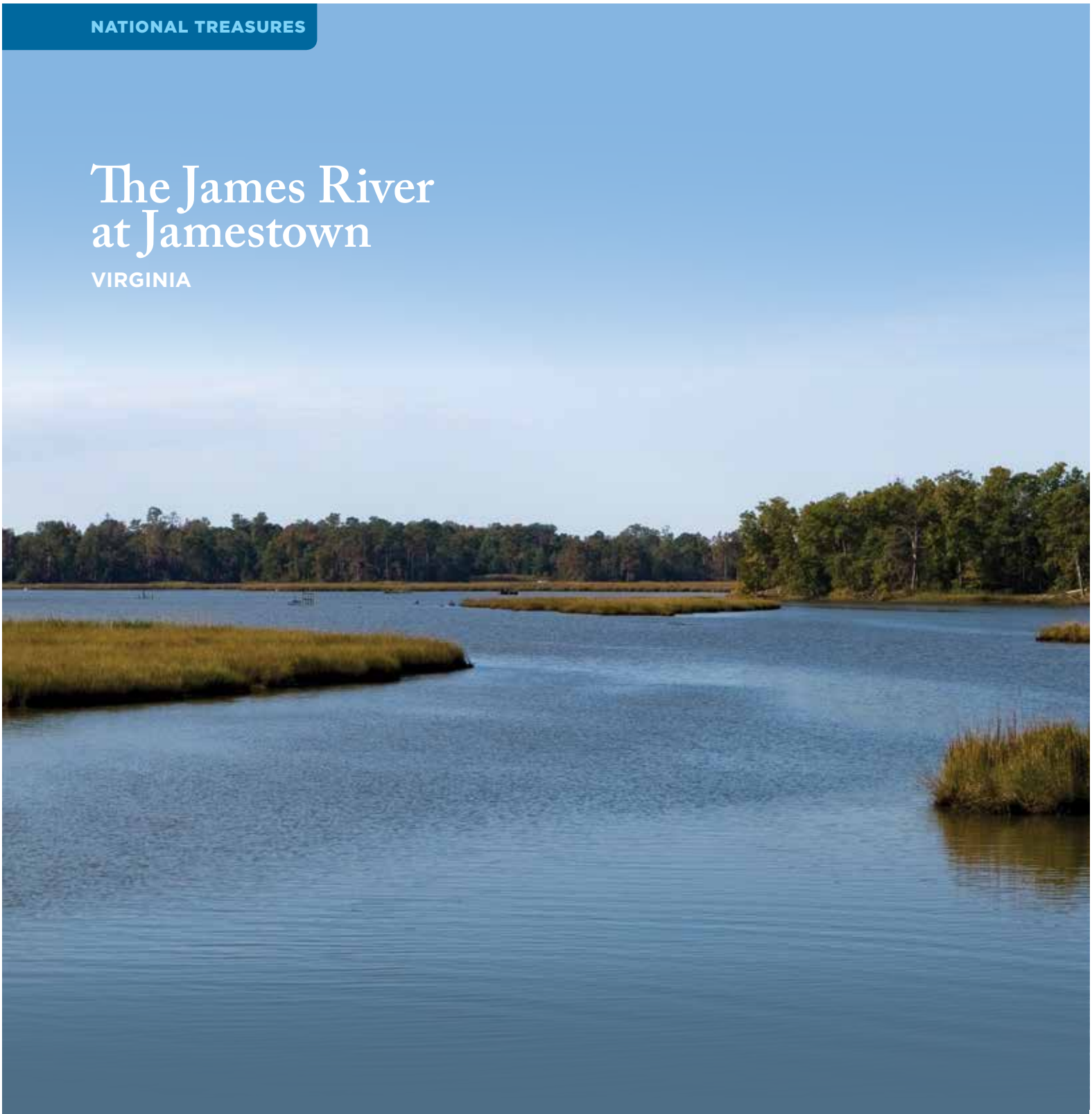
The James River at Jamestown

VIRGINIA



THE JAMES IS THE FOUNDING river of the nation, with the first successful English colony in the New World established along its banks. It's a place where civilizations came together. Now, 400 years later, visitors from around the world come to experience history where it happened.

THE JAMES and its pristine landscape connect some of our nation's most important historic sites, including Jamestown Island, Colonial Parkway, and Carter's Grove. Visitors today experience a riverscape that is largely unchanged from the 17th century.

HISTORY Named to the National Trust's 2013 11 Most Endangered Historic Places list, the James River has been the site of significant events stretching back before the founding of the United States. As the location of the first successful English colony in America at Jamestown in 1607, a transportation route during the Revolutionary War, the site of Civil War battles, and the keystone segment of the nation's first nationally designated water trail, the James is integral to the story of America, as well as the region's environmental and economic well-being.

THREAT Dominion Virginia Power has proposed building a transmission line across the James River at Jamestown that includes 17 towers, some up to 295 feet tall. This project would dramatically alter the landscape and put at risk decades of investment by the public and private sectors to protect this important part of our country's past.

OPPORTUNITY The National Trust is advocating to save the James River through state and federal regulatory review processes. It also mounted a strategic public outreach campaign to urge Dominion to find an alternative route.

FAST FACT *The United Kingdom's Queen Elizabeth II has visited Jamestown twice, most recently on Jamestown's 400th anniversary in 2007.*

REVERSE PAGE: The James River has been the site of significant historical events stretching back before the founding of the United States. FROM LEFT: In the spring of 2015, the National Trust launched its Down to the Wire campaign to help galvanize opposition to proposed power lines that would cross the river; Jamestown, the first successful English colony in the United States was settled along the river's banks in 1607; The cultural resources along the James River are essential elements of America's early history and the region's environmental and economic well-being.

COVER PHOTO AND ABOVE, MIDDLE: KRIS WEINHOLD; ABOVE, LEFT AND RIGHT: ELLI MORRIS

National Trust *for* Historic Preservation®

THE JAMES RIVER TRANSMISSION LINE – SUMMARY OF PROPOSED ALTERNATIVES

I. Executive Summary

Background: The National Trust for Historic Preservation has been advocating against construction of a 500 kV overhead transmission line proposed by Dominion Virginia Power. The line, as currently proposed, would cross the James River in the viewshed of Jamestown Island, Colonial Parkway, Carter's Grove plantation and the Captain John Smith Chesapeake National Historic Trail. The National Trust has been actively working to encourage Dominion to pursue an alternative project since 2013 when the James River was named to our list of 11 Most Endangered Historic Places.

The need for Dominion's proposed project is being driven by the impending shutdown of two of the three generating units at the Yorktown Power Station. Two coal-fired units (Yorktown 1 and 2) are required to close due to a federal law called MATS (Mercury Air Toxics Standard). Absent federal regulatory intervention, the last date that Yorktown 1 and 2 can operate without violating MATS is in April 2017.

Yorktown 3 is an oil-burning generating unit that it is not required to close by MATS. However, it is limited to running 8% of the time due to MATS. Once Yorktown 1 and 2 close, a plan should be in place to ensure that the energy system in the North Hampton Roads Area (NHRA) of Virginia complies with National Energy Regulatory Commission (NERC) reliability standards during times of peak demand (i.e., during the summer when electrical needs are the highest). Dominion's preferred overhead alternative addresses the NERC compliance issue and meets the power needs of the region, but would create significant harm to nationally significant historic resources along the James River.

Dominion has consistently represented its preferred 500kV overhead alternative as the only realistic solution. A recent Op-Ed in the Richmond Times Dispatch authored by a Dominion representative stated that:

> "There is no better solution. Dominion considered dozens of alternatives. They all came up short. They could not deliver enough electricity to meet the needs of the Peninsula, were of unproven reliability, were even more costly for customers than putting emissions controls on the Yorktown coal units, could not be completed on time, or would be more disruptive to the environment."

In contrast, the National Trust has consistently stated our position that, if this problem is approached with a problem-solving mindset, other alternatives could be identified that would satisfy all relevant electrical criteria and save the

irreplaceable historic resources along the James River. To that end, the National Trust retained the firm of Tabors Caramanis Rudkevich (TCR) to identify one or more alternatives that would not require an overhead crossing of the James River and would meet all relevant planning and reliability criteria.

Review Process: TCR performed engineering (power flow) analyses and developed four alternatives that would meet the energy reliability needs, cost less, can be constructed in less time, and do not require constructing an overhead transmission line across the river.

Dominion's proposed James River project has two parts: the 500 kV river crossing and a new 230 kV line that runs south from James City County. The alternatives that TCR developed assume that the 230 kV portion of the project is built, and seek to replace only the 500 kV river crossing portion of the project.

To identify the four alternatives, TCR used information that Dominion has filed with the Federal Energy Regulatory Commission or has provided through the federal permit review process being led by the Army Corps of Engineers. TCR also used power flow modeling software that is standard in the industry. The four alternatives identified by TCR are not an exhaustive list of potential alternatives.

Results Summary: The four alternatives require a mix of reconductoring (upgrading wires on existing towers), reconfiguring (operating the electrical system differently), and operating Yorktown 3 (oil-fired plant not required to close by MATS) to meet summer peak demand and/or as a voltage regulator. The fourth alternative is a construction option that would involve building new 230 kV lines in existing Right of Ways (ROW) or along highways.

Alternative	Estimated Cost	Estimated Time to Construct
A – Reconductor & Reconfigure	$78 million	< 12 months
B – Yorktown 3 online during Summer Peak	Increased generation costs only*	Available today
C – Yorktown 3 Standby	$12 million	< 12 months
D – Critical ROW Bypass	$72 - $132 million	< 20 months
Dominion's Preferred Overhead James River Crossing	$100 million + $85 million (mitigation funding)	20 months

* Under July – September 2016 conditions, these costs are estimated to be $12 million/year.

Conclusion: There are at least four alternative projects that could be pursued that avoid the need to construct an overhead 500KV transmission line across the James River. Each of these alternatives costs less to construct, can be built more quickly, meets all relevant reliability standards and energy needs in the region and protects the historic landscape and resources along the James River.

II. Summary of Alternatives

To satisfy NERC criteria, a project must be able to protect grid reliability under various planning scenarios. The main drivers for the James River project are: extreme events that could result in the outage of all lines in a right of way (Extreme Right of Way Contingencies), an outage of both of the existing 230 kV lines that cross the James River near Newport News (Tower Contingency), or a series of sequential outages of 230 kV lines in the region (Single Element Contingency). The following is a brief summary of the four alternatives, which satisfy these criteria. More details about the alternatives are available in the Appendix.

Alternative A – Reconductor and Reconfigure

- Reconductor 230 kV line Lightfoot – Kings Mill (section of line 209, ~9 miles)
- Reconductor 115 kV line Lanexa – Toano (section of line 58, ~6.5 miles)
- Enable the generator at Yorktown 3 to run continuously as a synchronous condenser (voltage support)
- Reconfigure the system under Summer Peak conditions:
    - Energize existing 115 kV line Toano – Kings Mill (section of line 58)
    - After an outage of line 209 or 285, energize 115 kV line Lanexa – Dow Tap (West end of line 34), de-energize 115 kV line Yorktown – Grafton (East end of line 34), and split the Skiffes Creek 115 kV so that line 34 is not connected to other facilities at Skiffes Creek
- Reconductor 230 kV line Chuckatuck – Newport News and Newport News – Shellbank (~18 miles in total)
- Reconductor 230 kV line Poolesville – Winchester (~29 miles)*

    * NOTE: Alternatively, a Special Protection Scheme (SPS) could be developed that would allow shedding of 225 MW of load upon overload of 230 kV Benns Church – Copeland, and keep Yorktown 3 on stand-by (would only occur if one of two Extreme Right of Way contingencies occur, and would last only until Yorktown 3 is started, up to 8-10 hours); see Alternative C. A SPS can be developed that identifies power users who volunteer to have load dropped in exchange for payments.

Alternative B – Yorktown 3 On Summer Peak

- Start and dispatch Yorktown 3 at 310 MW** (minimum load, per DVP letter to NPCA 9/12/16) under summer peak conditions

• Under all other seasonal conditions analyzed (winter peak and spring minimum load), TCR identified no violations to NERC Standards or DVP Planning Criteria in the absence of the overhead 500KV line

• Overhead lines in the NHRA area are predominantly thermally limited; with lower ambient temperatures, transmission capacity increases significantly

• Under the conservative assumption that summer peak conditions occur 5 days/week for 12 weeks per year, the annual capacity factor of Yorktown 3 would be **6.4%** (well below the 8% limit under MATS)

> ** NOTE: As implied or explicitly stated in different filings, DVP has indicated that Yorktown 3 will be available at least through 2026.

Alternative C – Yorktown 3 Stand-by

• Start and dispatch Yorktown 3 at 310 MW (minimum load) under summer peak conditions upon the occurrence of a critical Single-Element Contingency

• Enable the generator at Yorktown 3 to run continuously as a synchronous condenser

• Reconfigure the system under Summer Peak conditions (pre-contingency):

> • Energize existing 115 kV line Toano – Kings Mill (section of line 58)
> • Energize 115 kV line Lanexa – Dow Tap (line 34), and split the Skiffes Creek 115 kV so that line 34 is not connected to other facilities at Skiffes Creek

• Develop a SPS to drop 225 MW of load at selected NHRA feeders upon overload of 230 kV Benns Church – Copeland (would only occur if one of two Extreme Right of Way contingencies occur; would last only until Yorktown 3 is started, estimated to be 8-10 hours)***

> *** NOTE: An SPS can involve seeking fast-response contingency reserves through key large users or through other demand management alternatives. Alternatively, if 230 KV lines Chuckatuck-Shellbank and Poolesville-Winchester are reconductored, no SPS is necessary; see Alternative A.

Alternative D – New 230kV Paths

• Tap existing 230 kV line (#2075) near Brookwoods

• Tap existing 230 kV line (#224) near Slaterville

• Build new 230 kV line between Brookwoods and Slaterville (~18 miles, *along I-64 or route 249*)

- Build new 230 kV line between Hayes and Harmony (~25 miles, *on existing right of way*)
- Reconductor/rebuild 230 kV line Lanexa – Slaterville (~5.75 miles)
- Enable the generator at Yorktown 3 to run continuously as a synchronous condenser
- Reconfigure the system under Summer Peak conditions:
    - Energize existing 115 kV line Toano – Kings Mill (section of line 58)
    - Energize 115 kV line Lanexa – Dow Tap (West end of line 34) and split the Skiffes Creek 115 kV so that line 34 is not connected to other facilities at Skiffes Creek
    - After the outage of line 285, de-energize line Chickahominy – Lanexa circuit 2

Alternatives to
Surry – Skiffes Creek 500 kV Overhead Project

Identification and Power Flow Analysis

Richard D. Tabors, Ph.D.

USACE, Norfolk, VA

October 28, 2016

Agenda

- Scope of Work
- Project Summary
- Background
  - Surry – Skiffes Creek Project
  - NERC Standards and Dominion Transmission Planning Criteria
  - Available Data and Analysis Methodology
  - Main Drivers for Transmission Solutions in NHRA
- Alternatives to Surry – Skiffes Creek 500 kV

Scope of Work

- Tabors Caramanis Rudkevich (TCR) was retained by the National Trust for Historic Preservation (NTHP) to identify alternatives to the Surry – Skiffes Creek 500 kV overhead transmission project, and to evaluate them using power flow simulations. The alternatives must meet NERC Reliability Standards, be implementable and should be as cost-effective as possible.

Project Summary

- TCR based its analyses on Dominion Virginia Power (DVP) reported reliability criteria and FERC filed transmission data (FERC Form No. 715)
- TCR identified and fully evaluated four complementary, specific alternatives to the Surry-Skiffes proposed river crossing *each of which meets all reliability requirements, is generally less costly and can be implemented in a shorter period of time*

Alternatives	Estimated Cost	Estimated time frame
A – Reconductor & Reconfigure	$78 million	< 12 months
B – Yorktown 3 online during Summer Peak	increased generation costs only*	Available today
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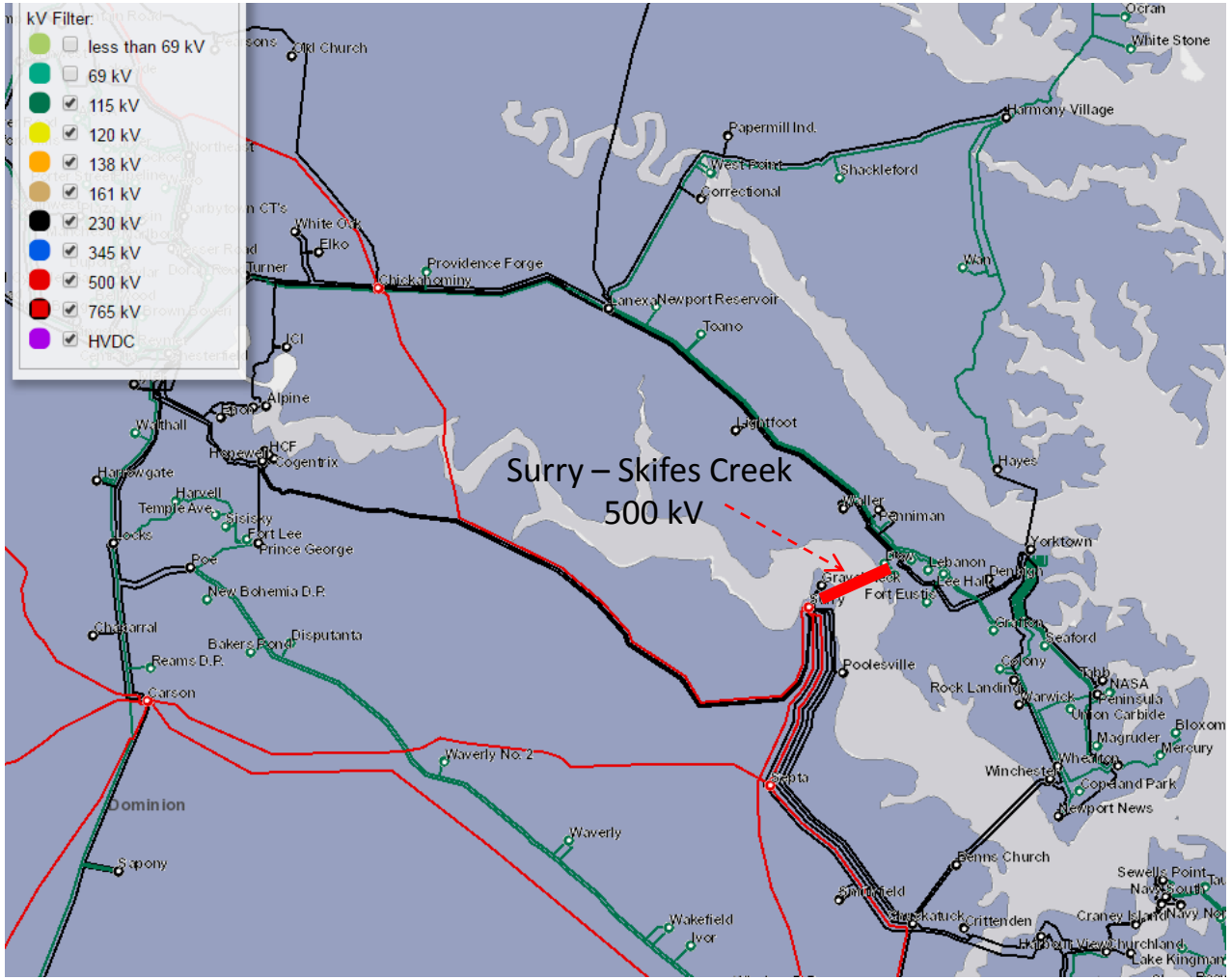
D – Critical ROW Bypass	$72 - $132 million	< 20 months
Overhead James River crossing	$100 million + $85 million (mitigation)	20 months

* Based on the revenue shortfall (fuel and other operation cost minus PJM energy market revenue) of operating Yorktown 3 for 12 weeks, 5 days/week, under July – September 2016 conditions, these are estimated at $12 million/year.

Surry – Skiffes Creek Transmission Line

- The Surry – Skiffes Creek 500 kV overhead transmission line is part of the Surry – Skiffes Creek – Whealton project, which also includes the Skiffes Creek switching station, a new 230 kV line from Skiffes Creek to Whealton, and substation upgrades.
- Per our Scope of Work, we evaluate alternatives only to the Surry – Skiffes Creek 500 kV overhead line (and the 500 kV portions of the switching station), and not to the other pieces of the overall project.



Source: PJM System Map

NERC Transmission Planning Standard

- Dominion Virginia Power plans transmission upgrades based upon the NERC Standard TPL-001-4, which has been in effect since October of 2013
- TPL-001-4 replaces NERC TPL-001-0, TPL-002-0, TPL-003-0 and TPL-004-0
- DVP often uses vocabulary from earlier standards in describing requirements for the Surry-Skiffes Creek project.
- Standard TPL-001-4 is not fully prescriptive. Each transmission owner (TO) has the ability to develop its own criteria to meet TPL-001-4, specifying, among other things, acceptable transmission facility limits

- TCR has based its analyses on the DVP Transmission Planning Criteria under NERC Standard TPL-001-4

Summary of Most Critical DVP Transmission Planning Criteria

- There are three categories of reliability requirements that drive the need for solutions in the North Hampton Roads Area (NHRA)
  - This is consistent with analysis reported by DVP (3/21/16 letter to NPCA and attachments)
  - Once these requirements are met, all other requirements are met also
- These requirements are to maintain power flows within the "*Load Dump*" limit of all transmission facilities that remain in service after pre-specified multi-element outages, as described in the table
- Dominion's Planning Criteria are not specific about Extreme Events: "*…more severe but less probable scenarios should also be considered. As permitted by NERC Planning Standards, judgment shall dictate whether and to what extent a mitigation plan would be appropriate.*"*
  - In the analysis, we assume that the criteria for these events are similar to those for Categories P6-P7, except possibly for the amount of load loss required to return the flow on all facilities to acceptable levels (Short Term Emergency limits).

Category	Description
Planning Event P6 Multiple Contingency (two overlapping singles)	Independent, sequential outage of two individual transmission facilities, with adjustments made after the first outage (also known as *N-1-1*)
Planning Event P7 Multiple Contingency (common structure)	Loss of two adjacent circuits on a common structure (tower)
Extreme Event	The most severe Extreme Event in the area is the simultaneous outage of all transmission facilities on a Right of Way

* Dominion – Transmission Planning Criteria, Version 11, Effective 3/27/2015, page 7.

Available Data*

- Each utility that operates integrated transmission system facilities that are rated at or above 100 kV, must annually submit to the FERC the following information as part of its Form No. 715 - Annual Transmission Planning and Evaluation Report filings:
  - Power flows used in transmission planning efforts
  - Transmission planning criteria
  - Transmission system maps and diagrams
- PJM Interconnection publishes the model results that it has developed as part of the Regional Transmission Expansion Plan (RTEP) process, including the definition of each contingency used to model Planning Events to meet NERC Standards

* NTHP requested data from DVP. None was provided.

Power Flow Tool Use and Conditions Simulated

- TCR performed the power flow simulations using PowerWorld Simulator Release 18
  - PowerWorld is an industry standard and is in the modeling toolbox of FERC and of PJM and most other system operators
- The power flow cases used in the analyses model a representative and wide range of years and system conditions included in the FERC Form No. 715 filings of DVP
  - 2016 Summer Peak
  - 2016 Winter Peak
  - 2016 Spring Minimum Load
  - 2021 Summer Peak
  - 2026 Summer Peak

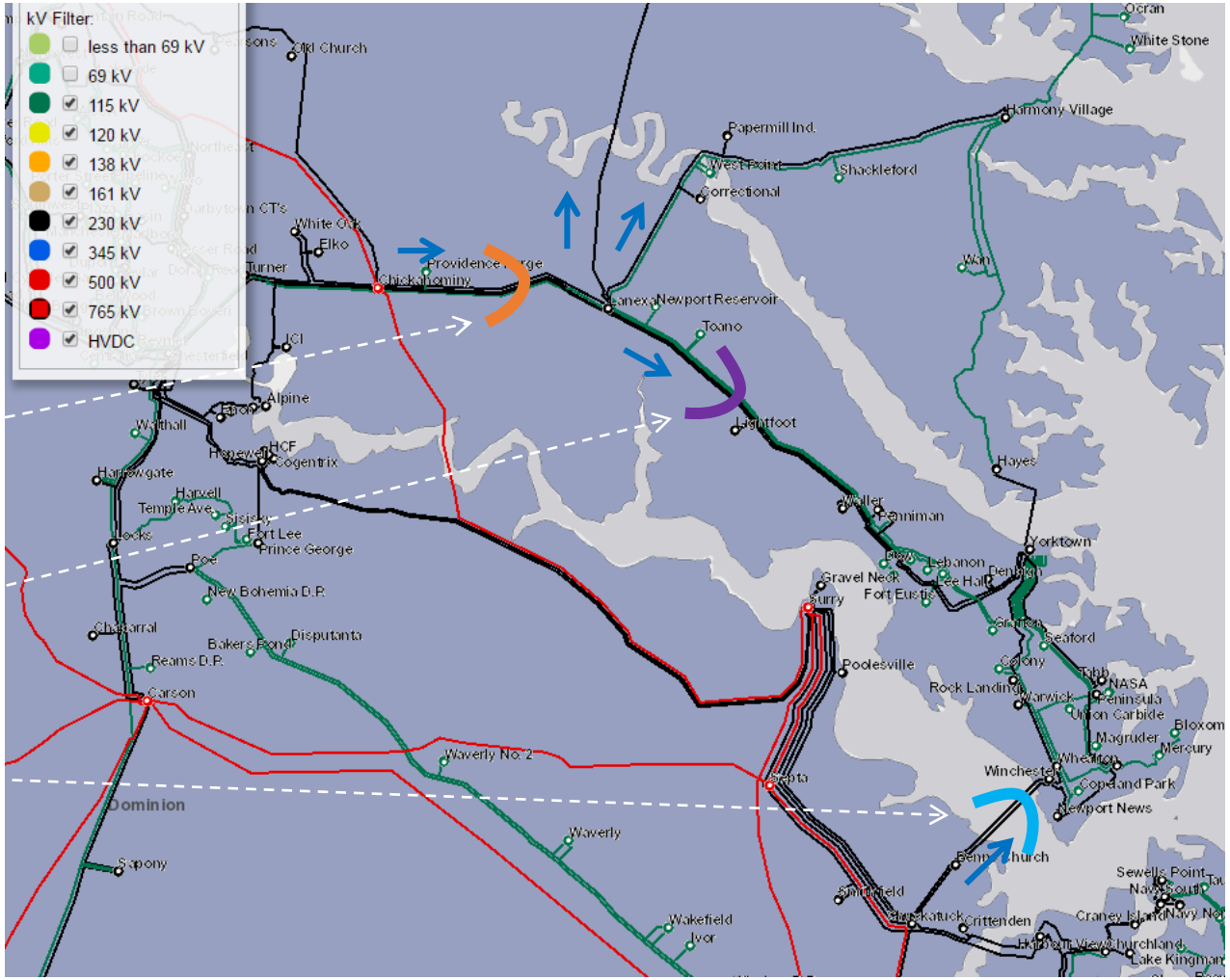
Analysis Methodology

- Based on the power flow analysis summary tables provided by DVP to NPCA (letter dated March 21, 2016), TCR verified that violations to NERC Standard TPL-001-4 occurred in the absence of Surry – Skiffes Creek 500 kV, and identified and evaluated alternatives that would meet the Standard
- TCR used the power flows and other information filed by DVP in FERC Form No. 715, and the contingency definitions published by PJM as part of its RTEP model
  - Other than removal of Surry – Skiffes Creek 500 kV from the models, the power flow cases used in the TCR analyses are identical to those filed by DVP (e.g., TCR made no modifications to the load or generation profiles except as indicated in the Alternatives)
  - PJM does not include Extreme Contingencies in the PJM RTEP model. As such, TCR developed the Extreme Contingencies based on the letter from DVP to NPCA, other documents submitted as part of the Surry – Skiffes Creek proceeding, and engineering judgment

Main Drivers for Transmission Solutions in NHRA

Extreme Events and Tower Outages

- Without Yorktown and Surry – Skiffes Creek, the following single contingencies require mitigation:
  - Outage of all four lines in the Chickahominy – Lanexa Right of Way (Extreme Event)
  - Outage of all four lines in the Lanexa – Skiffes Creek Right of Way (Extreme Event)
  - Outage of the existing 230 kV James River crossing double circuit (tower contingency, Planning Event P7)

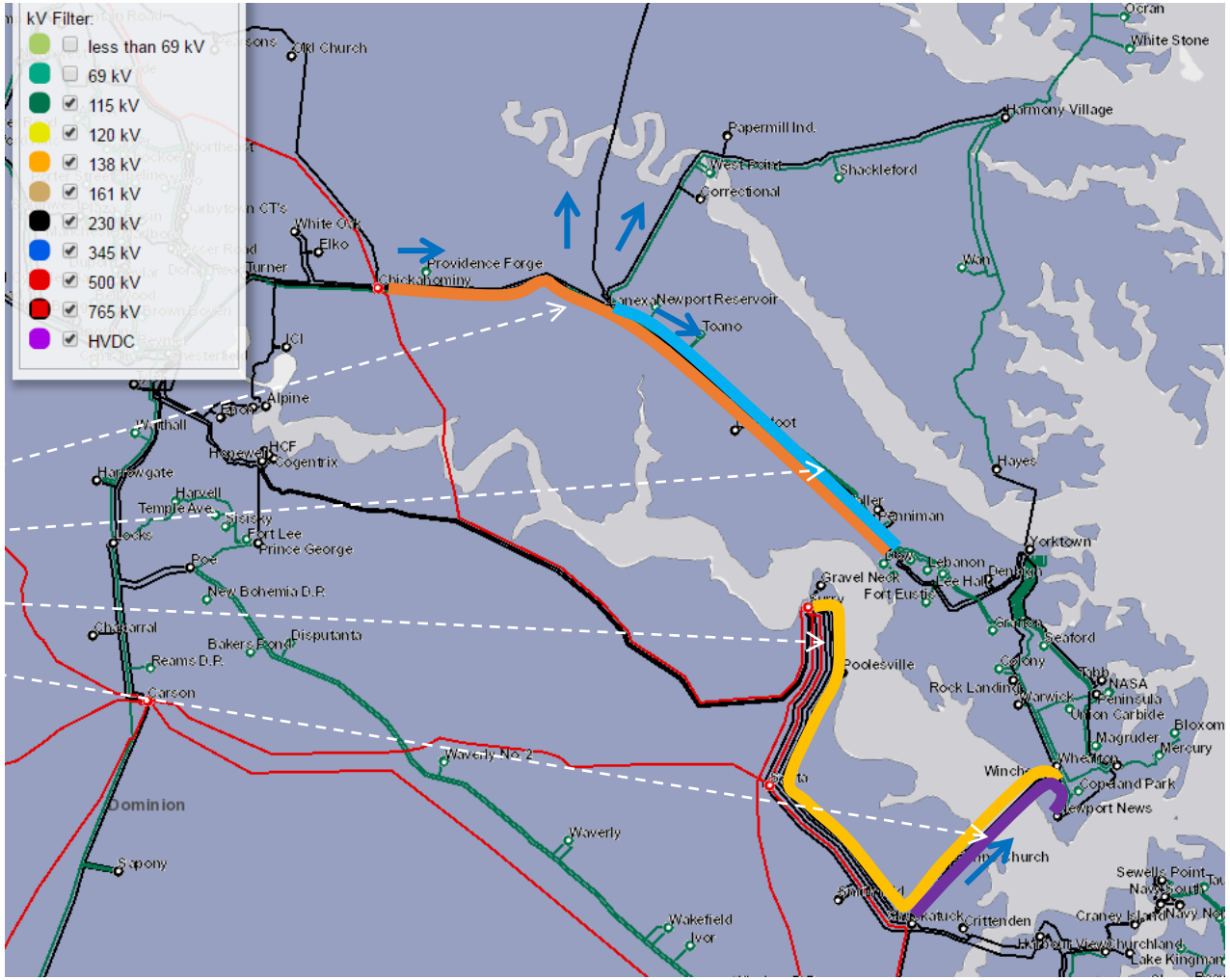


Source: PJM System Map

Main Drivers for Transmission Solutions in NHRA

Sequential Independent Outages (N-1-1: P6 Cat)

- Without Yorktown and Surry – Skiffes Creek, after the occurrence of any of the following single contingencies, there is a need to mitigate the next (potential) contingency:
  - Chickahominy – Skiffes Creek 230 kV
  - Lanexa – Skiffes Creek 230 kV
  - Surry – Winchester 230 kV
  - Chuckatuck – Newport News 230 kV
- Given that these are sequential events, per NERC Standard and DVP Criteria adjustments can be made after the occurrence of the first outage



Source: PJM System Map

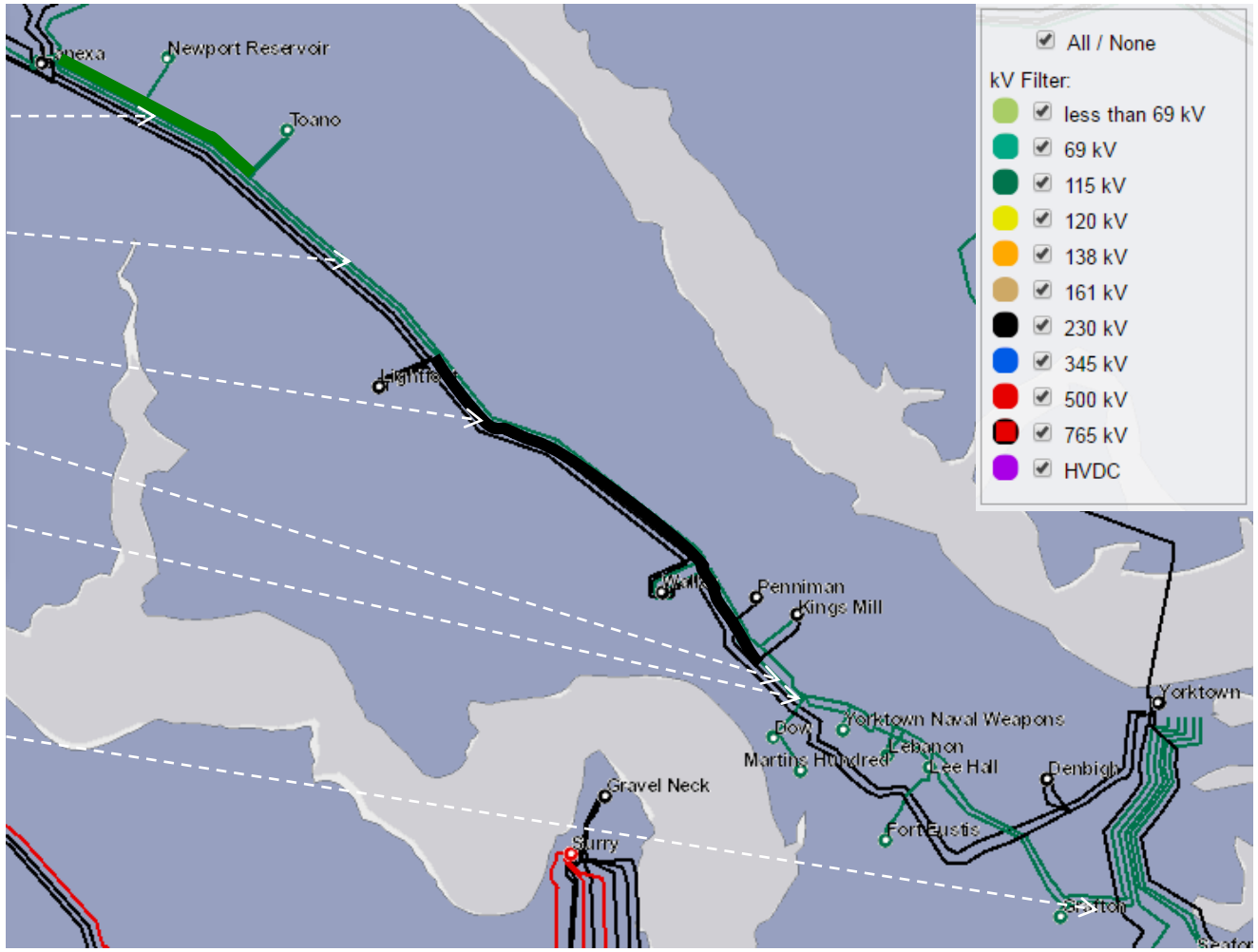
Alternative A – Reconductor and Reconfigure

Increase nominal import capacity from West of NHRA by 509 MW, to deal with N-1-1 and tower contingencies

- Reconductor existing 115 kV line Lanexa – Toano
- Energize existing 115 kV line Toano – Kings Mill*
- Reconductor existing 230 kV line Lightfoot – Kings Mill

Increase import capacity by another 54 MW after a major 230 kV outage

- Energize existing 115 kV line Lanexa – Dow Tap (West end of line 34),* split the Skiffes Creek 115 kV so that line 34 is not connected to other facilities at Skiffes Creek, and de-energize 115 kV line Yorktown – Grafton (East end of line 34), after the outage of parallel 230 kV lines 209 or 285



Source: PJM System Map

* These are normally energized in operations, but are de-energized in the DVP power flow models filed with the FERC in 2016

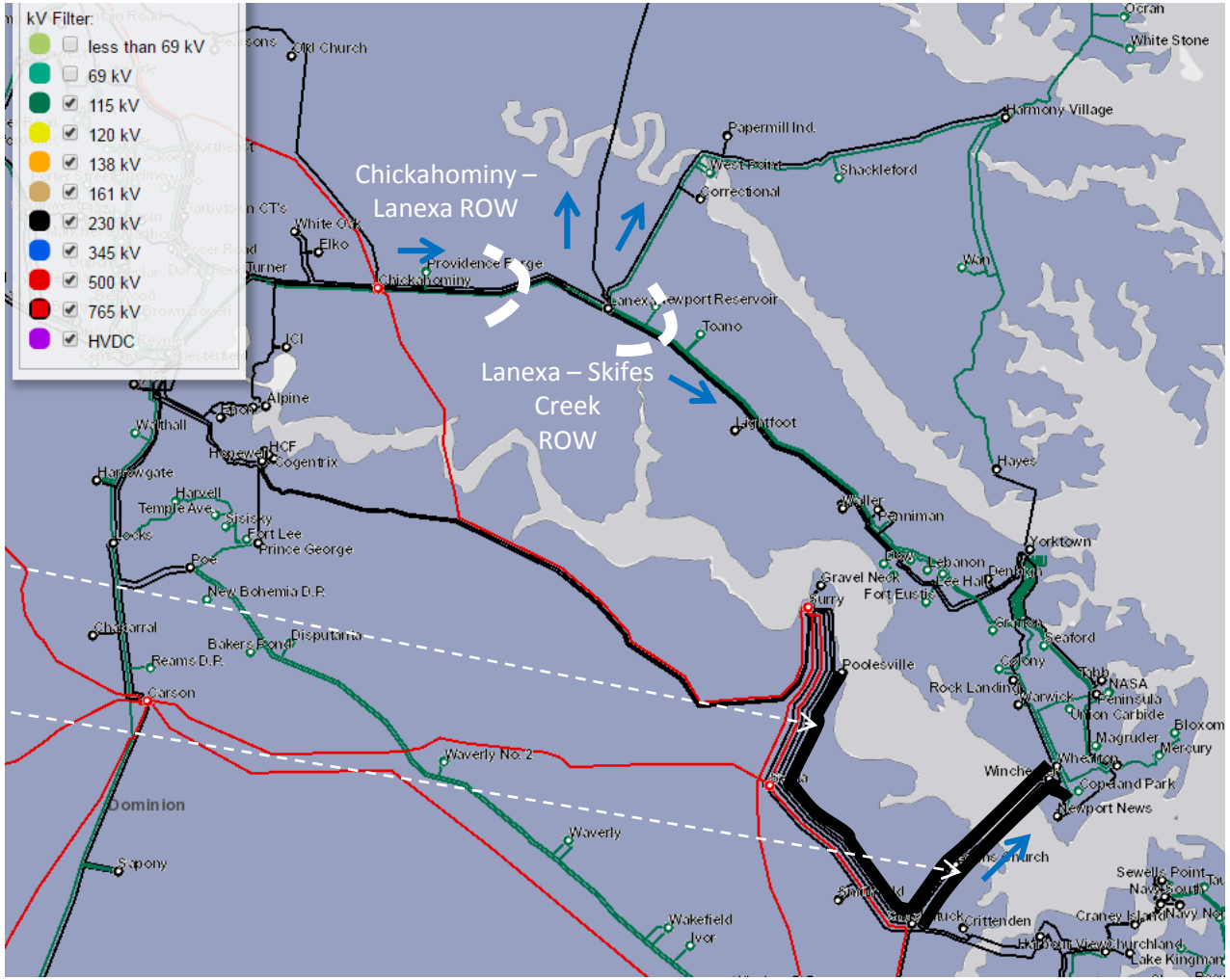
Alternative A – Dealing with Extreme Events

Sustain voltage under worst contingencies and reduce MVAr flows

- Enable the generator at Yorktown 3 to run continuously as a synchronous condenser*

Increase import capacity from South East by 250 MW to meet Extreme (Right of Way) contingencies that outage most of the supply from the West

- Reconductor 230 kV line Poolesville – Winchester
- Reconductor 230 kV line Chackatuck – Shellbank



* Doing so does not preclude Yorktown 3 from generating on an as-needed basis.

Alternative A – Reconductor and Reconfigure

- Reconductor 230 kV line Lightfoot – Kings Mill (section of line 209, ~9 miles) to increase its summer *Load Dump Rating* by 20% to 650 MVA
- Reconductor 115 kV line Lanexa – Toano (section of line 58, ~6.5 miles) to increase its summer *Load Dump Rating* by 20% to 200 MVA
- Enable the generator at Yorktown 3 to run continuously as a synchronous condenser
- Reconfigure the system under Summer Peak conditions:
  - Energize existing 115 kV line Toano – Kings Mill (section of line 58)
  - After the outage of line 209 or 285, energize 115 kV line Lanexa – Dow Tap (West end of line 34), de-energize 115 kV line Yorktown – Grafton (East end of line 34), and split the Skiffes Creek 115 kV so that line 34 is not connected to other facilities at Skiffes Creek
- Reconductor 230 kV line Chuckatuck – Newport News and Newport News – Shellbank (~18 miles in total) to increase its summer *Load Dump Rating* by 25% to 840 MVA and 686, respectively*
- Reconductor 230 kV line Poolesville – Winchester (~29 miles) to increase its summer *Load Dump Rating* by 12% to 750 MVA*

** Otherwise, develop SPS to shed 225 MW of load upon overload of 230 kV Benns Church – Copeland, and keep Yorktown 3 on stand-by (would only occur if one of two Extreme Right of Way contingencies occur, and would last until Yorktown 3 is started, up to 8-10 hours); see Alternative C*

Alternative B – Yorktown 3 On Summer Peak*

- Start and dispatch Yorktown 3 at 310 MW** (minimum load, per DVP letter to NPCA 9/12/16) under summer peak conditions
  - Under all other seasonal conditions analyzed (winter peak and spring minimum load), TCR identified no violations to NERC Standard TPL-001-4 or DVP Planning Criteria in the absence of Surry – Skiffes Creek 500 kV
  - Overhead lines in the NHPA area are predominantly thermally limited; with lower ambient temperatures, transmission capacity increases significantly
- Under the conservative assumption that summer peak conditions occur 5 days/week for 12 weeks per year, the annual capacity factor of Yorktown 3 would be **6.4%** (well below the 8% limit under MATS; assumed a Yorktown 3 nominal capacity of 790 MW)

*The DVP IRP indicates that Yorktown 3 will be available at least through 2022. The 2026 Summer Peak power flow filed with FERC indicates that Yorktown 3 is available and dispatched at 630 MW in 2026.

** In the 2026 Summer Peak power flow case, Yorktown generation remains at 630 MW. Under outage conditions of Yorktown 3 in 2026, the generation shortfall is covered by starting Possum Point 5 (full output) and three of the Northern Neck units, and by shutting down two of the Gravel Neck units; in addition, the same transmission system reconfiguration specified under Alternative C is made.

Alternative C – Yorktown 3 Stand-by

Meet all N-1-1 contingencies (similar to Alternative B)

Voltage support

Increase nominal import capacity from West of NHRA by 272 MW, to deal with tower contingencies

Meet Extreme (ROW) Events

- Start and dispatch Yorktown 3 at 310 MW (minimum load, per DVP letter to NPCA 9/12/16) under summer peak conditions upon the occurrence of a critical single-element contingency (see previous slide that discusses the main N-1-1 contingency drivers)
- *Enable the generator at Yorktown 3 to run continuously as a synchronous condenser*
- Reconfigure the system under Summer Peak conditions (pre-contingency):
  - Energize existing 115 kV line Toano – Kings Mill (section of line 58)*
  - Energize 115 kV line Lanexa – Dow Tap (line 34),* and split the Skiffes Creek 115 kV so that line 34 is not connected to other facilities at Skiffes Creek
- Develop a Special Protection Scheme (SPS) to drop 225 MW of load at selected NHRA feeders upon overload of 230 kV Benns Church – Copeland (would only occur if one of two Extreme Right of Way contingencies occur; would last only until Yorktown 3 is started, estimated to be 8-10 hours)[1, 2]

* These are normally energized in operations, but are de-energized in the power flow models filed by DPV with FERC

[1] *Dominion could implement this SPS by seeking fast-response contingency reserves from key large users or through other demand management alternatives*

[2] *Otherwise, reconductor 230 kV lines Chuckatuck – Shellbank and Poolesville – Winchester; see Alternative A*

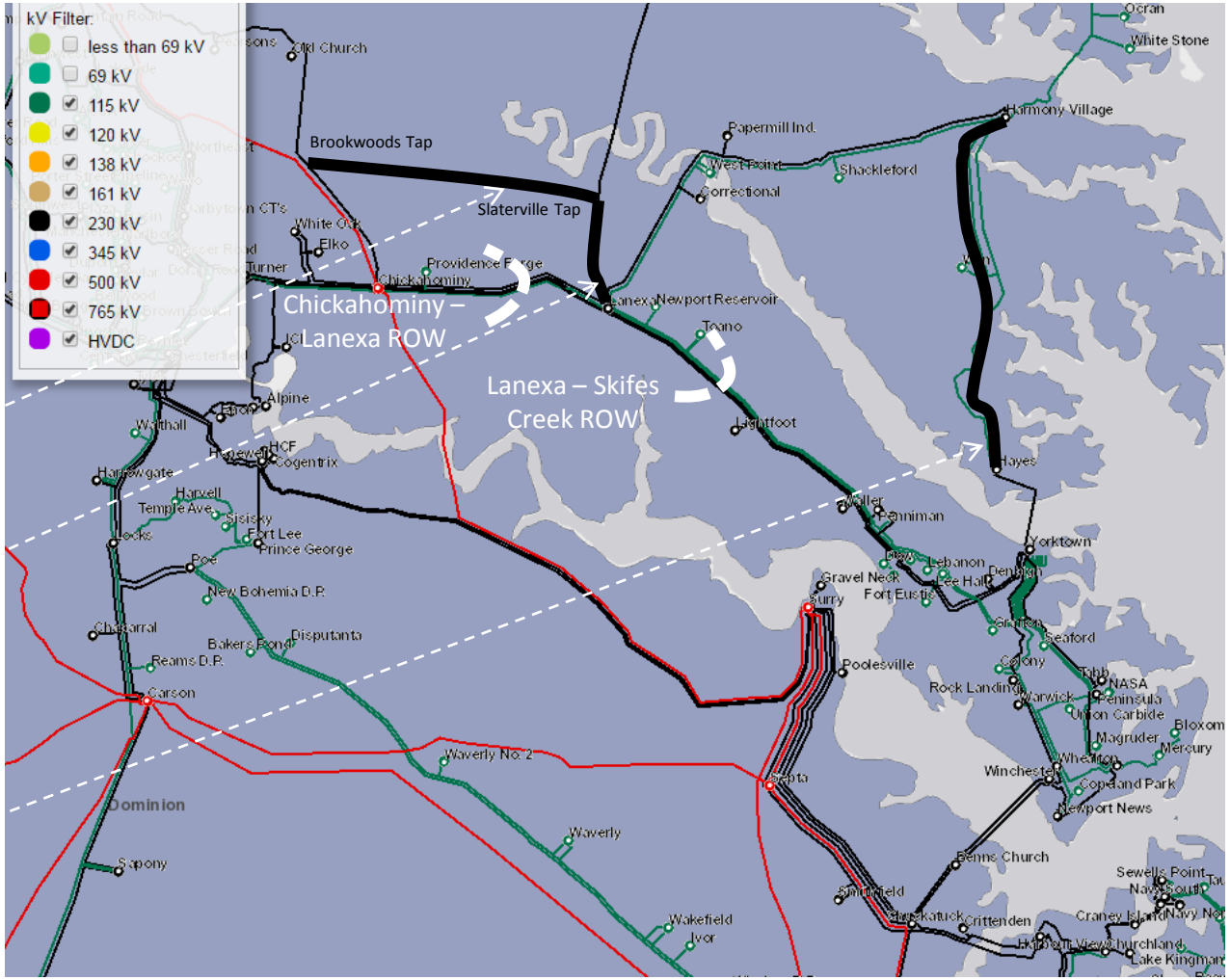
Alternative D – Bypassing Critical ROWs

Create parallel path to Chickahominy – Lanexa ROW to solve associated Extreme Event

- Tap existing 230 kV line (#2075) near Brookwoods
- Tap existing 230 kV line (#224) near Slaterville
- Build new 230 kV line between Brookwoods and Slaterville
- Reconductor/rebuild 230 kV line Lanexa – Slaterville

In conjunction with existing Lanexa – Harmony 230 kV line, create parallel path to Lanexa – Skiffes Creek ROW to solve associated Extreme Event and support N-1-1 events

Build new 230 kV line between Hayes and Harmony



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- Reconductor/rebuild 230 kV line Lanexa – Slaterville (~5.75 miles) to increase its summer *Load Dump Rating* by 40% to 620 MVA
- Enable the generator at Yorktown 3 to run continuously as a synchronous condenser
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  - After the outage of line 285, de-energize line Chickahominy – Lanexa circuit 2

Summary of Proposed Alternatives

- TCR identified and fully evaluated four complementary, specific alternatives to the Surry-Skiffes proposed river crossing *each of which meets all reliability requirements, is generally less costly and can be implemented in a shorter period of time*

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Dartmouth College

Richard D. Tabors, Ph.D. is an economist and scientist with 35 years of domestic and international experience in energy planning and pricing, international development, and water and wastewater systems planning. He is currently President and Principal of *Tabors Caramanis Rudkevich* an energy, water and wastewater consulting group in Boston, and Visiting Scholar and co-director of the Utility of the Future Project at the MIT Energy Initiative. Prior to forming *Tabors Caramanis Rudkevich* he was president of *Across the Charles.* Dr. Tabors was Vice President of Charles River Associates from 2004 to 2012.

From 1976 until 2006 Dr. Tabors held a variety of position at Massachusetts Institute of Technology culminating in the title of Senior Research Engineer and Senior Lecturer. These positions involved research development and supervision as well as academic teaching and included being Assistant Director of the power systems engineering laboratory (LEES) and associated director of the Technology and Policy master's program. Prior to MIT Dr. Tabors was Assistant Professor of City and Regional Planning and a member of the teaching faculty of the College of Arts & Sciences at Harvard University. At present he is a visiting professor of Electrical Engineering at the University of Strathclyde, Glasgow, Scotland where he was awarded an Honorary Doctorate in Engineering in July 2016.

Dr. Tabors was a member of the team at MIT that developed the theory of spot pricing (*Spot Pricing of Electricity* Kluwer Academic, 1989) upon which real-time pricing (RTP) and locational marginal pricing (LMP) of electricity and transmissions services are based. While still at MIT Dr. Tabors and coauthors Michael Caramanis & Roger Bohn formed Tabors Caramanis & Associates (1988) that was sold to Charles River Associates in 2004.

Dr. Tabors' research continues in the development and implementation of locational pricing in both the electricity and natural gas sectors. He currently leads an effort to design a platform-based market structure for the products and services provided by distributed electric energy resources (DERs).

Dr. Tabors provides expert assistance and testimony in regulatory and arbitration cases in the energy sector at the Federal, State and Provincial levels in North America and provides technical assistance in electricity markets and market development worldwide. His strength both in academia and in private practice is in the development and management of effective, research, client and problem focused teams that bring intellectual originality and rigor to the challenges of energy markets.

EXPERIENCE

2014-Present *President and Principal* Tabors Caramanis Rudkevich, an Energy and Environmental Consulting Group, Boston, MA and Senior Consultant

2013-Present Visiting Scholar and Co-Director Utility of the Future Project, MIT Energy Initiative.

2012–2014 *President and Principal* Across the Charles, Cambridge, MA

2004–2012 *Vice President*, Charles River Associates

- Co-director of Energy & Environment practice area.

2004–Present *Visiting Professor of Electrical Engineering*, University of Strathclyde, Glasgow, Scotland

1986–2006 *Senior Lecturer*, Technology and Policy Program, Massachusetts Institute of Technology (MIT)

1988–2004 *Founder and Principal*, Tabors Caramanis & Associates, Inc.

1989–1998 *Lecturer*, Department of Electrical Engineering and Computer Science, MIT

- "Introduction to Power Systems Operations and Planning."

1992–1998 *Senior Research Engineer*, Laboratory for Electromagnetic and Electronic Systems, MIT

1985–1998 *Assistant Director*, Laboratory for Electromagnetic and Electronic Systems, MIT

- Responsible for laboratory administration and research in power systems economics and planning, research on power systems monitoring and control, principal investigator on research program in performance based monitoring and control.

1990–1993 *Principal Research Associate*, MIT

- Co-Faculty "Planning for Water and Sewerage" and "Dealing with the Complete System," MIT Summer Session.

1984–1989 Co-Faculty "Power Systems Planning & Operation: Methodologies for Dealing with an Uncertain Future", MIT Summer Session.

1978-1988 *Lecturer*, Department of Urban Studies and Planning, MIT

1973-1988 *Principal*, Meta Systems

- utilities group in power systems planning, pricing and systems analysis

1985–1987 *Faculty*, Course 11.944, Department of Urban Studies and Planning (co-taught as KSG S115 with P. Rogers) “Energy Sector Planning in Developing Countries.”

1971–1976 *Research Associate and Member*, Center for Population Studies, Harvard University

- Research on resource and environmental planning in developing nations of South Asia and Africa.

1978–1984 *Program Manager*, Utility Systems, MIT Energy Laboratory

- Economic and systems research and development in electric and gas utility systems; including the integration of new generation systems (photovoltaics) into the grid.

1979-1983 *Project Manager and Principal Investigator*, Electric Generation Expansion Analysis System (EGEAS) Project, under contract to EPRI, MIT Energy Laboratory.

1977-1982 *Project Manager and Principal Investigator*, Photovoltaics Project, under contract to U. S. Department of Energy, MIT Energy Lab.

1976-1977 *Economist*, Photovoltaics Project, MIT Energy Laboratory and Lincoln Laboratory.

1976-1977 *Energy Economist*, New England Energy Management Information Systems (NEEMIS), Energy Laboratory, MIT.

1974-1976 *Assistant Professor of City and Regional Planning*, Harvard University.

1973-1976 *Research Fellow*, Environmental Systems Program, Division of Engineering and Applied Physics, Harvard University.

1971–1977 *Co-Faculty*, with Professor R. Revelle, Natural Science 118, & 119, Human Population and Natural Resources, and Population & Environment and in Urban Setting, Harvard University.

1973-1974 *Lecturer on City and Regional Planning*, Graduate School of Design, Harvard University.

1971 *Resident Representative*, Harvard University, East Pakistan (Bangladesh) Land, Water and Power System Study, Dacca, East Pakistan.

1970 *Graduate Administrative and Teaching Assistant* to A. K. Campbell, Dean, Maxwell Graduate School of Citizenship and Public Affairs, Syracuse University.

1969–1970 *Syracuse University Intern*, Economic Division, USAID Pakistan.

- Informal advisor on Regional Economic Planning to the Urban Development Directorate, Planning Department, Government of East Pakistan (Bangladesh).

CONSULTING EXPERIENCE

- For integrated market participant in Canada, provided due diligence in evaluation of electricity market structure.
- For merchant transmission developer, provides project financial and development assistance in technology and site selection (2013 – Present)
- For multiple private power development groups, provides project valuation for generation and transmission. (2000 – Present)
- For the City of New York provided technical and analytic support in the evaluation of the possible closing of the Indian Point Nuclear Generating Station including analysis of the impact of the Fukushima Nuclear accident (2011)
- Provided technical and economic strategy and regulatory assistance to off-shore wind developer (2009 – Present)
- In cooperation with Merrill Energy, provide expert advice on implementation of legislation to recover capital cost of transmission investment in Peru. (2010)
- Direct and provide consulting advice to the Federal Electricity & Water Authority in the United Arab Emirates on corporate reorganization. (2007-2011)
- Provide expert testimony to major US independent power producer in arbitration with steam host. (2007 – 2009)
- Direct and provide expert services and consulting advice to Electricite du Liban on revenue recovery through development of AMI systems. (2006 – 2008)
- Direct and provide consulting services to Electricite du Liban on restructuring of distribution services. (2006 – 2008)
- Provide expert testimony in multiple contract disputes between bankrupt Independent Power Producer and power marketer. (2004 – 2006)
- Provide expert analytic assistance to Private Equity Fund on purchase of generation assets within the United States (2006- 2007).
- Member, Board of Directors, NeuCo Corporation. (2005 - 2012)

- Direct and provide consulting services to Abu Dhabi Water and Electricity Authority on distribution system performance. (2003–2005)
- Direct and provide expert testimony on the development of the MidWest Independent System Operator. (2002–Present)
- Direct and provide expert testimony on long-term contract market in California. (2002–Present)
- Direct and provide expert testimony in purchase, contracting and regulatory approval of Midwestern transmission system. (2002–2003)
- Direct and provide expert testimony in 9-billion dollar California Electric refund case (2001–2012)
- Direct and provide expert testimony and consulting to major U.S. market and generator in the redesign of the California electricity market. (2002–2010)
- Member of the Blue Ribbon Task Force on design of electricity auctions of the California Power Exchange with Alfred Kahn, Peter Cramton and Robert Porter. (2000–2001)
- Member, Board of Directors of Dynamic Knowledge Corporation, Glasgow, Scotland. (2001–Present)
- Consultant to more than 20 power development companies for evaluation of locational value of new generation and transmission. (1999–Present)
- Consultant to and member of Technology Advisory Board, Excelergy Corporation, development of utility billing and system auction software. (1999–2002)
- Consultant to a Midwest utility for development of transmission congestion pricing structure. (1999–2001)
- Consultant to transmission asset development team of major U.S. corporation. (1999–2000)
- Consultant to and member of advisory board of Altra Energy Systems, electronic trading software and platform development company for electronic trading of electricity. (1998–2001)
- Consultant to major U.S. paper manufacturer for federal regulatory change required to interconnect a new co-generation facility. (1998–2000)
- Consultant to major Midwest utility in the development of an independent transmission company and the required tariffs. (1998–2002)
- Consultant with Enron Capital and Trade Resources on U.S. electricity restructuring with specific assignments in California, New York, Massachusetts and New England. Includes testimony in California “Blue Book” en banc hearings and participation in California Competitive Power Market Working Group. (1994–2001)

- Consultant to the Office of the Attorney General, Commonwealth of Massachusetts for Electric Utility Industry Restructuring. (1995–1998)
- Consultant with Sithe Energy on electricity pricing and electric industry restructuring. (1995–1998)
- Consultant with Independent Power Producers of New York (IPPNY) on restructuring of electric sector in New York. (1995–1998)
- Consultant to the Department of the Attorney General, State of Rhode Island and Providence Plantation for electric utility industry restructuring. (1996–1997)
- Consultant to the New England Competitive Power Coalition providing support for development of a blueprint for restructuring the New England Power Pool. (1995–1997)
- Consultant to ABB/Systems Control on transmission pricing and power systems operations. (1994–1997)
- Consultant to a major western utility for the development of transmission pricing strategies. (1994–1996)
- Development of real-time pricing strategies and rates for Oglethorpe Power Company, Atlanta, GA. (1995–1996)
- Consultant on the background to electric industry restructuring to Central Vermont Public Service. (1995)
- Development of real-time pricing rate response experiments for NYSERDA, EPRI and ESSERCo in ConEd and NYSEG service territories: Response to real-time pricing. (1989–1994)
- Development of marginal, cost-based, transmission system pricing system for the National Grid Company (NGC) of the United Kingdom. (1991–1993)
- Development of real-time rate structure and evaluation of customer impacts for Central Maine Power Company. (1990–1991)
- Development of purchase and transmission strategy for major U.S. independent power producer. (1990)
- Conservation and load management analysis and testimony for Boston Gas Company. (1987–1988)
- Development of Electric Power Systems Consulting Group, Meta Systems Inc. (1985–1988)

- Variable energy cost/spot pricing studies under contract to Integrated Communications Systems of Atlanta. Utilities included Mid-South and Pacific Gas and Electric, Southern California Edison, Central and South West. (1984-1987)
- Metcalf & Eddy Engineering, analysis of economic benefits of cogeneration/district heating for Columbia Point housing, Boston Redevelopment Authority. (1984–1985)
- Value of reliability study for Public Service of New Mexico. (1984)
- With East-West Center, Honolulu, Hawaii, study of electric futures of northeast Asia, Japan, Korea and Taiwan. (1983–1984)
- Independent variable energy cost spot pricing studies for Georgia Power, Florida Power and Light, Florida Power Corp., Tampa Electric and Gulf Power. (1983–1984)
- Petroleum pricing study, Philippines for IBRD. (1983–1984)
- Lignite pricing for electric power generation, Thailand. For IBRD (1982–1983)
- Independent, review of electric power futures for combustion engineering. (1982)
- Consultant, Microwave Associates, Inc., on electric load management and control. (1980-1981)
- Urban energy impact statement for HUD. (1979–1980)
- Consultant, Urban Systems Research and Engineering. Projects included: Analysis of Boston wastewater management plan for C.E.Q.; definition of 'modal' urban areas for environmental impact analysis using the EPA developed SPACE/SEAS model; Interceptor project to evaluate the impact of EPA interceptor grants program or land use patterns in suburban and rural areas of EPA Regions 2, 4, 6; Rural growth project analyzing regional development in non-metropolitan multi-county areas in the United States. (1971–1977)
- Urban systems research and engineering analysis of Boston wastewater management plan for C.E.Q. (1977)
- Bangladesh energy study for Asian Development Bank and UNDP. (1975–1976)
- Urban systems research and engineering, definition of model urban areas for environmental impact analysis using the EPA developed SPACE/SEAS model. (1975–1976)
- Land use and environmental quality modeling and case study analysis of land use impacts on water and air quality. Case studies focused on the Mill River basin in the New Haven SMSA. (1974–1975)
- Member, Technical Advisory Panel for Educational Evaluation in Massachusetts, Office of the Commissioner in Education, Commonwealth of Massachusetts. (1973–1974)

- Lake Chad polder development study of agricultural development with low-lift irrigation pumping in the area immediately surrounding Lake Chad. (1974)
- Urban systems research and engineering, interceptor sewer project to evaluate the impact of EPA interceptor grants program on land use patterns in suburban and rural areas of EPA Regions, 2,4,6. (1974)
- Decision-making and flood plain management in the Connecticut River valley, study for New England River Basin Commission. (1973)

FIELDS OF EXPERTISE

- Energy economics / energy pricing
- Power systems operations and planning
- Asset valuation: Generation, Transmission and Generation
- Water and wastewater management
- Corporate strategic planning and analysis
- Corporate reorganization and management

PROFESSIONAL AFFILIATIONS

- Institute of Electrical and Electronic Engineers
- American Waterworks Association
- International Association of Energy Economists
- Energy Bar Association

REGULATORY COMMENT AND TESTIMONY

- “Economics and Integration of Photovoltaic System into the Utility Grid,” to Senate Committee Staff on Science and Technology, September 1981.
- Comment on “Regulation of Electricity Sales—For Resale and Transmission Service.” With F. C. Schweppe, R. E. Bohn, M. C. Caramanis. (FERC docket 85-17-000 Phase II) October 1, 1985.
- Expert Witness, St. Peter, MN vs. SMMPA, Utility Planning and Forecasting, 1986.

- "Real Time Pricing: Central Maine Power Corporation" before the State of Maine Regulatory Commission, March 1991, sponsored by Central Maine Power.
- "Discussion of FERC Docket No. RM 93-19-000, Transmission Pricing Issues." With M. C. Caramanis. November 1993.
- Testimony before the California Public Utility Commission en banc hearings on industry restructuring, September, 1994 sponsored by Enron Capital and Trade Resources.
- Testimony before the Massachusetts Public Utility Commission hearings on industry restructuring, April, 1995 sponsored by Enron Capital and Trade Resources.
- Testimony before the New York Public Service Commission Collaborative on Industry Restructuring, May 1995 sponsored by the Independent Power Producers of New York.
- Testimony before the New York Public Service Commission on Buyback Rates sponsored by Independent Power Producers of New York and Sithe Energies, Docket Nos. 93-E-1075 and 93-E-0912, August 1995.
- Testimony before the New York Public Service Commission on Two Party Transactions Proposal of NYPSC, Docket No. 96-E-0798, 1996.
- Testimony submitted to the Commonwealth of Massachusetts, Department of Public Utilities on The Market for Power in New England: The Competitive Implications of Restructuring sponsored by the Office of the Attorney General. With CRA, April 1996.
- Testimony before the state of Rhode Island and Providence Plantations Public Utility Commission on Electric Industry Restructuring and Market Power sponsored by the Attorney General, State of Rhode Island, Docket No. 2320, April 1996.
- Testimony before the Commonwealth of Massachusetts, Department of Public Utilities in Panel Format on The Independent System Operator / NEPOOL / FERC Order No. 888 and on the Power Exchange.
- Testimony before FERC Technical Panel on Transmission Pricing October, 1996 and May 1997.
- Testimony before the State of Maryland Public Service Commission on Restructuring, August 1997.
- Testimony before the Pennsylvania Public Utilities Commission on Capacity Benefit Margin, 1998.

- Testimony before the New Jersey Board of Public Utilities in the matter of the Energy Master Plan Phase II Proceedings to Investigate the Future Structure of the Electric Power Industry on restructuring issues, Docket Nos. EX94120585Y, EO97070457, EO97070460, EO97070463, EO97070466, March 1998.

- Testimony before the Public Service Commission of Wisconsin, Investigation on the Commission's Own Motion Into the Development of an Independent System Operator for the Electric Transmission System of Wisconsin (05-BE-100), April 1998.

- Testimony before the United States Congress, House of Representatives, Committee on Commerce, Electronic Commerce: The Energy Industry in the Electronic Age, July 15, 1998.

- Testimony before Maine Public Utilities Commission, Maine Public Service Company, Petition for Authorization for Sale of Generating Assets, Docket No. 98-584, August 1998.

- Testimony before the Federal Energy Regulatory Commission, American Electric Power Company and Central and Southwest Corporation, on behalf of Enron Power Marketing, Inc., in re AEP/CSW proposed merger, Docket Nos. EC98-40-000, ER98-2770, ER98-2786,. April 28, 1999.

- Testimony before the Alberta Energy and Utilities Board in regards to ESBI Alberta Ltd.'s General Rate Application, Phase II, 1999/2000, on transmission tariff design and cost allocation mechanisms.

- Testimony before the Federal Energy Regulatory Commission, Sierra Pacific Company, on Behalf of Sierra Pacific Power Company, regarding the justness and reasonableness of an Interconnection and Operating Agreement for a new transmission project, Docket Nos. ER99-28-001, ER99-28-003, EL99-38-002, ER99-945-002, April 27, 2000.

- Testimony before the Federal Energy Regulatory Commission on behalf of Powerex Corporation and the Transaction Finality Group on Ripple Effects of proposed Pacific Northwest refunds, Hydro operations in the Pacific Northwest and proposed price mitigation in the Pacific Northwest, Docket Nos. EL01-10-000; EL01-10-001, August 28, 2001.

- Testimony before the Federal Energy Regulatory Commission on behalf of Powerex Corporation and the Transaction Finality Group on the need for price mitigation in the Pacific Northwest, Docket Nos. EL01-10-000; EL01-10-001, October 29, 2001.

- Testimony before the Federal Energy Regulatory Commission on behalf of the Electric Power Supply Association (EPSA) regarding Market Based Rates, docket EL01-118-000, January 2002.

- Testimony before the Federal Energy Regulatory Commission on behalf of Dynegy Power Marketing, et al on Market Power Mitigation rules within MD02 proposal of California ISO, Docket Nos. EL00-95-001; ER02-1656-000, June 2002.

- Testimony before the Federal Energy Regulatory Commission on behalf of Powerex Corporation and CSG on the calculation of Mitigated Market Clearing Prices in the California Refund Case, Issue 1 on November 6, 2001, January 31, 2002 and February 25, 2002, Docket Nos. EL00-95-045 and EL00-98-042; Issues 2 and 3 on July 3, 2002 and July 26, 2002, and August 9, 2002, and of a declaration Review of Initial Report on Company-Specific Separate Proceedings and Generic Reevaluations; Published Natural Gas Price Data; and Enron Trading Strategies, August 2002, filed on behalf of Powerex on October 15, 2002.

- Testimony before the Federal Energy Regulatory Commission on behalf of Dynegy Corporation on Long-Term Contracts in California; Docket Nos. EL02-6—000; EL02-62-000, October 17, 2002, November 14, 2002.

- Testimony before Arbiter in Portland Oregon on behalf of Powerex against Alcan on the termination of a supply contract. November, 2002

- Testimony before the Federal Energy Regulatory Commission supporting the benefits of the International Transmission Company, Docket No. EC01-137-002 Exhibit IT-200December, 2002.

- Testimony before the Federal Energy Regulatory Commission on behalf of Cinergy Corporation on delay of Day 2 of implementation and support of the general rules of the Midwest Independent System Operator, Docket No. EL03-35, January 10, 2003

- Testimony before the Federal Energy Regulatory Commission on behalf or Portland General Electric regarding Circular Schedules or Death Star Transactions, Docket Nos. EL02-114-000 and EL-02-115-001, February 24, 2003.

- Testimony before Arbitration Panel in Vancouver, BC on behalf of ProGas against Ocean States Power on the determination of natural gas contract prices. March, 2003.

- Testimony before the Federal Energy Regulatory Commission on behalf of Powerex Corporation regarding Gaming Practices in western markets, Docket Nos. EL00-95-000 et al., March 3, 2003.

- Testimony before the Federal Energy Regulatory Commission on behalf of Powerex Corporation in the “100 Days of Discovery,” Docket Nos. EL00-95-000 et al., March 20, 2003.

- Testimony before the Federal Energy Regulatory Commission on behalf of NRG on FERC pricing proposal for the NEISO in southwestern Connecticut; Docket No. ER03-563-000, May 27, 2003.

- Testimony before the Federal Energy Regulatory Commission on behalf of Cinergy Corporation on PJM-AEP RTO Inquiry, Rebutting Testimony of AEP Witnesses Baker, Draper and Tomasky. Docket No. ER03-262 et al. October 9, 2003.

- Testimony before the Federal Energy Regulatory Commission on behalf of Cinergy Corporation on PJM-AEP RTO Inquiry, Direct Testimony on Net Benefits of AEP Integration, Docket No. ER03-262 et al. January 7, 2004.

- Testimony before the Federal Energy Regulatory Commission on behalf of Cinergy Corporation on Midwest ISO Transmission and Energy Market Tariff issues pertaining to FTR allocation, grandfathered agreements, resource adequacy, mitigation, and system support, Docket ER04-691, Direct Testimony on May 7, 2004 and Rebuttal Testimony on May 21, 2004.

- Testimony before the Federal Energy Regulatory Commission on behalf of Cinergy Corporation on Midwest ISO Transmission and Energy Market Tariff issues pertaining to reliability, efficiency and discrimination concerns of carve out approaches for grandfathered agreements, Docket Nos. ER04-691 and EL04-104, Direct Testimony on June 25, 2004 and Rebuttal Testimony on July 16, 2004.

- Testimony before Arbitration Panel in Calgary, Alberta on behalf of ProGas against Ocean States Power on the determination of natural gas contract prices, August 2004.

- Testimony before the Federal Energy Regulatory Authority on behalf of Portland General Electric Company in defense of accusation market manipulation (EL02-114-000 and EL02-115-001), 2004.

- Testimony before Arbitration Panel in Bankruptcy Liberty Generating Station, Philadelphia on behalf of National Energy Group, 2005.

- Testimony before the Federal Energy Regulatory Authority on behalf Constellation Energy Commodities group, Inc. in support of cost and revenue studies, 2005.

- Testimony before Arbitration Panel in Bankruptcy of Mirant Corporation in support of corporate valuation. 2005.

- Testimony before Arbitration Panel in contract dispute between COSMAR and Calpine Corporation, in support of Calpine, 2008.

- Testimony before the Kansas Public Utility Commission in support of the expansion of transmission facilities in Kansas in support of Westar Corporation. 2009 and 2010.

- Testimony before the Federal Energy Regulatory Commission (ER 10-1138) on behalf of Northwestern Energies, June 2012

- Testimony before the Federal Energy Regulatory Commission on behalf of First Energy Service Company (ER13-535-000) in opposition to the proposed Minimum Offer Price Rule changes December 2012 and March 2013.

- Testimony before the Federal Energy Regulatory Commission on behalf of NEPOOL (ER13-895-000) in opposition to changes in market timing rules related to acquisition of natural gas. (with Seabron Adamson)

- Expert Report in support of the Coushatta Tribe of Louisiana v. Richard Meyer and Meyer & Associates before the State Court of Louisiana (20011-2014) (2016 and ongoing)

- Expert Reports and Testimony before the FERC Enforcement Bureau for multiple clients accused of market manipulation of US organized power markets (Ongoing)

- Testimony before the Ohio Public Utility Commission on behalf of First Energy Solutions in opposition to proposed tariff changes by Duke Energy Ohio. April 2013.

- Testimony before the Federal Energy Regulatory Commission on behalf of NEPOOL (ER14-1050-000 / 001) in opposition to proposed Incentive Payment proposal changes in FCM rules. (2014-2015)

- Testimony before the Maryland Public Service Commission on behalf of the State of Maryland and the Maryland Energy Administration in the matter of the merger of Exelon Corporation and PEPCO Holding, Inc, (Case No. 9361) 2014 -2015.

Filed before the United State Supreme Court

- Led the *Amici* in *Amicus Curiae* of Electrical Engineers, Energy Economists and Physics in Support of the Court in No. 00-568. State of New York, et al v. Federal Energy Regulatory Comm'n, et al and Enron Power Marketing, Inc v Federal Energy Regulatory Comm'n et al May, 2001

- Signed as *Amicus* in *Amicus Curiae* of Leading Economists and Educators who have Designed, Studied, Taught and Written about Electricity Markets in support of the Court in No. 11-1486, Electric power Supply Association, et al, v Federal Energy Regulatory Commission, et al. June 2012

PUBLICATIONS

Books, Book Chapters, and Monographs

The Definition of Multifunctional Planning Regions: A Case Study of East Pakistan. A report to the East Pakistan Land, Power and Water Study, Harvard University Center for Population Studies, May 1971.

"Preferences for Municipal Services of Citizens and Political Leaders: Somerville, MA, 1971." With M.A. Vinovskis. *Population Policymaking in the American States: Issues and Processes*, D.C. Heath and Co., May 1974.

The Syracuse Metropolitan Regions: A Background for Paretian Environmental Analysis. Environmental Systems Program, Harvard University (ESP Monograph), September 1974.

Population Policymaking in the American States: Issues and Processes. With Bergman, Elihu, D. Carter, R. Cook, and D. Weir. D.C. Heath and Co., May 1974.

"Framework for the Analysis of State and Local Population Policy." *Population Policymaking in the American States: Issues and Processes*, D.C. Heath and Co., May 1974.

Interceptor Sewers and Urban Sewers. With Binkley, Collins, Kanter. D.C. Heath and Co., October 1975.

Land Use and the Pipe: Planning for Sewerage. With M. Shapiro and P.P. Rogers. D.C. Heath and Co., November 1976.

"Infrastructure Planning." In ASPO, *Rural and Small Town Planning*, The Old West Regional Commission, 1978.

"Utility Services." In So, Stollman, Beal, and Arnold, eds., *The Practice of Local Government Planning*, International City Management Assoc., December 1979.

"Energy Demand Estimation." With R. deLucia, In Jacoby and deLucia, eds., *Energy Planning in Developing Countries: The Case of Bangladesh*, John Hopkins Press, 1982.

"Traditional/Renewable Energy Sources." With R. DeLucia. In Jacoby and deLucia, eds., *Energy Planning in Developing Countries: The Case of Bangladesh*, Johns Hopkins Press, 1982.

"Utility Spot Pricing to Coordinate Deregulated Utilities, Customers and Generators." With R. Bohn and F. Schweppe. In Plummer, Ferrar and Hughes, eds., *Electric Power Strategic Issues: Deregulation and Diversification*, Johns Hopkins Press, 1982.

Electric Generation Expansion Analysis System, Vols. 1 & 2. With M. Caramanis and F.C. Schweppe. With Stone & Webster Engineering, Vols. 3, 4 & 5, EPRI, Palo Alto, CA, Report No. EL-2561, 1983.

"Electrical Utility Load Management Systems." A.H. El-Abiad ed., *Power Systems Analysis and Planning*, McGraw-Hill, 1983.

"Cogeneration: Ownership and Operating Economics." A.H. El-Abiad ed., *Power Systems Analysis and Planning*, McGraw-Hill, 1983.

"The New (Alternative) Electric Generation Technologies: An Evaluation of Their Potential." A.H. El-Abiad ed., *Power Systems Analysis and Planning*, McGraw-Hill, 1983.

"Using Spot Pricing to Coordinate Deregulated Utilities, Customers and Generators." With R. Bohn, and F. Schweppe. In Plummer, Ferrar and Hughes, eds., *Electric Power Strategic Issues*, Public Utilities Reports Inc., 1983.

"An Approach to Deregulating the Generation of Electricity." With R. Bohn, B. Golub, and F.C. Schweppe. In Plummer, Ferrar and Hughes, eds., *Electric Power Strategic Issues: Deregulation and Diversification*, Public Utility Reports, 1984.

"Utility Finance and Planning in Japan, Korea and Taiwan." With M. Castillo-Bonet. In Kim, Smith and Rose, eds*., Electric Futures of Asia and the Pacific*, East West Press Center, Honolulu, 1986.

Electricity in Northeast Asia: The Experiences of Japan, Korea, and Taiwan. Greenwood Press, Westport, CT, 1987.

Spot Pricing of Electricity. With F.C. Schweppe, M.C. Caramanis, and R. Bohn. Kluwer Academic Press, 1988.

Energy Aftermath: How We Can Learn from the Blunders of the Past to Develop our Energy Future. With T.H. Lee and B.C. Ball. Harvard Business School Press, Boston, 1989.

"Transitional Strategies for Emissions Reduction in the Electric Power Sector." With B. L. Monroe, III. In J. Tester and N. Ferraro, eds., *Energy and Environment in the 21st Century*, MIT Press, 1991.

"Engineering Economic Analysis: Applications to Electric Utility Investment Planning." In M. Baughman ed., *Engineering Economic Analysis: Overview and Current Applications*, IEEE Tutorial, 1992.

"Unbundling the U.S. Electric Power Industry: A Blueprint for Change." With Fernando, Kleindorfer, Pickel, and Robinson. Tabors Caramanis & Associates, March, 1995.

"Overcoming Barriers to Deployment of Plug-in Electric Vehicles." National Research Council of the National Academies, 2015.

Articles and Reviews

"A Preliminary View of Economic Change and Urbanization: Bangladesh 2000." In Thomas and Lavan, eds., *West Bengal and Bangladesh: Perspectives from 1972*, Asian Studies Center, Michigan State University, South Asia Series No. 21, 1973.

"Urbanization and War: Inertia in Urban Migration in Bangladesh." Presented to the XXVI Annual Meeting of the Association for Asian Studies, Boston, MA, April 1974.

"Land Values and Public Investment in Urban Fringe Areas: A Case Study of Clay, New York." With M. Shapiro. Papers and Proceedings of the Northeast Regional Science Association, 1975.

Review of Greenberg et al., "Solid Waste Planning in Metropolitan Regions" in *Annual of Regional Science*, June 1978.

"A Louisiana Case Study: Towards a Single System of Substrate Regions." With C. S. Binkley. *Growth and Change*, January 1980.

"Homeostatic Utility Control." With F. C. Schweppe, J. L. Kirtley, H. R. Outhred, F. H. Pickel, and A. J. Cox. *IEEE Transactions on Power Apparatus and Systems*, Vol. PAS-99, No. 3, May/June 1980.

"Rate and Penetration Analysis, the Impact of Distributed Photovoltaic Power Systems within the Utility Grid System." With A. Cox, S. Finger, and A. Burns. *IEEE Transactions, IEEE 14th Photovoltaic Specialists Conference*, 1980.

"Economic Integration of New Energy Technologies into the Grid Using Homeostatic Control." Invited paper, IEA Conference on New Energy Conversion Technologies, April 1981.

"Economic Operation of Distributed Power Systems within an Electric Utility." With S. Finger and A. Cox. *IEEE Transactions on Power Apparatus and Systems*, Vol. PAS-100, No. 9, September 1981.

"Solar Energy/Utility Interface: The Technical Issues." With D.C. White. *Energy, The International Journal*, January 1982.

"Homeostatic Control for Electric Power Usage." With F. C. Schweppe and J. L. Kirtley. *IEEE Spectrum*, Vol. 19, No. 7, pp. 44–48, July 1982.

"The Introduction of Non-Dispatchable Technologies as Decision Variables in Long-Term Generation Expansion Models." With M. C. Caramanis, K. S. Nochur, and F. C. Schweppe. *IEEE Transaction on Power Apparatus and Systems*, Vol. PAS-101, No. 8, August 1982.

"Wisconsin Study Shows Homeostatic Control has High Potential for Industrial Loads." With F. C. Schweppe. *Modern Power Systems*, Vol. 3, No. 1, pp. 43-46, January 1983.

"Homeostatic Control: The Utility Customer Marketplace for Electric Power." With F. C. Schweppe and J. L. Kirtley. In *Local Heat and Power Generation: A New Opportunity for British Industry*, Interscience Enterprise, U.K., 1983.

"Deregulating the Electric Utility Industry." With F. C. Schweppe and R. Bohn. *The Energy Journal*, January 1984.

"Electricity Spot Prices in Developing Countries." *National Development*, November 1984.

"Evaluation of Spot Price Based Electricity Rates." With F.C. Schweppe and M. C. Caramanis. *IEEE Transactions on Power Apparatus and Systems*, Vol. PAS-104, no. 7 July 1985.

"Natural Gas Fired Combined Cycle Generators: Dominant Solutions in Capacity Planning." With D. Flagg. *IEEE Transactions on Power Apparatus and Systems*, No. 85 SM 492-4, 1985.

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