LTRTP Workshop Policy Study

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Scenario Analysis & Special Studies

TEAC Special Session – Order 1920

October 1, 2024

Agenda

- Study Scope
- Key Takeaways
- Assumptions and Methods
- Capacity Expansion Results
- Resulting Net-Injections Across PJM's Macro Areas
- Next Steps

Study Scope and Purpose

LTRTP Workshop Policy Study (WPS): Scope and Purpose

- Prior to FERC issuing Order No. 1920, PJM developed a 2032 study model based on LTRTP Workshop feedback and outcomes
  - Prototype concepts and test modeling capabilities
    - Test ISAC workbook
  - Provide situational awareness of potential transmission needs
  - Accelerate implementation in 2024 upon manuals’ approval

- The WPS does not conform to Order No. 1920 and PJM will not take long-term actions based on it
- PJM thinks the WPS provides a concrete and useful starting point for discussions on Order No. 1920 scenario development

Study Key Takeaways

Takeaways

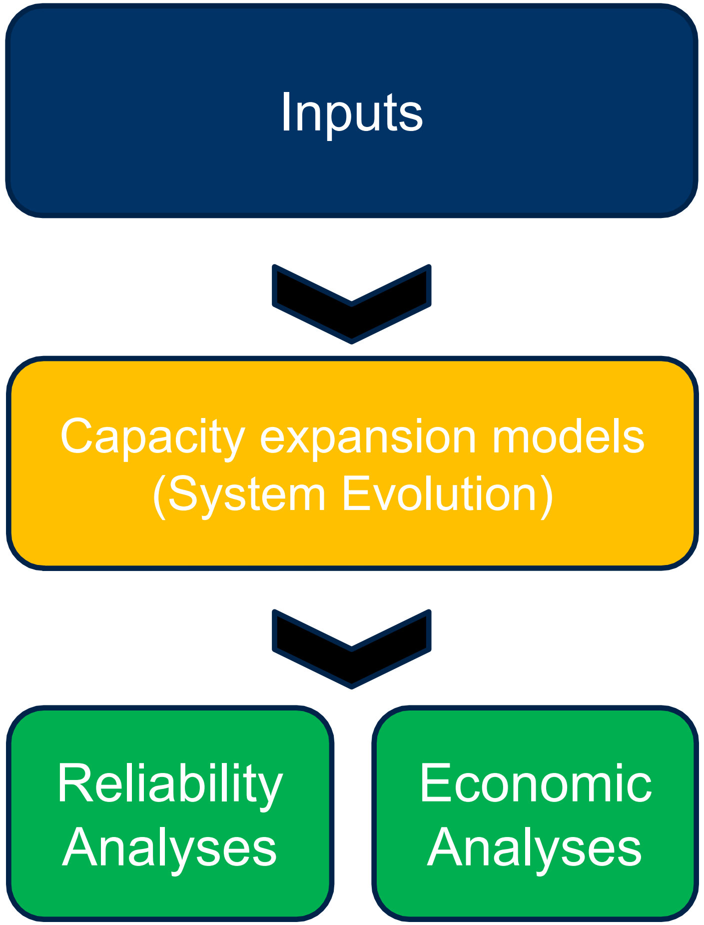
- Generation growth in the center and load in the South in 2032 **relative to 2029**
  - **Load**: Significant growth (6.6GW), especially in DOM (4.5GW)
  - **Retirements**: 20GW *unannounced* (mainly in ComEd, PENELEC, AEP)
  - **Generation additions (based on queue)**: esp. in AEP, APS, and in DOM
    - 92 GW needed for resource adequacy above ISA

      About four MW of renewables and batteries needed per MW of load
    - Solar increasingly economic but wind needed for winter reliability with batteries
    - Gas remains economic (6.4GW)
    - Generation policies do not significantly affect expansion, given the queue
- Growing flows from AEP & APS → DOM, E/SW-MAAC (& ComEd in summer)

Methods and Assumptions

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



Modeling Process

Capacity Expansion Process

Inputs

- Technology
- Economics
- Market rules
- Interconnection requests
- Policies

Zonal Expansion

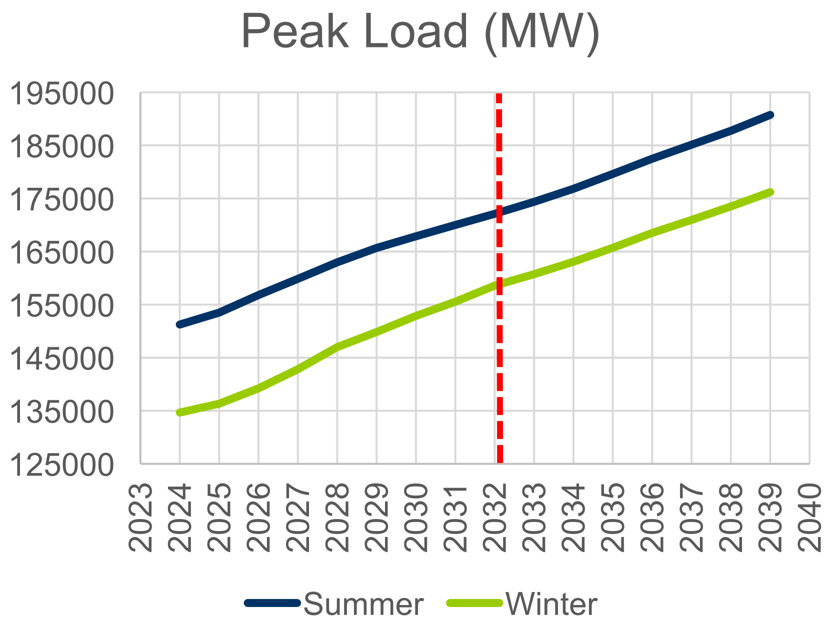
- Economic expansion given technology, economics, policies, resource adequacy constraints, etc., *for each state/zone*
- Aim to capture possible future market outcomes

Siting

- Break down state/zone/fuel type expansion into individual projects
- Develop nodal models

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)

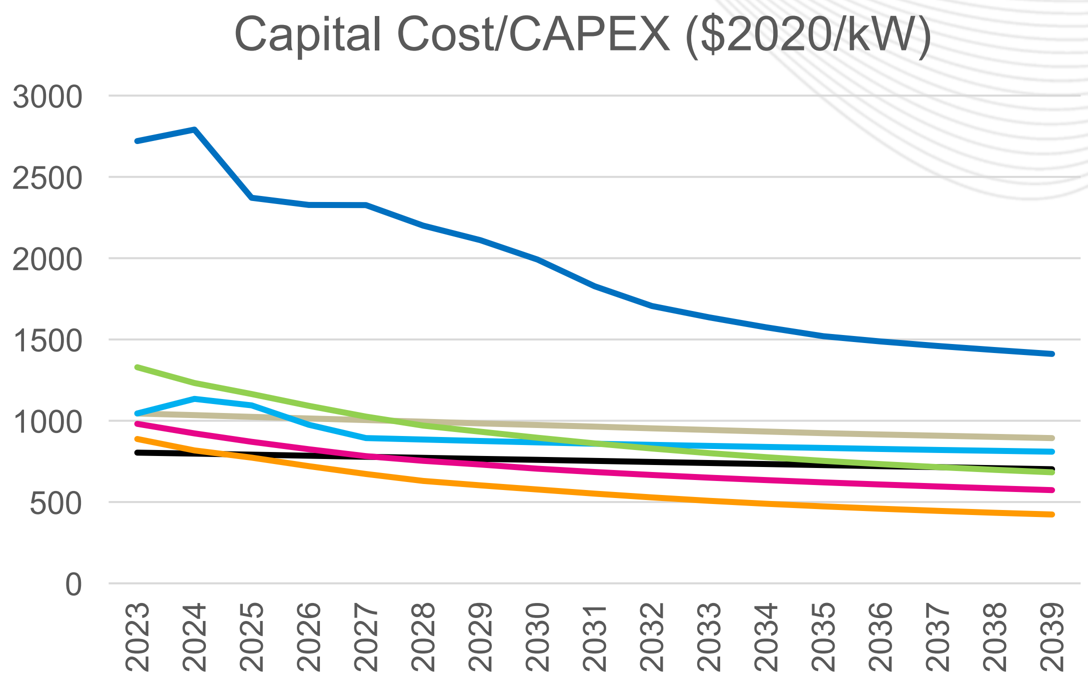
	Solar		Battery		Hybrid		New Gas	
	Fast Lane Only	*All*	*Fast Lane Only*	*All*	*Fast Lane Only*	*All*	*Fast Lane Only*	*All*
AEC	31	352	94	1532	55	135		
AEP	9708	36292	912	10730	1173	9261		1971
APS	1072	4223	50	2834	337	1662		3370
ATSI	565	5320	0	2318	117	444	459	517
BGE	0	125	300	1250	0	0		
COMED	736	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

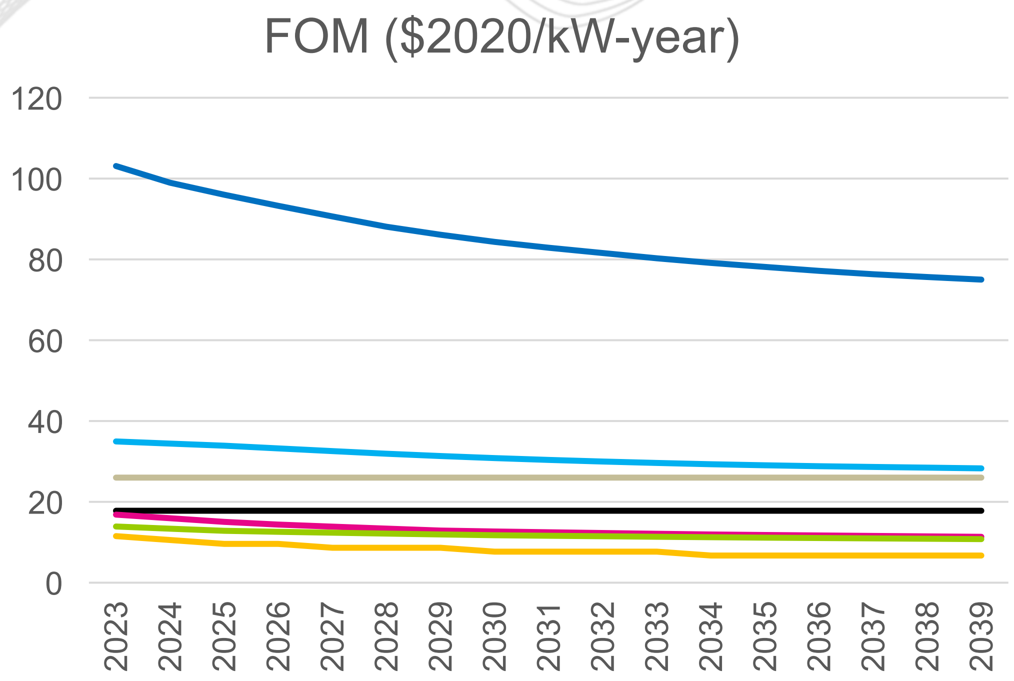
Onshore Wind

	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 4h; hybrids closed loop (w/ battery half the solar nameplate); CAPEX includes IRA Investment Tax Credit of 30% (no accounting of local IRA bonuses)

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)

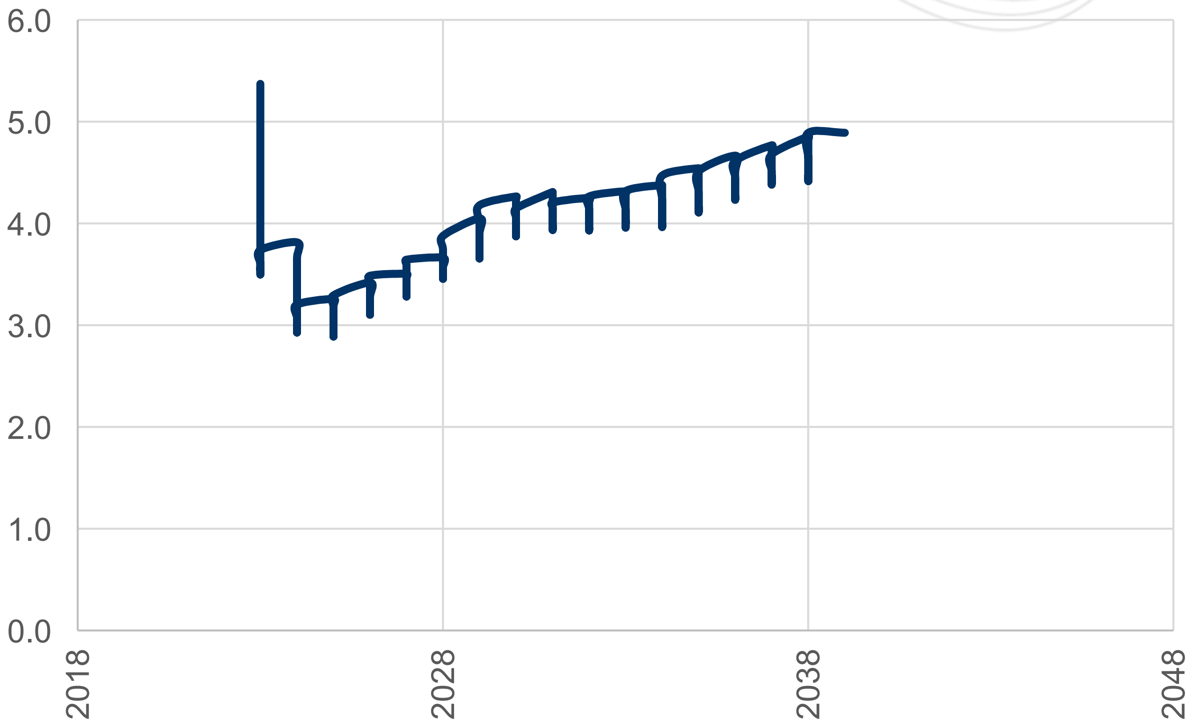
Levelized Capital Carrying Rate (LCCR)

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

Natural Gas Price ($2020/MMBtu; Henry Hub)



Source: PJM's 2023 RTEP Market Efficiency

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

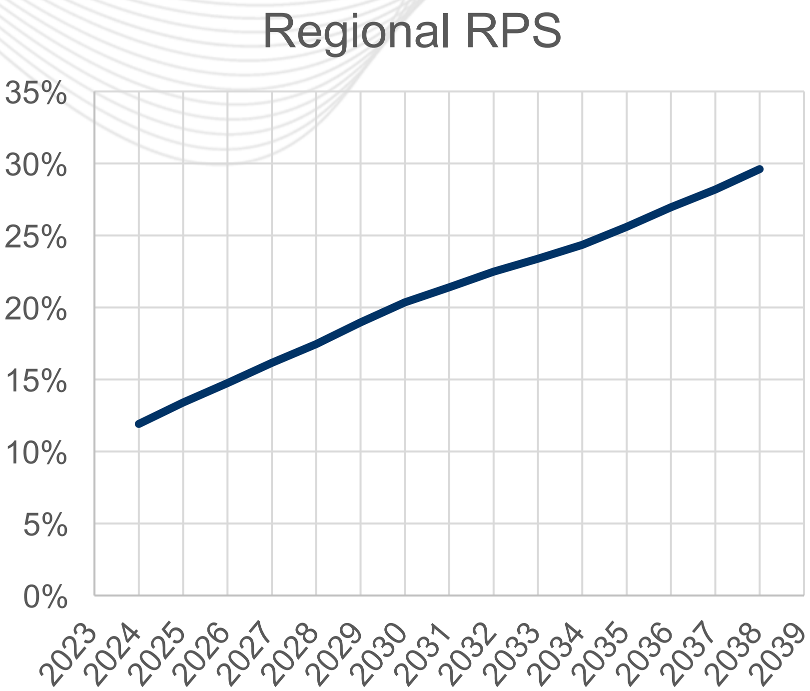
Source: EEEI

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

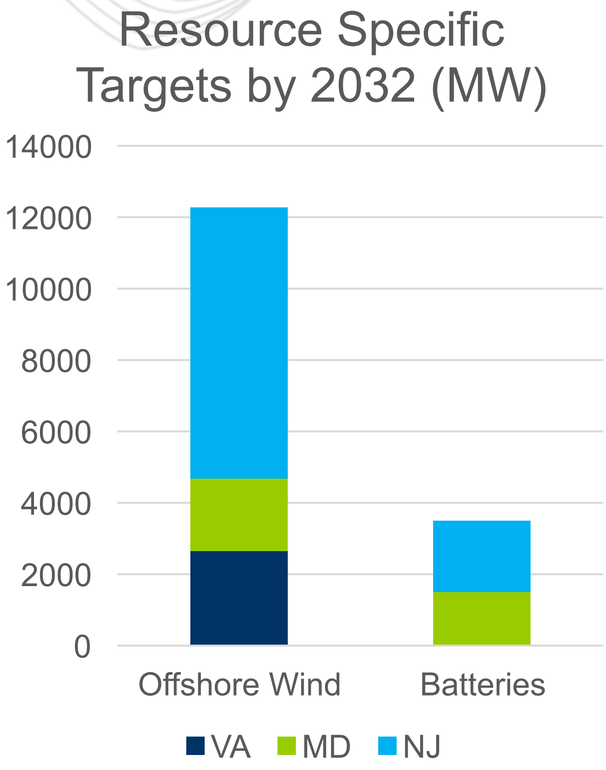
Economic and Technology: Other Factors

- 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 appendix)
- 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

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

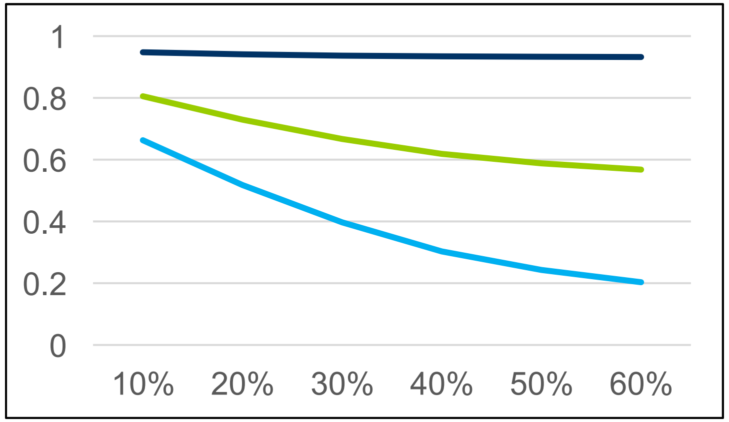
ELCC Assumptions

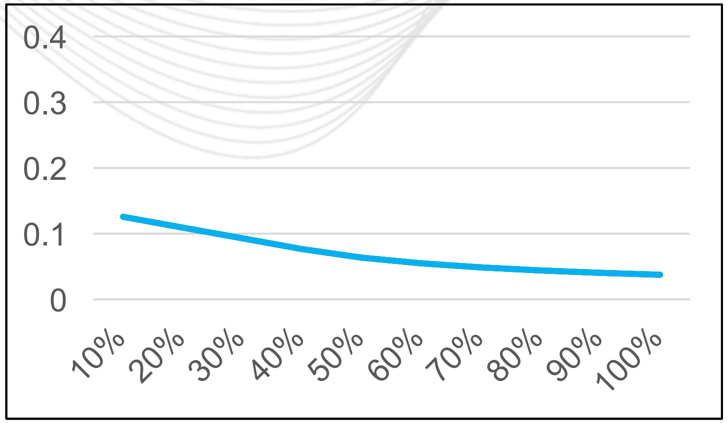
Battery

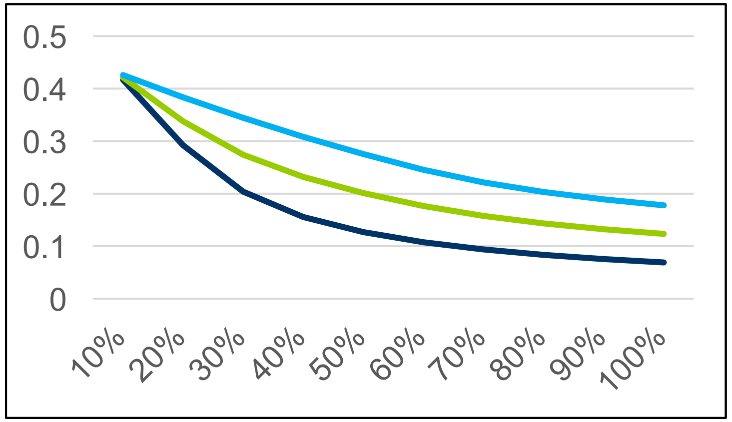
Onshore

Solar

Summer

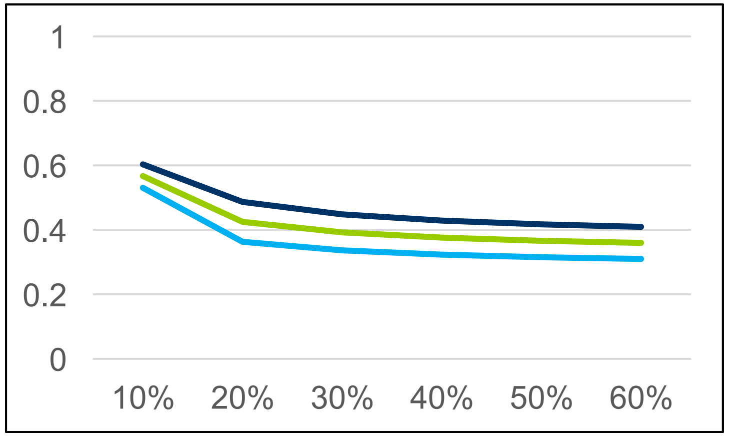




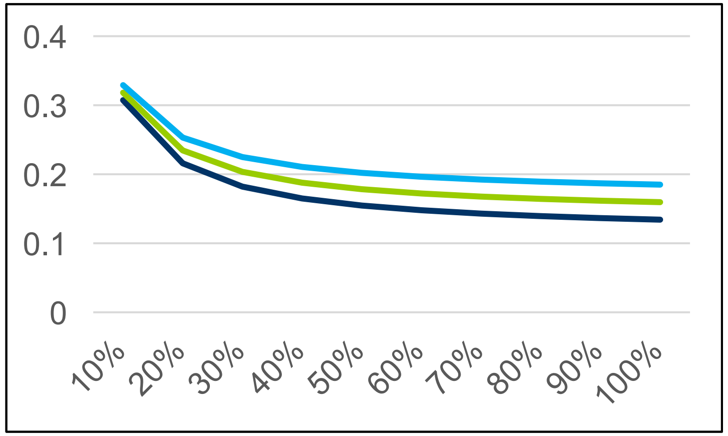


Battery Low Battery Medium Battery High

Winter



percent of nameplate to annual peak load



percent of nameplate to annual peak load

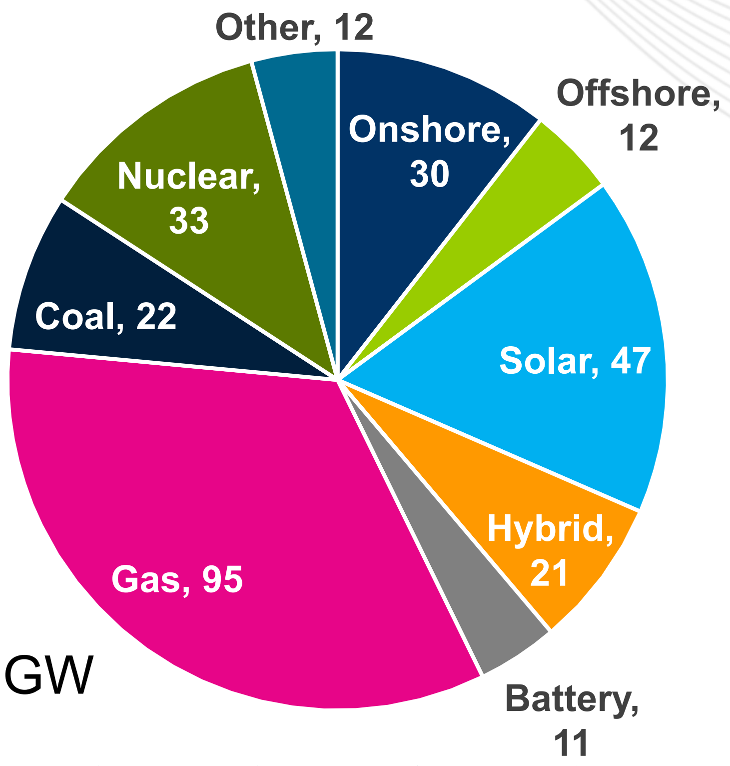
- Solar winter ELCC set to 0
- Hybrid: solar ELCC + 0.5 battery ELCC
- Offshore: 1.7 × onshore ELCC
- CC and CT: 0.95 summer, 0.85 winter
- Coal: 0.87
- Nuclear: 0.99

- 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

Study Models

Capacity Expansion Results: 2032 Resource Mix

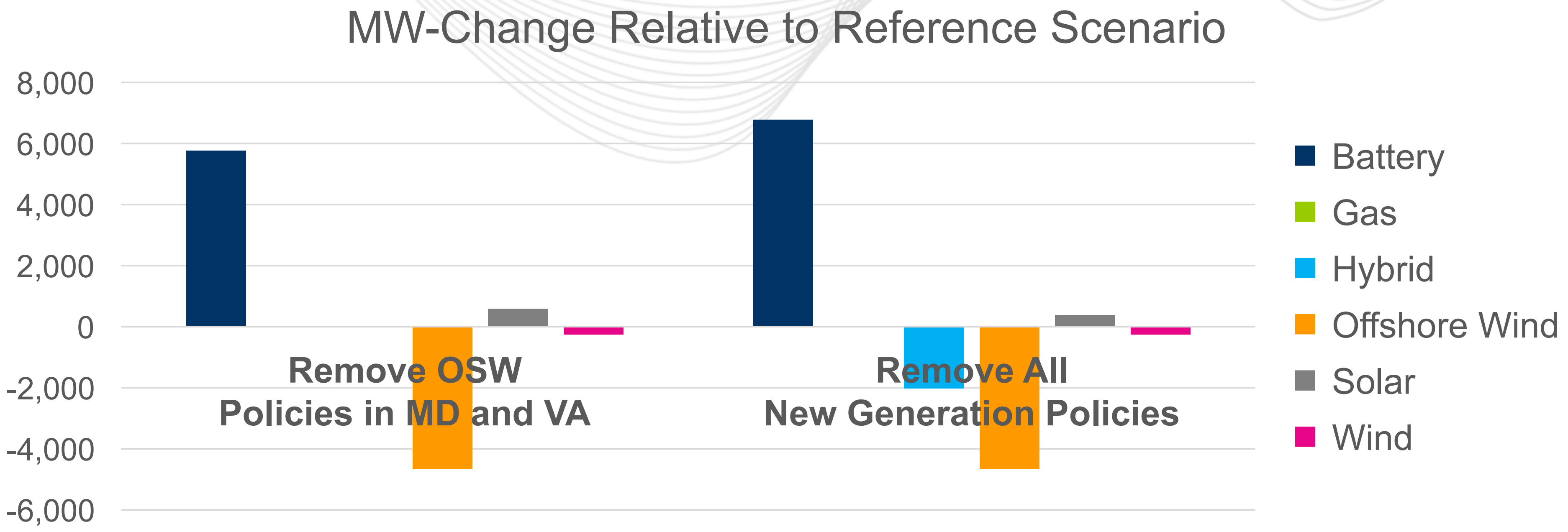


Tot. 282 GW

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 ~4 MW of renewables/ batteries per MW of load
- Combined cycle remains economic
- Portfolio near 1-in-10 (CIFP solved load 174.9GW vs 172.1 for 2032 peak)

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
- Zonal breakdown in appendix

Nameplate Changes Relative to RTEP 2029 (Approximate)

Generation increasingly in the center and South

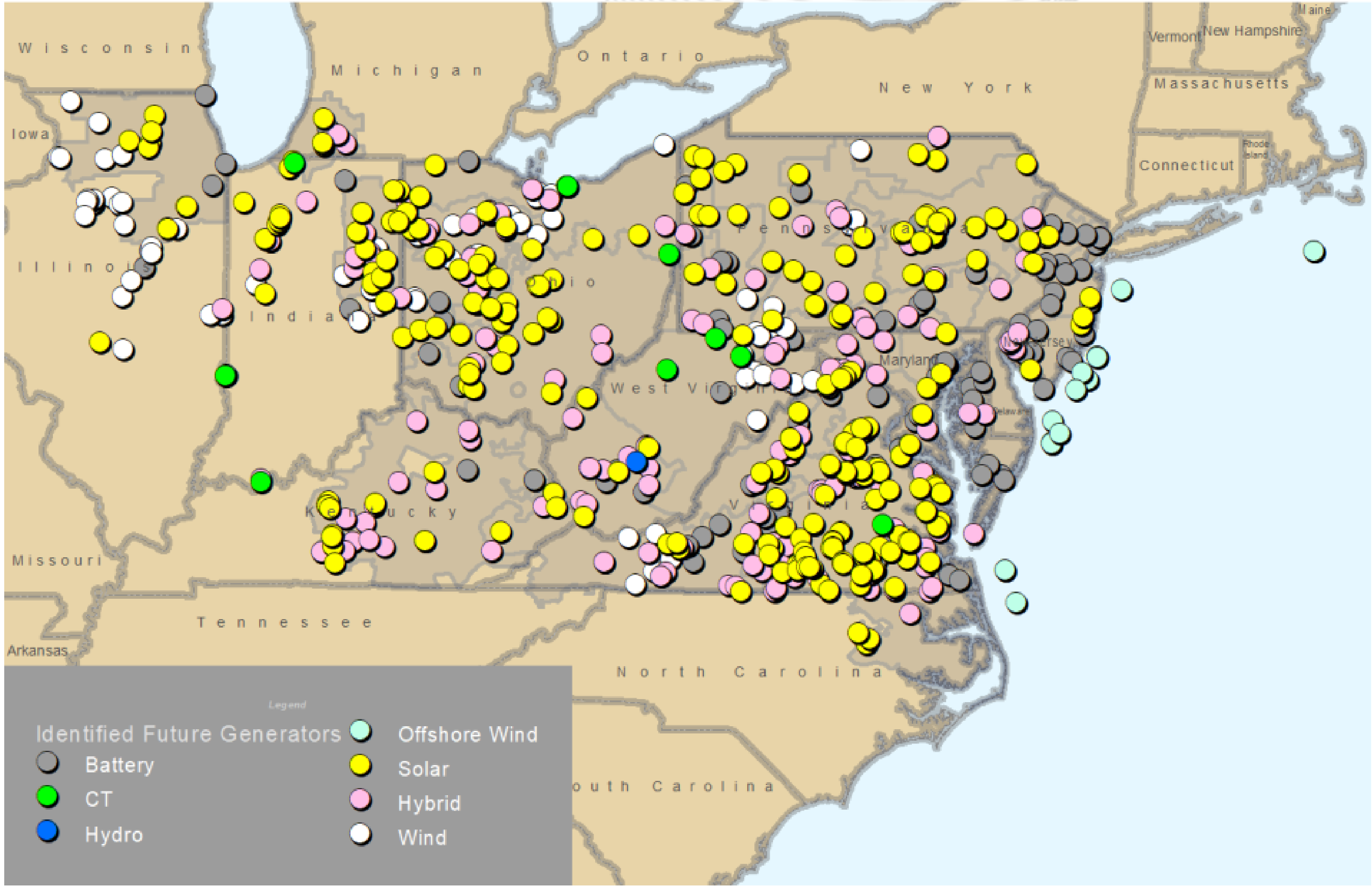
- Generation growth in AEP (renewable/batt.) APS (thermals)
- Generation (solar) *and* load growth in DOM
- Generation growth (wind) and retirements in ComEd
- Retirements in WMAAC (PENELEC) with little replacement generation

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.

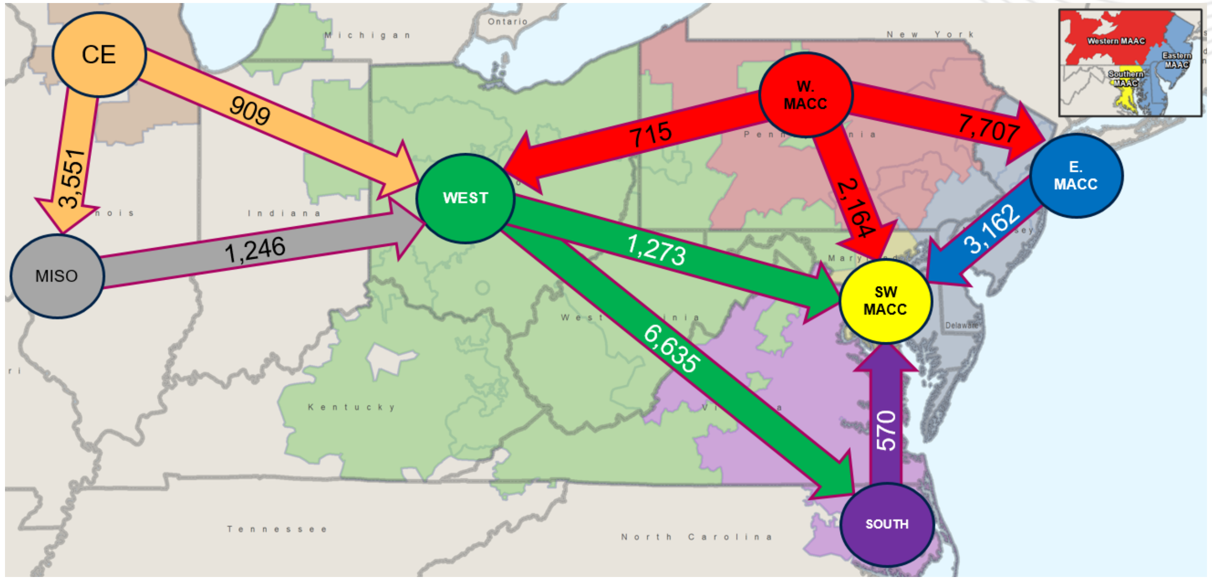
Geographic Distribution Of New Resources



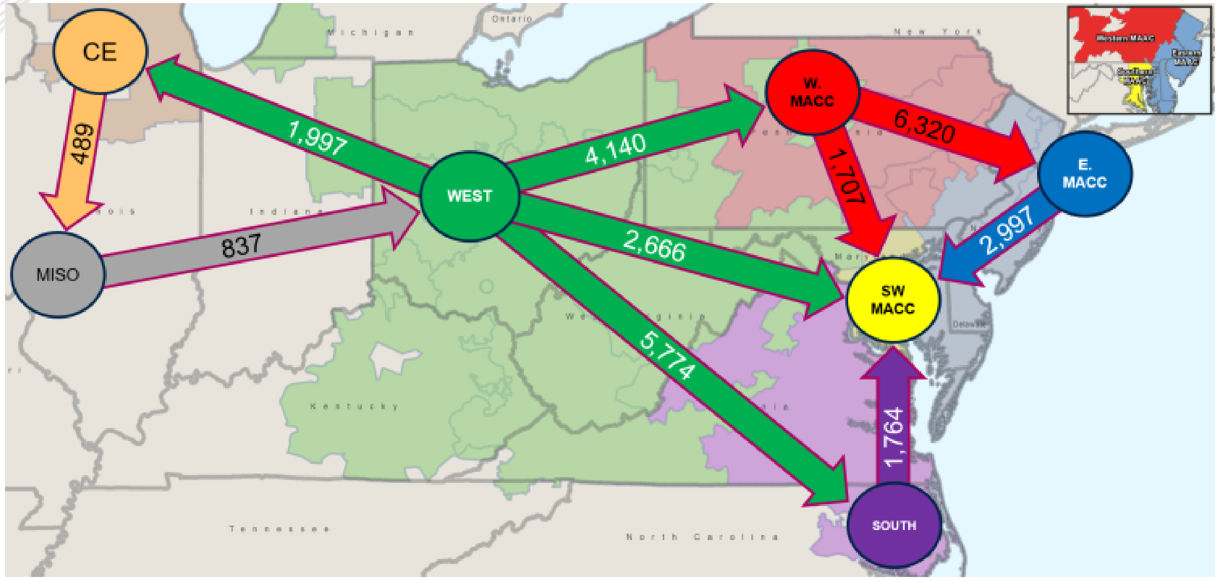
- See appendix for map with projects' nameplates

Net Injections Across PJM's Macro-Areas

- RTEP 2029



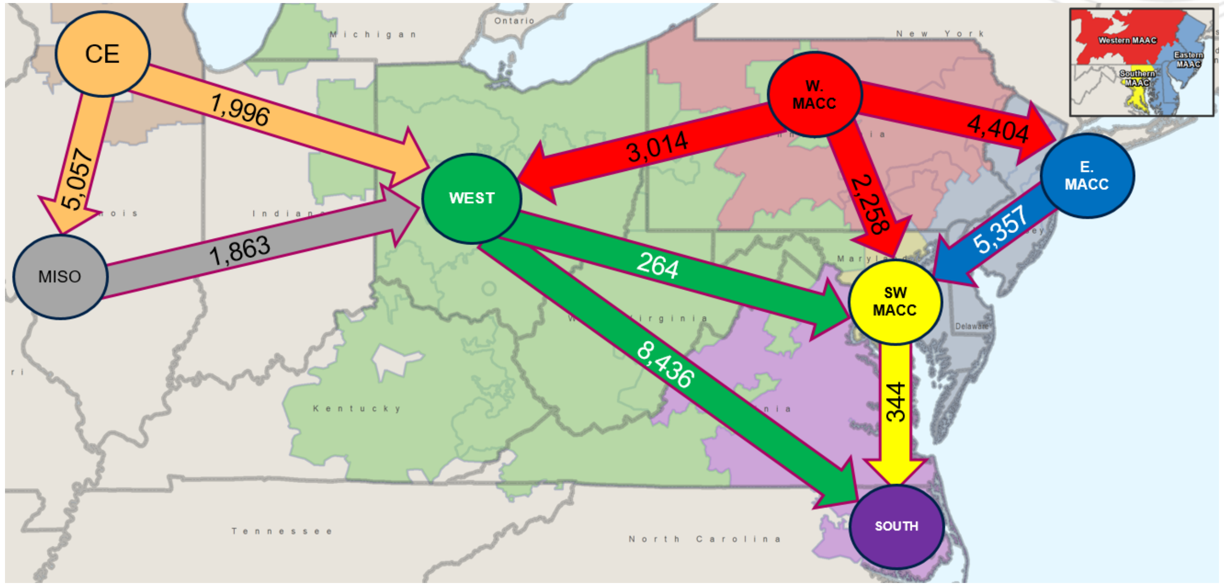
- WPS 2032



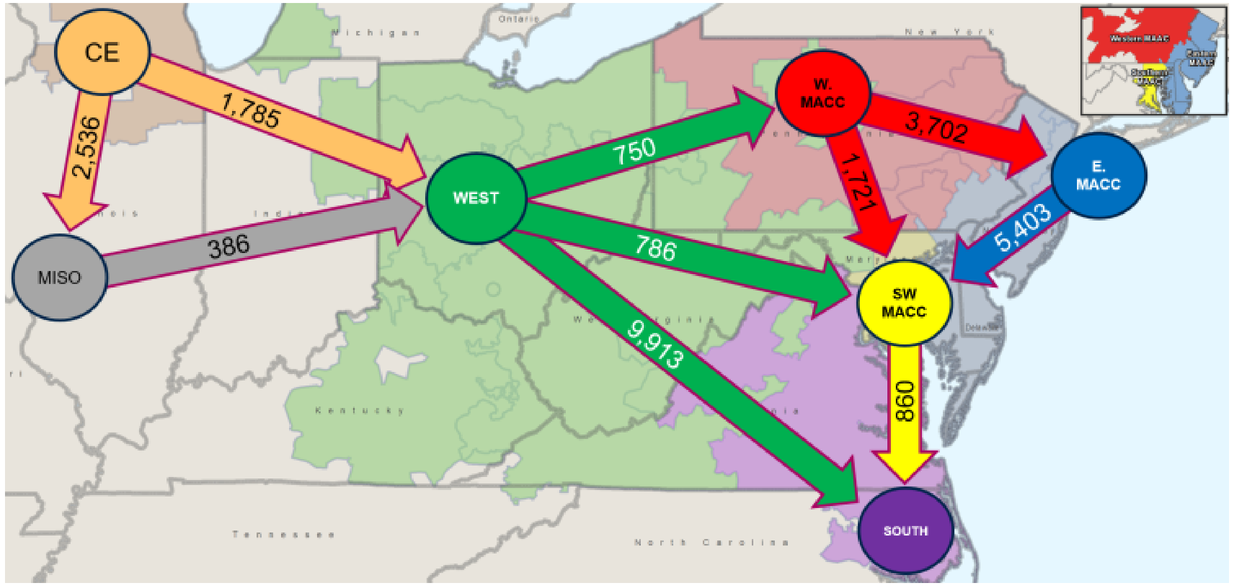
- Increasing flows from the center to the edges of the footprint
    - Growing flows towards MAAC
    - Flow reversal in ComEd which becomes importer in summer
    - Reduce exports from WMAAC
    - Reduced imports and higher exports in Dom

Winter

- RTEP 2029

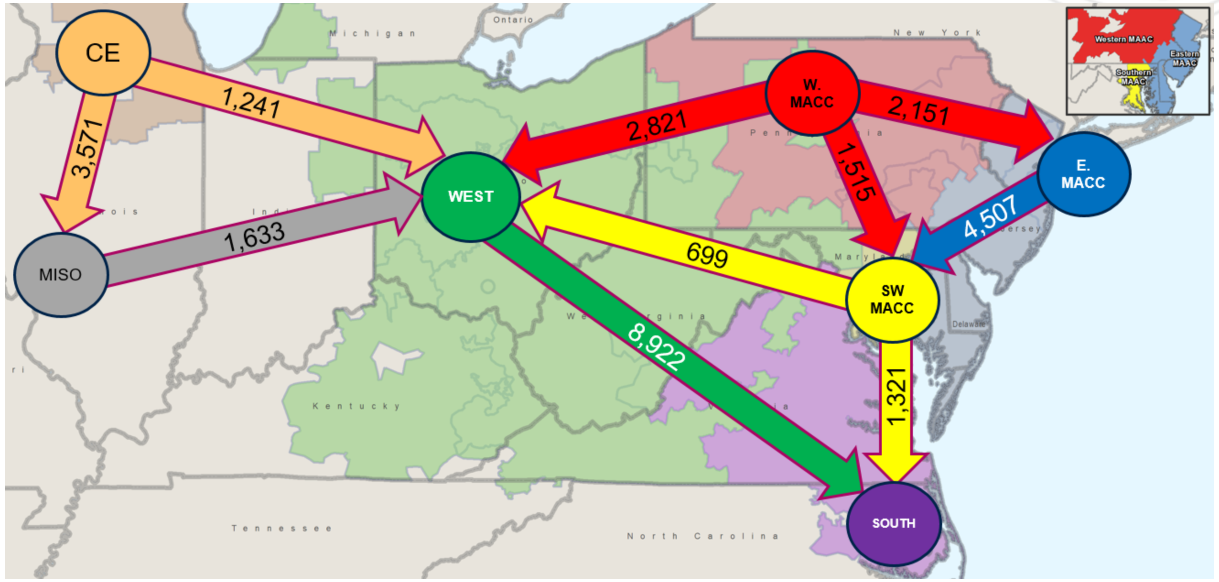


- WPS 2032

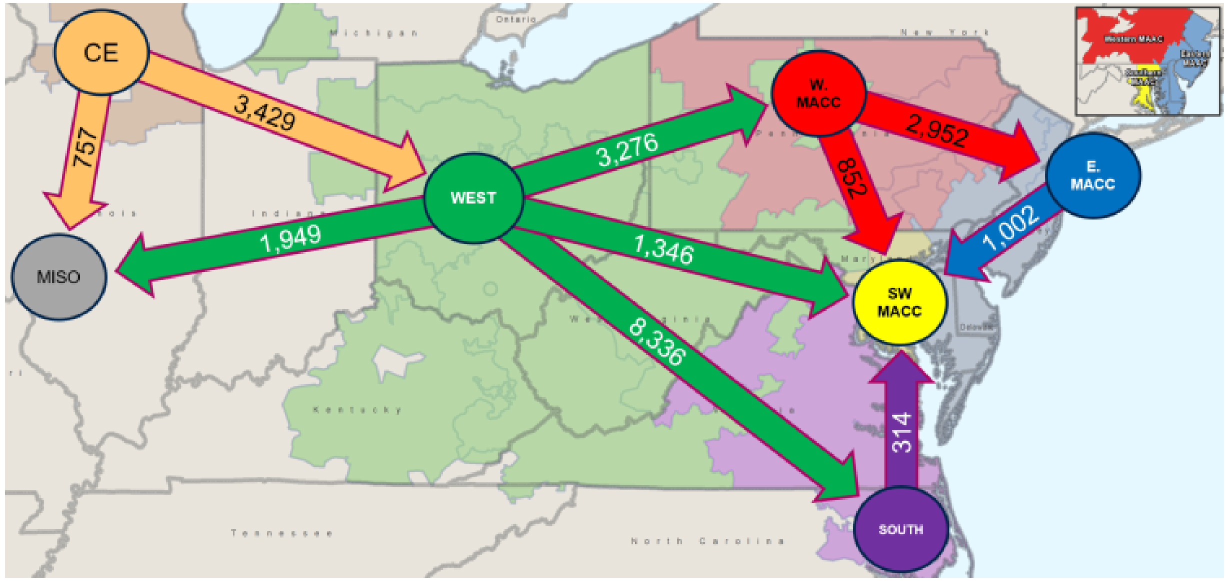


- Increased west-to-south flows
    - Dominion becomes even larger importer in winter (solar heavy)
    - ComEd exports despite retirements (wind heavy)
    - Reduced exports from WMAAC

- RTEP 2029



- WPS 2032



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

Next Steps

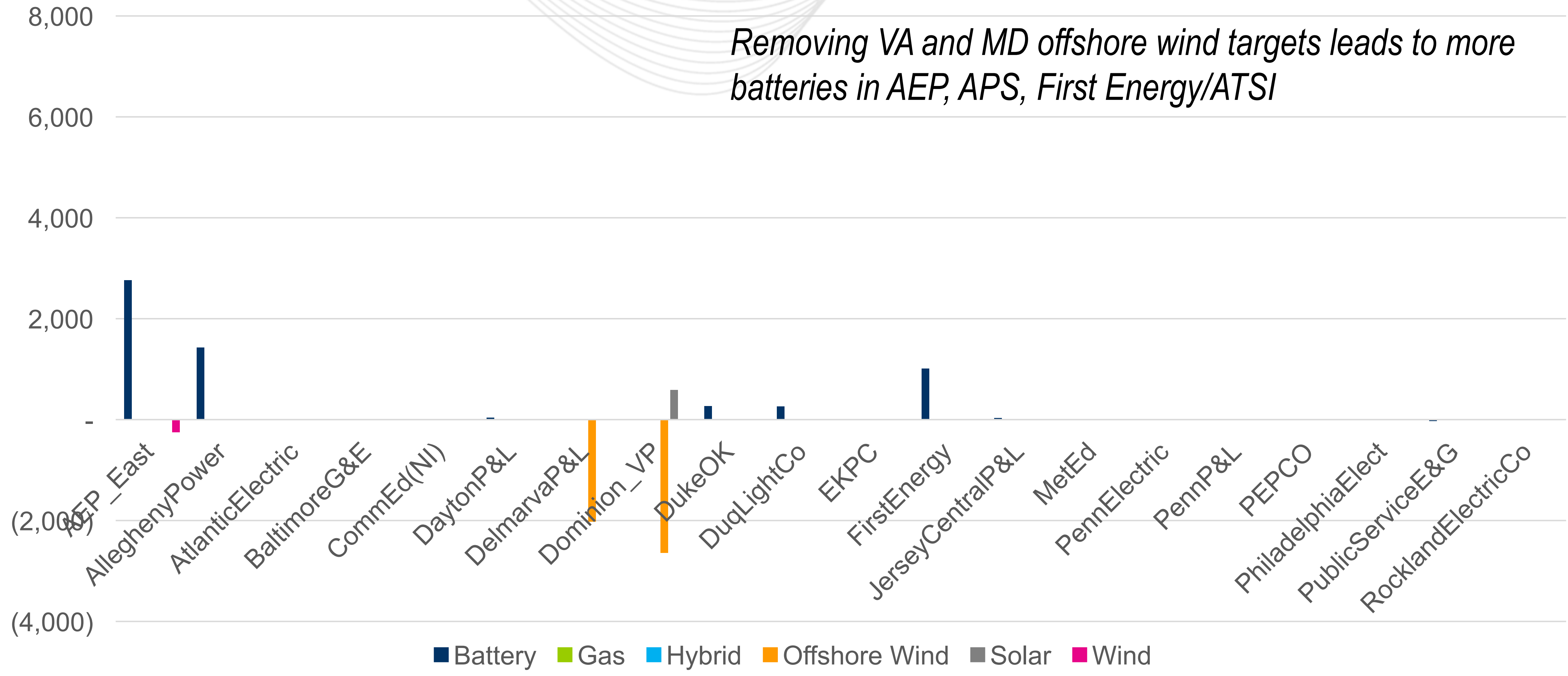
- Present WPS at Oct. 1st Special TEAC together with ISAC workbook *methodology* discussion
- PJM is conducting analysis on the WPS cases
  - Analysis results will be shared with stakeholders with ISAC and other stakeholders (target beginning of 2025)
- Continue scenario development discussions at Oct. 27th Special TEAC

Next Steps

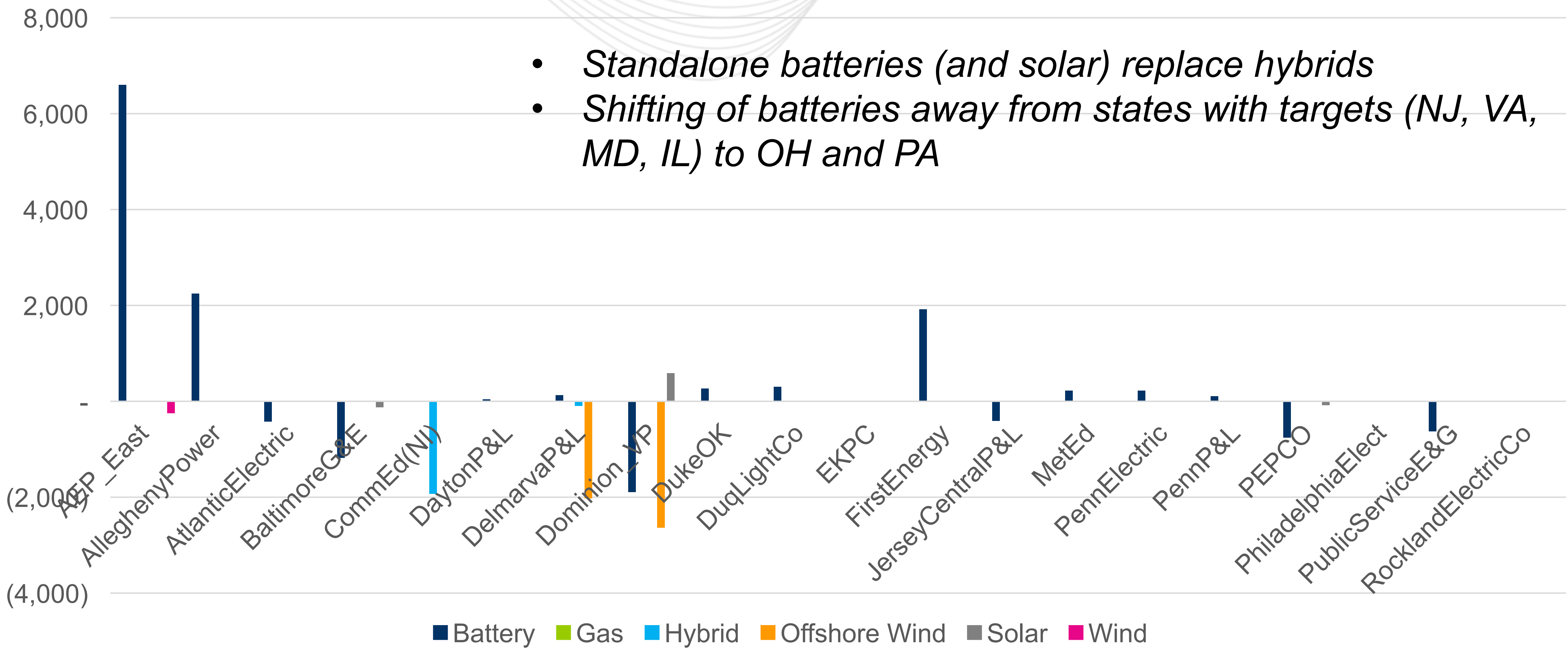
- PJM is conducting analyses on the WPS cases
  - Analysis results will be shared with stakeholders in a future special TEAC (target beginning of 2025)
- Continue scenario development discussion on Oct. 27th special TEAC

Appendix

Sensitivity: Remove OSW Policies in MD and VA (MW-change relative to Reference)

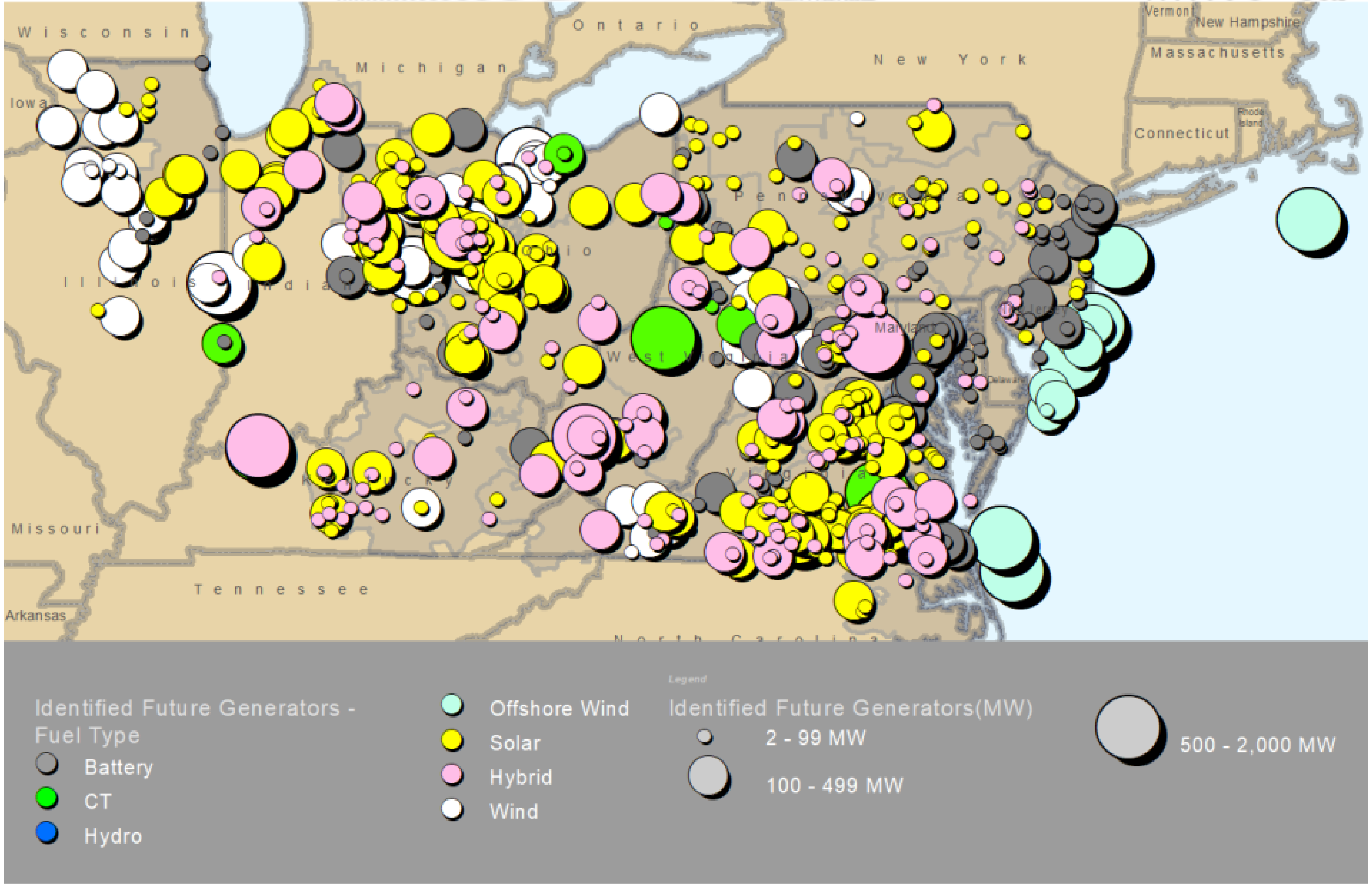


Sensitivity: Remove All New Generation Policies (MW-change relative to Reference)



- *Standalone batteries (and solar) replace hybrids*
- *Shifting of batteries away from states with targets (NJ, VA, MD, IL) to OH and PA*

Replacement Generation Relative to 2029



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

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

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

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

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

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

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

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

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

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LTRTP Workshop Policy Study

Member Hotline

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PROTECT THE POWER GRID

THINK BEFORE YOU CLICK!

BE ALERT TO MALICIOUS PHISHING EMAILS

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