Existing power plants sharing grid access with new resources can lower costs and double PJM's generation capacity

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Working Paper

Suggested citation: Paliwal, Umed, Amol Phadke (2025). "Existing power plants sharing grid access with new resources can lower costs and double PJM's generation capacity, Center for Environmental Public Policy, Goldman School of Public Policy, University of California, Berkeley.

Fast-tracking 15 GW of firm capacity to avoid shortages in PJM

The Challenge

- **Unprecedented Demand Surge Driven by Data Centers:** PJM's electricity demand is projected to surge by 30 GW by 2030, an unprecedented rate of growth. This is overwhelmingly driven by data centers, which are projected to add 17.2 GW of new load and position PJM to host nearly half of all U.S. data center capacity by 2030.
- **Gas Supply Chain Bottlenecks:** Conventional solutions like natural gas plants are hampered by significant supply chain constraints. New gas plants ordered now are unlikely to be operational before 2030-2032.
- **Gridlock in the Interconnection Queue:** Low-cost renewable energy projects that could help meet demand face excessive 3-4 year delays for grid connections, with 167 GW of clean capacity currently stranded in the interconnection queue.
- **Soaring Costs and Reliability Risks:** Capacity market prices have surged nearly tenfold to almost $270/MW-day, increasing annual costs to consumers from $2.2 billion to $14.7 billion. This price spike signals a significant shortfall of firm, dispatchable capacity.
- **Looming Capacity Shortfall:** PJM faces a potential 25 GW capacity shortfall by 2030. This gap emerges from a projected 32 GW increase in peak load and 8 GW of retiring generation, which is not being met by the 5.6 GW of realistic additions from the queue and 9.3 GW from the RRI fast-track initiative.

The Solution

- **Unlocking Idle Grid Connections:** 52 GW of PJM's 141 GW thermal capacity operates below 15% capacity factor, severely underutilizing their interconnections and transmission infrastructure. Similarly, solar plants (19%) and wind plants (16%) use only a fraction of their available grid interconnection capacity. PJM has 25 GW of RE capacity but only 6GW is recognized as firm capacity becuase of the intermittency.
- **Bypassing the Queue:** Deploying new generation and storage at these existing, underutilized points of interconnection can provide cost-effective energy and capacity without building new transmission infrastructure, bypassing the congested queues.
- **Massive Clean Energy Potential:** PJM can add 153 GW of clean energy capacity through surplus interconnection, including 102 GW of solar, 28 GW of wind, and 23 GW of energy storage at existing power plant sites.
- **Meeting Future Demand:** This surplus potential can provide 13.6 GW of firm peak capacity (meeting 46% of projected 2030 peak demand growth) and 288 TWh of annual energy (covering 108% of projected energy demand growth), while dramatically accelerating deployment timelines from 5-7 years to 1-2 years.
- **Unlock $31 Billion in Savings:** Using existing grid infrastructure eliminates the need for costly and time-consuming network upgrades. This pragmatic approach unlocks an estimated $31 billion in interconnection cost savings.

Policy Recommendations

- **Standardize Commercial Agreements:** PJM should create a pro forma Surplus Interconnection Service Agreement, modeled on MISO's "Energy Displacement Agreement," to reduce transaction costs and streamline negotiations between unaffiliated parties.
- **Provide a Path to Permanent Interconnection:** FERC and PJM must eliminate the "one-year cliff" investment risk for repowering projects by creating a clear pathway for a surplus user to obtain permanent interconnection rights when a host generator retires.
- **Increase Market Transparency on Grid Opportunities:** PJM should enhance market transparency by providing tools that help developers identify locations with significant underutilized grid capacity.
- **Improve Hybrid Resource Valuation:** PJM should reform its Effective Load Carrying Capability (ELCC) methodology to accurately value the reliability contributions of co-located hybrid resources, ensuring proper compensation in the capacity market and incentivizing their deployment.

Gas and Coal Dominate 62% of PJM Capacity

Current Generation Portfolio

Thermal Generation

78.2%

Coal, Gas, Nuclear: 156.0 GW

Renewable Energy

12.5%

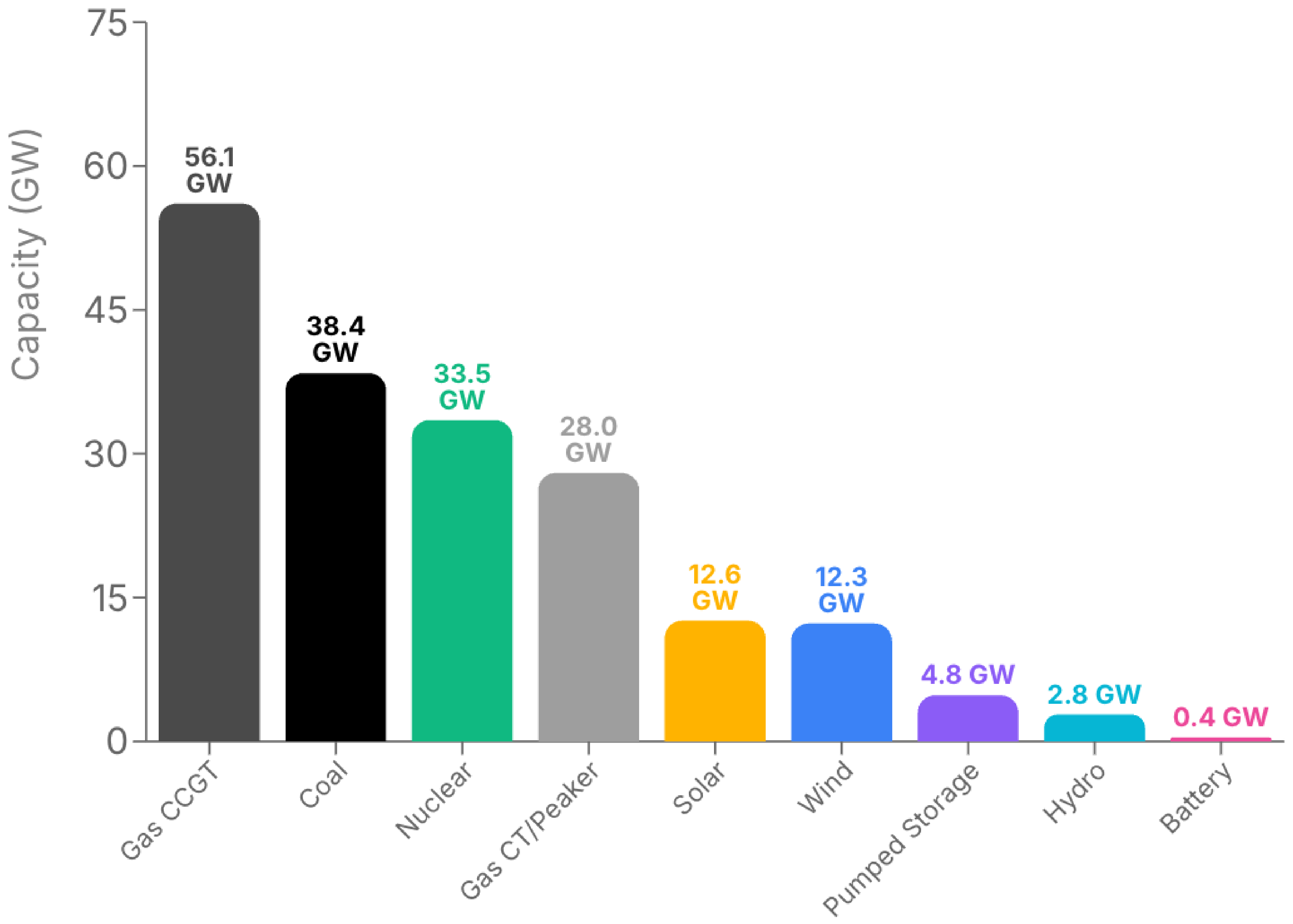
Wind + Solar: 24.9 GW

Technology Mix Breakdown

- **Gas dominates** with 84.1 GW (42.3%) - CCGT leads at 56.1 GW
- **Coal persists** at 38.4 GW (19.3%) despite retirement pressures
- **Nuclear baseload** provides 33.5 GW (16.8%) with high reliability
- **Limited storage** - only 5.2 GW (2.6%) from pumped hydro + batteries

Source: PJM 2025 Q1 State of the Market Report

Installed Capacity by Technology (GW)



PJM 2030 Forecast Jumps 30 GW in Four Years

Four-Year Forecast Evolution (2022-2025)

Peak Load Forecast Increase

+19.6%

From 2022 to 2025 forecast

30.1 GW increase in expectations

Energy Forecast Increase

+32.4%

From 2022 to 2025 forecast

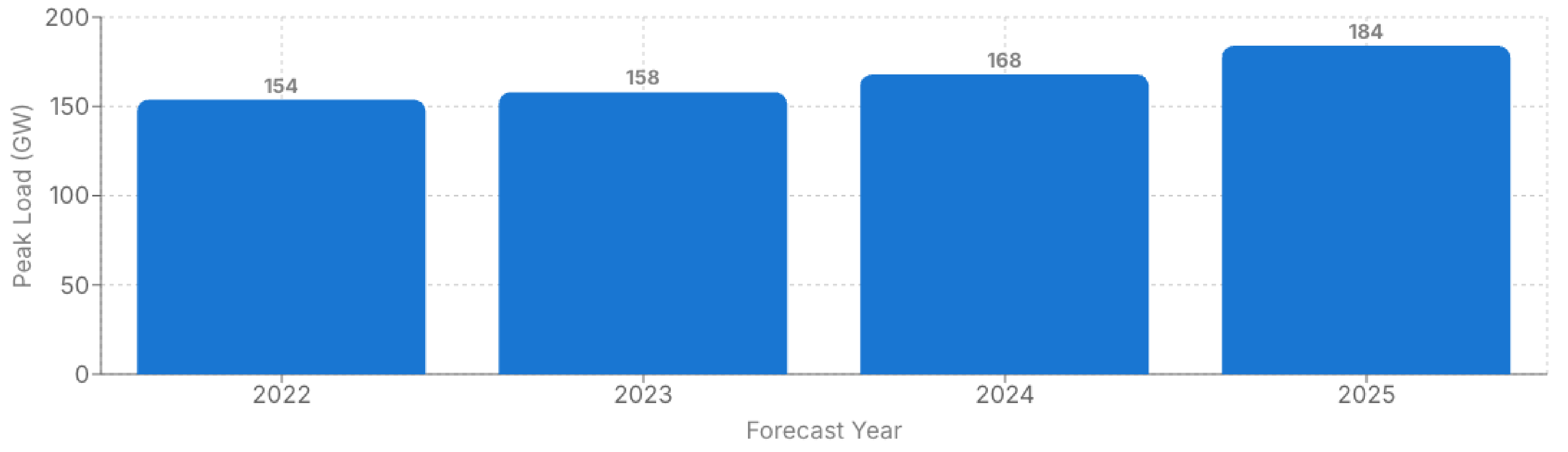
269 TWh increase in expectations

PJM Load Growth Surging: Unprecedented Demand Acceleration

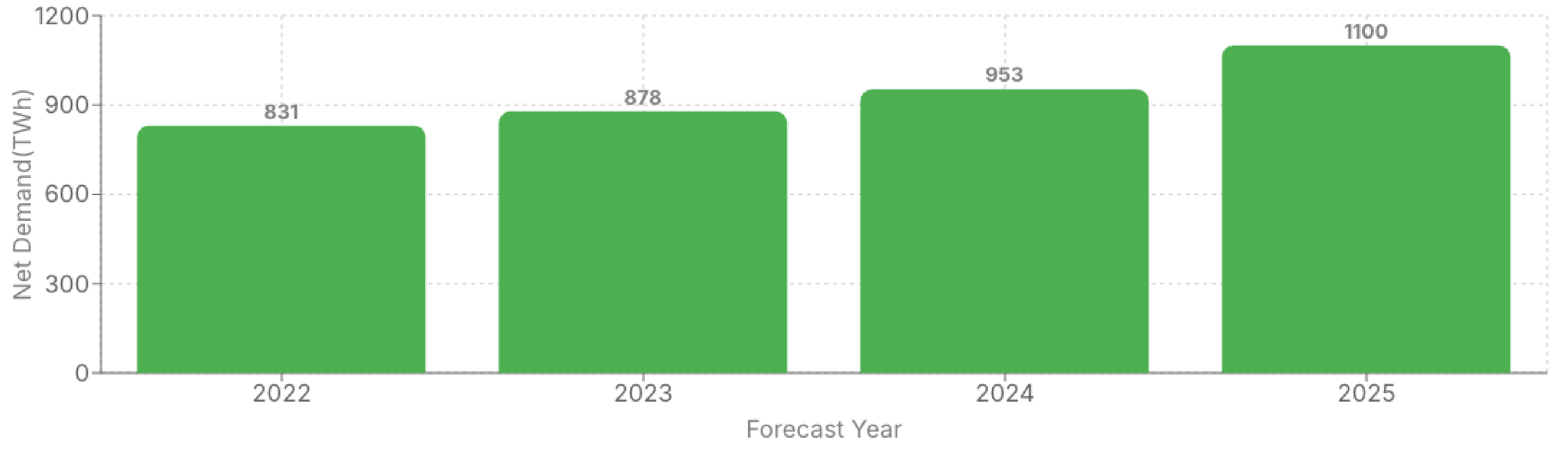
- PJM's 2030 load forecasts have increased by **30 gigawatts** in just four years - the fastest forecast acceleration in decades
- The 2030 energy forecast has jumped by **269 terawatt hours** - equivalent to California's entire annual electricity consumption
- This explosive load growth is primarily driven by **new data centers** proliferating across the PJM region
- Given this trend, it is likely that the **2030 load forecast may increase again** in next year's projections
- Grid planners have **not witnessed this level of growth** in decades, creating extraordinary planning challenges
- This unprecedented **uncertainty** makes grid planning extraordinarily difficult as AI workloads exceed all projections

Source: PJM Load Forecast

2030 Peak Load Forecasts

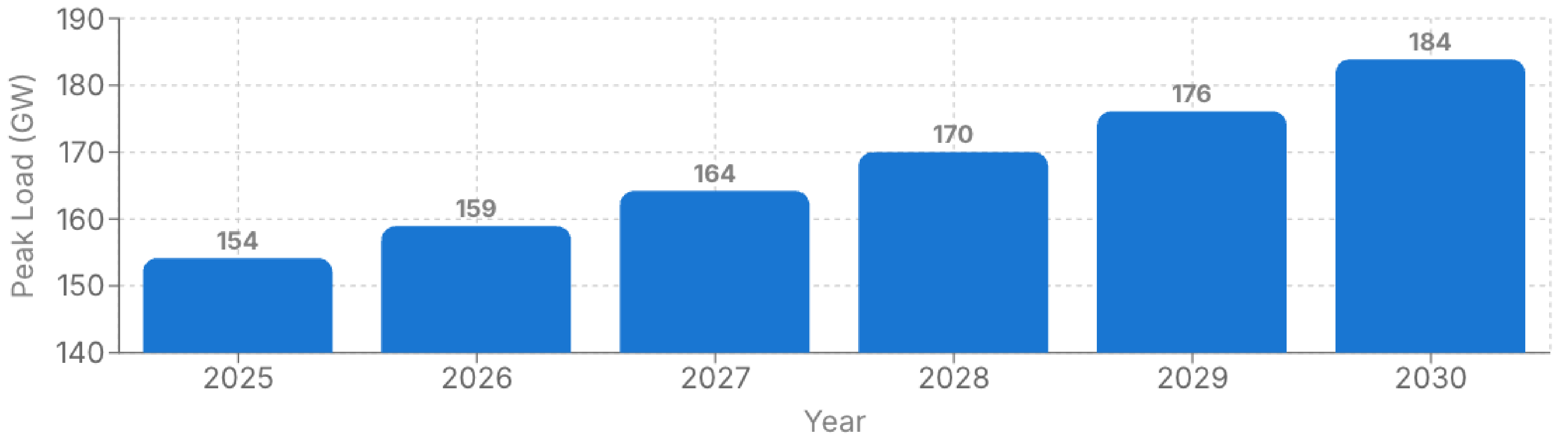


2030 Energy Forecasts

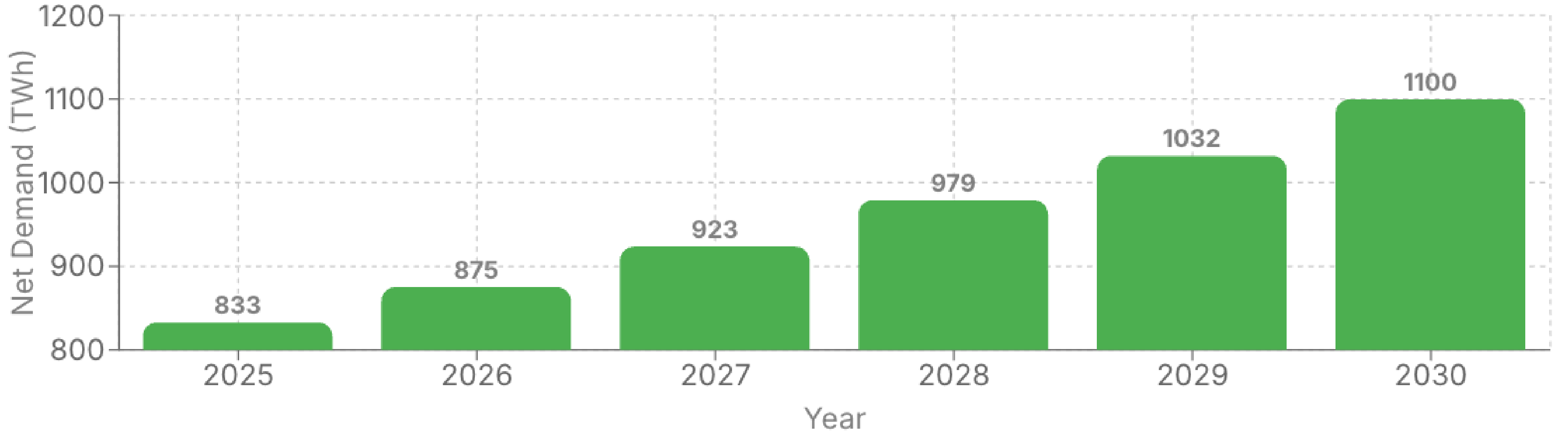


PJM Expects 5.7% Annual Energy Growth Through 2030

Peak Load Forecast (2025-2030)



Energy Forecast (2025-2030)



2024 Load Forecast

Peak Load Growth

+19.3%

Total increase: 29.7 GW

3.6% annual growth rate

Energy Growth

+32.0%

Total increase: 267 TWh

5.7% annual growth rate

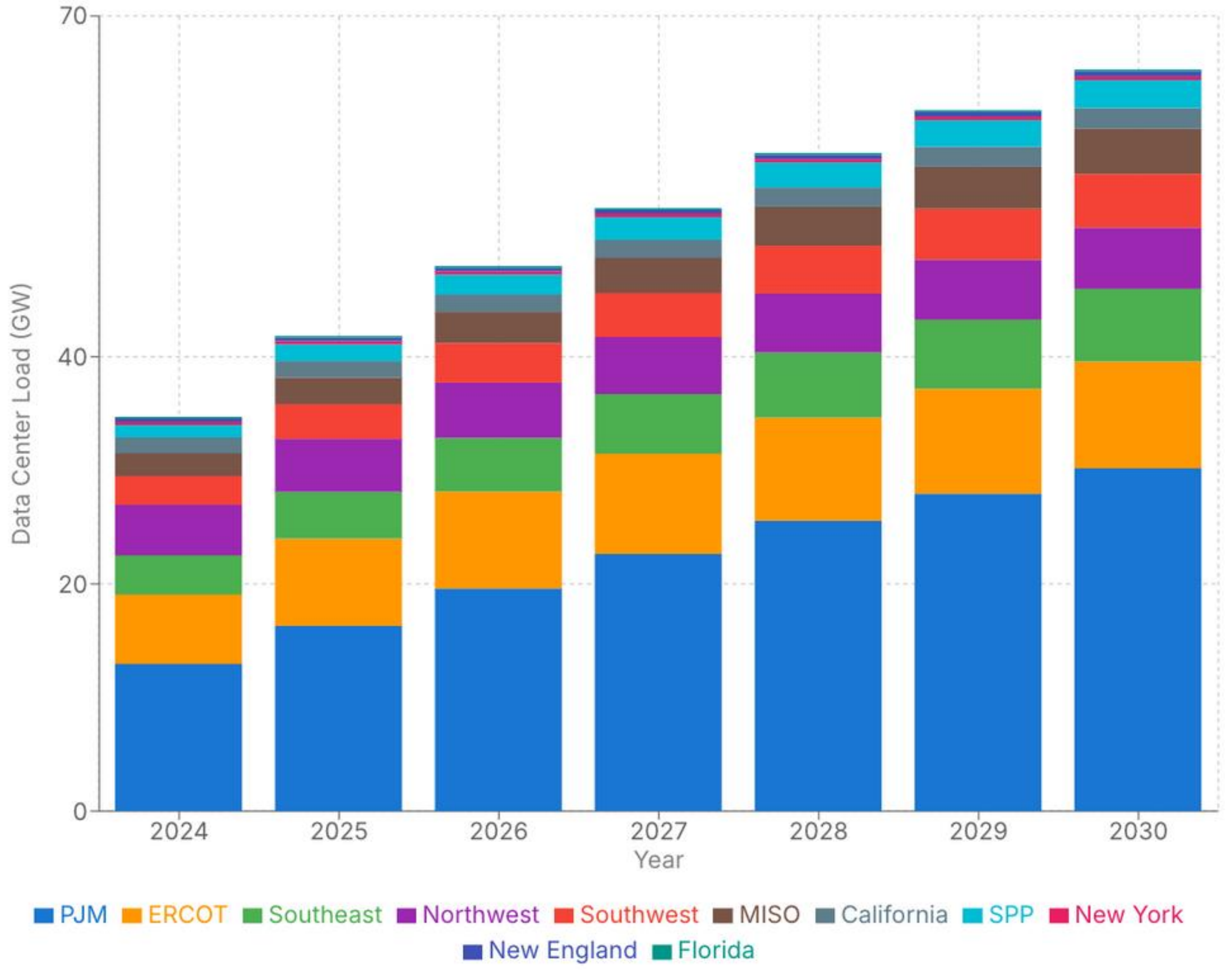
Key Growth Drivers & Implications

- In the 2024 forecast, PJM expects **sustained high growth** through 2030, with peak load increasing nearly 30 GW over five years
- Energy demand growing at **5.7% annually** - far exceeding historical averages of 1-2%
- The **267 TWh increase** by 2030 represents massive new infrastructure requirements
- This growth trajectory requires **unprecedented grid investments** and generation capacity additions

Source: PJM Load Forecast 2024

PJM would house half of all Data Centers in the US by 2030

Regional Data Center Load Forecast



Data Center Growth in PJM Territory

PJM Data Center Load Growth

+132.9%

Increase: 17.2 GW
2024-2030

US Market Share

46.2%

PJM share in 2030
Up from 37.3% in 2024

Key Data Center Growth Drivers

- Data centers drive **17.2 GW of new load** in PJM by 2030, representing the largest source of demand growth
- PJM will account for **46.2% of US data center load** by 2030, up from 37.4% in 2024
- Virginia hosts **5.6 GW of operational data center IT capacity**, with concentration in Loudoun County ("Data Center Alley")
- Dominion Energy reports **40.2 GW of contracted pipeline** capacity in Virginia as of December 2024
- Ohio emerges as key hub with **5.9 GW of IT capacity** under construction or development, led by AWS and Google

Source: BloombergNEF 2025 Data Center Market Outlook

PJM has 170 GW capacity stuck in interconnection queues

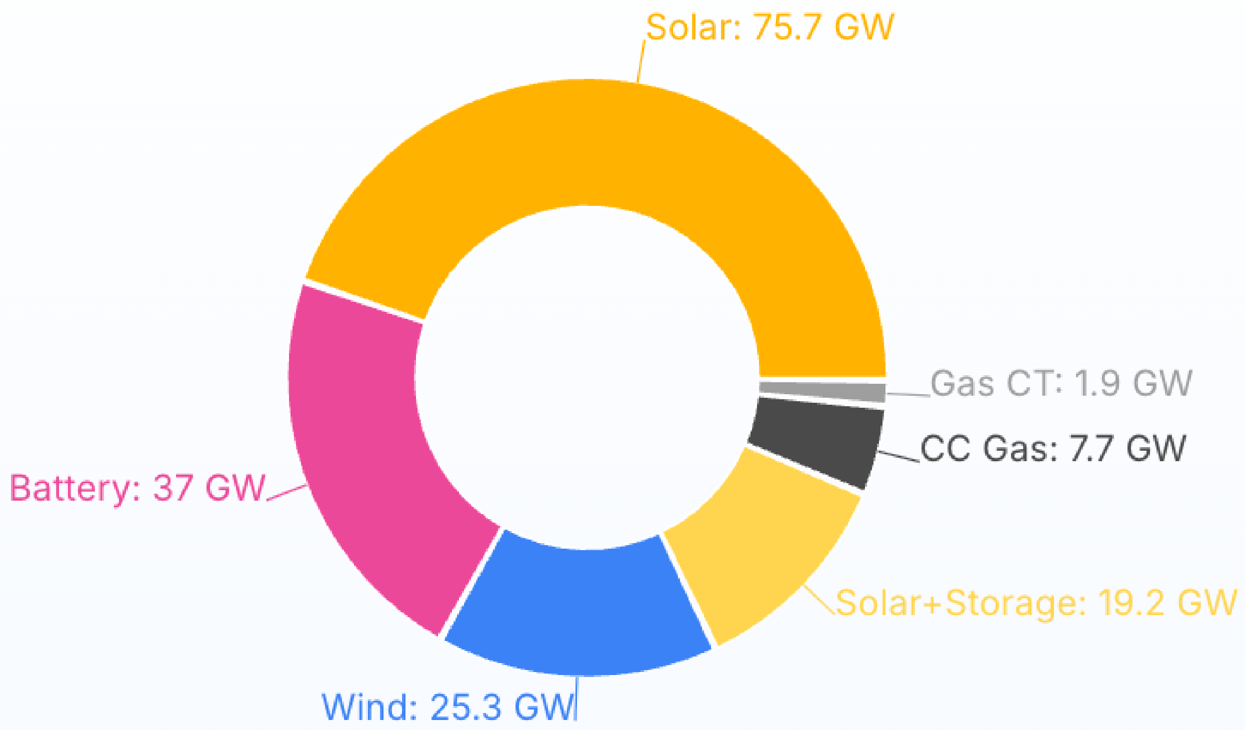
📈 **167.1 GW**
Total capacity waiting in PJM queue

⚡ **94.3%**
Renewable & storage share of queue capacity

⏱ **3.4 Years**
Average time in PJM queue before completion

⚠️ **68.4%**
Historical withdrawal rate from queue

Technology Distribution (%)



Total Queue Capacity: **167.1 GW**

Renewables Constitute 94.3% of Queue

- **Solar capacity:** 75.7 GW (45.3%) of standalone solar, with an additional 19.2 GW in solar+storage hybrids, totaling 94.9 GW or 56.8% of the queue.
- **Battery storage:** 37 GW (22.1%) of standalone storage capacity, supporting grid flexibility and renewable integration.
- **Wind projects:** 25.3 GW (15.1%) of wind capacity in the queue, primarily onshore installations.
- **Historical completion rate:** Based on past trends, approximately 20% of queue capacity is expected to reach commercial operation.

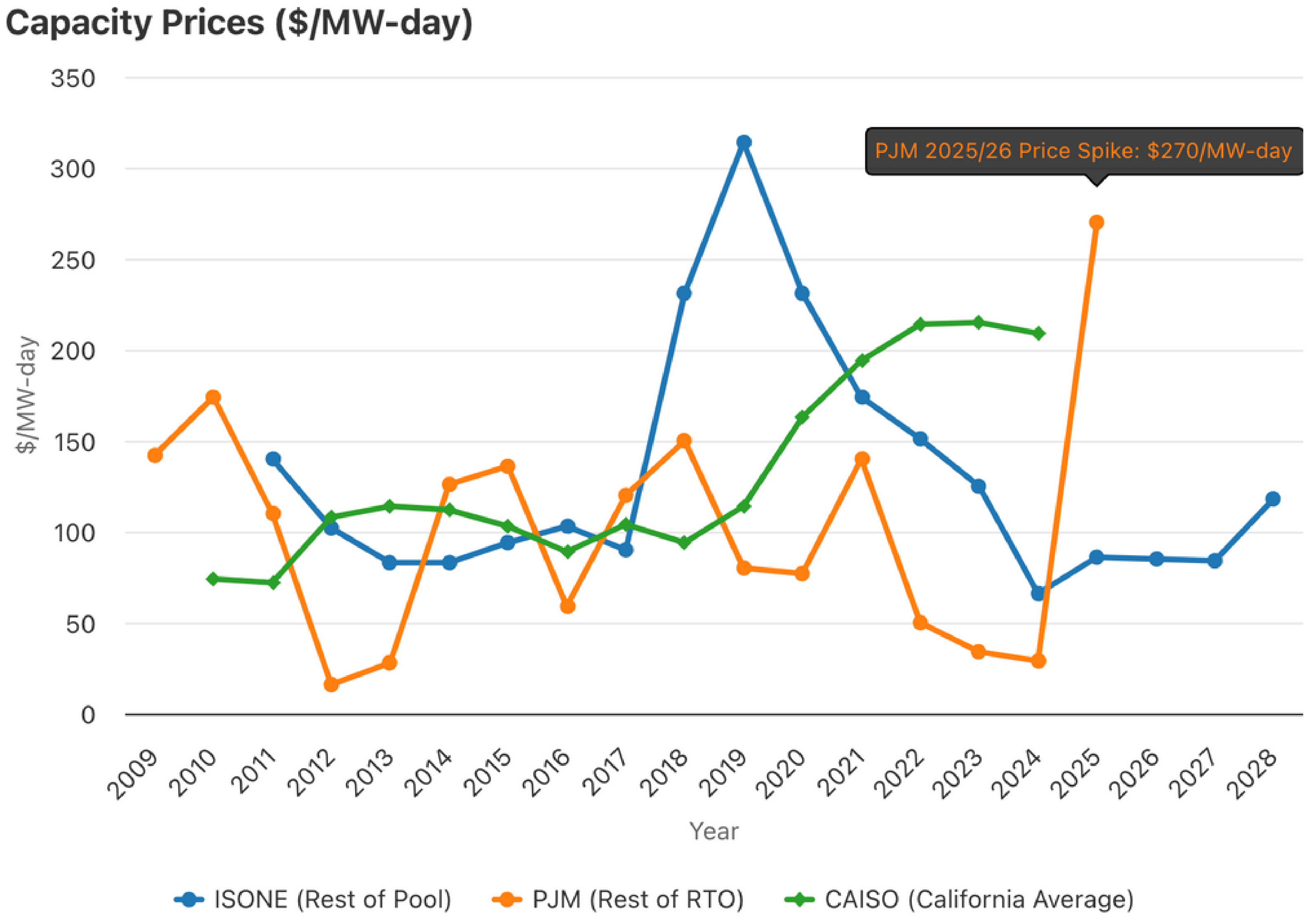
- **Gas projects:** Combined cycle and gas turbine projects comprise 9.6 GW (5.7%) of the queue.
- **Queue breakdown:** 88.7% of projects are active, 6.7% suspended, and 4.6% under construction as of March 31, 2025.

Source: PJM State of the Market Report - Q1 2025, Section 12: Generation and Transmission Planning

Firm capacity shortfalls are pushing capacity market prices higher

Capacity Prices Across Regions

Historical capacity prices in $/MW-day for ISONE, PJM, and CAISO from 2009-2028



Note: PJM price for 2025/26 increased dramatically from $28.92 in the previous auction to $269.92 /MW-day

PJM Capacity Auction Results

Key outcomes from the PJM 2025/26 delivery year capacity auction

Dramatic Price Increases

Base Price Spike
Prices in most of the PJM region spiked to $269.92 per megawatt-day for the 2025/26 delivery year, up from $28.92 per megawatt-day in the previous auction.

Zonal Price Caps
Prices hit zonal caps of $466.35 per megawatt-day in Maryland's Baltimore Gas and Electric zone and $444.26 per megawatt-day in the Dominion zone, covering parts of Virginia and North Carolina.

Total Cost Impact
As a result of these increases, the total cost to consumers soared from $2.2 billion in the previous auction to $14.7 billion.

Source - BNEF 2024

RRI Projected to supply 11 GW by 2030

Why RRI Was Introduced (October 2024)

Address Near-Term Reliability Crisis
32 GW demand growth expected by 2030, potential shortfalls by 2026

Queue Process Overwhelmed
5+ year wait times, 2-year pause on new applications during reform

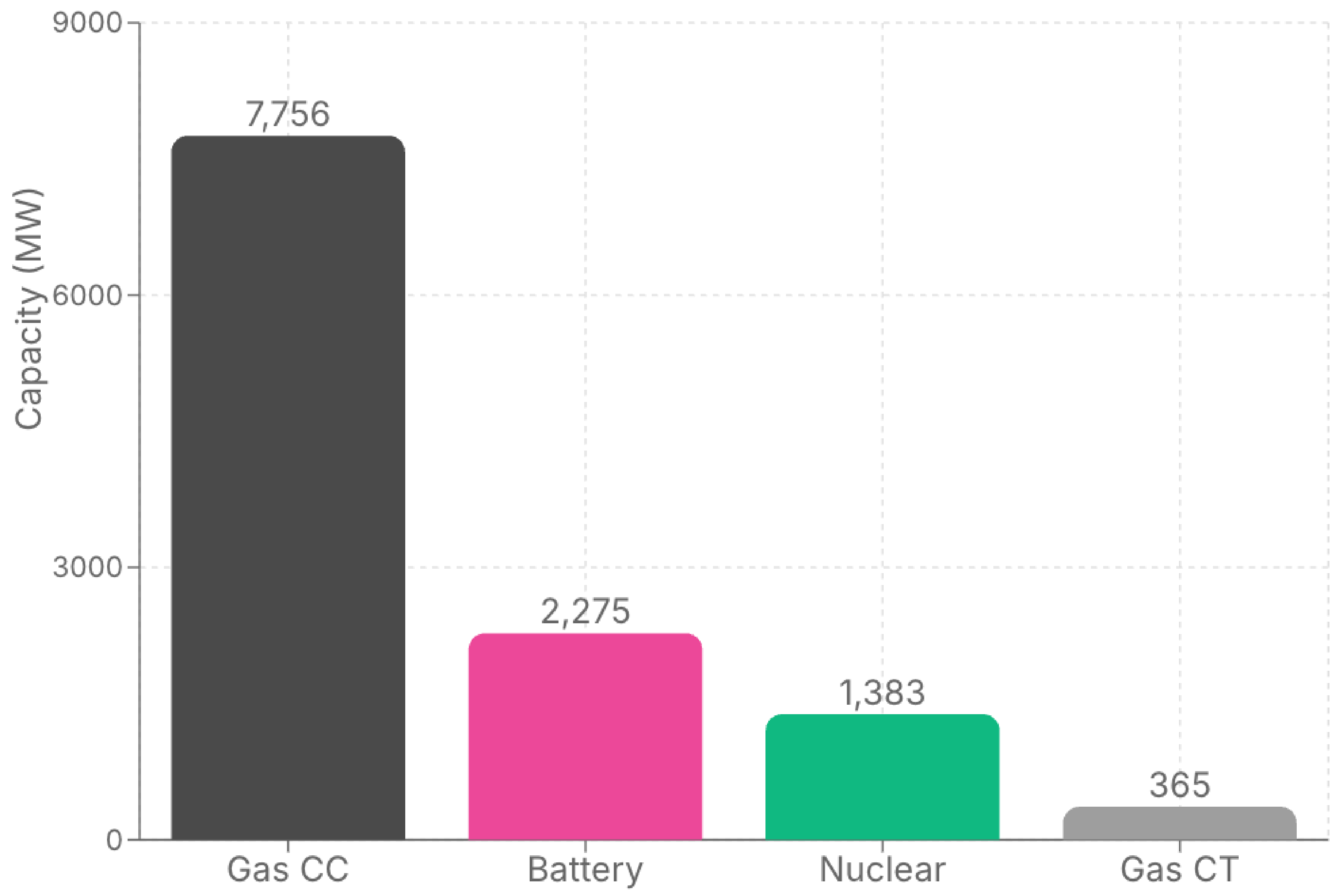
Fast-Track Shovel-Ready Resources
One-time opportunity to expedite 50 projects that could come online quickly

Extraordinary Circumstances
Transition from serial to cluster-based interconnection process created bottleneck

RRI Critical Flaws

- Only 10/100 points for 2026-30 readiness
- Gas turbines have 4-6 year lead times, making it harder to come online before 2030
- Won't address 2026 shortfall risk
- Increases costs without reliability benefit

RRI Capacity by Fuel Type (11,793 MW Total)



Source: PJM Reliability Resource Initiative Summary Results (May 6, 2025)

PJM Faces 25.1 GW Capacity Shortfall by 2030

PJM faces a potential 25.1 GW capacity shortfall by 2030, with critical risks emerging as early as 2026. Despite RRI fast-track additions, timing misalignment between retirements and new resources threatens grid reliability.

Resource Adequacy Assessment

Total Capacity Need

40 GW

Peak Load Growth: 32 GW

Retirements: 8 GW

Expected Additions

14.9 GW

Realistic Queue: 5.6 GW

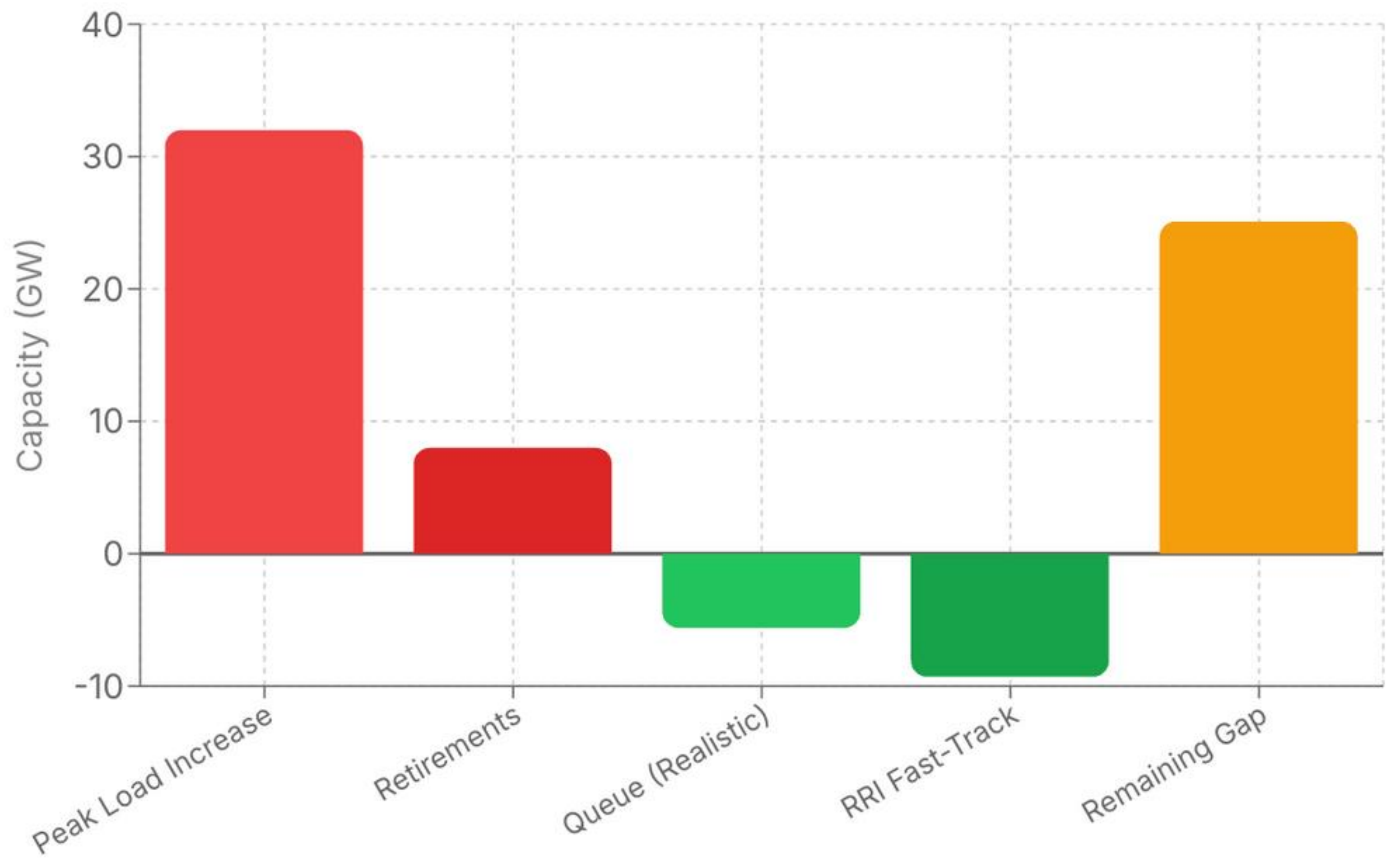
RRI Fast-Track: 9.3 GW

Critical Gap: 25.1 GW

- **5.2% queue realization** - only 5.6 GW of 107 GW queue expected
- **3.6% annual growth** vs 1% historical average creates unprecedented demand
- **Limited retirements** - only 3.9 GW coal (51% of planned)
- **Risk by 2026** - shortfalls possible before RRI resources online
- **Timing mismatch** - RRI resources won't be fully online until 2030-2031
- **Construction delays risk** - historical data shows 2-3 year delays common

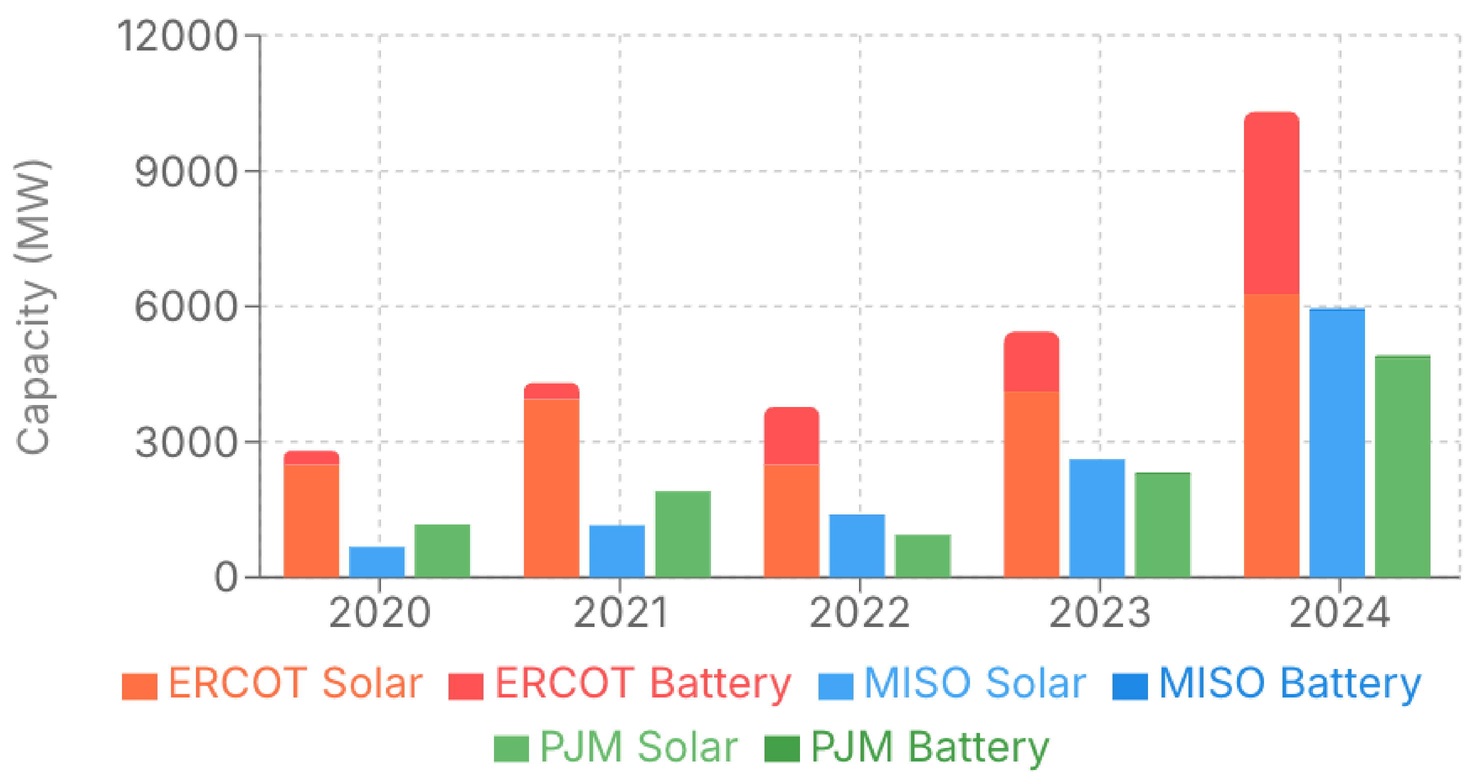
Sources: PJM 2025 Reports, RRI Results

Capacity Needs Waterfall (GW)



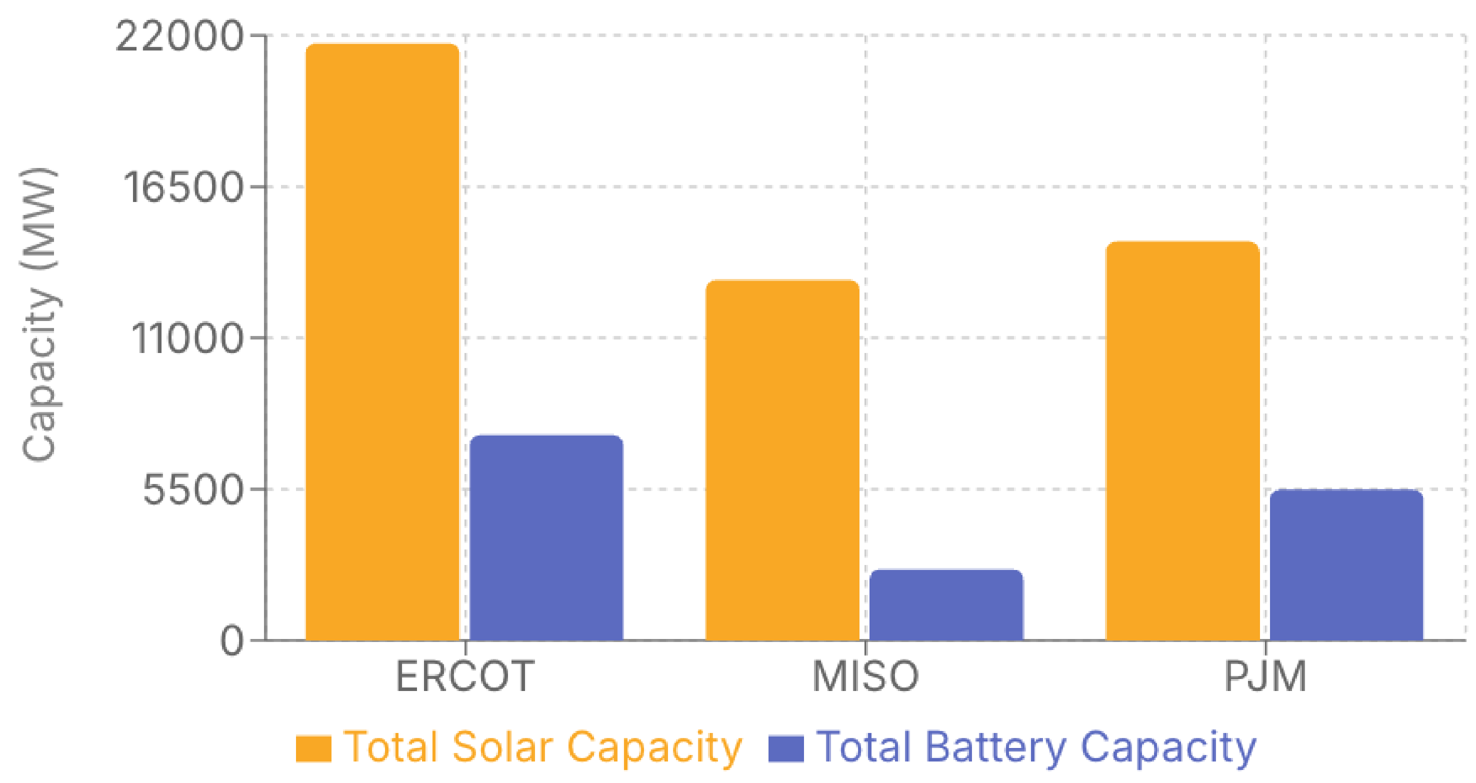
PJM lags behind in solar and storage additions

Annual Solar & Battery Installations (MW)



2024 was a record year: ERCOT added 6.3 GW solar + 4.0 GW battery, MISO added 5.9 GW solar, PJM added 4.8 GW solar.

Total Installed Capacity by End of 2024 (MW)



By end of 2024: ERCOT leads with 21.7 GW solar and 7.5 GW battery, PJM has 14.5 GW solar, MISO has 13.1 GW solar.

ERCOT solar: 15.5⟶21.7 GW (+6.3 GW in 2024)

MISO solar surge: 7.2⟶13.1 GW (+5.9 GW in 2024)

PJM solar growth: 9.7⟶14.5 GW (+4.8 GW in 2024)

Combined US 2024: 30 GW solar + 10.5 GW battery added

New gas is unlikely come online before 2030

Gas Plant Development Timeline

For a gas plant ordered February 2025, the projected online date is 2030-2032

1

Phase 1

Turbine Delivery

4-5 Years

- GE Vernova: 48-60 month lead times
  Limited to manufacturing 20 GW annually by 2027
- Siemens: Backlogged to 2029
  Limited expansion plans despite high demand
- Mitsubishi: J-series queued to 2029
  Plans only 'very planned expansion with discipline'

2

Phase 2

Interconnection

3-5 Years

- PJM's queue now takes 4-5+ years, 286 GW backlogged as of 2024
- Grid upgrades add another 1-2 years, Additional time if significant transmission upgrades required

3

Phase 3

Construction

2-3 Years

- Combined-cycle plants: 24-36 months
- Simple-cycle (peaking): 18-24 months

Best Case	Likely Case	Worst Case
5 years	**6-7 years**	**8+ years**
Online by Feb 2030	Online by Feb 2031-2032	Online after 2033

Industry Dynamics: Long Lead Times and Turbine Shortages

Gas turbine shortages and capacity constraints create extended timelines

Industry Leaders Confirm Long Lead Times

> *"New gas projects won't be available at scale until 2030, and then only in certain pockets of the U.S. This is an industry that really hasn't seen any active development or construction in years... all of that puts pressure on cost."*
>
> — John Ketchum, NextEra Energy CEO (2024)

> *"We have to be very thoughtful to make sure that we don't add too much capacity, even though we are starting to sell slots into 2029. We're going to continue to be very sequential on how we invest."*
>
> — Scott Strazik, GE Vernova CEO (2024)

Turbine Shortage: Market Impacts

- Engie withdrew Texas gas plant applications due to "equipment procurement constraints"
- GE Vernova limiting $300M investment to improving existing plants, not expansion
- Industry analysts project turbine shortage will continue through 2030 due to manufacturing constraints

Conclusion

Existing gas plants already in development can only meet approximately 25% of projected peak capacity needs by 2030. New gas plants ordered today would not come online until after 2030.

Source - HeatMap News 2025

Thermal plants are underutilizing their interconnection capacity

Interconnection Underutilization

Thermal plants like peaker gas plants and oil/gas steamers operate at extremely low capacity factors. Peaker gas plants operate at 9% capacity factor and oil/gas steamers operate at 4.1% capacity factor, meaning for 91% of the time and 96% of the time, respectively, the interconnection capacity sits idle. This massive underutilization reflects the backup role of these assets.

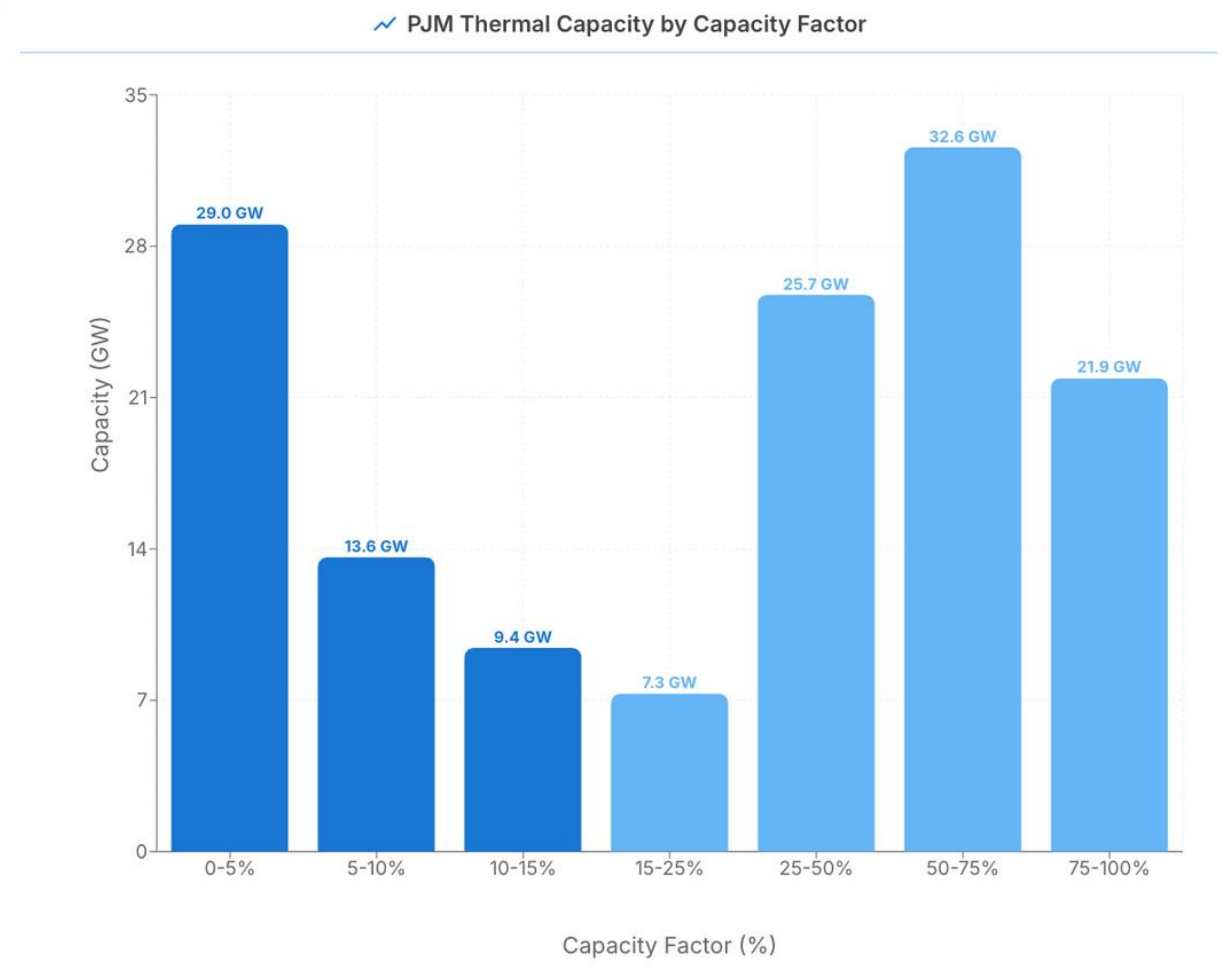
2024 Thermal Capacity Factors

- **Gas CCGT:** 66%
- **Coal:** 36%
- **Gas CT:** 9%
- **Oil/Gas Steam:** 4.1%

Underutilized Interconnection Capacity

- **52.1 GW** operates at <15% capacity factor
- Dominated by gas turbines (25.1 GW) and coal plants (11.5 GW)
- 147 plants underutilizing valuable grid connections

Source: PJM State of the Market Report 2024, EIA Form 860, and EIA Form 923



RE plants are underutilizing their interconnection capacity

Two Dimensions of Underutilization

Renewables underutilizing interconnection capacity from both firm capacity and energy perspectives

RE Energy Production Gap

Solar operates at 19.1% and wind at 16.1% capacity factor, leaving 82.4% of interconnection capacity idle

ELCC Value Disparity

PJM assigns only 8-11% ELCC for solar and 41% for wind, compared to 95% for nuclear and 74% for gas combined cycle

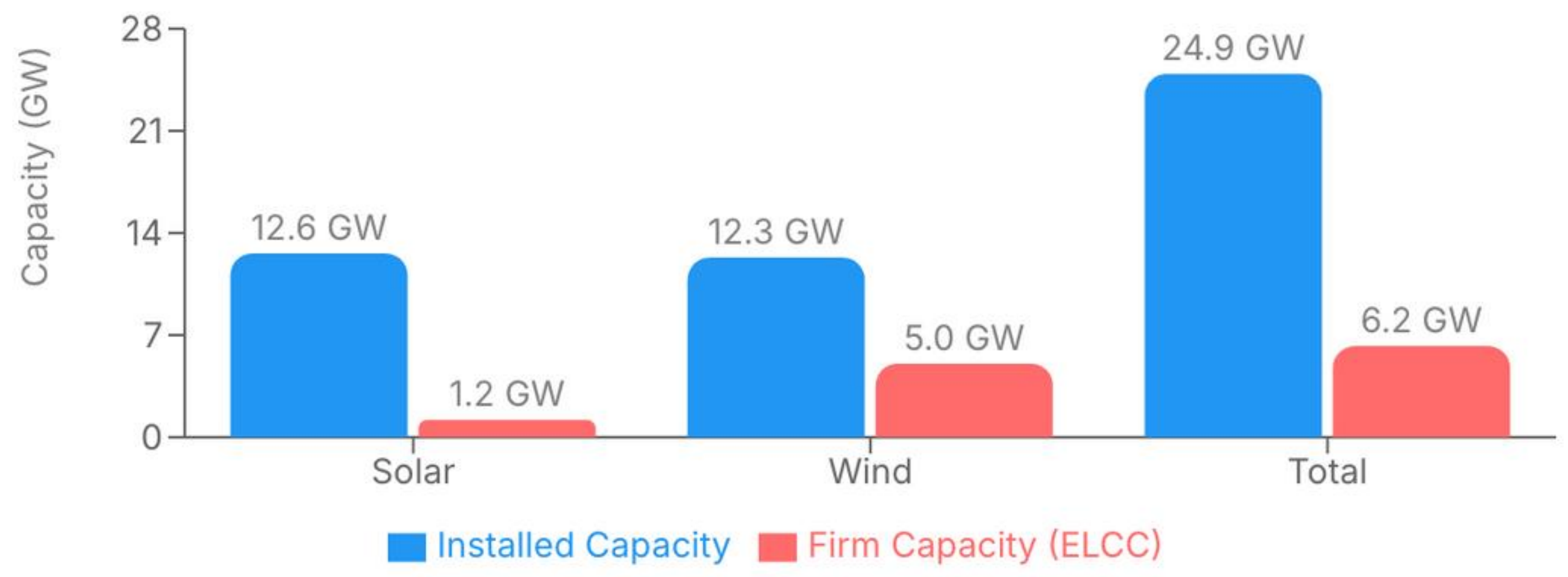
Firm Capacity Shortfall

24.9 GW of installed renewable capacity provides only 6.2 GW of firm capacity — just 25% of nameplate capacity

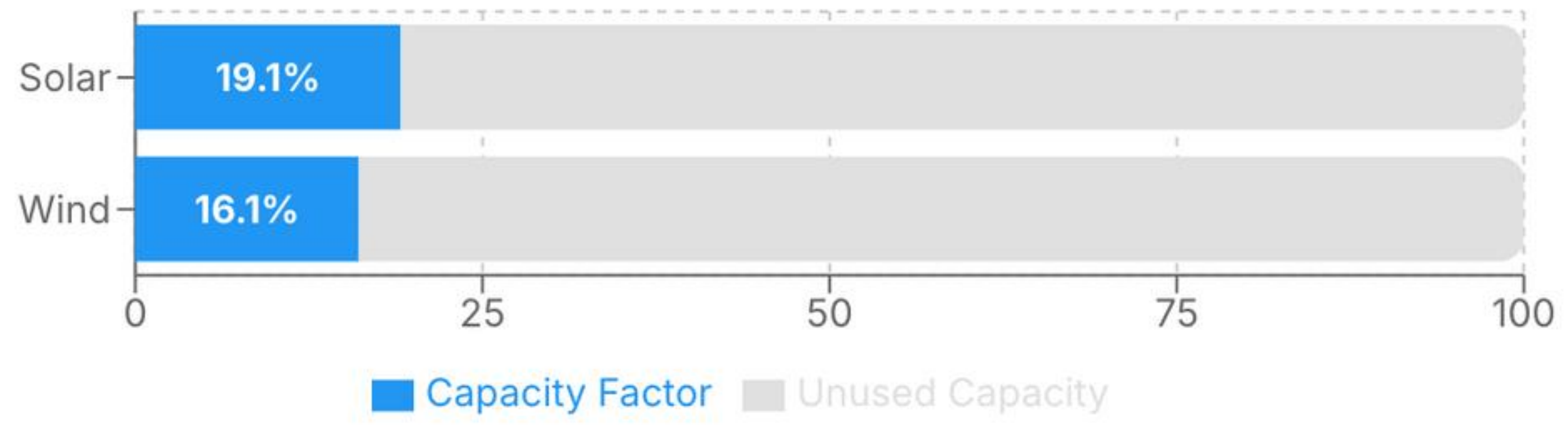
Storage as the Solution

4-hour storage receives 50% ELCC, 6-hour gets 58%, while 10-hour storage gets 72% — significantly higher than standalone renewables

Firm Capacity vs. Installed Capacity (GW)



Renewable Energy Capacity Factors (%)



6H Storage ELCC comparable with Gas

PJM ELCC Values

Effective Load Carrying Capability measures a resource's contribution to meeting peak demand. Higher ELCC means more reliable capacity during critical grid hours.

PJM's Methodology: Uses probabilistic analysis to assess resource performance during system stress, considering:

- Output during peak demand periods
- Weather-correlated performance
- Marginal value as more units are added

ELCC by Technology

Solar's Low ELCC (11%): Requires ~9 MW of solar to provide 1 MW of reliable capacity

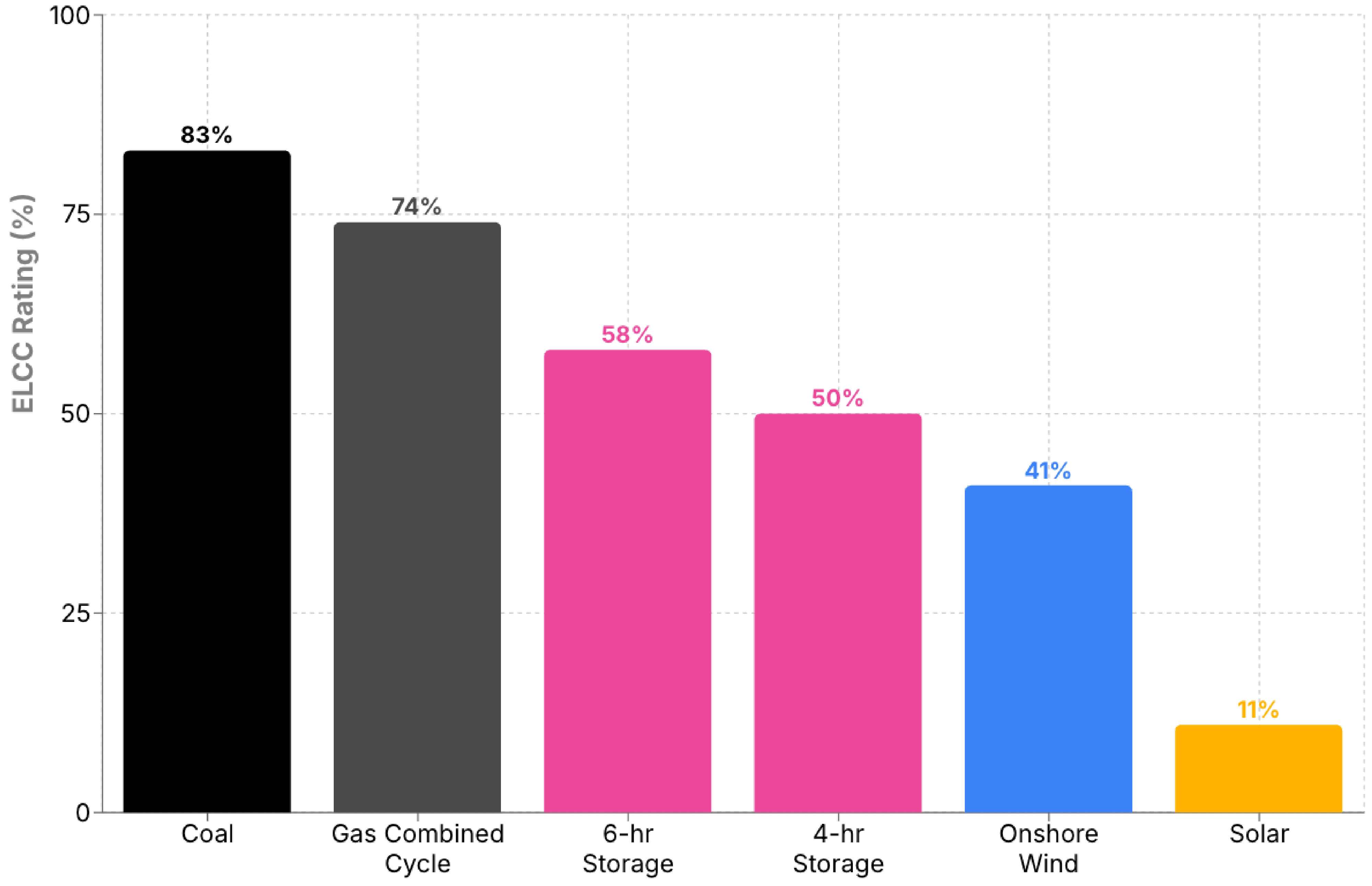
Wind's Better Performance (41%): Nearly 4x more capacity value than solar in PJM

Storage Duration Matters: 6-hr storage (58%) provides 16% more value than 4-hr (50%)

Thermal Advantage: Coal (83%) and Gas CC (74%) still provide highest reliability

Source: PJM, 2026/2027 BRA

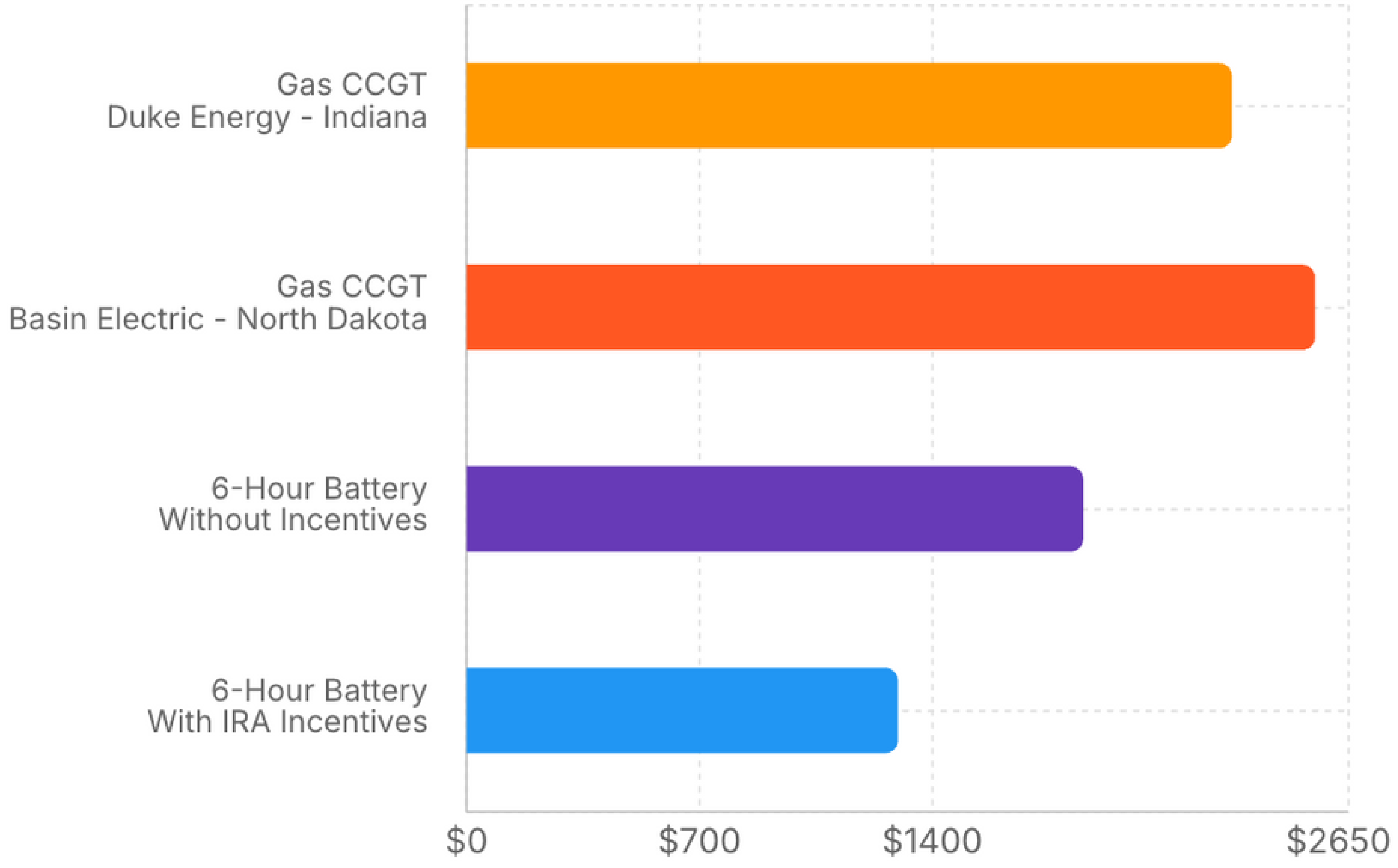
Effective Load Carrying Capability (ELCC) - 2026/2027 BRA



Storage capital costs are cheaper than gas

Capital Cost Comparison ($/kW)

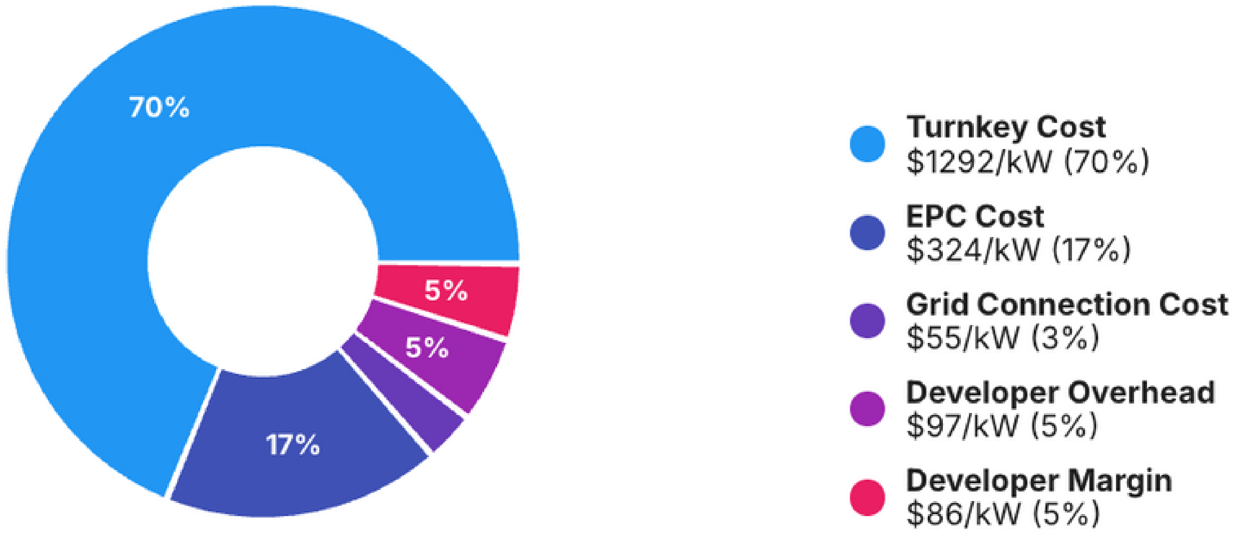
6H Battery with IRA: $1297/kW



Source: BNEF 2025 and PUC Filings

6H Battery Cost Components (wo Incentives)

Total: $1853/kW



Source: BNEF 2025

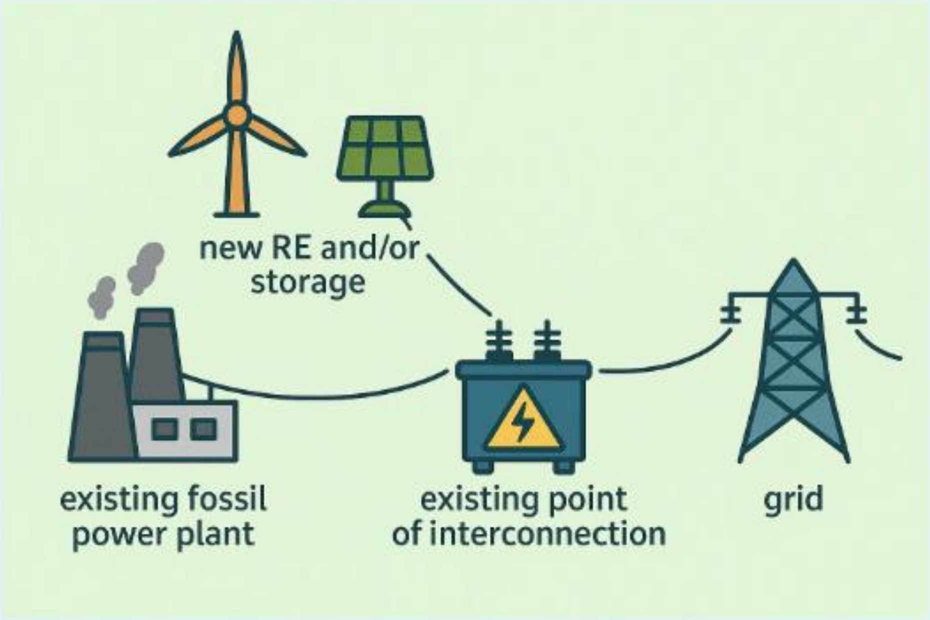
Battery Storage Outperforms Gas Plants

- Gas costs rising ($2,300-2,550/kW)
- Battery costs dropping every year
- Battery supply chain advantages over gas

- 2018: 2,000 cycles (6-year life)
- 2024: 10,000-15,000 cycles (20+ years)

Maximizing efficiency of existing assets: Surplus Interconnection

Renewables at Thermal Plants

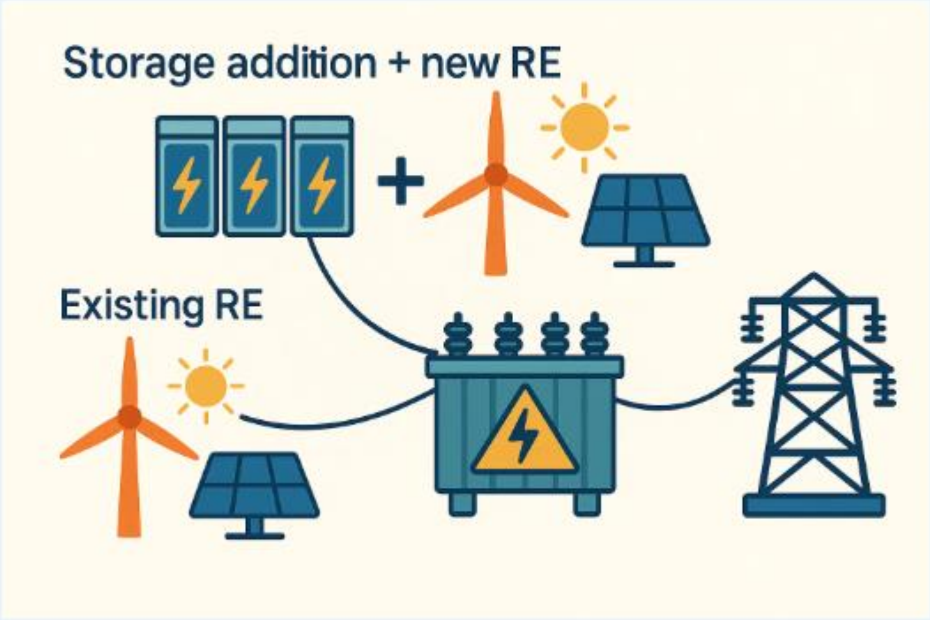


Existing thermal plants have underutilized interconnection capacity that can be leveraged for renewables

Key Implementation Points:

- Thermal plants, especially peakers, significantly underutilize their interconnection capacity
- FERC Order 845 provides regulatory pathway for surplus interconnection
- Reduced costs through shared infrastructure and site development
- Creates transition pathway beyond fossil generation assets
- Bypasses lengthy interconnection queues for faster deployment

Storage at Renewable Plants



Current renewable plants use only 18% of their interconnection capacity due to intermittency

Key Implementation Points:

- Battery storage can be added at existing renewable plants using surplus interconnection capacity
- Batteries absorb excess generation that would otherwise be curtailed
- Energy dispatched even when renewables aren't generating, smoothing output
- Batteries shift generation from low-value to high-value hours
- With batteries managing generation profiles, more renewables can be added

Surplus Interconnection Projects

🏭 Thermal

Crete Energy Venture

🏢 Earthrise Energy
📍 Will County, IL - PJM

🏭 Original Capacity	➕ Added Capacity
301MW Gas	**250MW Solar (2 projects)**
Online: Operating	Online: In Development

Source: Earthrise Portfolio

Gibson City

🏢 Earthrise Energy
📍 Ford County, IL - MISO

🏭 Original Capacity	➕ Added Capacity
237MW Gas	**270MW Solar (2 projects)**
Online: Operating	Online: In Development

Source: Earthrise Portfolio

Shelby County

🏢 Earthrise Energy
📍 Shelby County, IL - MISO

🏭 Original Capacity	➕ Added Capacity
352MW Gas	**360MW Solar (2 projects)**
Online: Operating	Online: In Development

Source: Earthrise Portfolio

☀️ RE

Polaris Solar

🏢 DTE Energy
📍 Michigan - MISO

🌬️ Original Capacity	➕ Added Capacity
168MW Wind	**100MW Solar**
Online: Operating	Online: 2025

Source: DTE Solar

Pine River Solar

🏢 DTE Energy
📍 Michigan - MISO

🌬️ Original Capacity	➕ Added Capacity
161.4MW Wind	**80MW Solar**
Online: Operating	Online: April 2025

Source: DTE Announcement

Scott Solar + Storage

🏢 Dominion Energy + RES
📍 Powhatan County, VA

☀️ Original Capacity	➕ Added Capacity
12MW Solar	**12MW/48MWh Storage**
Online: 2019	Online: May 2022

Source: Scott Solar

Methodology Summary

Resource Assessment

- Assessed RE resource availability within a 6 mile buffer zone around each thermal and renewable plant in PJM
- Applied 50+ exclusion criteria including physical constraints (land cover, slope, etc.), environmental protections (protected areas, national parks, etc.), and local ordinances
- Estimated local solar and wind potential using suitable area and average solar and wind generation density

Economic Analysis

- Estimated local hourly solar and wind generation near each power plant in PJM using meteorological data from ERA5
- Estimated local solar and wind LCOE using capaital cost data from BNEF and compared with the variable costs of thermal plants to identify economic crossover points
- Applied relevant IRA incentives including energy community bonus tax credits at power plant locations

Portfolio Optimization

- Estimated optimal mix of soalr, wind and storage which maximizes interconnection use while limiting curtailment below 5%
- For thermal plants, estimated optimal solar and wind capacity that can be added, and for renewable plants, estimated additional solar and wind capacity that can be enabled by adding 6-hour storage.
- Selected high-quality resources with capacity factors above 30% for wind and 20% for solar to ensure economic viability

Load Growth Analysis

- Compared surplus interconnection potential with PJM's peak and energy load growth projections for 2030
- Estimated interconnection utilization increase for renewable plants through battery storage and renewable additions
- Quantified avoided interconnection and network upgrade costs based on historical cost data from PJM

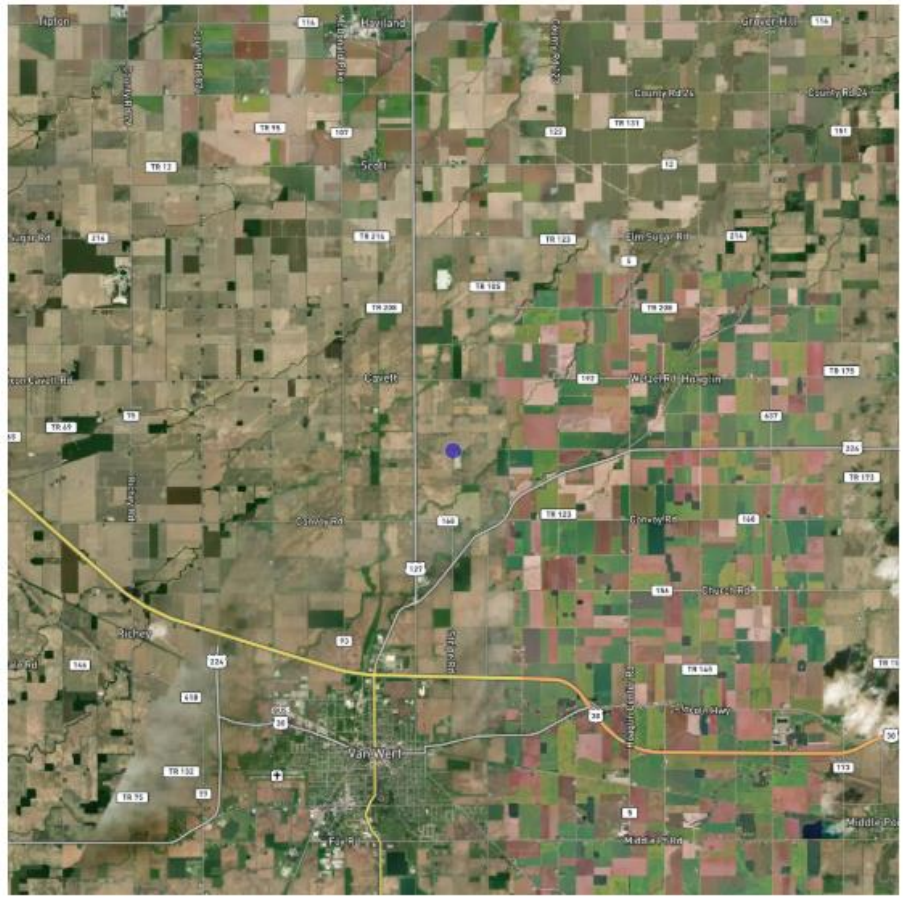
Case Study: Blue Creek Wind Farm

Facility Information

LOCATION	INSTALLED CAPACITY	OWNER	COD
Van Wert, Ohio	**302 MW**	**Avangrid Renewables LLC**	**2012**

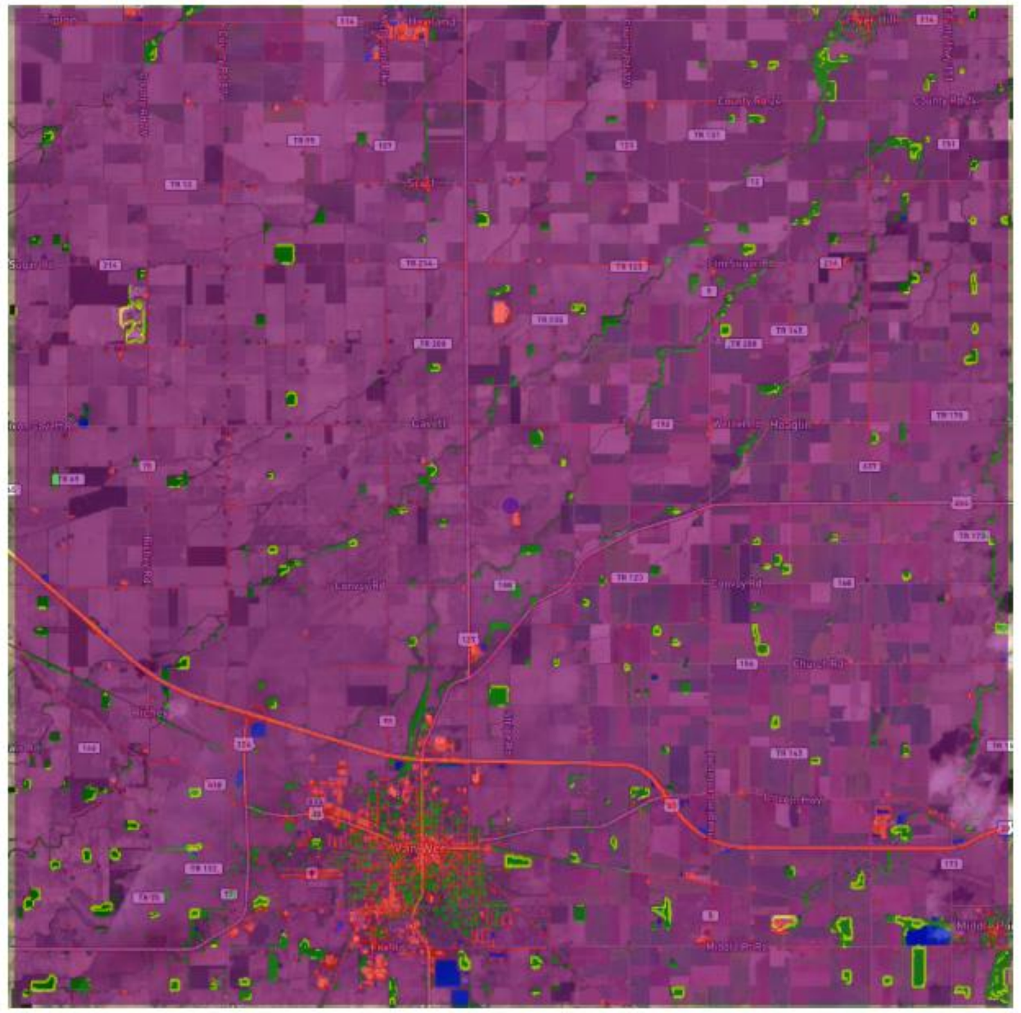
Satellite View of Wind Farm

6×6-Mile Buffer Zone



Blue Creek Wind: Local Solar and Wind Potential

Classification Map



Sensitive Habitat · Water/Ice Covered · Urban Area · Unfavorable Topography · Buildable · Other

RE Potential within 6 miles of Blue Creek Wind

- Assessed RE resource availability within a 6-mile buffer zone around the Blue Creek Wind Project
- Applied 50+ exclusion criteria including physical constraints, environmental protections, and local ordinances
- Estimated local solar and wind potential using suitable area and generation density analysis

85% of area within this 6 mile square is buildable

17,400 MW Solar Potential

2,088 MW Wind Potential

5 TW of solar and wind potential near existing interconnection points

Thermal Plants

249
Facilities

141,114
MW Capacity

Technology Breakdown

- 93 — Gas Combustion Turbine — **29,084 MW**
- 76 — Gas Combined Cycle — **59,521 MW**
- 47 — Coal — **42,060 MW**
- 55 — Oil, Gas, Steam — **10,448 MW**

Plants in Urban Areas

20
Facilities
8% of Total

8,297
MW Capacity
6% of Total

RE Potential Near Thermal Plants

1,782
GW
Solar Potential

214
GW
Wind Potential

Total Potential: 1,996 GW

Renewable Plants

313
Facilities

23,834
MW Capacity

Technology Breakdown

- 223 — Solar Plants — **12,470 MW**
- 90 — Wind Plants — **11,364 MW**

Plants in Urban Areas

6
Facilities
2% of Total

520
MW Capacity
2% of Total

Additional RE Potential Near Renewable Plants

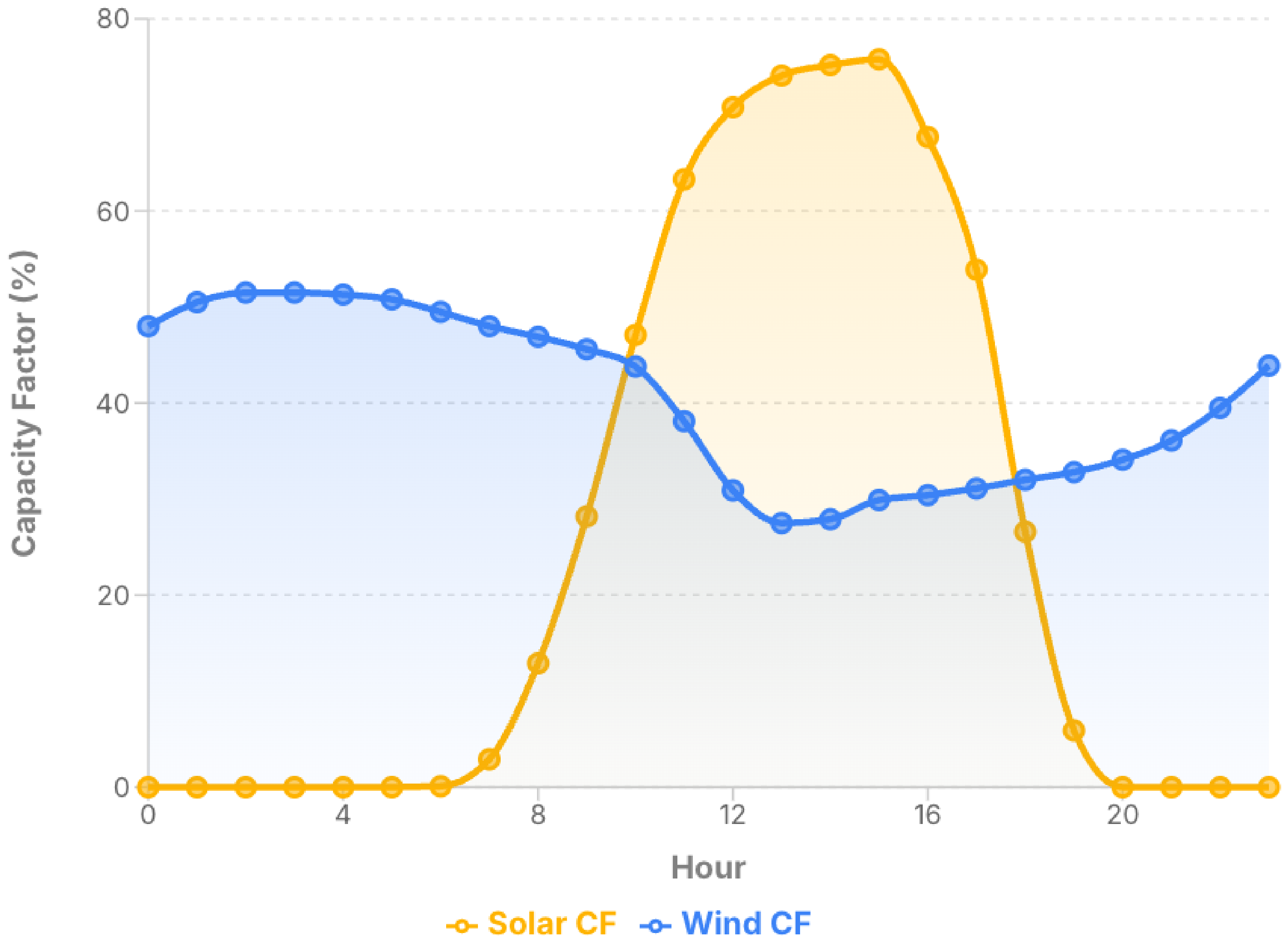
2,898
GW
Solar Potential

348
GW
Wind Potential

Total Potential: 3,246 GW

Blue Creek Wind: Local Solar and Wind LCOE

Diurnal Capacity Factors at Blue Creek Wind Project



Hourly average capacity factors showing solar peaks during midday and wind's more consistent generation pattern

Capacity Factors

Solar (AC)	Wind
22.7%	30.4%

Levelized Cost of Energy

Solar

2025		2030
$31/MWh	→	**$22/MWh**

Wind

2025		2030
$19/MWh	→	**$15/MWh**

By 2030 All of Thermal Capacity Expensive Compared to Local RE LCOE

Capacity Below Thermal Variable Costs

2024

- In 2024, 60.8 GW of thermal capacity already has variable costs higher than local solar LCOE
- 126.2 GW of thermal capacity operates at costs exceeding wind LCOE

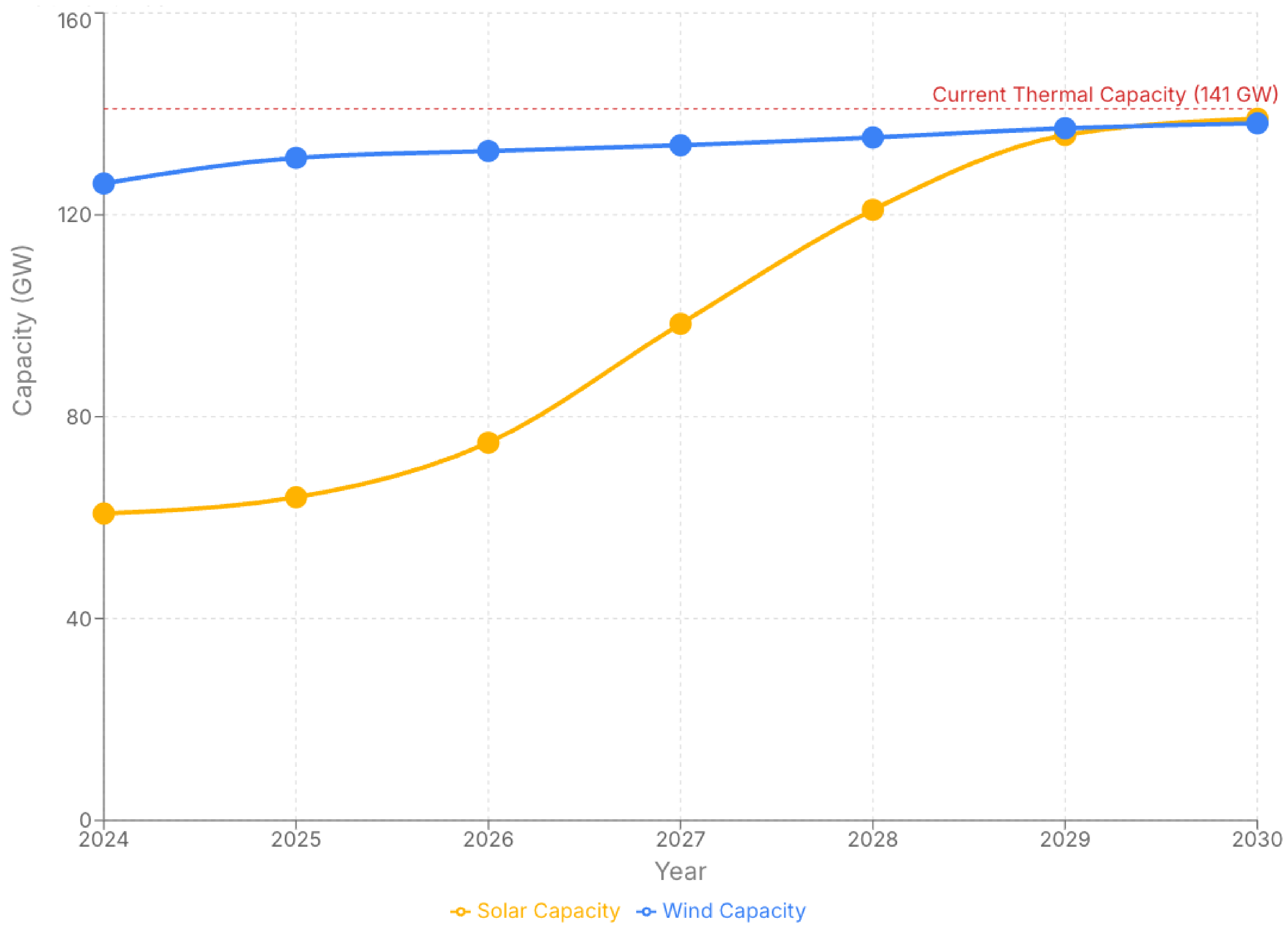
2030

- By 2030, solar LCOE will be competitive with 139.0 GW of thermal generation
- Wind generation costs will undercut 138.1 GW of thermal capacity

Growth (2024-2030)

- From 2024 to 2030, an additional 78.2 GW of thermal capacity becomes uneconomic compared to local solar
- An additional 11.9 GW of thermal capacity becomes uneconomic compared to wind generation

Renewable Capacity Below Thermal Variable Costs



Tax Credit Repeal Dampens Economics

IRA Tax Credit Impact

Impact of Losing IRA Tax Credits

With IRA tax credits being repealed under new 2025 legislation, renewable LCOE will increase significantly.

Currently, tax credits allow renewables to compete with a large portion of PJM's thermal fleet. Without these credits, renewable competitiveness will drop dramatically.

The loss of tax credits will make renewables uncompetitive with most thermal plants again.

Solar Crossover

GW of thermal capacity with variable costs higher than local solar LCOE

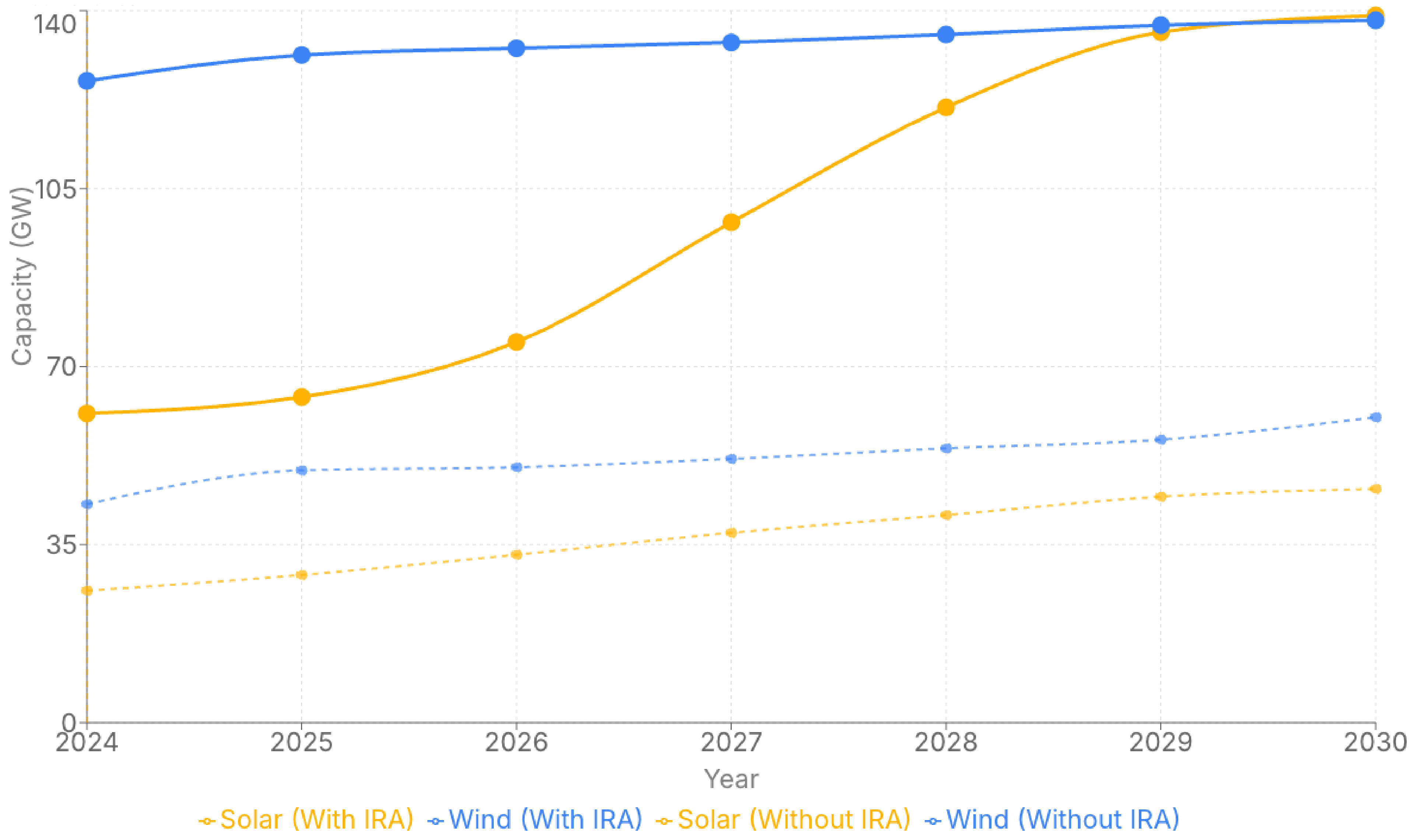
2024	2030
With IRA: **60.8 GW** Without: **26 GW** **+34.8 GW**	With IRA: **139 GW** Without: **46 GW** **+93.0 GW**

Wind Crossover

GW of thermal capacity with variable costs higher than local wind LCOE

2024	2030
With IRA: **126.2 GW** Without: **43 GW** **+83.2 GW**	With IRA: **138.1 GW** Without: **60.1 GW** **+78.0 GW**

Renewable Capacity Competitive with Thermal: IRA Impact



Note: Solid lines show renewable capacity competitive with thermal plants when IRA tax credits are included. Dashed lines show competitive capacity without IRA subsidies. The gap illustrates the critical role of IRA in accelerating renewable deployment.

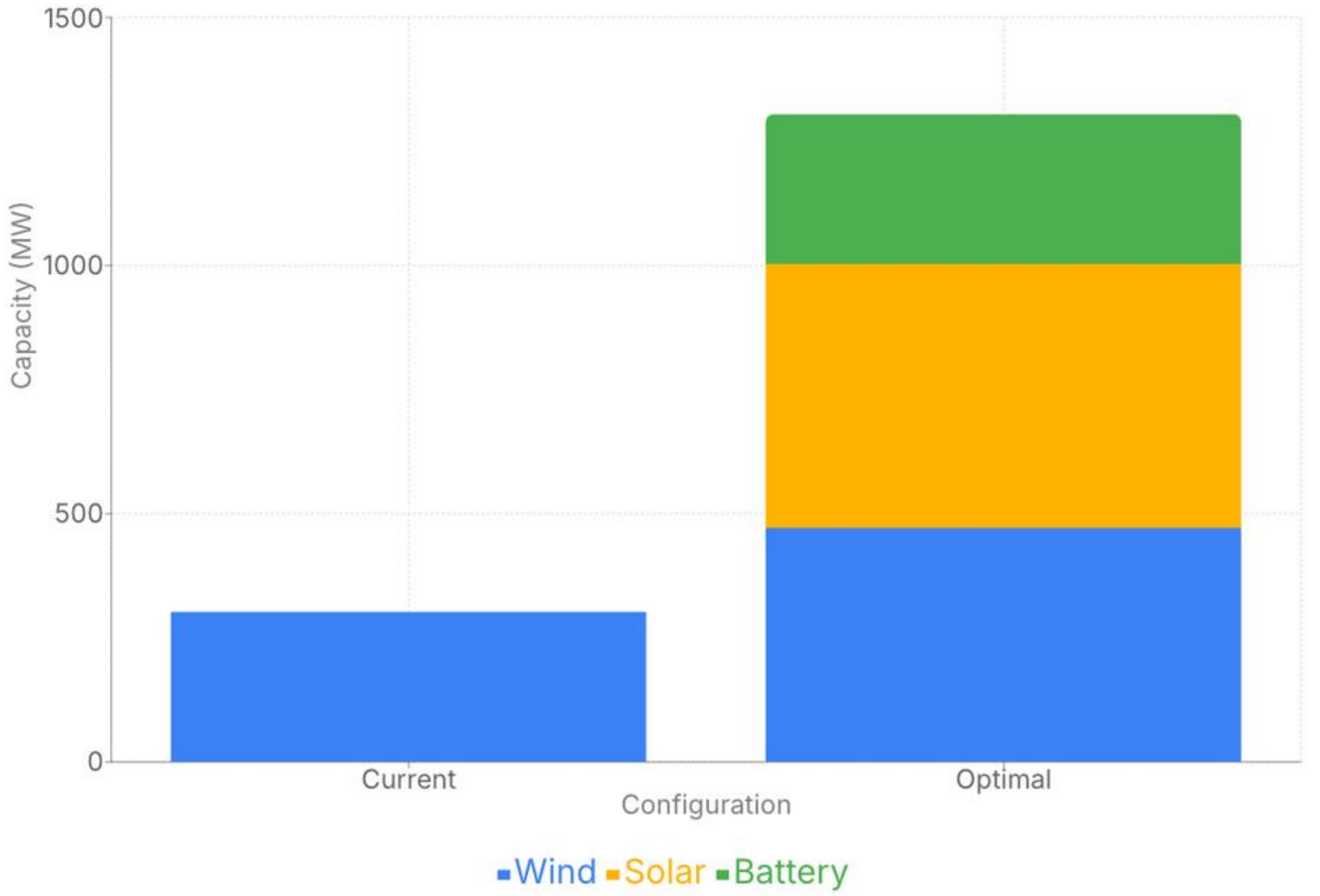
Blue Creek Wind: 532 MW of Solar and 169 MW Wind enabled by 302 MW of 6H storage

Optimal Capacity Configuration

3.3x
Capacity Increase

50.1%
CF Improvement

30.4% → 80.4% Capacity Factor
+1,057 GWh/year additional energy



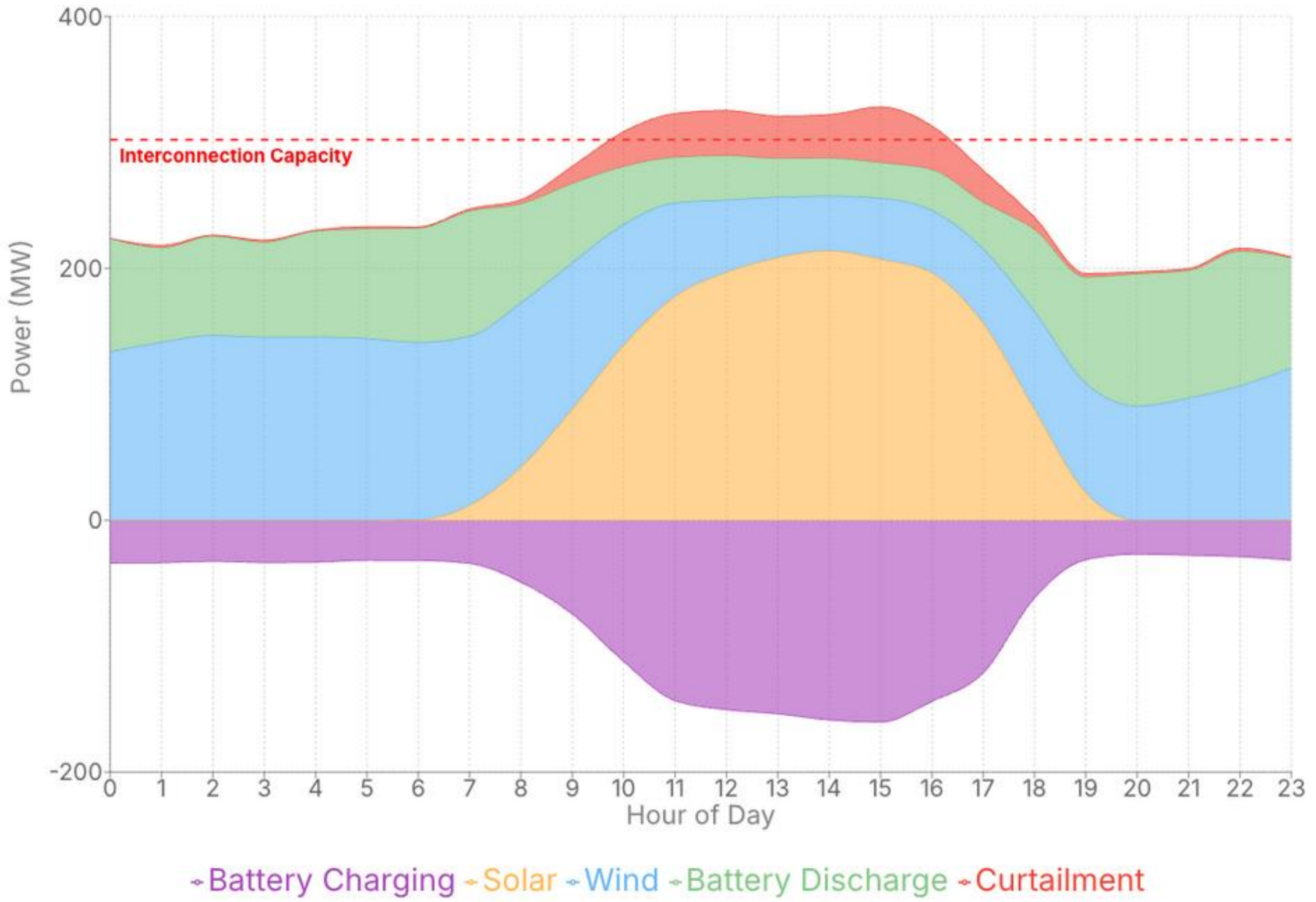
24-Hour Energy Flow Pattern (Annual Average)

System Performance Summary

243
MW Avg Output

6
Hour Battery

5%
Curtailment



78 GW of RE can be added at PJM thermal plants

RE Integration Potential Results

78 GW of renewable energy capacity can be integrated near existing thermal plants in PJM by 2030

- Solar integration potential: 74 GW
- Wind integration potential: 5 GW

- **39 GW** of RE can be integrated today using surplus interconnection

Sensitivity analysis:

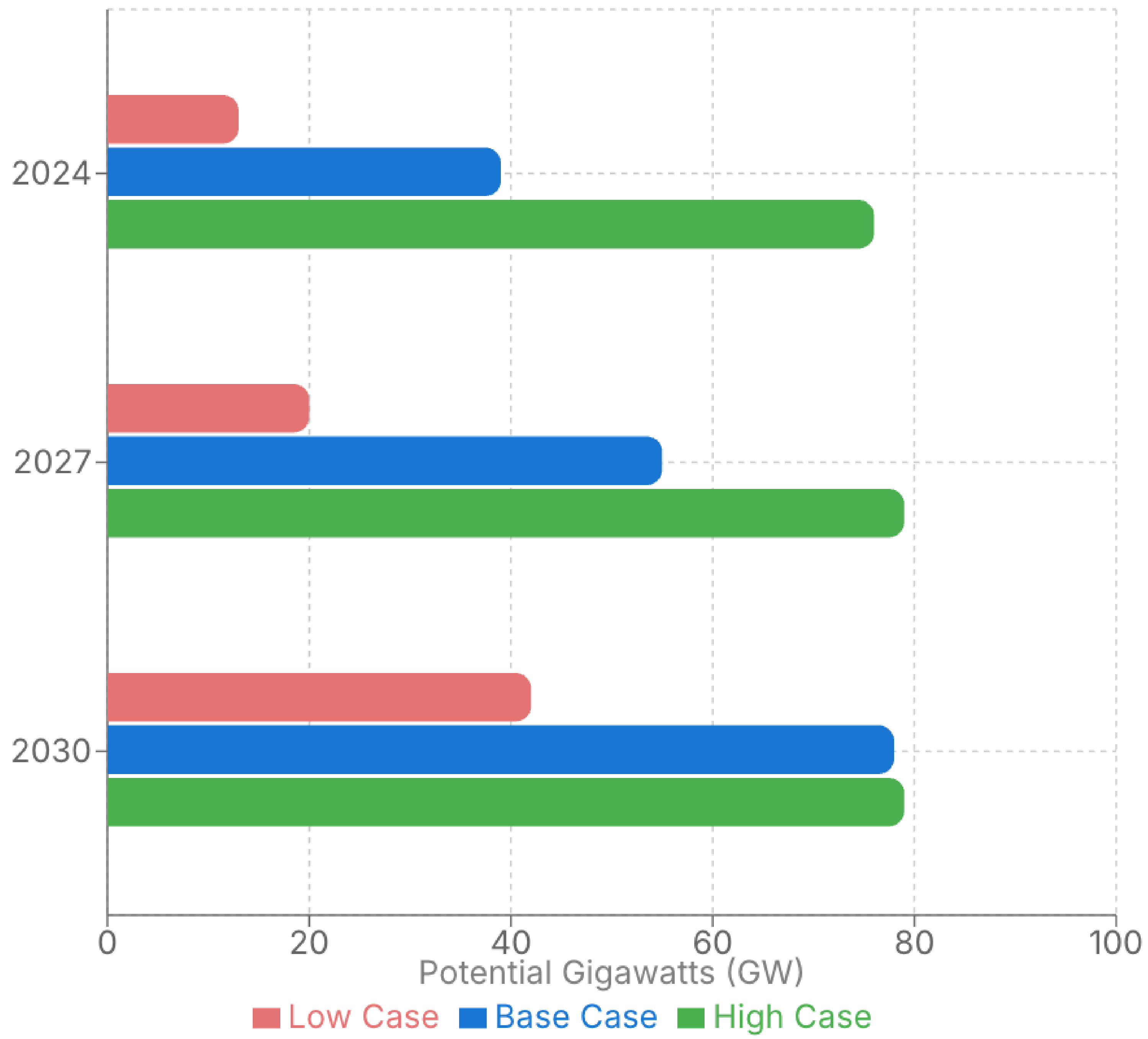
We varied the cost of fuel by taking one standard deviation below and above the average fuel prices to test the economics of thermal versus local solar and wind:

- Low fuel prices (1σ below average): 13 GW (2024) → 42 GW (2030)
- High fuel prices (1σ above average): 76 GW (2024) → 79 GW (2030)

- Uncertainty range narrows 41%: from 63 GW → 37 GW

- **Even worst-case scenario shows 42 GW potential - exceeding current renewable targets**

Total RE Integration Potential by Year



Solar only Scenario: 75 GW of Solar can be added at Thermal Plants

Solar-Only Deployment Scenario

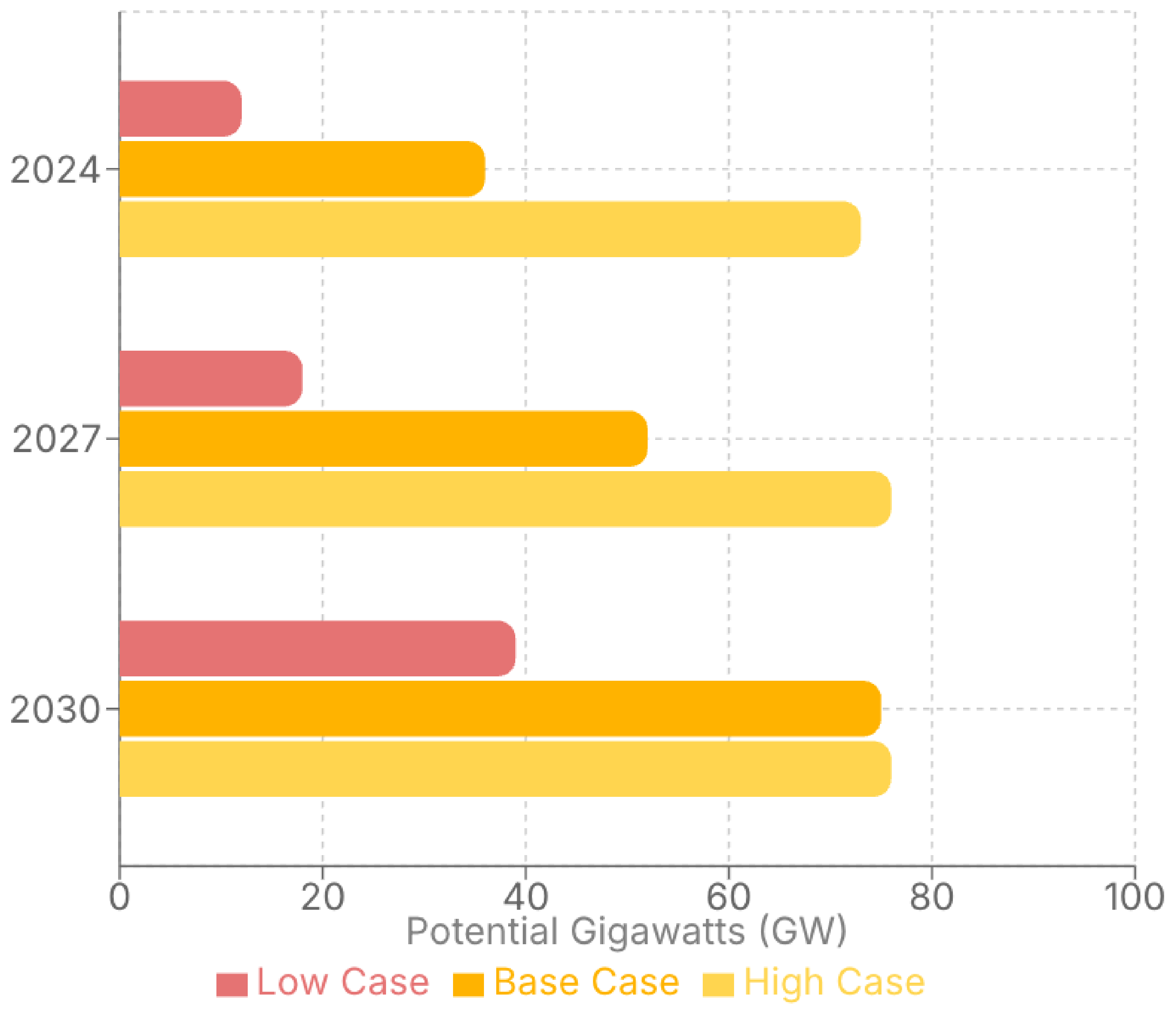
We analyzed a solar-only scenario where only solar is installed at existing thermal plants, recognizing that wind development has become increasingly challenging due to permitting and siting constraints.

75 GW of solar can be integrated at existing thermal sites by 2030

- Base case: **36 GW** (2024) → **75 GW** (2030)
- High fuel prices: **73 GW** (2024) → **76 GW** (2030)
- Low fuel prices: **12 GW** (2024) → **39 GW** (2030)

- Uncertainty range narrows from 61 GW (2024) → 37 GW (2030), demonstrating increasing economic viability regardless of fuel prices

Solar-Only Integration Potential by Year



Tax Credit Repeal reduce RE integration potential by 47 GW

IRA Expiration Cuts RE Addition Potential at Thermal Sites from 78 GW to 31 GW

Without IRA incentives, the levelized cost of renewables increases significantly, making local solar and wind projects that were economically competitive with thermal generation uneconomic after tax credit removal. Only the most cost-effective renewable projects near thermal plants remain viable without subsidies.

With IRA (2-Year Window)

- **78 GW** of renewable capacity can be added at thermal sites by 2030
- 74 GW solar + 5 GW wind potential
- **39 GW** economically viable immediately

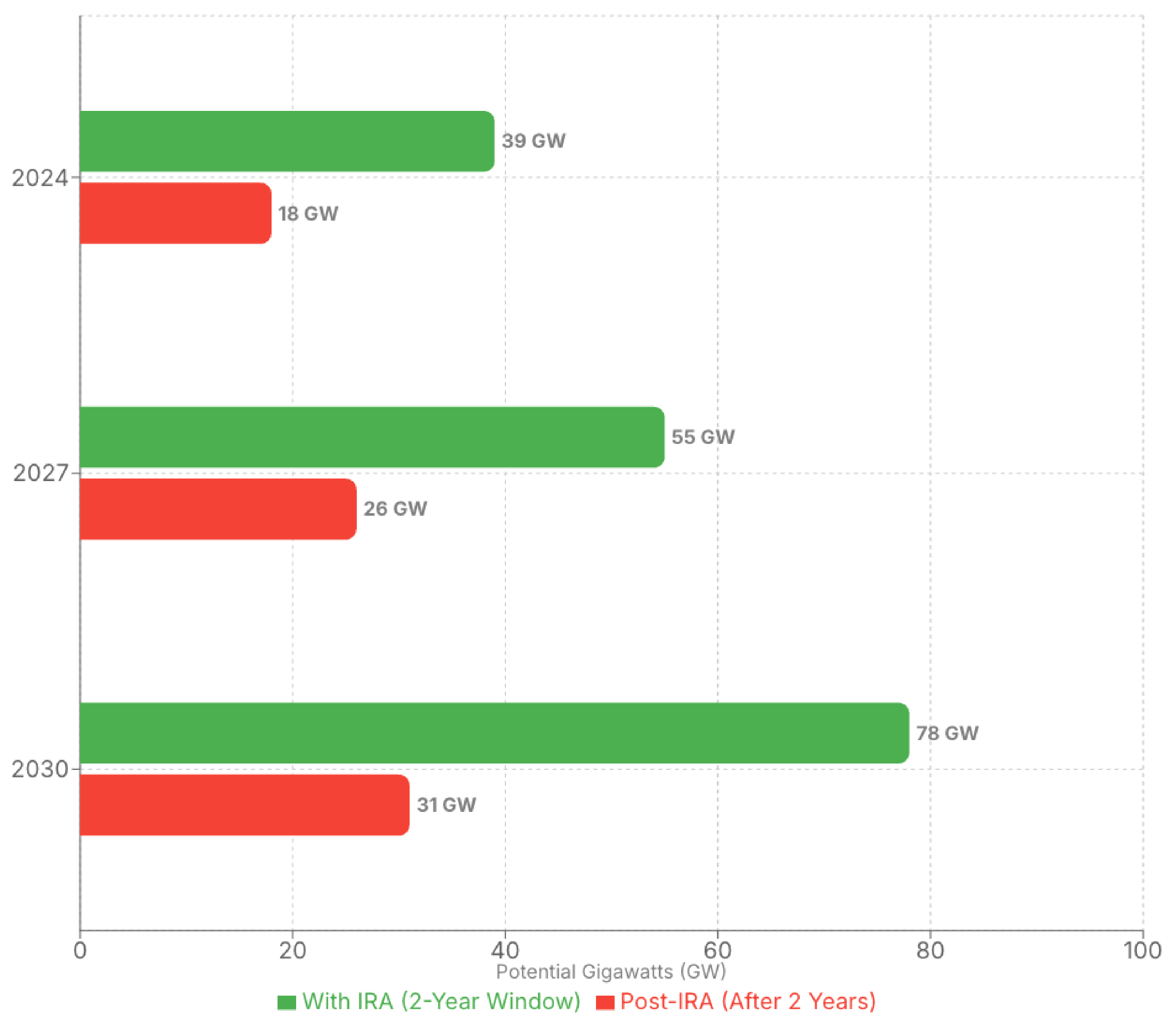
Post-IRA (After 2 Years)

- Only **31 GW** of renewable capacity can be added at thermal sites by 2030
- 26 GW solar + 5 GW wind potential
- Only **18 GW** economically viable immediately

Lost Opportunity Without IRA

Total Capacity Loss:	-47.3 GW
Solar Loss:	**-47.2 GW**
Wind Loss:	**-0.1 GW**

IRA Impact on RE Integration Potential (GW)



51 GW of RE enabled by 23 GW of storage can be added at existing RE plants

Enhancing PJM's Existing Renewable Fleet

At each RE site, we estimated the optimal portfolio of solar and wind capacity that can be added additionally by adding 6-hour battery storage. Adding 6-hour battery storage to existing renewable plants enables addition of further renewable capacity.

The optimization algorithm estimates the solar and wind capacity that maximizes the interconnection utilization while limiting curtailment to below 5%. We analyzed 133 renewable plants (≥10 MW) in PJM.

Solar Capacity	Wind Capacity	Storage Capacity
+28.3 GW	**+22.9 GW**	**+23.4 GW**

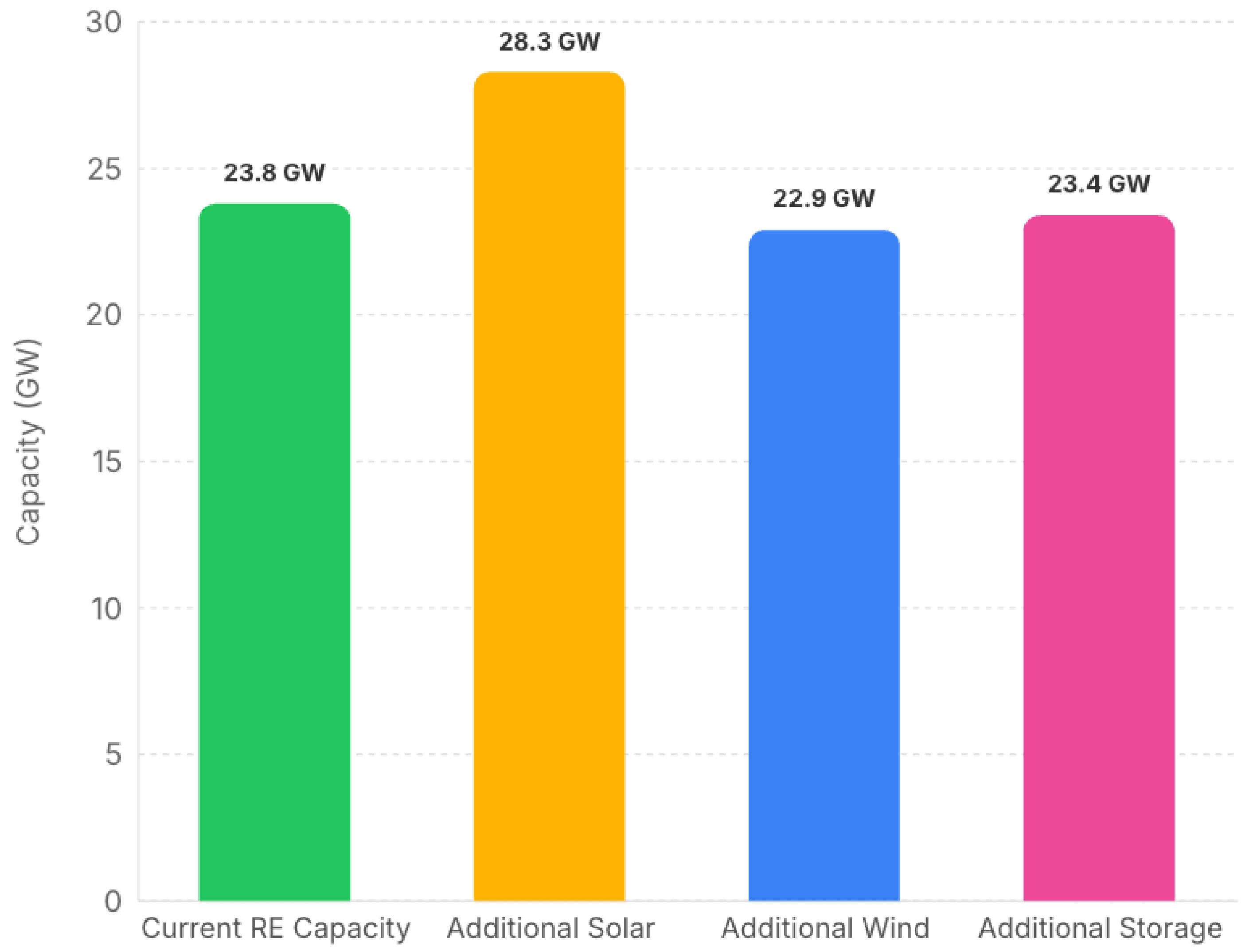
Current RE Capacity: 23.8 GW

Total After Enhancement: 23.8 + 51.2 = 75.0 GW

215% Overall Increase

The 23.4 GW of 6-hour battery storage adds firm capacity with an ELCC of 62% in PJM, providing reliable grid support during peak demand periods.

Additional Capacity at Existing RE Sites (GW)



Additional capacity potential: 28.3 GW solar + 22.9 GW wind + 23.4 GW storage

Renewables can become firm capacity with capacity factor of 75%

Increasing Renewable Capacity Factors

Solar Assets

Battery capacity required: 12.5 GW

Solar assets can more than double utilization from **24.1%** to **74.7%** capacity factor by adding battery storage and more renewable generation.

Wind Assets

Battery capacity required: 11.4 GW

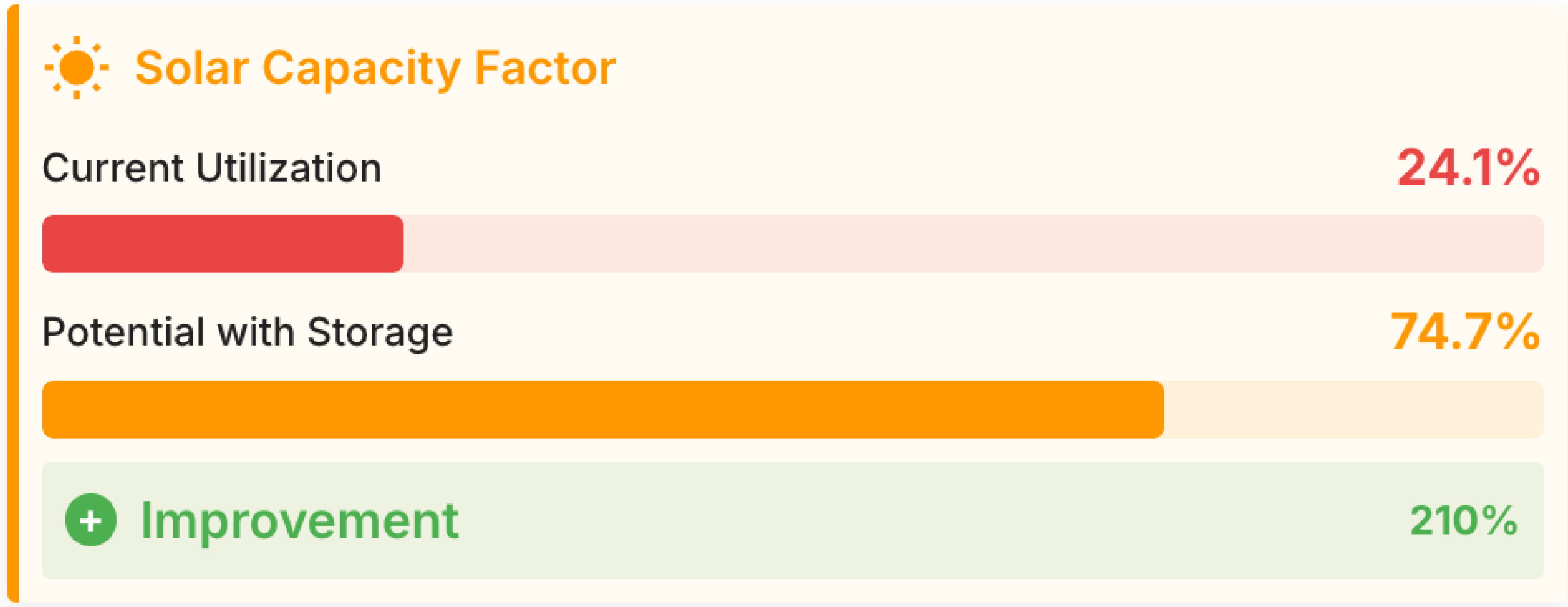
Wind assets show a 137% improvement in utilization with strategic battery storage, increasing capacity factors from **35%** to **82.8%**.

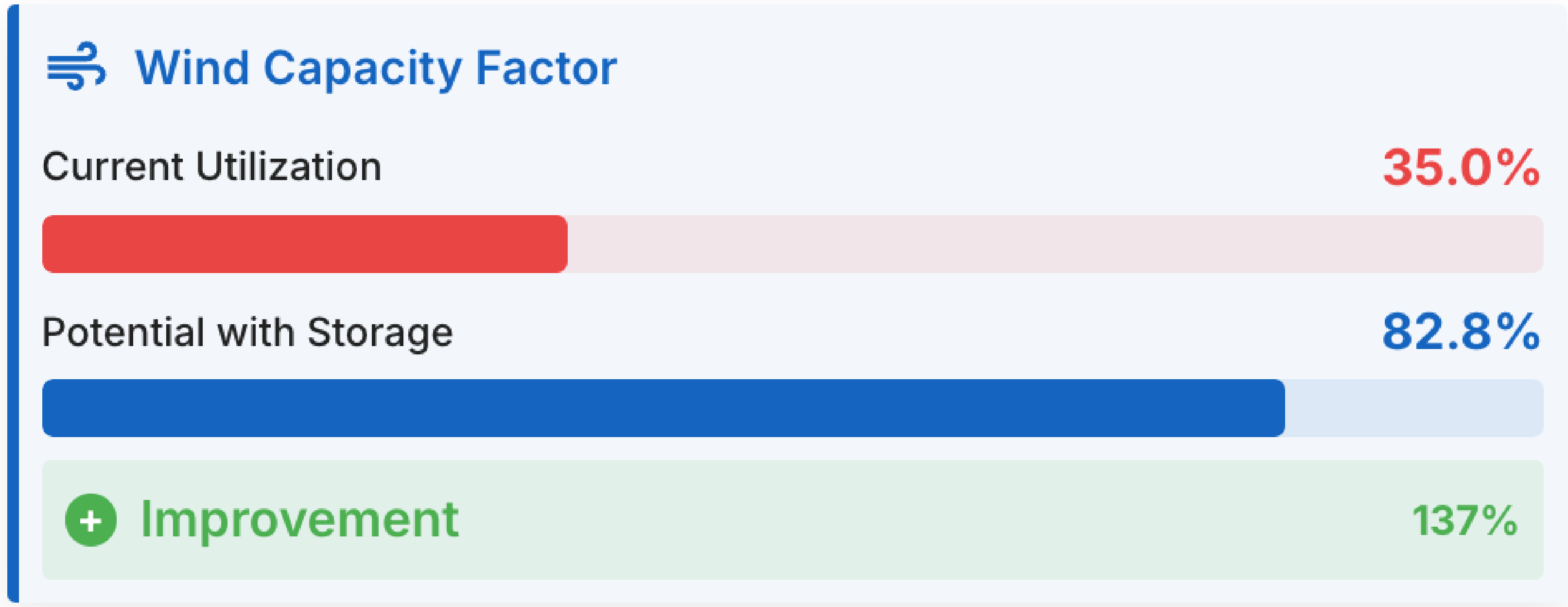
Increasing Grid Value

Six-hour battery storage gets **62% capacity value** in PJM, transforming intermittent renewable resources into firm capacity that can support the grid.

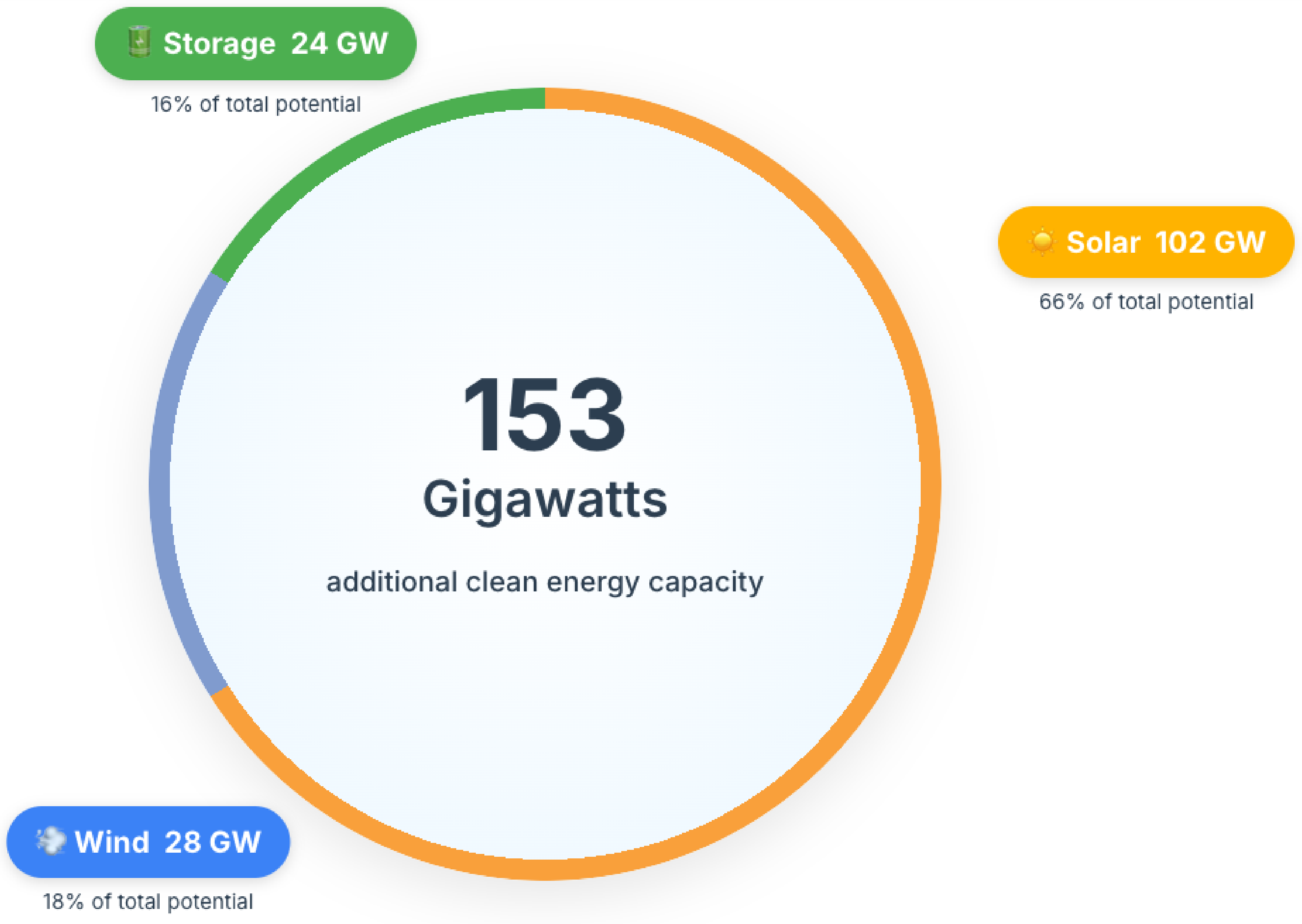
Note: Capacity factors shown are simulated values based on the latest solar panels with fixed-axis tracking and latest wind turbines from Siemens Gamesa, which may be higher than typical values currently observed in the field.

Renewable Asset Capacity Factors with Storage





153 GW of RE + Storage can be added at existing power plants in PJM



102 GW of additional solar capacity near existing renewable and thermal plants

28 GW of additional wind capacity through interconnection sharing

24 GW of storage enables higher penetration of renewables

Surplus Interconnection can help avoid shortfalls in PJM

Surplus Interconnection Potential

Peak Capacity

Adding six-hour battery storage at existing renewable sites can provide **13.57 GW** of peak capacity, which is **46%** of the peak demand growth in PJM from 2025 to 2030.

How we got this number:

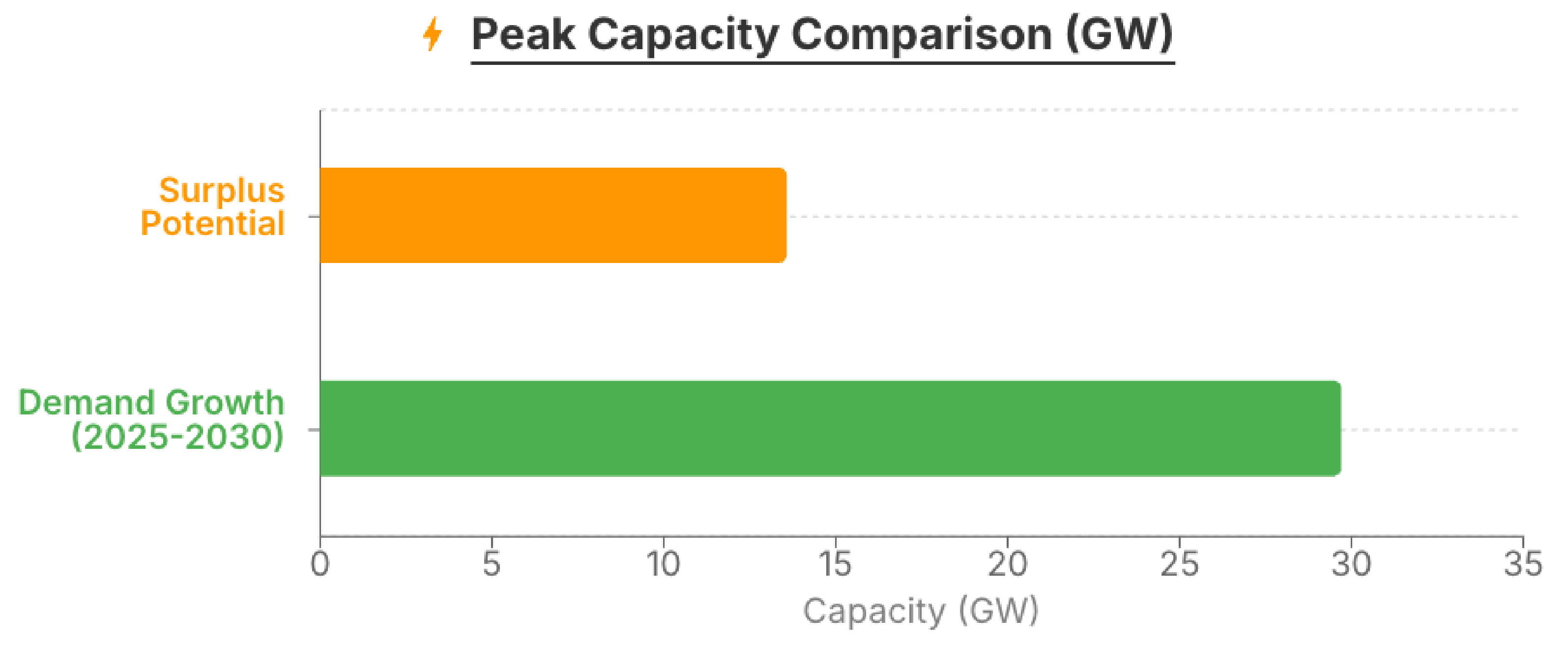
- We can install 14.5 GW of six-hour battery storage capacity
- The ELCC of six-hour battery storage in PJM according to 2026/2027 Base Residual Auction is 58%
- 14.5 GW × 0.58 = 8.4 GW firm capacity

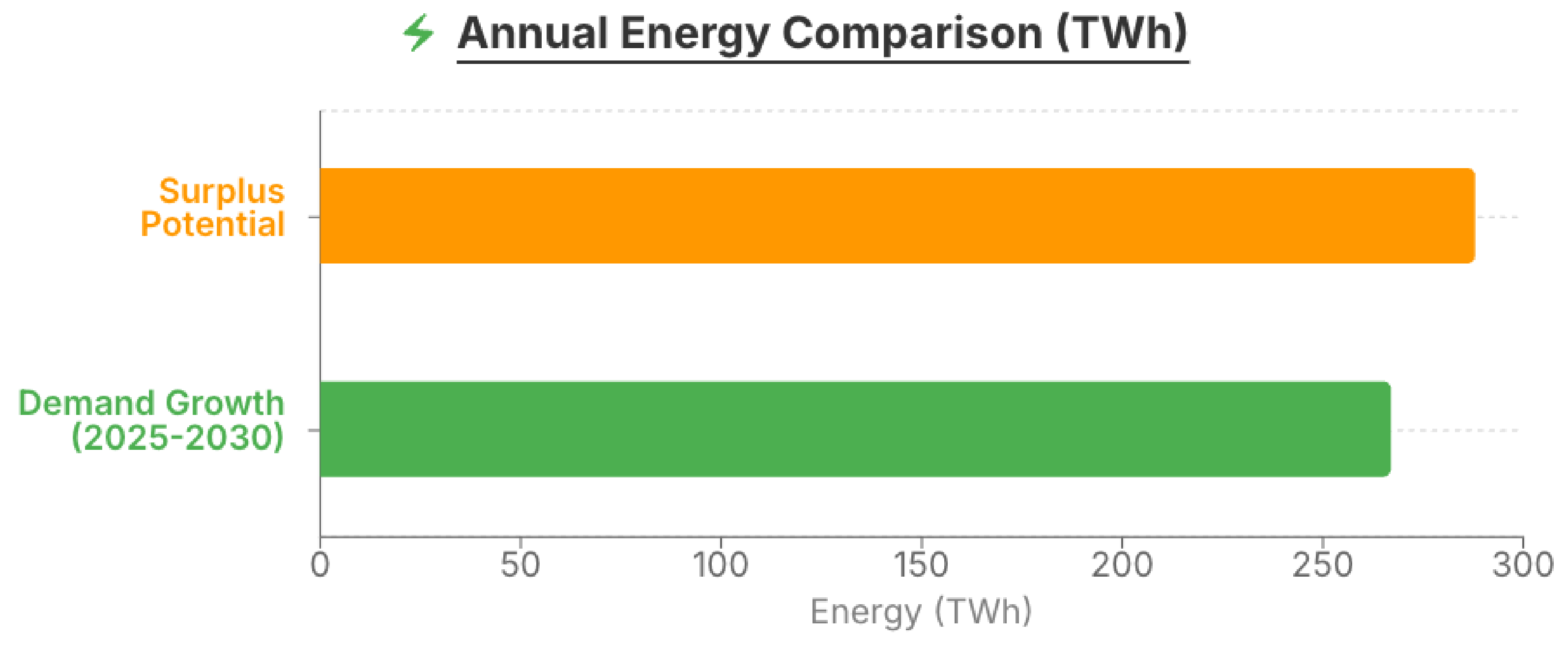
Annual Energy

Adding renewables near existing thermal plants and additional renewable capacity enabled by storage near existing renewable plants can provide **288 TWh** of electricity annually, which is **108%** of the energy demand growth in PJM from 2025 to 2030.

Energy production breakdown:

- Energy production from renewable sites: 104.7 TWh
- Energy production from thermal sites: 183.7 TWh





$31B of savings in interconnection costs

$ Total Potential Savings

$31.4B

By leveraging existing infrastructure

$1172
Savings per PJM household

- Reduces interconnection costs
- Reduces new transmission infrastructure requirements
- Cost savings from faster deployment of cheaper clean energy and replacing generation from expensive thermal plants

ⓘ This $31.4B is a conservative estimate that only accounts for interconnection cost savings for 144.1 GW of renewable capacity using an average cost of $218/kW (Source: Lawrence Berkeley National Lab). Additional benefits from co-location of solar, wind, and batteries, and increased utilization of bulk transmission would significantly increase the total value of savings, but are not included in this figure.

Source: Lawrence Berkeley National Laboratory interconnection cost data and PJM market analysis

Shared Benefits Across Stakeholders

Surplus interconnection creates benefits for all stakeholders:

RE Developer	Tax Credit; Reduced Interconnection Costs; Faster Development
Existing Plant Owner	Additional Revenue Streams; Diverse Portfolio
Consumer	Low Cost Electricity; Tax Revenue; Less Pollution
Power System	Reliability; Higher Tx Utilization; Low Capacity Prices
Economy	Reliable Supply; Faster Supply; Low Cost Power

Quick deployment and incremental scaling reduce stranded asset risk

Uncertain Demand Growth Drivers

AI & Data Centers
Explosive growth with unpredictable timing - some facilities need 1GW+

Manufacturing Reshoring
Policy-driven industrial expansion with uncertain location and scale

Transportation Electrification
EV adoption varies 10x between forecasts - massive grid impact uncertainty

Grid planners face unprecedented uncertainty in timing, location, and magnitude of new loads - traditional planning breaks down

Deployment Strategy Comparison

Traditional New Generation

- 5-7 year development timeline
- Large upfront commitment (500MW+)
- High stranded asset risk
- Requires accurate long-term forecasts

SIS + Battery Storage

- 12-18 month deployment
- Modular additions (50-200MW blocks)
- Deploy capacity as demand materializes
- Leverages existing interconnection

The "Build As You Need" Advantage with SIS

Surplus Interconnection Service transforms how utilities can respond to uncertain demand growth by enabling incremental, just-in-time capacity additions:

Risk Mitigation Benefits:

- Match CAPEX deployment to actual load growth
- Avoid overbuilding in uncertain markets
- Preserve optionality as forecasts evolve
- Minimize stranded asset exposure

Operational Flexibility:

- Start with 100MW, scale to 500MW+ over time
- Respond to surprise data center announcements
- Adjust to actual EV adoption rates
- Redeploy assets if local demand shifts

SIS enables utilities to transform stranded asset risk into strategic flexibility - critical for navigating the unprecedented uncertainty of the energy transition

FERC Approves PJM Surplus Interconnection Service Reforms

Four Key Changes Approved by FERC

PJM filed tariff revisions on December 20, 2024 to remove restrictions and expand surplus interconnection service access

1. Additional Interconnection Facilities

Explicitly allows construction of new physical interconnection facilities where needed. Enables parallel operation of surplus unit with existing generator - critical for solar+storage configurations. Previously unclear if additional facilities were permitted.

2. Removes "Material Impact" Restrictions

Strikes language that terminated requests for ANY impact on queue determinations or material impacts on system limits. Now only blocked if new network upgrades required. This "materiality review" previously killed most surplus requests.

3. Earlier Access to Surplus Service

Expands eligibility to projects with executed ISA/GIA but not yet built. Previously only operational facilities could offer surplus. Allows requests during construction phase - aligns with FERC Order 2023 requirements.

4. Energy Storage Eligibility

Clarifies that resources "seeking to receive electric energy from the grid and store it for later injection" can use surplus service. Removes ambiguity about storage eligibility that existed in prior tariff language.

Previous Restrictions Removed

PJM would automatically terminate surplus requests if:

- Any impact on network upgrade determinations for queued projects
- Material impacts on short circuit capability limits
- Material impacts on steady-state thermal and voltage limits
- Material impacts on dynamic system stability

Result: "Materiality review" effectively blocked most surplus requests

Expected Benefits

- Faster deployment of new capacity without queue delays
- Existing solar can add batteries using surplus service
- Better utilization of existing interconnection capacity
- May help reduce capacity prices
- Aligns PJM with MISO's more flexible approach

Two Critical Barriers Still Block Surplus Interconnection in PJM

Barrier 1: Commercial Friction

Complex Negotiations Between Unaffiliated Parties

The Challenge:

SIS requires incumbent generator to share valuable interconnection rights with a new developer. When parties aren't affiliated, this creates complex commercial negotiations.

What Must Be Negotiated:

- Rights and responsibilities of each party
- Operational coordination to stay within POI limits
- Liability allocation and indemnification
- Payment terms and cost sharing
- Dispatch coordination and curtailment priorities

$ Transaction Costs

High legal fees and lengthy negotiations deter smaller developers

Bespoke Agreements

Each project requires custom legal documents from scratch

MISO's Solution:
Pro forma "Energy Displacement Agreement" provides standardized template with pre-negotiated terms for common scenarios

Barrier 2: The "One-Year Cliff"

Fatal Investment Risk for Repowering Projects

FERC Policy Creates Investment Trap:

When host generator retires and terminates its Interconnection Service Agreement, surplus user's rights expire after maximum one year.

Real-World Scenario:

1. Developer invests $200M+ in solar/storage at retiring coal plant
2. Coal plant retires as planned
3. One year later: grid access vanishes
4. Developer forced into 5+ year queue process
5. Project becomes stranded asset

Impact on Market

No rational investor will finance repowering projects under this risk profile, blocking the single biggest opportunity for SIS deployment

Critical Context:
This is "arguably the single greatest barrier" to using SIS for large-scale replacement of retiring fossil generation

Blueprint for a Surpls-Enabled Grid: Four Key Recommendations

1. Standardize Commercial Agreements

Problem:

Bespoke negotiations for each project create high transaction costs and delays

Solution:

Develop pro forma "Surplus Interconnection Service Agreement" template with standard terms for operations, liability, and dispatch coordination

Model: MISO's "Energy Displacement Agreement"

2. Path to Permanent Interconnection

Problem:

"One-year cliff" creates fatal risk for repowering retiring plants

Solution:

- Link SIS with proposed CIR Transfer process
- Grant surplus users "right of first refusal" for POI
- Allow conversion via limited impact study

Critical for brownfield development at retiring sites

3. Surplus Capacity Heatmap

Problem:

Identifying surplus opportunities requires extensive data analysis

Solution:

Enhance "Queue Scope" tool to visually flag:

- Thermal plants with <15% capacity factor
- Renewable sites with <40% interconnection use

Public tool to democratize opportunity identification

4. Improve Hybrid Resource Valuation

Problem:

Current ELCC models undervalue hybrid resources, leading to lower capacity market compensation

Solution:

- Develop co-optimized modeling for hybrid operations
- Account for surplus interconnection flexibility
- Use dynamic, scenario-based accreditation
- Capture true reliability value of shared POI assets

Critical for accurate surplus resource compensation

Behind-the-Meter Data Centers: Leveraging Surplus Interconnection

Innovative Behind-the-Meter Solution

Configuration Setup

Data center is located behind-the-meter of an existing gas peaker plant, with new oversized solar arrays + 16-hour battery storage added on-site

How It Works

95% of the time: Data center receives power from solar + battery storage.
5% of the time: When solar/battery unavailable, gas plant provides backup power

Gas Plant Dual Role

1) Provides electricity to grid during peak demand when needed
2) Acts as backup power source for data center (5% of time)

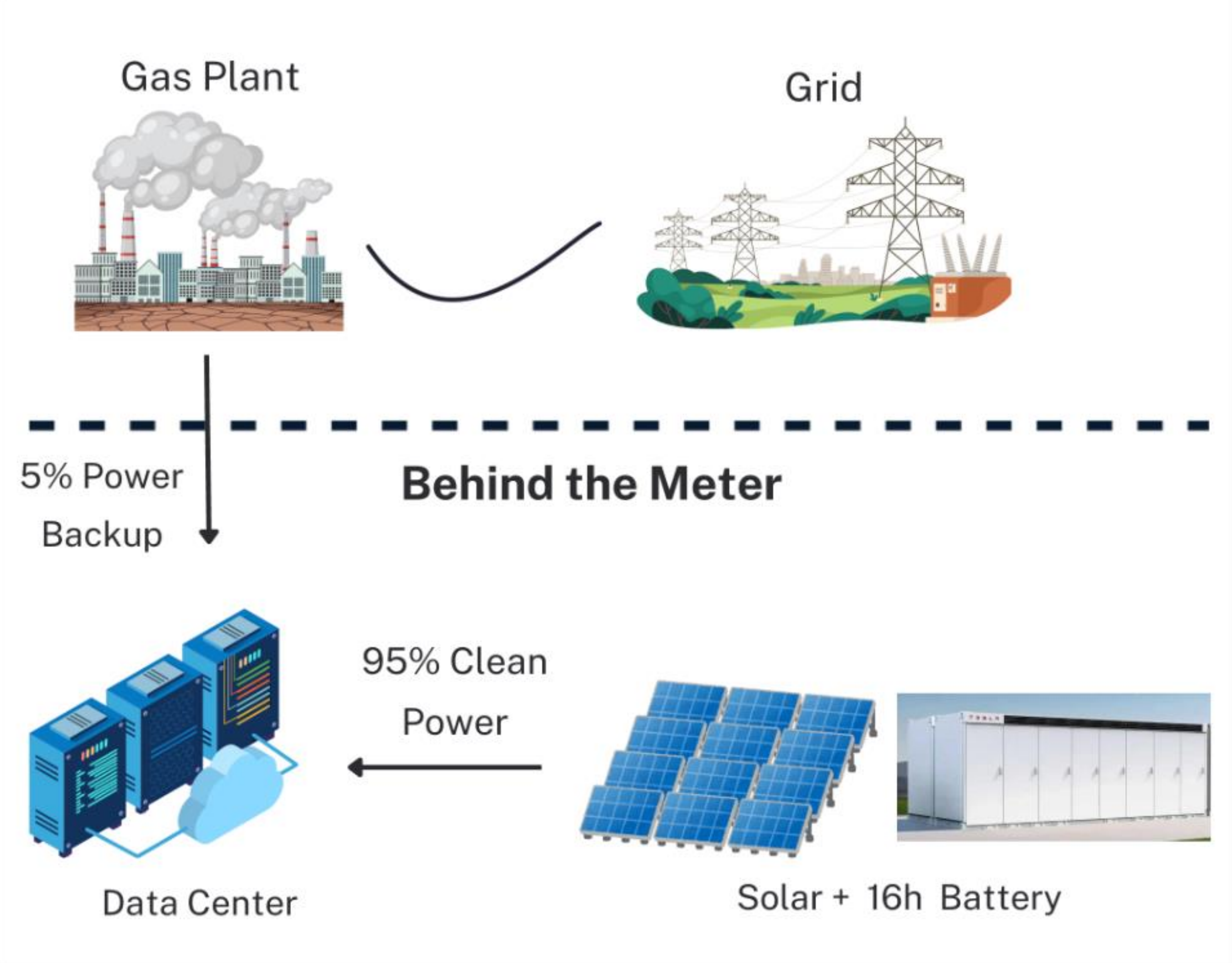
Fast Implementation

Complete build in 1-2 years (vs 5-6 years for new gas plant or grid connection)

Key Benefits

- Uses existing gas plant interconnection (no new transmission)
- 95% carbon-free operation with solar + battery
- Gas plant remains available for grid emergencies

Surplus Interconnection to Power Data Centers



Thank you!