

Transmission Expansion Advisory Committee

February 3, 2011

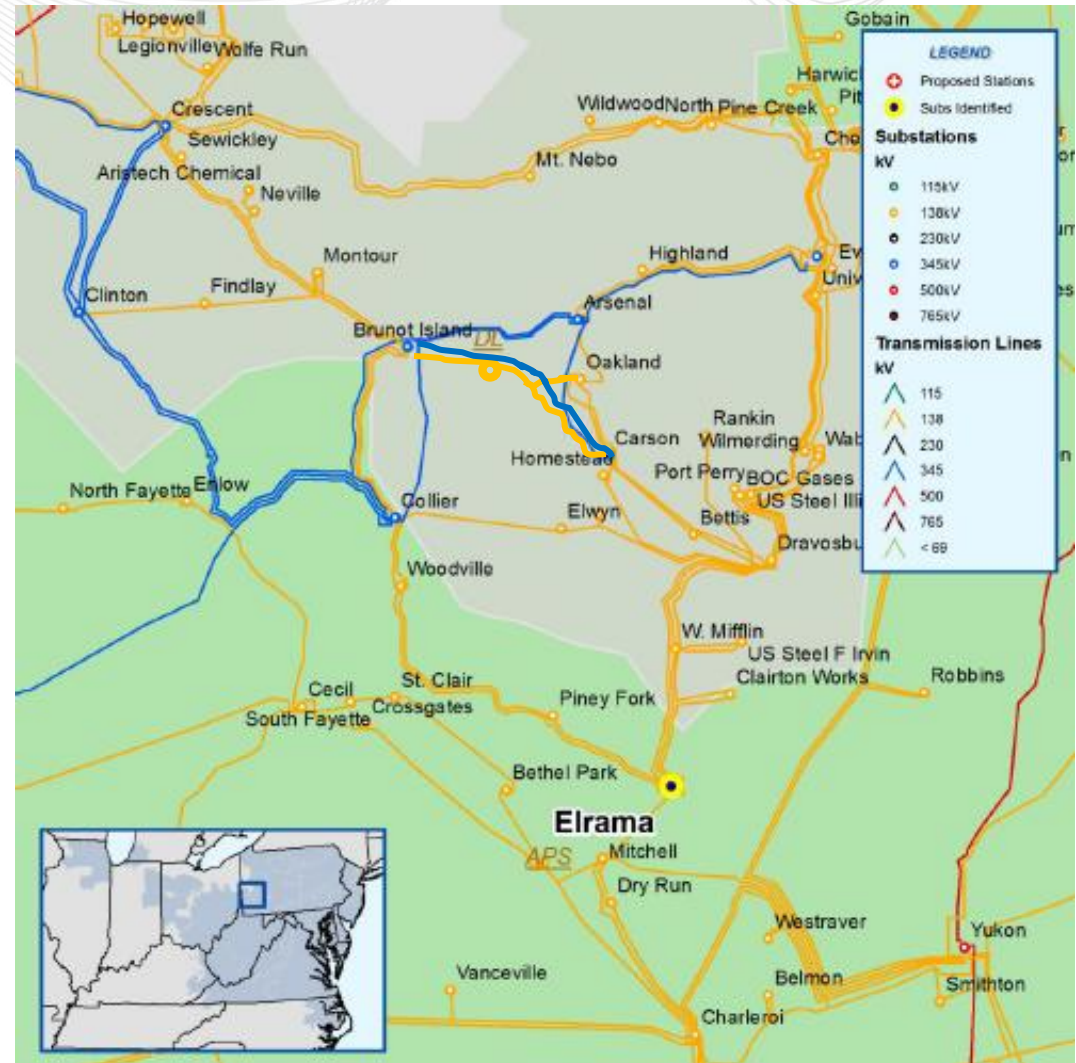
Issues Tracking

- Open Issues
 - Post 2016 machine list to PJM.com
 - Complete, 2016 machine list posted to January 2011 TEAC meeting materials

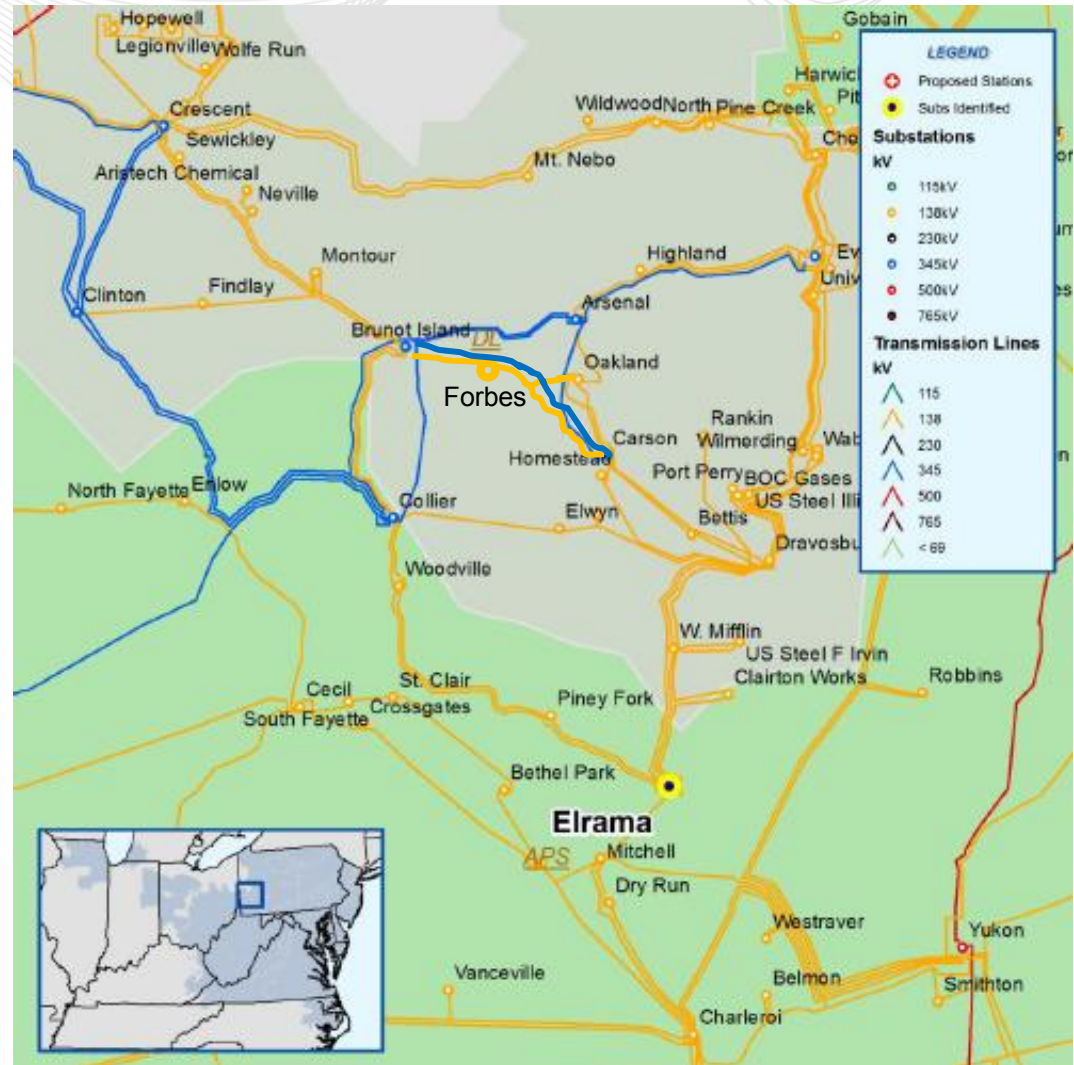
- New Issues

Baseline Reliability Update

- Revision for Brady Project
- Initially identified in 2007 RTEP N-1-1 study of 2012 summer case
 - Overloads of Carson – Oakland 138 kV and Arsenal – Brunot Island 345 kV
- Initial projects to change scope (\$291.3M):
 - B0501 - New Brady 345 kV substation and 345 / 138 kV transformer at Brady
 - B502 - New Underground Carson - Brady - Brunot Island 345 kV circuit
 - B0503 - Loop existing Carson - Oakland 138 kV into new Brady 138 kV substation

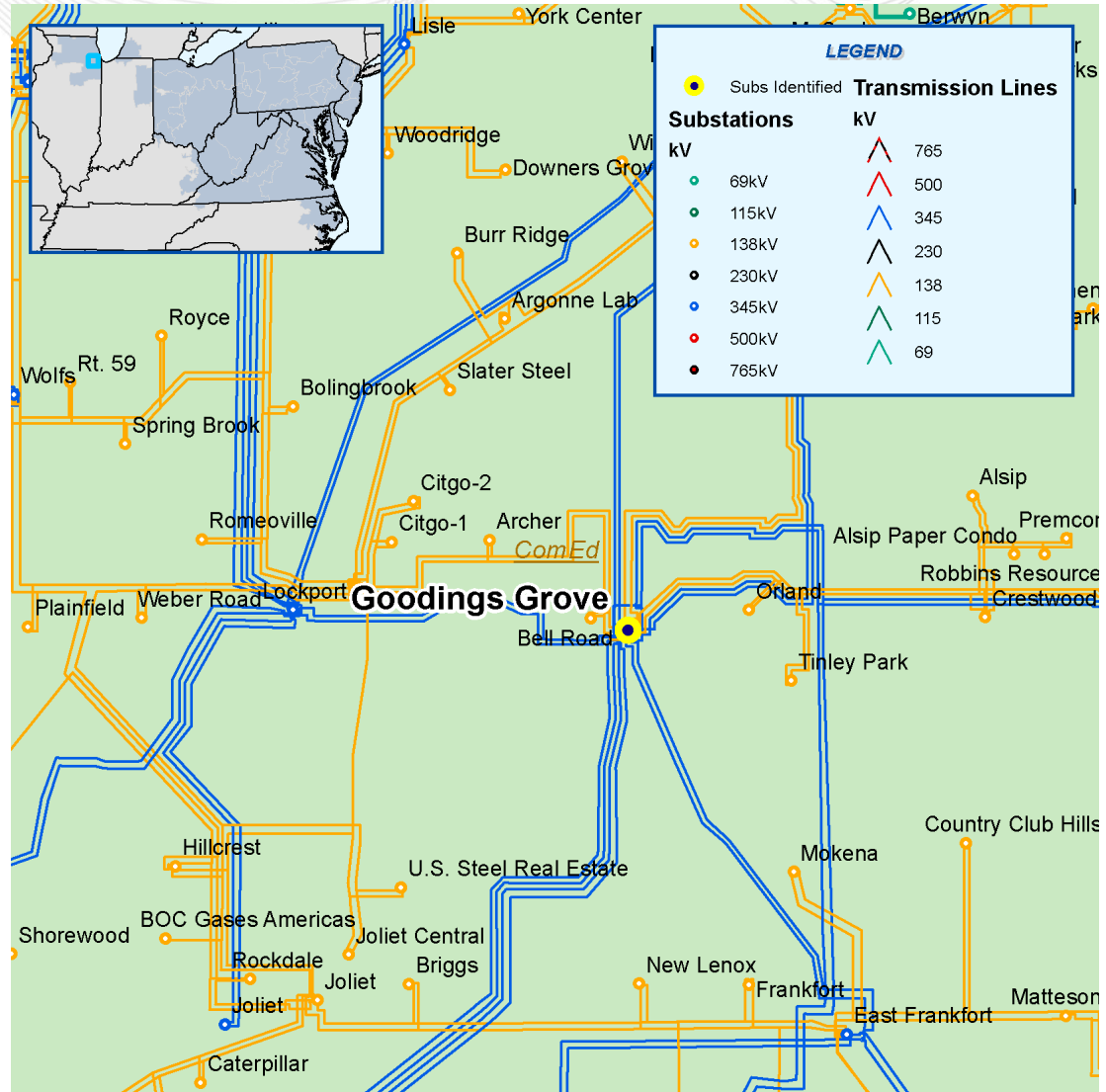


- Revised recommended Solution:
 - Construct new Brunot Island to Carson 345 kV line.
 - Convert Forbes to 138 kV Supply.
 - Extend & recable existing Carson - Oakland 138 kV.
- Expected IS Date:
 - Phased in approach
 - 6/12 to convert Forbes & recable portion of existing Carson - Oakland
 - 6/13 to recable remainder of Carson-Oakland
 - 6/16 to complete 345 kV loop
- Estimated project cost: \$188M

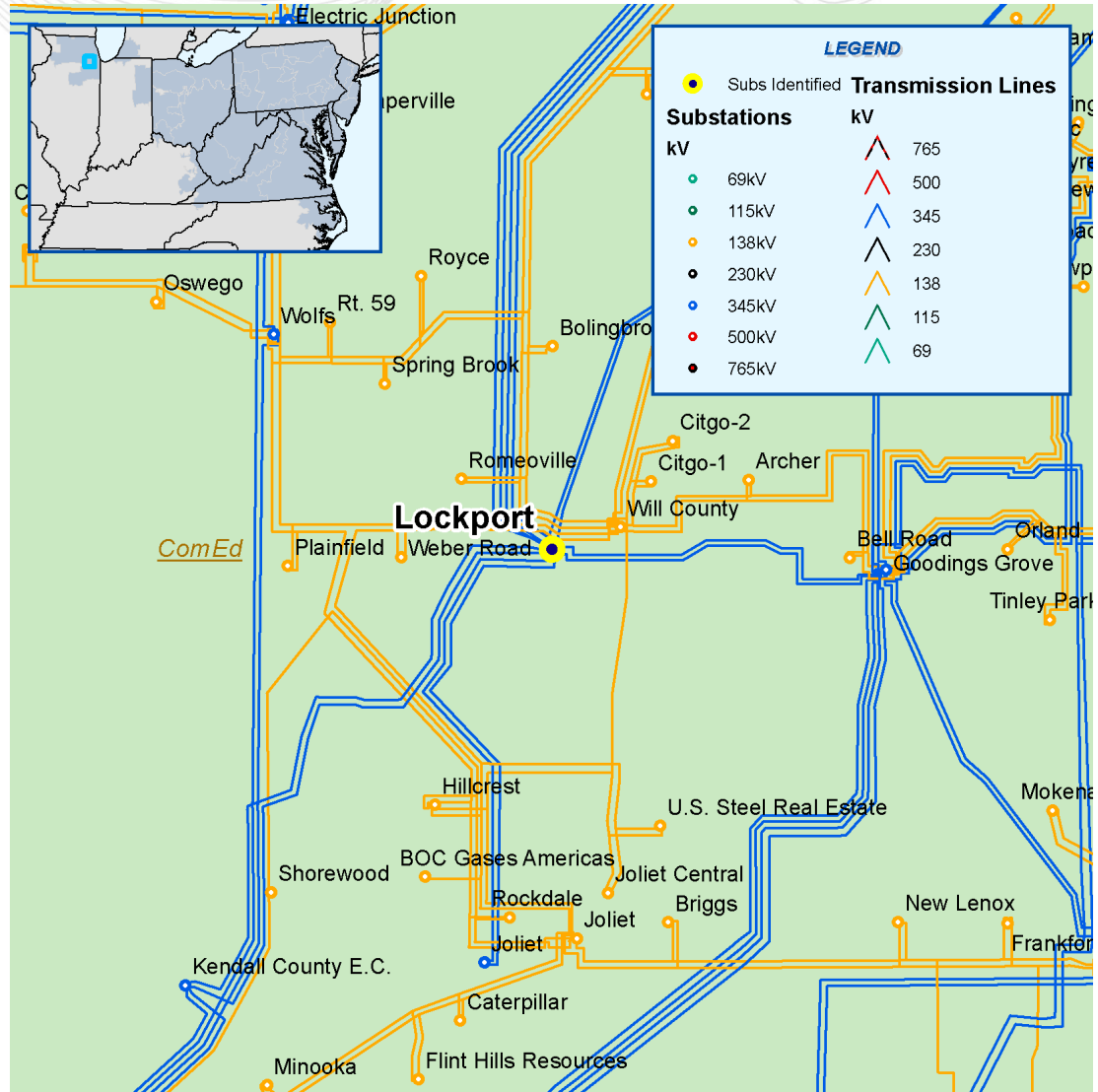


Supplemental Projects

- Replace two 345 kV circuit breakers at Goodings Grove TSS 116 on lines 11601 & 11602 with breakers with faster clearing times. (s0266)
- Estimated cost: \$ 4.6 M
- Required IS Date: 6/1/2012



- Replace four 345 kV circuit breakers at Lockport TSS 108 on lines 10805 & 10806 with breakers with faster clearing times. (s0267)
- Estimated cost: \$ 8.0 M
- Required IS Date: 6/1/2012



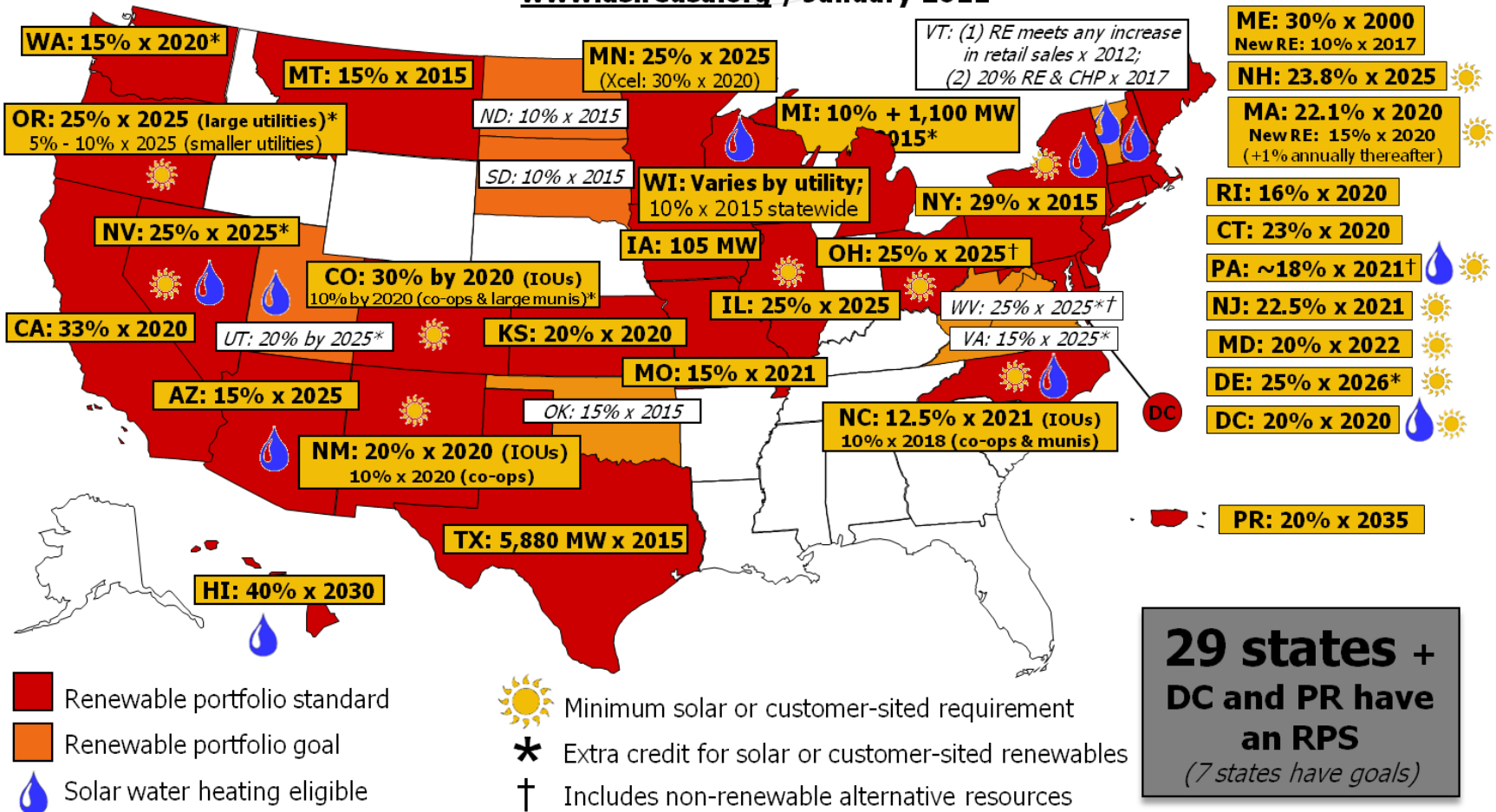
PJM Generation Scenario Analysis

- Study Scenario
 - Meet RPS requirements
- Sourcing Strategies
 - Meet RPS with PJM resources
 - Meet RPS with a combination of PJM resources and external resources
- Study Years
- Analysis Methods

What are the energy requirements to meet RPS requirements?

RPS Policies

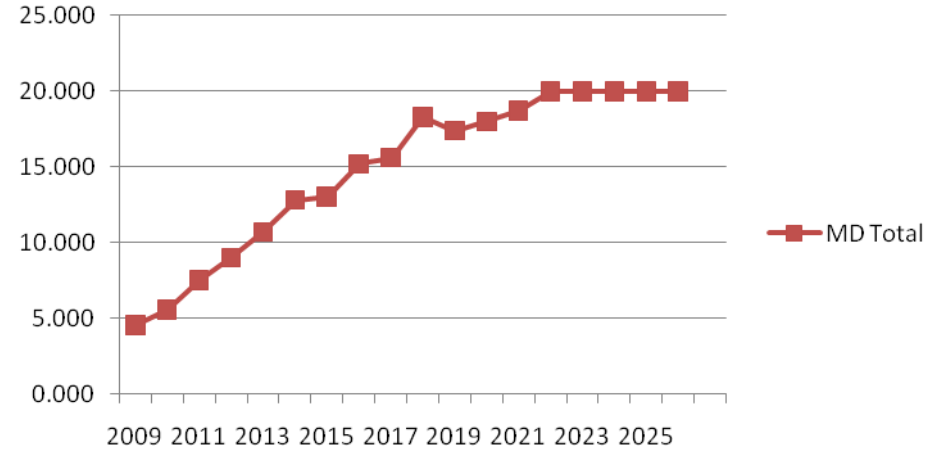
www.dsireusa.org / January 2011



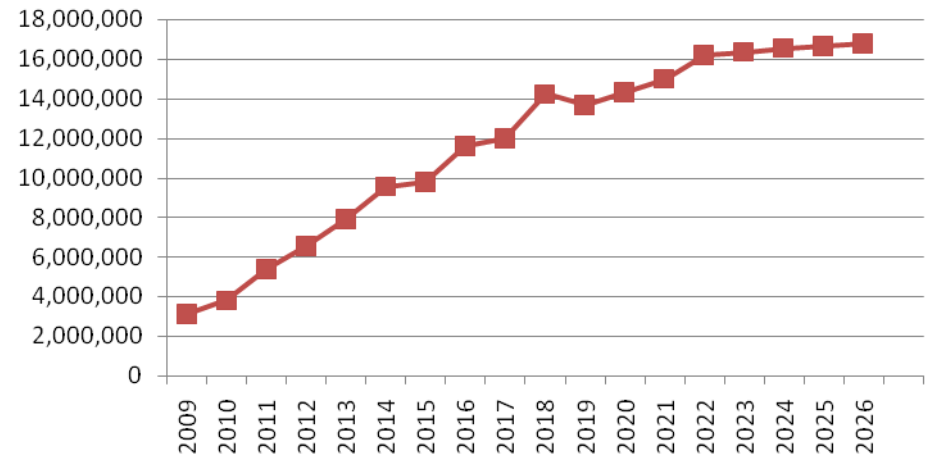
29 states + DC and PR have an RPS
(7 states have goals)

- 20% by 2022
- Solar – 2% by 2022
- Eligible Resources Include: Solar, Thermal Electric, Photovoltaic, Landfill Gas, Wind, Biomass, Hydro, Geothermal Electric, Municipal Solid Waste, Anaerobic Digestion, Tidal, Wave Energy, Ocean Thermal, Fuels Cells using renewable fuels

Maryland Total Percentage

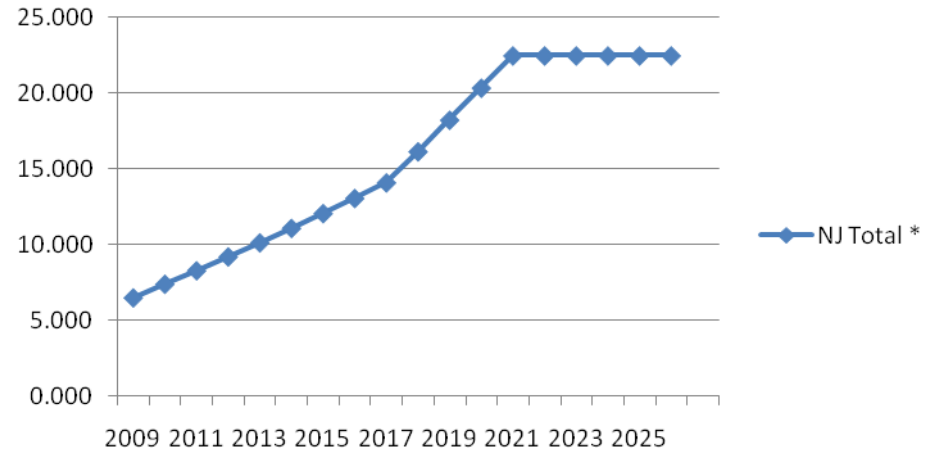


Maryland Total MWh

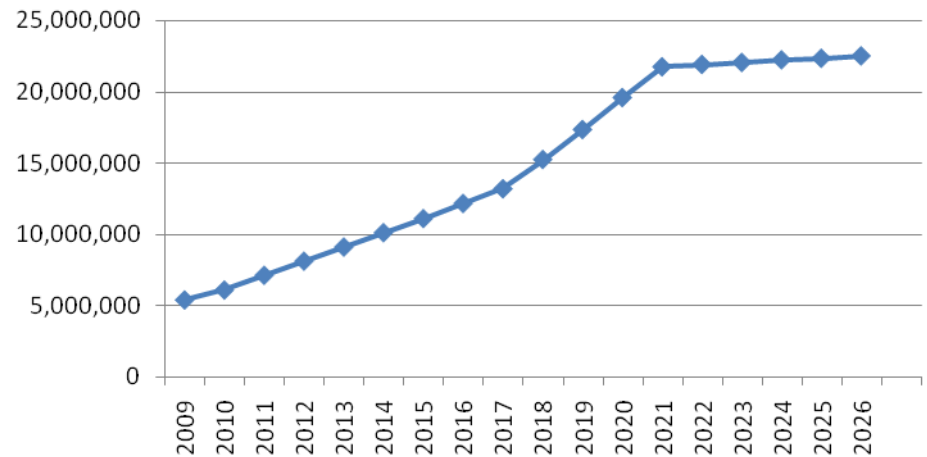


- 22.5% by 2020-2021
- Solar Electric 5,316 GWh by 2025 – 2026
- Eligible Resources Include: Solar, Thermal Electric, Photovoltaic, Landfill Gas, Wind, Biomass, Hydroelectric, Geothermal Electric, Resource Recovery facilities approved by DEP, Anaerobic Digestion, Tidal, Wave, Fuel Cells using Renewable Fuels

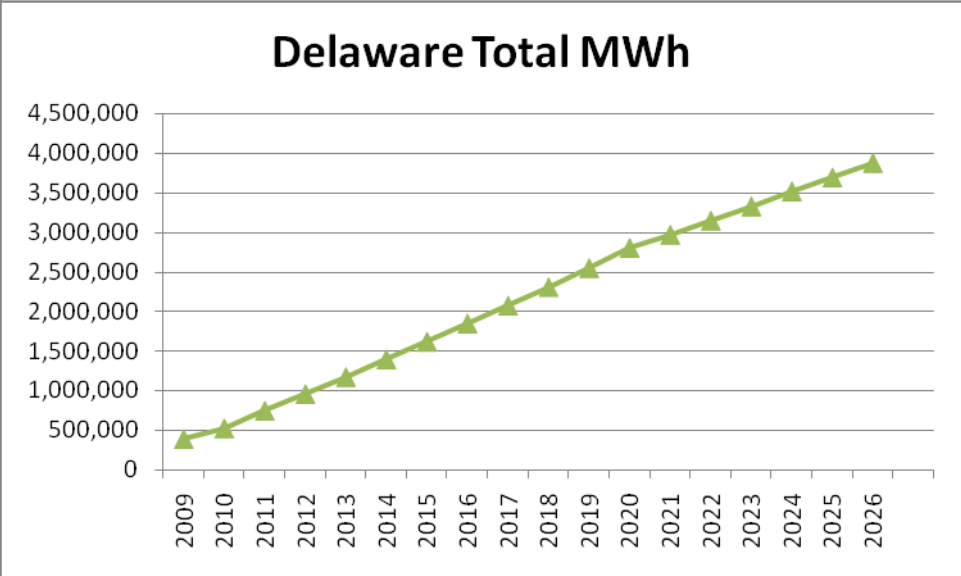
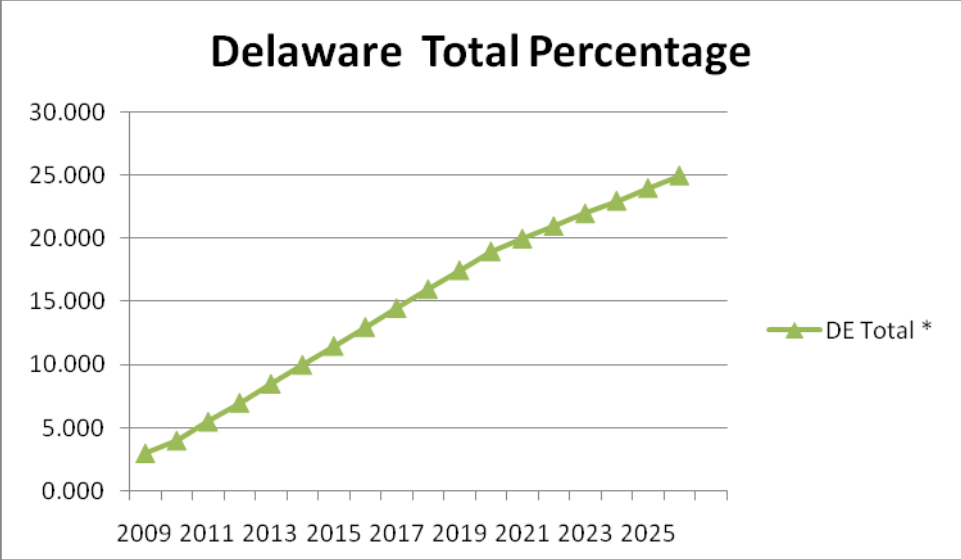
New Jersey Total Percentage



New Jersey Total MWh

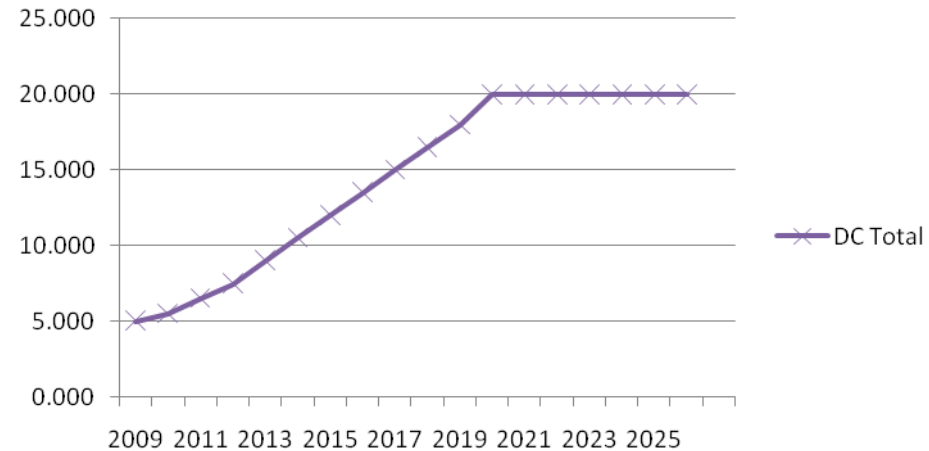


- 25% by 2025-2026
- Solar 3.5% by 2025 – 2026
- Eligible Resources Include: Solar, Thermal Electric, Photovoltaic, Landfill Gas, Wind, Biomass, Hydroelectric, Geothermal Electric, Anaerobic Digestion, Tidal, Wave, Ocean Thermal Fuel Cells using Renewable Fuels

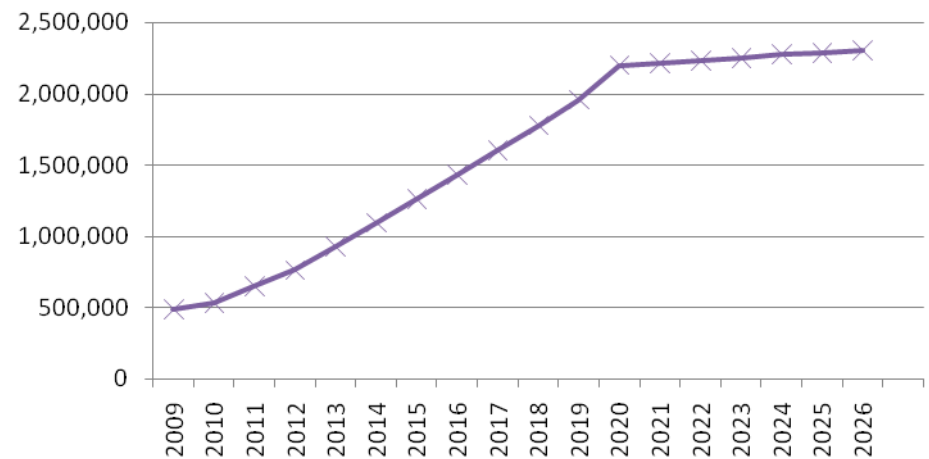


- 20% by 2020
- Solar 0.4% by 2020
- Eligible Resources Include: Solar Water Heat, Solar Space Heat, Solar Thermal Electric, Photovoltaic, Landfill Gas, Wind, Biomass, Hydroelectric, Geothermal Electric, Fuel Cells, Municipal Solid Waste, Solar Space Cooling, Cofiring, Tidal, Wave, Ocean Thermal

District of Columbia Total Percentage

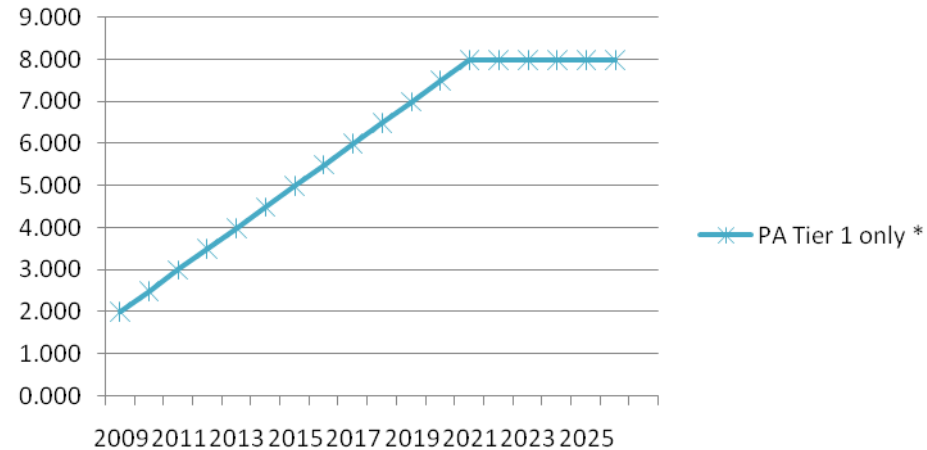


District of Columbia Total MWh

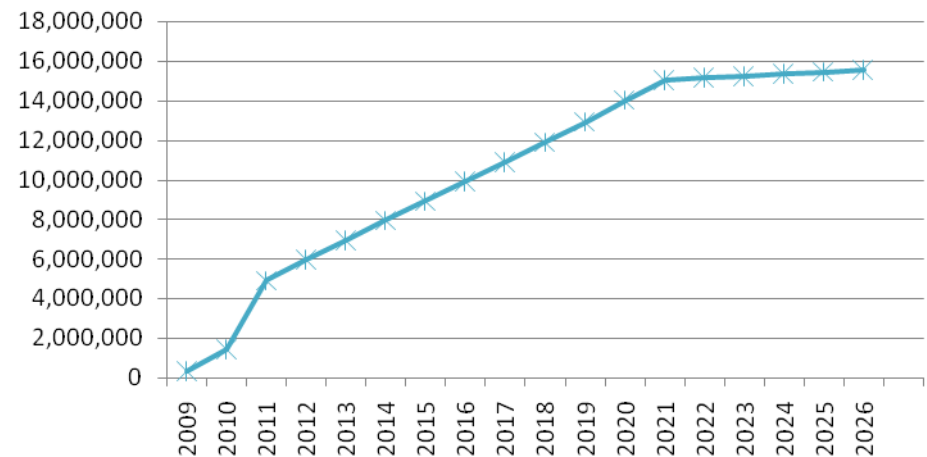


- ~ 18% by 2020-2021
- Tier I: ~8% by 2020-2021 including PV
- Tier II: 10% by 2020-2021
- Tier I resources include: PV, solar-thermal, wind, low-impact hydro, geothermal, biomass, biologically derived methane, coal mine methane and fuel cells
- Tier II resources include: waste coal, distributed generation, demand side management, large scale hydro, municipal solid waste, wood pulping, and IGCC
- For this study, PJM will account for Tier 1 resources only

Pennsylvania Total Percentage

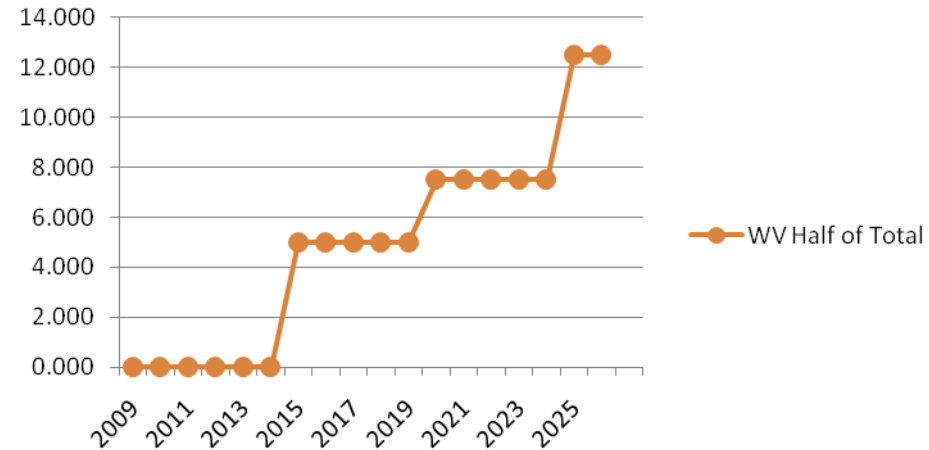


Pennsylvania Total MWh (Tier I)

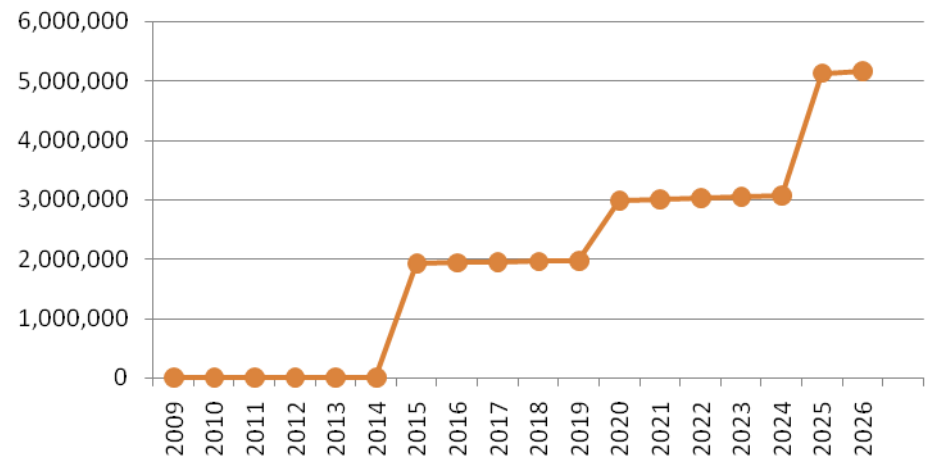


- 25% alternative and renewable by 2025
- Eligible Resources Include: Solar Thermal Electric, Photovoltaic, Landfill Gas, Wind, Biomass, Hydroelectric, Geothermal Electric, Fuel Cells, Municipal Solid Waste, other non-renewable alternative energy resources (coal technology, coal bed methane, natural gas, fuel from coal gasification, pumped storage hydro), Anaerobic Digestion, Small Hydro, Biodiesel
- Given the “other non-renewable alternative energy resources”, this study will assume half of the requirement

West Virginia Total Percentage

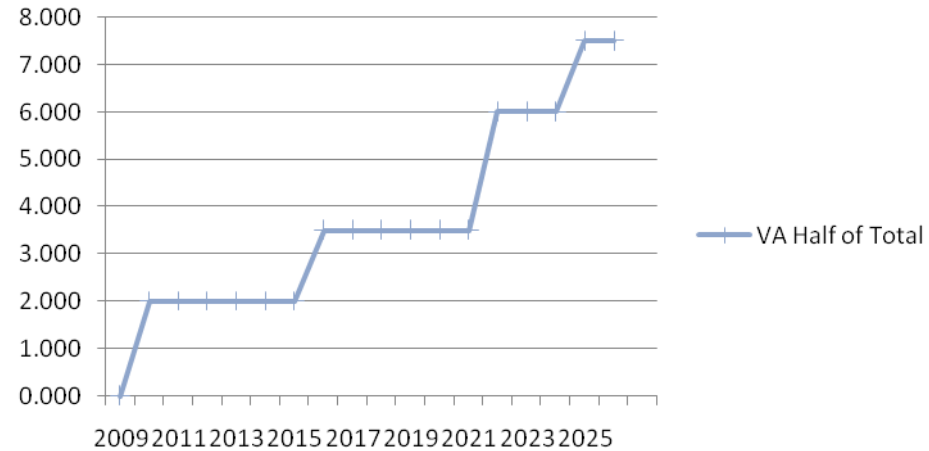


West Virginia Total MWh

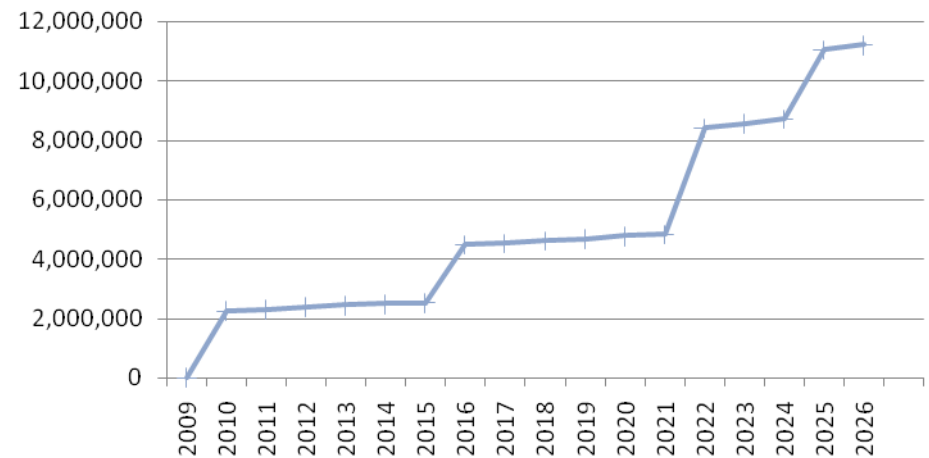


- 15% of base year (2007) by 2025
- Eligible Resources Include: Solar, Thermal Electric, Photovoltaic, Landfill Gas, Wind, Biomass, Hydro, Geothermal Electric, Energy from Waste, Anaerobic Digestion, Tidal Energy, Wave Energy
- PJM study will assume half of the target because the requirement is based on 2007 sales less average nuclear production between 2004 - 2006, only applies to IOU's and double credit for wind and solar

Virginia Total Percentage

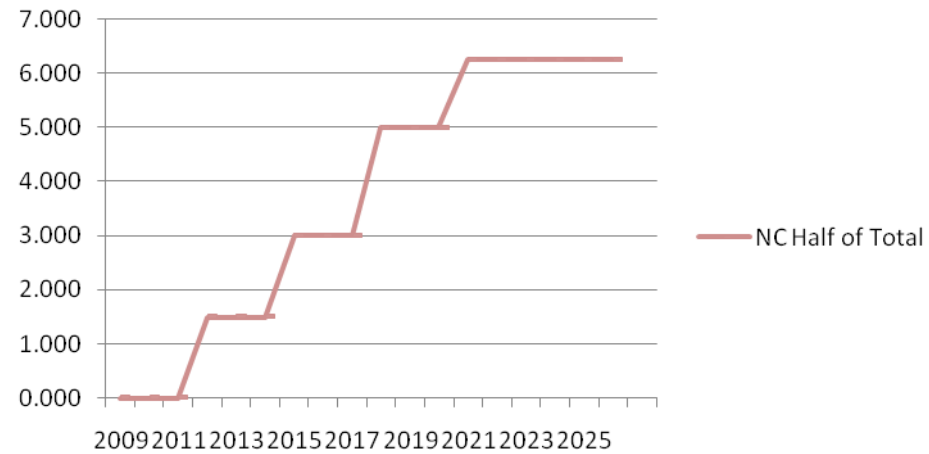


Virginia Total MWh

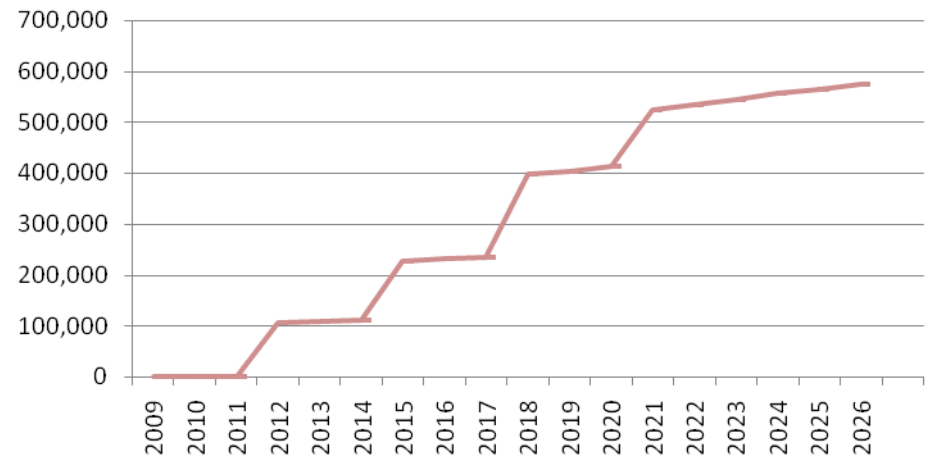


- 12.5% by 2021
- Solar – 0.2% by 2018
- Eligible Resources Include: Solar Water Heat, Solar Space Heat, Solar Thermal Electric, Solar Thermal Process Heat, Photovoltaic, Landfill Gas, Wind, Biomass, Geothermal Electric, CHP/Cogeneration, Hydrogen, Anaerobic Digestion, Small Hydro, Tidal Energy, Wave Energy
- PJM study will assume half of the target because energy efficiency and CHP can account for up to 25% through 2021 and 40% thereafter

North Carolina Total Percentage

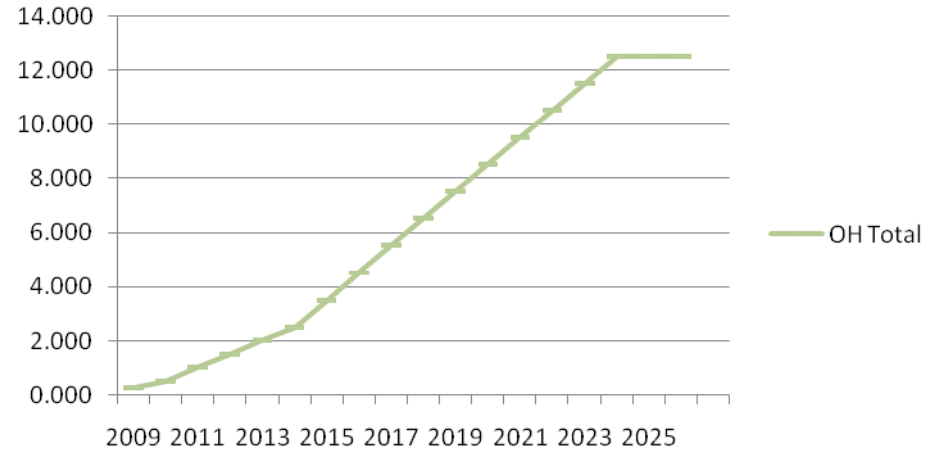


North Carolina Total MWh

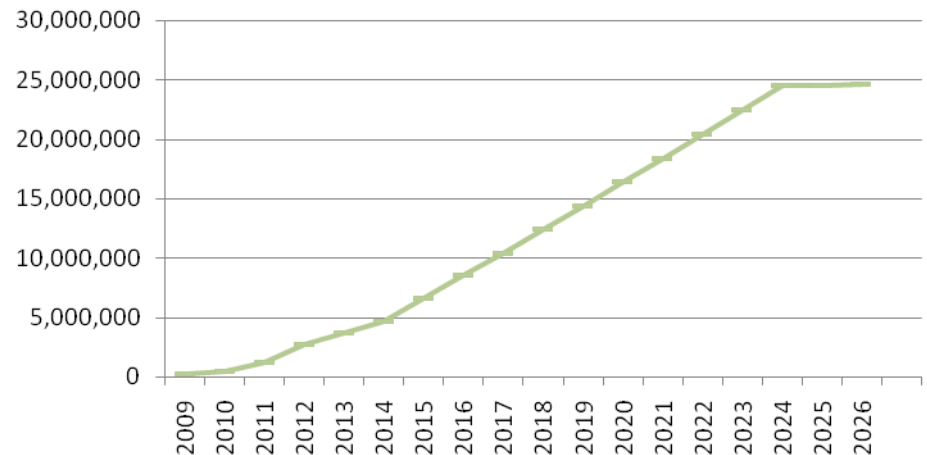


- 12.5% by 2025
- Solar – 0.5% by 2024
- Eligible Resources Include: Solar, Thermal Electric, Photovoltaic, Landfill Gas, Wind, Biomass, Hydro, Geothermal Electric, Fuel Cells, Municipal Solid Waste, Waste Heat, Energy Storage, Clean Coal, Coal Mine Methane, Advanced Nuclear, Anaerobic Digestion, Microturbines

Ohio Total Percentage

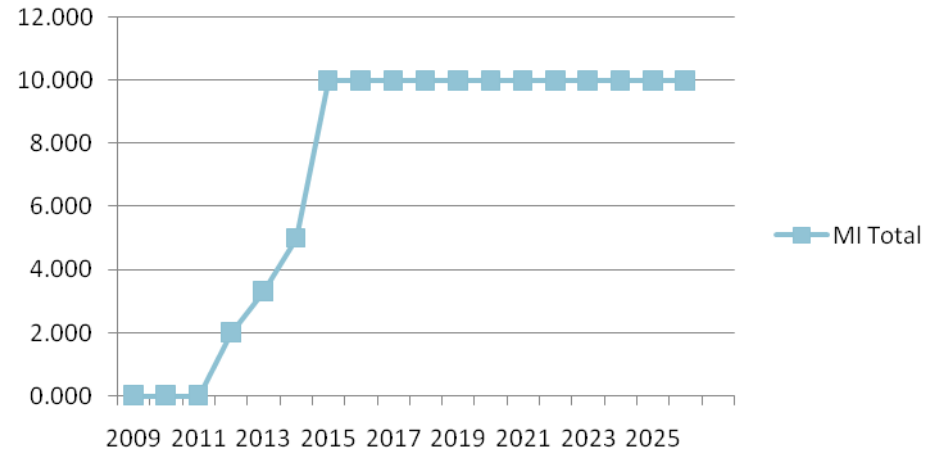


Ohio Total MWh

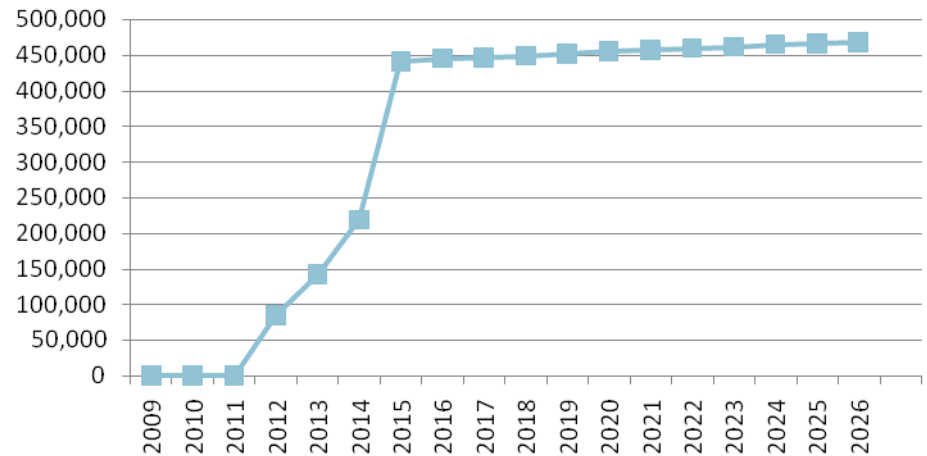


- 10% by 2015
- Eligible Resources Include: Solar, Thermal Electric, Photovoltaic, Landfill Gas, Wind, Biomass, Hydro, Geothermal Electric, Municipal Solid Waste, CHP/Cogeneration, Coal fired with CCS, Gasification, Anaerobic Digestion, Tidal, Wave Energy

Michigan Total Percentage

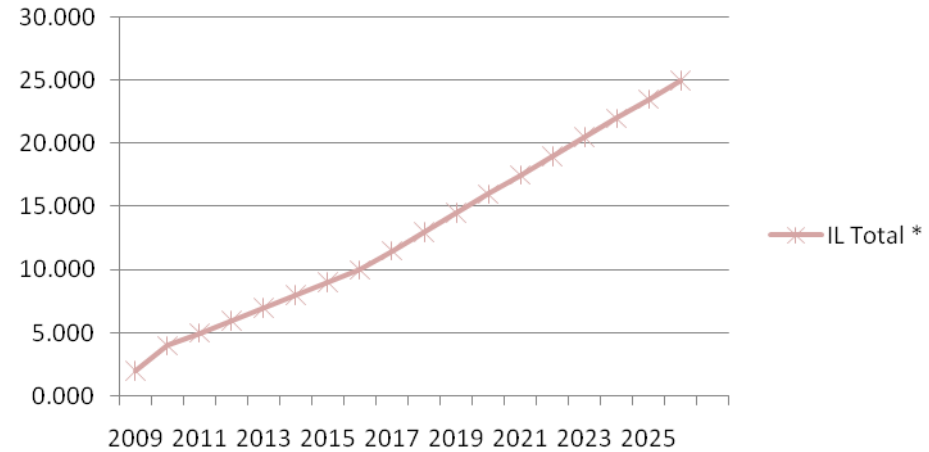


Michigan Total MWh

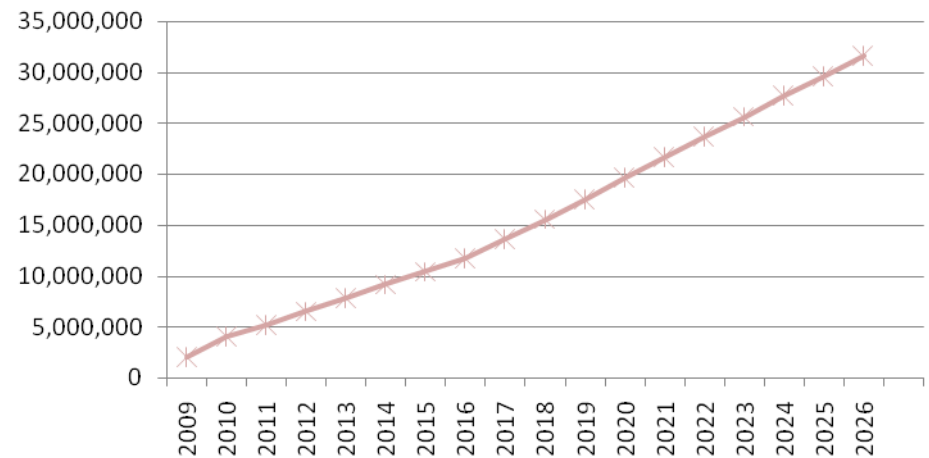


- 25% by EY 2026
- Solar – 6% by EY 2026
- Eligible Resources Include: Solar, Thermal Electric, Photovoltaic, Landfill Gas, Wind, Biomass, Hydro, Biodiesel

Illinois Total Percentage



Illinois Total MWh



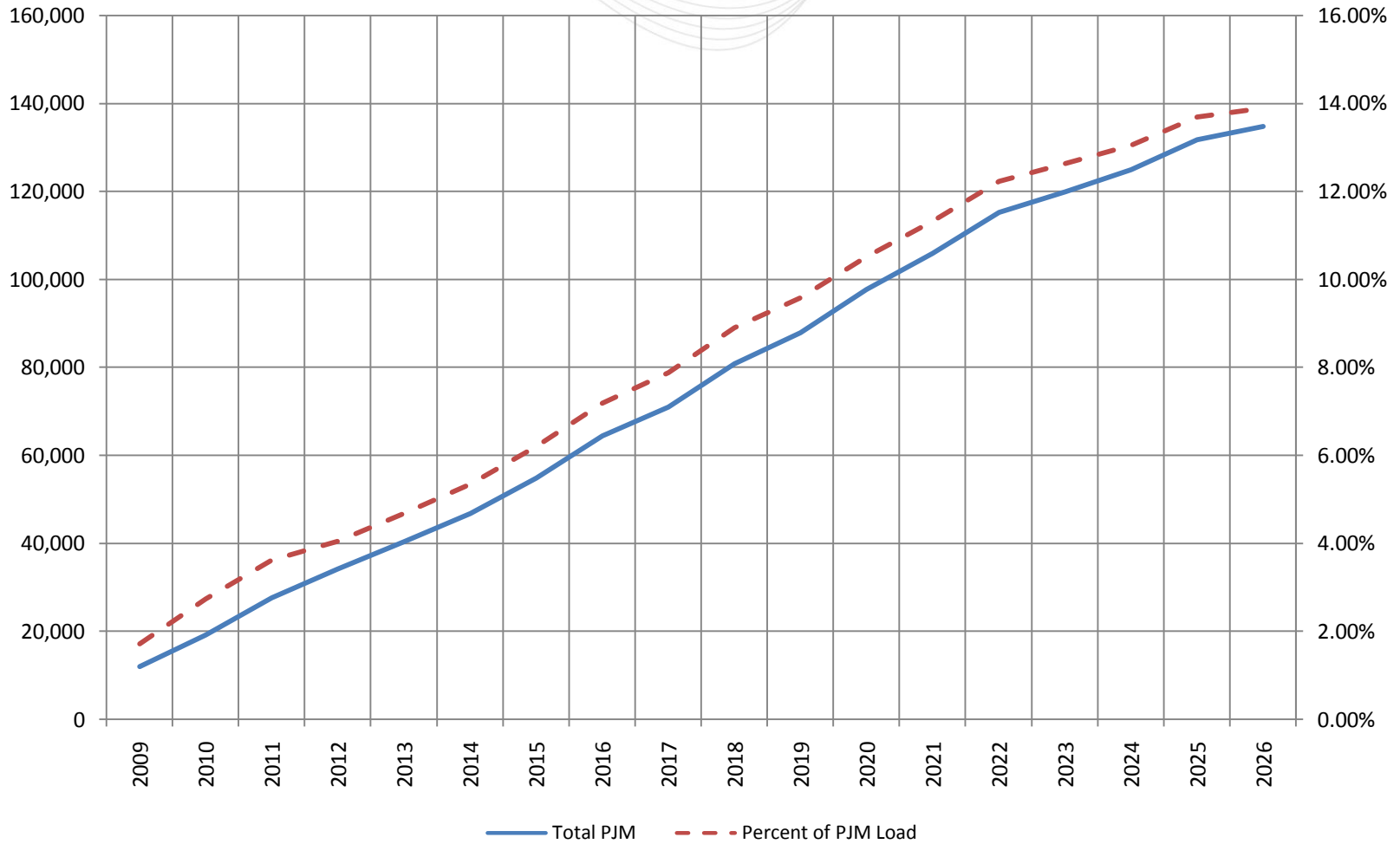


Renewable Energy Requirement Assumptions

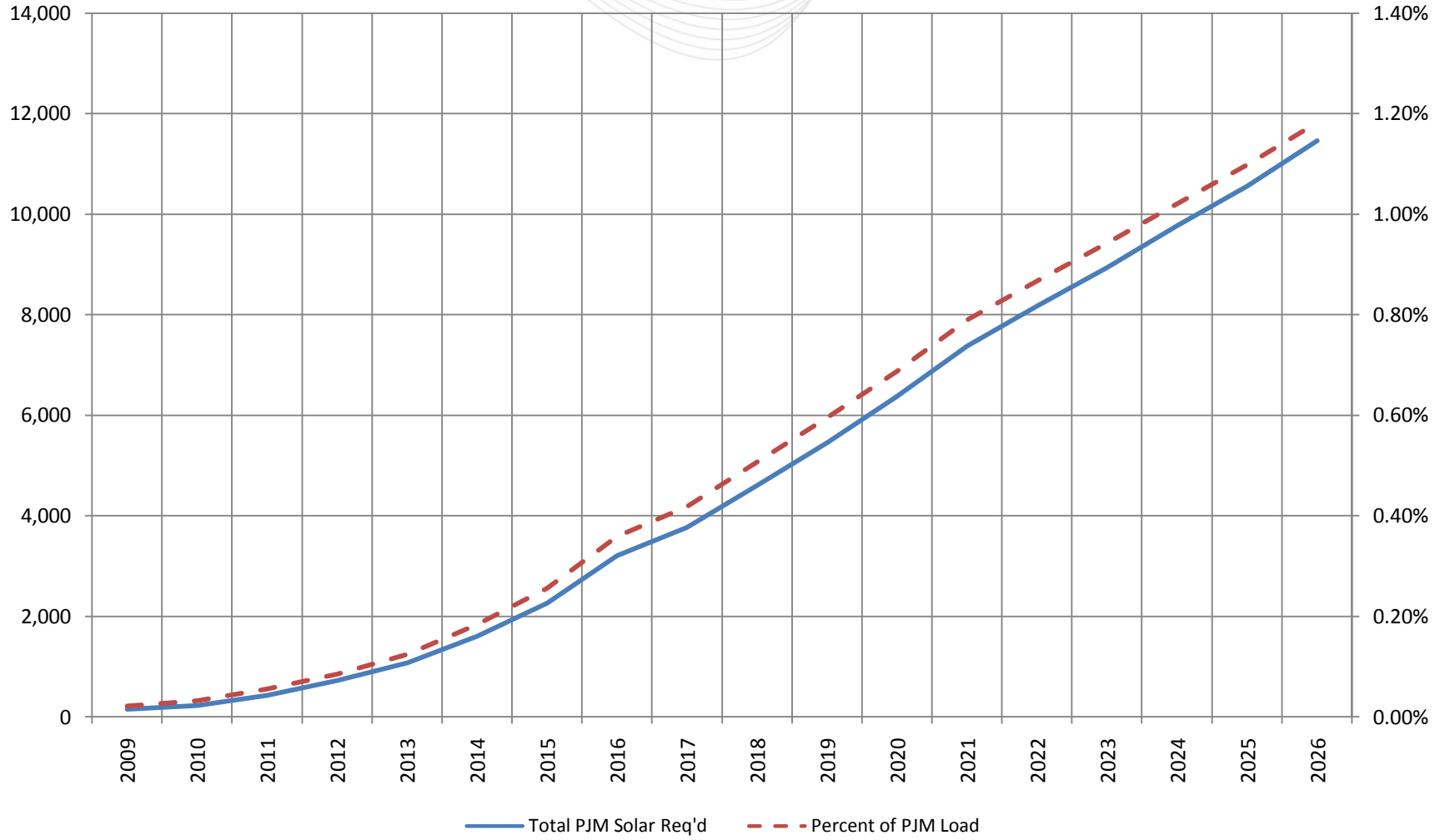
| | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 |
|------------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|-------------|-------------|-------------|-------------|-------------|-------------|
| NJ | 5,424,095 | 6,118,658 | 7,154,171 | 8,145,084 | 9,135,633 | 10,139,022 | 11,131,108 | 12,190,249 | 13,216,344 | 15,271,734 | 17,375,158 | 19,614,957 | 21,773,700 | 21,939,075 | 22,077,225 | 22,263,300 | 22,368,600 | 22,535,775 |
| MD | 3,130,720 | 3,823,829 | 5,407,292 | 6,582,032 | 7,908,351 | 9,573,198 | 9,821,102 | 11,627,915 | 12,016,828 | 14,239,666 | 13,671,316 | 14,336,080 | 15,001,931 | 16,205,104 | 16,357,396 | 16,546,818 | 16,652,072 | 16,795,858 |
| DE | 394,426 | 528,187 | 751,097 | 962,360 | 1,176,434 | 1,399,440 | 1,622,478 | 1,852,942 | 2,076,690 | 2,311,232 | 2,550,695 | 2,806,433 | 2,973,180 | 3,150,063 | 3,329,172 | 3,518,977 | 3,694,656 | 3,877,300 |
| DC | 485,767 | 530,667 | 650,754 | 763,605 | 927,288 | 1,093,869 | 1,260,684 | 1,434,551 | 1,603,350 | 1,779,674 | 1,958,094 | 2,202,360 | 2,215,740 | 2,235,420 | 2,253,600 | 2,277,180 | 2,290,080 | 2,307,360 |
| PA | 306,303 | 1,421,483 | 4,880,857 | 5,949,575 | 6,937,070 | 7,928,000 | 8,901,787 | 9,904,126 | 10,866,193 | 11,886,048 | 12,905,580 | 14,004,345 | 15,016,416 | 15,130,388 | 15,225,162 | 15,357,598 | 15,432,442 | 15,546,313 |
| WV | 0 | 0 | 0 | 0 | 0 | 0 | 1,914,864 | 1,932,692 | 1,939,698 | 1,953,880 | 1,965,640 | 2,981,781 | 2,995,209 | 3,016,722 | 3,034,950 | 3,061,443 | 5,122,000 | 5,156,415 |
| VA | 0 | 2,245,720 | 2,302,463 | 2,378,288 | 2,438,984 | 2,484,757 | 2,520,478 | 4,484,945 | 4,535,479 | 4,606,007 | 4,678,531 | 4,770,518 | 4,834,872 | 8,427,010 | 8,561,599 | 8,721,722 | 11,048,082 | 11,217,431 |
| NC | 0 | 0 | 0 | 106,390 | 109,359 | 111,590 | 226,758 | 231,008 | 234,072 | 397,026 | 404,278 | 413,105 | 524,536 | 534,577 | 544,447 | 555,971 | 564,703 | 574,551 |
| OH | 198,737 | 400,538 | 1,197,432 | 2,682,456 | 3,650,364 | 4,634,962 | 6,544,154 | 8,488,450 | 10,405,251 | 12,372,396 | 14,335,629 | 16,406,018 | 18,380,569 | 20,411,960 | 22,418,678 | 24,486,848 | 24,521,608 | 24,617,920 |
| IN | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| MI | 0 | 0 | 0 | 84,854 | 142,562 | 218,847 | 441,231 | 445,155 | 446,433 | 449,247 | 451,305 | 455,724 | 457,086 | 459,666 | 461,598 | 464,835 | 465,879 | 468,201 |
| KY | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| TN | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| IL | 2,016,492 | 4,083,360 | 5,216,950 | 6,512,580 | 7,848,190 | 9,144,640 | 10,434,150 | 11,757,400 | 13,618,760 | 15,566,850 | 17,557,760 | 19,667,840 | 21,643,650 | 23,663,550 | 25,637,505 | 27,680,620 | 29,597,310 | 31,642,250 |
| Total PJM | 11,956,540 | 19,152,442 | 27,561,015 | 34,167,224 | 40,274,235 | 46,728,324 | 54,818,794 | 64,349,433 | 70,959,100 | 80,833,760 | 87,853,986 | 97,659,161 | 105,816,889 | 115,173,535 | 119,901,332 | 124,935,311 | 131,757,431 | 134,739,374 |

- Updated based on PJM 2011 Load Forecast
- RPS information taken from www.dsireusa.org
- West Virginia assumed to be half because alternative resources can be used which include: pumped storage, waste coal, double credit for renewables, certain coal technology and energy efficiency
- Virginia assumed half because requirement is based on 2007 sales less nuclear production, it only applies to IOU's and there is a double credit for wind and solar.
- North Carolina - Assumed half because energy efficiency and CHP can count for up to 25% through 2021 and 40% thereafter, and out of state resources can count for up to 25%
- Pennsylvania – “Tier I” only i.e. wind, solar, biomass, geothermal

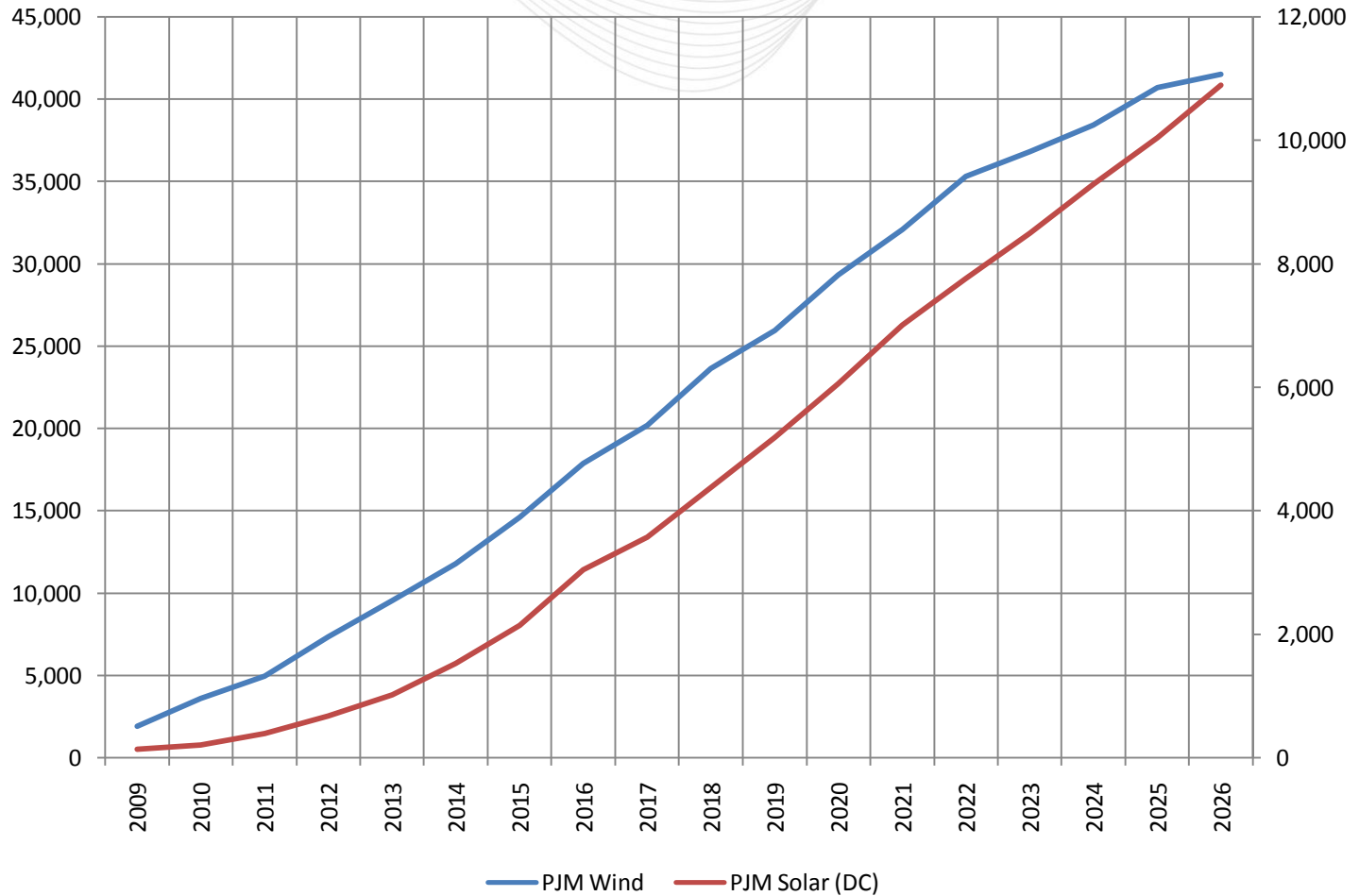
Renewable Energy Required in PJM (GWh)



Solar Energy Required in PJM (GWh)

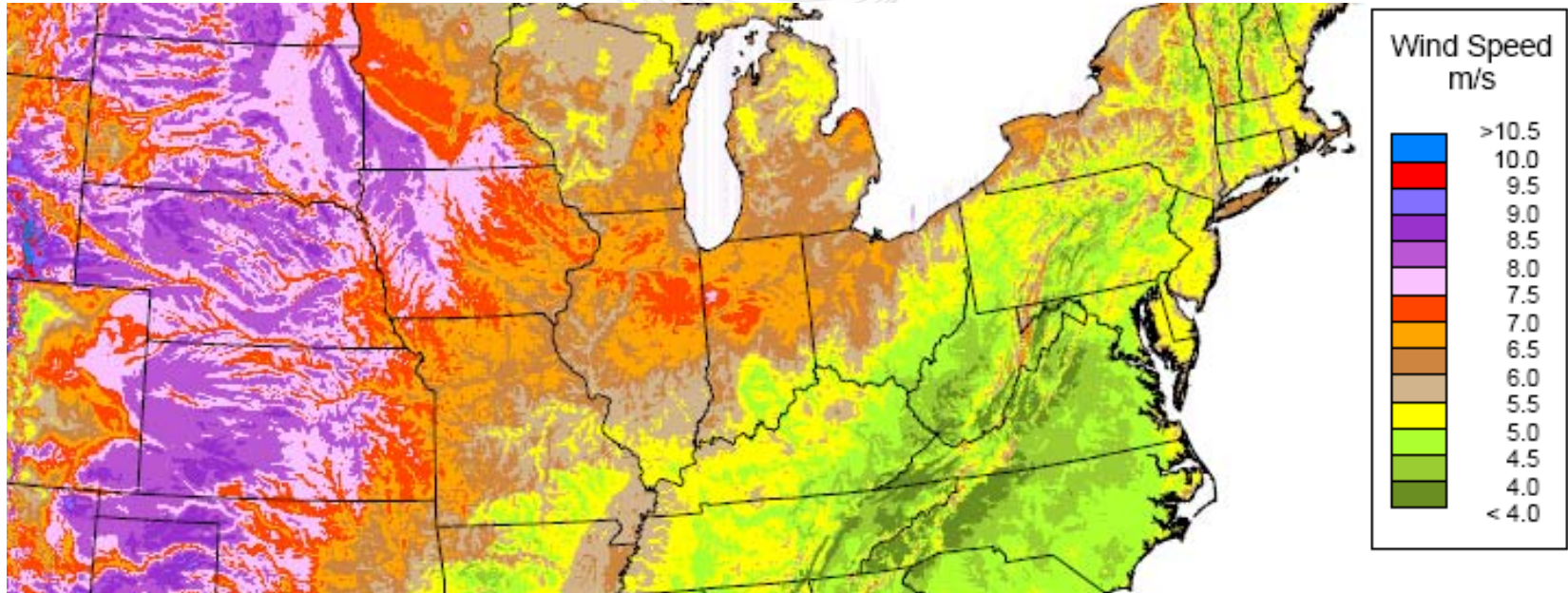


Wind and Solar Requirements in PJM (MW)

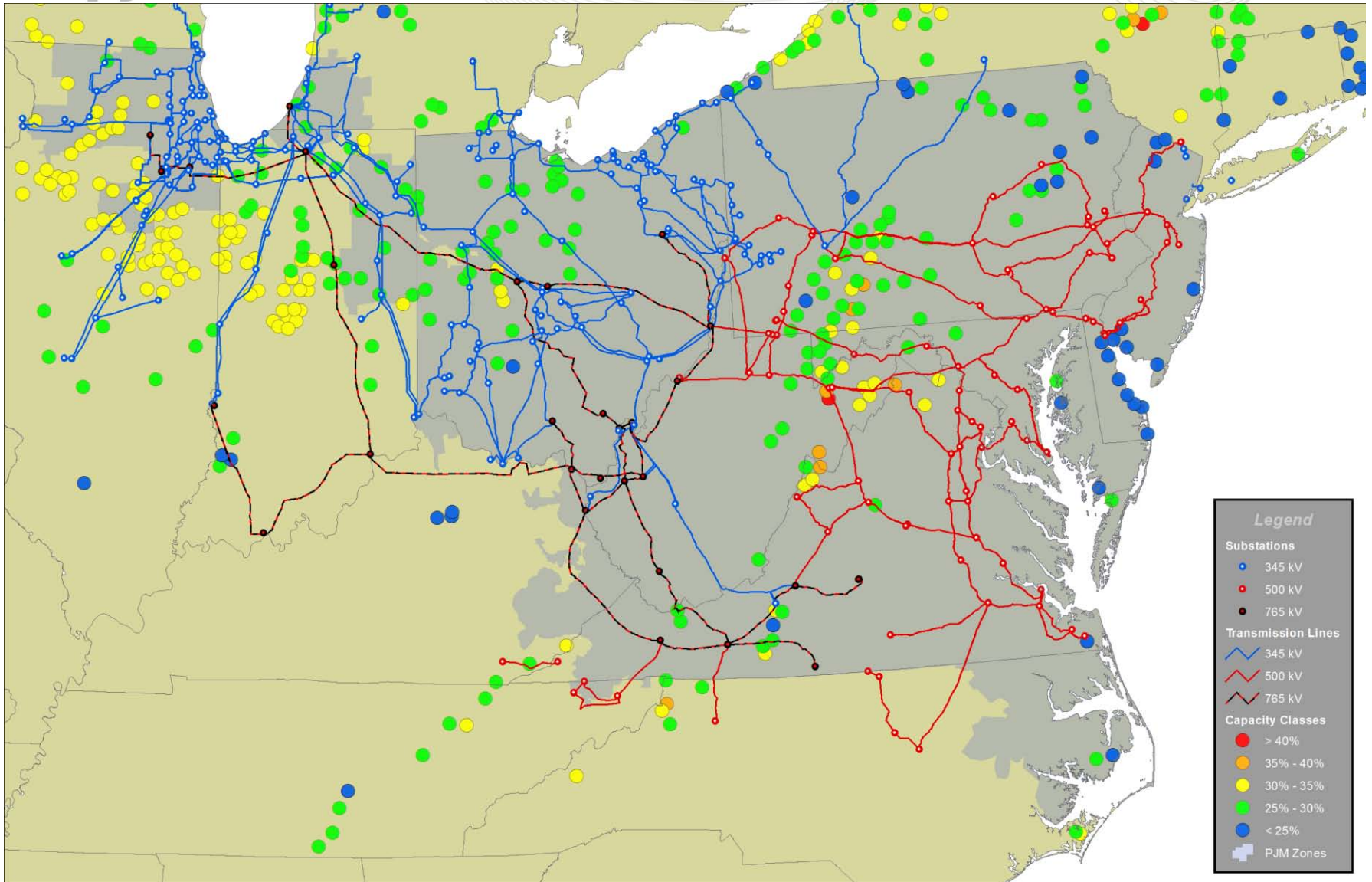


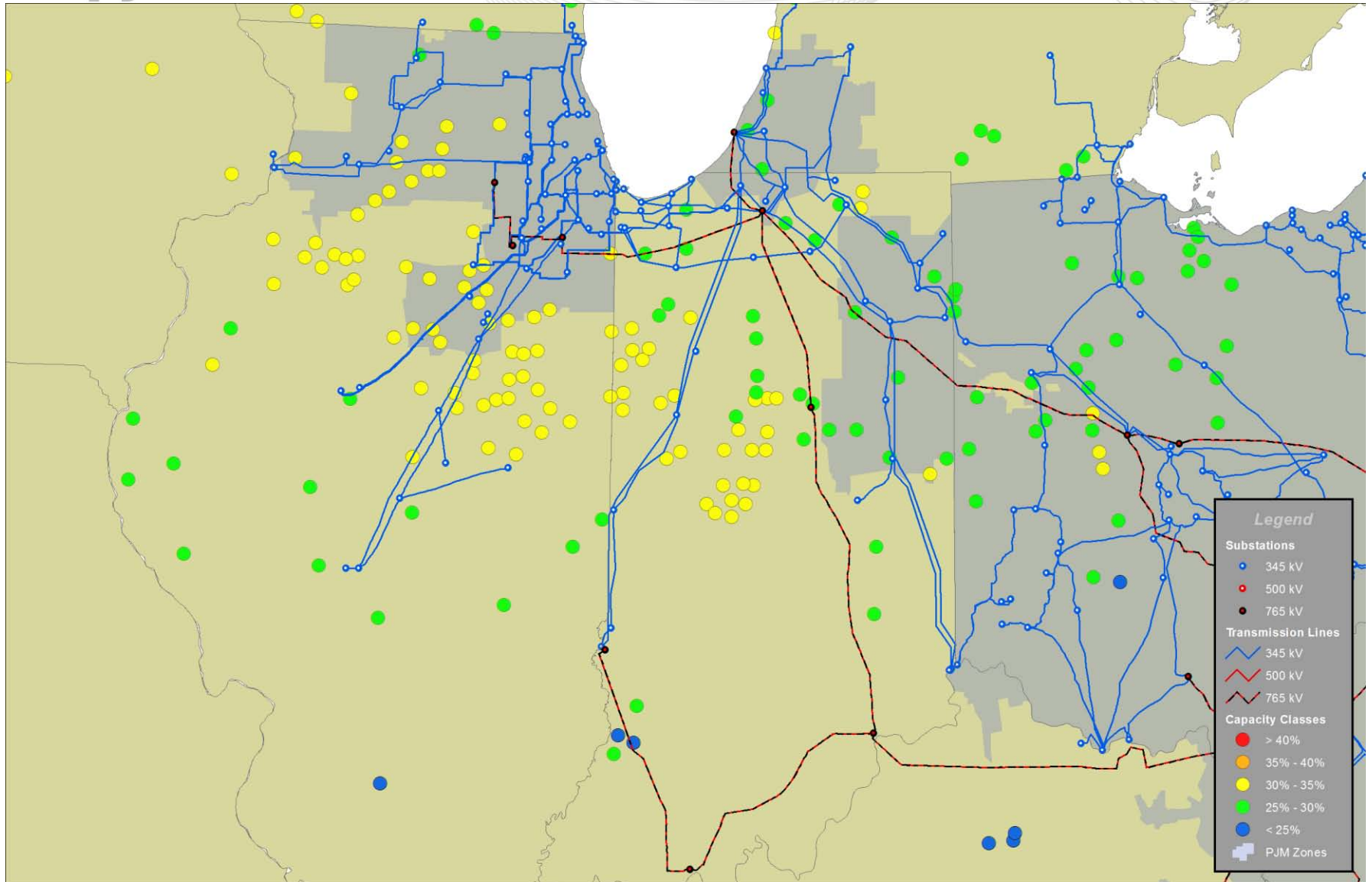
Assumes a 30% cap factor for wind
Assumes a 12% cap factor for solar

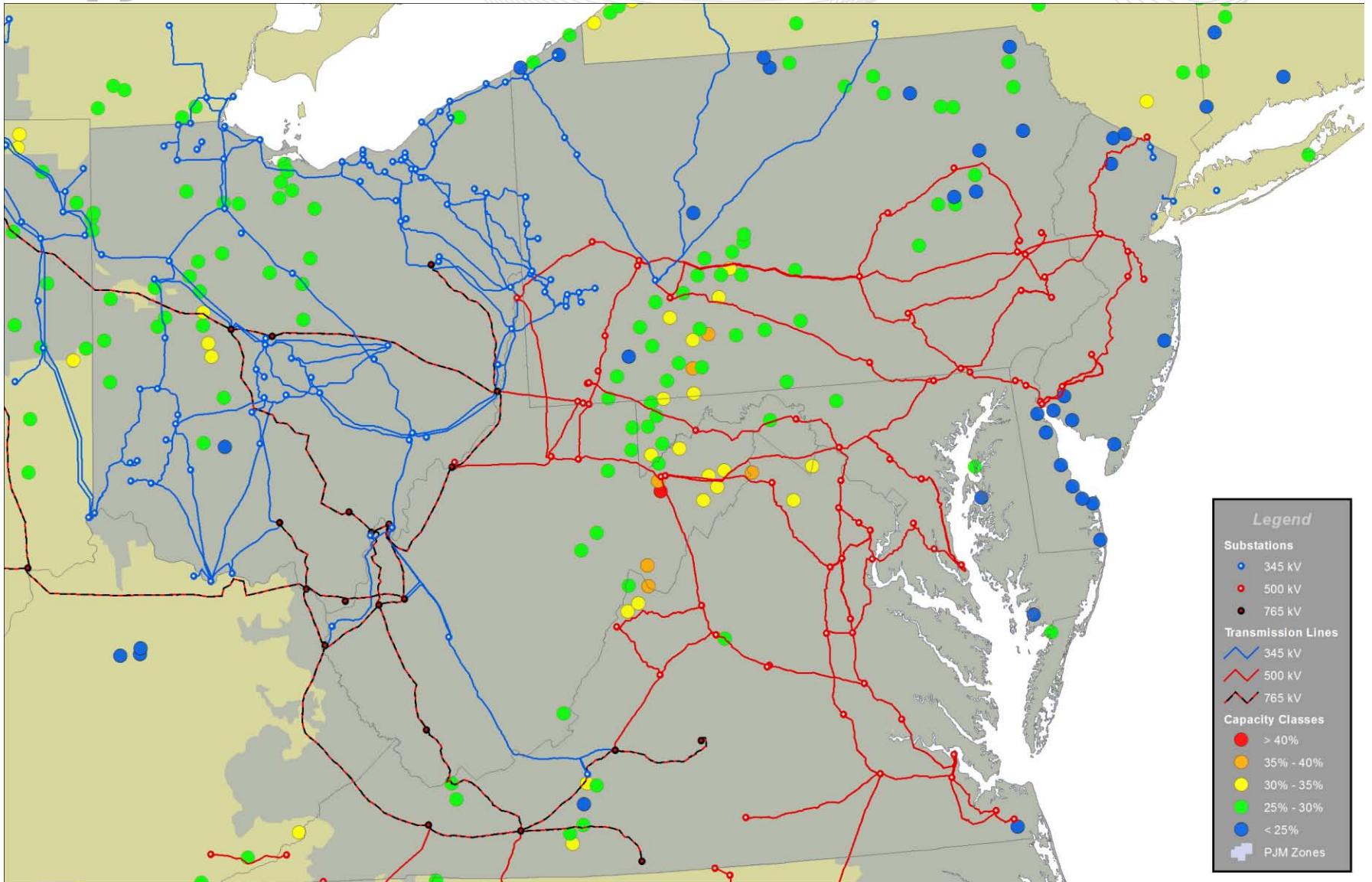
How will the analysis source the renewable resources?

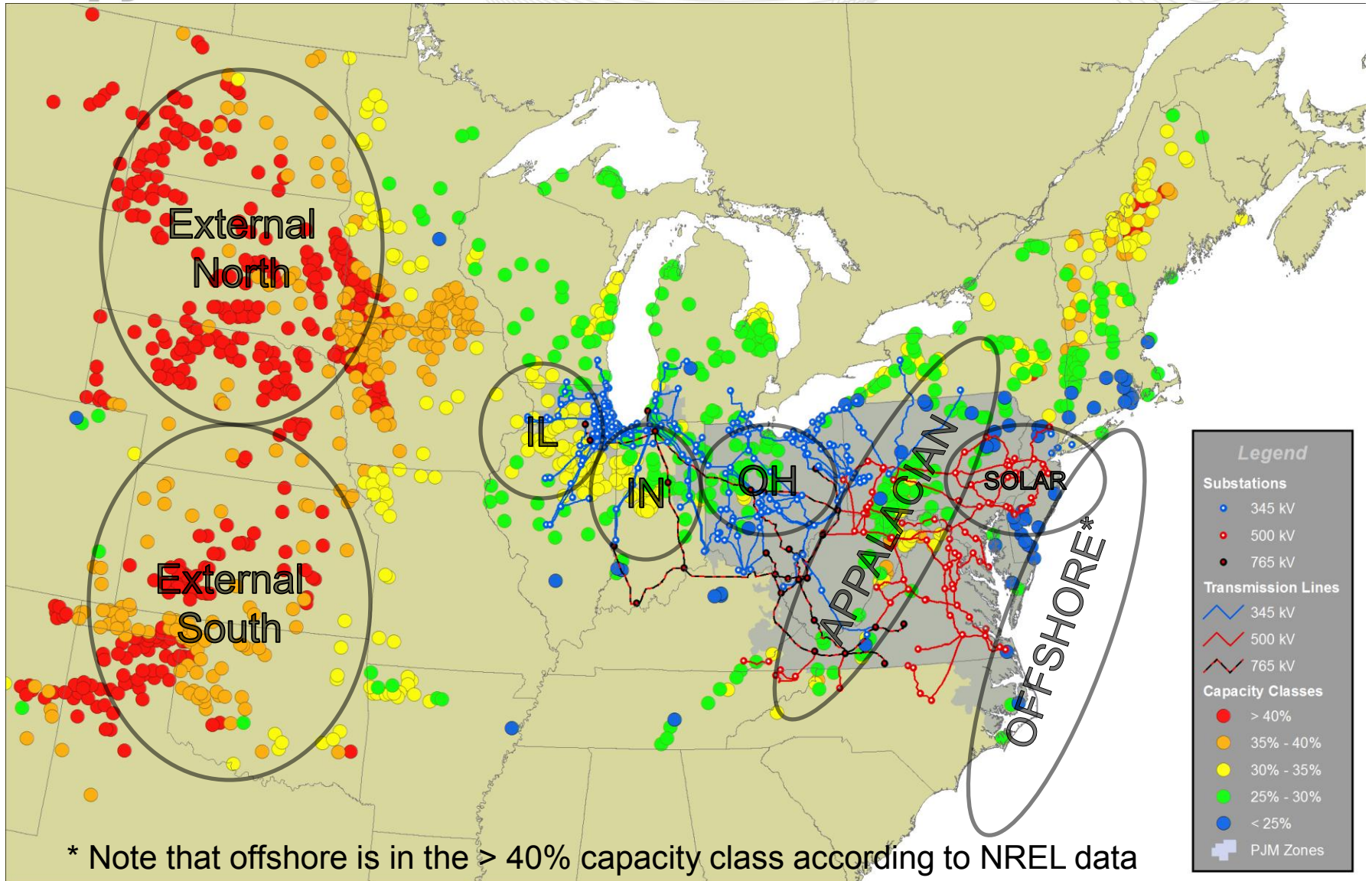


- United States Department of Energy – National Renewable Energy Laboratory Data
- Offshore wind speed from NJ to VA (not pictured above) ranges from 8 – 9 m/s
- Data source
 - http://www.windpoweringamerica.gov/pdfs/wind_maps/us_windmap_80meters.pdf









* Note that offshore is in the > 40% capacity class according to NREL data

- **Appalachian Mountains**
 - Amount that could be added may be limited due to geography
- **Magnitude in OH, Indiana, Illinois**
- **Offshore**
 - Low Offshore – less – 4,000 MW (radial)
 - High Offshore – 10,000 MW (networked)
- **External**
 - No external delivery
 - Serve PJM through $\frac{1}{2}$ internal + $\frac{1}{2}$ external resources

- Continue to develop sourcing assumptions
 - Where would the units be connected?
 - How much generation should be added?
 - Initially assume a 30% capacity factor to estimate the amount of wind that would need to be connected.
 - The amount of generation will be validated through production cost simulations to ensure we meet the RPS requirements
 - Where should the generation be added?
 - Use queue information to determine location of wind generation for PJM for initial analysis that studies meeting RPS with PJM resources
 - Use PJM queue information and identified MISO locations for analysis that studies meeting RPS with PJM resources and external resources
 - Select sites with the best wind resource data

- 2021 (start to add wind & offshore)
 - 2000 MW in Offshore Zone
 - Add Wind in other zones (use RPS as guide for magnitude)
 - Approximately 7200 MW solar (assuming a 12% capacity factor)
 - Add Natural Gas Units

- 2026 (need more capability than just wind)
 - 2000+ MW in Offshore Zone
 - Add additional Wind in other zones (use RPS as guide for magnitude)
 - Approximately 11,000MW solar (assuming a 12% capacity factor)
 - Add Natural Gas Units
 - Add two Nuclear Units

| 2021 | | |
|---|-------|---------|
| Target Installed Nameplate based on State Targets* | Solar | 7,000 |
| | Wind | 32,000 |
| | Total | 39,000 |
| Forecast Restricted Demand** (2011 PJM Load Forecast) | | 166,560 |
| Installed Reserve Margin | | 15% |
| Installed Capacity Needed | | 191,544 |
| Installed Capacity Credit*** | Solar | 2,660 |
| | Wind | 4,800 |
| | Total | 7,460 |
| Current Installed Capacity | | 185,544 |
| Additional Capacity Needed | | 6,000 |

| 2026 | | |
|---|-------|---------|
| Target Installed Nameplate based on State Targets | Solar | 11,000 |
| | Wind | 41,000 |
| | Total | 52,000 |
| Forecast Restricted Demand** (2011 PJM Load Forecast) | | 172,904 |
| Installed Reserve Margin | | 15% |
| Installed Capacity Needed | | 198,840 |
| Installed Capacity Credit*** | Solar | 4,180 |
| | Wind | 6,150 |
| | Total | 10,330 |
| Current Installed Capacity | | 185,544 |
| Additional Capacity Needed | | 13,296 |

* Assumes 30% capacity factor for Wind and 12% capacity factor for solar

** Assumes 10,000 MW of DR

*** Assumes 38% for solar and 15% for wind

| | | | Capacity Factor | Percentage Distribution | 2021 Installed MW Target | 2026 Installed MW Target |
|-------------------|-------------|----------------------|------------------|-------------------------|--------------------------|--------------------------|
| Renewable Sources | Solar | Solar | 12 | 100% | 7,000 | 11,000 |
| | Wind | External North | To Be Determined | | | |
| | | External South | | | | |
| | | Illinois | | | | |
| | | Indiana | | | | |
| | | Ohio | | | | |
| | | Appalacian Mountains | | | | |
| | | Offshore | | | | |
| TOTAL | | | | 0% | 32,000 | 41,000 |
| Other Sources | Natural Gas | | | | TBD | TBD |
| | Nuclear | | | | 0 | TBD |

- Develop power flow cases based on study assumptions
- Power flow screening to identify potential limiting facilities
 - Study will focus on 345 kV and above transmission for western wind resources and 230 kV transmission for off-shore wind injections
- Develop production cost simulation models
 - Model future renewable resources linked to the appropriate wind profiles

- **Production Cost Simulations**
 - Used to confirm sufficient energy from renewable resources to meet RPS
 - Used to identify constrained facilities inhibiting delivery of energy
- **Develop transmission solutions to mitigate issues identified through the production cost simulations**
- **Reliability Criteria Testing**
 - Generation Deliverability
 - Light Load
 - NERC Category C (except C3)

Email RTEP@pjm.com with any comments

Next Steps

Review Issues Tracking