LTRTP Workshop Policy Study: Analysis Results

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Agenda

- Takeaways
- Capacity expansion and model building recap
- Reliability analysis results
- Economic analysis results

Takeaways

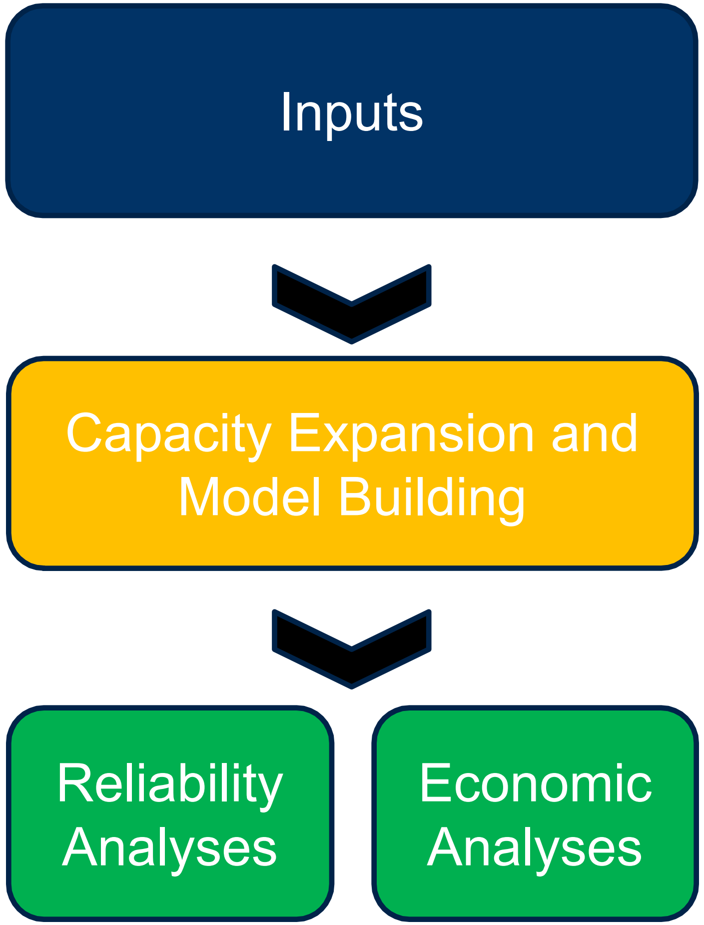
- Significant load growth (esp. in DOM, 4.5 of 6.5GW) and widespread retirements (20GW, esp. in ComEd , PENELEC, AEP) relative to RTEP 2029, with new capacity needed for resource adequacy located mainly in PJM West and southern DOM
- Increased PJM West-to-East/South transfers and DOM south-to-north transfers
  - Reliability analysis confirms 2024 RTEP W1 needs
  - Additional needs, esp. in DOM and APS at higher voltages (and AEP and ComEd)
  - PJM variant of proposal 262 from 2024W1 relieves overloaded facilities in DOM and APS but more reinforcements could be needed, e.g. through expansion, depending on supply/demand developments
- Economic analysis shows that congestion strongly overlaps with reliability needs

Takeaways: *LTRTP is critical to inform the NT RTEP – so that solutions are compatible with LT needs – and ensure that LT needs are efficiently and timely addressed*

Capacity Expansion and Model Building Recap

Capacity Expansion Modeling Primer

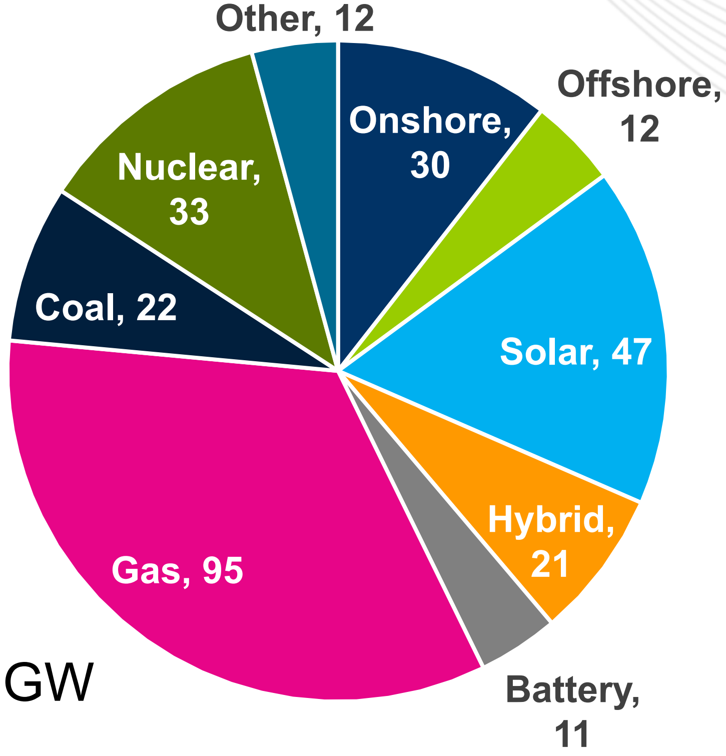
- Capacity Expansion Identifies system cost minimizing resource mix subject to load, resource adequacy, policy constraints, given future technology
- Approximate competitive market outcome (under efficient markets)
- Widely used in the industry



Assumptions (details in appendix)

- **Model-year:** 2032
- **Topology**: Approximate 2024 RTEP *with conductor ratings* (2023 RTEP + 2022 RTEP W3)
- **Load:** PJM 2024 load forecast report
- **Policies**, based on ISAC workbook (see appendix):
  - Retirements, RPS, and resource-specific targets
  - Offshore: NJ SAA 1.0 (7.6GW), MD with ORECs (2GW), VA IRP Commitments (2.6GW)
- **Expansion candidates**:
  - Build limits based on queue by fuel/zone/state (see appendix)
  - Wind needed for winter reliability; allow additional wind by doubling the size of projects in the queue up to 500 MW and including withdrawn projects with ready ISAs
  - New Gas Units (beyond ISA/Fast Lane): for this study we consider projects in OH, WV, IN, KY
- **Resource adequacy**: ELCC-based summer and winter constraints based on pre-CIFP methodology with discounting for gas to account for correlated outages (see appendix)

Capacity Expansion Results: 2032 Resource Mix



Tot. 282 GW

ELCC	Battery	Solar	Hybrid	Onshore	Offshore	Gas
Summer	0.93	0.16	0.63	0.11	0.31	0.95
Winter	0.57	0.02	0.28	0.23	0.48	0.85

- 60%-40% solar-wind split
  - Solar increasingly cheaper but wind needed for winter reliability
  - Batteries also needed for reliability (some ELCC saturation)
  - Need ~4MW of renewable/battery per MW of load
- New generation policies do not significantly affect the expansion given the queue (see appendix)
- Combined cycle remains economic
- Portfolio near 1-in-10 (CIFP solved load 174.9GW vs 172.1 for 2032 peak)

Nameplate Changes Relative to RTEP 2029 (Approximate)

Generation increasingly in the center and South

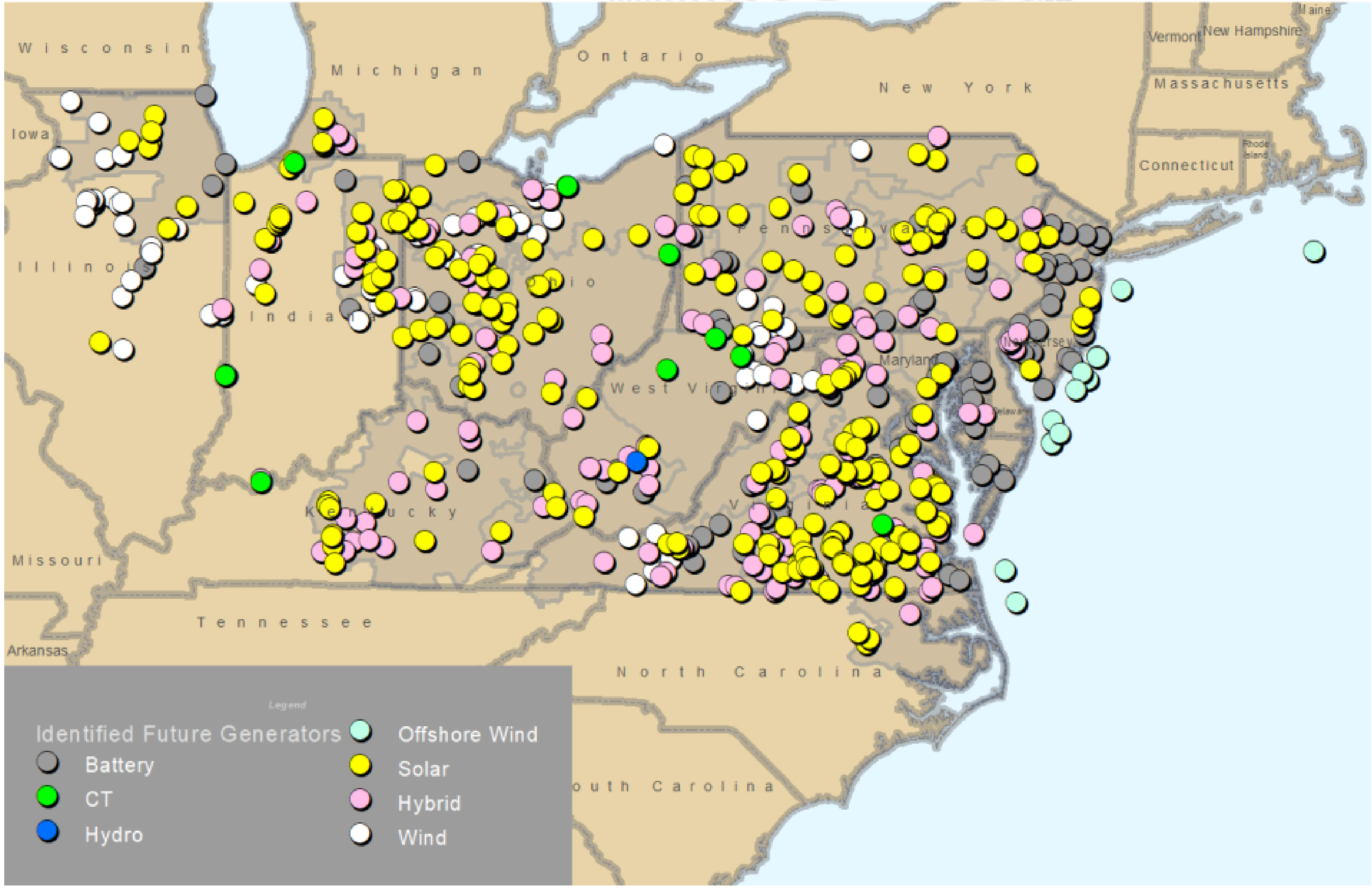
- Generation growth in AEP (renewable/batt.) APS (thermals)
- Generation (solar) *and* load growth in DOM
- Generation growth (wind) and retirements in ComEd
- Retirements in WMAAC (PENELEC) with little replacement generation

92GW of resources needed for Resource Adequacy, beyond those already in RTEP 2029

	Solar	Onshore	Offshore	Battery	Hybrid	Renew-able	Battery (Total)	Announced Retirement	Policy Retirement	New Thermal	Thermals' change	Load Change
AECO	31			391	135	126	459	132				47
AEP	9828	10448		2488	9261	29537	7119			1971		417
APS	1072	3826		869	1662	6560	1700	180		3299		35
ATSI	565	1596		443	444	2605	665			517		35
BGE	125			1250		125	1250	2114				145
COMED	736	4797		260		5533	260					44
DAY	966	1100		352	554	2620	629			10		12
DEOK				213			213					41
DOM	9807		2640	2148	4490	16937	4393	29		569		4512
DPL			1767	244	93	1860	291	577				53
DUQ				285	60	60	315					49
EKPC	737			76	1639	2376	896					34
JCPL	102		2400	484	60	2562	514	217				238
METED	95			75	109	204	130					215
OVEC												0
PECO					3	3	2	760				153
PENLEC	622	377		45	13	1012	52					37
PEPCO	82			795	635	717	1113	216				131
PPL	597			20	40	637	40					90
PSEG			1342	773		1342	773					339
RECO												4
Total	**25365**	**22144**	**8109**	**11211**	**19198**	**74816**	**20810**	**4225**	**20292**	**6366**	**-13926**	**6631**

Notes: "Thermals' change" excludes RTEP 2029 announced retirements; GHG rule impacts are excluded.

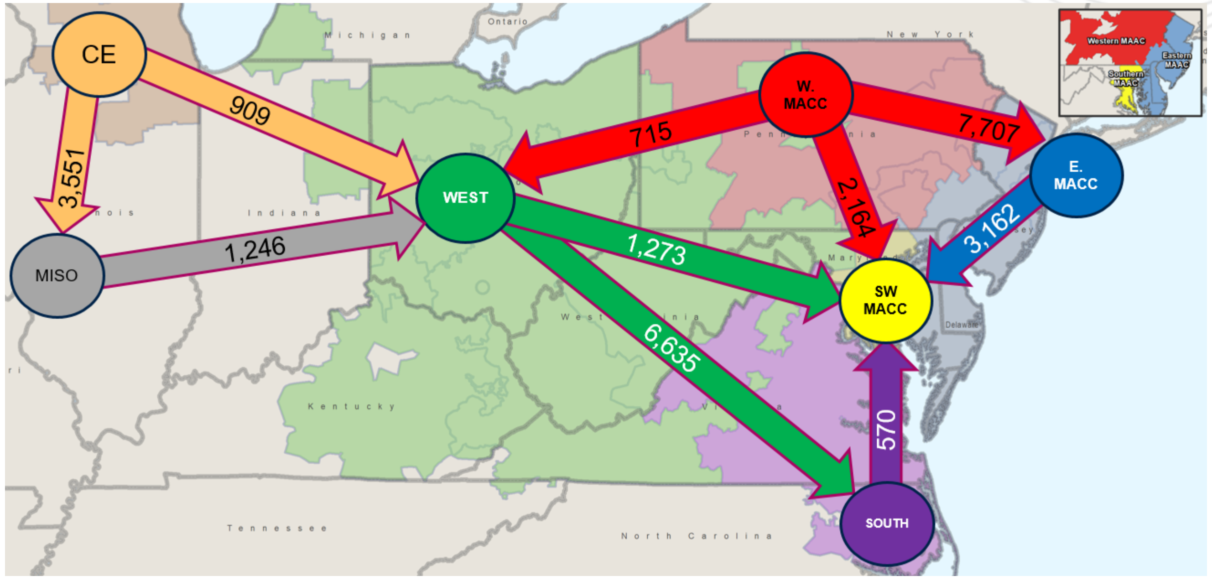
Geographic Distribution Of New Resources

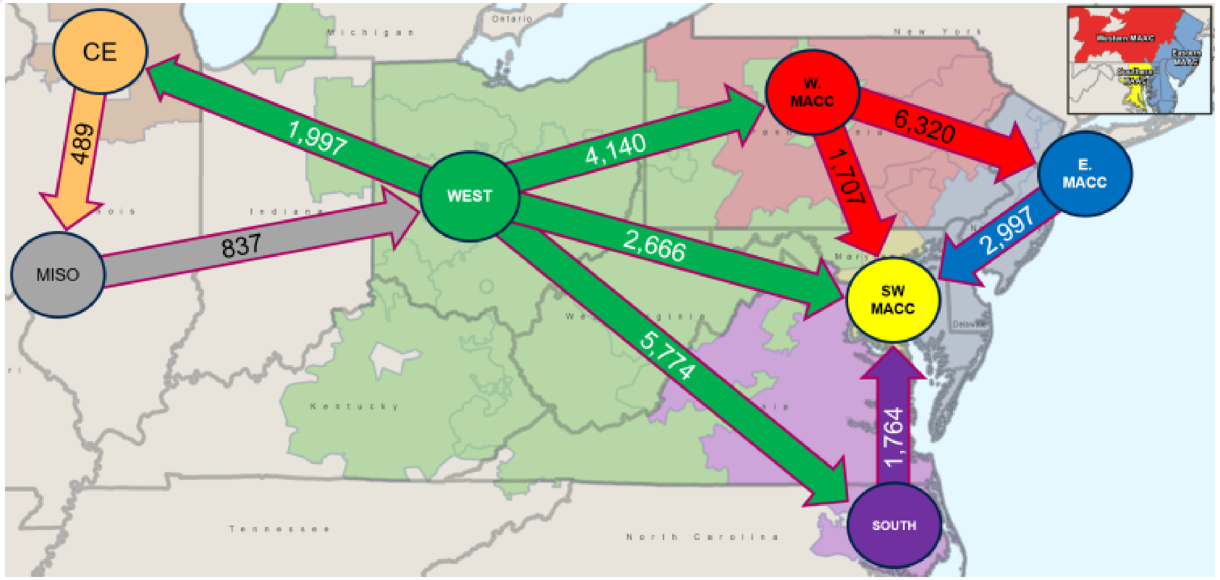


- PJM West accounts for 2/3 of new nameplate capacity relative to 2029
- PJM East and South account for 90% of added load relative to 2029
- See appendix for map with projects' nameplates

Summer

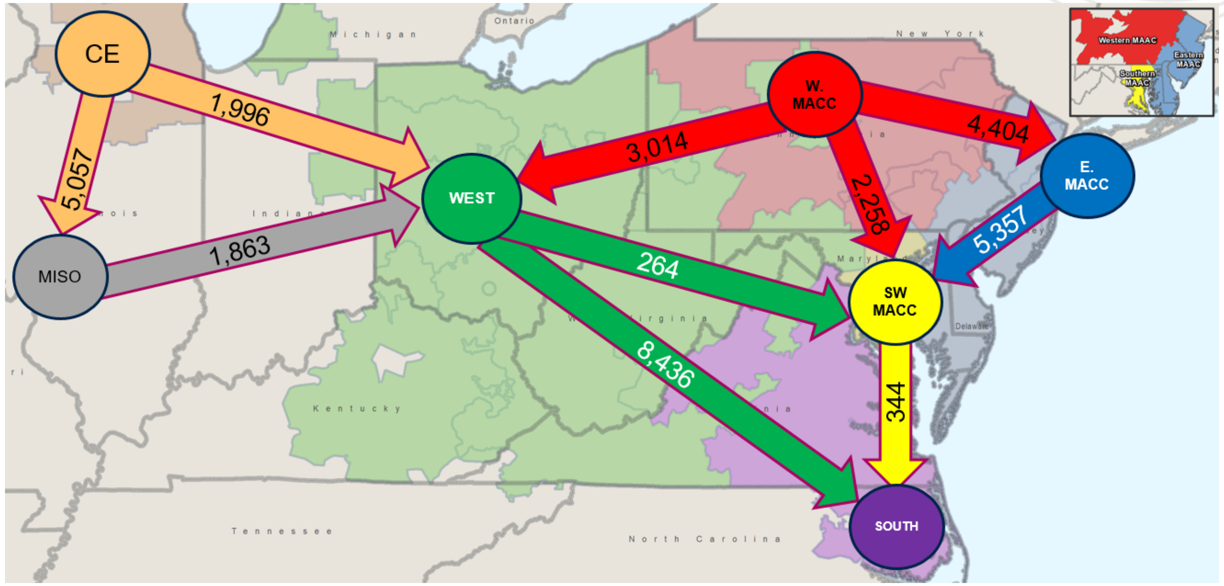
- RTEP 2029
- WPS 2032

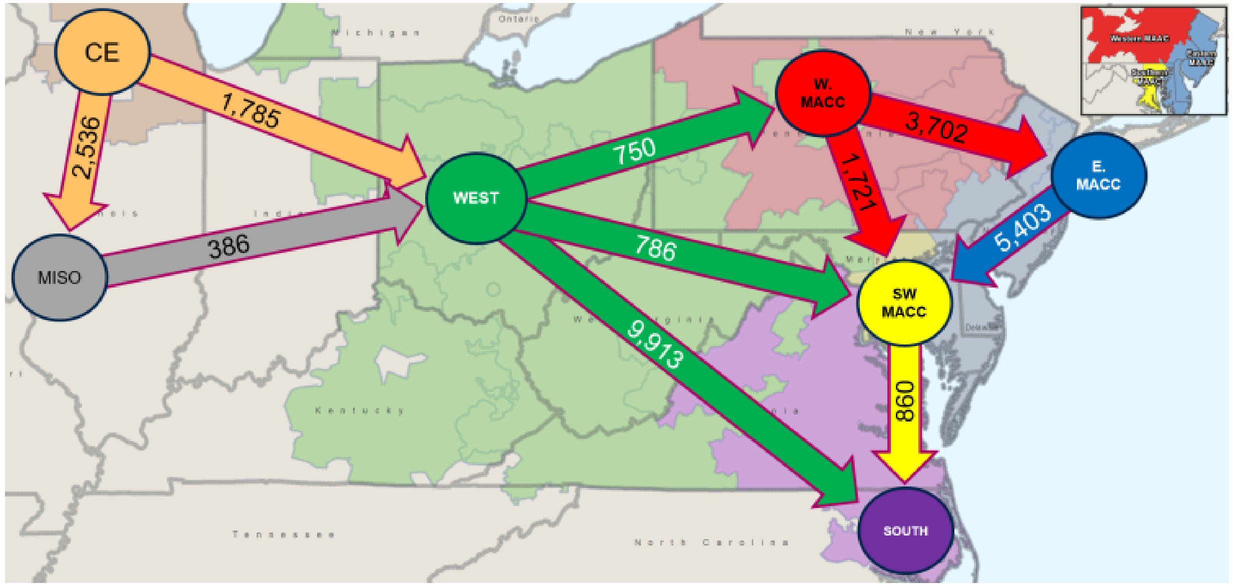




- Increasing flows from the center to the edges of the footprint
  - Growing flows towards MAAC
  - Flow reversal in ComEd which becomes importer in summ
  - Reduce exports from WMAAC
  - Reduced imports and higher exports in Dom

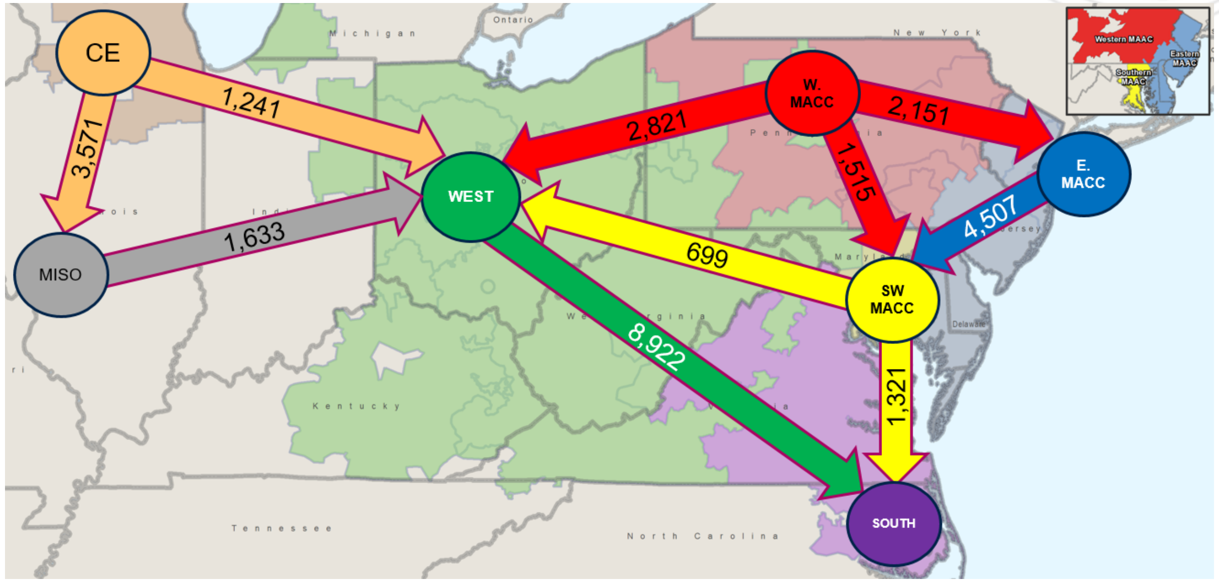
- RTEP 2029
- WPS 2032



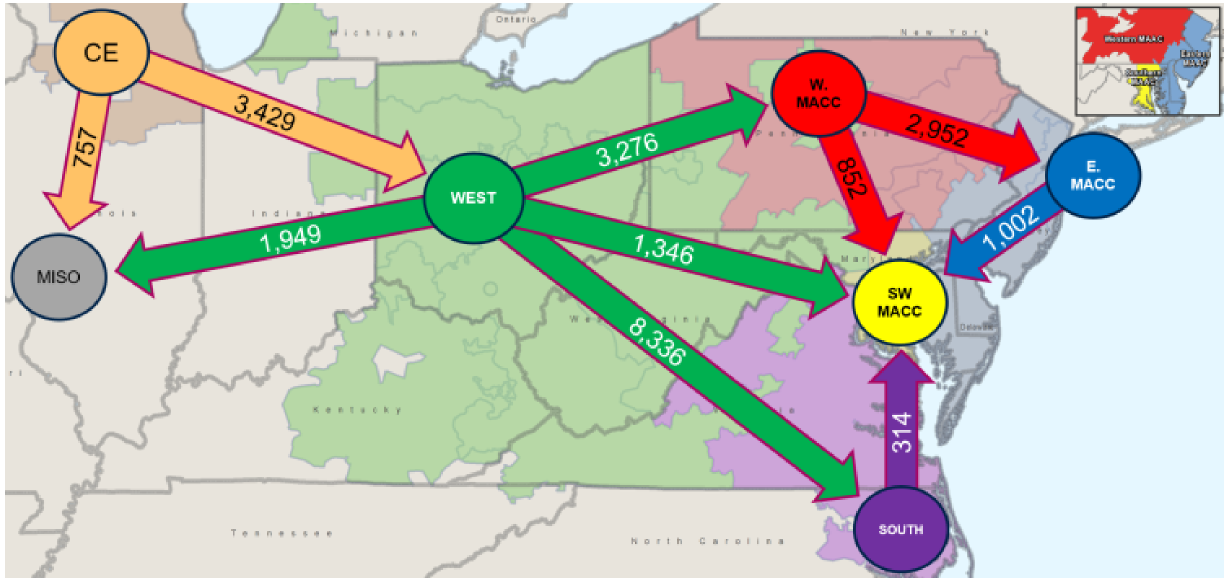


- Increased west-to-south flows
  - Dominion becomes even larger importer in winter (solar heavy)
  - ComEd exports despite retirements (wind heavy)
  - Reduced exports from WMAAC

- RTEP 2029



- WPS 2032



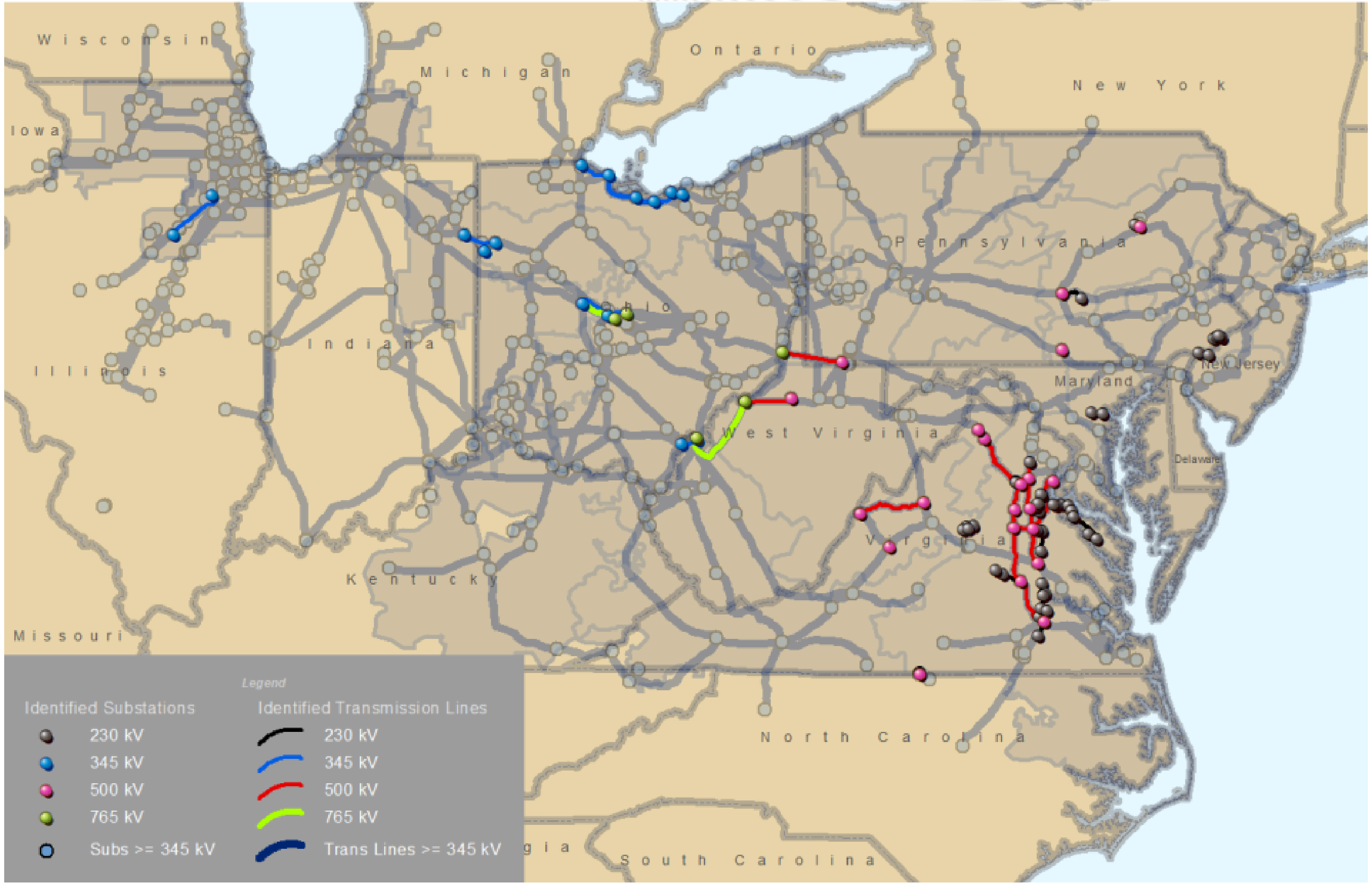
- Large flows from West (including from ComEd and WMAAC) to East and South

Reliability Analysis Results

Workshop Policy Study Reliability Analyses

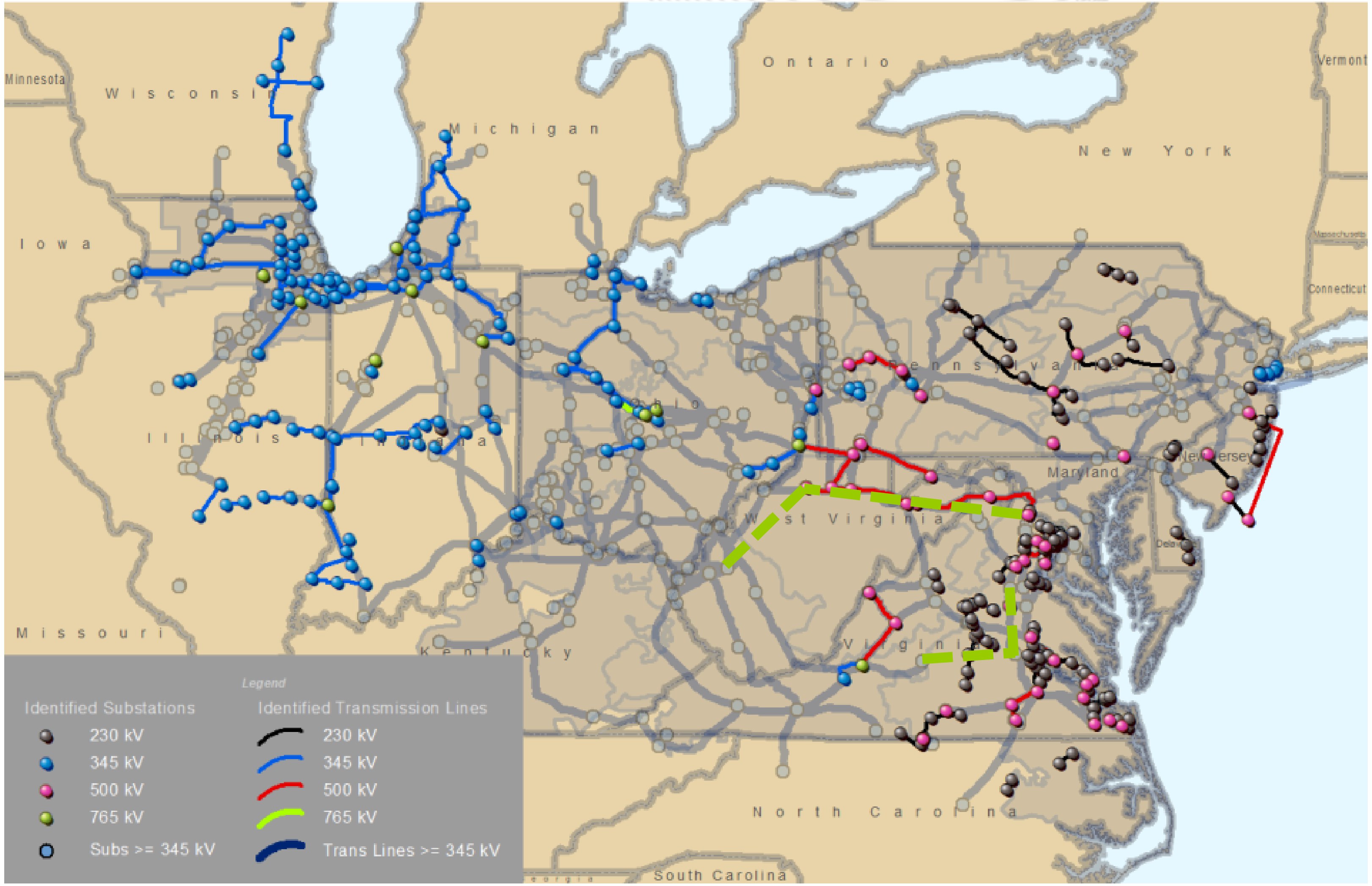
- Use conductor ratings (terminal equipment ratings set equal to conductor ratings)
- PJM conducted a mini-RTEP on the WPS scenario
  - Summer, Winter, and Light Load
  - *N*-1, *N*-2 (except light load), Generation Deliverability (GD), Load Deliverability (LD; ComEd, Dominion, BGE)
    - LD analysis identifies NO additional reliability issues (not reported in the remainder of the slide deck)
  - Thermal analysis only (no voltage)

Overlaps, Workshop Policy Study and RTEP



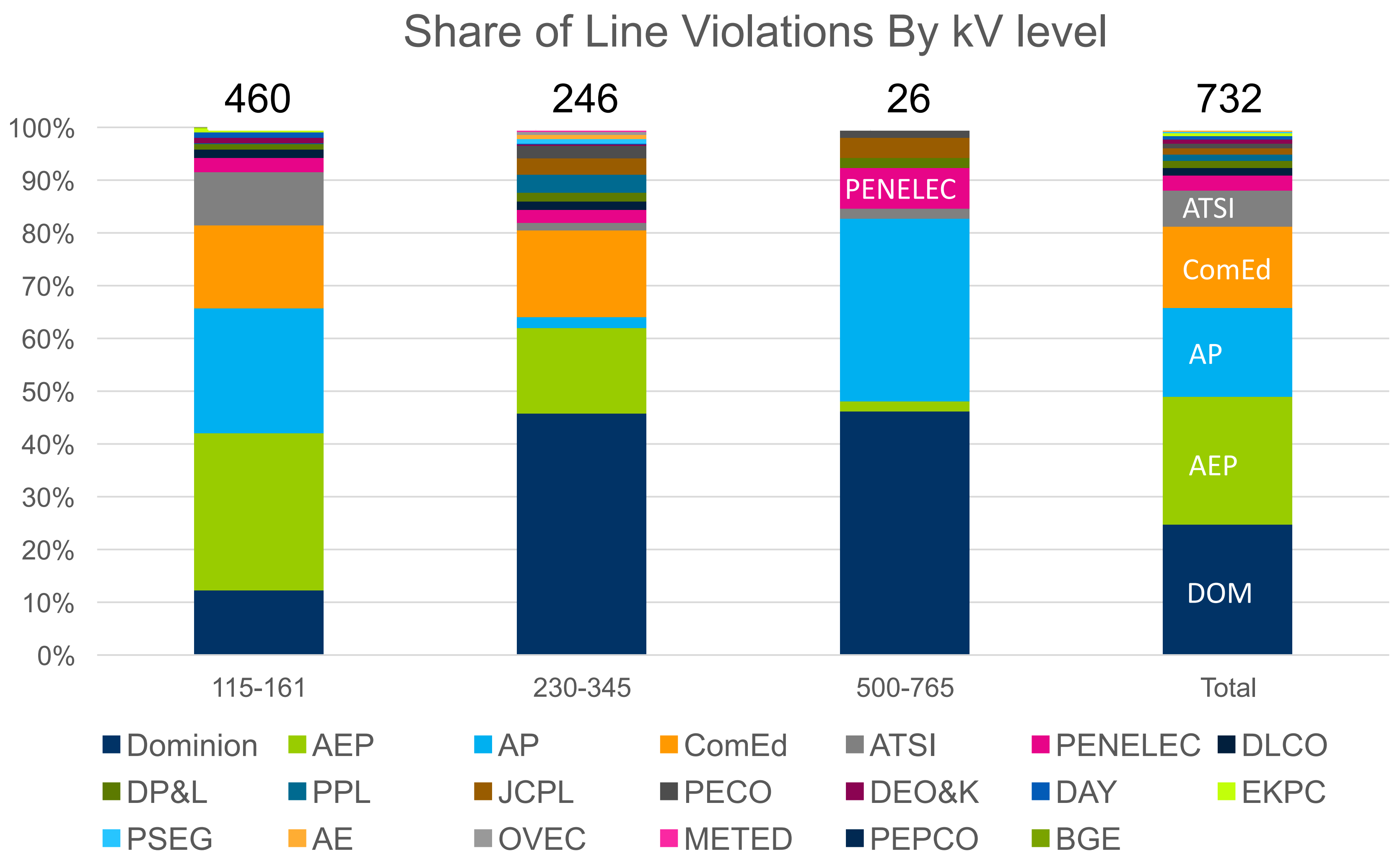
- The WPS confirms the needs identified in 2024 RTEP and posted in Window 1 (2024W1)

Workshop Policy Study +230*kV* Line Overloads (Excluding overlaps with RTEP)



- WPS identifies additional needs, especially in APS and DOM's higher voltage systems
- 2024W1 reinforcements under consideration reasonably align with APS and DOM's additional needs identified in the WPS (simplified reinforcements' paths marked as on the map)
- Slide below provides some considerations on 2024W1 reinforcements under the WPS scenario
- Maps by season in appendix

Thermal Violations on Transmission Lines (Unique Facilities)



- *Six zones Account for 90% of line overloads*
  - 500-765*kV*: DOM, AP
  - 230-345*kV*: DOM, AEP, ComEd
  - 115-161*kV*: AEP, AP, ComEd, DOM
- Breakdown by zone, *kV* level, season, and test type in appendix

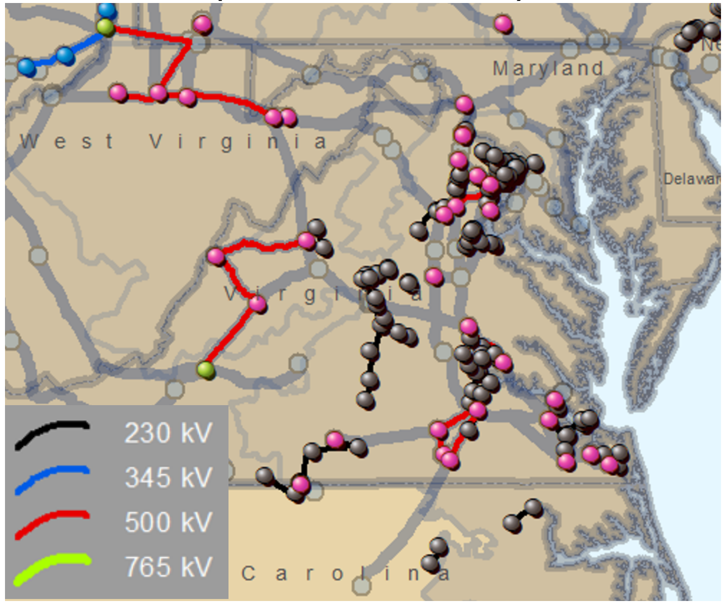
(excluding already identified RTEP issues)

- Large load increases in the north and solar additions in the south
  - *Heavy transfers from the west*
  - *Heavy south-north transfers*
- Majority of problems in Summer Generation Deliverability (GD) because of added solar
- *N*-2 issues in Summer on 230*kV* lines due to tripping of already strained 500*kV* lines in DOM and APS

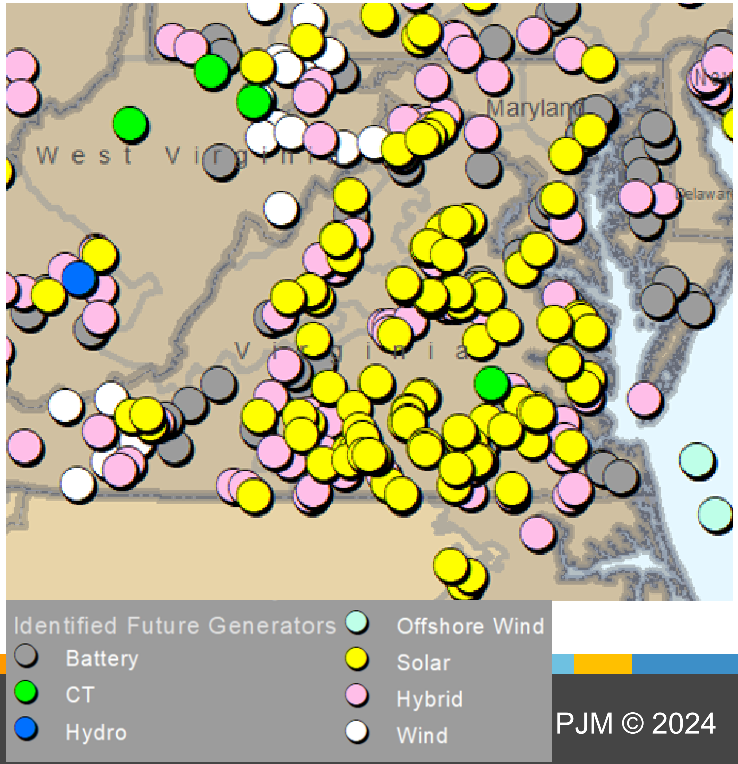
Note: tie lines in the table are counted with 0.5 weight to avoid double counting at regional level

kV level	All cases and tests	Summer GD	Summer N1	Summer N2	Summer Sub-tot	Winter GD	Winter N1	Winter N2	Winter Sub-tot	Light Load GD	Light Load N1	Light Load Sub-tot
115-161	57	**50**	13	9	50	6		1	6	33	18	35
230-345	113	**63**	55	**53**	101	5		2	7	34	12	34
500-765	12	**11**	3	4	11	1		1	1	4	1	4
Total	181	123	71	66	161	11		4	13	70	31	72

Summer (Lines +230kV)



New Generation

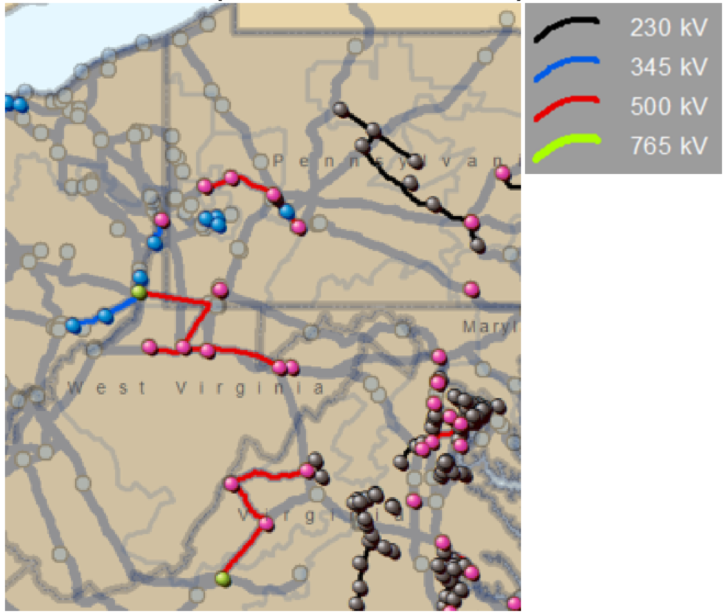


APS
(excluding already identified RTEP issues)

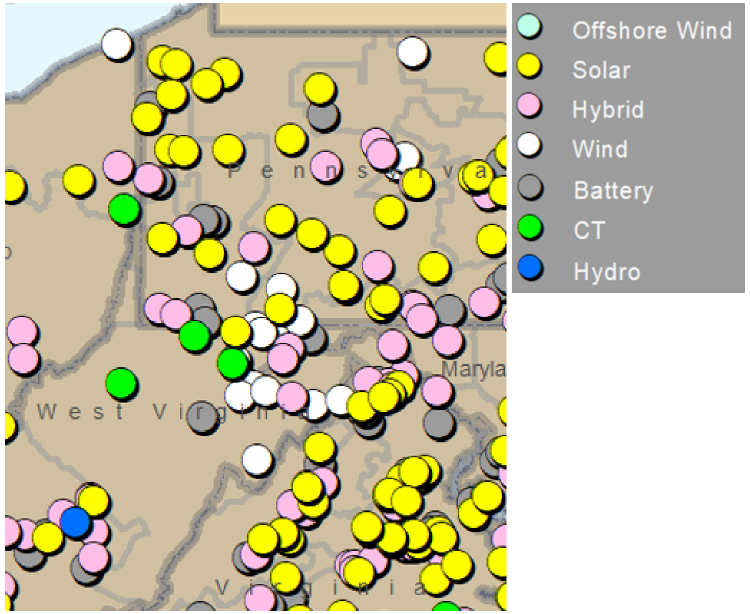
- More new generation, especially thermal, than APS peak load
- New generation creates Generation Deliverability (GD) issues that spillover to higher voltage system
- *GD and N*-2 issues in Summer due to heavy West-East transfers overloading 500*kV* and issues created by tripping of those lines, notably on tie-lines (six tie-lines out of 12 overloaded 500*kV* lines in APS; not as many 230*kV in APS*)*

kV level	All cases and tests	Summer				Winter				Light Load		
		GD	N1	N2	Sub-tot	GD	N1	N2	Sub-tot	GD	N1	Sub-tot
115-161	109	**49**	11	**62**	80	23	5	21	38	**52**	11	52
230-345	5	**5**		1	5							
500-765	9	**6**	4	**5**	8	3		3	4	2	1	2
Total	123	59	15	68	93	26	5	24	42	54	12	54

Summer (Lines +230kV)



New Generation



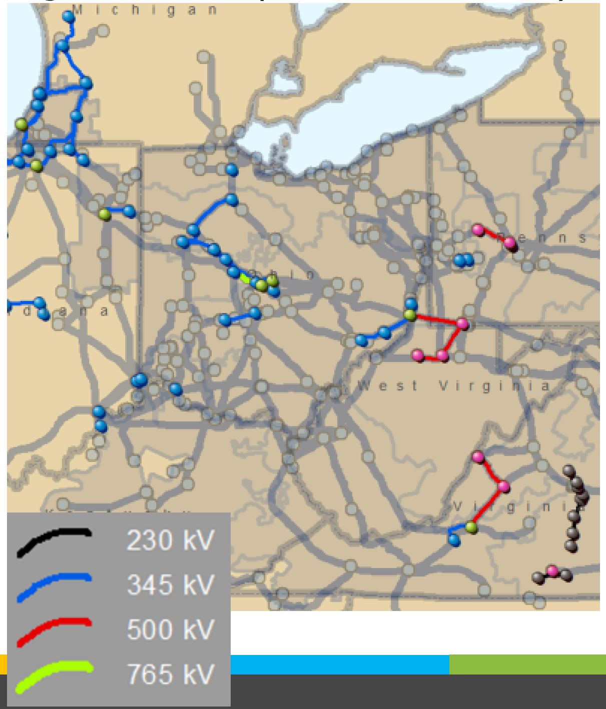
* *Note tie lines in the table are counted with 0.5 weight to avoid double counting at regional level*

AEP
(excluding already identified RTEP issues)

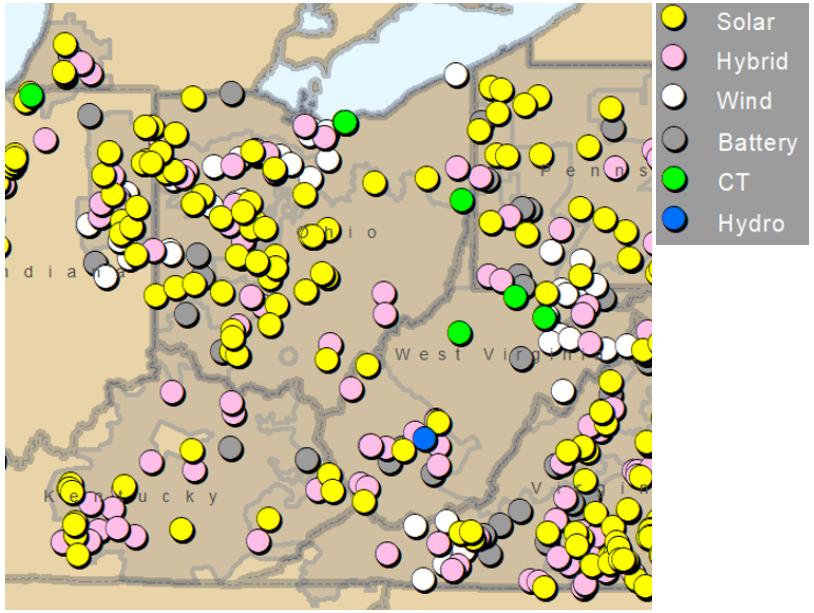
- Large amount of new generation and batteries above retirements
- New generation creates significant Generation Deliverability issues at lower voltage level in Summer and Light Load that spillover to medium voltage level in the Light Load case
  - Robust higher voltage system
  - New generation struggles getting up to higher voltage system

kV level	All cases and tests	Summer				Winter				Light Load		
		GD	N1	N2	Sub-tot	GD	N1	N2	Sub-tot	GD	N1	Sub-tot
115-161	137	**64**	21	29	70	14	6	25	27	**96**	46	96
230-345	40	10	1	13	20	7	5	5	7	**33**	14	33
500-765	1	1			1					1	1	1
Total	178	74	22	41	90	21	11	29	34	129	61	129

Light Load (Lines +230kV)



New Generation



Note: tie lines in the table are counted with 0.5 weight to avoid double counting at regional level

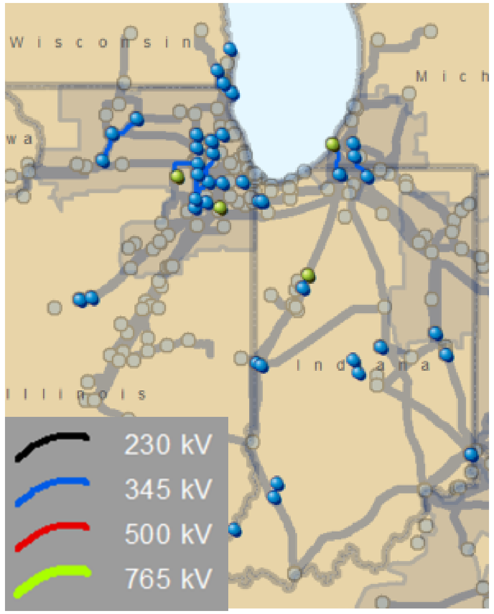
ComEd
(excluding already identified RTEP issues)

- Large retirements replaced by wind
  - ComEd becomes importer in summer due to lower wind performance
- Summer imports create heavy loading on 345*kV* system and *N*-2 issues due to loss of multiple 345*kV* lines
- High wind generation in Light Load and Winter cases create Generation Deliverability issues

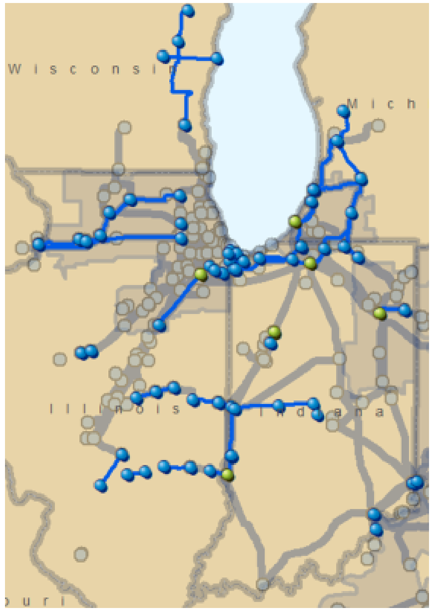
Note: tie lines in the table are counted with 0.5 weight to avoid double counting at regional level

kV level	All cases and tests	Summer				Winter				Light Load		
		GD	N1	N2	Sub-tot	GD	N1	N2	Sub-tot	GD	N1	Sub-tot
115-161	72	9	17	**27**	**41**	**24**	5	12	**28**	**27**	13	**29**
230-345	41	3	4	**25**	26	7	1	4	7	**17**	4	17
500-765												
Total	113	12	21	52	66	31	6	16	35	44	17	46

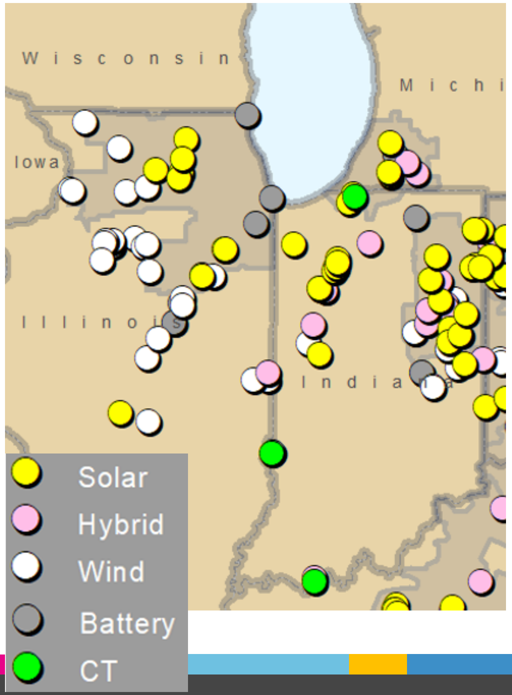
Summer (Lines +230kV)



Light Load



New Generation



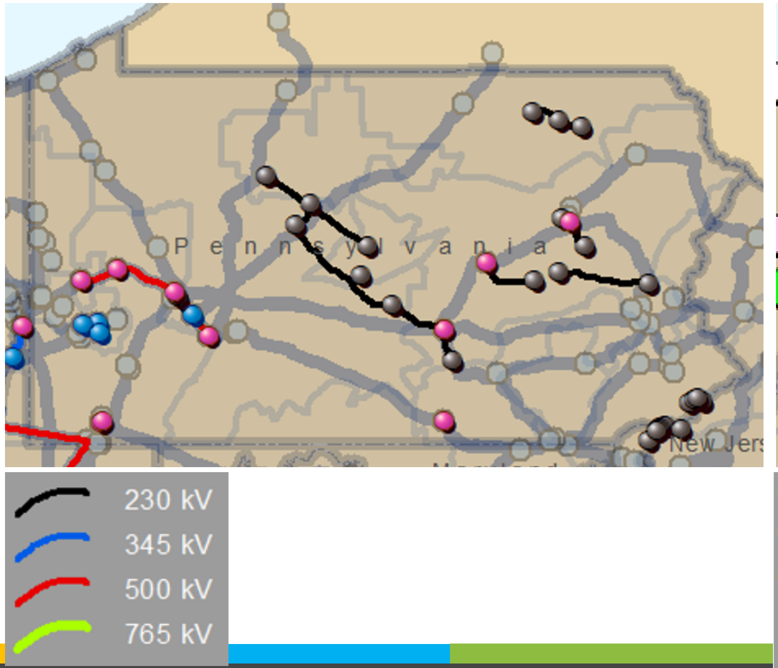
PENELEC
(excluding already identified RTEP issues)

- Large retirements replaced primarily by heavy transfers from the West (and towards MAAC) contributing to 500*kV* overloads
- *N*-2 issues on low and medium *kV* system created by loss of heavily loaded 500*kV* lines
- PENELEC system is also tightly coupled to and influenced by changes to the APS system

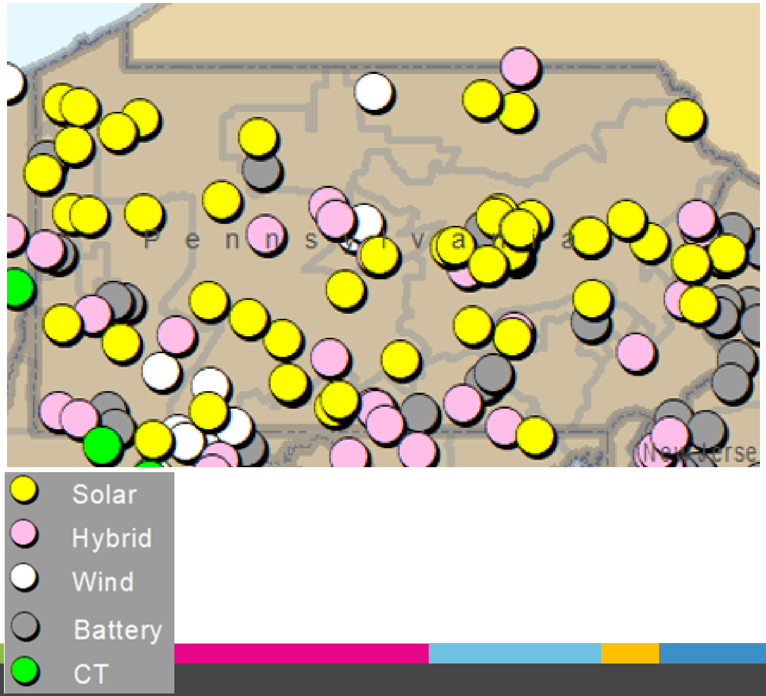
Note: tie lines in the table are counted with 0.5 weight to avoid double counting at regional level

kV level	All cases and tests	Summer				Winter				Light Load		
		GD	N1	N2	Sub-tot	GD	N1	N2	Sub-tot	GD	N1	Sub-tot
115-161	13	12		3	13	3			3	2	1	2
230-345	6	**4**		**3**	6					2		2
500-765	2	**2**	1	1	2	1			1	1		1
Total	21	18	1	6	21	3		0	3	5	1	5

Summer (Lines +230kV)



New Generation



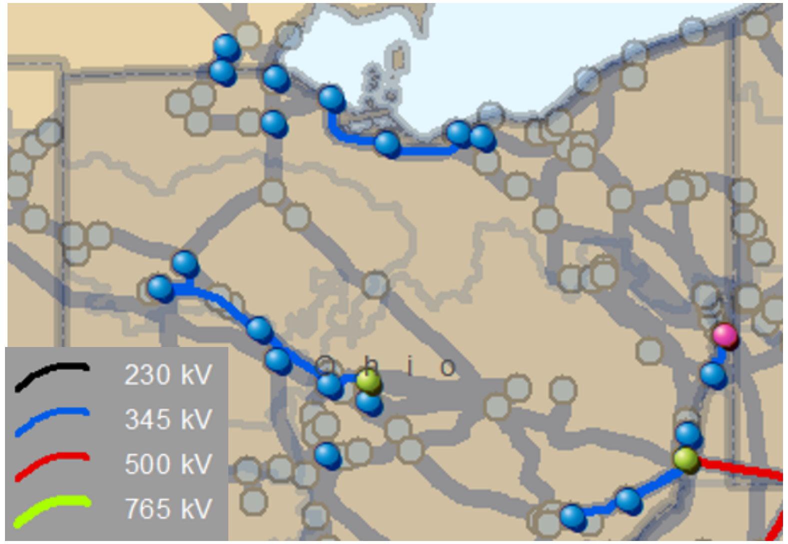
ATSI
(excluding already identified RTEP issues)

- Significant overlap with RTEP overloads on 345*kV* lines that interconnect West and East ATSI but loadings higher in WPS
- Likely loss of this heavily loaded 345*kV* corridor is causing Generation Deliverability and *N*-2 issues in Summer as flows to the East now have to pass through 138*kV* system

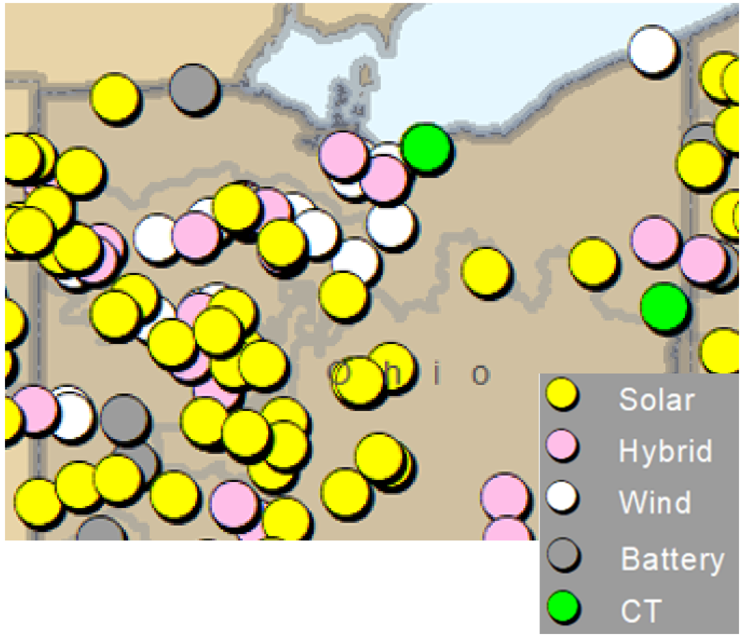
Note: tie lines in the table are counted with 0.5 weight to avoid double counting at regional level

kV level	All cases and tests	Summer				Winter				Light Load		
		GD	N1	N2	Sub-tot	GD	N1	N2	Sub-tot	GD	N1	Sub-tot
115-161	47	**33**	10	**26**	41	1		4	5	10	3	10
230-345	4	**3**		1	3					1		1
500-765	1			1	1							
Total	51	35	10	28	44	1		4	5	11	3	11

Summer (Lines +230kV)

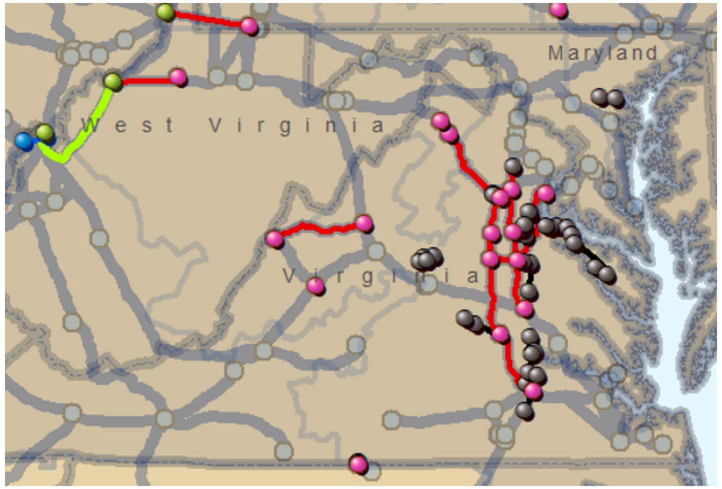


New Generation

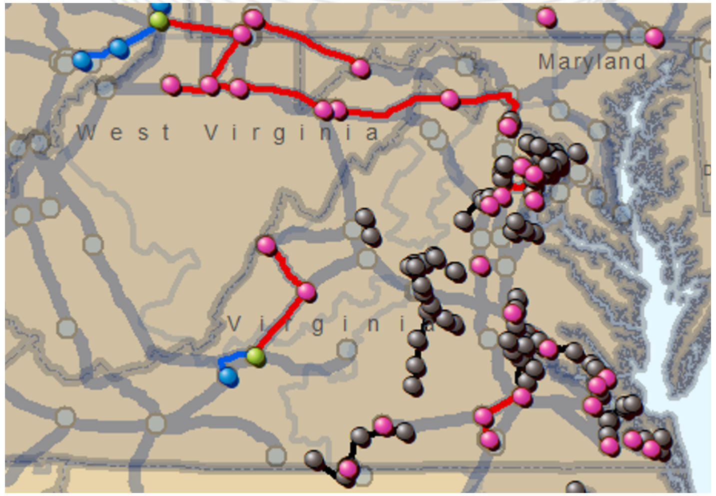


Considerations On 2024 RTEP W1 Solutions

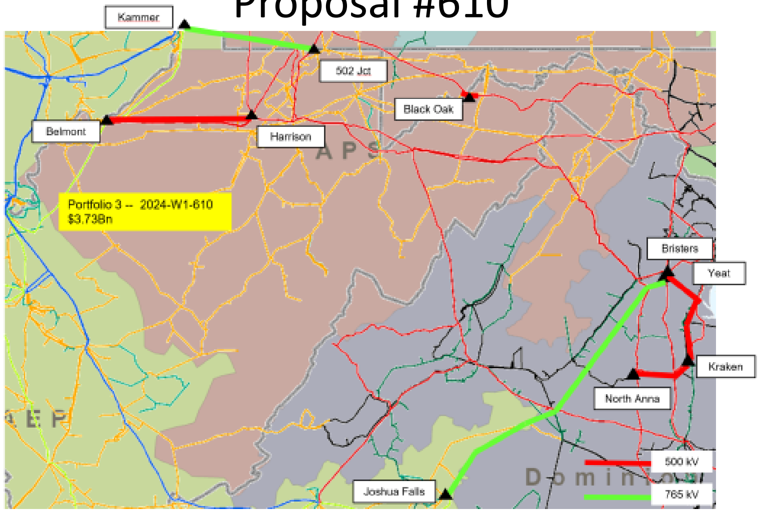
RTEP/WPS Overlaps



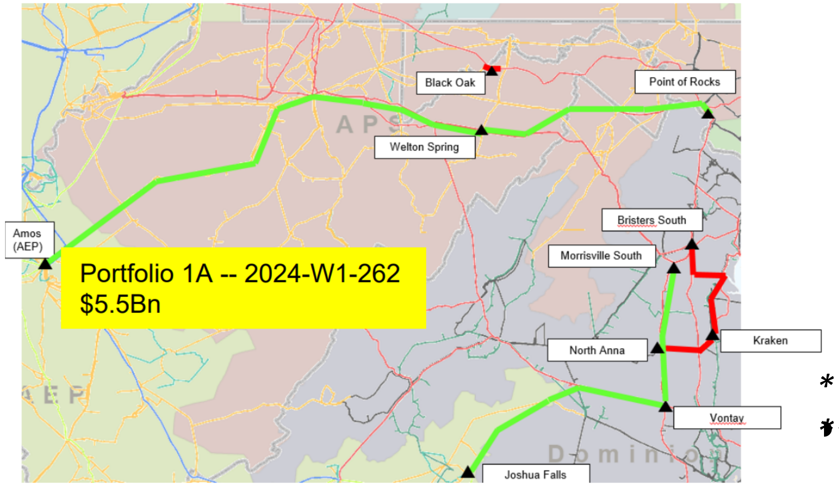
Additional Issues Identified in WPS



Proposal #610



Proposal #262



- Proposal #262 overlaps better than Proposal #610 with the additional needs identified in WPS
- PJM performed a sensitivity* adding the 765kV components of Proposal #262 to the WPS
- Those components reduce the loading on**:
  - All 15 APS 500kV overloaded facilities (21% reduction in summer)
  - 23 of 26 DOM 500kV overloaded facilities (20% reduction in summer)
  - 128 of 139 DOM 230kV overloaded facilities (15% reduction in summer)
- Proposal #262 is compatible with WPS – more reinforcements could be needed, e.g. through expansion, based on load/gen developments

** Base-case assessment (no contingency analysis)*

*** Facility count includes RTEP overlaps*

Economic Analysis Results

Economic analysis

- Assumptions consistent with PJM/MISO Interregional Transfer Capability Study (except for terminal equipment ratings and monitored flowgates)
  - WPS capacity expansion
  - MISO F2A external world and fuel prices
  - Other inputs as in 2024 RTEP Market Efficiency (load, interchange, interfaces, hurdle rates)
- Topology as in WPS reliability models (terminal equipment has conductor ratings)
- Monitored flowgates (PROMOD event file):
  - PJM Market Efficiency monitored flowgates and Generation Deliverability critical flowgates 230*kV* and above

Annual Congestion (mil. $)

	kV Level	Congestion (mil. $)	Number of facilities	Overlap with reliability Congestion	N. of Facilities
Lines	*230*	2,282	33	2,022	30
	345	792	31	724	19
	500	471	10	464	5
	Sub-total	3,545	74	3,210	54
Trans-formers	*230*	6	3	6	2
	345	89	6	0	1
	Sub-total	95	9	6	4
Total		**3,640**	84	**3,216**	58

- Congestion strongly overlaps with reliability needs:
  - ~70% in terms of number of 230*kV* or higher *kV* facilities and ~90% in dollar terms

Annual Congestion by Zone (lines only; mil. $)

kV level	Dominion	AEP	ComEd	PSEG	JCPL	DLCO	PECO	DP&L	OVEC	APS	Total
230	**2,064**			155	62						2,282
345		**414**	**314**	29		32			1		792
500	**392**				59		11	7		1	471
Sub-total	**2,456**	414	314	185	121	32	11	7	1	1	**3,545**
Overlaps with Reliability											
230	1,960				62						2,022
345		378	312			32			1		724
500	392				59		6	6			464
Sub-total	2,352	378	312		121	32	6	6	1		3,210

Curtailments by Zone (GWh)

	Dominion	AEP	ComEd	EKPC	JCPL	APS	DAY	DPL	ATSI	PENELEC	PPL	DEOK	Total
Solar	8999	4308	563	552	0	154	193	88	52	14	13	12	**14948**
Onshore	8	1705	3636		507	215				3	0		**6075**
Total	**9007**	**6014**	**4199**	552	507	368	193	88	52	17	14	12	**21023**

Emissions (mil. lbs.)

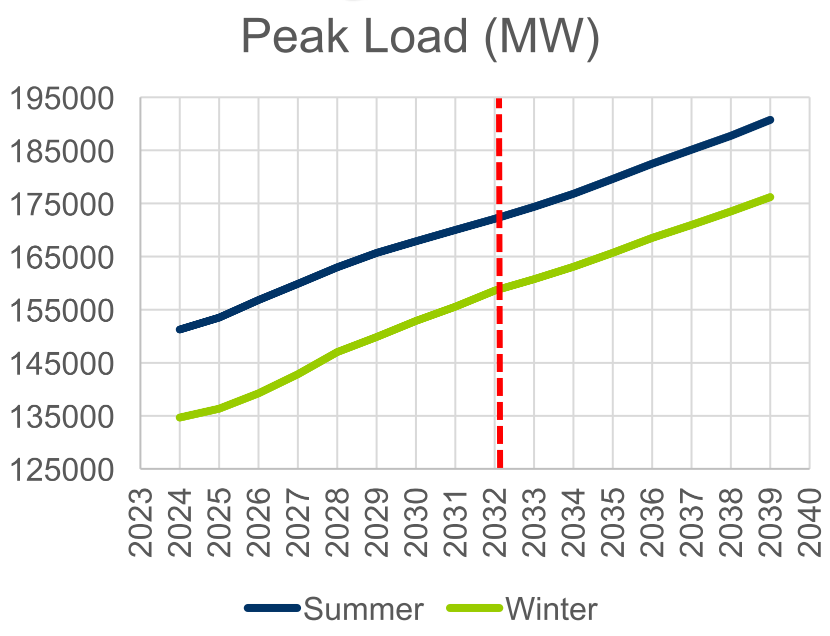
RTEP 2028			***WPS***			***Difference** (WPS-RTEP)*		
CO_2 (bil. lbs)	*SO_2 (mil. lbs)*	*NOX (mil. lbs)*	*CO_2 (bil. lbs)*	*SO_2 (mil. lbs)*	*NOX (mil. lbs)*	*CO_2 (bil. lbs)*	*SO_2 (mil. lbs)*	*NOX (mil. lbs)*
683	9116	315	413	2213	110	**-270**	**-6903**	**-205**

Notes: RTEP 2028 and WPS used different gas prices; WPS monitored facilities are 230*kV* and above

Appendix

Load and Initial Conditions

- **Model year**: 2032
- **Topology**: 2023 RTEP + 2022 RTEP Window 3 solutions
- **Load**:
  - PJM's 2024 Load Forecast Report
  - Energy Exemplar's Eastern Interconnection (EEEI) hourly profiles
- **Initial Resources**:
  - 2024 RTEP, 2029 model-year resources (existing plus ISAs minus announced deactivations; approximate)
  - Add Fast Lane (treated as ISAs/GIAs)
  - Remove policy retirements through 2029 (see policy slide below)



Expansion Candidates (MW)

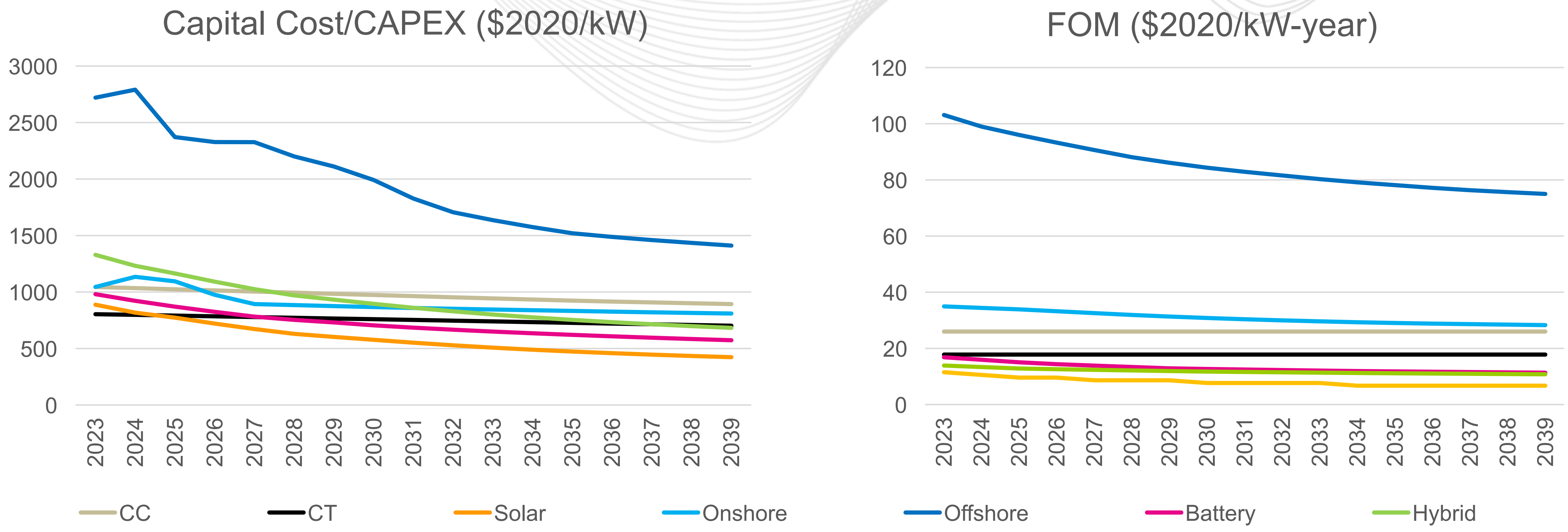
	Solar		Battery		Hybrid		New Gas	
	Fast Lane Only	*All*	*Fast Lane Only*	*All*	*Fast Lane Only*	*All*	*Fast Lane Only*	*All*
AEC	31	352	94	1532	55	135		
AEP	9708	36292	912	10730	1173	9261		1971
APS	1072	4223	50	2834	337	1662		3370
ATSI	565	5320	0	2318	117	444	459	517
BGE	0	125	300	1250	0	0		
COMED	736	13028	260	8516	0	1695		
DAY	966	2258	125	390	27	554		10
DEOK	0	430	0	475	0	30		
DL	0	5	55	455	13	60		
DOM	1794	22524	317	11663	360	4490	569	569
DPL	0	1056	59	789	0	173		
EKPC	737	6374	76	176	217	1639		
JCPL	102	397	250	494	60	60		
METED	95	482	75	655	39	109		
OVEC	120	430	0	0	0	119		
PECO	0	72	0	0	0	3		
PENELEC	622	4700	45	737	13	1128		
PEPCO	0	127	0	795	0	635		
PPL	597	1558	20	282	40	528		
PSEG	0	4	520	1262	0	0		
Total	17144	99758	3158	45172	2451	21994	1028	6437

Onshore Wind

	Original Projects		**Double up to 500 MW**		**Total**
	Fast Lane Only	*All*	*Doubling of Original*	*Withdrawn (w/ doubling)*	
AEP	476	2201	1991	10345	14537
APS	0	856	856	2114	3826
ATSI	0	298	202	1096	1596
COMED	200	4797	4306	3816	12920
DAY	0	0	0	1600	1600
DOM	0	0	0	1667	1667
DPL	0	0	0	500	500
PENELEC	0	377	377	2048	2802
PPL	0	0	0	2914	2914
Total	676	8529	7732	25722	41983

- The capacity expansion model uses build limits by state, zone, and fuel type
  - All fast lane and "original" wind projects are included in the expansion initial condition
  - Other candidates are selected by the model based on economics subject to constraints
  - Consider only gas projects in OH, WV, IN, KY

Economics and Technology: Fixed Costs



- Sources: Renewables and batteries, S&P; CC and CT, Quad Review (levels) and NREL ATB 2023 (learning curves) for CAPEX, and EEEI for FOM
- Note: Batteries are 4-hour; hybrids are closed loop (w/ battery half the solar nameplate); CAPEX includes IRA Investment Tax Credit of 30% (IRA's local bonuses not modeled)

Economics and Technology: Fixed Costs (continued)

Geography adjustment costs

	CT	*CC*	*Solar*	*Onshore*	*Offshore*	*Battery*	*Hybrid*
MAAC	112%	119%	105%	99%	112%	101%	105%
Other West	96%	98%	99%	75%		100%	98%
COMED	124%	125%	108%	109%		101%	109%
Dominion	102%	110%	99%	103%	104%	101%	102%
EKPC	96%	96%	99%	75%		103%	100%

Sources: EIA

	CT	*CC*
EMAAC	102%	105%
SWMAAC	96%	96%
WMAAC	103%	104%
Rest of RTO	100%	100%

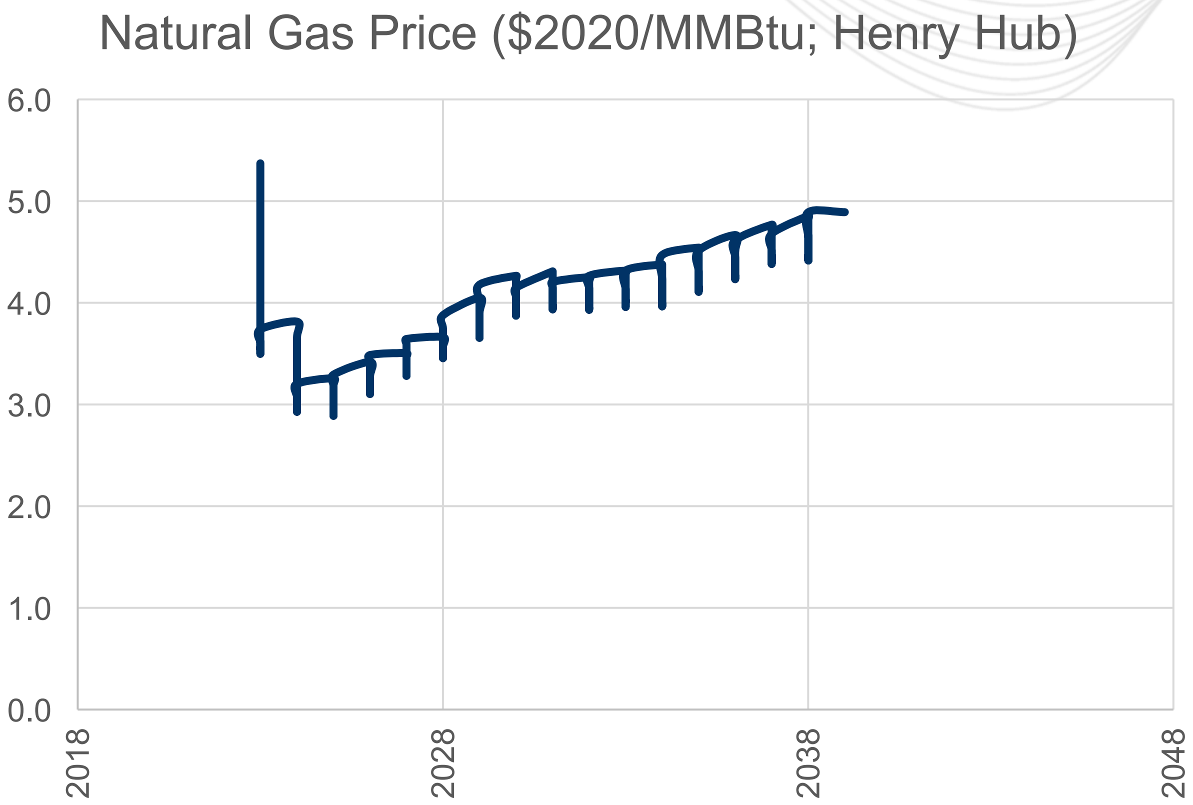
Source and note: Quad Review; for CC & CT CAPEX)

Levelized Capital Carrying Rate (LCCR)

CT	6.4%
CC	6.2%
Offshore	8.4%
Solar	7.1%
Hybrid	6.9%
Wind	7.7%
Battery	10.8%

- Sources: EEEI for thermals and S&P for other technologies
- LCCR is CAPEX annualization coefficient
  - Referred to as Capital Recovery Factor in NREL's ATB and Effective Charge Rate in Brattle's Quad Review)
  - Reflects After-Tax WACC and asset life

Economics and Technology: Variable Costs



Source: PJM's 2023 RTEP Market Efficiency

	CT	*CC*
VOM ($2020/MWh)	4.6	1.9
Heat Rate (MMBtu/MWh)	9.9	6.4

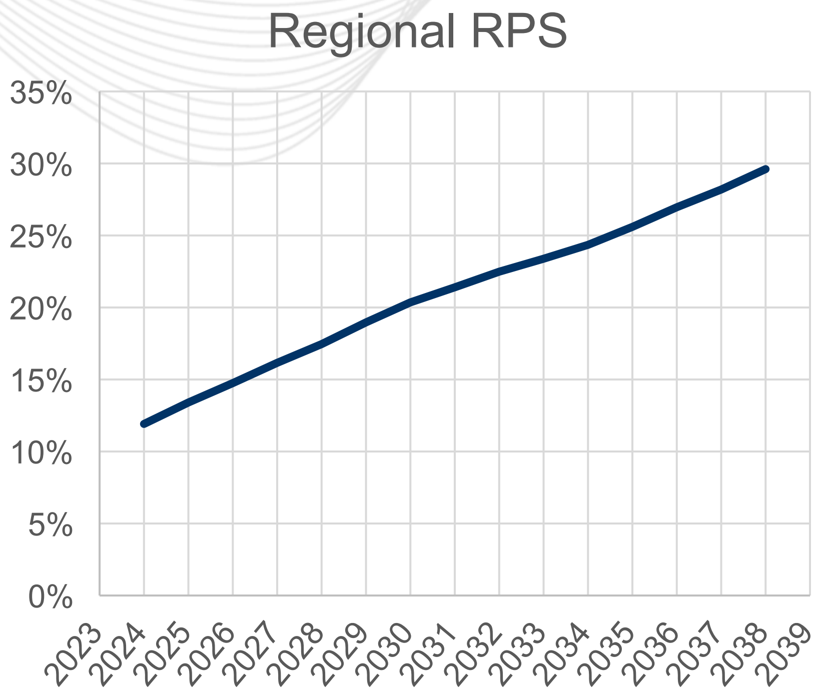
Source: EEEI

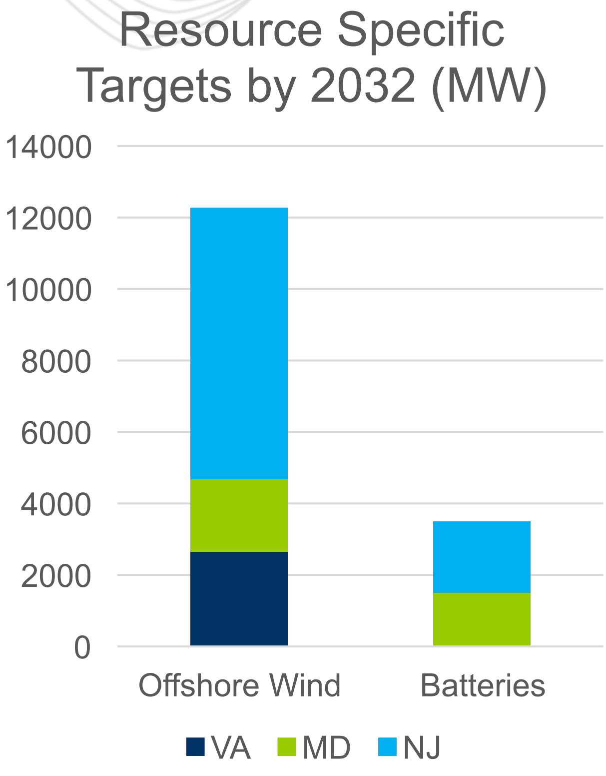
- Other Fuel Costs: EEEI
- Fuel Transportation Costs: EEEI

Economic and Technology: Other Factors

- Time discount rate: 6.8% from PJM’s 2023 RTEP Market Efficiency
- Hourly renewable capacity factors: EEEI
- Other technical parameters, for example existing units ICAP and heat-rates: EEEI

Policies





- The WPS models each state specific RPS geographic and technology eligibility rules (see below)
- IRA modeled as 30% ITC

- NJ SAA 1.0
- MD with ORECs
- VA IRP Commitments

- Set ELCC-based capacity constraints to obtain resource adequate expansion
  - Use Pre-CIFP, average ELCC calculator
    - Discount gas ELCC below 1-EFORd to approximate CIFP innovations (modeling of correlated outages and use of better data)
    - Run tool for many different resource-mixes to determine approximate relationships between installed capacity and ELCC in summer and winter depending on the amount of batteries relative to solar and wind (*next slide*)
  - Set summer and winter capacity constraints in the expansion*
    - Run capacity expansion with different ELCC curves
  - Validate expansion
    - Re-run ELCC calculator on 2032 resource mix and pick capacity expansion run with best fit

$$* \underbrace{\sum_{fuel\ type} ICAP_{fuel\ type} \times ELCC^{season}_{fuel\ type}}_{Firm\ Capacity} \geq \underbrace{Peak\ Load^{season} \times (1 + 9\%)}_{Target}$$

ELCC Assumptions

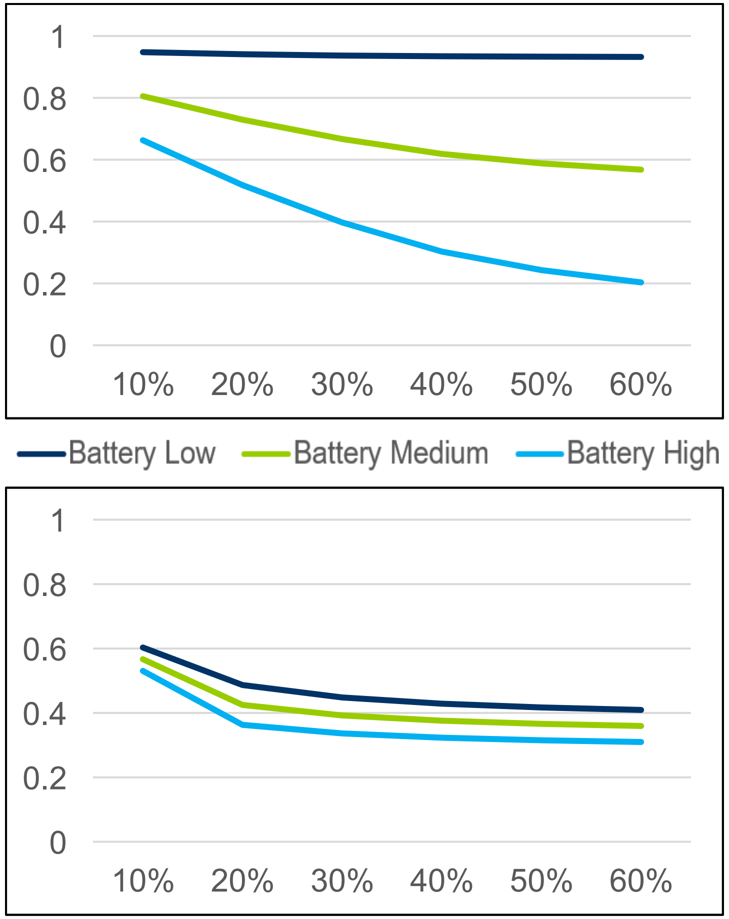
Battery

Onshore

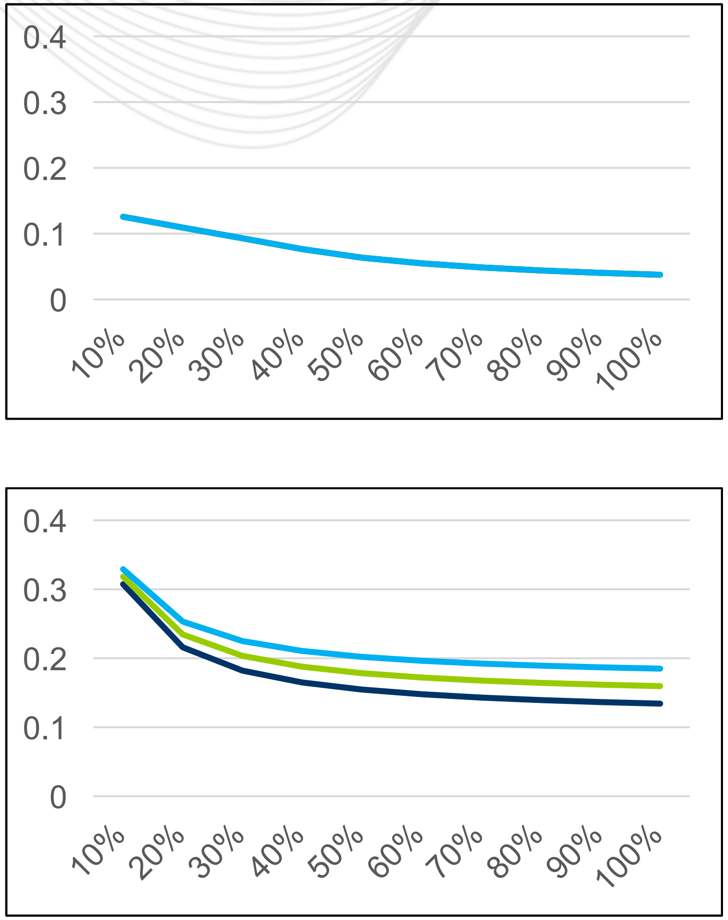
Solar

Summer

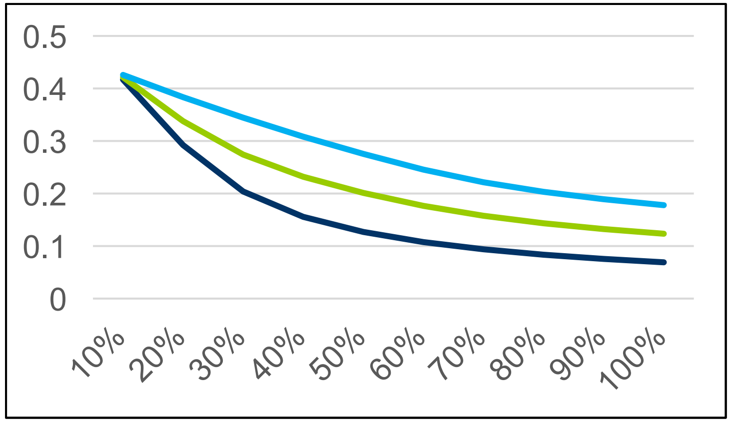
Winter



percent of nameplate to annual peak load



percent of nameplate to annual peak load



- Solar winter ELCC set to 0
- Hybrid: solar ELCC + 0.5 battery ELCC
- Offshore: 1.7 × onshore ELCC
- CC and CT: 0.95 summer, 0.85 winter
- Coal: 0.87
- Nuclear: 0.99

Siting

- Capacity expansion model defines expansion by zone, state, and technology type, e.g., “add 8GW of solar in AEP Ohio”
- Select from list of candidates from the queue as follows
  – Add all fast lane projects and “original” wind project first (e.g. 2GW)
  – For remaining portion (e.g. 6GW)
    - Prioritize project by status as follows*: Suspended, FSA, Active, Withdrawn (for onshore)
    - Within status, prioritize based on queue order (e.g. AF queue before AG), CIR (largest projects first), request date

* If status group MFO > 50% of capacity that remains to be sited, then scale, otherwise use projects from next status group

2030 Policies, Example

- New Jersey:
  - Renewable Portfolio Standard:
    - 50% (or 35.9 TWh)
    - 2.21% solar carve-out (or 1.2 TWh)
    - Only in-state solar is eligible
  - Resource Specific Targets:
    - 2000MW batteries
    - 5106MW Offshore wind
- Delaware:
  - Renewable Portfolio Standard :
    - 28% (or 3.0 TWh)
    - 5% solar carve-out, no geographic eligibility restrictions (or 0.4 TWh)

Policy Mapping Into Capacity Expansion Constraints

- NJ

$$REC_{solar}^{NJ} \geq 1.2$$

$$REC_{solar}^{NJ} \leq GEN_{solar}^{NJ}$$

$$REC_{solar}^{NJ} + REC_{ONW}^{NJ} + REC_{OFW}^{NJ} \geq 35.9$$

$$\sum_{g \in NJ \cap OFW} ICAP_g \geq 5106$$

$$\sum_{g \in NJ \cap batteries} ICAP_g \geq 2000$$

- DE

$$REC_{solar}^{DE} \geq 0.05 \times Load^{DE}$$

$$REC_{solar}^{DE} + REC_{ONW}^{DE} + REC_{OFW}^{DE} \geq 0.28 \times Load^{DE}$$

- Regional REC demand/supply

$$\sum_{state \in PJM} REC_{type}^{state} \leq GEN_{type}^{PJM}$$

- Definitions

$$GEN_{type}^{geo} = \sum_{g \in geo \cap type} \frac{gen_g}{1{,}000{,}000}$$

Other States

- MD

$$REC_{solar}^{MD} \geq 4.7$$

$$REC_{solar}^{MD} \leq GEN_{solar}^{MD}$$

$$REC_{solar}^{MD} + REC_{ONW}^{MD} + REC_{OFW}^{MD} \geq 25.4$$

$$REC_{OFW}^{MD} \leq GEN_{OFW}^{DPL}$$

$$\sum_{g \in NJ \cap OFW} ICAP_g \geq 2022.5$$

$$\sum_{g \in NJ \cap batteries} ICAP_g \geq 1500$$

- DC

$$REC_{solar}^{DC} \geq 0.0$$

$$REC_{solar}^{DC} + REC_{ONW}^{DC} + REC_{OFW}^{DC} \geq 7.4$$

- IL

$$REC_{solar}^{IL} \geq 19.9$$

$$REC_{solar}^{IL} \leq GEN_{solar}^{IL} + GEN_{solar}^{IN} + GEN_{solar}^{KY}$$

$$REC_{ONW}^{IL} \geq 16.3$$

$$REC_{ONW}^{IL} \leq GEN_{ONW}^{IL} + GEN_{ONW}^{IN} + GEN_{ONW}^{KY}$$

Other States (Continued)

- PA

$$REC_{solar}^{PA} \geq 0.0$$

$$REC_{solar}^{PA} \leq GEN_{solar}^{PA}$$

$$REC_{solar}^{PA} + REC_{ONW}^{PA} + REC_{OFW}^{PA} \geq 5.7$$

$$REC_{OFW}^{PA} \leq GEN_{OFW}^{JCPL}$$

$$REC_{ONW}^{PA} \leq \sum_{geo \in JCPL \cup ATSI \cup AP \cup DLC \cup PN \cup PL \cup ME \cup PECO} GEN_{ONW}^{geo}$$

$$REC_{solar}^{PA} \leq \sum_{geo \in JCPL \cup ATSI \cup AP \cup DLC \cup PN \cup PL \cup ME \cup PECO} GEN_{solar}^{geo}$$

VA

$$75\% \times \left(REC_{solar}^{DOM} + REC_{ONW}^{DOM} + REC_{OFW}^{DOM}\right) \leq GEN_{solar}^{VA} + GEN_{ONW}^{VA} + GEN_{OFW}^{VA}$$

$$REC_{solar}^{DOM} + REC_{ONW}^{DOM} + REC_{OFW}^{DOM} \geq 41\% \times Load^{DOM}$$

$$REC_{solar}^{AEP} + REC_{ONW}^{AEP} + REC_{OFW}^{AEP} \geq 30\% \times Load^{AEP}$$

$$\sum_{g \in DOM \cap (ONW \cup solar)} ICAP_g \geq 10{,}000$$

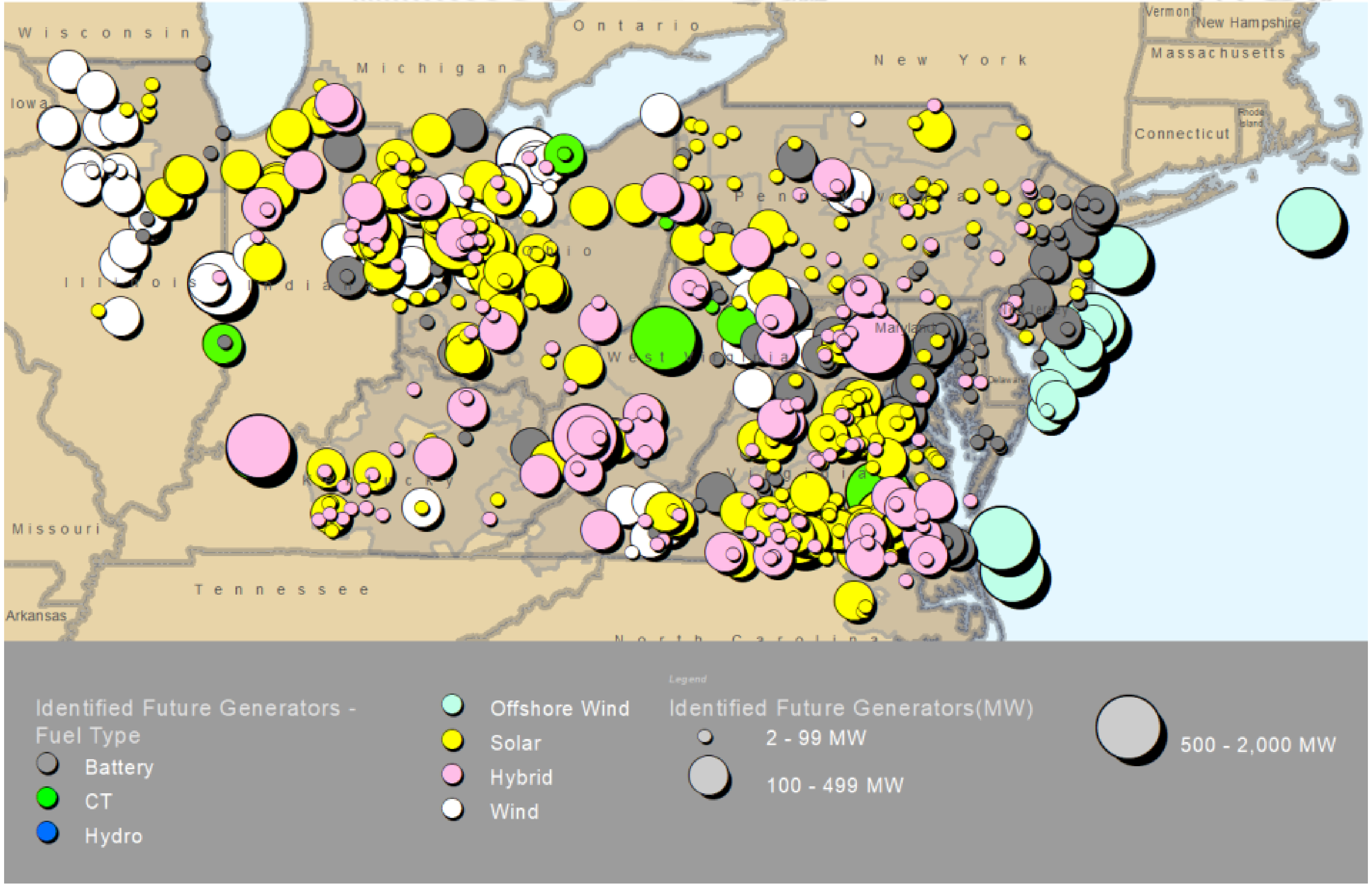
$$\sum_{g \in AEP \cap (ONW \cup solar)} ICAP_g \geq 600$$

$$\sum_{g \in VA \cap OFW} ICAP_g \geq 2652$$

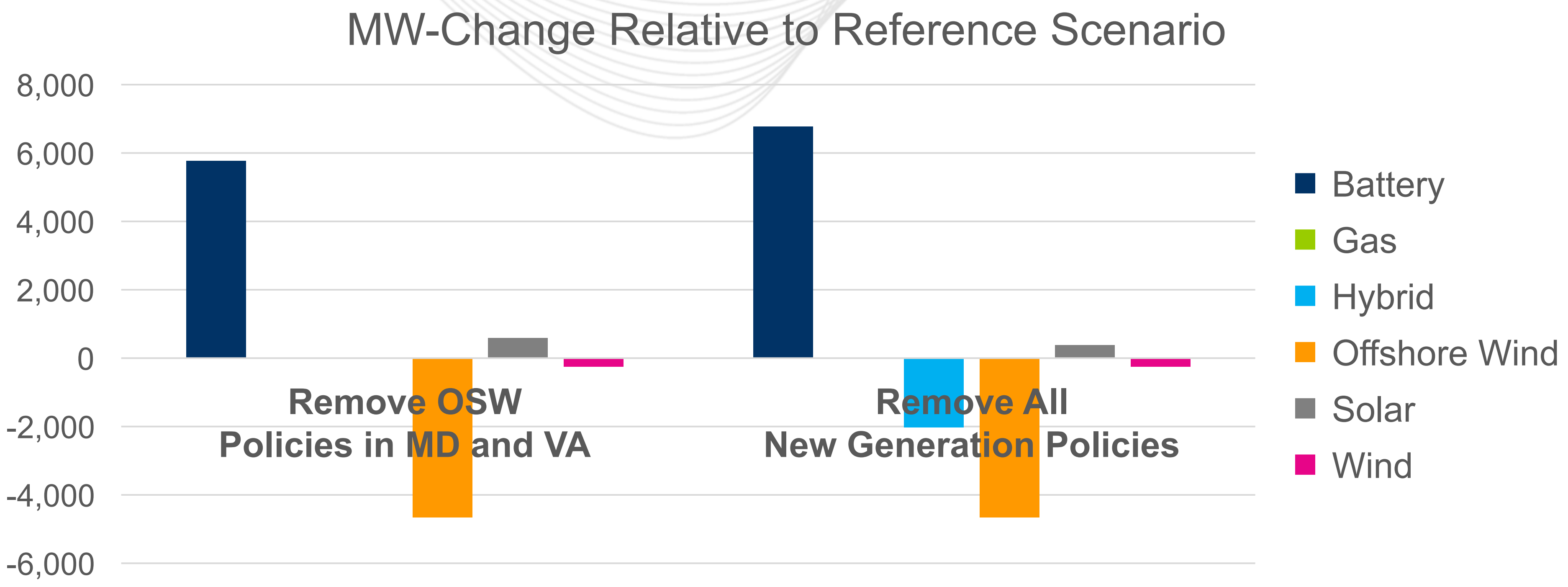
$$\sum_{g \in DOM \cap batteries} ICAP_g \geq 1700$$

$$\sum_{g \in AEP \cap batteries} ICAP_g \geq 250$$

Replacement Generation Relative to 2029

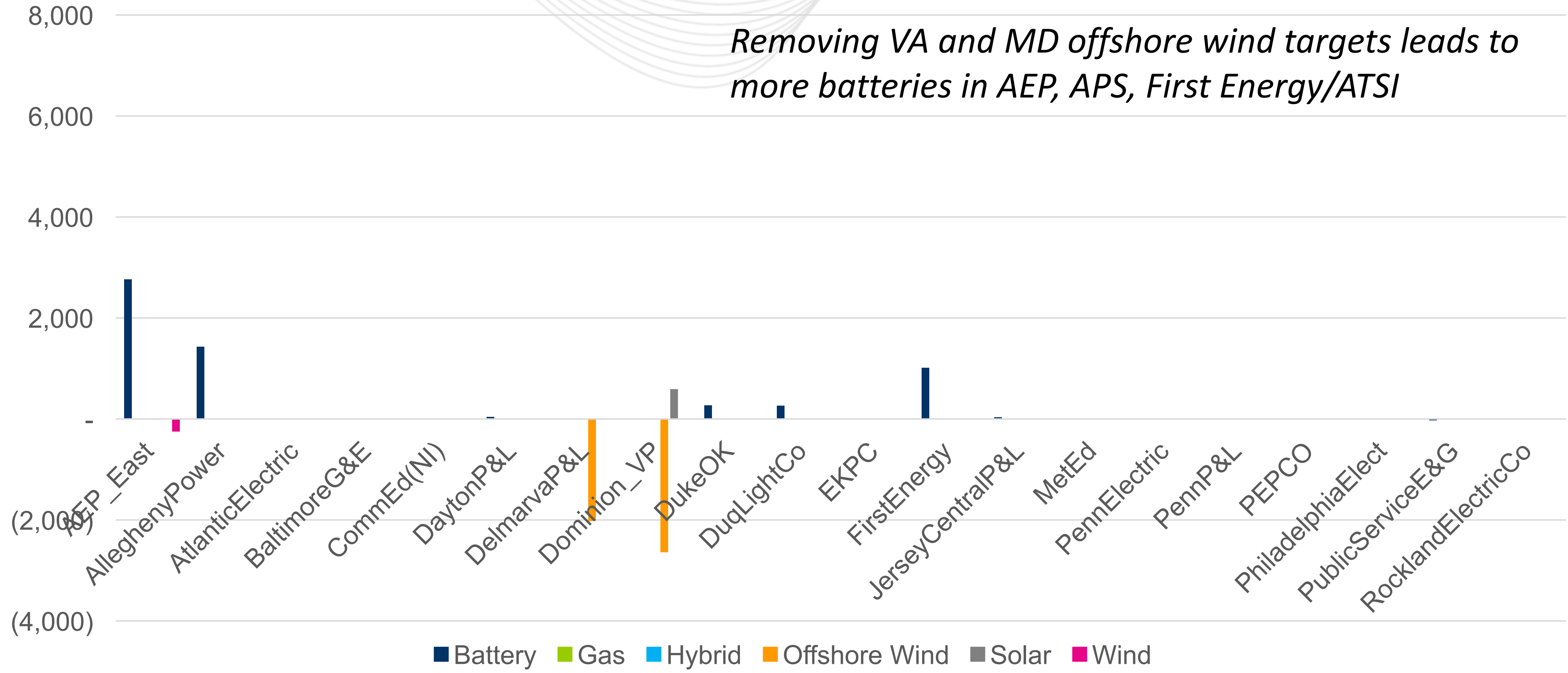


The Effect of New Generation Policies (Given the Queue)

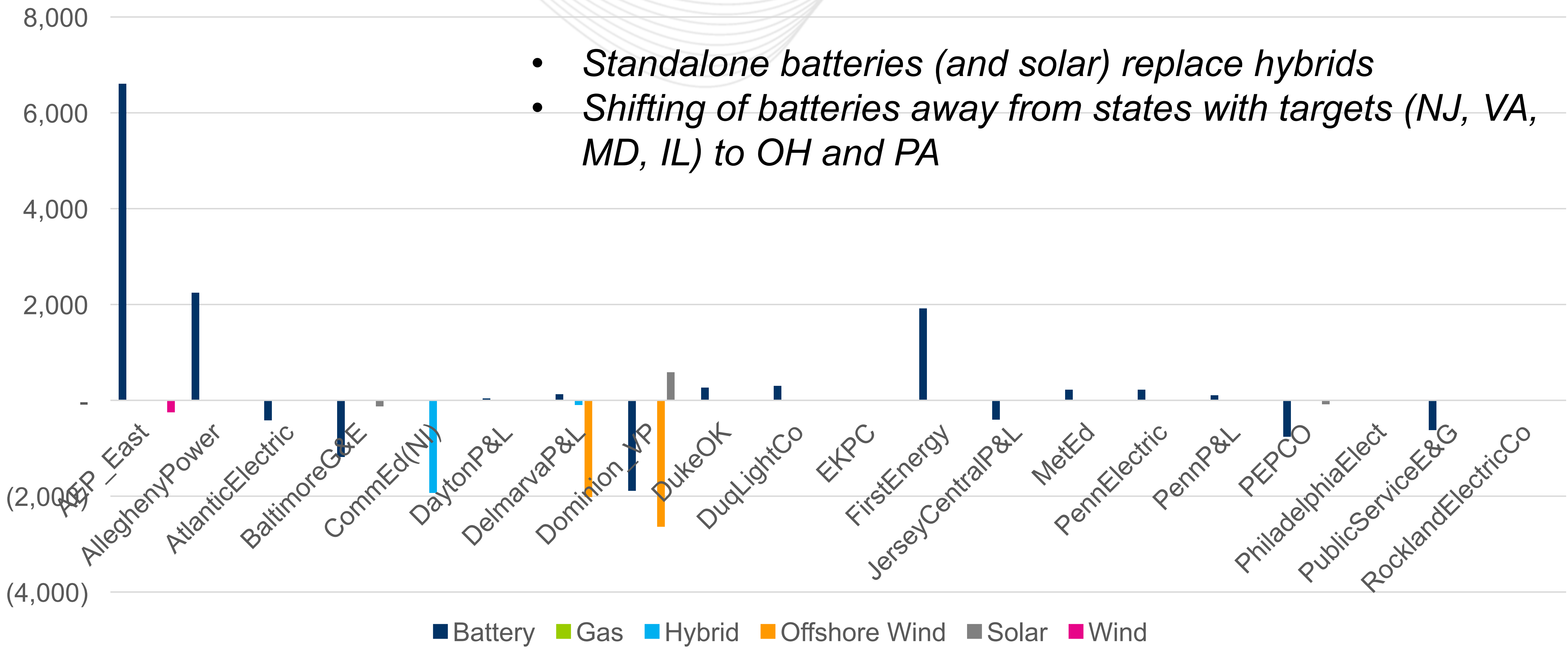


- **New generation policies have small impacts on resulting capacity expansion**
  - Removing OSW leads to more solar, wind, and batteries – especially batteries
  - Removing other policies leads to more standalone batteries and solar replacing hybrids

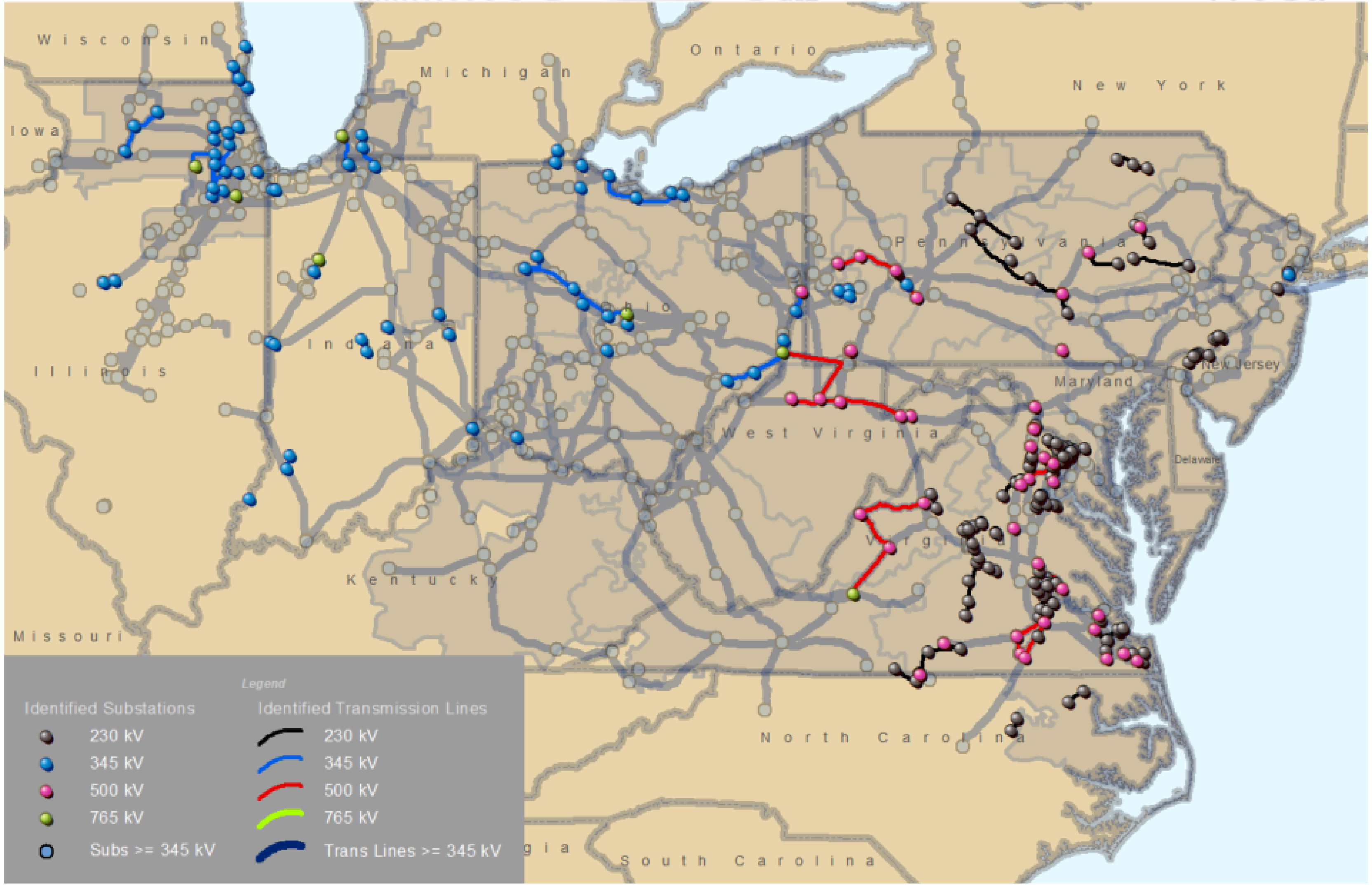
Remove OSW Policies in MD and VA, Zonal Breakdown (MW-change relative to Reference)



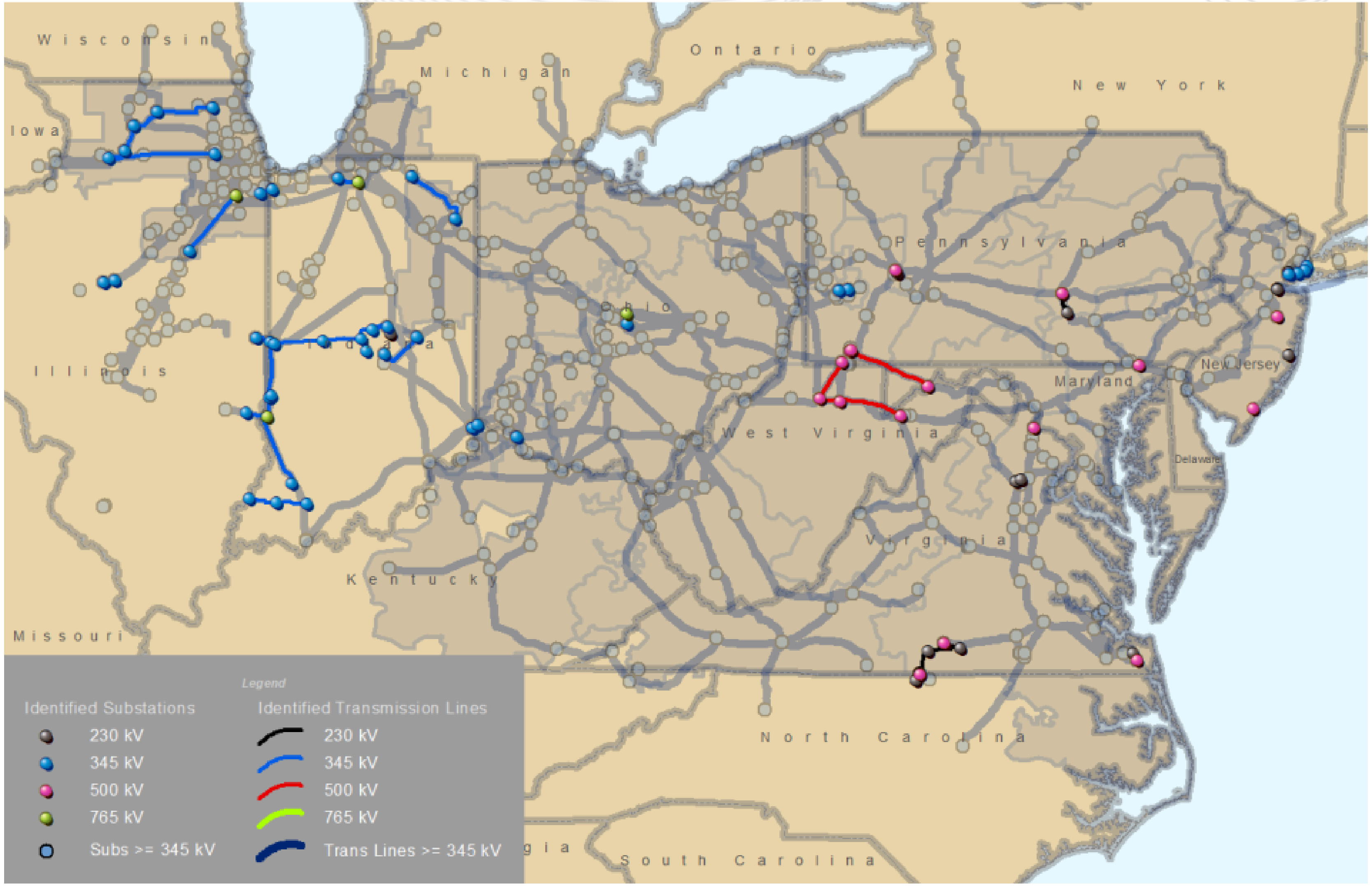
Remove All New Generation Policies, Zonal Breakdown (MW-change relative to Reference)



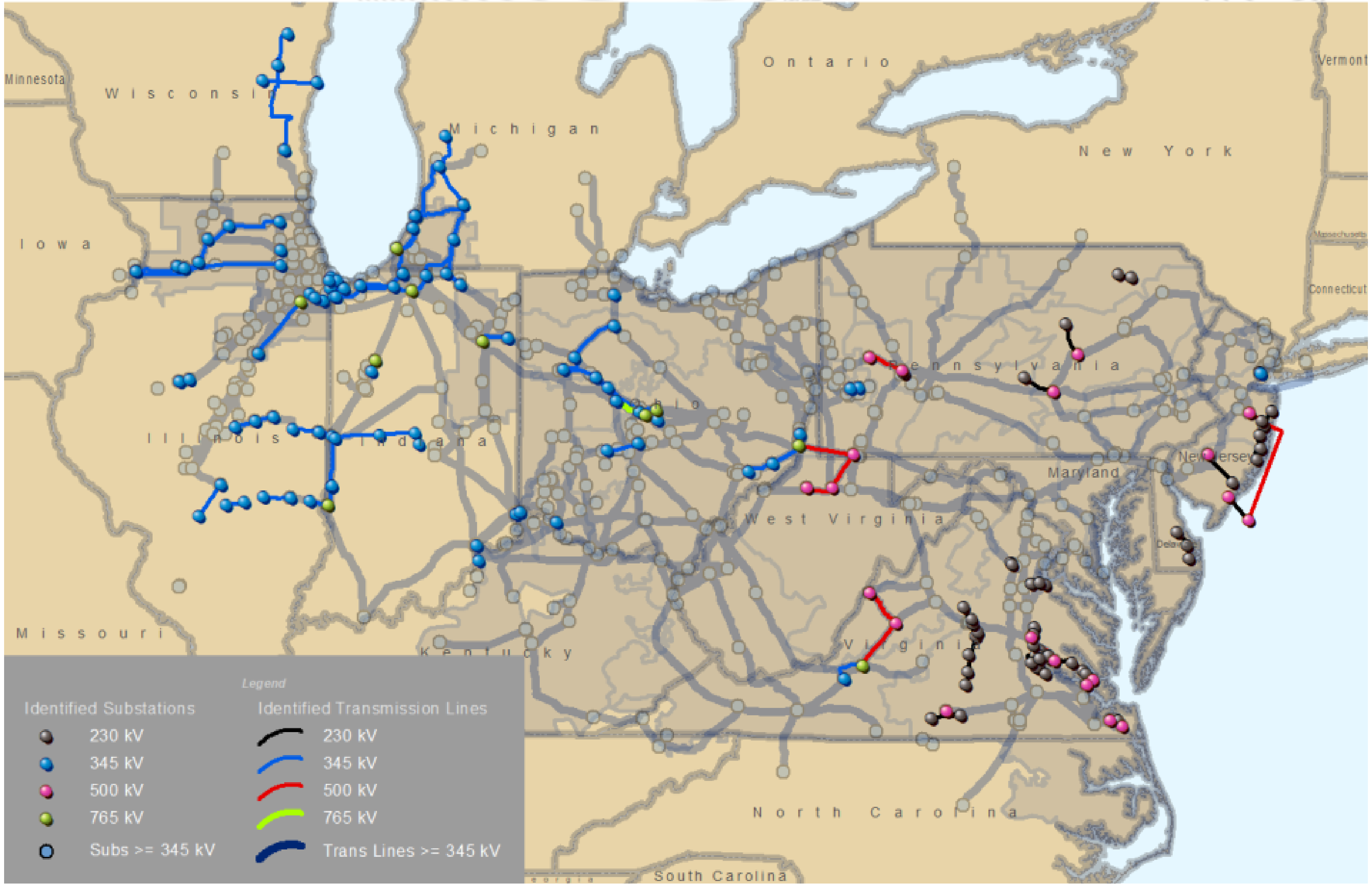
Workshop Policy Study +230*kV* Line Overloads: **Summer** (Excluding overlaps with RTEP)



Workshop Policy Study +230*kV* Line Overloads: **Winter** (Excluding overlaps with RTEP)



Workshop Policy Study +230*kV* Line Overloads: **Light Load** (Excluding overlaps with RTEP)



Reliability Issues by Zone and *kV* Level

	kV level	AE	BGE	DP&L	JCPL	METED	PECO	PENELEC	PPL	PEPCO	PSEG	Dominion	AEP	AP	ATSI	ComEd	DAY	DEO&K	DLCO	EKPC	OVEC	Total
Lines	115		1					12	1			**55**		1								69
Lines	138			5				1				2	**137**	**109**	**47**	**72**	5	5	7	2		389
Lines	161																			3		3
Lines	230	1		4	8	1	6	6	9	1	2	**113**	1	5								154
Lines	275	1																				1
Lines	345										1		**40**	1	4	**41**	1	1	4		2	91
Lines	500			1	1		1	**2**				**12**	1	**9**	1							26
Lines	**Total**	2	1	10	9	1	7	21	9	1	2	181	178	123	51	113	5	6	11	4	2	732
Transformers	115							4				20		1								25
Transformers	138								1				5	5	1	24		1	3		1	40
Transformers	230							1		1		16										18
Transformers	345												5			2						7
Transformers	500												1									1
Transformers	**Total**							5	1	1		36	11	6	1	26		1	3		1	91

Reliability Issues by Season, Test, and *kV* level

	kV level	All cases and tests	Summer				Winter				Light Load		
			GD	N1	N2	Sub-tot	GD	N1	N2	Sub-tot	GD	N1	Sub-tot
Lines	115	**69**	61	12	10	61	9	1	1	9	34	18	36
	138	**389**	**168**	62	**152**	**249**	65	17	63	102	**193**	73	**195**
	161	**3**	2			2	1	1	1	1	1		1
	230	**154**	**90**	61	**59**	**131**	9	1	2	11	47	13	47
	275	**1**					1			1	1		1
	345	**91**	17	7	**44**	**53**	17	8	12	18	**55**	19	**55**
	500	**26**	**18**	7	10	**21**	6		3	7	8	2	8
	Total	**732**	356	148	275	517	107	27	81	148	338	125	342
Transformers	115	25	21	11	6	25		3	1	3	17	11	18
	138	40	11	10	31	34	5	5	12	12	5	4	5
	230	18	10	7	7	18	1	1	2	3	6	3	6
	345	7	1		1	2	2		1	3	5	2	5
	500	1									1		1
	Total	91	43	28	45	79	8	9	16	21	34	20	35