project data and any like assets or programs that are deployed in the entire service territory. The system value should be equal to or greater than the project value.

Distributed Energy Resources	Units	Project	System
Distributed generation: number of units	#	0	0
Distributed generation: installed capacity	kW	0.0	0.0
Distributed generation: total energy delivered	* kWh	0	0
Energy storage: number of units	#	141	141
Energy storage: installed capacity	kW	14,000	14,000
Energy storage: total energy delivered	* kWh	2,623,200	2,623,200
Plug-in electric vehicles charging points: number of units	#	0	0
Plug-in electric vehicles charging points: installed capacity	kW	0.0	0.0
Plug-in electric vehicles charging points: total energy delivered	* kWh	0.0	0.0
DER/DG interconnection equipment: number of units	#		

* *Energy delivered should be reported just for the quarter being reported, not cumulative for the project to-date.*

Distributed Energy Resource Descriptions	Project	System
Distributed Generation Interface Description	In this application, the flywheel plant is not considered distributed generation. It is providing the regulation ancillary service to PJM.	

Additional Project Descriptions

The site configuration starts at the existing 69kV line and proceeds to the 12/16/20 69kV to 13.8kV power transformer and then to the 15kV class Substation Switch Gear. The switch gear is split into two separate circuits with 10MW on each circuit which are loop fed into five 13.8kV to 480V pad mounted distribution transformers. Connected to each pad mount transformers are two 1MW groupings of Flywheels. Each 1MW grouping consists of ten 100kW flywheels.

Distributed Energy Resources' Installed Costs	Units	Project Funded	Cost Share
DER Interface Control Systems	$		
Communications Equipment	$		
DER/DG Interconnection Equipment	$		
Renewable DER	$	0	0
Distributed Generation Equipment	$	0	0
Stationary Electric Storage Equipment	$	6,018,482	7,090,823
PEVs and Charging Stations	$	0	0
Other Costs	$		

Other Cost Description

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Project	DE-OE000020C Beacon Power (20 MW Flywheel Frequency Regulation Plant)				
Filing	build_quarterly	Build Metrics Quarterly Report Quarter 1, 2014			
Period	Start: Jan 1, 2014	End: Mar 31, 2014		Submission Due Date:	April 30, 2014

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Project	DE-OE000020C Beacon Power (20 MW Flywheel Frequency Regulation Plant)				
Filing	build_quarterly	Build Metrics Quarterly Report Quarter 2, 2014			
Period	Start: Apr 1, 2014	End: Jun 30, 2014		Submission Due Date:	July 31, 2014

Distributed Energy Resources - Build Metrics

All data should be cumulative. Project data pertains to the assets or programs that are funded by the ARRA and Recipient Cost Share. System data should include both project data and any like assets or programs that are deployed in the entire service territory. The system value should be equal to or greater than the project value.

Distributed Energy Resources	Units	Project	System
Distributed generation: number of units	#	0	0
Distributed generation: installed capacity	kW	0.0	0.0
Distributed generation: total energy delivered	* kWh	0	0
Energy storage: number of units	#	180	180
Energy storage: installed capacity	kW	18,000	18,000
Energy storage: total energy delivered	* kWh	3,297,800	3,297,800
Plug-in electric vehicles charging points: number of units	#	0	0
Plug-in electric vehicles charging points: installed capacity	kW	0.0	0.0
Plug-in electric vehicles charging points: total energy delivered	* kWh	0.0	0.0
DER/DG interconnection equipment: number of units	#		

* *Energy delivered should be reported just for the quarter being reported, not cumulative for the project to-date.*

Distributed Energy Resource Descriptions	Project	System
Distributed Generation Interface Description	In this application, the flywheel plant is not considered distributed generation. It is providing the regulation ancillary service to PJM.	

Additional Project Descriptions

The site configuration starts at the existing 69kV line and proceeds to the 12/16/20 69kV to 13.8kV power transformer and then to the 15kV class Substation Switch Gear. The switch gear is split into two separate circuits with 10MW on each circuit which are loop fed into five 13.8kV to 480V pad mounted distribution transformers. Connected to each pad mount transformers are two 1MW groupings of Flywheels. Each 1MW grouping consists of ten 100kW flywheels.

Distributed Energy Resources' Installed Costs	Units	Project Funded	Cost Share
DER Interface Control Systems	$		
Communications Equipment	$		
DER/DG Interconnection Equipment	$		
Renewable DER	$	0	0
Distributed Generation Equipment	$	0	0
Stationary Electric Storage Equipment	$	5,946,528	7,168,885
PEVs and Charging Stations	$	0	0
Other Costs	$		

Other Cost Description

SMARTGRID.GOV	Project	DE-OE000020C Beacon Power (20 MW Flywheel Frequency Regulation Plant)		
	Filing	build_quarterly	Build Metrics Quarterly Report Quarter 3, 2014	
	Period	Start: Jul 1, 2014	End: Sep 30, 2014	Submission Due Date: October 31, 2014

Distributed Energy Resources - Build Metrics

All data should be cumulative. Project data pertains to the assets or programs that are funded by the ARRA and Recipient Cost Share. System data should include both project data and any like assets or programs that are deployed in the entire service territory. The system value should be equal to or greater than the project value.

Distributed Energy Resources	Units	Project	System
Distributed generation: number of units	#	0	0
Distributed generation: installed capacity	kW	0.0	0.0
Distributed generation: total energy delivered	* kWh	0	0
Energy storage: number of units	#	200	200
Energy storage: installed capacity	kW	20,000	20,000
Energy storage: total energy delivered	* kWh	4,156,100	4,156,100
Plug-in electric vehicles charging points: number of units	#	0	0
Plug-in electric vehicles charging points: installed capacity	kW	0.0	0.0
Plug-in electric vehicles charging points: total energy delivered	* kWh	0.0	0.0
DER/DG interconnection equipment: number of units	#		

* *Energy delivered should be reported just for the quarter being reported, not cumulative for the project to-date.*

Distributed Energy Resource Descriptions	Project	System
Distributed Generation Interface Description	In this application, the flywheel plant is not considered distributed generation. It is providing the regulation ancillary service to PJM.	

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Additional Project Descriptions

The site configuration starts at the existing 69kV line and proceeds to the 12/16/20 69kV to 13.8kV power transformer and then to the 15kV class Substation Switch Gear. The switch gear is split into two separate circuits with 10MW on each circuit which are loop fed into five 13.8kV to 480V pad mounted distribution transformers. Connected to each pad mount transformers are two 1MW groupings of Flywheels. Each 1MW grouping consists of ten 100kW flywheels.

Distributed Energy Resources' Installed Costs	Units	Project Funded	Cost Share
DER Interface Control Systems	$		
Communications Equipment	$		
DER/DG Interconnection Equipment	$		
Renewable DER	$	0	0
Distributed Generation Equipment	$	0	0
Stationary Electric Storage Equipment	$	5,967,770	7,151,092
PEVs and Charging Stations	$	0	0
Other Costs	$		

Other Cost Description

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Project	DE-OE000020C Beacon Power (20 MW Flywheel Frequency Regulation Plant)				
Filing	build_quarterly	Build Metrics Quarterly Report Quarter 3, 2014			
Period	Start: Jul 1, 2014	End: Sep 30, 2014		Submission Due Date:	October 31, 2014

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Project	DE-OE000020C Beacon Power (20 MW Flywheel Frequency Regulation Plant)		
Filing	build_quarterly	Build Metrics Quarterly Report Quarter 4, 2014	
Period	Start: Oct 1, 2014	End: Dec 31, 2014	Submission Due Date: January 31, 2015

Distributed Energy Resources - Build Metrics

All data should be cumulative. Project data pertains to the assets or programs that are funded by the ARRA and Recipient Cost Share. System data should include both project data and any like assets or programs that are deployed in the entire service territory. The system value should be equal to or greater than the project value.

Distributed Energy Resources	Units	Project	System
Distributed generation: number of units	#	0	0
Distributed generation: installed capacity	kW	0.0	0.0
Distributed generation: total energy delivered	* kWh	0	0
Energy storage: number of units	#	200	200
Energy storage: installed capacity	kW	20,000	20,000
Energy storage: total energy delivered	* kWh	4,571,400	4,571,400
Plug-in electric vehicles charging points: number of units	#	0	0
Plug-in electric vehicles charging points: installed capacity	kW	0.0	0.0
Plug-in electric vehicles charging points: total energy delivered	* kWh	0.0	0.0
DER/DG interconnection equipment: number of units	#		

* *Energy delivered should be reported just for the quarter being reported, not cumulative for the project to-date.*

Distributed Energy Resource Descriptions	Project	System
Distributed Generation Interface Description	In this application, the flywheel plant is not considered distributed generation. It is providing the regulation ancillary service to PJM.	

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Project	DE-OE000020(Beacon Power (20 MW Flywheel Frequency Regulation Plant)
Filing	build_quarterly — Build Metrics Quarterly Report Quarter 4, 2014
Period	**Start:** Oct 1, 2014 **End:** Dec 31, 2014 **Submission Due Date:** January 31, 2015

Additional Project Descriptions

The site configuration starts at the existing 69kV line and proceeds to the 12/16/20 69kV to 13.8kV power transformer and then to the 15kV class Substation Switch Gear. The switch gear is split into two separate circuits with 10MW on each circuit which are loop fed into five 13.8kV to 480V pad mounted distribution transformers. Connected to each pad mount transformers are two 1MW groupings of Flywheels. Each 1MW grouping consists of ten 100kW flywheels.

Distributed Energy Resources' Installed Costs	Units	Project Funded	Cost Share
DER Interface Control Systems	$		
Communications Equipment	$		
DER/DG Interconnection Equipment	$		
Renewable DER	$	0	0
Distributed Generation Equipment	$	0	0
Stationary Electric Storage Equipment	$	5,904,780	7,216,954
PEVs and Charging Stations	$	0	0
Other Costs	$		

Other Cost Description