

Firming Cost of Renewables in the U.S. and Comparison with Europe

Based on Lazard LCOE v18.0 | Prepared by Nenuphar Advisors

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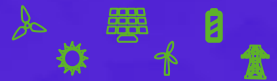
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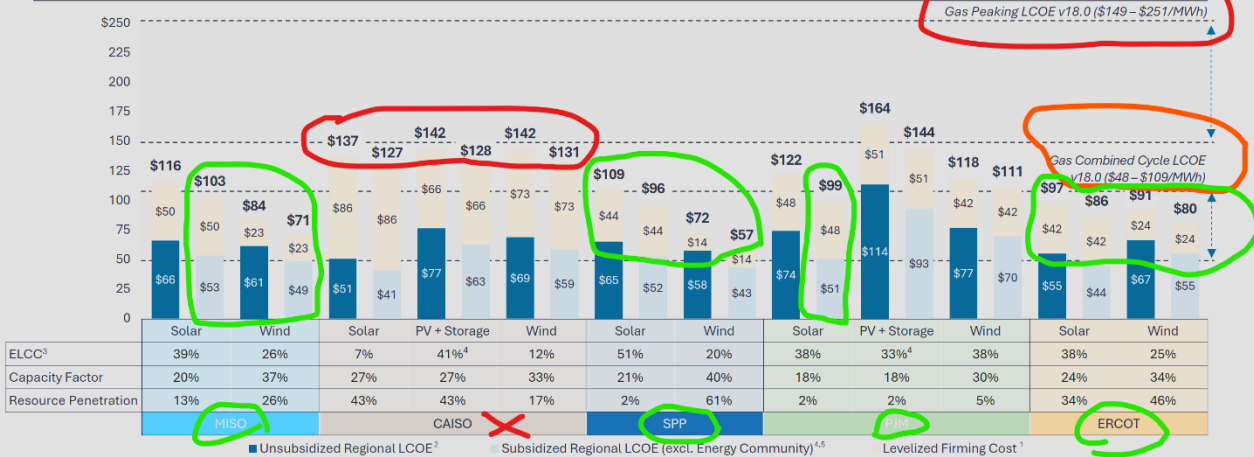


Energy Generation	Energy Storage	Energy System
Levelized Cost of Energy	Levelized Cost of Storage	Cost of Firming Intermittency
A COST OF FIRING INTERMITTENCY		

Cost of Firming Intermittency—Results

The Cost of Firming Intermittency or “firming cost” is the incremental cost to firm¹ solar, solar + storage or wind resources through additional monthly capacity payments to a firming resource under current regional system planning constructs

LCOE plus Levelized Firming Cost (\$/MWh)²



Source: Lazard estimates and publicly available information.
Note: Total, including firming cost, does not represent the cost of building a 24/7 firm resource on a single project site but, instead, the LCOE of a renewable resource and the additional capacity costs required to achieve the resource adequacy requirement in the relevant reliability region based on the net cost of new entry ("Net COE"). ISO ELCC data as of April 2025 and representative of annualized ELCC values.
1. Firming costs reflect the cost of additional capacity required to supplement the net capacity of the renewable resource (nonreplace capacity * (1 - ELCC)) and the Net COE of a new firm resource (capital and operating costs, less expected market revenues). Net COE is assessed and published by grid operators for each regional market. Grid operators use a natural gas peaker as the assumed new resource in MISO (\$10.63/kW-mo), PJM (\$10.29/kW-mo) and ERCOT (\$9.92/kW-mo). In CAISO, the assumed new resource is a 4-hour lithium-ion battery storage system (\$18.92/kW-mo). For the PV + Storage cases in CAISO and PJM, assumed storage configuration is 50% of PV capacity and 4-hour duration.
2. Reflects the average of the high and low of Lazard's LCOE v18.0 for each technology using the regional capacity factor, as indicated, to demonstrate the regional differences in project costs.
3. ELCC is an indicator of the incremental reliability contribution of a given resource to the electricity grid based on its contribution to meeting peak electricity demand. For example, a 1 MW wind resource with a 15% ELCC provides 0.15 MW of capacity contribution and would need to be supplemented by 0.85 MW of additional firm capacity in order to represent the addition of 1 MW of firm system capacity.
4. For PV + Storage cases, the effective ELCC value is represented. CAISO and PJM assess ELCC values separately for the PV and storage components of a system. Storage ELCC value is provided only for the capacity that can be charged directly by the accompanying resource up to the energy required for a 4-hour discharge during peak load. Any capacity available in excess of the 4-hour maximum discharge is attributed to the system at the solar ELCC. ELCC values for storage range from 55% to 75% for PJM and CAISO, respectively.
5. This sensitivity analysis assumes that projects qualify for the full ITC, have a capital structure that includes sponsor equity, debt and tax equity and assumes the equity owner has taxable income to monetize the tax credits.
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Objective of the Chart

To show the average cost of providing firm (dispatchable) power using renewables (solar, wind, solar+storage, wind+storage) with capacity backup, compared to Gas Peaking Plants and Natural Gas Combined Cycle (CCGT) plants.

Main Conclusion (Highlighted in Green):

- ✓ In ERCOT, MISO, SPP, and PJM: Wind + Storage and Solar + Storage:
 - Always show an LCOE + Firming Cost that is lower or competitive with Gas Peaking Plants (\$149–251/MWh), and often even with Natural Gas Combined Cycle (CCGT) plants (\$48–109/MWh).

 **Don't forget that Natural Gas in the U.S. is 3 times cheaper than in Europe, which clearly and definitively removes Natural Gas from the equation of best backup energy sources in Europe.**

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TECHNOLOGY ANALYSIS:

1. Solar + Storage:

LCOE + Firming in MISO: ~\$86/MWh

SPP: ~\$66

PJM: ~\$66

ERCOT: ~\$73

CAISO: ~\$164

 **Conclusion: Except in CAISO, Solar + Storage is clearly competitive with CCGT and much cheaper than Gas Peaking.**

2. Wind + Storage:

LCOE + Firming in MISO: ~\$71

SPP: ~\$66

PJM: ~\$73

ERCOT: ~\$72

CAISO: ~\$144

 **Conclusion: Wind + Storage consistently beats the cost of Gas Peaking and CCGT in all markets, except CAISO. MISO and SPP are the most competitive.**

3. Standalone Solar or Wind (without "Firming")

Even cheaper (e.g., Wind in MISO \approx \$61/MWh total), but without full dispatchability. The cost for "Firming" adds only a small premium (\approx \$20–\$30/MWh).

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🔥 COMPARISON WITH GAS:

■ Gas Peaking (Red Circle):

LCOE: \$149–\$251/MWh → Renewables with storage are always cheaper, even with firming.

■ Natural Gas Combined Cycle (CCGT) (Orange Circle):

LCOE: \$48–\$109/MWh

Only in CAISO and PJM do renewables with firming occasionally exceed this range (due to higher firming costs).

⚙️ OTHER IMPORTANT DATA:

Metric	Notes
ELCC (Effective Load-Carrying Capacity)	Higher for hybrid systems (e.g. Solar+Storage has 33–38%)
Capacity Factor	Higher for Wind (30–37%) than Solar (20–27%)
Resource Penetration	MISO: 43%, SPP: 44%, ERCOT: 61% (more renewables = more credible firming modeling)

💡 Strategic Implications

✅ MISO, SPP, ERCOT are now ready for baseload renewables with storage — cost-competitive AND clean.

⚠️ CAISO has firming challenges due to over-penetration and saturation, raising costs..

🔄 Firming cost ≠ dealbreaker anymore — in most U.S. regions, firmed renewables beat peakers and are within CCGT range.

Final Takeaways

Firmed renewables are now viable baseload in MISO, SPP, ERCOT.

Peakers are obsolete from a cost point of view in most areas.

Gas CCGTs are still competitive in PJM and CAISO, but barely.

Storage is the game-changer — especially where renewables already dominate.

THANK YOU FOR YOUR ATTENTION

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