



Transmission Expansion Advisory Committee (TEAC)

Recommendations to the PJM Board

PJM Staff Whitepaper
April 2018



EXECUTIVE SUMMARY

On February 13, 2018, the PJM Board of Managers approved changes to the Regional Transmission Expansion Plan (RTEP), totaling \$328.78 million, primarily to resolve baseline reliability criteria violations.

Since that time, PJM has identified additional baseline reliability criteria violations within the planning horizon as part of the 2017 RTEP. Transmission upgrades have been identified to resolve these reliability criteria violations. The increase in the RTEP to include the upgrades to resolve the new baseline reliability criteria violations is \$646.35 million; this includes a market efficiency upgrade to address congestion in the BGE area. In addition, a number of previously approved baseline projects have been canceled or their cost and scope has changed, resulting in a net decrease of \$7.8 million. The net impact due to these baseline reliability changes is an increase in the RTEP of \$638.55 million.

With these changes, the RTEP will include over \$36,077.83 million of transmission additions and upgrades since the first plan was approved by the Board in 2000.

The additional baseline projects are summarized in the following paper and were presented for the Board Reliability Committee's consideration and for recommendation to the full Board for approval. At the April 2018 meeting, the PJM Board approved the updated RTEP as requested.

2017 Baseline Reliability Upgrades Changes and Additions

One aspect of the development of the Regional Transmission Expansion Plan is an evaluation of the “baseline” system, i.e., the transmission system without any of the generation interconnection requests included in the current planning cycle. This baseline analysis determines the compliance of the existing system with reliability criteria and standards. Transmission upgrades required to maintain a reliable system are identified and reviewed with stakeholders through the Transmission Expansion Advisory Committee (TEAC) and Subregional RTEP committees. The cost of transmission upgrades to mitigate such baseline reliability criteria violations is the responsibility of the PJM load customers.

Reliability Project Summary

A summary of the more significant baseline projects with estimated costs equal to or greater than \$5 million is detailed below. A complete listing of all of the projects that were approved by the PJM Board along with their associated cost allocations is included in Attachment A and Attachment B to this white paper. The projects with estimated costs less than \$5 million include installation of a new capacitor bank and installation of a new circuit breaker.

Mid-Atlantic Region System Upgrades

- BGE Transmission Zone
 - Reconductor the Conastone-Graceton 230 kV lines (BGE), a segment of the Windy Edge-Glenarm 115 kV line and the Raphael Road-Northwest 230 kV lines. – \$39.6 million
- PPL Transmission Zone
 - Reconfigure transmission lines in the Berwick area of PPL, including a new 230/69 kV substation, rebuilding two segments of 69 kV transmission line and retirement of 11 miles of the Harwood-Berwick 69 kV line – \$57.0 million
- PSE&G Transmission Zone
 - Replace existing Roseland-Branchburg-Pleasant Valley 230 kV corridor, with new line and structures – \$546 million

Following is a more detailed description of the larger-scope projects that were approved by the PJM Board. A description of the criteria driving the need for the upgrade, as well as the required in-service date, is provided.

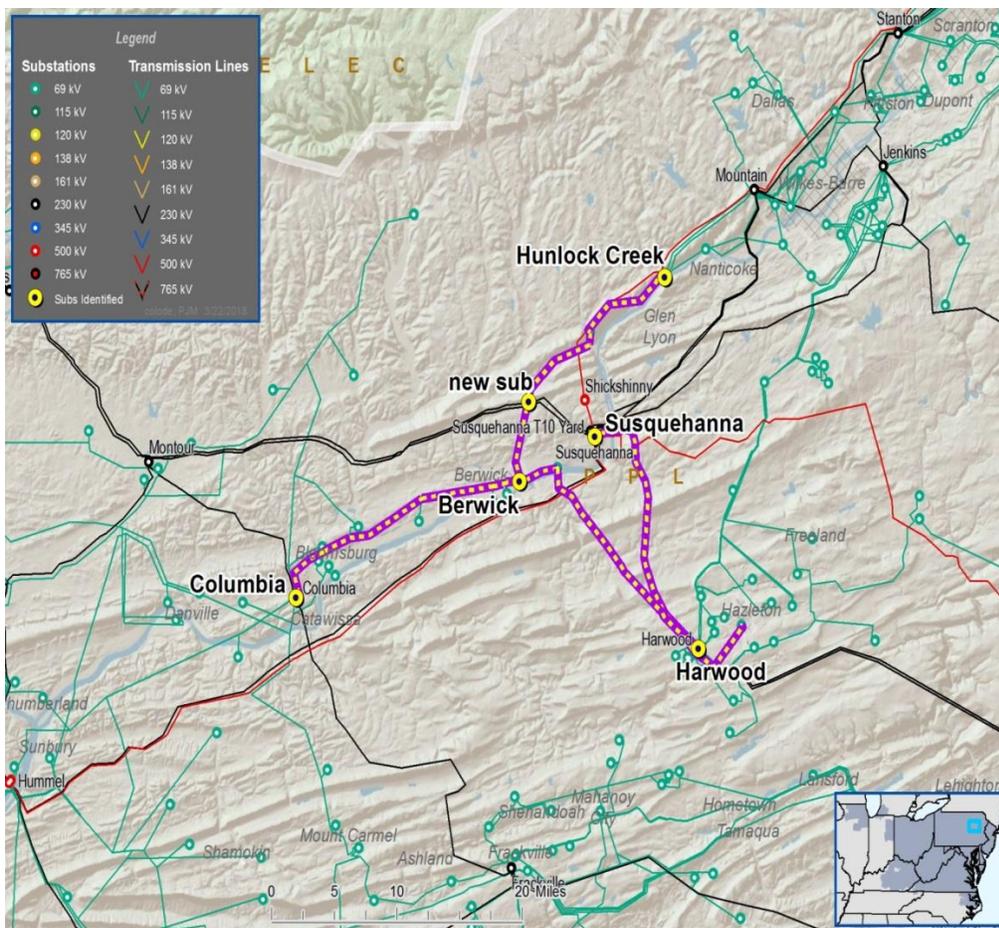
Baseline Project b2838 – Reconfiguration of Transmission Lines in the PPL Transmission Zone

Contingency analysis of the PPL Transmission Zone in the area of Berwick substation revealed several violations of PPL’s local FERC 715 planning criteria. Analysis shows that a fault plus stuck breaker (P4.6 of TPL-001-4) contingency at the Columbia 69 kV substation results in higher than acceptable (5 percent) voltage drop levels and creates lower than acceptable (0.90 pu) minimum voltages for substations fed off the Columbia-Berwick 69 kV line. Furthermore, this contingency results in a thermal overload of 107 percent of the emergency rating of the Hunlock-Berwick 69 kV line.

Additionally, the tower line contingency (P7.1 of TPL-001-4) for the loss of Susquehanna-Harwood 230 kV circuits 1 and 2, which share a common structure, will result in 115 percent of the emergency rating of the Hunlock-Berwick 69 kV line. This overload violates PPL’s Local FERC 715 planning criteria regarding post contingency line loading exceeding emergency ratings.

PJM planners worked closely with PPL to determine alternatives to address the issue including rebuilding approximately 15 miles of the Hunlock-Berwick 69 kV line and approximately 15 miles of the Harwood-Berwick 69 kV line from single circuit to double circuit. This solution has comparable cost; however, it increases the system exposure to fault.

Figure 1. Area surrounding b2838



The recommended solution to address these issues is a reconfiguration of the lines in the Berwick area including cutting the Columbia-Berwick 69 kV network lines by constructing a new 230/69 kV substation approximately 4.5 miles from the existing Berwick 69 kV Switchyard; rebuilding approximately 5 miles of Hunlock-Berwick 69 kV line from single circuit to double circuit to connect the new 230/69 kV substation to the Berwick Area loads; building approximately 3.2 miles of single circuit 69 kV tap lines to connect the Berwick Area loads to new double circuit; and retiring 11 miles of the Harwood-Berwick 69 kV line. The estimated cost for this work is \$57 million, and the required in-service date is September 2021. The local transmission owner, PPL, will be designated to complete this work.

Baseline Project b2986 – Replace Roseland-Branchburg-Pleasant Valley 230 kV corridor in the PSEG Transmission Zone

PSEG’s local FERC 715 planning criteria include equipment assessment criteria. The Roseland-Branchburg-Pleasant Valley line has an average structure age of 90 years and shares a transmission corridor with the Roseland-Branchburg 500 kV line. Based on these and other contributing factors, PSEG commissioned external consultants to assess tower foundations and structures along the 52-mile Pleasant Valley-Branchburg-Roseland transmission corridor.

Figure 2. Tower Condition on Roseland-Branchburg Segments

Tower Condition on Circuits U-2221, M-2265 (162 towers)	# of towers (%)
Towers with foundation requiring extensive reconstruction	40 (25%)
Towers exceeding 95% structural loading capability	144 (89%)
Towers exceeding 100% structural loading capability	129 (80%)
LIDAR conflict (# spans)	17*(10%)

*LIDAR clearance issues as of Sept. 29, 2017

Figure 3. Tower Condition on Branchburg-Pleasant Valley Segments

Evaluate Towers on Circuits I-2209, Q-2243, Z-2357, L-220-12 (102 towers)	# of towers (%)
Towers with foundation requiring extensive reconstruction	27(26%)
Towers exceeding 95% structural loading capability	77(76%)
Towers exceeding 100% structural loading capability	14(14%)
LIDAR conflict (# spans)	7*(7%)

*LIDAR clearance issues as of Sept. 29, 2017

Figure 4. Tower condition examples on Roseland-Branchburg-Pleasant Valley



The assessment revealed that about 25 percent of the structures will require either extensive foundation rehabilitation or total foundation replacement. Additionally, 54 percent of the towers are exceeding their load bearing capability and an additional 30 percent of the towers are within 5 percent of exceeding their load bearing capability. Furthermore, 9 percent of the spans violate acceptable ground clearances based on LIDAR testing. Based on the findings of the assessment, the equipment has reached its end of life.

PJM and PSEG worked together to consider the following three possible solution alternatives:

- 1) Remove and retire the 230 kV corridor without replacing.

Evaluation of option no. 1 showed severe voltage issues on the JCPL 34.5 kV network, as well as widespread voltage issues resulting from N-1 and N-1-1 analysis. From a system reliability performance perspective, this is considered to be a very poor alternative

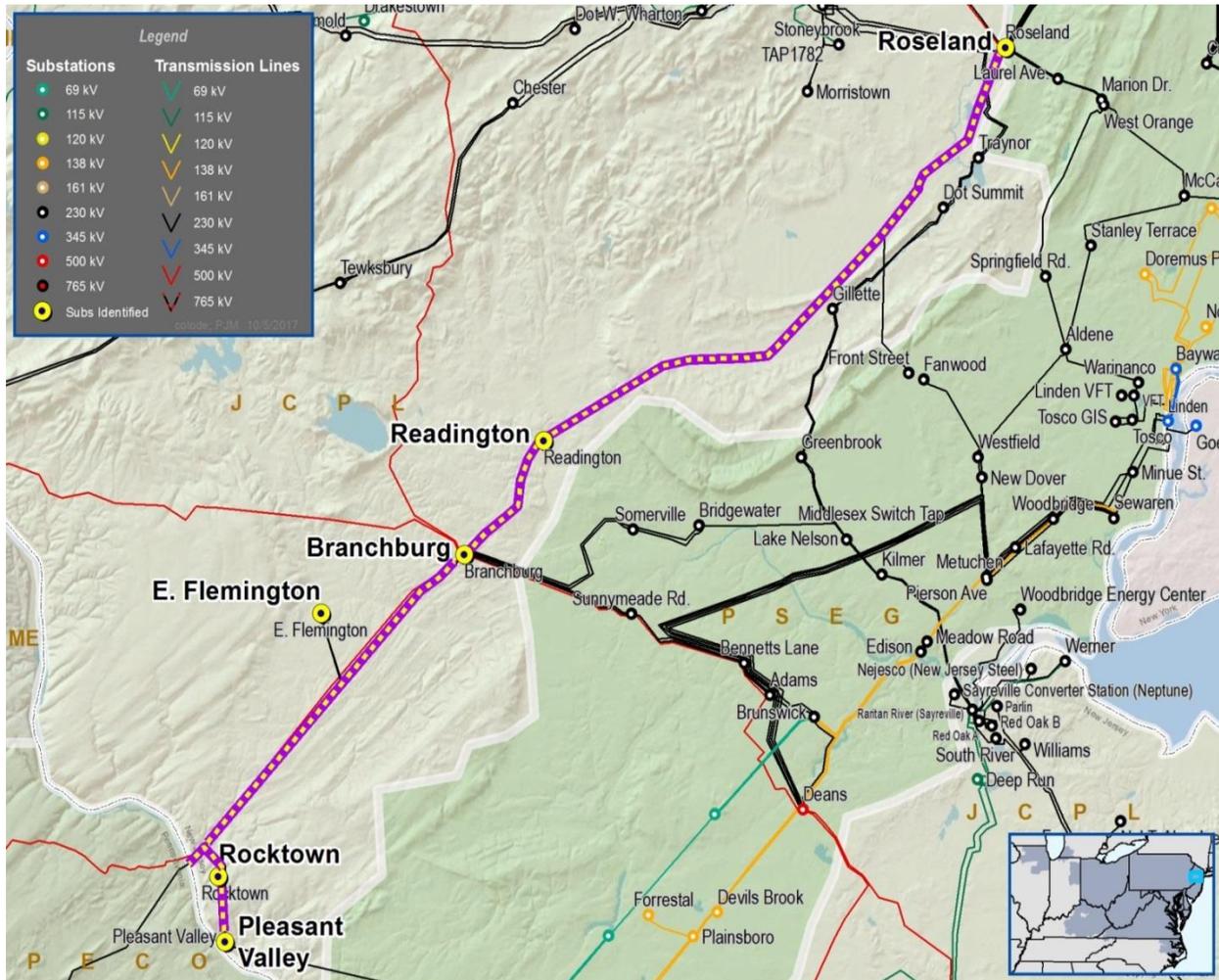
- 2) Install new parallel circuit on new right-of-way and remove existing 230 kV corridor.

Evaluation of option no. 2 showed potential permitting challenges due to the incorporation of new right-of-way and associated work to loop in and out of several 230/34.5 kV substations. Due to these issues, installing a new parallel circuit is the highest cost option.

- 3) Replace the existing 230 kV single-circuit corridor with new dual-circuit structures and initially string one 230 kV circuit.

Evaluation of option no. 3 shows that replacing the existing facilities maintains system reliability and eliminates the safety risk of the existing damaged structures. This option requires no new right-of-way, substations or reactive devices and will not result in additional studies due to changing topology. Minimal new siting, permitting and construction are required for this option, as opposed to the other potential alternatives.

Figure 5. Area surrounding b2986



The recommended solution to address the equipment condition issues is to replace the existing Roseland-Branchburg-Pleasant Valley 230 kV corridor with new dual-circuit structures with a single 230 kV circuit. The estimated cost for this work is \$546 million, and the required in-service date is 2018. The local transmission owner, PSEG, will be designated to complete this work.

2016/17 RTEP Long Term Proposal Window

PJM opened the second Long Term Market Efficiency proposal window from November 1, 2016, through February 28, 2017, to solicit proposals addressing future simulated congestion.

Market efficiency analysis is a part of the overall Regional Transmission Expansion Plan (RTEP) process that accomplishes the following objectives:

1. Determine which reliability upgrades, if any, have an economic benefit if accelerated or modified.
2. Identify new transmission upgrades that may result in economic benefits.

3. Identify economic benefits associated with “hybrid” transmission upgrades. Hybrid transmission upgrades include proposed solutions, which encompass modification to reliability-based enhancements already included in RTEP that when modified would relieve one or more economic constraints. Such hybrid upgrades resolve reliability issues but are intentionally designed in a more robust manner to provide economic benefits in addition to resolving those reliability issues.

Market efficiency analysis is conducted using market simulation tools of future annual periods for both the capacity market and energy market. Economic benefits of transmission upgrades are determined by comparing results of simulations, which include the study upgrade, to results of simulations that do not include the study upgrade. Projects are measured using two Tariff/Operating Agreement criteria. First, the project must address either an identified congestion driver or a capacity market constraint. Second, the project total energy and capacity benefits must exceed the costs by at least 25 percent. Project energy benefits are measured by comparing the benefits in the form of net load payments and/or production costs with and without the proposed project for a 15-year study period. Projects affecting the capacity market derive additional capacity benefits in the form of net load capacity payments and/or capacity costs.

PJM staff provided participants with a list of targeted congestion facilities, along with their simulated congestion values, in order to solicit proposals during the Long Term Proposal Window. The list of these facilities along with the simulated congestion for study years 2021 and 2024 is shown in Figure 6. In the 2016/17 RTEP Long Term Proposal Window, PJM received project proposals to address future simulated congestion and capacity market constraints.

Figure 6. Facilities Recommended for Project Proposals and Simulated Congestion

Constraint	Area	Type	2021 Congestion Frequency (hours)	2021 Market Congestion (\$ mil)	2024 Congestion Frequency (hours)	2024 Market Congestion (\$ mil)
Graceton to Conastone 230 kV	BGE	Line	972	\$58.3	1,044	\$72.1
Bagley to Graceton 230 kV	BGE	Line	1,265	\$33.0	1,518	\$49.6
Susquehanna to Harwood 230 kV	PPL	Line	166	\$4.0	201	\$5.6
Bosserman to Olive 138 kV	AEP	Line	17	\$0.4	71	\$2.0

There were 96 proposals submitted during the Long Term window that closed in February of 2017. Proposals submitted ranged in cost from \$0 to \$371.3 million and included transmission owner upgrades and Greenfield projects from incumbent transmission owners and non-incumbent entities. The breakdown of project proposals by area is shown in Figure 7.

Figure 7. Proposals by Area

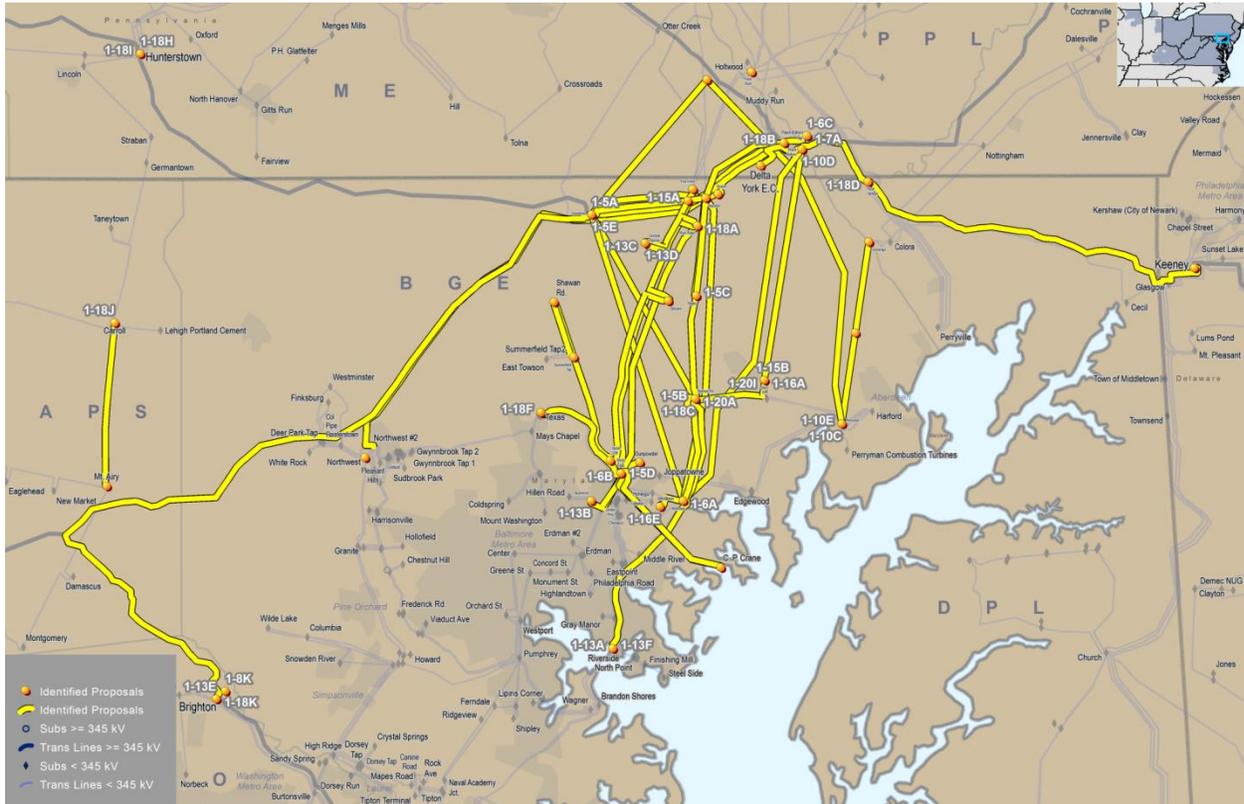
Area of Proposal	Number of Proposals	Greenfield Proposals	TO Upgrade Proposals
AEP	11	5	6
APS	4	3	1
ATSI	1	0	1
BGE	47	33	14
ComEd	5	3	2
Dayton	3	3	0
DEOK	1	1	0
Dominion	20	3	17
EKPC	1	1	0
ME	2	2	0
PECO	12	6	6
PEPCO	3	2	1
PPL	7	4	3
AMIL (External)	1	1	0
LGEE (External)	1	1	0
NISP (External)	3	2	1
OVEC (External)	1	1	0
Grand Total	96	52	44

Baseline Project b2992 – Reconductor Conastone-Graceton-Bagley 230 kV Transmission Line in the BGE Transmission Zone

As presented in Figure 6, PJM identified the Conastone-Graceton and Graceton-Bagley 230 kV lines as targeted congestion facilities. Simulations performed in advance of the 2016/17 Long Term Proposal Window identified over \$91 million in market congestion on these two facilities based on 2021 input assumptions and simulation results.

PJM received a cluster of 46 proposals (32 greenfield proposals and 14 upgrade proposals) from nine entities to address the Conastone-Graceton-Bagley congestion (i.e., BGE Congestion). The project costs ranged from \$5.97 million to \$483.21 million. See Figure 8 for a map of the BGE proposals.

Figure 8. Proposals received in 2016/17 Long Term Proposal Window addressing BGE Congestion



PJM staff conducted an extensive analysis on the proposals to determine which projects satisfy the market efficiency criteria of having a benefit/cost ratio >1.25, fully addressing the congestion driver, and being economically justified.

The energy benefits associated with the proposed projects were determined using the methodologies specified in Schedule 6 of the PJM Operating Agreement. PJM’s annual energy benefits calculation for lower voltage facilities is weighted 100 percent to zones with a decrease in net load payments as a result of the proposed project. Change in net load payments comprises the change in gross load payments offset by the change in transmission rights credits. No capacity benefits were identified with these proposed projects.

PJM market efficiency analysis showed that a number of the proposals submitted to address congestion on the Conastone-Graceton-Bagley 230 kV line did not pass the benefit to cost ratio threshold of 1.25. Of the proposals that did pass the B/C ratio, some did not fully address the congestion drivers or shifted congestion to other facilities. Most of the proposals addressing these drivers were also shown to shift congestion onto other facilities and would require additional costs than originally proposed.

PJM continued analysis of the proposals that both passed the B/C ratio and fully addressed the congestion drivers, to determine which project addresses the identified congested facilities in the most cost effective manner.

Based on the analysis performed, PJM selected BGE’s 5E proposal, which reconductors Conastone-Graceton and Raphael Road-Northeast 230 kV lines along with adding bundled conductor to the Graceton-Bagley-Raphael Road double circuit lines as the optimal solution to the identified congestion:

- Proposal 5E has a B/C ratio of 5.23, which is among the highest across the proposals submitted for the BGE constraints.
- Additionally, proposal 5E fully addresses the target congestion driver as well as the downstream congestion on other 230 kV and 115 kV circuits in the area.
- PJM determined that the potential shifted congestion caused by the recommended proposal 5E is within acceptable limits (<\$1 million/year, average 2021, 2024 simulated congestion).

In addition to the market efficiency base case analysis, for the recommended proposal 5E, PJM performed sensitivity analysis on key input variables. These sensitivities included a range of natural gas prices and PJM load forecasts. A RTEP reliability analysis to ensure that the project did not cause any reliability issues was required. No reliability violations were identified and the project passed all sensitivity scenarios studied.

PJM also conducted a constructability review of the components proposed by project 5E and did not identify any issues as a result.

In conclusion, the proposal 5E shown in Figure 9 is being recommended to the Board for approval for inclusion into the RTEP. This proposal consists of upgrades and changes to existing equipment and will be designated to the incumbent transmission owner: Proposal 5E consists of the following elements:

- Reconductor the Conastone to Graceton 230kV lines
- Upgrade substation equipment at Conastone
- Add bundled conductors to the Graceton-Bagley-Raphael Road 230kV double circuit lines
- Reconductor the Raphael Road to Northeast 230 kV double circuit lines
- Upgrade substation equipment at Windy Edge substation

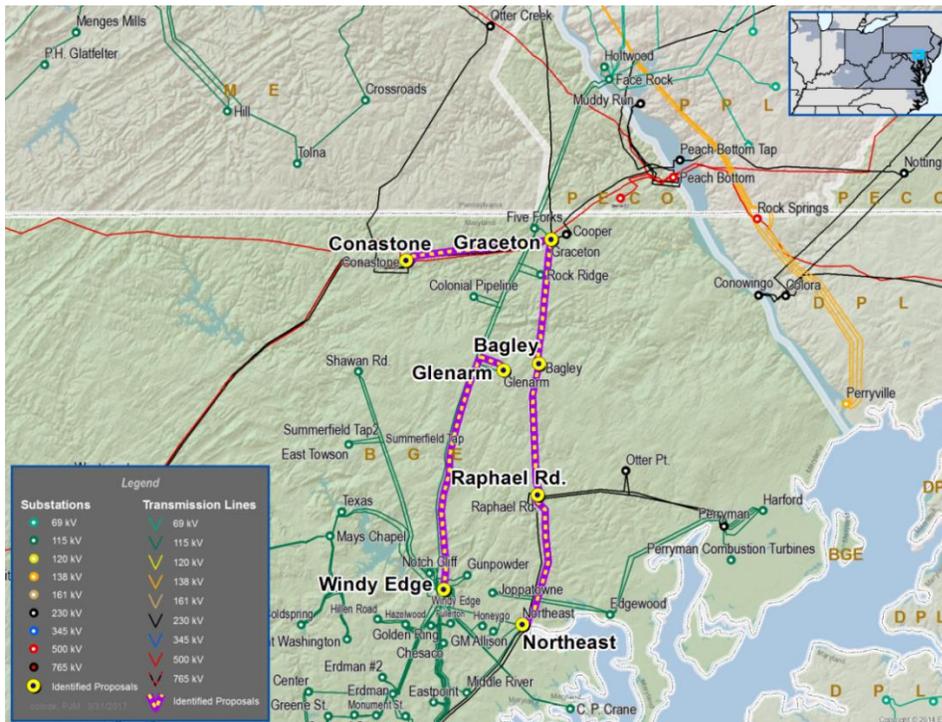
The estimated cost for the proposal 5E is \$39.6 million, and the in-service date is March 2021. The local transmission owner/proposing entity, BGE, will be designated to complete this work.

Figure 9. Recommended Market Efficiency RPM Projects

PJM Baseline ID	PJM Window Project ID	Project Description	Transmission Zone	Constraint Project Addresses	Project Cost (\$M)	In-Service Date	B/C Ratio
b2992	201617_1-5E	Reconductor the Conastone to Graceton 230kV lines. Upgrade substation equipment at Conastone. Add bundled conductors to the Graceton-Bagley-Raphael Road 230kV double circuit lines. Reconductor the Raphael Road to Northeast 230 kV double circuit lines. Upgrade substation equipment at Windy Edge substation.	BGE	Conastone-Graceton-Bagley 230 kV	39.6	2021	5.23

The map in Figure 10 shows the location of the recommended project.

Figure 10. Area surrounding b2992



Changes to Previously Approved Projects

Two projects, totaling \$7.8 million, are being canceled as they are no longer needed to satisfy reliability criteria. Both of these projects are in the Allegheny Power transmission zone. One project involved converting an existing 230 kV substation into a six breaker ring bus configuration and the other project was to upgrade terminal equipment on an existing 138 kV line. Given the lower load forecasts over the last several RTEP planning cycles and other changes in the area, these projects are no longer required. The net change to the RTEP to incorporate all of these changes is a decrease of \$7.8 million.

Review by the Transmission Expansion Advisory Committee (TEAC)

The need for the projects noted in this report was reviewed with stakeholders at several meetings throughout 2017 and 2018, most recently at the March 2018 TEAC and Subregional RTEP Committee meetings. Written comments were requested to be submitted to PJM to communicate any concerns with the recommendations. As of the writing of this report, there have been no comments received on the projects presented to the TEAC.

Cost Allocation

Preliminary cost allocations for the approved projects are shown in Attachment A and Attachment B. Attachment A shows the projects with cost allocations to a single zone. Attachment B shows the projects with cost allocations to multiple zones.

Cost allocations for the projects were calculated in accordance with the Schedule 12 of the Open Access Transmission Tariff (OATT). Baseline reliability project allocations are calculated using a distribution factor methodology that allocates the cost to the load zones that contribute to the loading on the new facility. Baseline projects required exclusively to address local transmission owner FERC Form 715 planning criteria are allocated to the local transmission owner zone. The allocations will be filed at the FERC 30 days following approval by the Board.

Board Approval

The PJM Board Reliability Committee was requested to endorse the new baseline reliability projects and associated cost allocations and recommend to the Board approval of the baseline upgrades to the 2017 RTEP.

The baseline upgrades will be incorporated into the published RTEP after approval by the PJM Board. The RTEP will be published on the PJM website.

Reliability Project Single Zone Allocations

Upgrade ID	Description	Cost Estimate (\$M)	Trans Owner	Cost Responsibility	Required IS Date
b2838	Build a new 230/69 kV substation by tapping the Montour-Susquehanna 230 kV double circuits and Berwick-Hunlock & Berwick-Colombia 69 kV circuits.	\$57.00	PPL	PPL	6/1/2017
b2986	Replace the existing Roseland-Branchburg-Pleasant Valley 230 kV corridor with new structures.	\$546.00	PSEG	PSEG	6/1/2018
b2987	Install a 30 MVAR capacitor bank at DPL's Cool Springs 69 kV substation. The capacitor bank would be installed in two separate 15 MVAR stages allowing DPL operational flexibility.	\$1.75	DPL	DPL	6/1/2022
b2988	Replace the Twin Branch 345 kV breaker "JM" with 63 kA breaker and associated devices including switches, bus leads, control cable, and a new DICM.	\$2.00	AEP	AEP	10/1/2020

Reliability Project Multiple Zone Allocations

Upgrade ID	Description	Cost Estimate (\$M)	Trans Owner	Cost Responsibility	Required IS Date
b2992.1	Reconductor the Conastone to Graceton 230 kV 2323 & 2324 circuits. Replace 7 disconnect switches at Conastone Substation.	\$17.20	BGE	AEP (2.25%)/APS (2.58%)/BGE (44.61%)/ComEd (0.51%)/Dayton (0.40%)/DEOK (1.39%)/DL (0.14%)/Dominion (27.05%)/EKPC (0.52%)/PENELEC (0.02%)/PEPCO (20.53%)	3/1/2021
b2992.2	Add Bundle conductor on the Graceton-Bagley-Raphael Road 2305 & 2313 230 kV circuits	\$15.60	BGE	AEP (2.25%)/APS (2.58%)/BGE (44.61%)/ComEd (0.51%)/Dayton (0.40%)/DEOK (1.39%)/DL (0.14%)/Dominion (27.05%)/EKPC (0.52%)/PENELEC (0.02%)/PEPCO (20.53%)	3/1/2021
b2992.3	Replacing short segment of substation conductor on the Windy Edge to Glenarm 110512 115 kV circuit	\$0.10	BGE	AEP (2.25%)/APS (2.58%)/BGE (44.61%)/ComEd (0.51%)/Dayton (0.40%)/DEOK (1.39%)/DL (0.14%)/Dominion (27.05%)/EKPC (0.52%)/PENELEC (0.02%)/PEPCO (20.53%)	3/1/2021
B2992.4	Reconductor the Raphael Road-Northeast 2315 & 2337 230 kV circuits	\$6.70	BGE	AEP (2.25%)/APS (2.58%)/BGE (44.61%)/ComEd (0.51%)/Dayton (0.40%)/DEOK (1.39%)/DL (0.14%)/Dominion (27.05%)/EKPC (0.52%)/PENELEC (0.02%)/PEPCO (20.53%)	3/1/2021