Declining Reserves for U.S. Electric Grid — Blackouts Predicted

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Agenda

- Executive Summary
- Disorderly Generation Retirements
- PJM Resource Retirements, Replacements, and Risks (4 R's)
- PJM 4 R's "High Entry" Scenario with Updated Load Growth
- Blackouts Predicted for PJM
- Potential Blackouts in Other RTO/ISO
- Summary Conclusions
- Advantages of Modeling with GridClue.com
- More Information

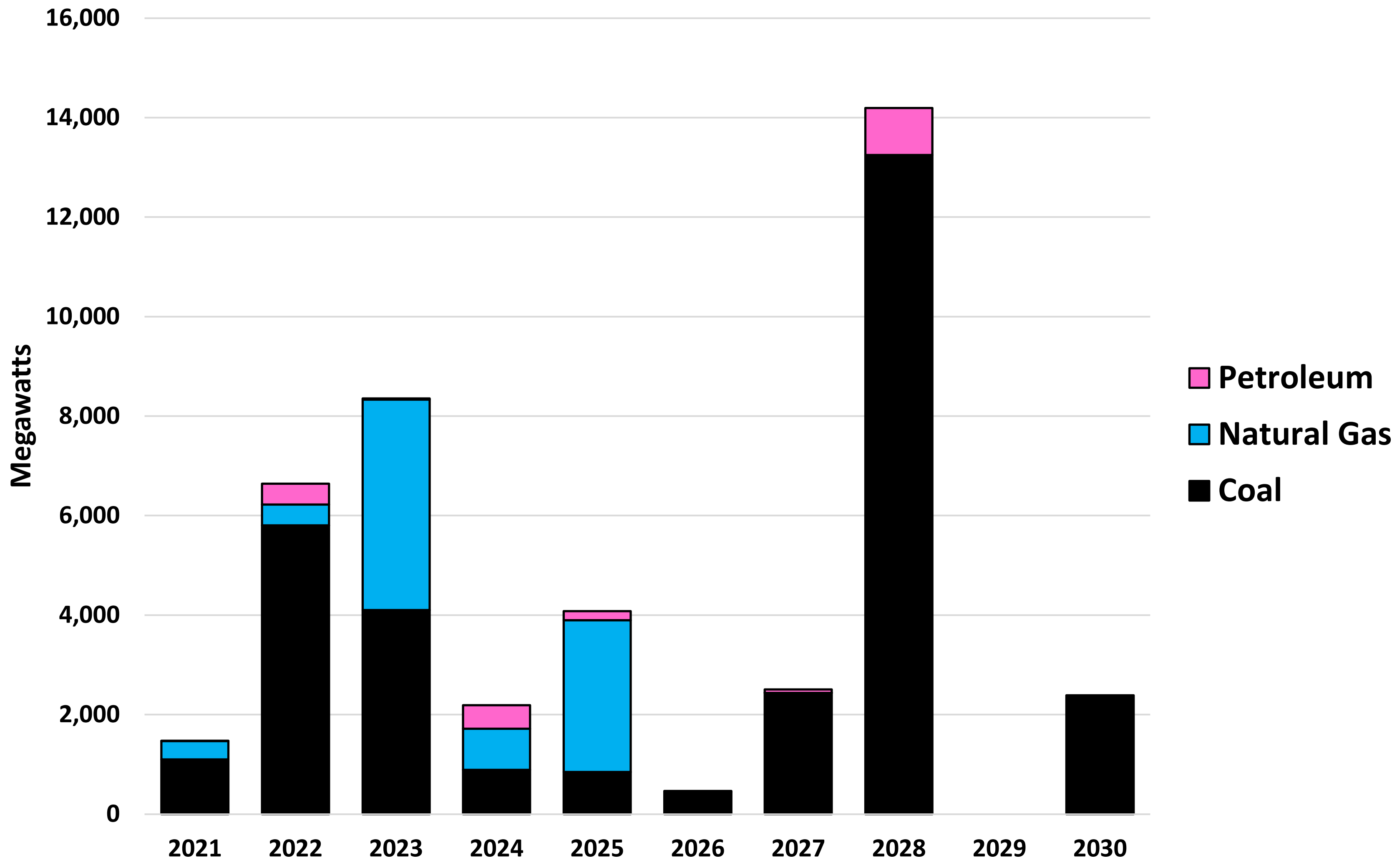
Executive Summary

- Disorderly Retirements of Coal and Gas Plants: 2024-2030
- PJM 4 R's Report: Unit-By-Unit Research on Retirements
- Our PJM Case Study: Good Modeling of Intermittent Resources Requires Calculations for 8,760 Hours of Year
  - Solar: For Each Hour of the Day in Each of 12 Months
  - Wind: For Each of 12 Months Due to Large Seasonal Variations
  - Alternative Averaging—"Effective Load Carrying Capacity" (ELCC) or "Technology Factors"—Implies Solar Resources at Midnight
- PJM Coal and Natural Gas Retirements with Wind and Solar Replacements Will Likely Result in Blackouts
- Societal Risks From Continual and/or Persistent Blackouts
- Other RTO/ISO Have Similar Issues with Dispatchable Resources Replaced by Intermittents

Disorderly Retirements

- Reasons for Fossil Fuel Generator Retirements:
  - Environmental Regulations—Both EPA and State-Specific
  - Court Approved Settlements after NGO and EPA Lawsuits
  - Worn-Out Plants, Especially Pre-1975 Steam Turbines
  - Uneconomic Operation in Electricity Markets
  - Government Initiatives to Reduce Greenhouse Gases
- Major Environmental Regulations Already Implemented
  - EPA “Acid Rain Program” to Reduce Sulfur Dioxides
  - Mercury & Air Toxics Standard (MATS)
  - Nitrogen Oxides/Ozone—For Example, EPA “Good Neighbor” Rule
- EPA Regulations with 2028 Compliance Dates
  - Coal Combustion Residuals (CCR)—i.e., Coal Ash Ponds
  - Wastewater Effluents, Especially Flue Gas Desulfurization (FGD)

Past and Expected Generating Unit Retirements in PJM



Source: U.S. EIA Form 860-M, Resilient Societies research of future retirements at generating unit level

PJM 4 R's Report

Balance Sheet Summary (2022–2030)

Retirements	New Entry Wind/Solar[6]	New Entry Standalone Storage	New Entry Thermal	Load Growth
40 GW **60% Coal** **30% Natural Gas** **10% Other**	**Low =** 48 GW-nameplate / 8 GW-capacity **High =** 94 GW-nameplate / 17 GW-capacity	**Low =** 3 GW **High =** 4 GW	**Low =** 4 GW **High =** 9 GW	**2023 Forecast =** 11 GW **Electrification Forecast =** 13 GW

Unless otherwise noted, thermal capacity values are expressed in ICAP, without adjustment for EFORd.

Table 1. Reserve Margin Projections Under Study Scenarios

Reserve Margin	2023	2024	2025	2026	2027	2028	2029	2030
Low New Entry								
2023 Load Forecast	23%	19%	17%	15%	11%	8%	8%	5%
Electrification	22%	18%	16%	13%	10%	7%	6%	3%
High New Entry								
2023 Load Forecast	26%	23%	21%	19%	17%	16%	17%	15%
Electrification	25%	22%	20%	18%	15%	14%	14%	12%

Source: "Energy Transition in PJM: Resource Retirements, Replacements & Risks," February 24, 2023

PJM 4 R's "High Entry" Scenario With Updated Load Growth

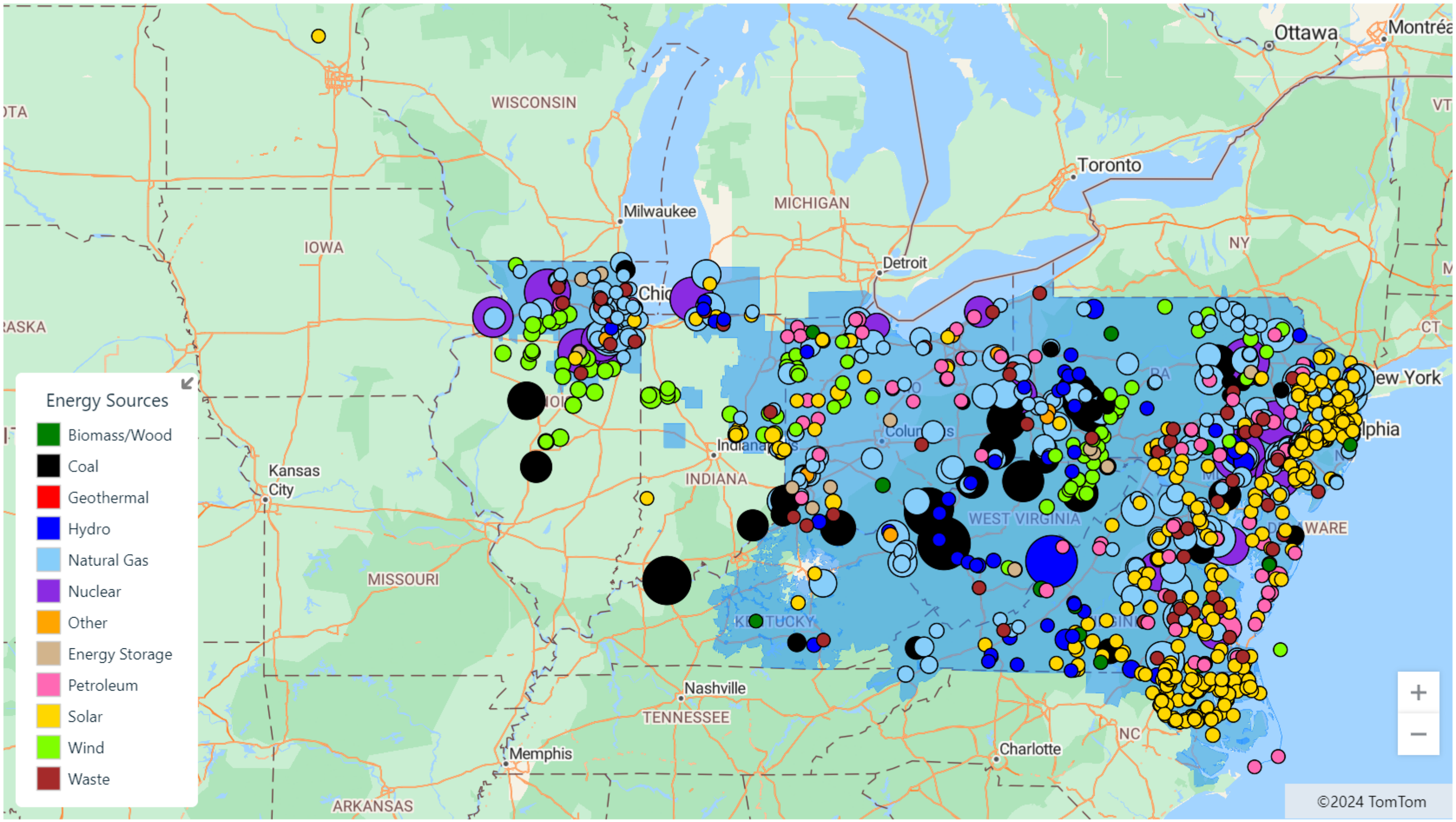
Projected PJM Load Growth by 2030

- February 2023 PJM 4 R's Report (2022-2030):
  - 2023 Forecast: 11 GW
  - Electrification Forecast: 13 GW
- Updates on Causes of PJM Load Growth:
  - Data Centers, Especially Northern Virginia and Columbus, Ohio
  - Newly Announced Manufacturing Facilities
  - Electrification, Including EV Charging
  - Semiconductor Chip Fabs in Columbus, Ohio
- PJM's Revised Projections for 2024-2034, as of Jan. 2024
  - Summer Peak Load Growth: 1.6% per year ⇨ **12% by 2030**
  - Winter Peak Load Growth: 1.9% per year ⇨ 14% by 2030
  - Net Energy for Load Growth: 2.3% per year ⇨ 17% by 2030

Sources: PJM report, "Energy Transition in PJM: Resource Retirements, Replacements & Risks"; GridStrategies report, "The Era of Flat Power Demand is Over"; Congressional testimony; "January 2024 PJM Load Forecast Report"

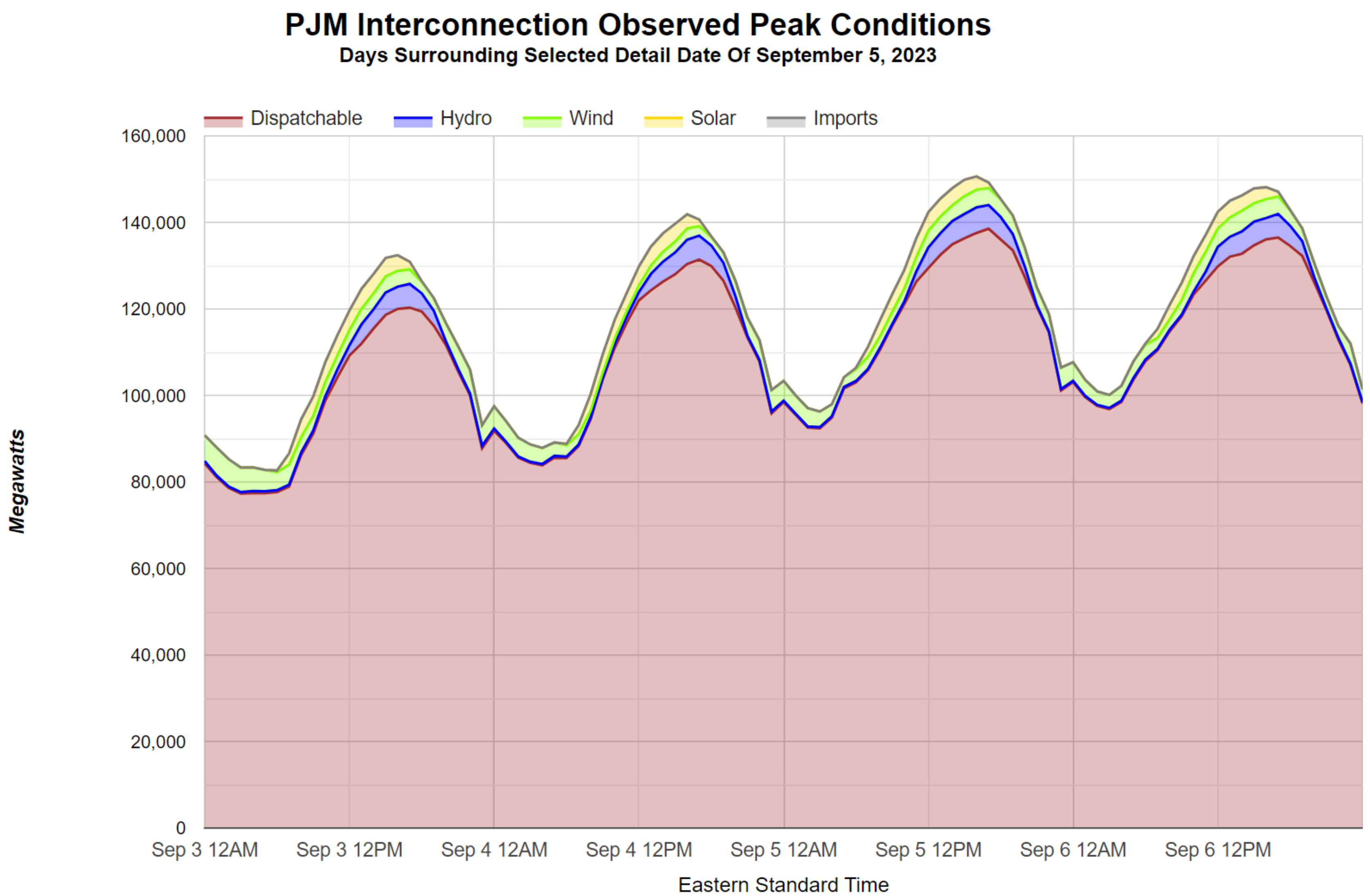
PJM Interconnection Major Generation Plants by Capacity

More info: Click on Plant Circles



This map shows generation resources For PJM Interconnection. Generation plants may be located outside the region's boundaries when utilities have ownership shares and transmission lines are available.

Source: U.S. EIA data; GridClue.com



Source: U.S. EIA data, GridClue.com

Net Loss of Dispatchable Resources in PJM—31 GW

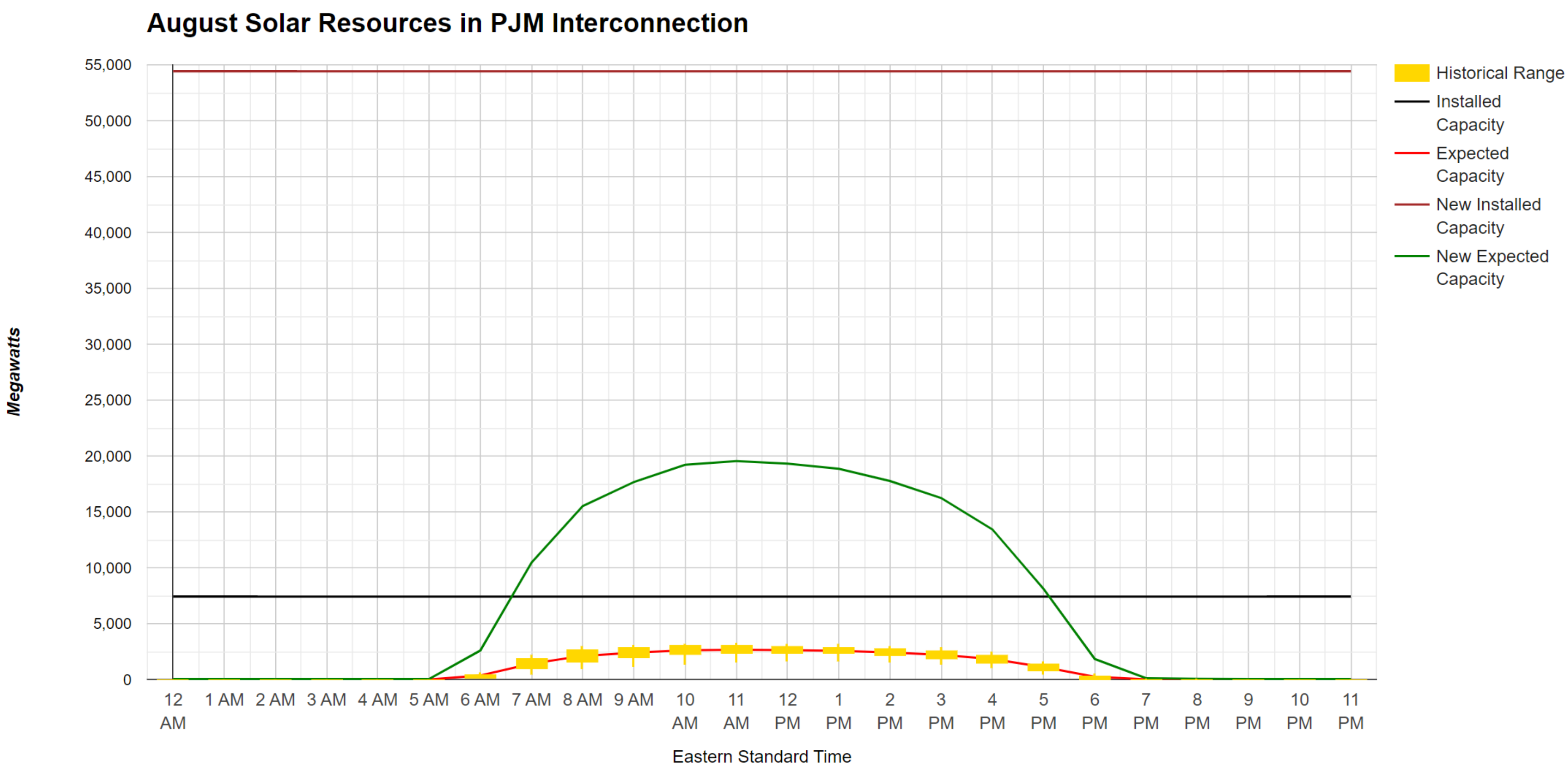
Dispatchable Resources in PJM Interconnection — PJM 4 R's Scenario by 2030

Resource	Installed Capacity (MW)	Change Capacity (+/-)	Capacity Factor	Availability Factor	Expected Capacity (MW)
Biomass/Wood	925	0	22.8%	80 %	740.0
Coal	43,272	-24000	29.1%	82 %	15,803.0
Geothermal	0	0	0.0%	90 %	0.0
Natural Gas	104,399	-3000	38.1%	80 %	81,119.2
Nuclear	34,467	0	90.2%	93 %	32,054.3
Other	11	0	22.4%	81 %	8.9
Other Fossil Fuels	561	0	13.5%	81 %	454.4
Petroleum	6,246	-4000	1.0%	81 %	1,819.3
Waste	1,267	0	39.9%	80 %	1,013.6
Total	**191,148**	**-31,000**			**133,012.7**

Run Model Clear

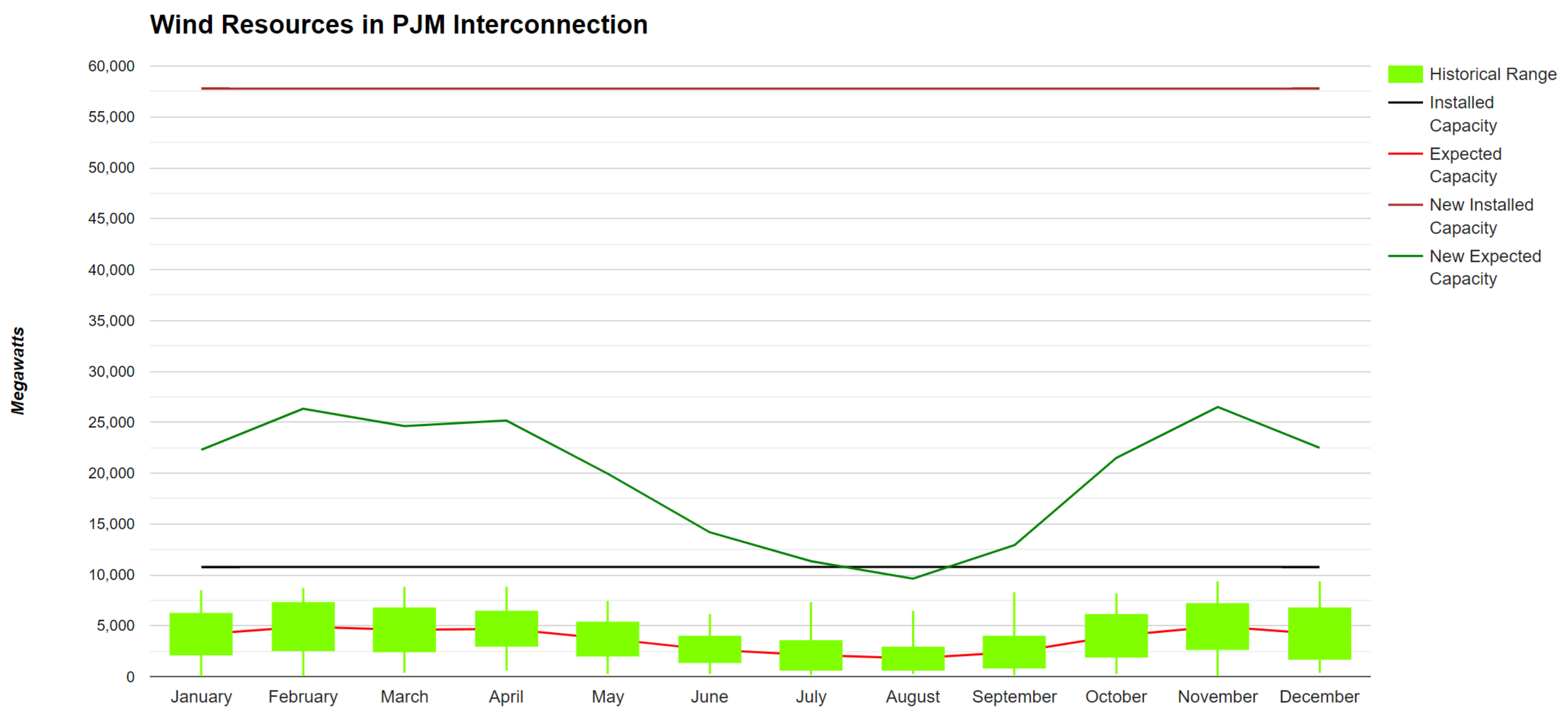
Source: U.S. EIA data; NERC GADS data, GridClue.com modeling

Modeled Addition of Solar in PJM—47 GW



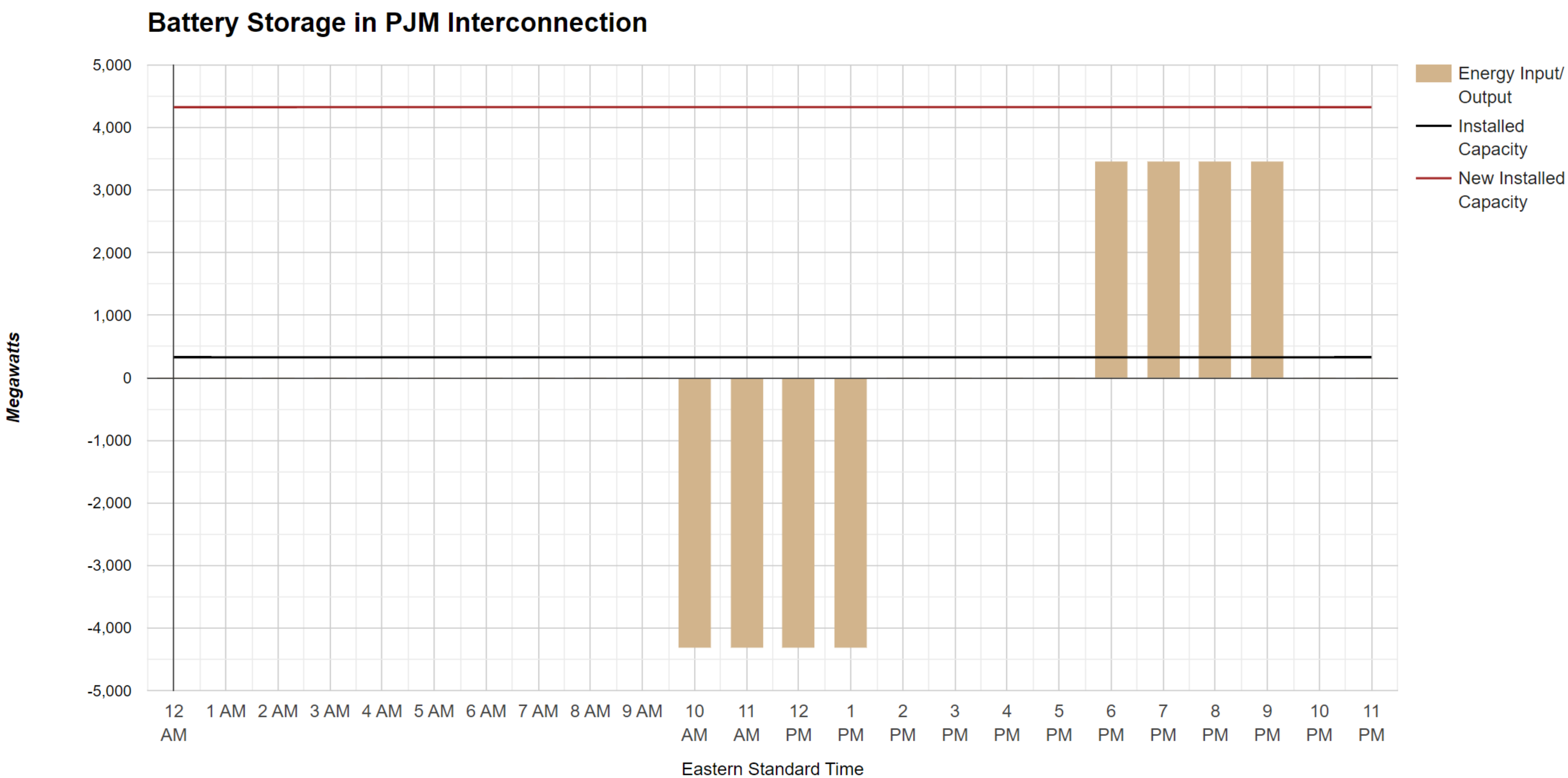
Source: U.S. EIA data; GridClue.com modeling

Modeled Addition of Wind in PJM—47 GW



Source: U.S. EIA data; GridClue.com modeling

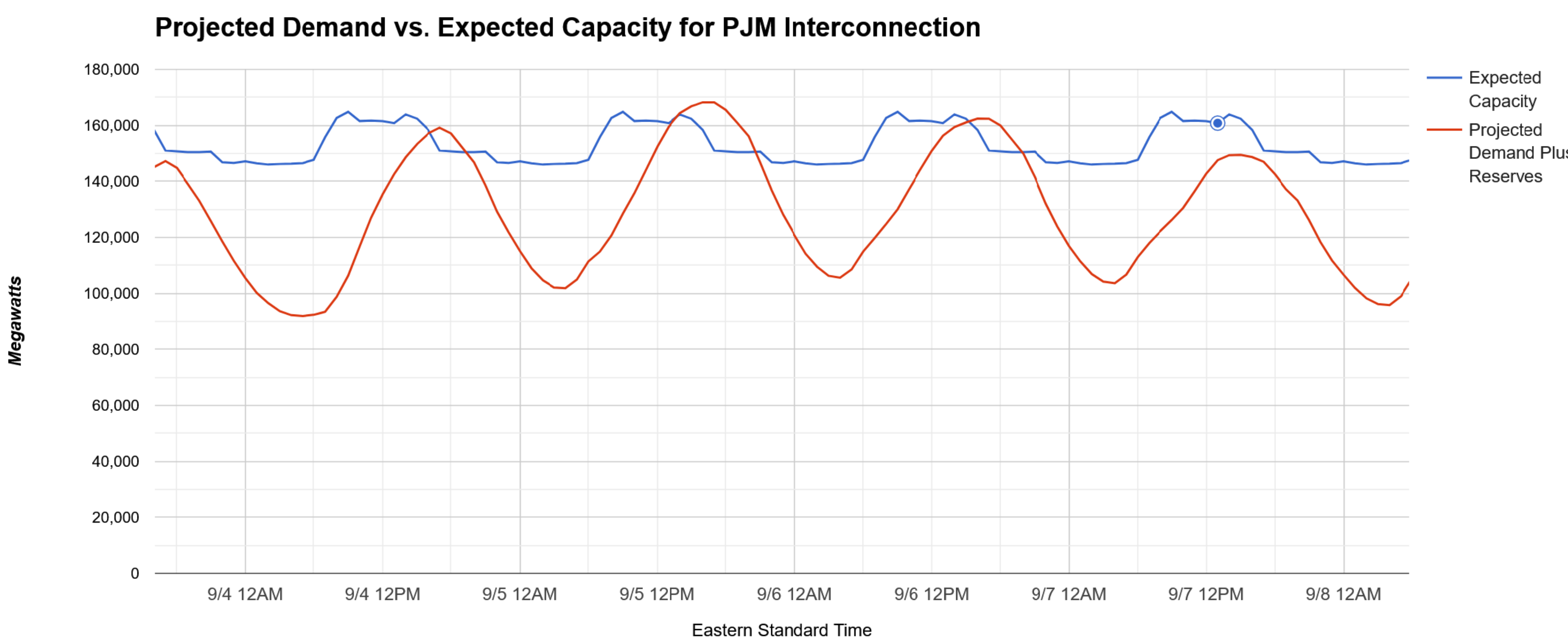
Modeled Addition of Batteries in PJM—4 GW



Source: U.S. EIA data; GridClue.com modeling

Blackouts Predicted for PJM

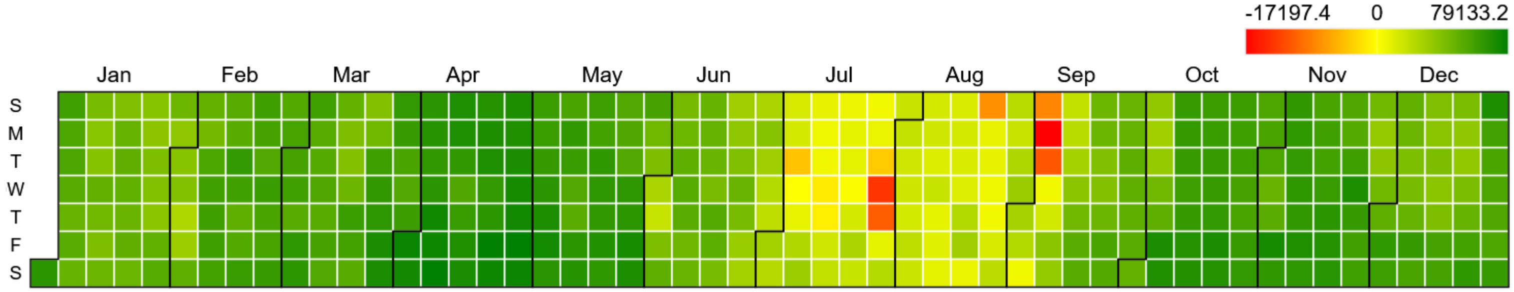
PJM—12% Summer Peak Load Growth by 2030



Source: U.S. EIA data; GridClue.com modeling

PJM—12% Summer Peak Load Growth by 2030

Modeled Electricity Adequacy for PJM Interconnection — 12% Summer Peak Load Growth By 2030



Daily Minimum Surplus/Maximum Deficit in Megawatts (MW)

For the modeled "High Entry" scenario in PJM Interconnection, expected generation capacity and imports minus demand (also subtracting necessary reserves) is estimated to be -17,197 megawatts, 10.2% below demand, at the critical hour of 5 PM EST on September 5.

For all of the 365-day Demand Profile, the estimate is 41 Loss of Load Hours (LOLH) over 10 days and 250,566 megawatt-hours of Expected Unserved Energy (EUE).

Scenario Assumptions: -24 GW coal retirements, -3 GW net natural gas retirements and replacements, -4 GW petroleum retirements; +47 GW solar, +47 GW wind, +4 GW batteries; 12% load growth; 5% operating reserves

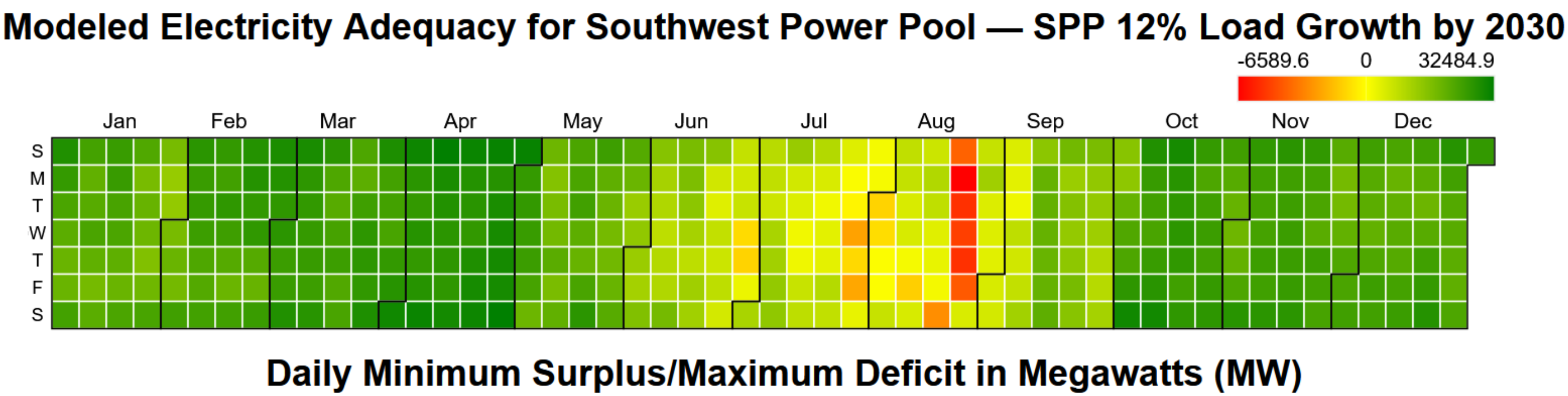
Societal Risks from Continual and/or Persistent Blackouts

- Disrupted Economy
- Opportunistic Looting
- Unexpected Load Sheds
- Cascading Grid Failures
- Wide-Area Outages
- Loss of Clean Water
- Spoiled Food
- Workers Leaving Posts
- Stranded Refugees
- Civil Disturbances
- Nuclear Accidents

Photo Credits, Top to Bottom & Background: Fernando Liano-AP, Reuters, The Atlantic, Getty Images

Potential Blackouts in Other RTO/ISO

Southwest Power Pool—12% Load Growth by 2030

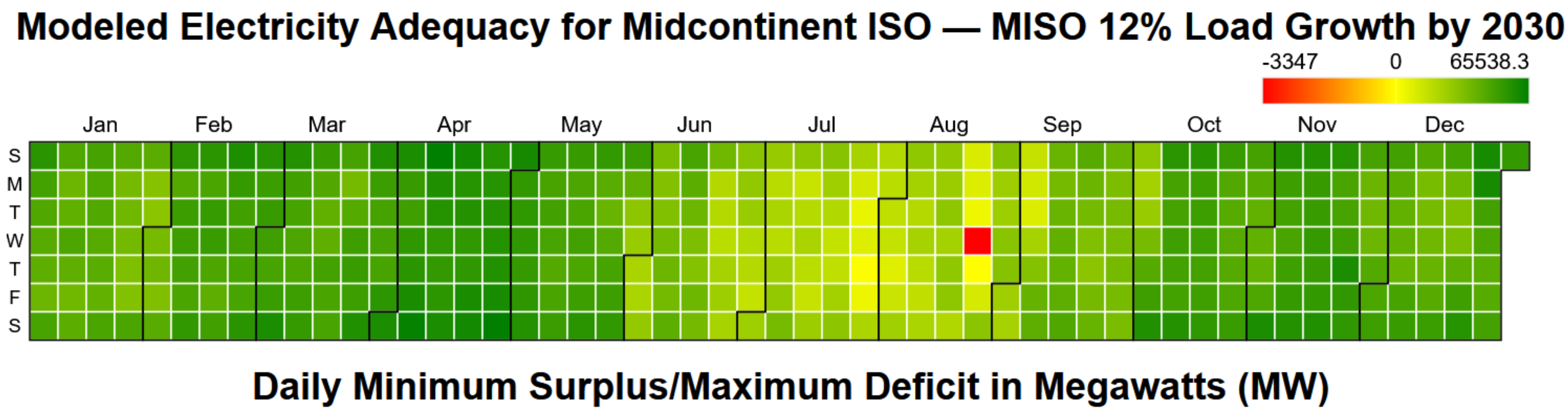


For the modeled scenario in Southwest Power Pool, expected generation capacity and imports minus demand (also subtracting necessary reserves) is estimated to be -6,590 megawatts, 10.3% below demand, at the critical hour of 4 PM CST on August 21.

For all of the 365-day Demand Profile, the estimate is 93 Loss of Load Hours (LOLH) over 16 days and 235,591 megawatt-hours of Expected Unserved Energy (EUE).

Scenario Assumptions: -7.7 GW coal retirements, -1.2 GW net natural gas retirements and replacements, 0 GW petroleum retirements; +3.6 GW solar, +4.3 GW wind, +1 GW batteries; 12% load growth; 5% operating reserves

Midcontinent ISO—12% Load Growth by 2030



For the modeled scenario in Midcontinent ISO, expected generation capacity and imports minus demand (also subtracting necessary reserves) is estimated to be -3,347 megawatts, 2.6% below demand, at the critical hour of 7 PM CST on August 23.

For all of the 365-day Demand Profile, the estimate is 4 Loss of Load Hours (LOLH) over 1 day and 6,376 megawatt-hours of Expected Unserved Energy (EUE).

Scenario Assumptions: -32 GW coal retirements, -1.9 GW net natural gas retirements and replacements, -0.6 GW petroleum retirements; +25 GW solar, +4.5 GW wind, +1.2 GW batteries; 7% load growth; 5% operating reserves

Summary Conclusions

- By end of decade, load will dramatically increase
- Large retirements of fossil fuel units, especially in 2028
  - Environmental regulations and initiatives
  - Uneconomic plants in markets with subsidized renewables
  - Equipment worn out by decades of use and over-ramping
- Optimistic expectations for replacements; e.g., PJM
  - 18 GW of PJM wind and solar operational through 2023, but added 94 GW wind and solar by 2030?
  - 75% of PJM natural gas retirements replaced 2024-2030?
- Likely Result: Deep load sheds over many days and hours
- Policy changes at both state and federal level needed
  - No single policy change will fix this problem
- *Will policymakers act before blackouts are upon us?*

Advantages of Modeling with GridClue.com

- Complete: Pre-Loaded EIA data for all of Continental U.S.
- Simple: Basic arithmetic for all 8,760 hours of year
- Transparent: Easily validated with export to Excel
- Quick: Scenarios run in seconds
- Understandable: Colorful graphs and data displays
- Free: Available online without password
  - Saved scenarios for government-accredited users

More Information

- The Foundation for Resilient Societies is a 501(c)(3) nonprofit with the mission of boosting critical infrastructure resilience and recoverability
- Our GridClue.com tool enables hour-by-hour modeling of resource adequacy for U.S. electric grids
- Thanks to our project sponsor, William Kaewert of Stored Energy Systems LLC (SENS)