Reliability Analysis Update

Transmission Expansion Advisory Committee

December 14, 2017

2017 RTEP
Reliability Analysis Update

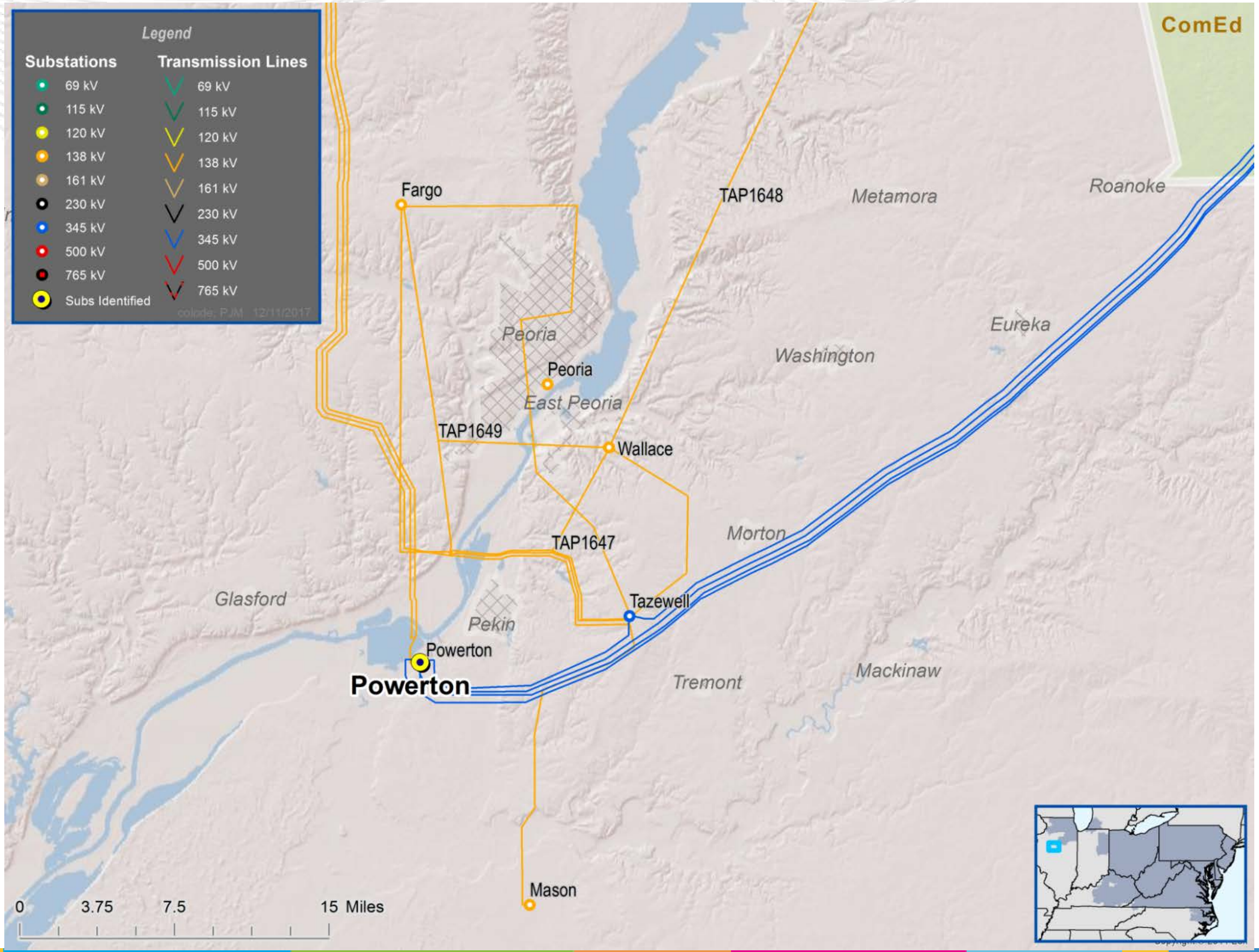
ComEd Transmission Zone

Problem: PJM Operational Performance

Problem Statement:

- High voltage in Powerton area in real time: Powerton unit 6 is required to run to control 345kV voltages in Powerton area
- Uplift Charges
- The reactive charges for Powerton are ~ $10M so far this year

Powerton Generation (ComEd Zone)	
Total Uplift Charges	
2017	$6,989,159.00
2016	$1,799,686.00
2015	$835,492.00



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ComEd Transmission Zone

Alternatives considered:

1. Install a shunt inductor at TSS 196 Katydid to resolve the issue on 345kV L0301. ($6M)
   - 345kV 0302 at TSS 908 Mole Creek still high but below 1.05
   - AA1-018 Otter Creek will be cutting in to 345kV L 0303 and adding a shunt inductor to avoid over voltage.

2. Install a shunt inductors at TSS 196 Katydid and TSS 908 Mole Creek ($12M plus land purchase that may be required)
   - AA1-018 Otter Creek will be cutting in to 345kV L 0303 and adding a shunt inductor to avoid over voltage.
   - Adding inductor at Mole Creek would assure operations would not have issues with line outage in future.

3. At TSS 908 Mole Creek cut in three additional 345kV Powerton lines ($33M plus land purchase that may be required)
   - Not fully studied yet
   - Would require purchasing additional property
   - Breaker and a half layout
   - AA1-018 or any other generator should not be required to install an inductor when cutting Powerton lines

All of the alternatives provide the following benefits:

- Cost savings to customers: no longer need to run higher cost generation to mitigate high voltage.
- Operational flexibility: no need to place generation (wind farms) at risk of being out of service during different outage scenarios.

Studies are in progress….

Final 2017 RTEP Proposal Window #1 Recommendations

DEOK Transmission Zone

Common Mode Outage and Basecase Analysis (Summer) (GD-S763, GD-S746, GD-S814, GD-S745, GD-S813, N1-S91, N1-S92 and N1-S126):

Date Project Last Presented:10/12/2017 TEAC, 11/01/2017 TEAC

Problem Statement:

- The Pierce 345 /138kV transformer #18 is overloaded for the loss of the Pierce 345/138kV transformer #17 with the breaker stuck at Pierce.
- The Pierce 345 /138kV transformer #17 and the connected Pierce –Beckjord 138kV circuit are overloaded for the loss of the Pierce 345/138kV transformer #18 with the breaker stuck at Pierce.

Alternatives considered:

2017_1-6A ($20.16M) :The two existing 345/138kV transformers that connect Pierce 345kV Substation to Beckjord 138kV Substation are fed radially. This project will Reconfigure Pierce 345kV Substation by adding new breakers, moving a feeder, adding a third 345/138kV transformer, and feed the Pierce-Beckjord transformers in a breaker and a half or double bus configurations. The three transformer feeds will be distributed across the three sets of buses at Beckjord.

2017_1-2E ($12.7 M): Build a 345 kV switching station ("Twelvemile") interconnecting the existing Silver Grove - Zimmer 345 kV transmission line and the Pierce - Buffington 345 kV transmission line

Portion of 2017_1-6A ($9.17M): Reconfigure Pierce 345KV substation and upgrade terminal equipment at Beckjord 138kV on the Beckjord – Pierce 138kV line

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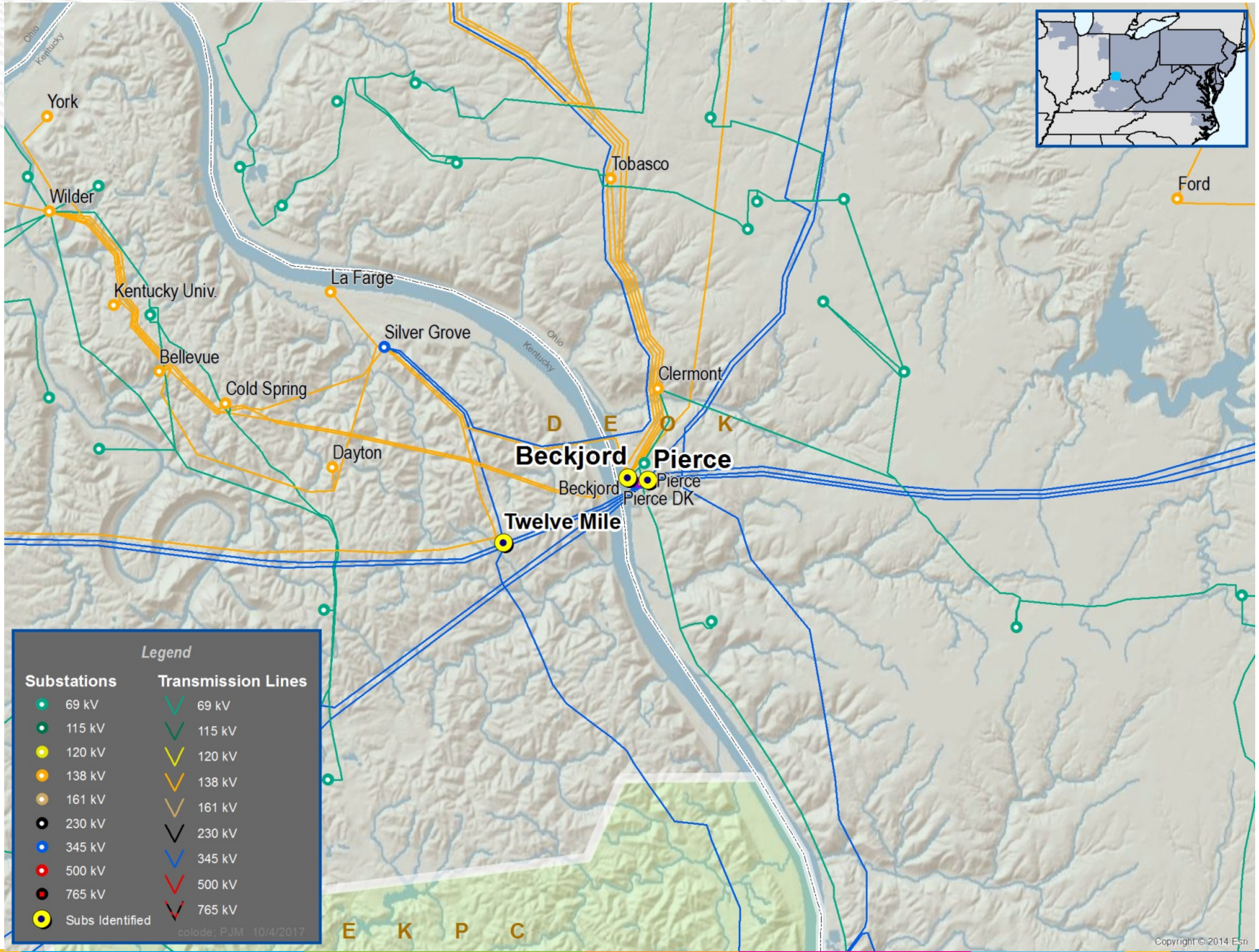

DEOK Transmission Zone

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Project ID	Project Sponsor	2017 RTEP Window #1 target reliability flowgates solved?	Cost Analysis
2017_1-2E	NTD	Yes; But causes an N-1-1 thermal overload on the Beckjord – Pierce 138kV line (violation)	Estimated overall project cost by sponsor of $12.7M ($9.7 NTD scope + $3M TO scope in current year) Cost cap = $14M (in-service year $'s) for NTD scope of work The fix for the new overload on the Beckjord – Pierce 138kv line is approximately $1M;
2017_1-6A	DEOK	Yes, with no additional overloads	The submitted cost $20.16M includes the Y3-064 merchant project cost, $0.5M, which shouldn't be included as baseline cost, The total estimated cost is $19.66M
Portion of 2017_1-6A	DEOK	Yes, with no additional overloads	The Estimated cost is $9.17M. If the towers are not needed, it could lead to a cost reduction of $1.25M from the total.

DEOK Transmission Zone

Recommended Solution: (Portion of 2017_1-6A)

Install a new 345kV breaker "1422" so Pierce 345/138KV transformer #18 is now fed in a double breaker, double bus configuration. **(B2977.1)**

Remove X-533 No. 2 to the first tower outside the station. Install a new first tower for X-533 No.2. **(B2977.2)**

Install new 345KV breaker B and move the Buffington-Pierce 345kV feeder to the B-C junction. Install a new tower at the first tower outside the station for Buffington-Pierce 345kV line. **(B2977.3)**

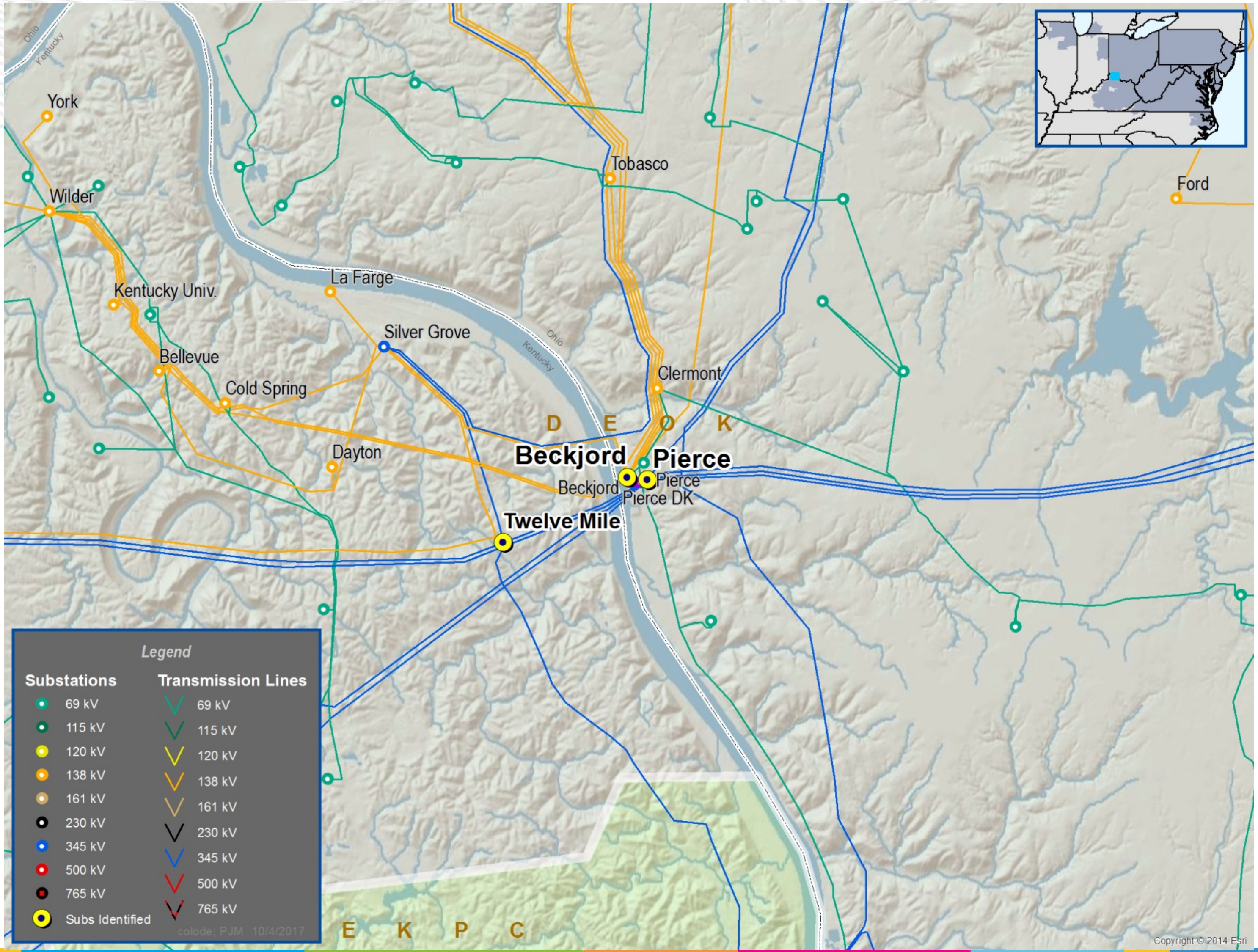
Remove breaker A and move the Pierce 345/138kV transformer #17 feed to the C-D junction. **(B2977.4)**

Replace breaker 822 at Beckjord 138kV substation to increase the rating from Pierce to Beckjord 138kV to 603MVA. **(B2977.5)**

Estimated Project Cost: $ 9.17 M

Required IS date: 6/1/2021

Project Status: Conceptual



DPL/PECO Transmission Zone

Generation Deliverability (Summer) (GD-S798 and GD-S815):

Problem Statement:

- The Edge Moor – Claymont – Linwood 230 kV circuit is overloaded for line fault stuck breaker contingency loss of the Edge Moor – Linwood 230 kV circuit and two units at Philips Island.

Alternatives considered:

2017_1-9A ($1.83 M)	2017_1-9H ($55.7 M)
2017_1-9B ($28.4 M)	2017_1-9I ($64 M)
2017_1-9C ($5.73 M)	2017_1-9J ($37.69 M)
2017_1-9D ($37.95 M)	2017_1-9K ($9.58 M)
2017_1-9E ($26.78 M)	2017_1-9L ($1.4 M)
2017_1-9F ($28.69 M)	2017_1-9M ($8.37 M)
2017_1-9G ($36.56 M)	2017_1-9N ($79.03 M)

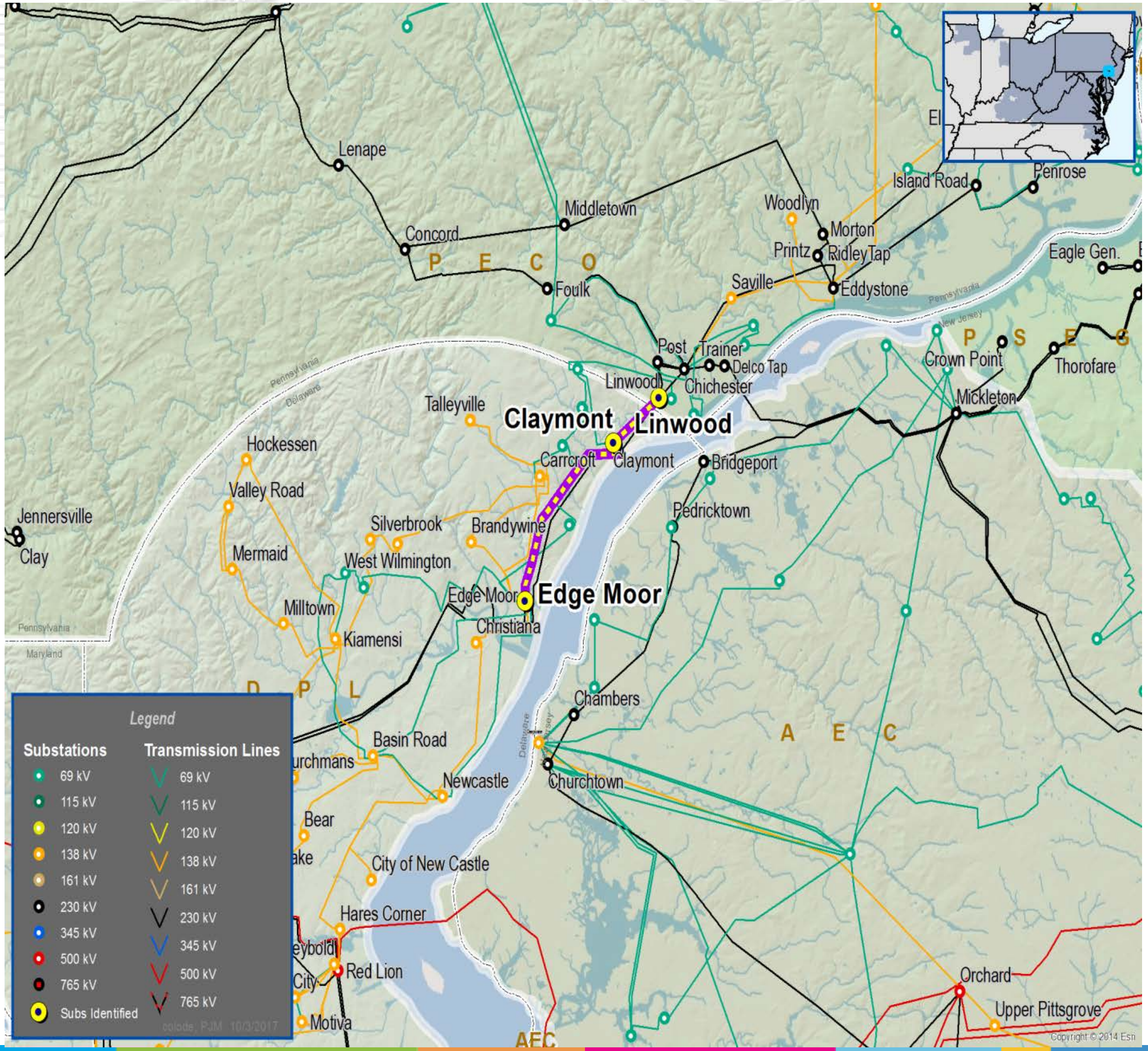
Preliminary Recommendation:

- Replace the 230 kV CB #225 at Linwood Substation (PECO) with a double circuit breaker (back to back circuit breakers in one device). 2017_1-9L

Estimated Project Cost: $ 1.4 M

Required IS date: 6/1/2022

Project Status: Conceptual



PJM Operational Performance

Baseline Reliability: Operational Performance

Problem Statement:

- PJM Operations continues to experience high voltage on the 500kV transmission system in the Carson area during periods of light system load.
- PJM Operations has implemented an operating memo to include switching out multiple 500kV transmission lines and scheduling necessary generation to run for high voltage control.

Immediate Need:

- Due to the immediate need, the timing required for an RTEP proposal window is infeasible. As a result, the local Transmission Owner will be the Designated Entity.

Recommended Solution:

- Install two 500kV 125 MVAR Statcoms at Rawlings and one 500kV 125 MVAR Statcom at Clover Substation. ($100 M) **(b2978)**

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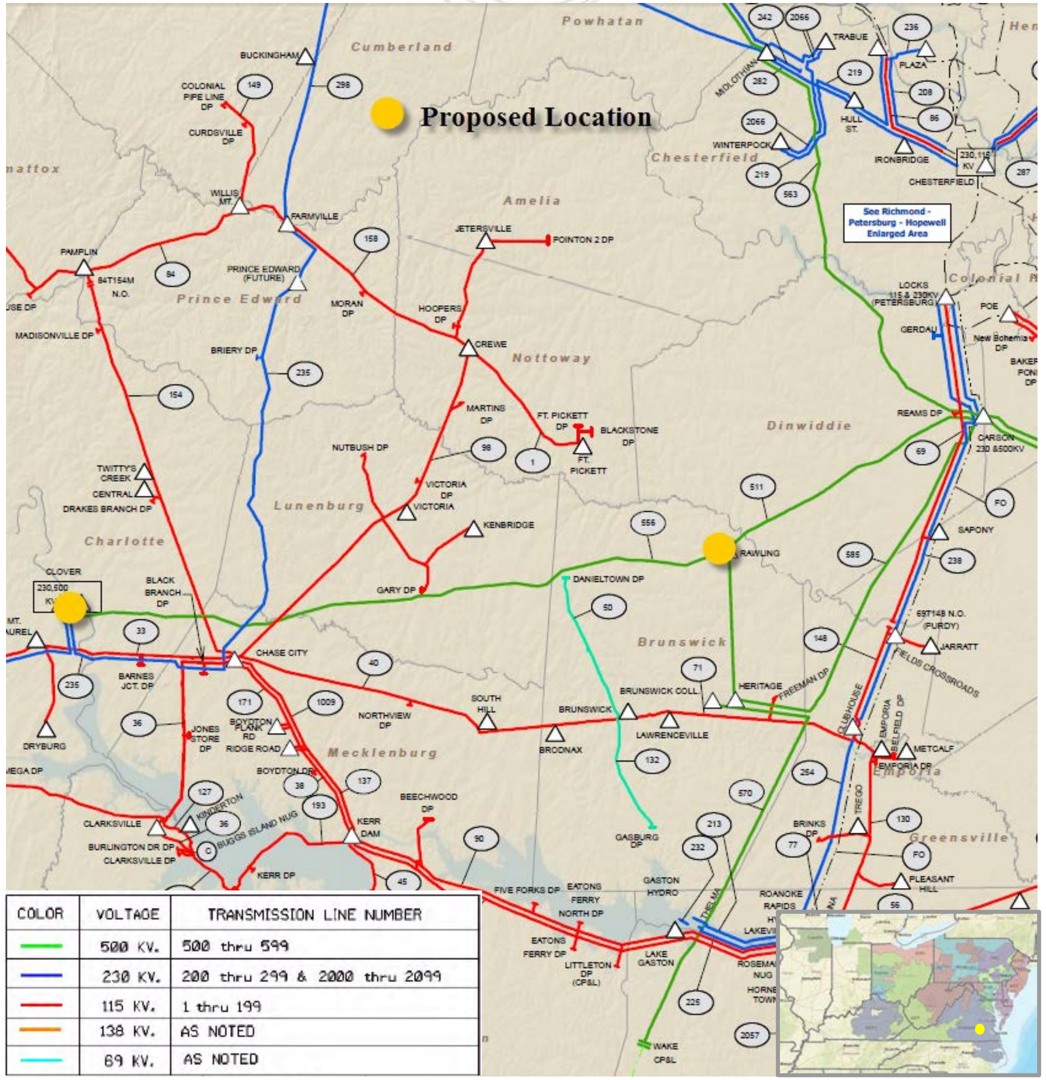

Install STATCOMs at Rawlings and Clover Substations

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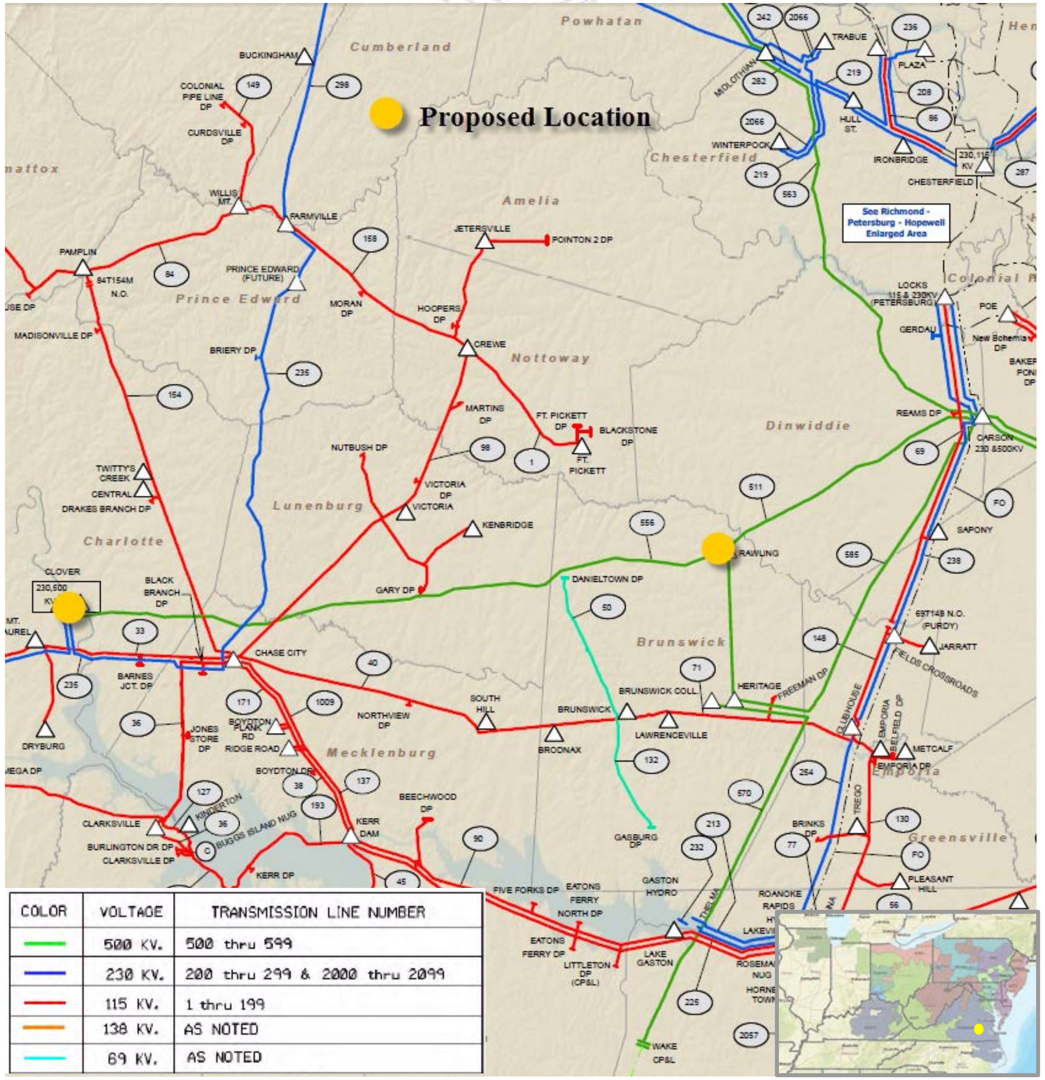
Alternatives:

- Install two 500kV 125 MVAR Statcoms at Clover and at Midlothian Substation. ($125 M)
- Install two 500kV 125 MVAR Statcoms at Carson and one 500kV 125 MVAR Statcom at Clover Substation. ($110M + real estate + transmission line cost)
- Install two 500kV 125 MVAR Statcoms at Rawlings and one 500kV 125 MVAR Statcom at Midlothian and at Clover Substation. ($140 M)
- Install one 500kV 150 MVAR Fixed Shunt Reactor bank at Rawlings Substation, at Clover Substation, and at Midlothian Substation. ($30.5 M)
  - Current manufacturer designed duty cycle recommendation limits the 500kV reactor bank breaker switching operations to 250. This will require periodic replacement of interrupters and a two week outage.

Estimated Project Cost: $100 M
Required IS Date: Immediate
Projected IS Date: May 2021
Project Status: Conceptual



Winter/Spring 2016 500kV System Real Time Voltages

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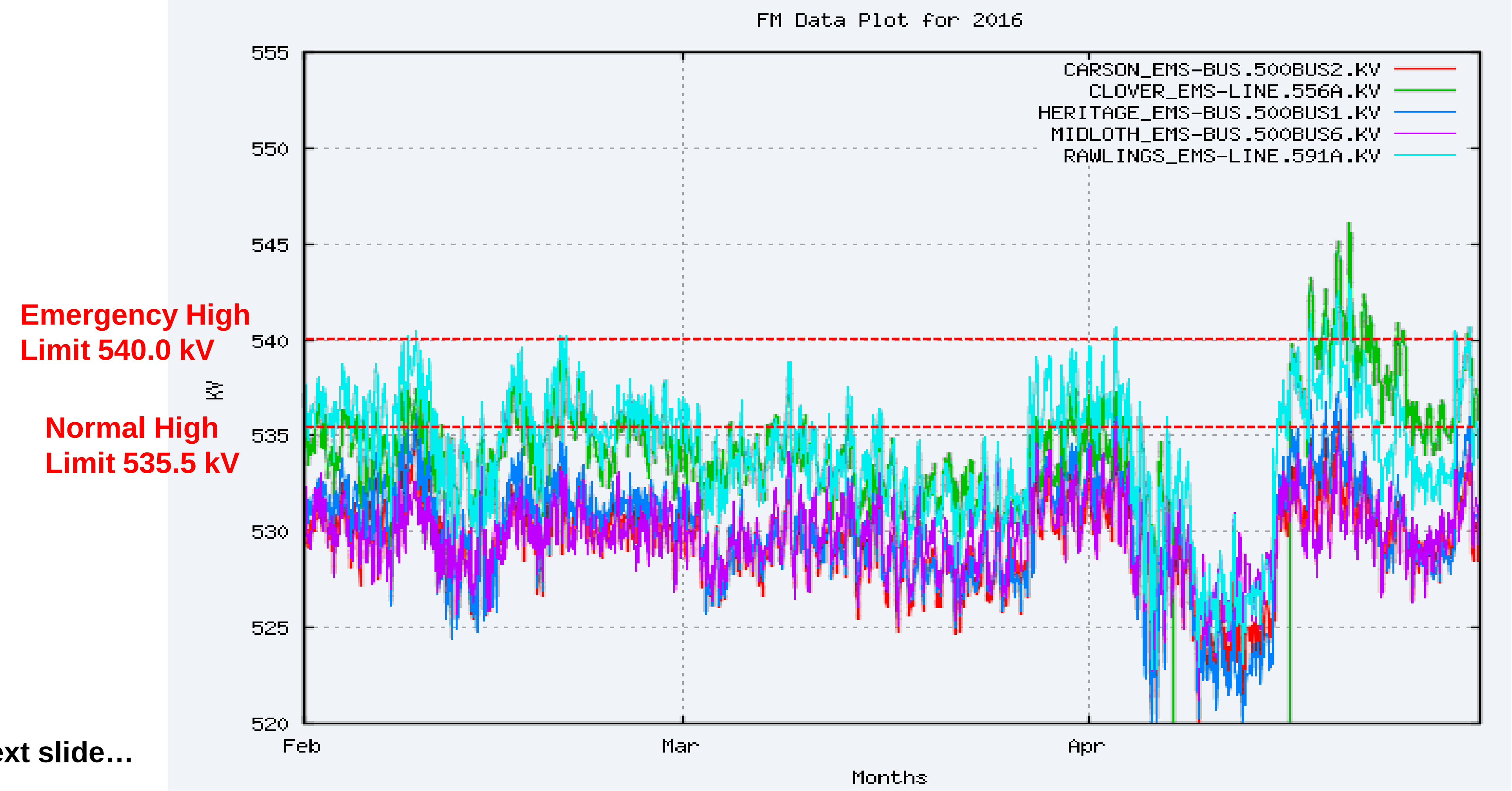

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Dominion Transmission Zone
Winter/Spring 2017 500kV System Real Time Voltages

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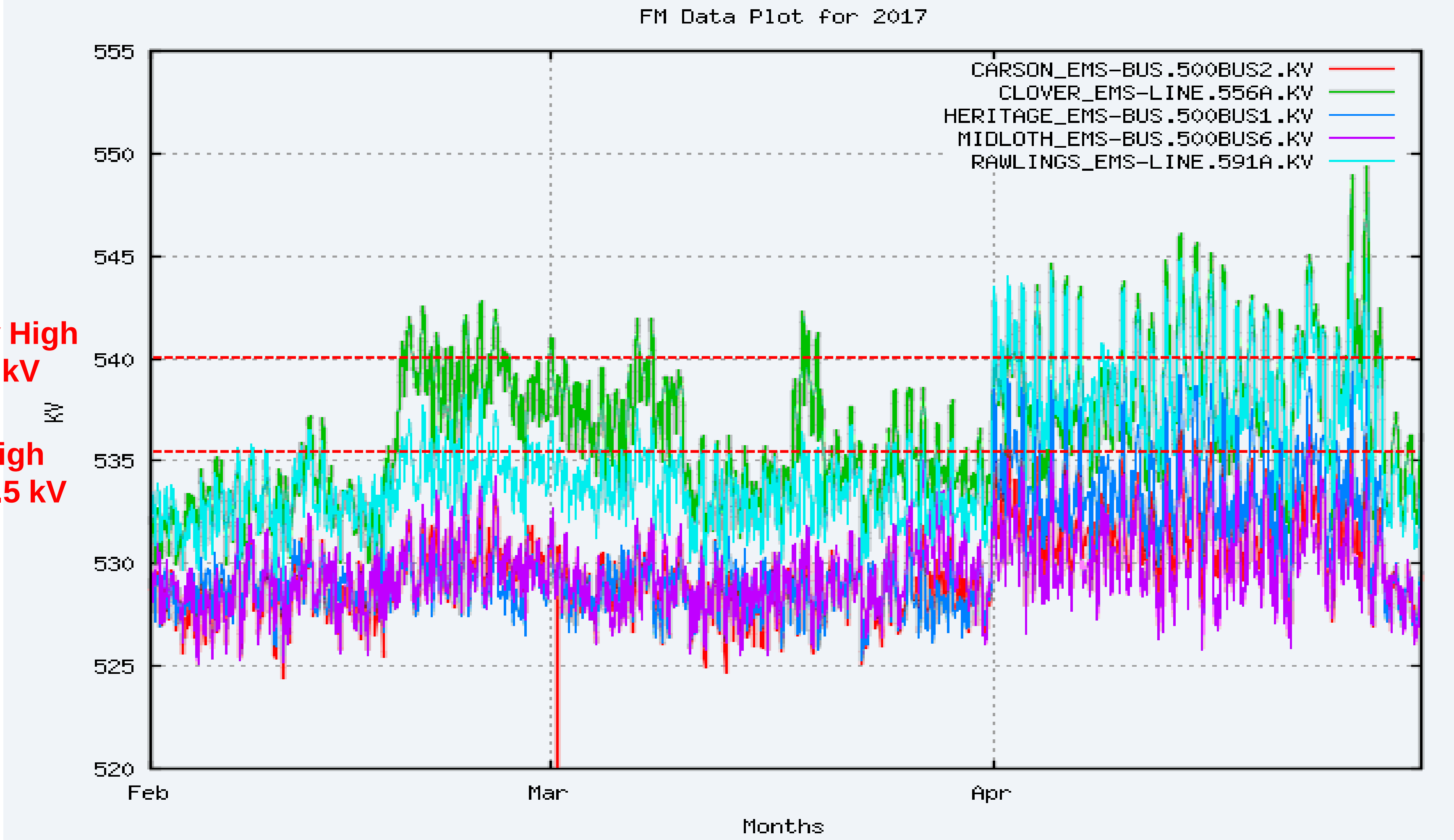
Emergency High Limit 540.0 kV

Normal High Limit 535.5 kV



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Spring 2017 Carson 500kV PJM Real Time Voltages

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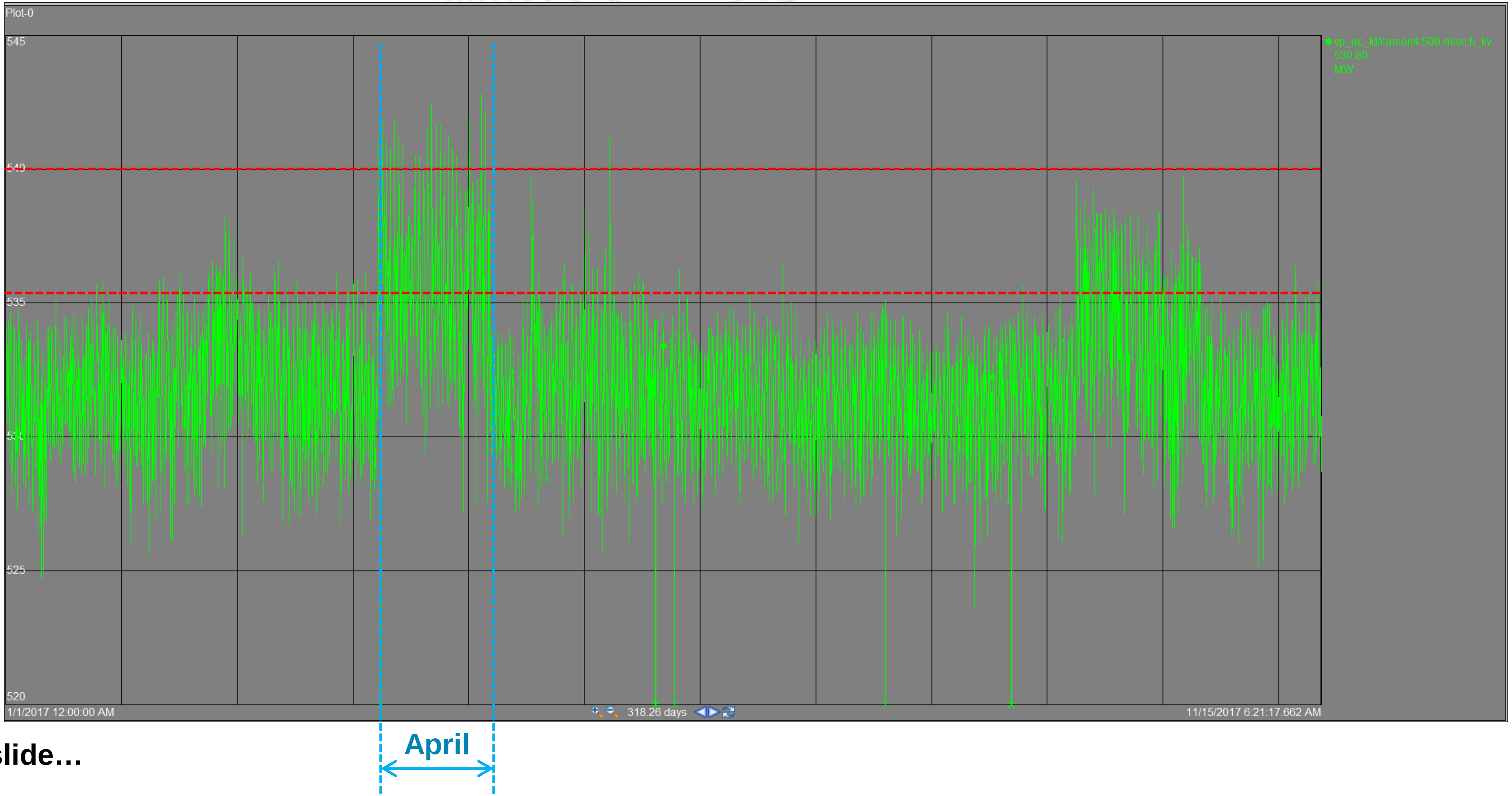
Emergency High Limit 540.0 kV

Normal High Limit 535.5 kV



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EMS 02/24/2017 Snapshot
500kV Bus Voltages Before and After

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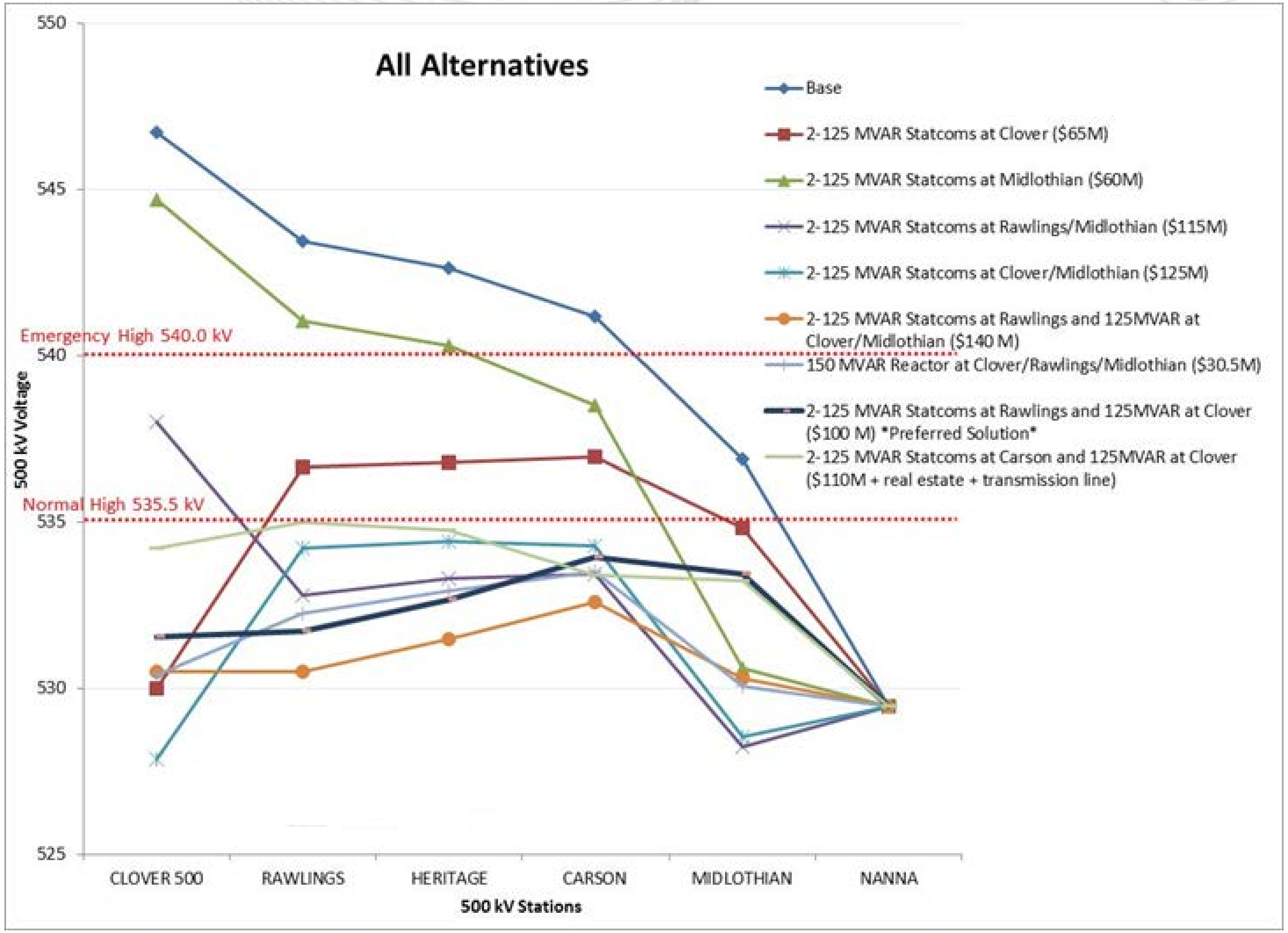

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Reactors

- Steady-state only
  - Must energize pre-contingency
- Significant operational and O&M issues with switching reactors (breakers and RL switchers)
  - Replacement of interrupter required on an annual basis
- No acceptable switching solution for 500kV

STATCOMs

- 3-in-1 device (some modes can operate simultaneously):
  - Dynamic VAR support
  - Fixed reactor bank
  - Fixed capacitor bank
- Additional control functions beyond VAR support:
  - Phase balancing (reduce negative sequence)
  - Oscillation damping
  - Blackstart support

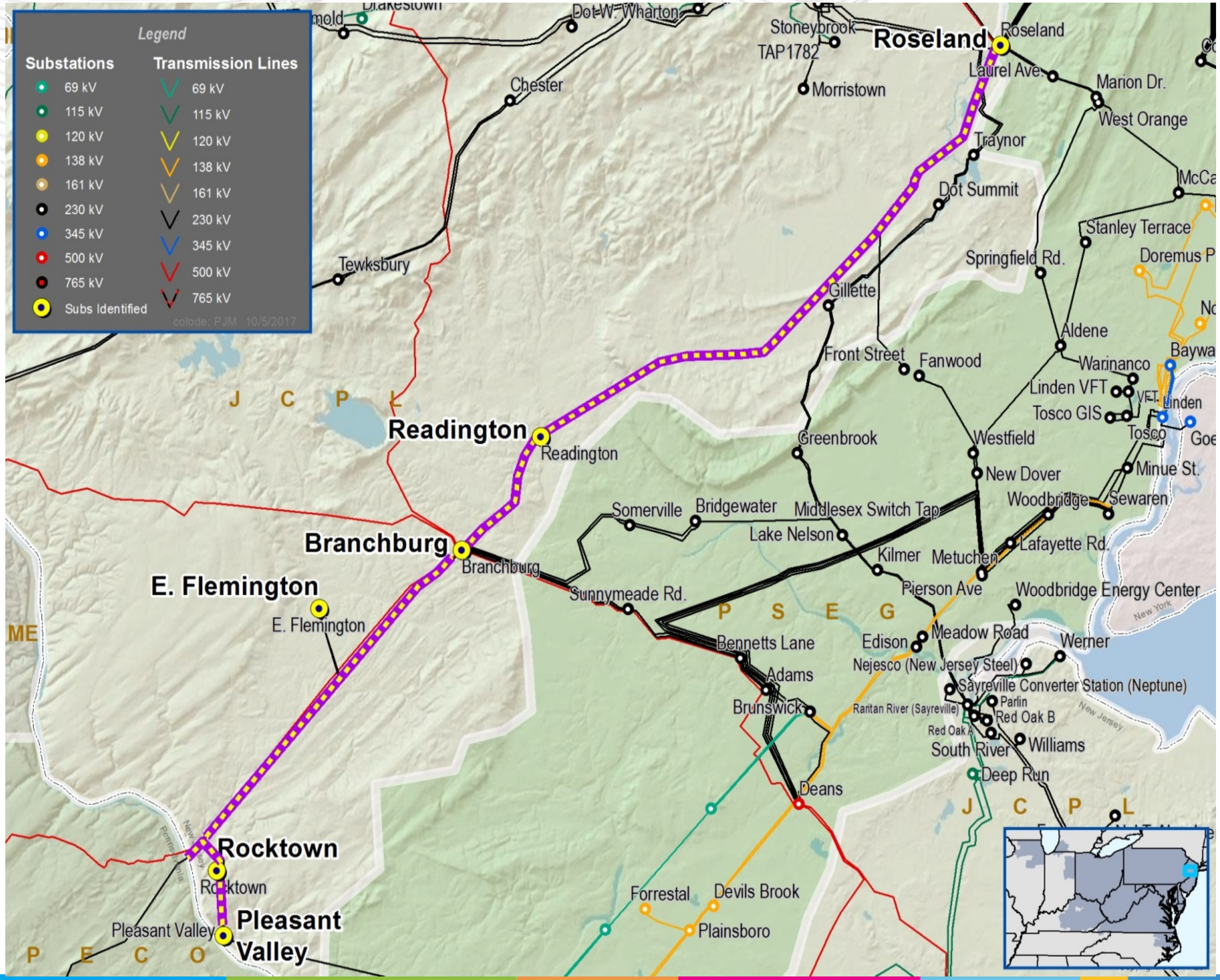
PSE&G FERC 715 Local Criteria - Equipment Assessment

Roseland – Branchburg – Pleasant Valley Corridor

PSE&G Transmission Zone

Roseland – Branchburg – Pleasant Valley Corridor

- PSE&G's FERC 715 Transmission Owner criterion addresses equipment condition assessments
  - PSE&G assessed the condition of the Roseland to Branchburg to Pleasant Valley 230 kV circuits.



- Refer to PSE&G criteria:

VII. EQUIPMENT ASSESSMENT AND STORM HARDENING

http://www.pjm.com/~/media/planning/planning-criteria/PSE&G-planning-criteria.ashx

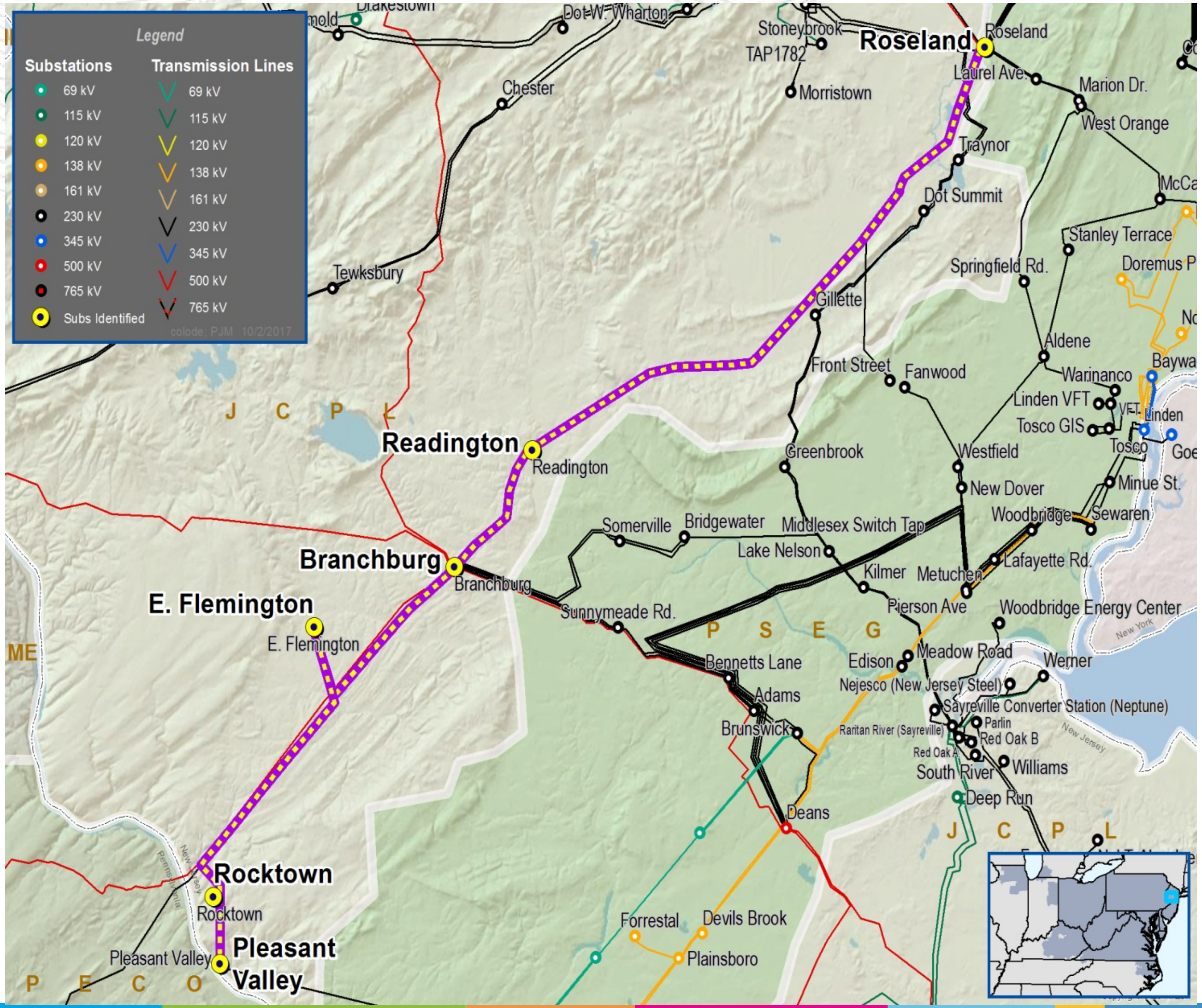
  - Roseland to Branchburg is approximately 30 miles of 230 kV circuit and the average structure age is approximately 90 years.
  - Branchburg to Pleasant Valley is approximately 22 miles of 230 kV circuit and the average structure age is approximately90 years.
  - Parallel to Roseland-Branchburg 500kV corridor
  - The terrain is variable and includes rural, National Wildlife Refuge and municipalities
  - This facility also serves 240 MVA sub-transmission load in adjacent territory (JCP&L)

Roseland – Branchburg – Pleasant Valley Corridor

- PSE&G commissioned external consultants to assess tower foundations and tower structures of the 50 mile Pleasant Valley-Branchburg-Roseland corridor
  - Assessment result:
    - The assessments identified towers with foundations needing reconstruction, towers exceeding loading capability, Also identified through LiDAR are NESC ground conflicts; the Project was developed as a result.
- These towers were built in 1927-1930. Small portions were rebuilt from 1961 to 2015 (see next slide). At 795 ACSR, some existing conductors are smaller than the current standard of 1590 ACSR.
- The two major components of the overall corridor are the Roseland – Branchburg segment and the Branchburg – Pleasant Valley segment

Roseland – Branchburg – Pleasant Valley Corridor

- Assessment Result:
  - Consultant findings – Transmission Tower Foundation assessment
    - About 25% of structures for Roseland – Branchburg – Pleasant Valley will require either extensive foundation rehabilitation or total foundation replacement.
  - Consultant findings – Tower line assessment
    - Due to the present condition, 54% of the towers are exceeding 100% of the tower's load bearing capability, and 84% of the towers are exceeding 95% of the tower's capability.
    - 9% of spans violate LiDAR ground conflicts



Roseland – Branchburg Segment

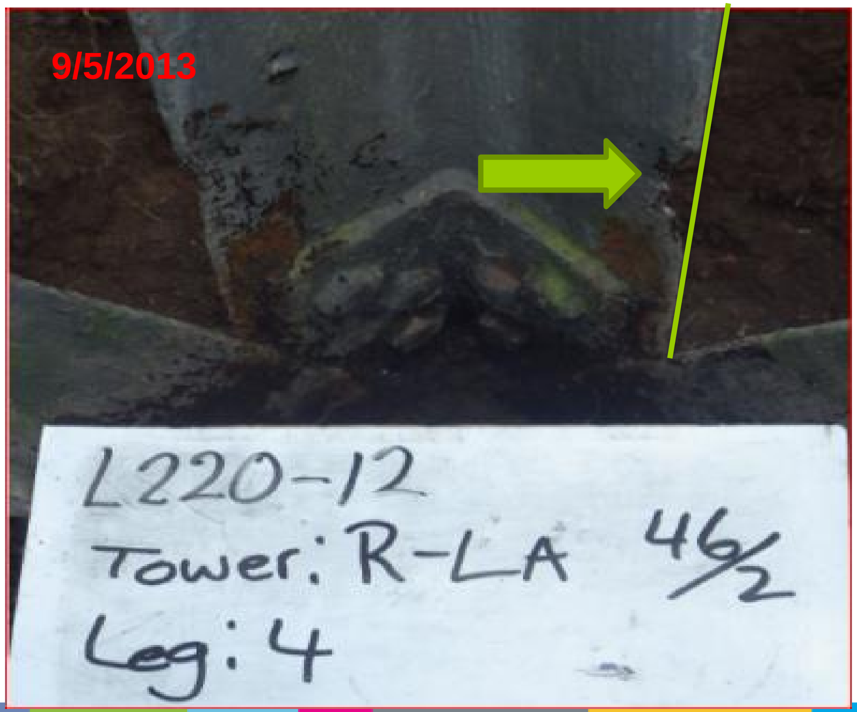
Tower Condition on Circuits U-2221, M-2265 (162 towers)	
Towers with foundation requiring extensive reconstruction	40 (25%)
Towers exceeding 95% loading capability	144 (89%)
Towers exceeding 100% loading capability	129 (80%)
LIDAR conflict (# spans)	17* (10%)

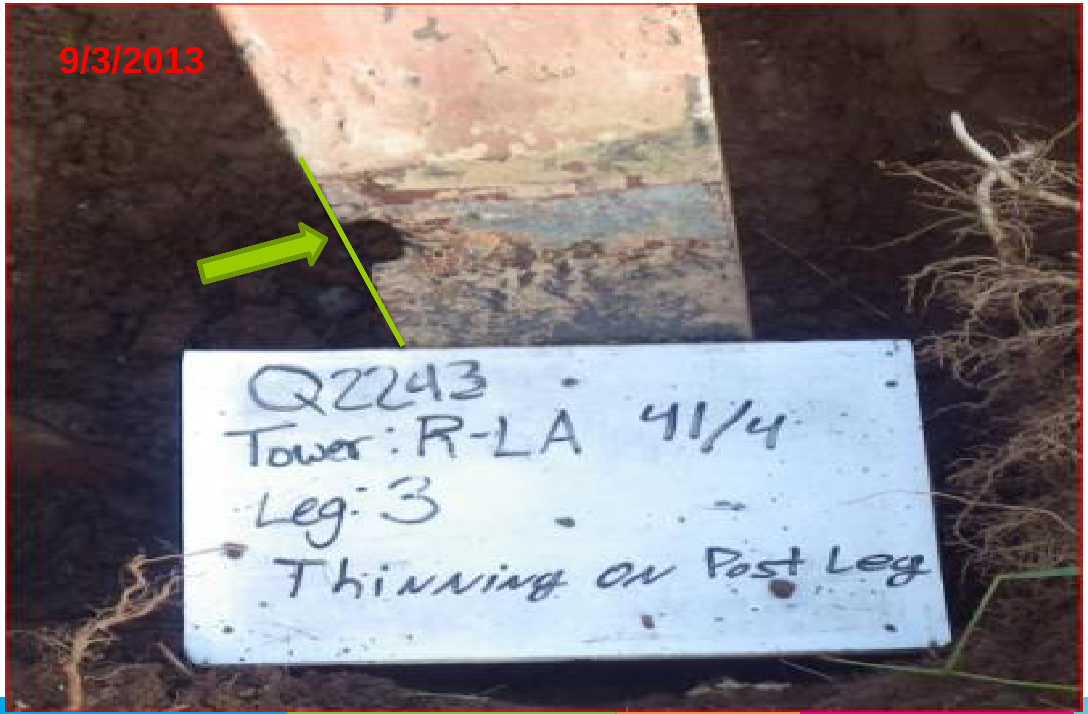
*LiDAR conflicts as of 9/29/2017

Branchburg – Pleasant Valley

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

*LiDAR conflicts as of 9/29/2017



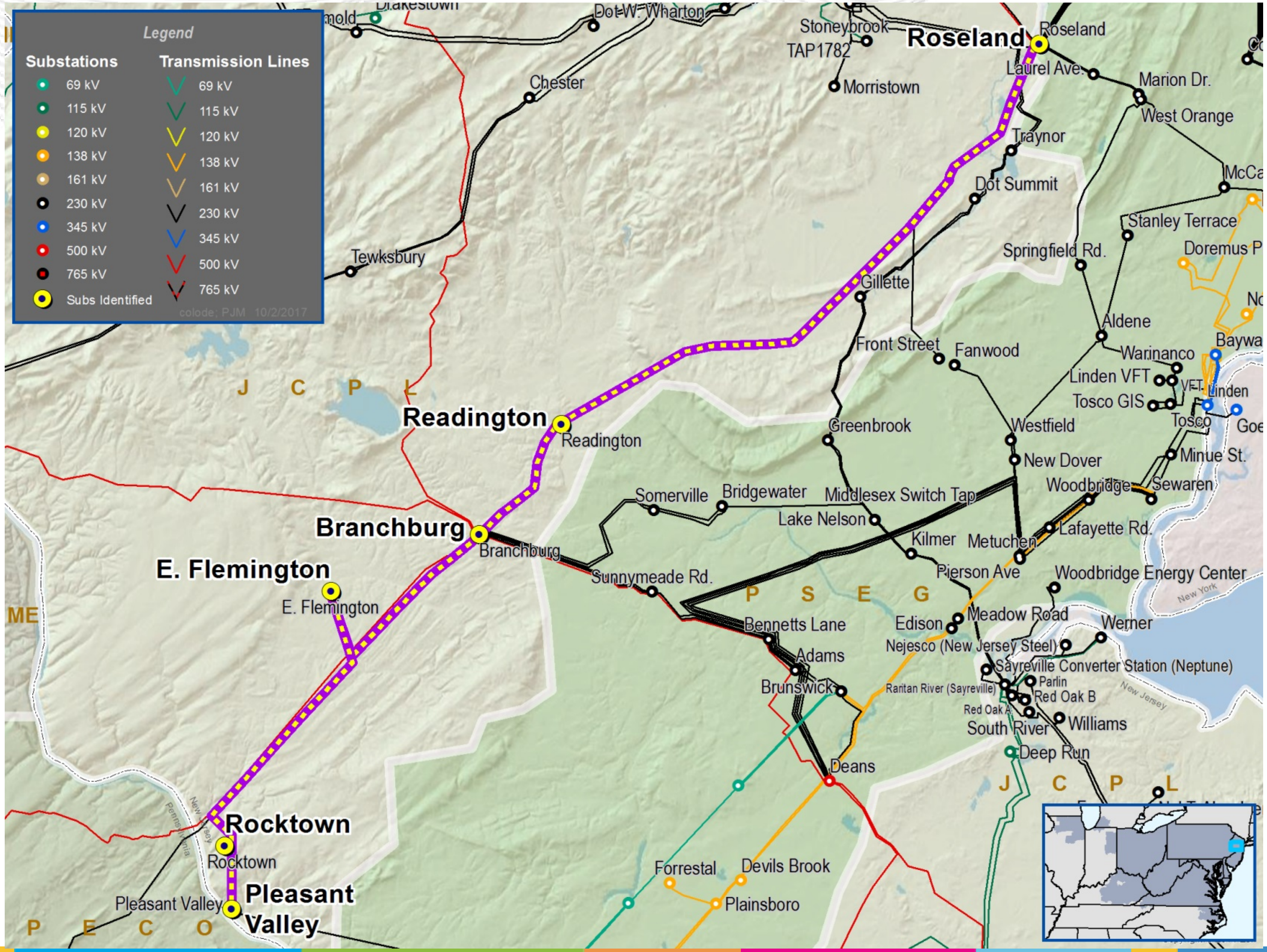


Roseland – Branchburg – Pleasant Valley Corridor

Problem:

PSE&G FERC 715 local Transmission Owner Criteria

- Equipment condition assessment for the entire corridor
- Equipment has reached its end of life



Solution Alternatives Considered

1. Remove and retire the 230 kV corridor without replacing

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

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

Solution Alternative #1: Remove the existing 230 kV corridor without replacing

- Would leave 240 MVA of JCP&L load supplied by 34.5kV sub-transmission with significant voltage and thermal violations
- Would require extensive construction, and associated cost, to relieve voltage and thermal violations on 34.5kV
- Loss of up to 996 MVA transmission system capacity
- Thermal/Voltage violations on the neighboring JCP&L system
- *Because of the above issues, removal without replacement is not a viable option*.

Solution Alternative #2: Install New Circuit and Remove Existing

- Potential permitting challenges due to new facility
- Martinsville, East Flemington, Readington and Rocktown require feeds from 230/34.5kV substations and associated additional lines to loop in an out of each station
- Would require more than 50 miles of new overhead construction, new ROW and new permitting
- *Due to the above issues, installing new equipment in new areas is the highest cost option*

Solution Alternative #3:
Replace the existing 230 kV corridor with new structures

- Maintain system reliability
- Eliminate safety risk from damaged structures
- No new ROW required
- No new substations or reactive devices required
- No topology change – additional studies, extensive protection coordination not needed
- Minimal new siting, permitting and construction involved
- Maintain transmission capacity between Branchburg and Lawrence substations

Potential solution:

- Replace the existing Roseland – Branchburg – Pleasant Valley 230 kV corridor with new structures.

Estimated Project Cost: $ 546 M

Required IS date: 2018

Projected IS date: 6/1/2022

Project status: Engineering

Supplemental Projects – First Review

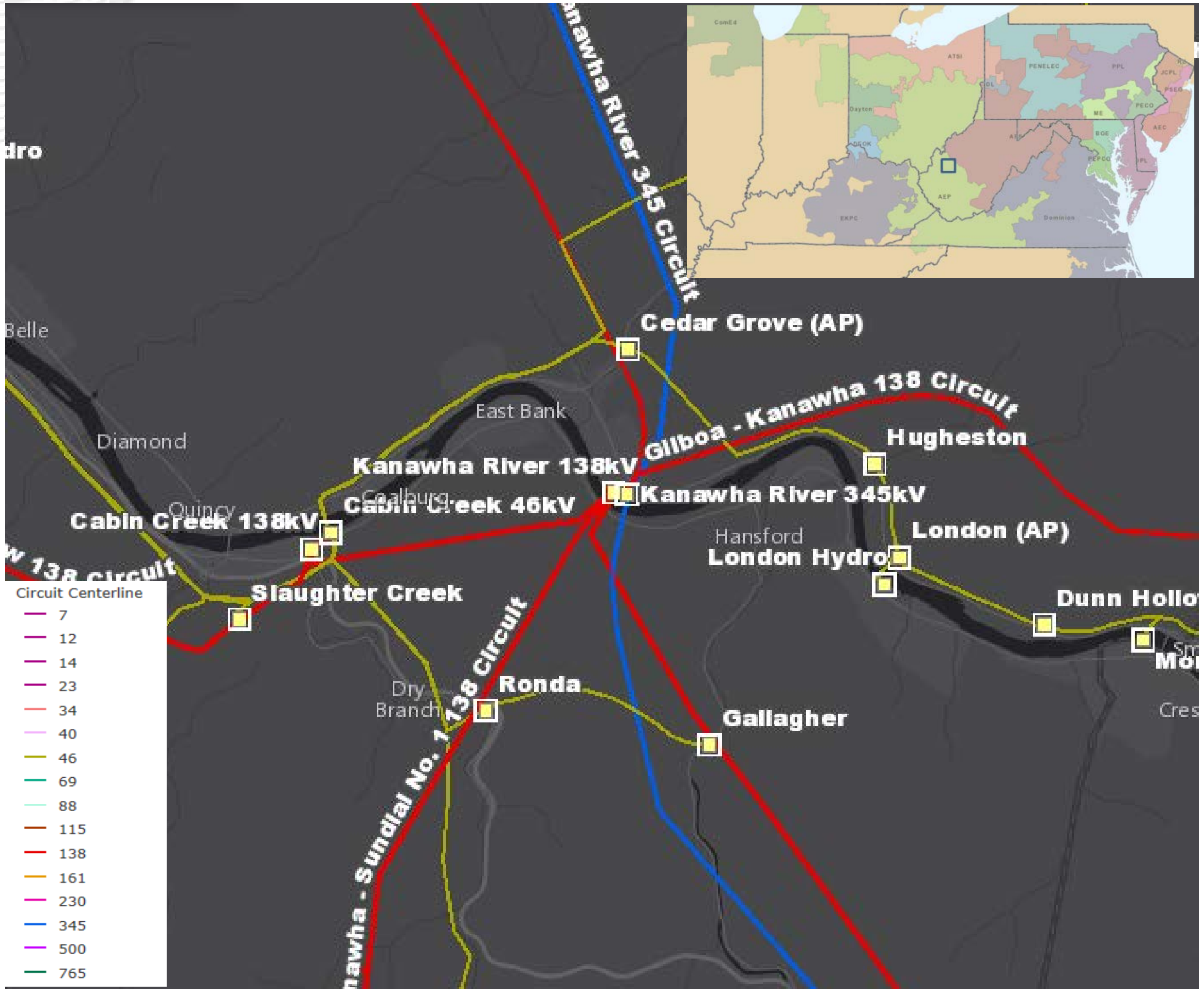
Supplemental Project

Problem Statement:

Equipment Material/Condition/Performance/Risk:

345 kV circuit breakers “Q”, “Q1”, and “Q2” are in poor condition due to corrosion issues and need replacement (vintage 1988). All three breakers are SF6, FX-22A type breakers which is an obsolete 345 kV model. AEP only has 8 of this type of breaker across the entire system and spare parts are difficult to come by. Additionally, the three subject breakers have significantly exceeded the designed number of 10 fault operations. Breaker Q has experienced 87 fault operations, Q1 has experienced 29 fault operations and Q2 has experienced 113 fault operations. All three breakers have also shown issues with their arcing contacts. Due to contact wear, not replacing the breakers can lead to catastrophic failure.

Kanawha River 345/138 “B” Bank will be replaced due to multiple issues and a high risk of failure (vintage 1973) . Failure of this transformer could cause damage to other equipment at the station an oil leakage in the yard. Transformer B has experienced short circuit breakdown caused by the large amount of significant through fault events in excess of 700°C, increased and upward trending of gassing, major periods of overheating, and high concentration of combustible gases (acetylene, ethylene, ethane, and methane). Moreover, studies identified in the AEP Transmission Operations Seasonal Performance Appraisal for the 2017 Winter season show that the failure of 345/138 kV Transformer B would create an overload scenario on 345/138 kV Transformer A for the loss of the Kanawha River-Matt Funk 345 kV circuit. The reliability of each transformer is critical if the other transformer is removed from service.



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The Kanawha River 345 kV Series Capacitor was installed on the APCo transmission system in 1991 to improve loadability of the Kanawha-Matt Funk 345 kV 108 mile line by reducing its apparent impedance. The existing series capacitor consists of three impedance compensation (i.e. reduction) segments. Segment 1 (10%), Segment 2 (20%), and Segment 3 (30%). Segments 1 and 2 are located on one platform while the segment 3 on a separate platform. The fiber optic cable used in Segment 1 is in complete failure. The power supply for Segment 2 has failed. The control cards for both Segment 1 and Segment 2 have been used to keep Segment 3 available. Segments 1 and 2 cannot be repaired due to lack of parts and Segment 3 may not operate when called upon due to inadequate protection and control equipment. The fiber optic cable in Segment 3 is also on the verge of failure based on recent testing. Due to its age, spare parts are unavailable because they are no longer produced by the manufacturer. The lifecycle of a capacitor in a substation environment is 30 years, and these capacitors are approaching their end of life. In addition, upgrading the protection and control equipment is not an option due to the fact that modern relaying packages are not compatible with the aged series capacitor.

Operational Flexibility and Efficiency

The 345 kV series capacitor is used to help maintain the reliability on the transmission grid and allows flexibility during maintenance and construction outages. Reliability is maintained by adhering to voltage and thermal limits to withstand additional system disturbances. Specifically, the 345 kV Series Capacitor Bank is needed to alleviate Interconnection Reliability Operating Limit (IROL) constraints.

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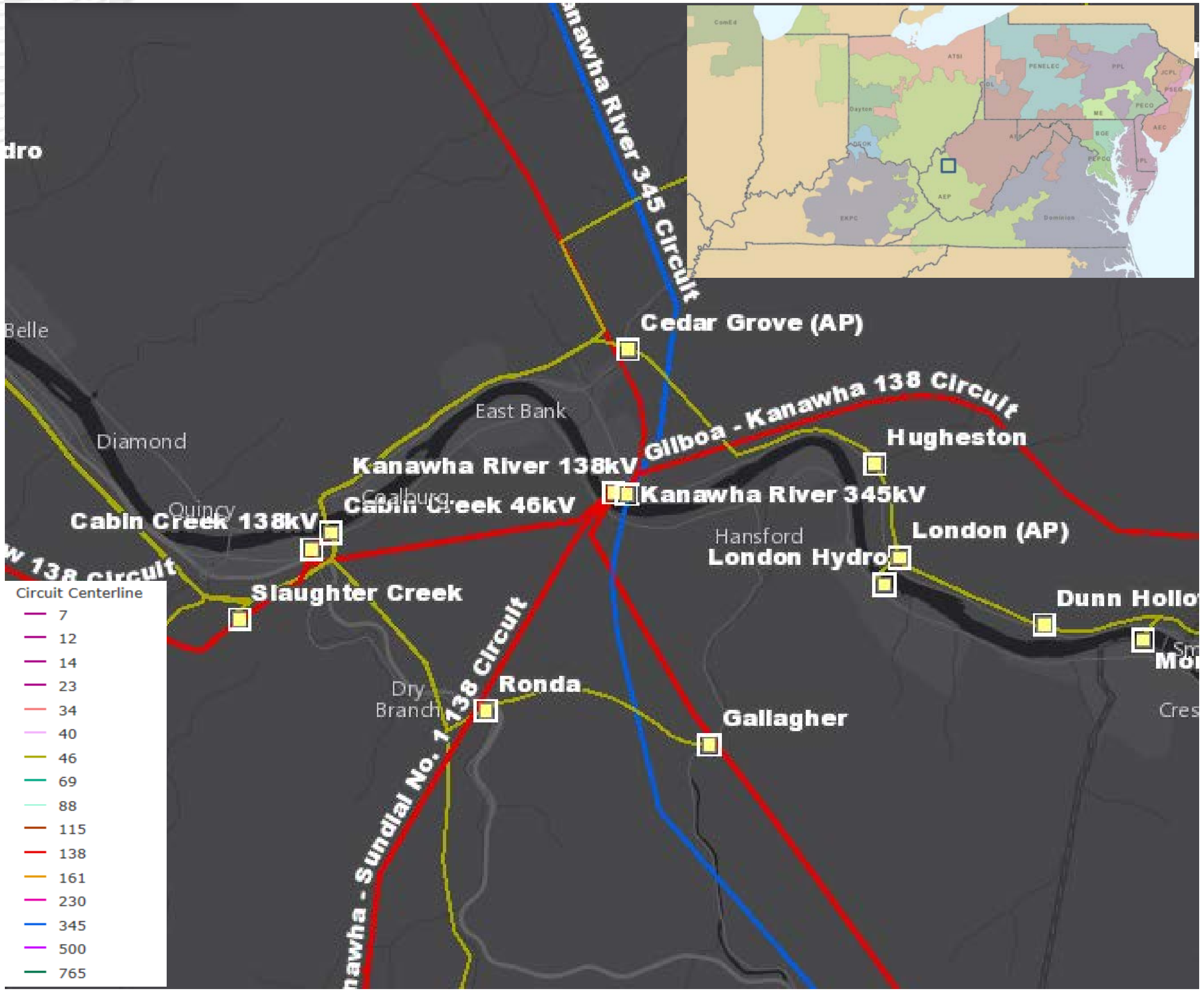

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The 345 kV Series Capacitor Bank is used during heavy power flow winter conditions and/or during a significant outage to alleviate voltage and thermal constraints. Since 2014, the series capacitor was used five times to help alleviate operational concerns. The 345 kV Series Capacitor Bank can provide voltage support to the 138 kV system during heavy transfers to the Dominion interface under multiple outage conditions.

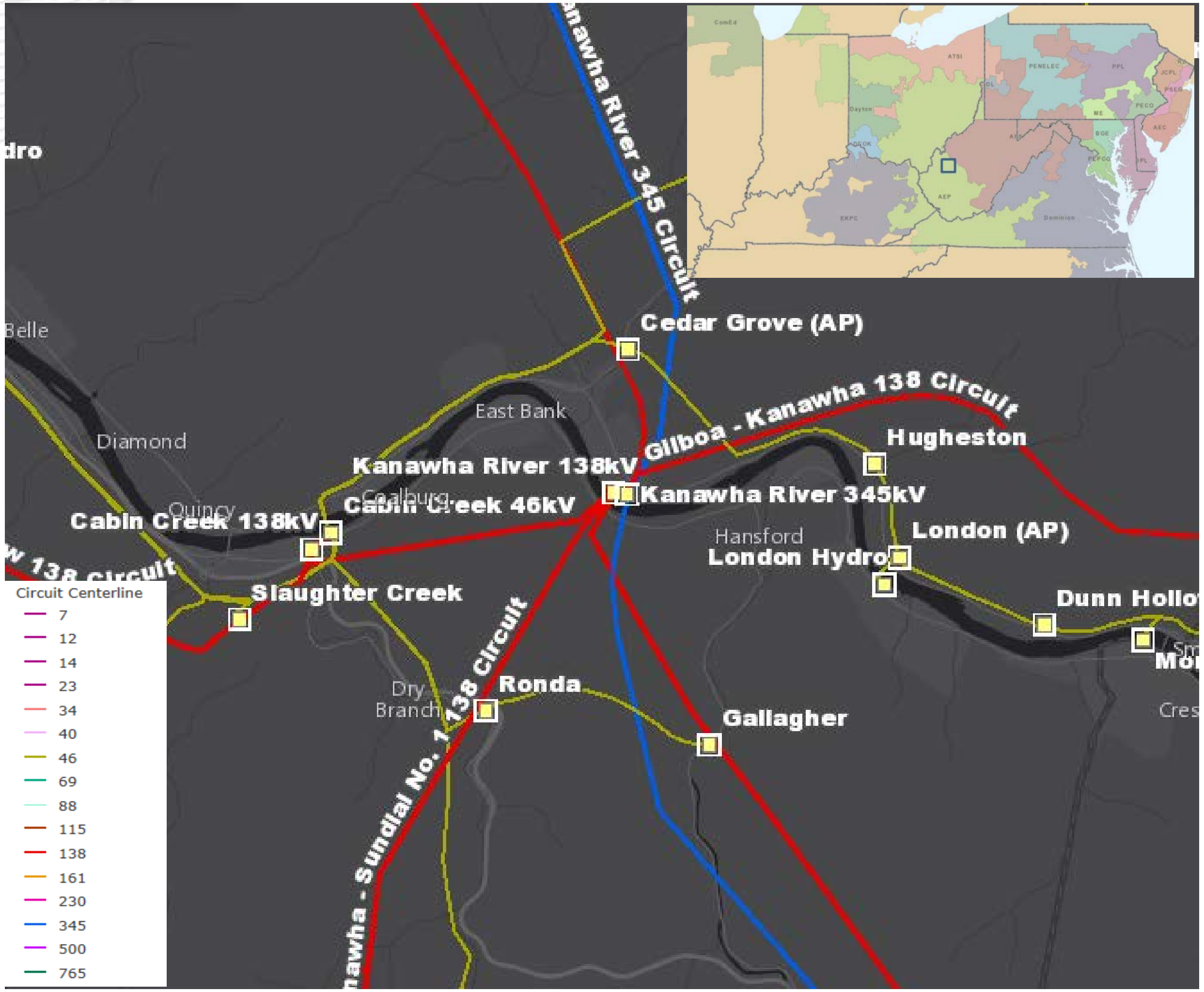
Potential Solution:
Replace three existing 3000 A 50 kA 345 kV circuit breakers Q, Q1 and Q2 with new 5000 A 63 kA circuit breakers. Replace the three sections of the existing Kanawha River Series Capacitor with a single 24 ohm 3000 A series capacitor. Replace existing 400 MVA 345/138/13.8 kV XF with a new 450 MVA 345/138/13.8 kV XF.

Total Estimated Transmission Cost: $30.0 M

Alternatives:
No viable cost-effective transmission alternative could be identified.

Projected In-service: 12/12/2019

Project Status: Scoping



Supplemental Project

Problem Statement:

Equipment Material/Condition/Performance/Risk/Operational Flexibility:

138kV breakers B, B1, B2, C, and C1 are all air blast breakers type PK-2B40 and 2B50. Air blast breakers are being replaced across the AEP system due to reliability concerns, intensive maintenance, and tendency to fail, catastrophically. During failures, sharp pieces of porcelain from bushings are expelled, which are a potential safety hazard to field personnel. In addition, manufacturers do not develop spare for these types of breakers. The Manufacturers' recommended number of fault operations is 10. Breaker B has experienced 47 fault operations, breaker B1 has experienced 127 fault operations, breaker B2 has experienced 102 fault operations, breaker C has experienced 63 fault operations, and breaker C1 has experienced 100 fault operations .

Drivers for 765/138 kV 600 MVA transformer # 1 (vintage 1969) include bushing damage and wear, dielectric strength breakdown (insulation breakdown), and short circuit strength breakdown due to through fault events. Additionally, transformer # 1 has high levels of Acetylene. Gas formations within a transformer are caused by electrical disturbances and/or thermal decomposition as a result of multiple thermal and/or electrical faults suffered through the life of the transformer.

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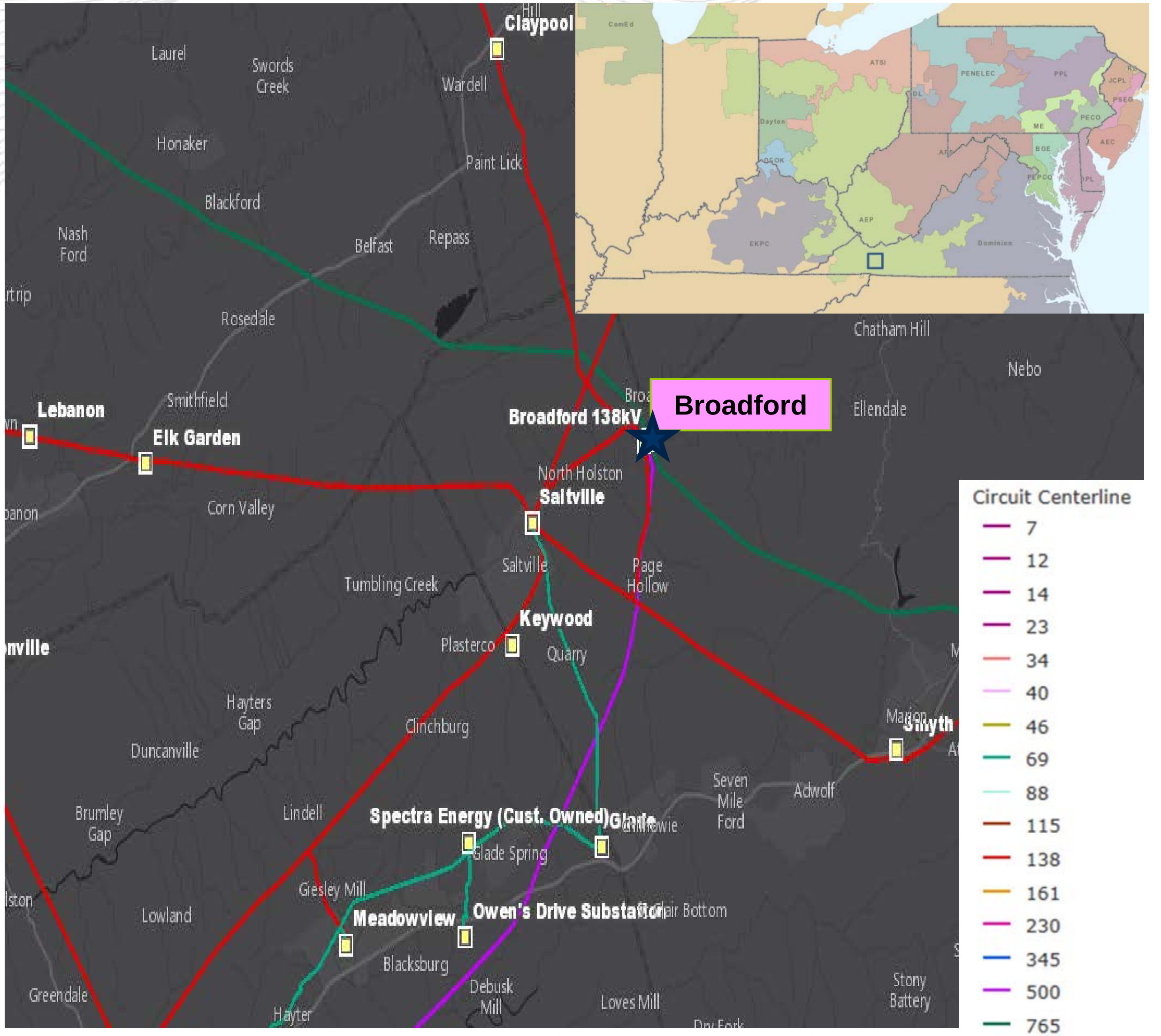

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Drivers for 765/500 kV 1500 MVA transformer # 4 (vintage 1969) include short circuit strength breakdown (due to through fault events), dielectric strength breakdown (insulation), and bushing wear. Additionally transformer # 4 also has high Ethane and Carbon Dioxide levels dissolved in the oil.

<u>Operational Flexibility and Efficiency:</u>

Due to the lengthy outages and space constraints within the existing 765 kV yard, both 765 kV transformer replacements will need to be done in the clear. To accommodate the new transformers position, circuit breakers N, N1, and P will be installed. Taking transformers #1 and #4 off the bus will allow us to separate dissimilar zones of protection, which can lead to relay misoperations. In addition, due to space constraints and construction requirements, the new transformers cannot be physically placed back in their original locations.

Currently at the 138 kV yard, both the Broadford – Wolf Hills and Broadford – Atkins circuits are terminated directly on the bus. This creates dissimilar zones of protection (line and bus) that can cause misoperations. Broadford – Wolf Hills is approximately 30 miles long and Broadford – Atkins is approximately 20 miles long; terminating both of these lines into a new breaker string will help reduce the exposure on each circuit. Installing circuit breakers D, D1, and D2 will mitigate this relay protection issue along with subjecting equipment to undue fault conditions. The station will be reconfigured and the work will be done in the clear to lessen the impact of the outages that need to be taken. In doing so, the reactor and circuit breaker C2 will be replaced as part of the station reconfiguration.

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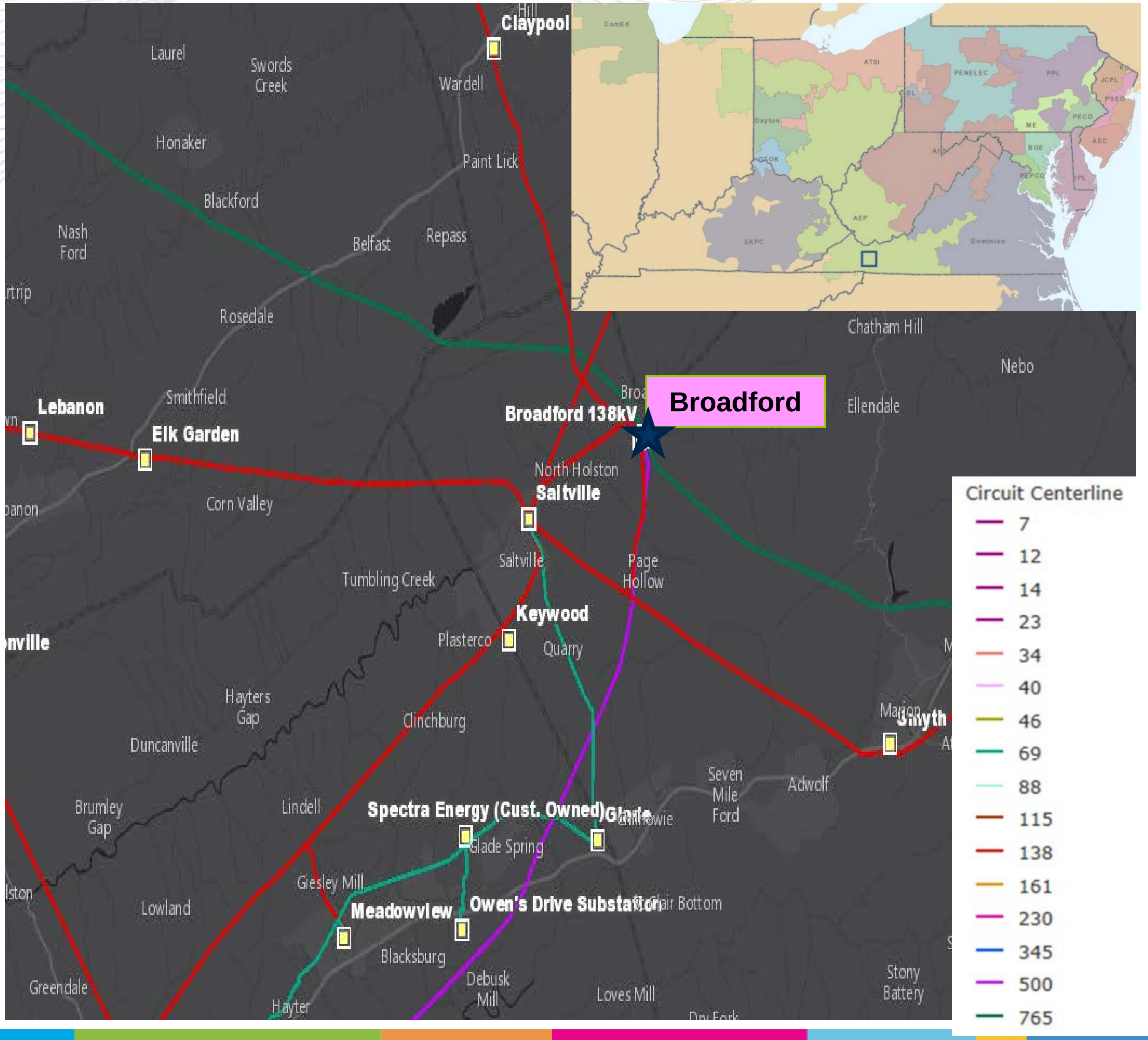

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Potential Solution:
Broadford 765 kV Yard: Replace existing 765/138 kV 600 MVA XF #1 with a new 765/138 kV 750 MVA XF (standard size). Replace 765/500 kV 1500 MVA XF #4 with a new 765/500 kV 1500 MVA XF. Install one new 765 kV 4000 A 50 kA circuit breaker to complete the existing "P" string. Install two new 765 kV 4000 A 50 kA circuit breakers in a newly constructed "N" string. Estimated Cost: $74M

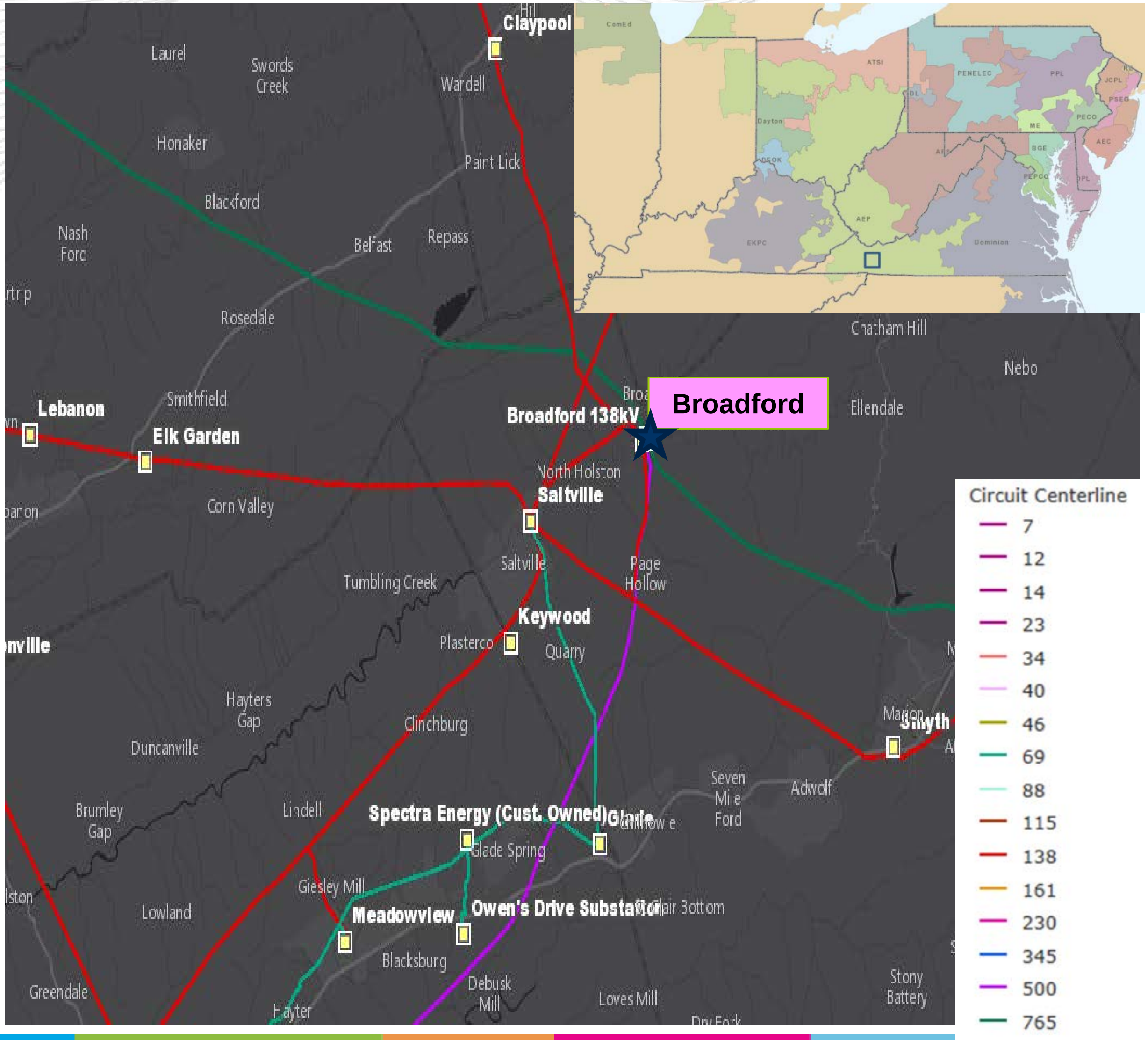
Broadford 138 kV Yard: Replace six existing 138 kV 3000 A 42 kA circuit breakers B, B1, B2, C, C1 and C2 with six new 138 kV 3000 A 63 kA circuit breakers. Install three new 138 kV 3000 A 63 kA circuit breakers in newly constructed D string. Replace existing 138 kV 3000 A 40 kA circuit breaker R with a new 138 kV 3000 A 40 kA breaker "CC". Replace existing 138 kV Reactor with a new 138 kV Reactor. Estimated Cost: $28M

Total Estimated Transmission Cost: $102M

Alternative
A complete station rebuild/relocation was discussed. However, this is not feasible from a constructability perspective. Rebuilding the entire station at a new site would also raise the cost well over $100 M.

Projected In-service: 12/01/2020

Project Status: Engineering



Supplemental Project

Problem Statement:

<u>Equipment Material/Condition/Performance/Risk/Operational Flexibility:</u>

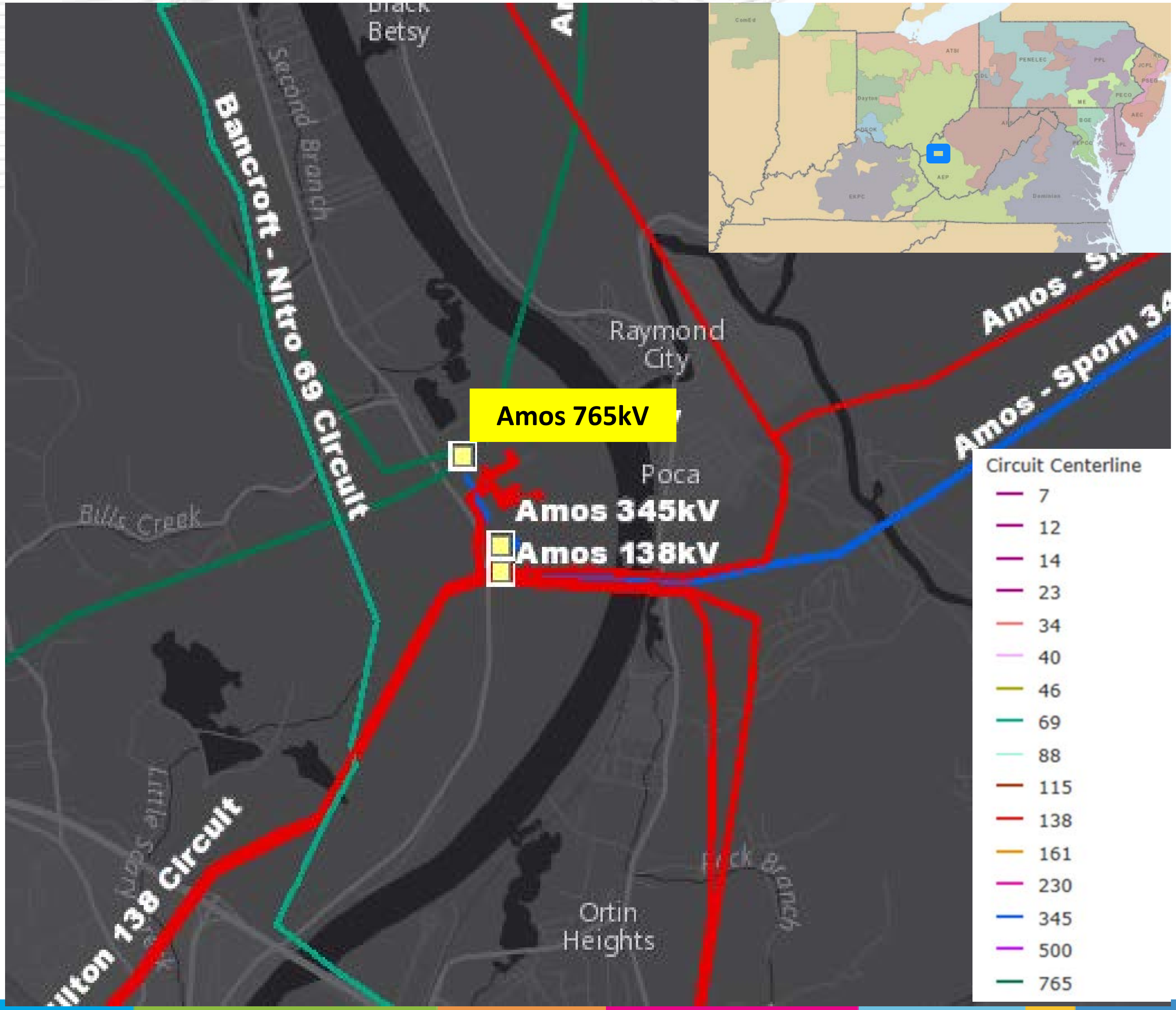
At Amos station, 765 kV circuit breakers ‘U’, ‘U1’ and ‘U2’ are 29 kA DELLE, PK-10D type air blast breakers that were manufactured in 1972. Air blast breakers are being replaced across the AEP system due to their history of catastrophic and violent failures. During failures, sharp pieces of porcelain from their bushings can be expelled from the breakers, resulting in potential safety hazards to field personnel. In addition, the ability to get spare parts is becoming increasingly difficult. Breaker ‘U’ has experienced 34 fault operations, breaker ‘U1’ has experienced 22 fault operations, and breaker ‘U2’ has experienced 26 fault operations. All of which are over the manufacturer’s recommended number of fault operations (10). These breakers are being replaced with higher kA ratings in order to meet AEP’s standard design for 765kV.

Potential Solution:
Replace existing 3000 A 29 kA 765 kV circuit breakers ‘U’, ‘U1’, and ‘U2’ with new 4000 A 50 kA 765 kV circuit breakers.
Estimated Transmission Cost: $12.5M

Alternative
No viable cost-effective transmission alternative could be identified.

Projected In-service: 12/13/2018

Project Status: Engineering



5th Brambleton TX and 230kV Bus-Tie - NOVEC

Problem Statement:
- NOVEC is installing a 5th transformer at Brambleton DP and a normally-open 230kV bus-tie between the incoming feeds (from DVP's Brambleton 230kV Bus#1 and Bus#2).

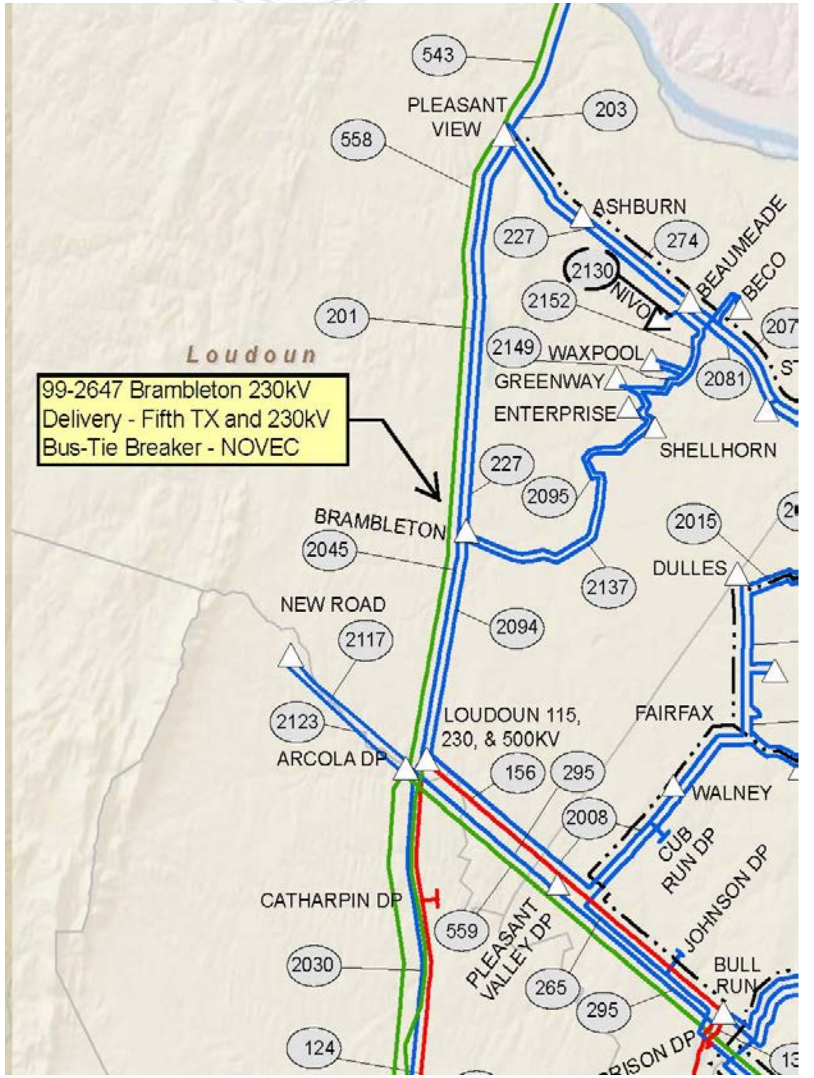
Potential Solution:
- Install all required protective relaying, metering, and associated equipment to accommodate NOVEC's 5th transformer and their ability to move load between the feeds from Brambleton 230 kV Bus #1 and Bus #2.

Estimated Project Cost: $500 K

Possible In-service Date: 10/30/2018

Project Status: Engineering

COLOR	VOLTAGE	TRANSMISSION LINE NUMBER
green	500 KV.	500 thru 599
blue	230 KV.	200 thru 299 & 2000 thru 2099
red	115 KV.	1 thru 199
orange	138 KV.	AS NOTED
cyan	69 KV.	AS NOTED



Supplemental Projects – Previously Reviewed

Supplemental Project
Previously Presented: 11/9/2017 TEAC

Problem Statement:

Equipment Material/Condition/Performance/Risk:

At Cloverdale station, 345 kV circuit breakers “P” and “P2” are 63 kA GEC, PK-4C type Air Blast breakers . Air blast breakers are being replaced across the AEP system due to reliability concerns, intensive maintenance, and their tendency to catastrophically fail. During failures, sharps pieces of porcelain from their bushings are typically expelled, which, can be a potential safety hazard to field personnel. In addition, the ability to get spare parts for these breakers is becoming increasingly difficult. The Manufacturers recommended number of fault operations is 10. Breaker “P” has experienced 25 fault operations.

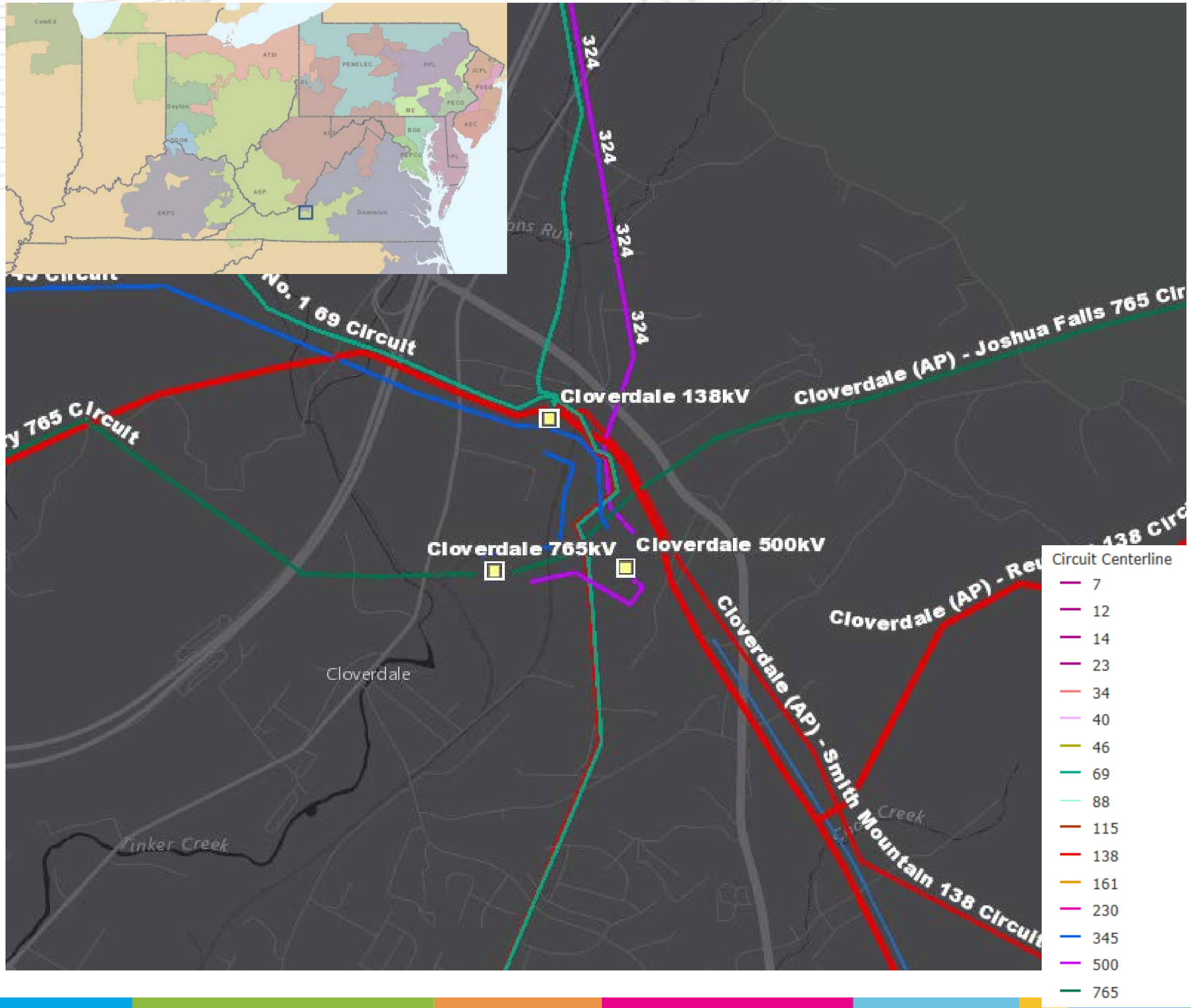
Selected Solution:

At Cloverdale station, replace 2- 345 kV PK type breakers (“P” & “P2”) with new 345 kV, 5000 A, 63 kA breakers. Install new 345 kV 5000 A disconnect switches on both breakers. Install new 345 kV surge arresters on both 345 kV Busses (#1 & #2). (S1447)

Estimated Transmission Cost: $4.7M

Projected In-service: 11/29/2018

Project Status: Engineering



Supplemental Project
Previously Presented: 11/9/2017 TEAC

Problem Statement:
Operational Flexibility and Efficiency
Motor Operated Air Break Switches (MOABs) have been utilized in the past as a less costly alternate to Circuit Breakers. MOABs at Extra High Voltage (EVH) unnecessarily subject expensive equipment, such as Transformers, to grid events in order to isolate a faulted section of the grid. This not only reduces the life of such expensive equipment, but also results in misoperations. It is AEP's practice to not install MOABs for fault sectionalizing at EHV. In addition, AEP is proactively replacing all EHV MOABs at existing stations with circuit breakers.

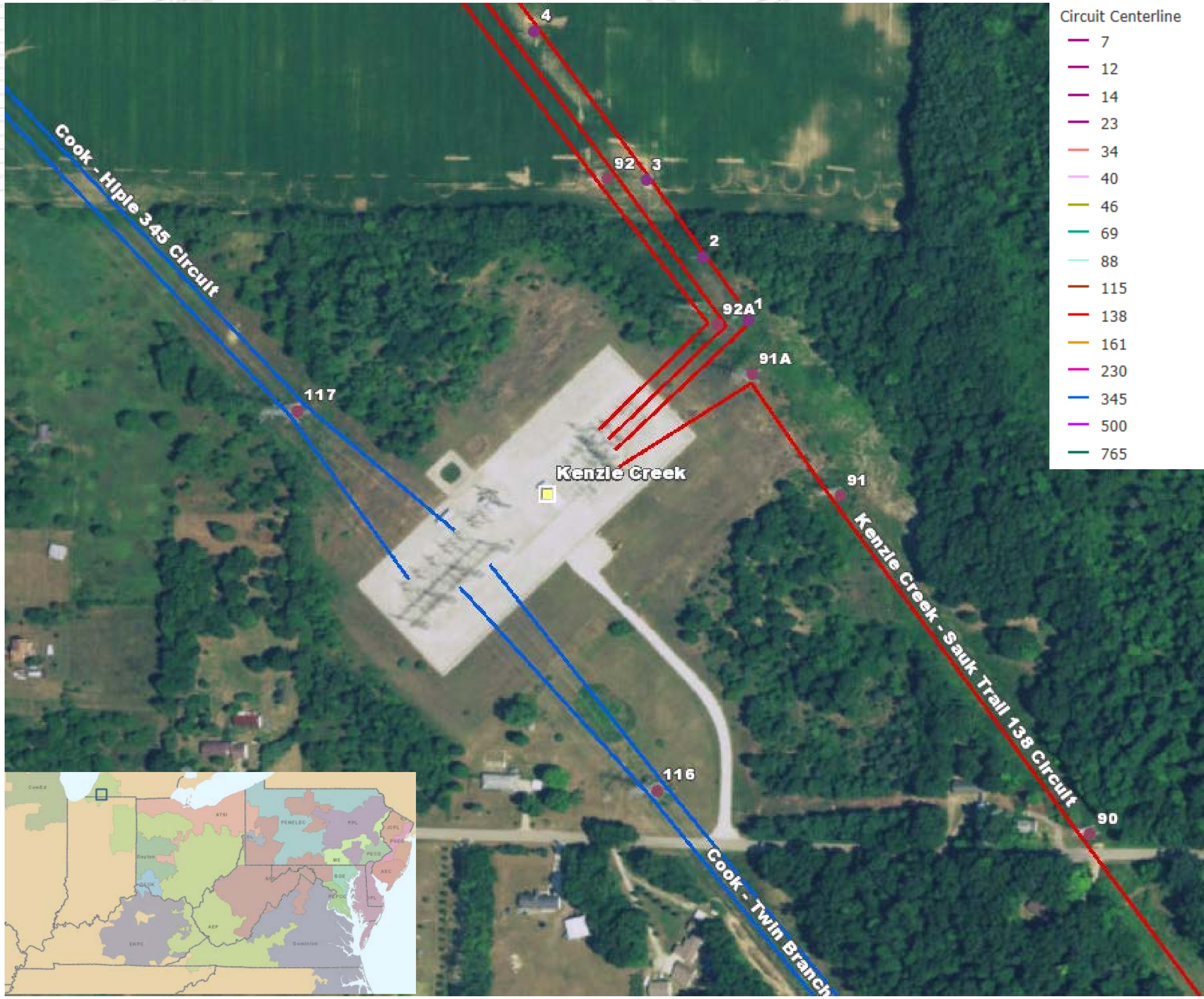
Selected Solution:

At Kenzie Creek station, retire 345kV MOABS 'W' and 'Y'. Install 3 345kV 5000A 63kA breakers in a ring bus configuration. Set up station to allow for future 'B' and 'C' breaker strings. (S1448)

Estimated Transmission Cost: $7.4M

Projected In-service: 12/31/2018

Project Status: Engineering



Supplemental Project

Previously Presented: 11/9/2017 TEAC

Problem Statement:

Equipment Material/Condition/Performance/Risk/Operational Flexibility:

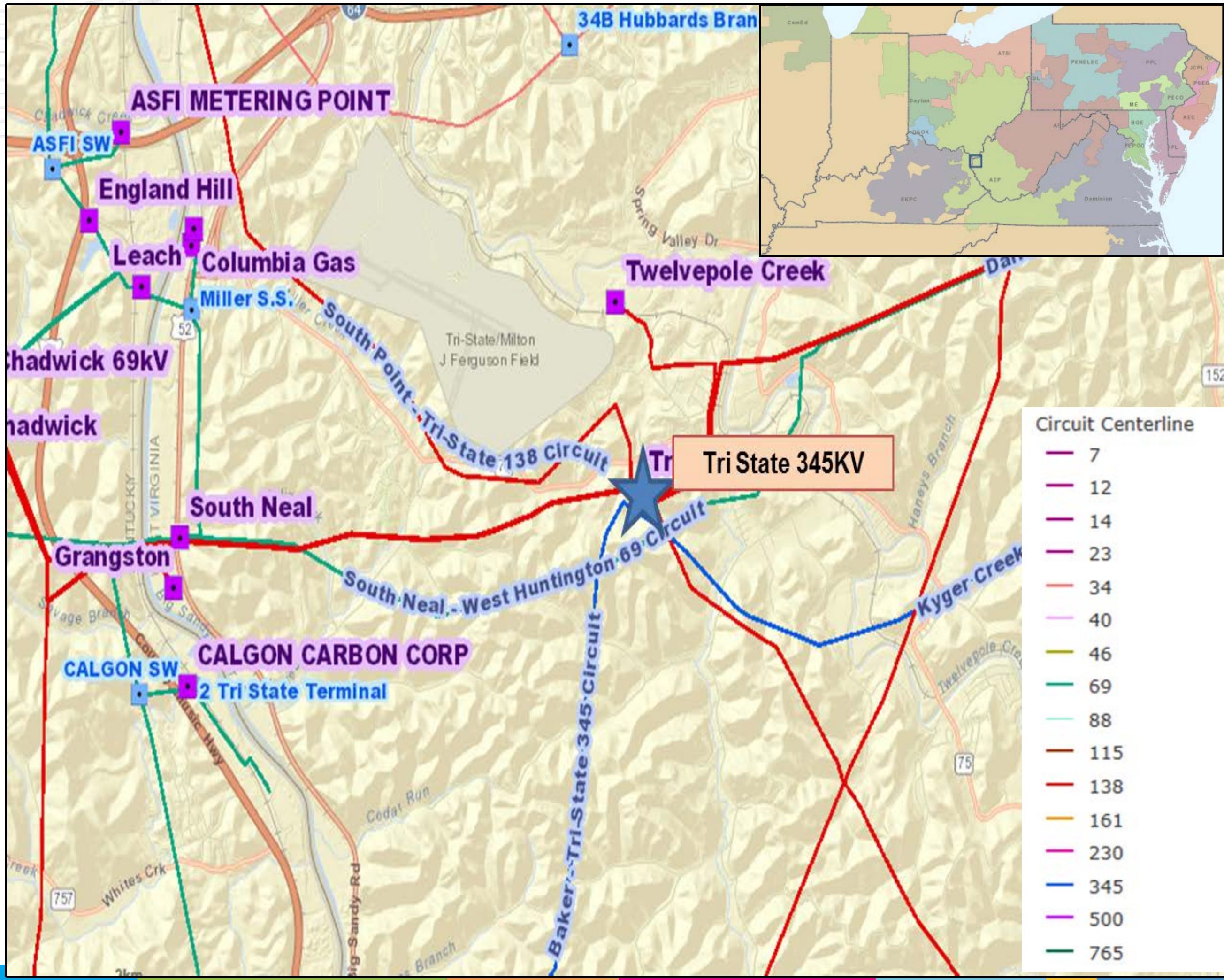
Breaker "H" at Tri-State is an Air Blast type breaker. Air blast breakers are being replaced across the AEP system due to reliability concerns, intensive maintenance, and their tendency to catastrophically fail. During failures, sharps pieces of porcelain from their bushings are typically expelled, which, can be a potential safety hazard to field personnel. In addition, the ability to get spare parts for these breakers is becoming increasingly difficult. CB "H" has experienced 32 fault operations compared to the manufacturer recommendation of 10.

The 345/138 kV transformer #1 (1965 vintage) is also being replaced due to dielectric breakdown (insulation), accessory damage (bushings/windings) and short circuit breakdown (due to amount of through faults).

The 345/138 kV transformer #2 is of the same age as Transformer #1, and the risk of failure of this unit will increase over the next few years due to its vintage and being a similar type as Transformer #1. In addition, there are elevated levels of ethane in the oil, some dielectric breakdown, and bushing damage.

Operational Flexibility and Efficiency:

The additional breakers being installed to create string G and the addition of one breaker on string H are being added break up dissimilar zones of protection (bus, line, and transformers), which could cause misoperations. In addition, this current lack of sectionalizing also makes it difficult for any maintenance work.



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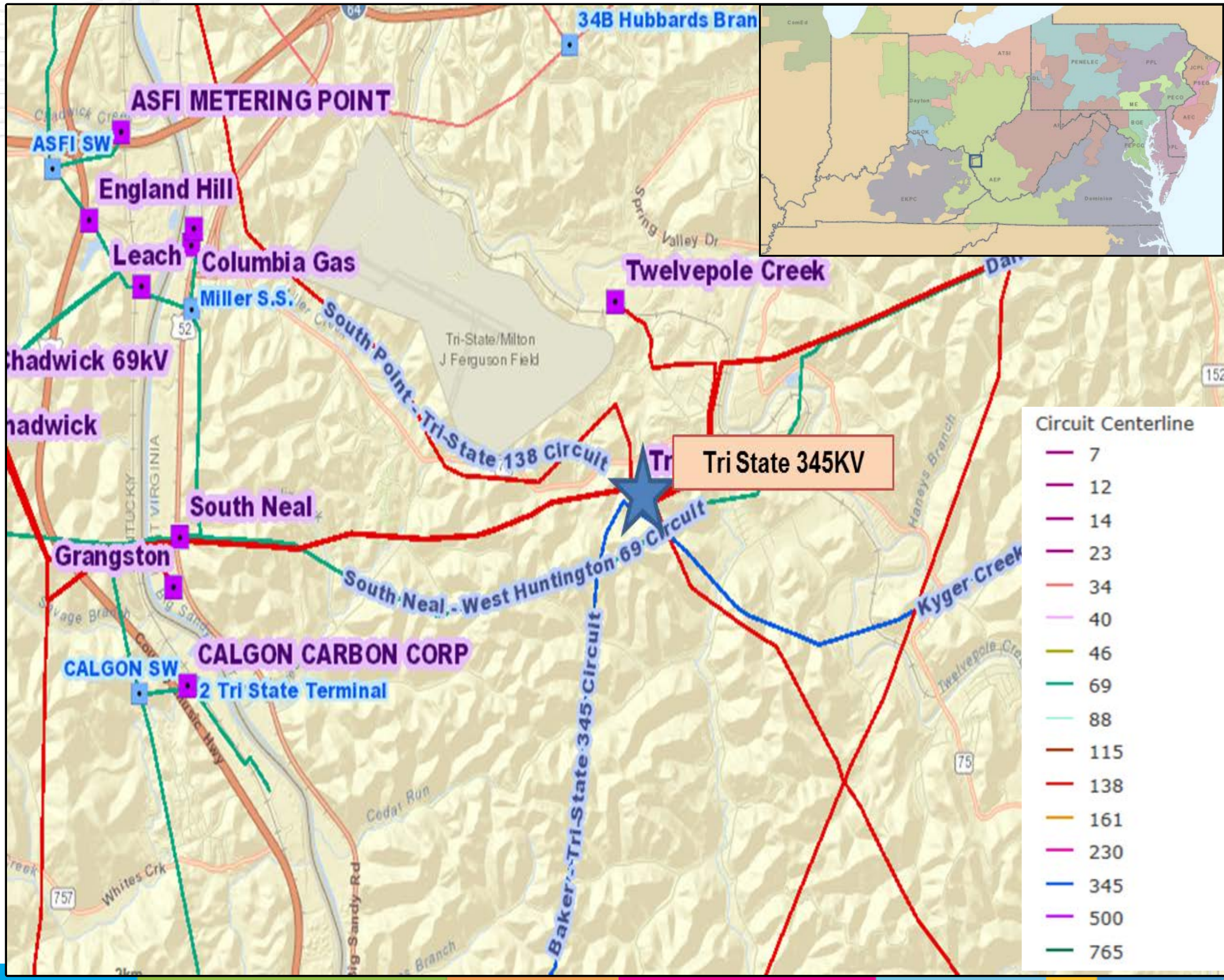
Selected Solution:

At Tri State station, replace circuit breaker “H” with a 345 kV 63kA breaker. Install 4 new 345 kV 63kA breakers in a new breaker and a half string configuration. Replace transformers 1 & 2 with 345-138 450 MVA units. (S1449)

Estimated Transmission Cost $9M

Projected In-service: 12/1/2018

Project Status: Engineering



Supplemental Project

Previously Presented: 11/9/2017 TEAC

Problem Statement:

<u>Equipment Material/Condition/Performance/Risk:</u>

At Desoto station, breaker C is an FX22A 3000A 50 kA Hydraulic breaker from 1985. Although only 32 years old, this breaker has experienced 124 fault operations which is significantly higher than the manufacturer recommendation of 3. In addition to this, there has been a rising trend of gas pressure on this breaker. Due to these identified issues, AEP recommends replacement of this breaker.

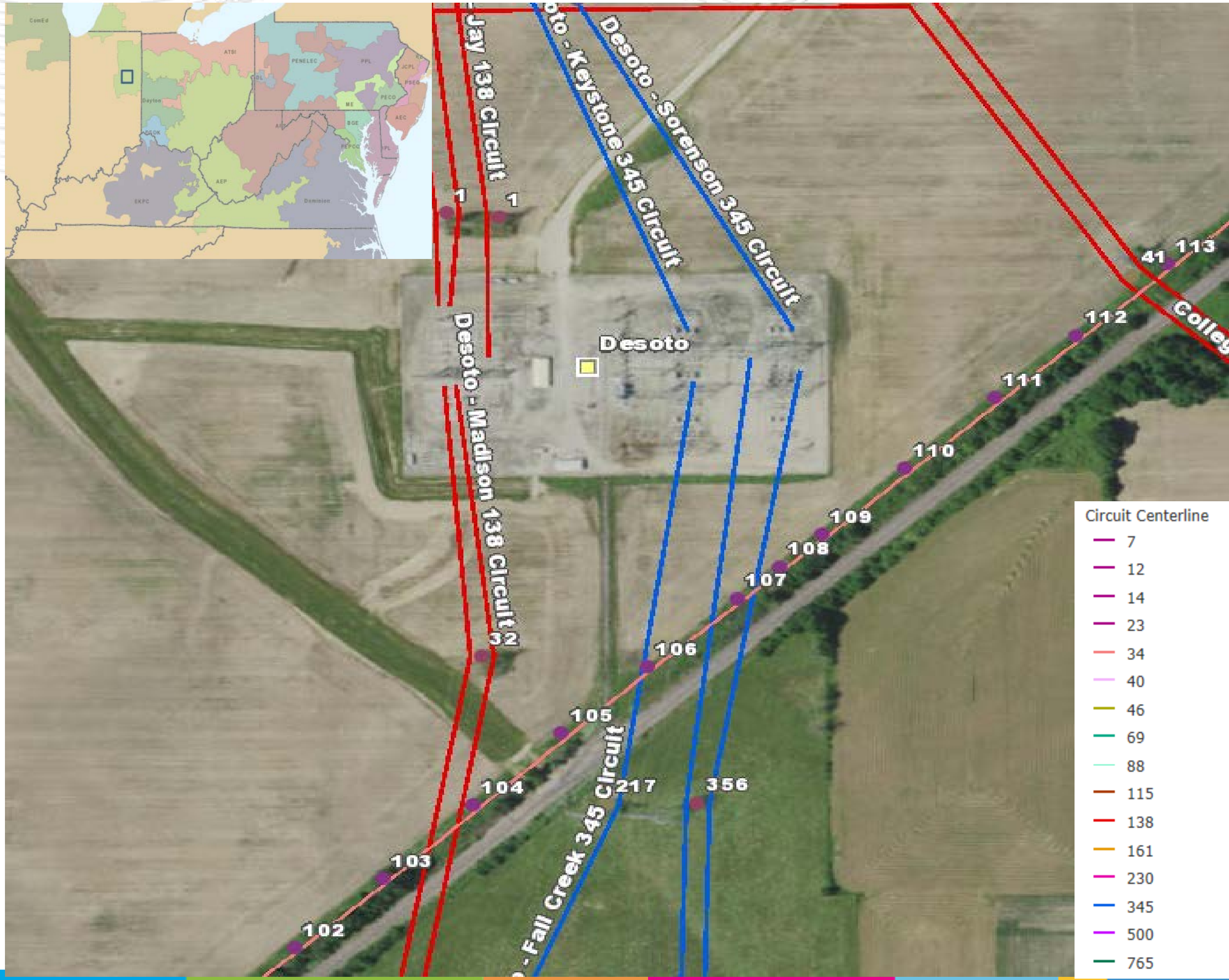
Selected Solution:

Replace 345kV breaker C with a GE Alstom 5000A 63kA 345kV breaker (S1450)

Estimated Transmission Cost: $1.0M

Projected In-service: 12/29/2017

Project Status: Construction



Tidd 345 – 138 kV Transformer B Replacement

Supplemental Project

Previously Presented: 11/9/2017 TEAC

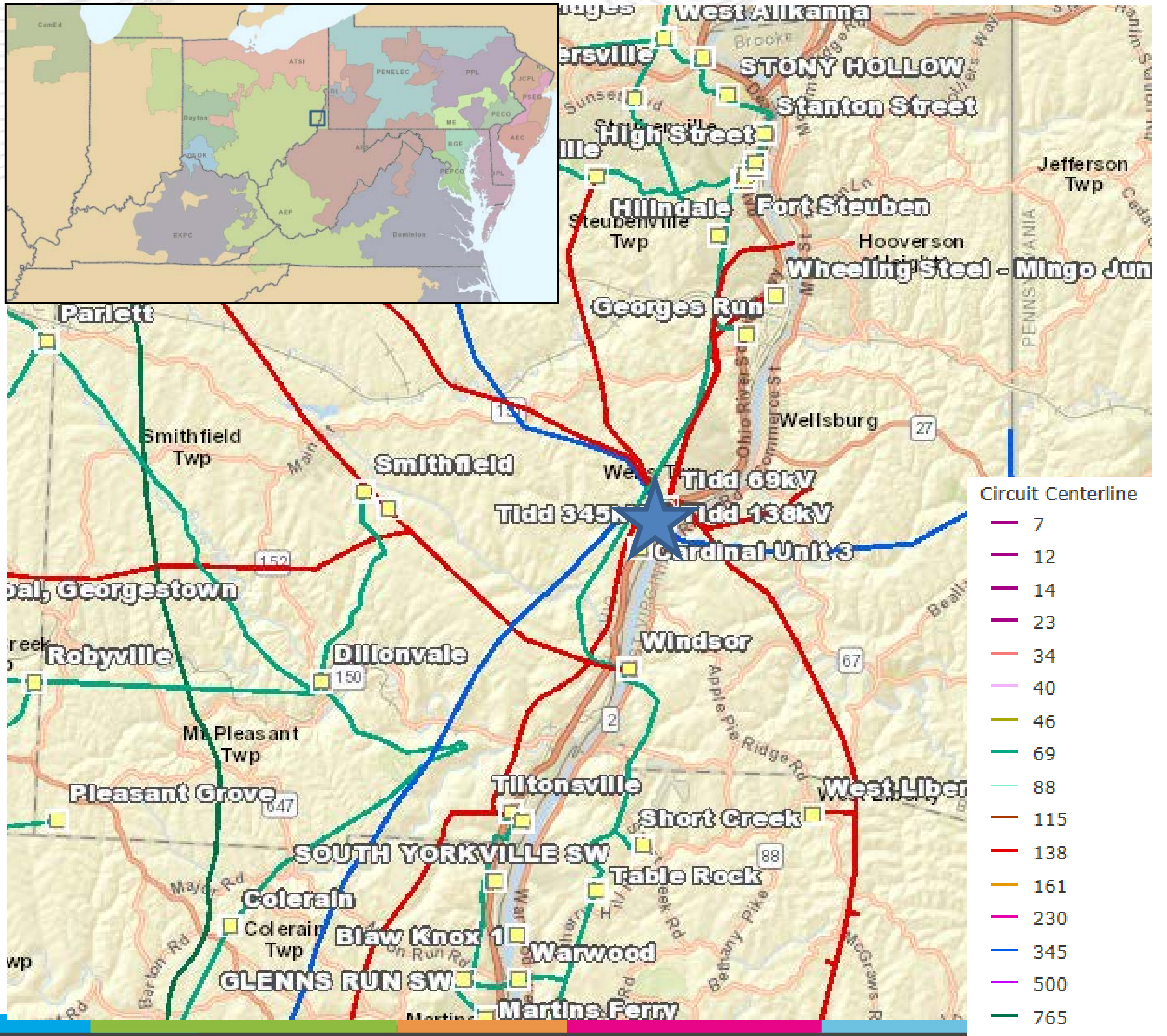
Problem Statement:

Equipment Material/Condition/Performance/Risk:

The Tidd 345-138kV transformer has failed, due to extreme levels of combustible gases (ethylene, ethane, methane). Asset Health Data required this unit to be removed from service for safety concerns in March 2017. The unit was made in 1957 and is 150 MVA. In its place a 450 MVA transformer will be installed, for additional system support. To limit the fault duty in the 138kV yard, series reactors will be installed (2%) on the low side of the transformer. This setup will mirror the parallel Tidd 345-138kV transformer C (450 MVA XFMR with 2% series reactor). This upgrade will serve to benefit the area's heavily-networked 138kV system.

Operational Flexibility and Efficiency:

Currently the two Tidd 345-138kV transformers are tapped directly off of the 345kV buses without high-side protection. For a transformer fault, or for scheduled transformer maintenance, 4- 345kV breakers must be isolated, which is a concern for operations and field personnel. This also requires an overly complex protection scheme for the 345kV buses and transformers. In addition, for a bus fault or scheduled bus maintenance, either transformer B or C is automatically taken out of service today. To resolve this reliability concern, a 345kV 3-breaker string will be installed on the high side of the two 345-138kV transformers.



Tidd 345 – 138 kV Transformer B Replacement

Continued from previous slide…

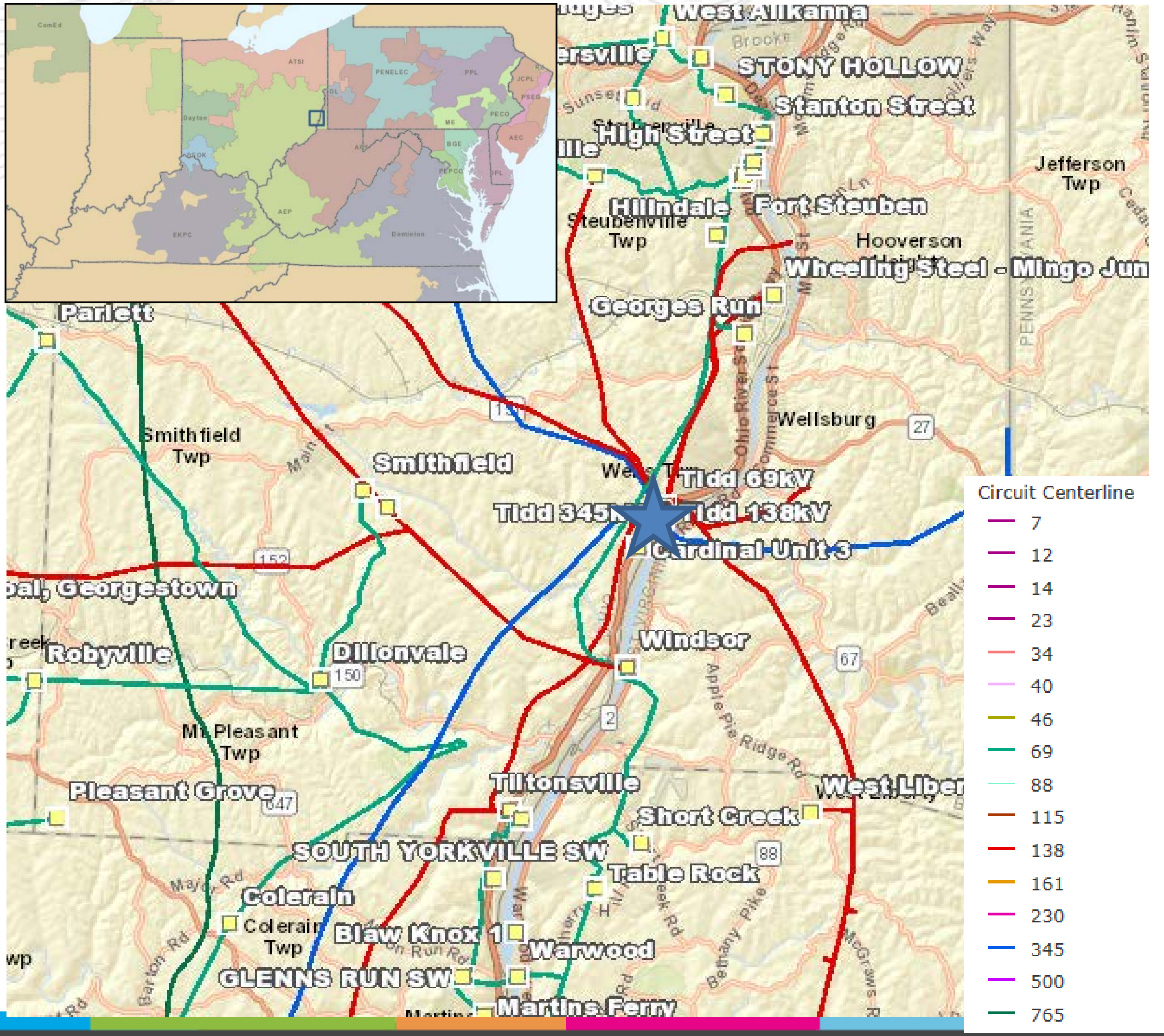
Selected Solution:

At Tidd station, replace the failed 150 MVA 345-138kV transformer with a 450 MVA unit; install a 138kV series reactor on the low-side of the transformer, to control fault currents in the 138kV yard; install a 345kV 3-breaker string on the high side of the transformers, along with new relay panels and SCADA functionality. Reconductor tie-line from 345kV yard to 138kV yard at Tidd, on the low-side of transformer B, due to increased capacity of the transformer. (S1451)

Estimated Transmission Total Cost $7.8M

Projected In-service: 12/01/2018

Project Status: Engineering



Supplemental Project
Previously Presented: 11/9/2017 TEAC

Problem Statement:

Davis Creek 345kV substation bus configure does not comply with current design standards

Single 345kV breaker failure will trip 63 miles of 345kV transmission and one to two 345-138kV auto-transformer(s)

345kV Breaker maintenance can only be performed during generator planned outages.

345-138kV auto-transformer maintenance requires generation outages and line outages due to current configuration

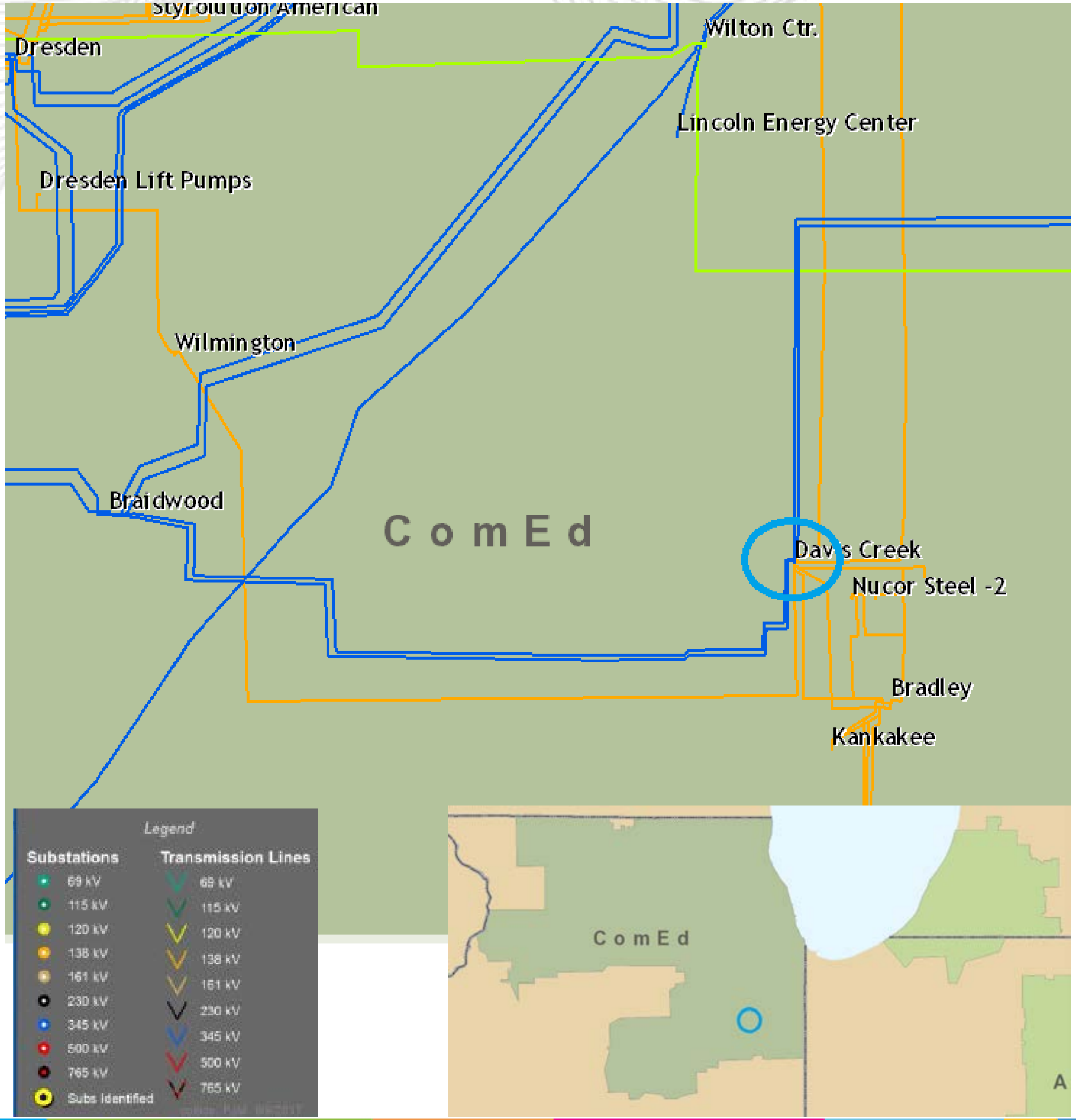
Selected Solutions:

Expand Davis Creek 345kV straight busses to breaker and half (S1444)

Estimated Cost: $34M

Projected In-service: 12/1/2018

Status: Engineering



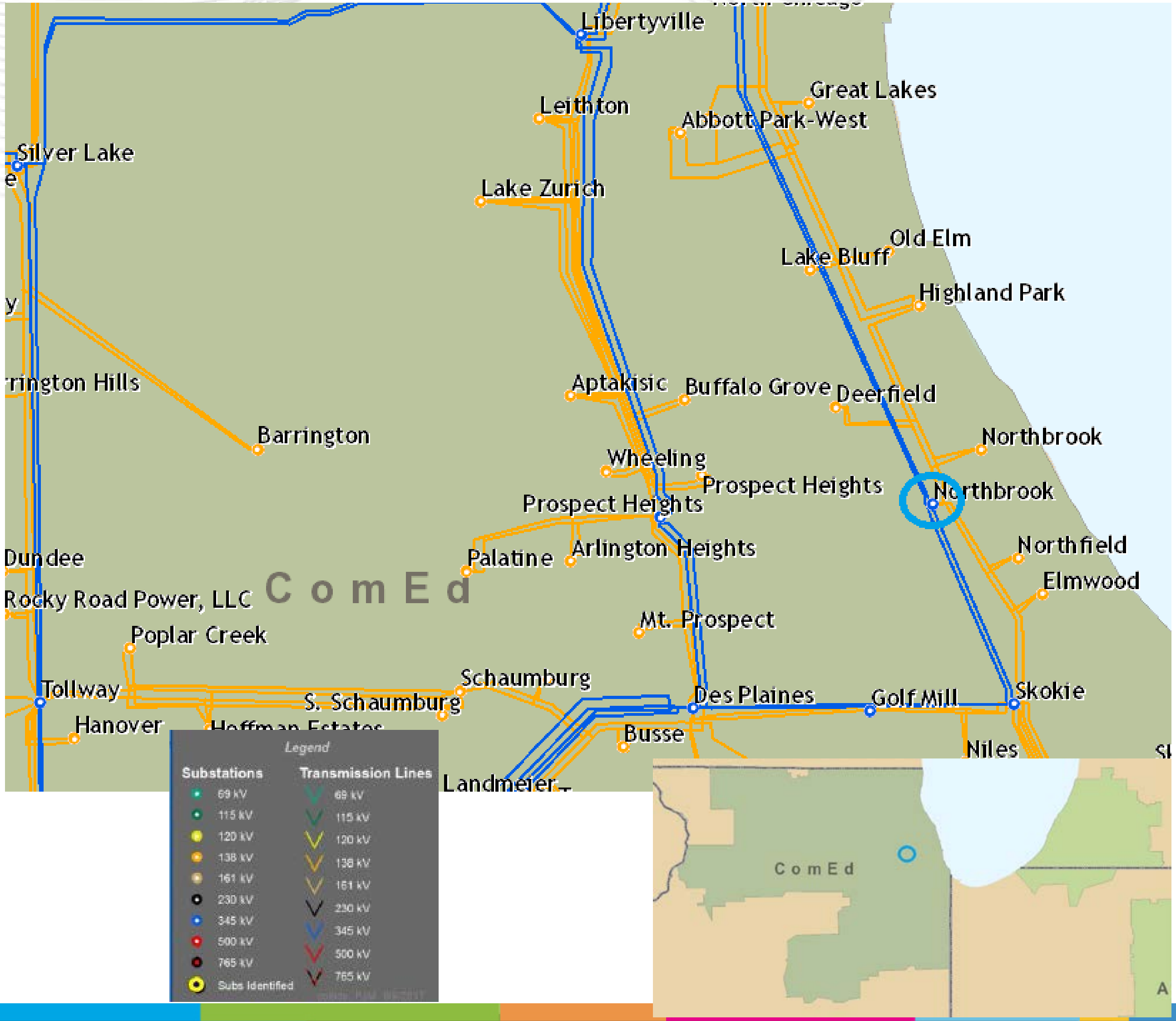
Supplemental Project
Previously Presented: 11/9/2017 TEAC

Problem Statement:
Address Ferro-Resonance and induced voltage issues at Northbrook 345kV
Special switching is required on the 345kV system at Northbrook and Waukegan
Station configuration does not meet current design standards
Single breaker failure trips 27 miles of 345kV transmission lines and one 345-138kV auto-transformer

Selected Solutions:
Install three 345kV breakers at Northbrook and allow independent operation of the transmission lines and transformers; (S1445.1)
Retire SPOG 3-34, requiring switching to be performed in a specified order. (S1445.2)

Estimated Cost: $8.5M
Projected In-service: 12/1/2019

Status: Engineering



Supplemental Project
Previously Presented: 11/9/2017 TEAC

Problem Statement:

Bedford Park 345kV is radially fed from Goodings Grove substation

Bedford Park is currently a straight bus with a disconnect for a bus tie

For a loss of one transmission line the disconnect is closed to restore two 345-138kV transformers. In order to open the disconnect and return the station to normal the two transformers need to be temporarily taken out of service to perform switching

Bedford Park does not meet current design standards

Insufficient water retention/detention presently for yard

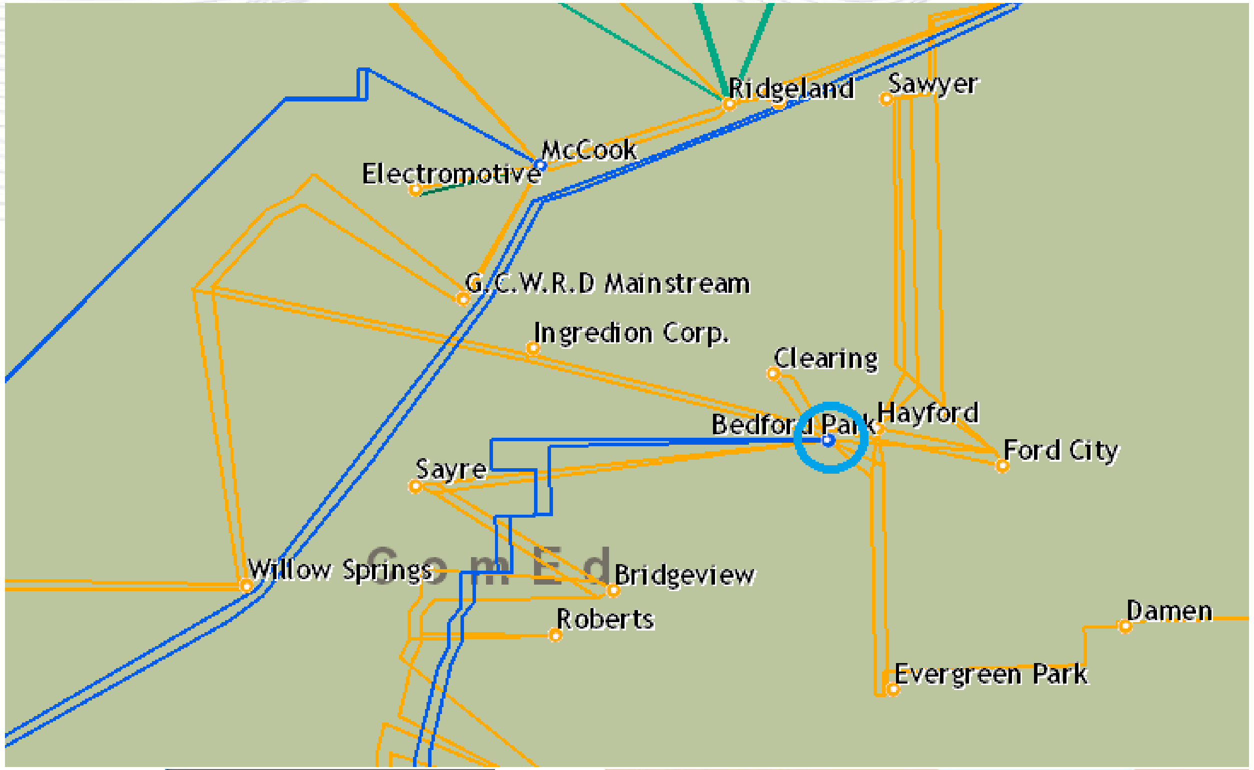
Selected Solutions:

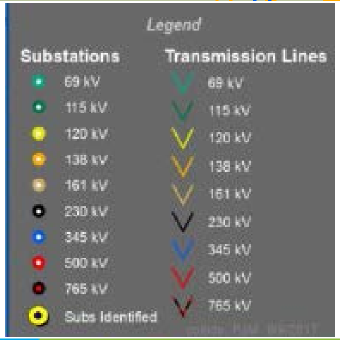
Replace Bedford Park open air 345kV bus with indoor GIS (S1446)

Estimated Cost: $28M

Projected In-service: 12/1/2020

Status: Engineering





Portugee Road 230kV Switching Station & 230kV Delivery Point

Date Project Last Presented: 11/9/2017 TEAC

Problem Statement:

- A customer has requested a 230kV delivery point to accommodate a new data center campus in White Oak Technology Park in Henrico County with projected loads over 100 MW.

Selected Solution:

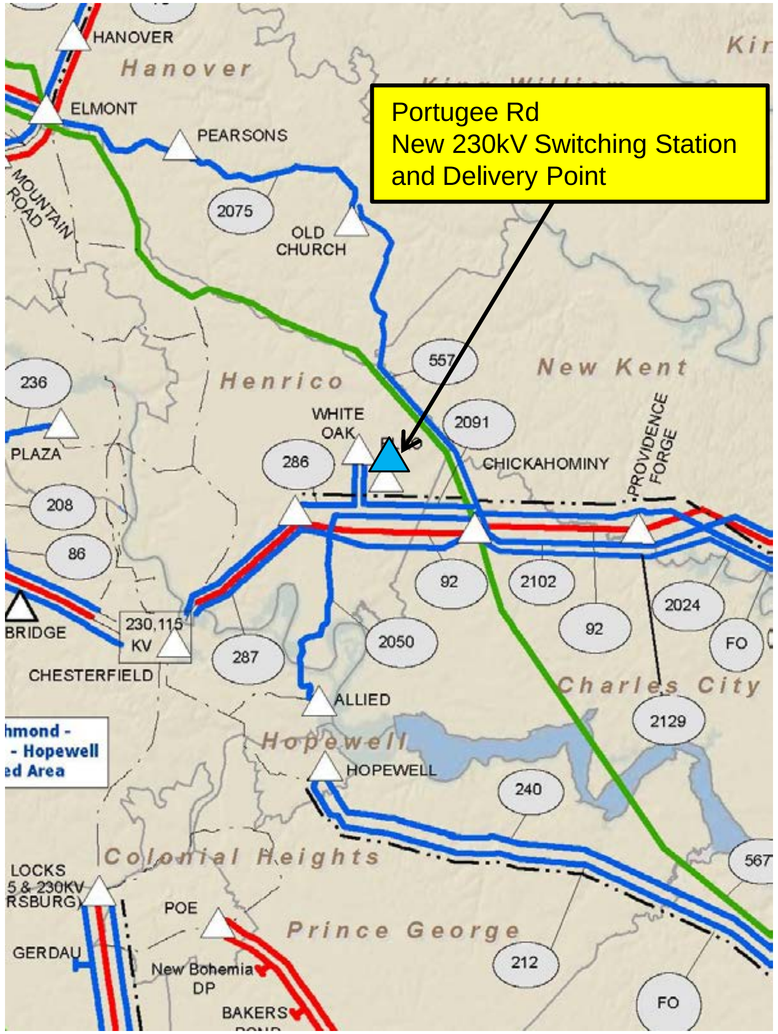
- Install a 230kV switching station and delivery point by tapping the 230kV Line #2091 (Chickahominy – White Oak) in and out of the proposed customer site. The new 230kV switching station will include a four breaker ring bus with space provided for an ultimate six-breaker ring bus to meet the future growing demands of the area. **(s1452)**

Estimated Project Cost: $11 M

Projected In-service Date: 10/25/2018

Project Status: Engineering

COLOR	VOLTAGE	TRANSMISSION LINE NUMBER
	500 KV.	500 thru 599
	230 KV.	200 thru 299 & 2000 thru 2099
	115 KV.	1 thru 199
	138 KV.	AS NOTED
	69 KV.	AS NOTED



Date Project Last Presented: 11/9/2017 TEAC

Problem Statement:

- 230kV Line #245(Green Run to Greenwich) and 230kV Line #2025 (Green Run to Lynnhaven) wave traps and associated line terminal equipment at Green Run substation need to be replaced due to age.

Selected Solution:

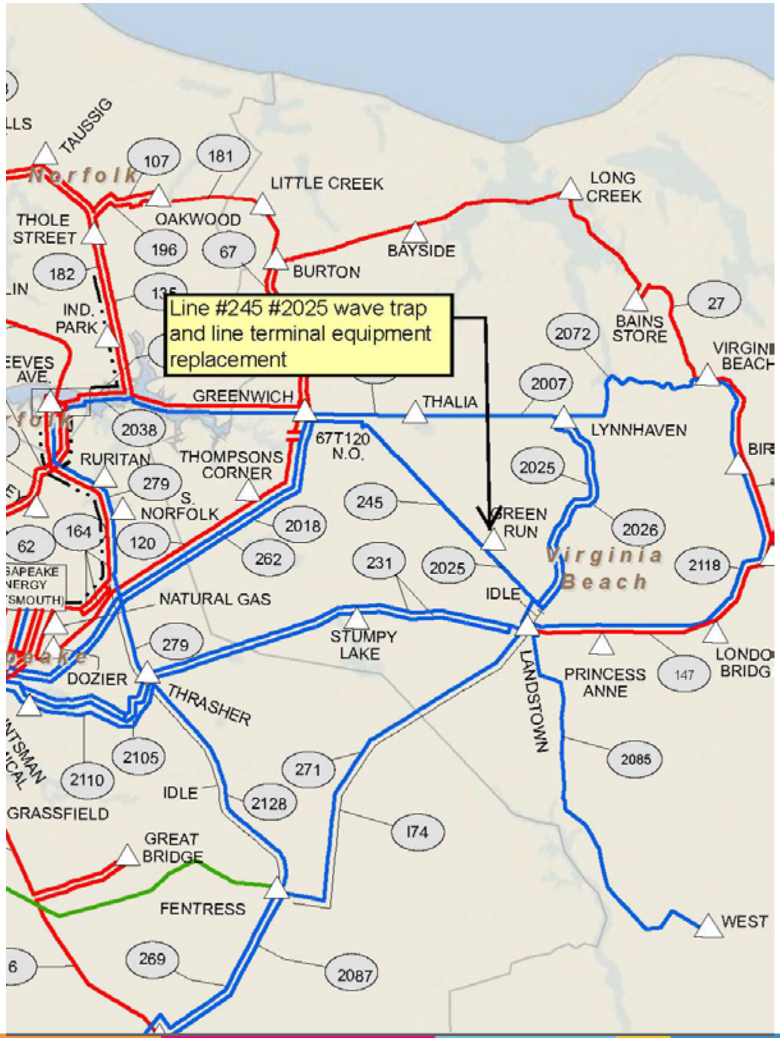
- Replace existing Line #245 & Line #2025 1600A wave traps at Green Run substation with 3000A wave traps. Replace high side circuit switchers at high side of TX#1 and TX#2. Summer emergency rating of Line #245 will be changed from 637MVA to 898MVA. The rating of Line #2025 will be changed from 637MVA to 722MVA. **(s1453)**

Estimated Project Cost: $1.2 M

Projected In-service Date: 12/15/2017

Project Status: Under Construction

COLOR	VOLTAGE	TRANSMISSION LINE NUMBER
	500 KV.	500 thru 599
	230 KV.	200 thru 299 & 2000 thru 2099
	115 KV.	1 thru 199
	138 KV.	AS NOTED
	69 KV.	AS NOTED



Dominion Transmission Zone: Supplemental
New 230kV DP for Albemarle EMC

Date Project Last Presented: 11/9/2017 TEAC

Problem Statement:

- NCEMC has requested a new 230kV delivery point on behalf of Albemarle EMC to replace three existing AEMC distribution served delivery points: Burgess, Cisco and Edenton DP's.
- The main drivers for the new 230kV delivery point are AEMC's 1) inability to serve future load from the existing distribution delivery points and 2) aging facilities.

Selected Solution:

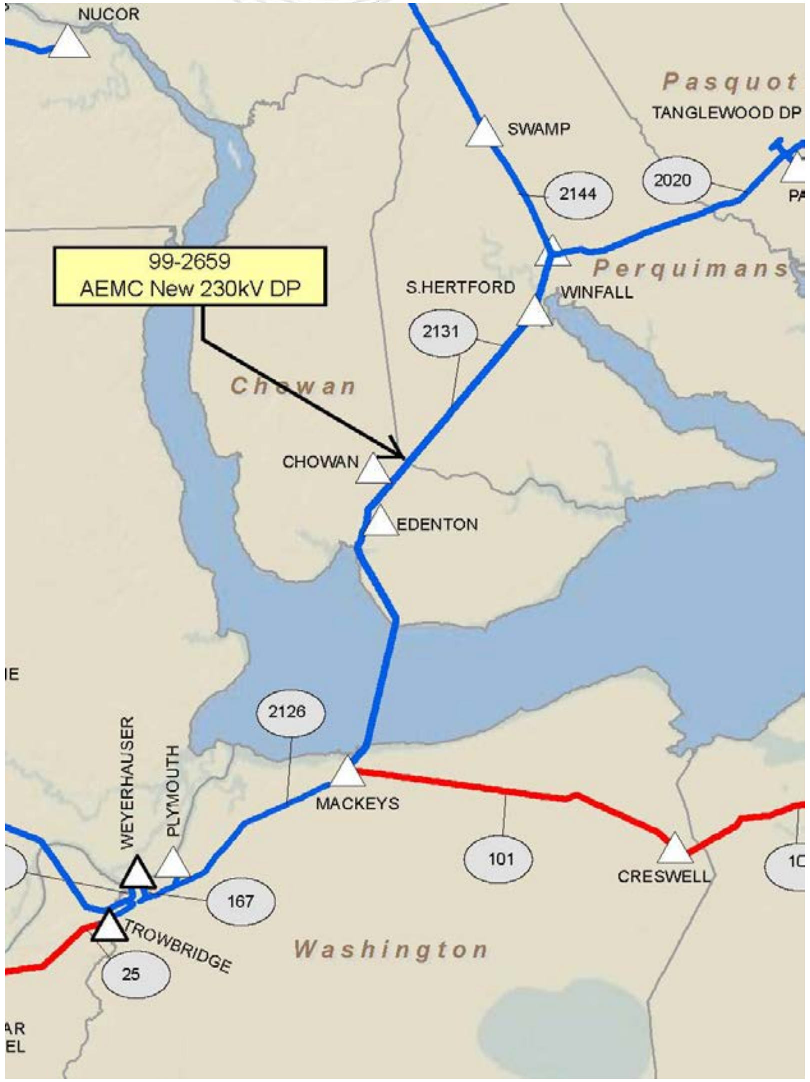
- Dominion Energy to support the installation of AEMC's new 230kV delivery point by installing three H frame structures, three 230kV switches, a 3 pole structure and replacing one single pole structure. **(s1454)**

Estimated Project Cost: $2.5 M

Projected In-service Date: 12/1/2019

Project Status: Conceptual

COLOR	VOLTAGE	TRANSMISSION LINE NUMBER
	500 KV.	500 thru 599
	230 KV.	200 thru 299 & 2000 thru 2099
	115 KV.	1 thru 199
	138 KV.	AS NOTED
	69 KV.	AS NOTED



Previously Presented: 11/9/2017 TEAC

Problem Statement:

- This project is needed to mitigate performance risk associated with the current equipment material and condition. Specifically, based on inspection data, deteriorated, cracked, and weathered crossarms and deteriorated poles were identified, which places this line in the top quartile of the DPL condition ranking.

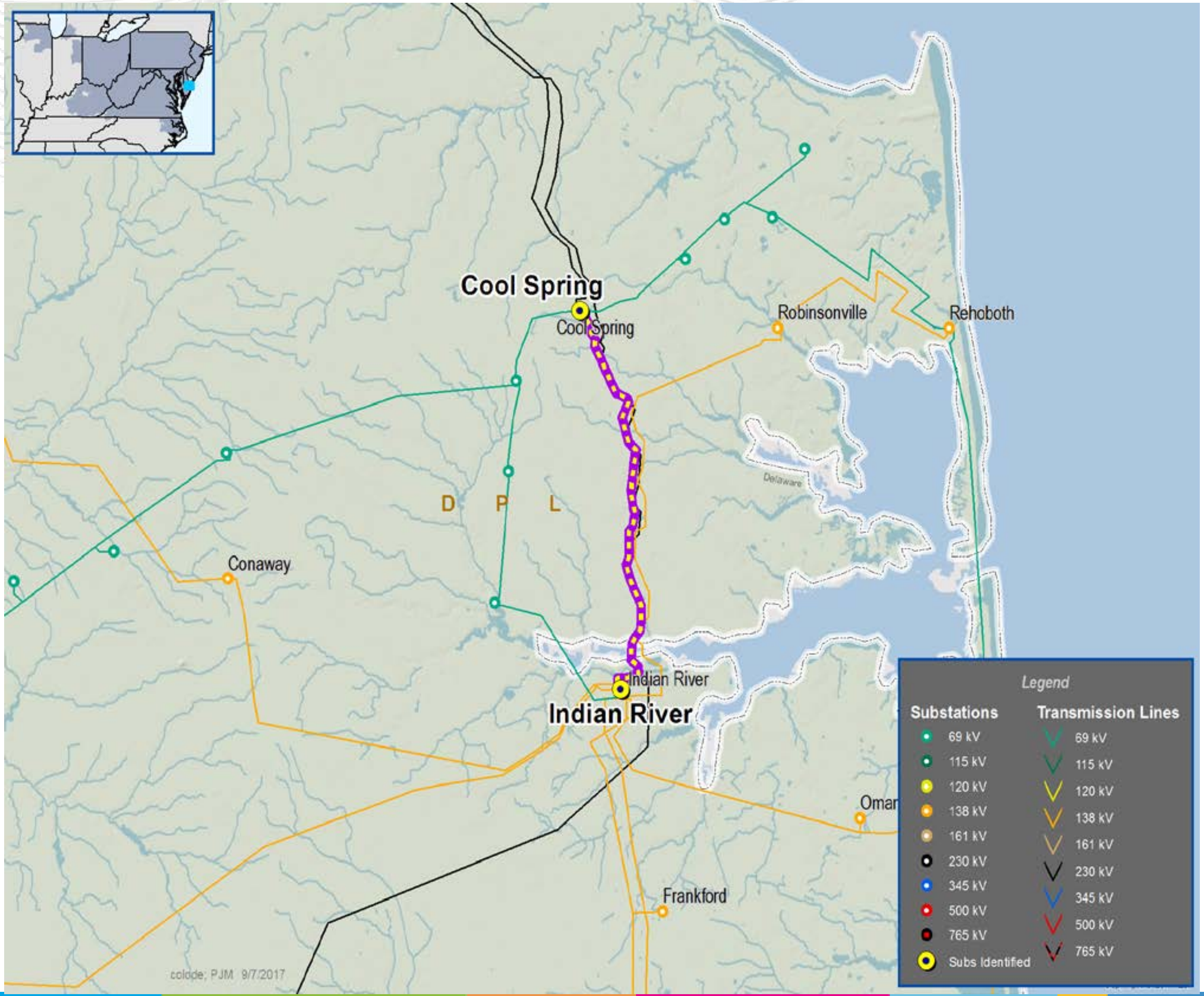
Selected Solution:

- Rebuild line 23070 circuit between Cool Spring and Indian River 230 kV substations. All structures, conductor, and static wire will be replaced with new steel poles, conductor, and OPGW. (S1455)

Estimated Project Cost: $17.8M

Projected IS Date: 12/31/2020

Project Status: Engineering



Short Circuit Update

PPL Transmission Area

Cancel and Replace B2756 upgrade
Problem: Short Circuit

- The Martins Creek 230kV breakers are overdutied

Old Upgrade (B2756):

- Install 2% reactors at Martins Creek 230kV. Estimated Cost - $10 M

New Upgrade:

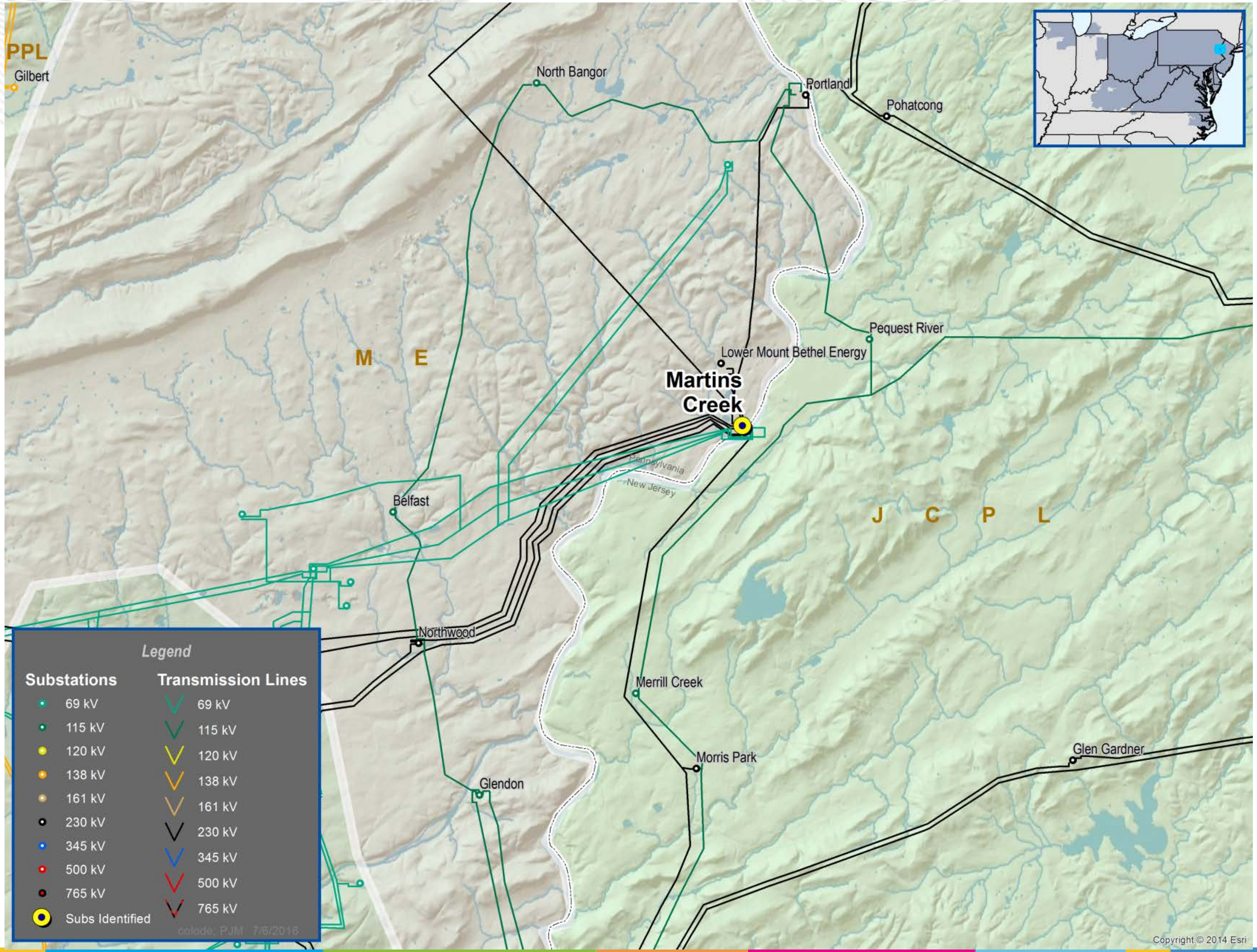
- Replace Martins Creek 230 kV circuit breakers with 80 kA rating. (B2979)

Estimated Cost: $ 14.3 M

Required IS Date: 06/01/2018

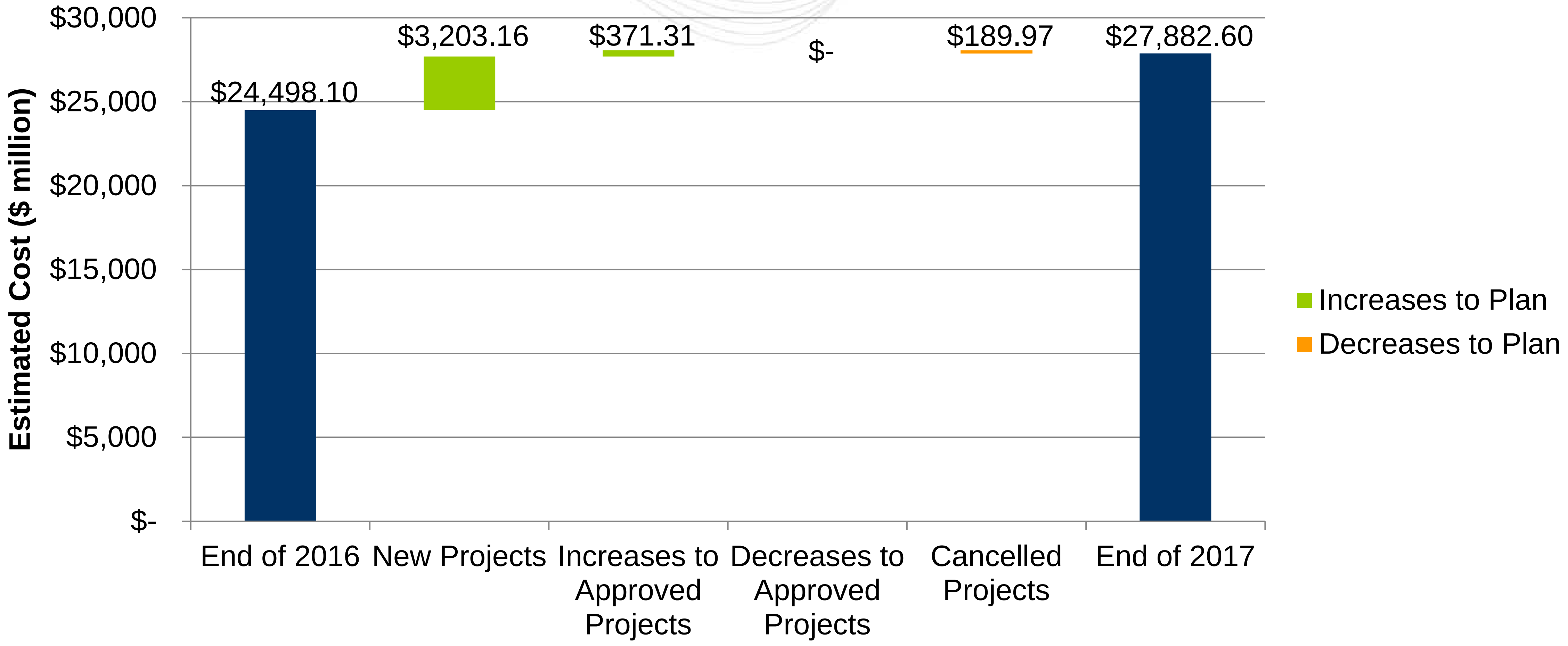
Reason for Replacing the Upgrade:

- In addition to the reactor, the 2022 short circuit analysis shows several breakers have to be replaced.
- Provides more margin
- Better operation performance

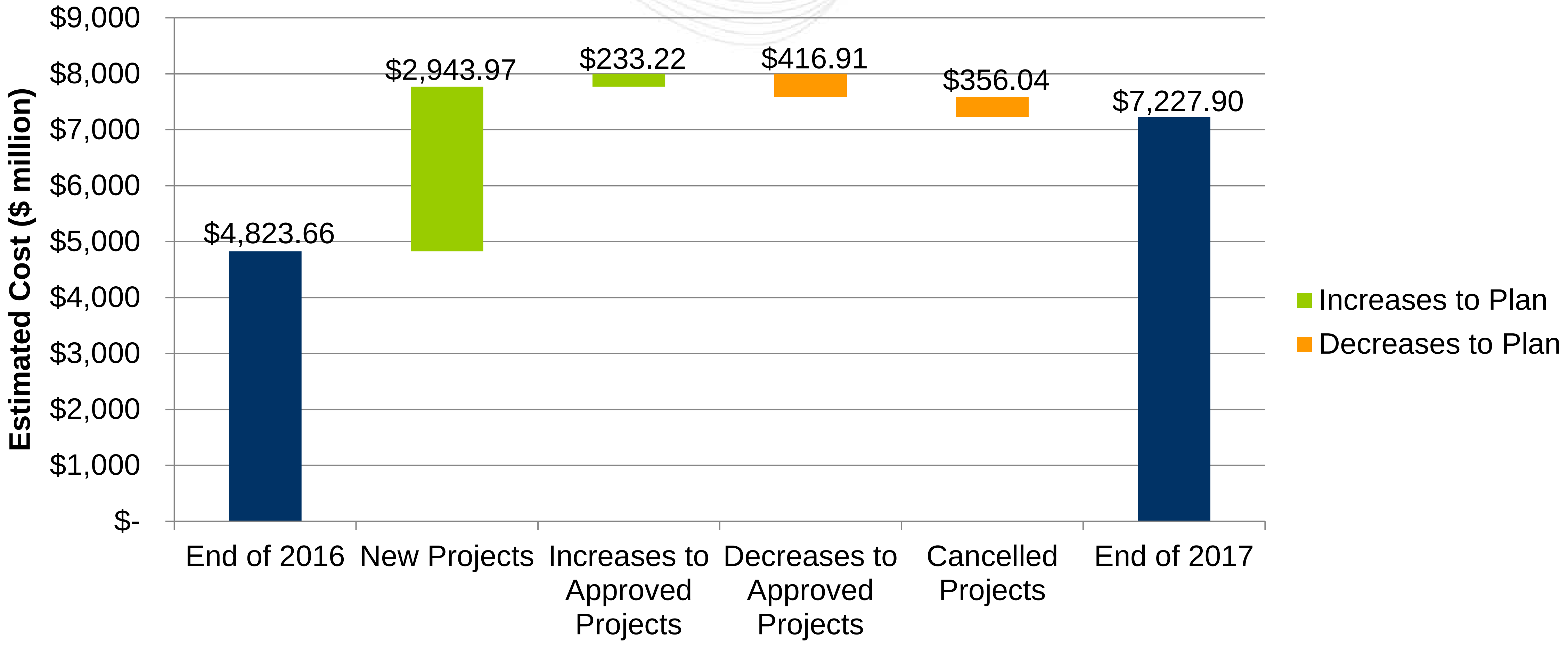


RTEP Baseline, Interconnection and Supplemental Project Statistics

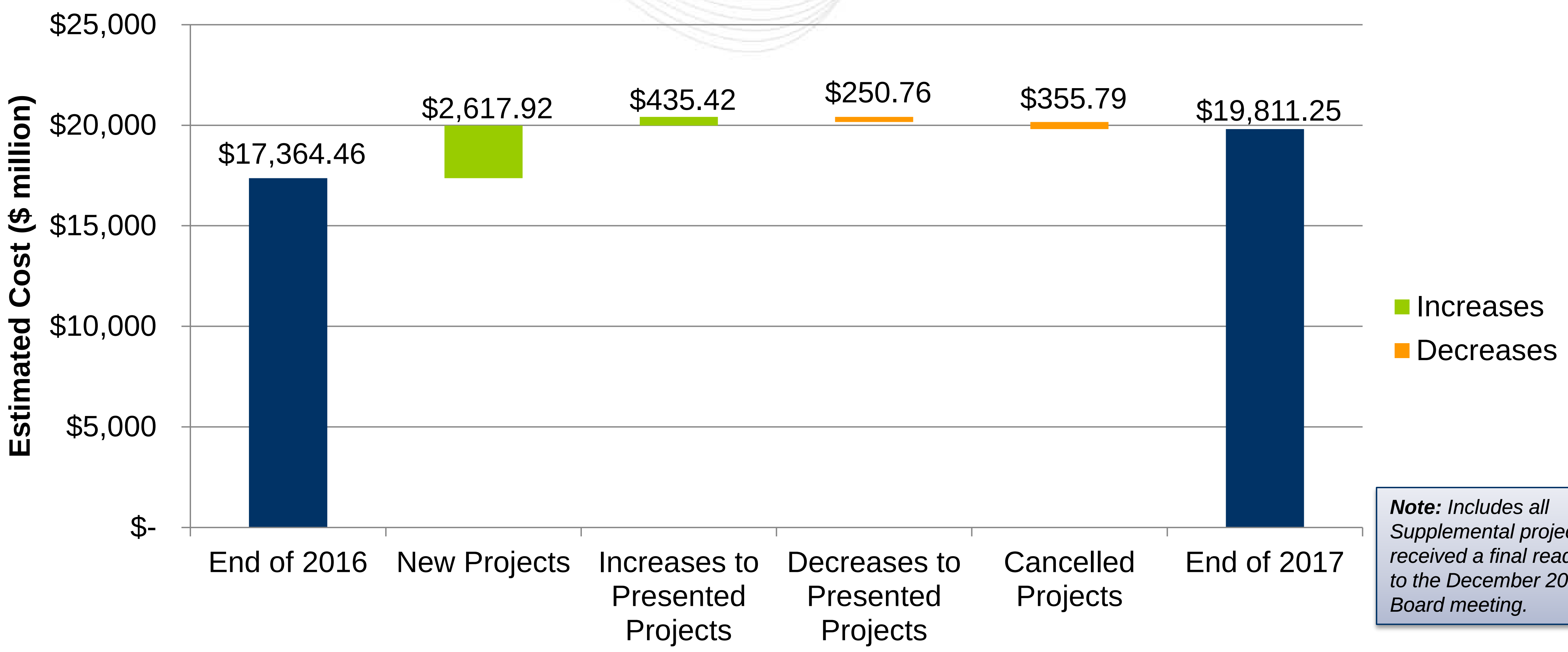
2017 Changes to the RTEP Baseline Projects



2017 Changes to the RTEP
Generation and Merchant Network Upgrade Projects

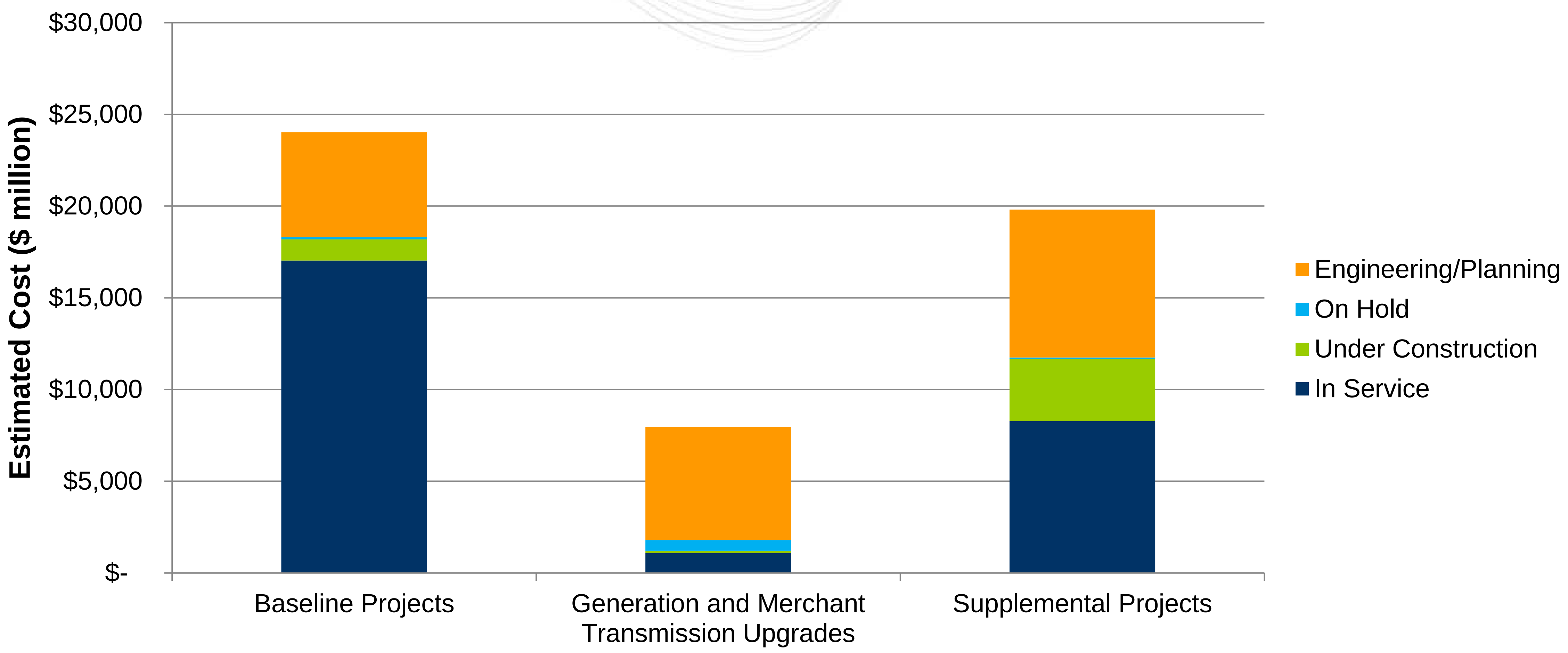


2017 Supplemental Projects Presented by TOs to TEAC/Subregional TEACs



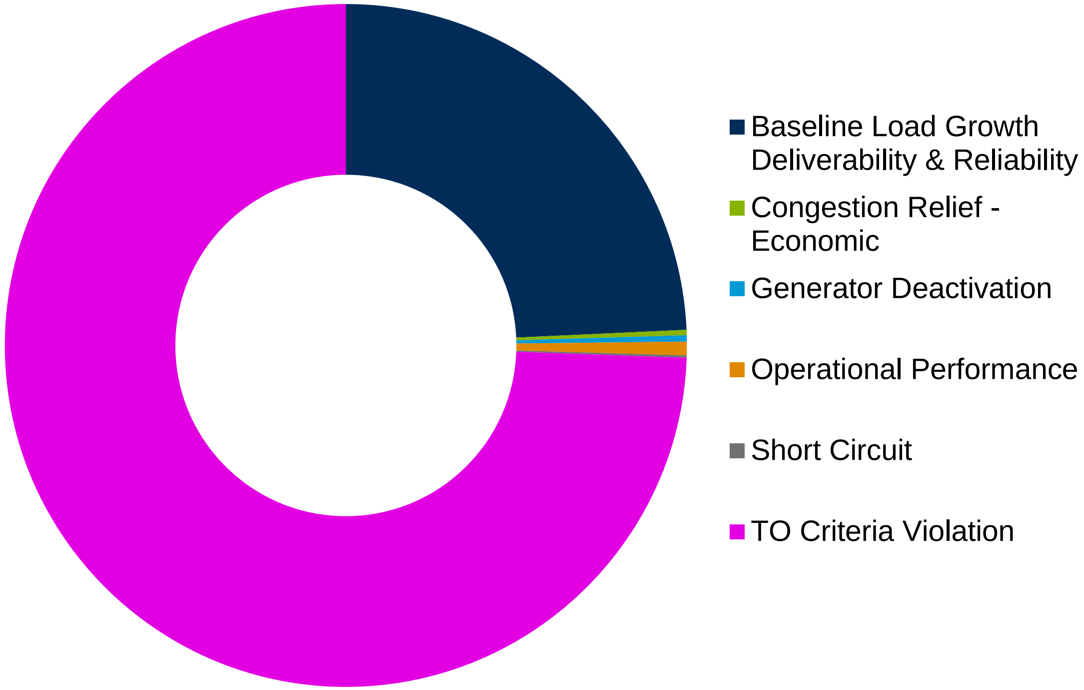
Note: *Includes all Supplemental projects that received a final read prior to the December 2017 PJM Board meeting.*

Status of Projects

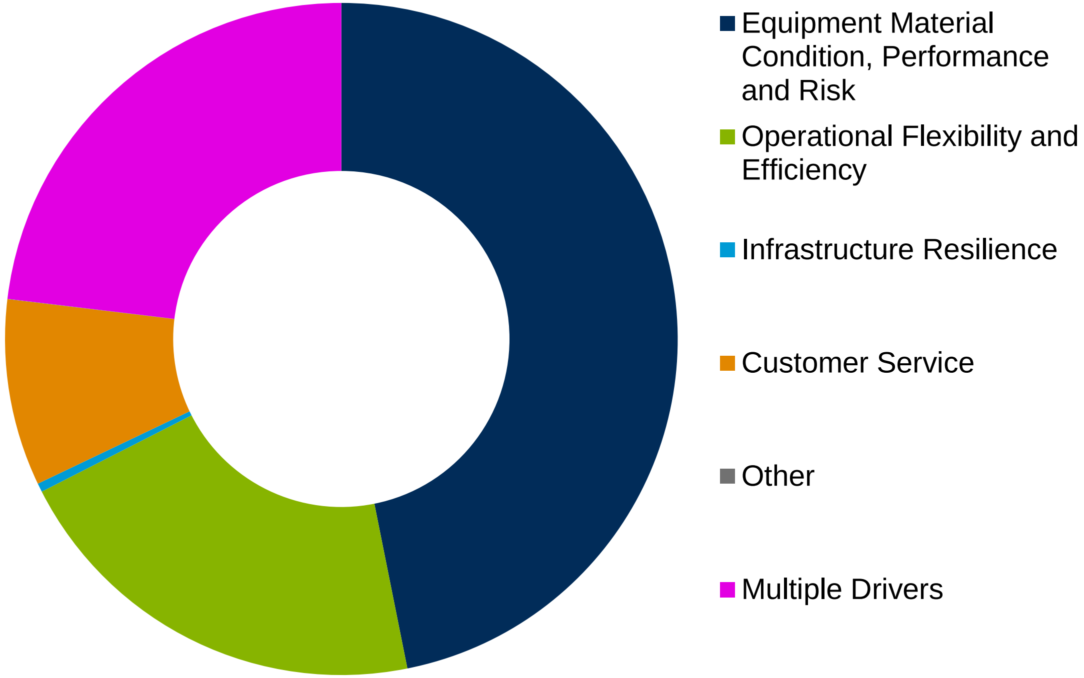


New Projects in 2017
Project Drivers

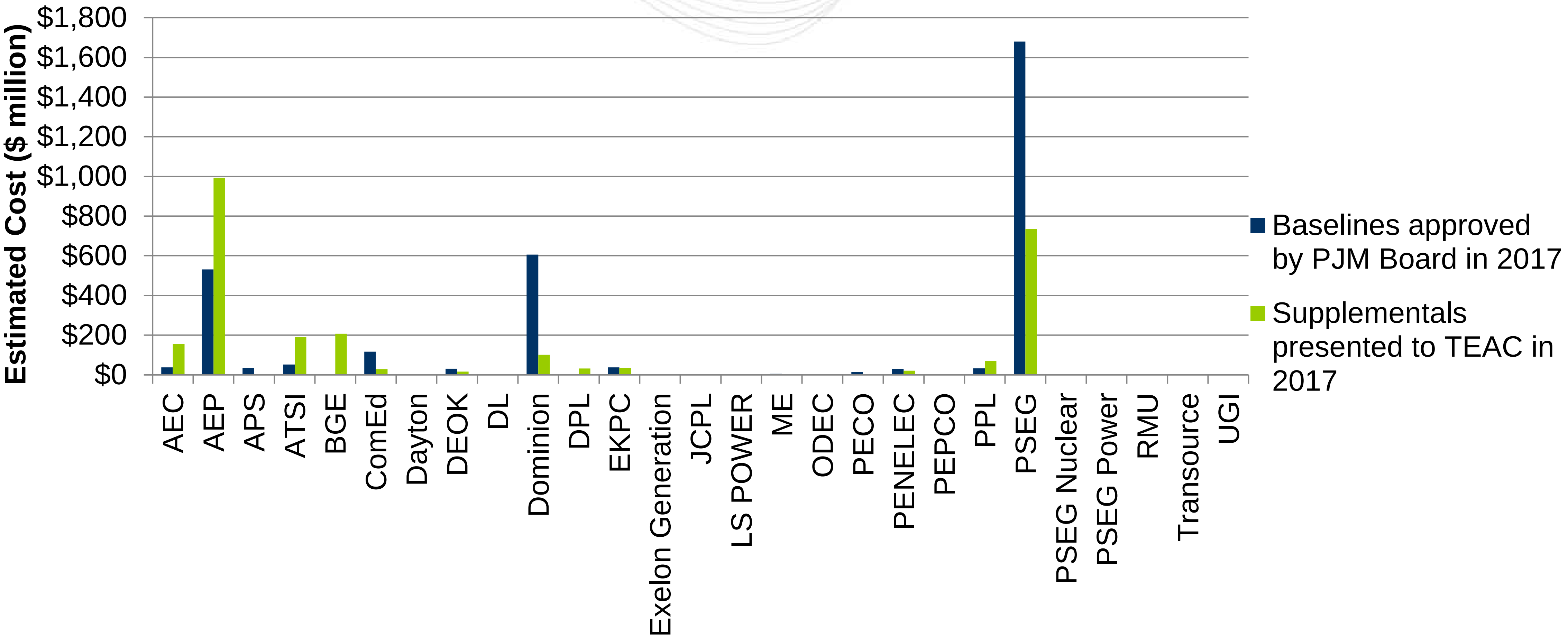
Baseline Projects Approved by PJM Board



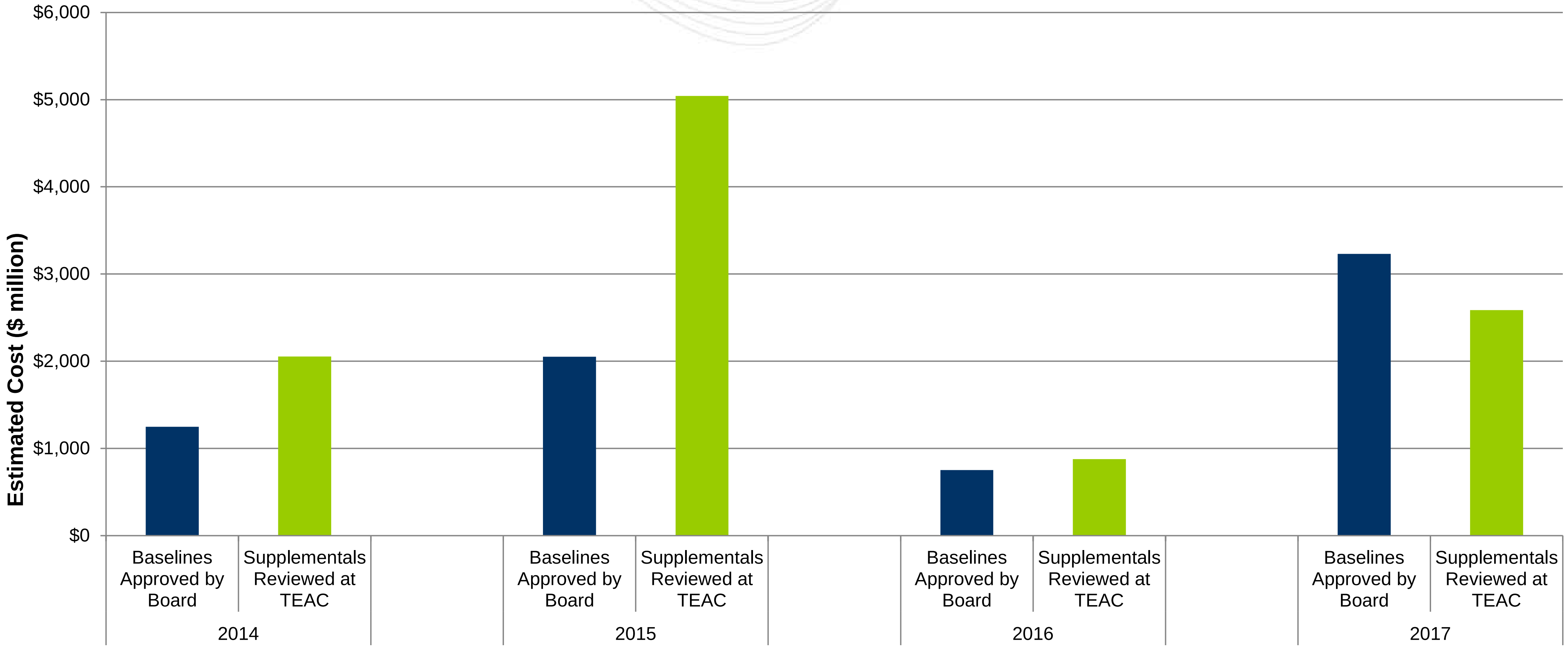
Supplemental Projects Presented by TOs



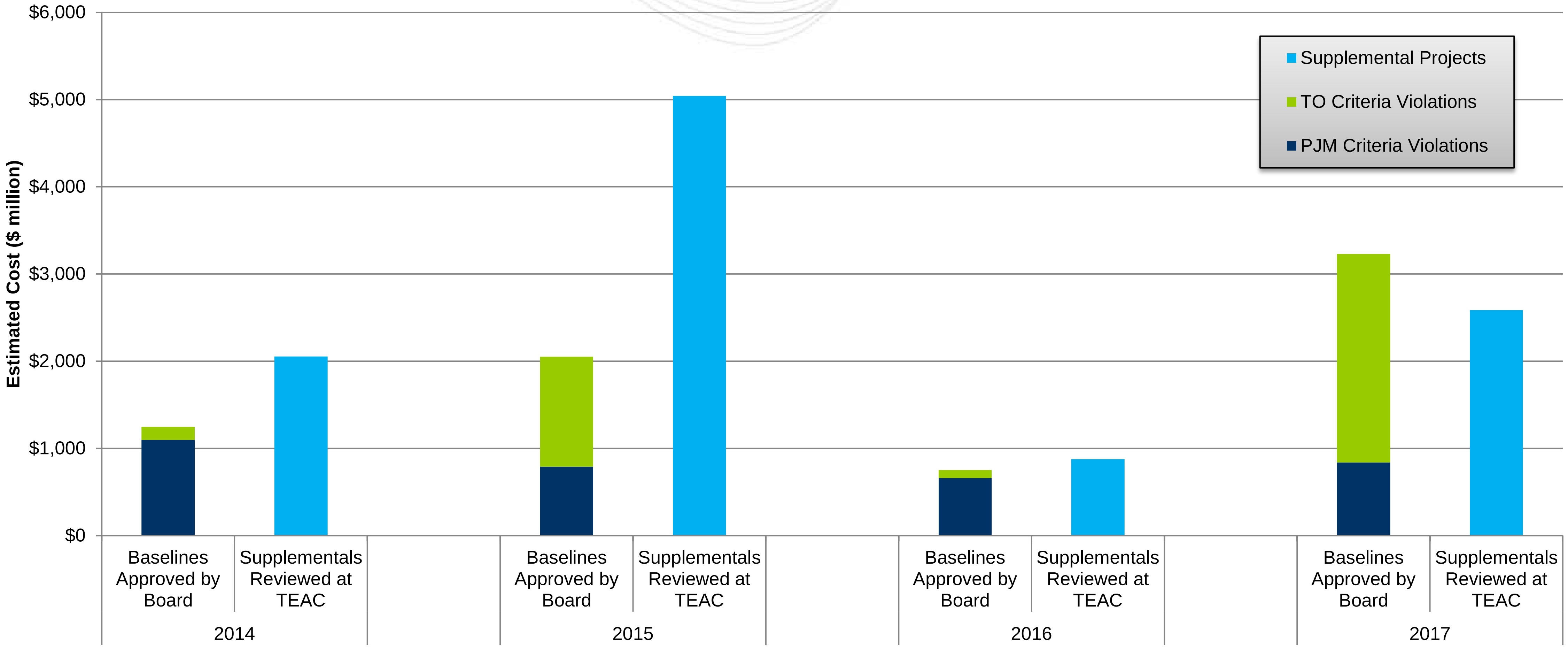
Distribution of New Baseline and Supplemental Projects



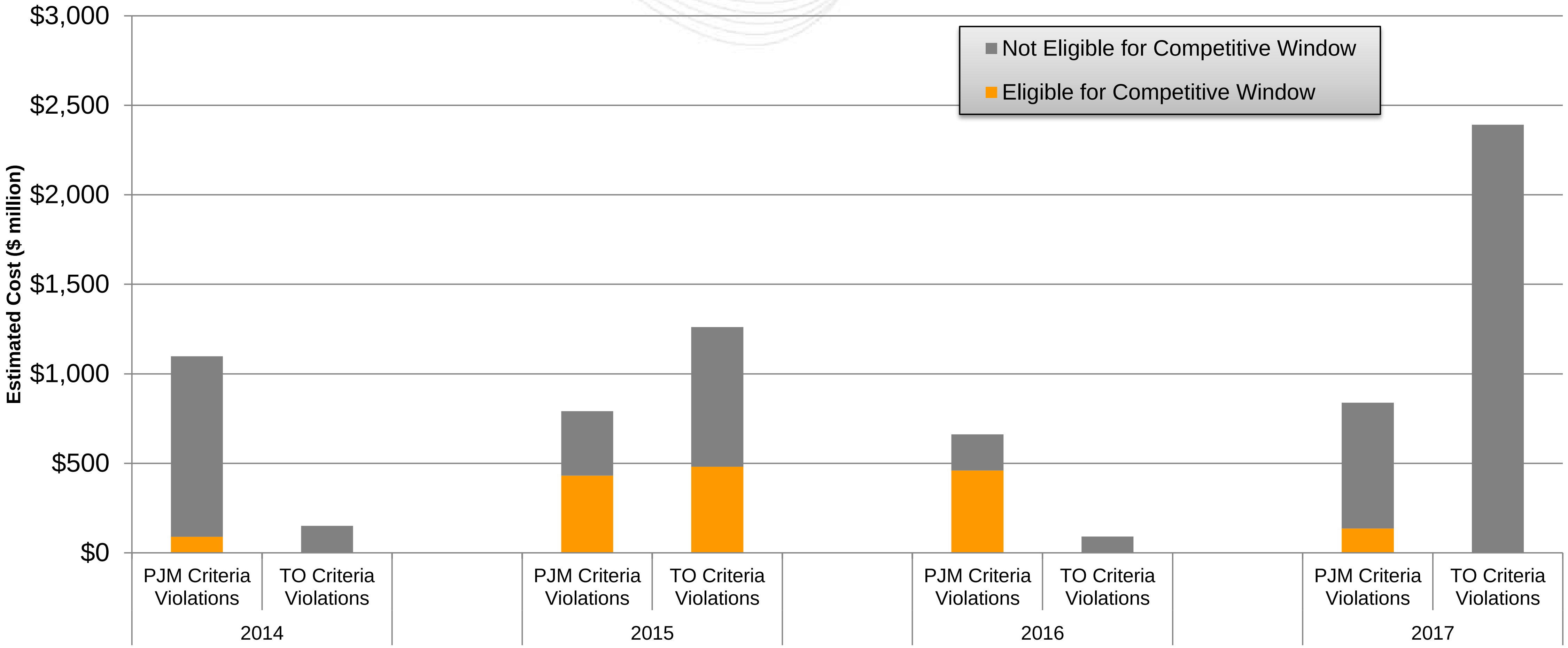
Baseline and Supplemental Projects by Year



Baseline and Supplemental Projects by Year

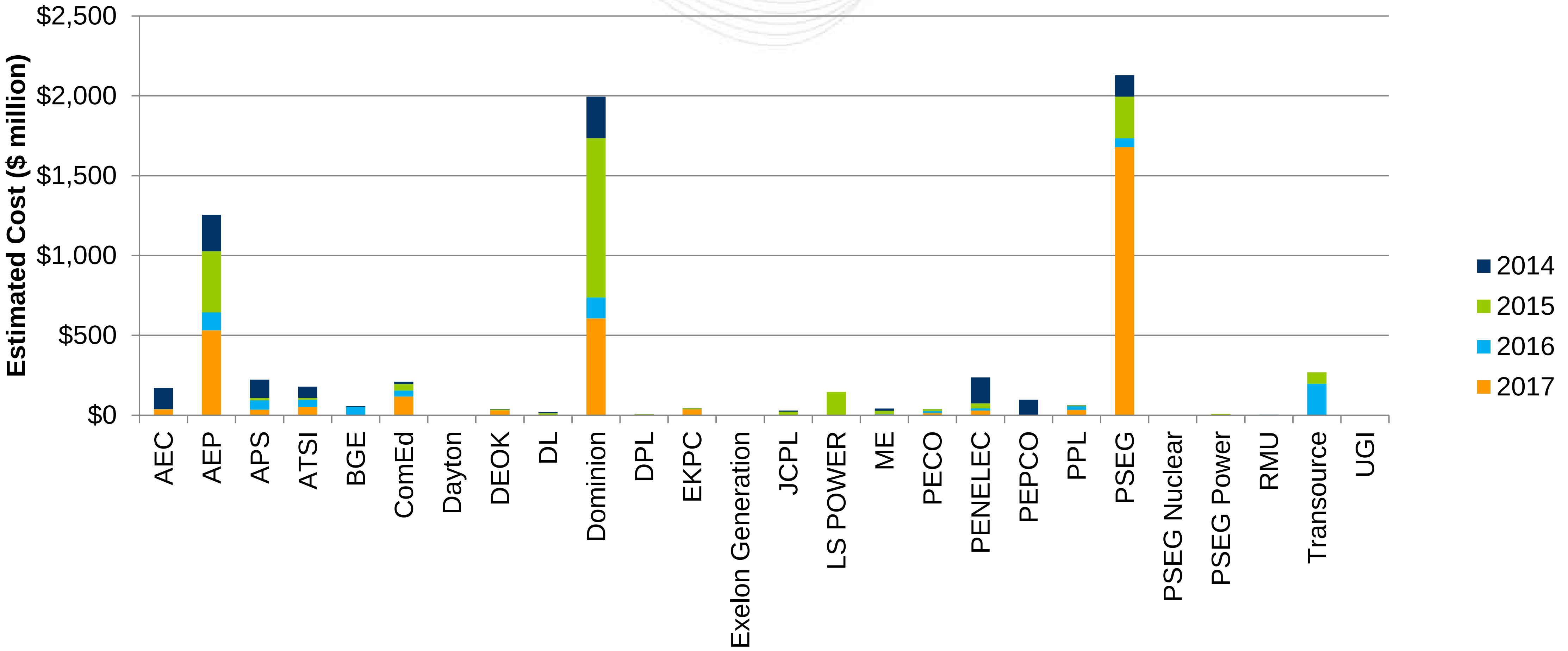


Baseline Projects by Year



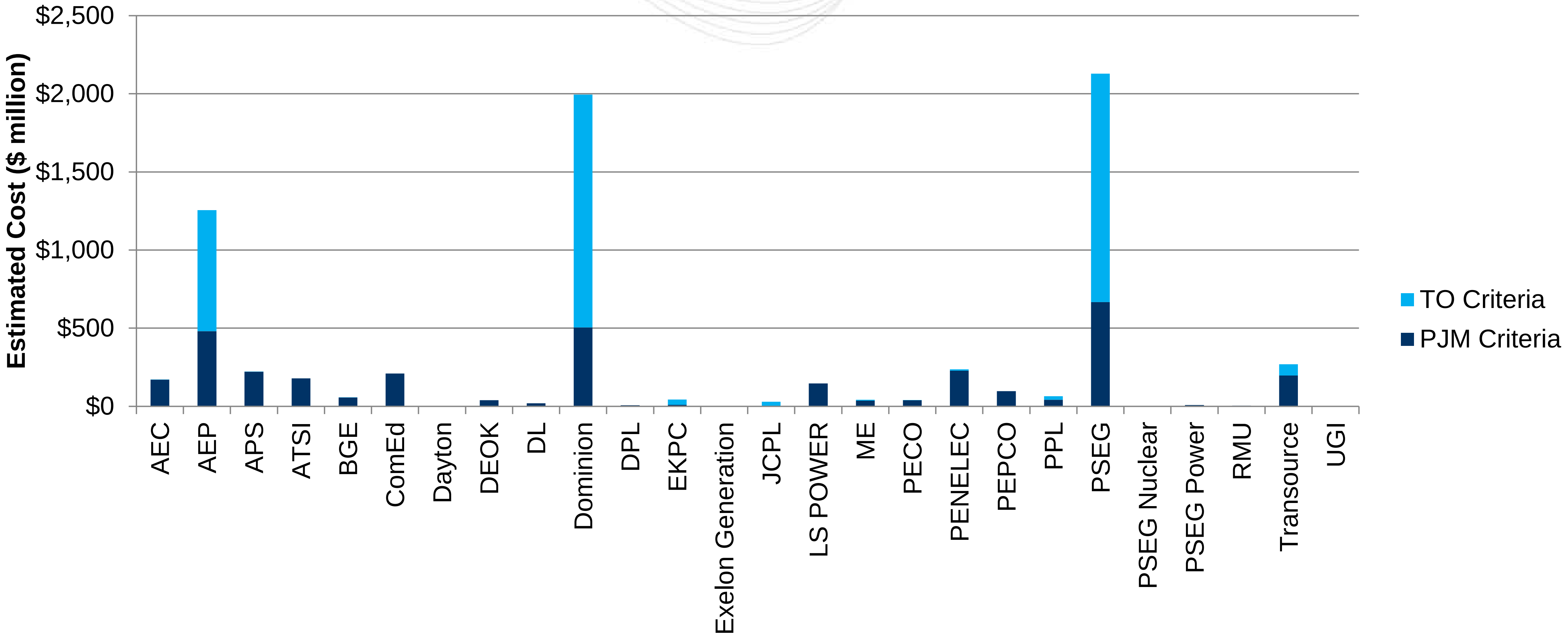
Baseline Projects by Transmission Owner Zone

Approved by PJM Board 2014-2017



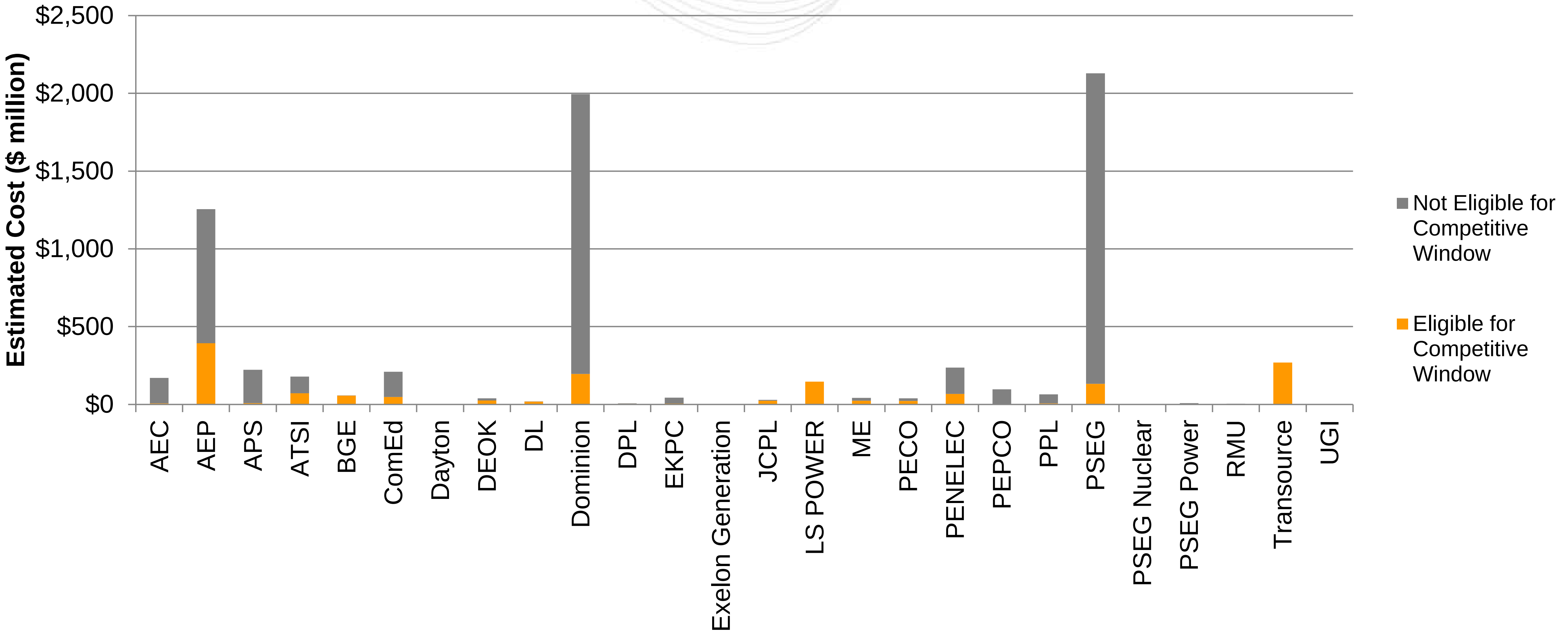
Baseline Projects by Transmission Owner Zone

Approved by PJM Board 2014-2017



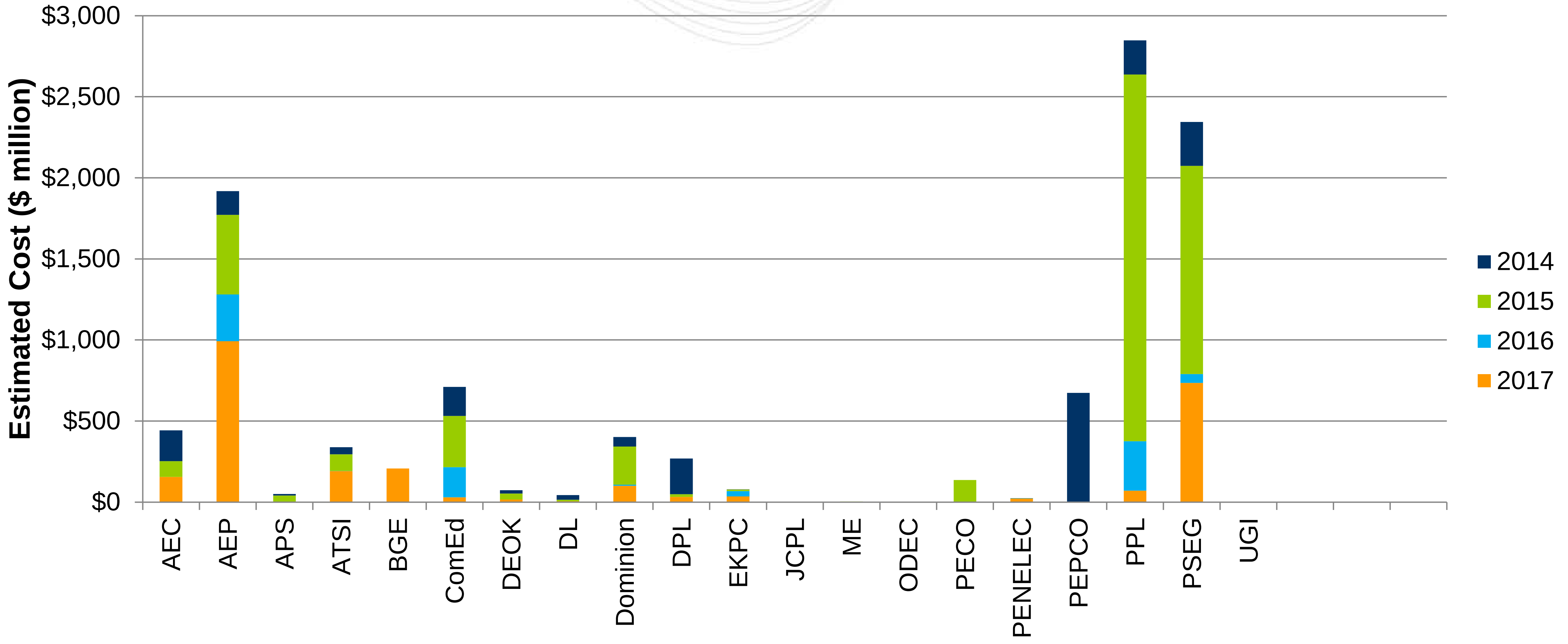
Baseline Projects by Transmission Owner Zone

Approved by PJM Board 2014-2017



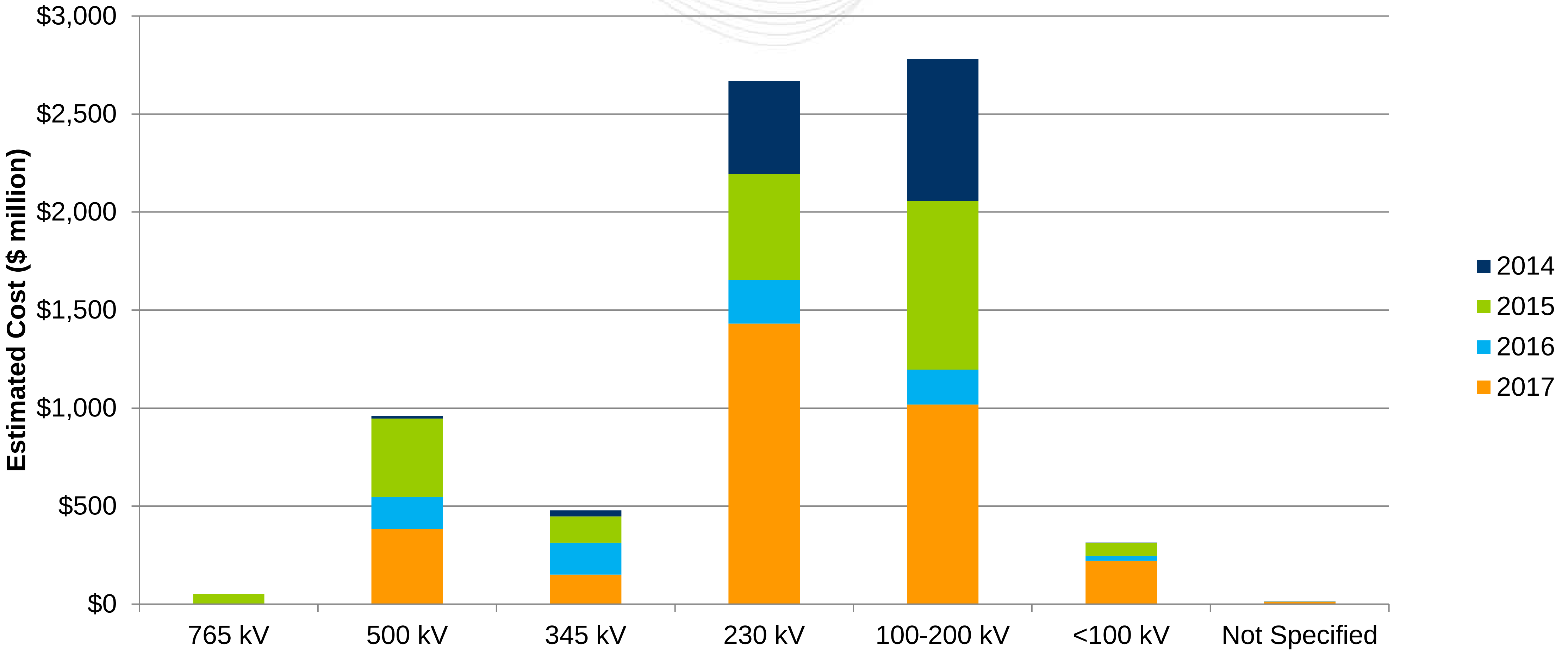
Supplemental Projects by Transmission Owner Zone

Presented to the TEAC/Subregional TEACs in 2014-2017



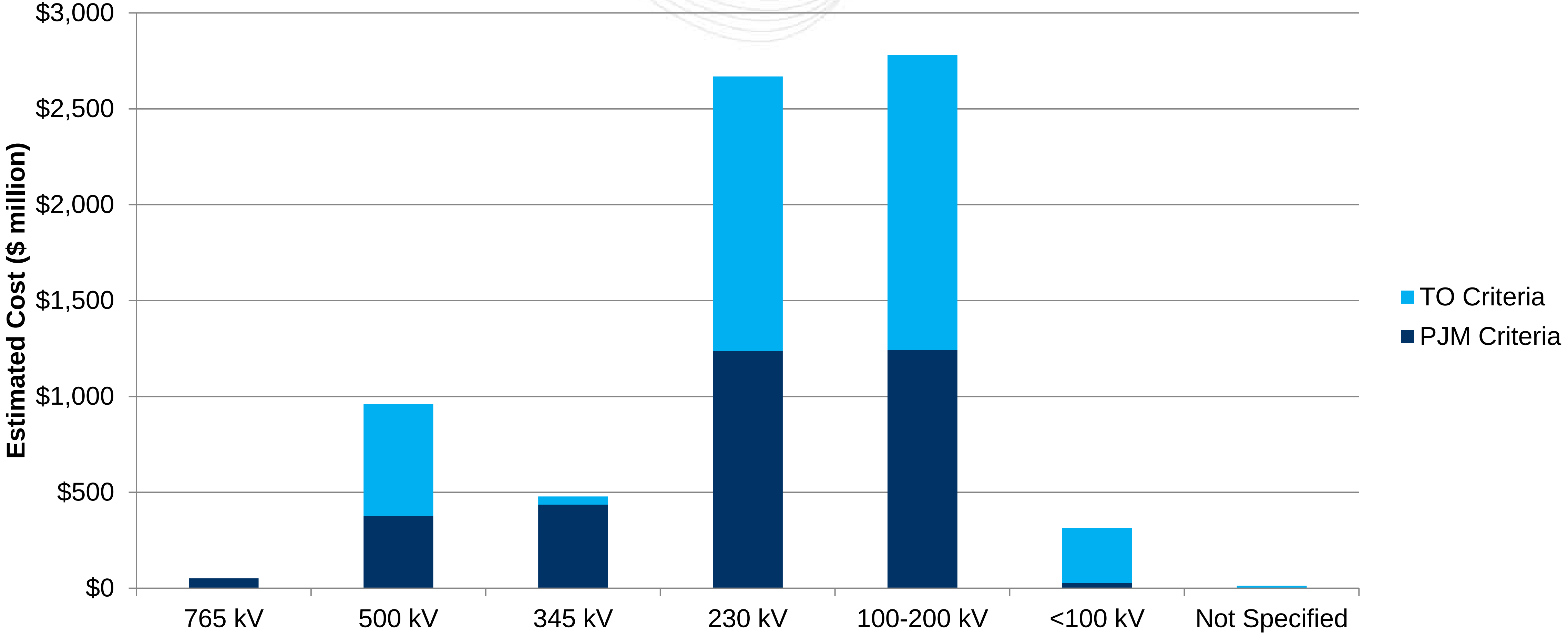
Baseline Projects by Voltage

Approved by PJM Board 2014-2017



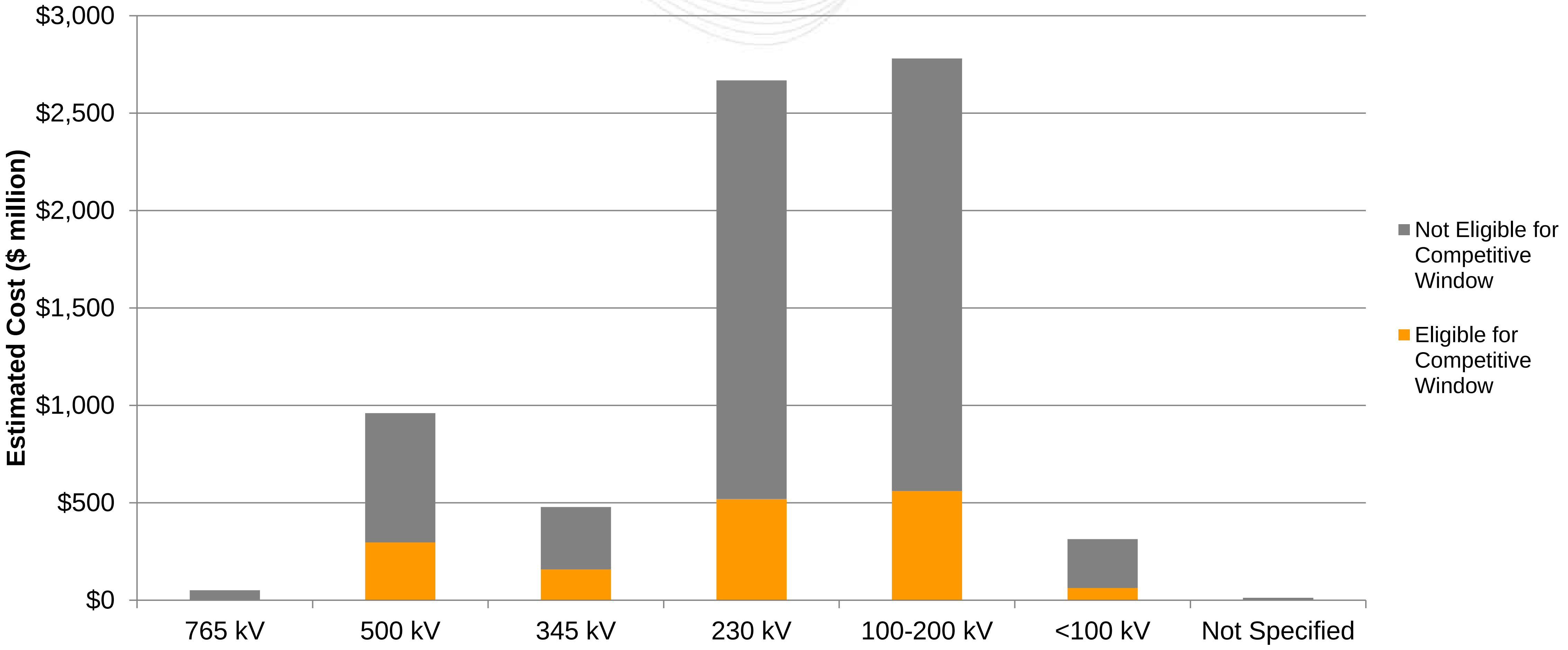
Baseline Projects by Voltage

Approved by PJM Board 2014-2017



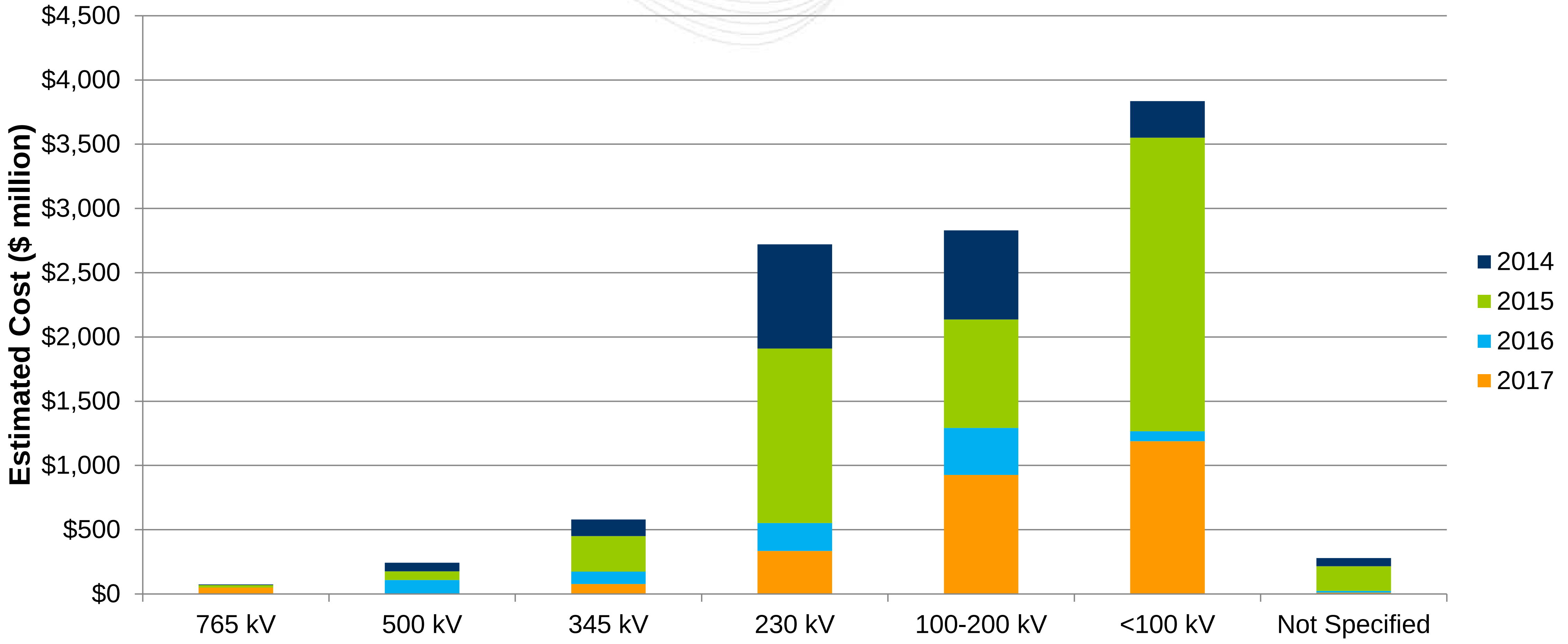
Baseline Projects by Voltage

Approved by PJM Board 2014-2017



Supplemental Projects by Voltage

Presented to the TEAC/Subregional TEACs in 2014-2017



2017 RTEP Next Steps

- 2018 RTEP Assumptions Review
- Anticipate February 2018 PJM Board Meeting
- TEAC and SRRTEP Schedule

Upcoming TEAC Meetings

December 2017

- 12/18 – Sub-regional RTEP – PJM South – Morning
- 12/18 – Sub-regional RTEP – PJM West – Afternoon
- 12/19 – Sub-regional RTEP – PJM Mid-Atlantic

2018

- TEAC meetings in the following Thursdays in 2018
- **1/11, 2/8, 3/8, 4/5, 5/3, 6/7, 7/12, 8/9, 9/13, 10/11, 11/8, 12/13**

Questions?

Planning Community

Revision History

- V1 – 12/8/2017 – Original Slides Posted
- V2 – 12/11/2017 – Slide #3, Added a map
- V3 – 12/11/2017 – Corrected issue with statistics (slides 57-74)
- V4 – 12/18/2017 – Correct titles and added axis labels on statistics charts (slides 57-74)