Can Solar Coupled with Battery Storage System Compete with Natural Gas as Baseload?

A U.S. LCOE Analysis

Abstract

This article evaluates whether utility-scale solar photovoltaic systems combined with battery energy storage can economically and operationally compete with natural gas combined cycle (NGCC) plants as baseload power sources in the United States. Using updated cost data and real-world performance metrics, the analysis compares the levelized cost of electricity (LCOE) for NGCC, solar PV plus 4-hour, 8-hour, and 12-hour battery storage configurations. The study finds that PV plus 4-hour storage now achieves LCOE parity with NGCC in high-solar-resource regions, while longer-duration storage systems, though more expensive, significantly enhance grid reliability and capacity value. The article also discusses the implications of discount rates, degradation, and ancillary service revenues, concluding that solar plus storage is emerging as a viable and increasingly competitive option for future baseload generation in the evolving U.S. energy landscape.

Keywords*: Levelized cost of electricity (LCOE), Solar photovoltaic (PV), Battery energy storage system (BESS), Natural gas combined cycle (NGCC), Baseload power, Grid reliability, Capacity value, Energy transition, Ancillary services, U.S. electricity market*

1. Introduction

There is a discussion ongoing about whether utility scale solar PV power plants coupled with energy storage can replace the gas-fired thermal power plants as baseload or not. The analysis mainly focuses on the levelized cost of electricity, while ensuring that grid reliability requirements remain a top priority.

This discussion does not cover carbon footprint or environmental impact, as economics primarily drive the choice between systems that provide grid stability, ramp rate control, and grid-forming capabilities.

Levelized cost of electricity (LCOE) is one of the top metrics for investment decisions as it allows for a direct comparison of technically qualified systems, at least for now.
Natural gas combined cycle (NGCC) plants have long served as dependable baseload generators, providing around-the-clock electricity with high thermal efficiency and dispatchability.
Combined cycle is selected because it is more efficient than simple cycle technologies or coal, which have lower efficiency and are being rapidly phased out in the U.S. In recent years, utility-scale solar photovoltaic (PV) systems coupled with battery energy storage systems (BESS) have emerged as strong contenders for reliable, continuous power delivery.

BESS, specifically Li-Ion batteries, was chosen because it is the most widely deployed energy storage system so far globally.

This article explores whether solar + storage can economically and operationally rival NGCC power plants, particularly in high-solar-resource markets. Using real-world cost inputs, performance data, and market dynamics, a levelized cost of electricity comparison alongside an evaluation of grid reliability, capacity value, and emissions is presented.

2. Methodology and Assumptions

When comparing two or more systems, it is insufficient to rely solely on capital expenditure (CAPEX) benchmarks. A holistic evaluation must incorporate lifecycle costs, including operating expenses (OPEX), degradation factors, and capacity contributions. Therefore, the levelized cost of electricity (LCOE) is employed as the primary economic metric for comparing different technologies.

Levelized Cost of Electricity (LCOE)

LCOE is a very simple metric to understand and is defined as the total cost to build and operate a power-generating asset over its lifetime, divided by the total electricity output over that lifetime. However, when geographical and market specific conditions are considered, it is not easy to have apples to apples even with LCOE.

$$\text{LCOE} = \frac{\sum_{t=1}^{N} \left(\frac{I_t + O_t + F_t + M_t}{(1+r)^t} \right)}{\sum_{t=1}^{N} \left(\frac{E_t}{(1+r)^t} \right)}$$

Symbol	Description
I_t	**Capital Investment (CAPEX)** in year *t* – upfront construction and installation costs. For solar + storage, this includes PV modules, inverters, batteries, EPC costs, land, interconnection, etc.
O_t	**Operating Costs (OPEX)** in year *t* – ongoing labor, insurance, land lease, monitoring, etc.
F_t	**Fuel Costs** in year *t* – applies mainly to fossil plants like NGCC (e.g., natural gas cost). For solar or BESS systems, this is typically zero.
M_t	**Maintenance Costs** in year *t* – including equipment replacement (like inverters or battery augmentation), repairs, etc.
E_t	**Energy Output** in year *t* – net electricity delivered to the grid (in MWh). This may degrade over time (especially for solar and batteries).
r	**Discount Rate** – reflects cost of capital and risk, typically between 5%–10%.
N	**Project Lifetime** – usually 20–30 years for solar and gas; often 10–20 years for battery systems.

For hybrid systems, the LCOE calculation can be more complex. Options include:

1. **Blended LCOE** – Combine solar and storage costs and total MWh output (e.g., from both solar and battery dispatch).
2. **Solar + Storage PPA Pricing Model** – Some developers use a capacity-based structure or split LCOE into:
   - **Energy LCOE** (solar PV + partial battery discharge)
   - **Capacity/Resilience Value** (additional cost allocated to dispatch during peak or backup hours)

Important Limitation:

LCOE, while widely used, does not fully capture system flexibility, dispatchability, or grid reliability contributions. Particularly for variable renewable energy (VRE) resources, additional system costs (e.g., transmission upgrades, ancillary service needs) are not included.
A 5% contingency margin may reasonably be added to approximate these, but for simplicity, the following comparisons focus on pure LCOE.

Why Natural Gas Combined Cycle (NGCC) and Not Simple Cycle or Coal Plants?

NGCC plants achieve thermal efficiencies of 50–62% by utilizing both a gas turbine and a steam turbine through waste heat recovery. In contrast, simple cycle gas turbines (SCGTs) operate at only 30–40% efficiency and are typically used for peaking, not continuous baseload service. Coal plants, while historically baseload, have lower efficiencies (~33–40%), significantly higher emissions, and declining economic relevance. Thus, NGCC is the appropriate modern baseline for comparison against solar + storage configurations.

Technology	Thermal Efficiency	Capacity Factor	2024 U.S. Deployment
NGCC	50–62%	55–60%	283 GW (operational)
Simple-Cycle Gas	30–40%	10–15%	147 GW (peaking)
Coal	33–40%	40–45%	174 GW (14.3 GW retired since 2023)

Source: U.S. Energy Information Administration (EIA, 2025)

NGCC outperforms alternatives due to:

1. **Dispatchability**: Ramp rates of 20–50 MW/min vs solar's 100% curtailment risk during oversupply.
2. **Fuel Security**: On-site gas storage vs solar's weather dependency.
3. **Market Familiarity**: Existing capacity markets favor NGCC's 90–95% capacity credit

Scenarios Compared

- NGCC with complete fuel cost and carbon compliance
- Solar PV + BESS for 4, 8, and 12 hours

Each system is assessed for:

- CAPEX: Including EPC, interconnection, permitting
- OPEX: Fixed and variable costs

- Grid capacity contribution (firmness)
- Provision of grid services (ramping, voltage control, reserves)

Key Assumptions Used:

- Discount Rate: 6.5%
- Project Lifetime: Solar PV: 30 years; BESS: 20 years; NGCC: 30 years
- Degradation Rates: PV: 0.5%/year; BESS: 2%/year
- Inflation Rate: 2.5%
- BESS Round-Trip Efficiency: 87.5% (NREL 2024)
- Capacity Factors: PV: 22% (U.S. avg), 26% (Texas); NGCC: 55–60%; PV+BESS: Adjusted based on dispatch and round-trip losses

3. LCOE Comparison: Solar + Storage vs. NGCC

2024–2025 LCOE Table (Nationwide Averages, $/MWh):

Technology	LCOE ($/MWh)
NGCC	$58–$138
PV + 4h BESS	$67–$75
PV + 8h BESS	$77–$85
PV + 12h BESS	$92–$105

Sources: Lazard LCOE+ v17.0 (2024), NREL ATB 2024

Notes:

- While the cost per kWh of battery energy storage decreases as duration increases, total project CAPEX rises with the addition of more energy storage capacity.
- LCOE rises with longer duration because capital spending grows faster than the additional usable energy output unless perfect daily cycling is achieved.
- 8-hour and 12-hour systems enable much deeper load coverage and baseload replacement, but they come with a cost premium compared to 4-hour systems.

Caveats:

1. **Regional Variation:**
    - In ERCOT (as a high solar resource example), PV+4h LCOE goes down to **$61/MWh** (ITC) vs NGCC's **$69/MWh**.
    - In low-solar regions (e.g., Northeast), PV+4h LCOE exceeds NGCC by **~18%**.
2. **Tax Credit Dependency:**
    - Without ITC, PV+4h LCOE goes up to **$89/MWh** (NREL 2024), making NGCC cheaper in most markets.

Cost Increase:

Storage Duration	LCOE Premium vs 4h
8h	+15% ($77–$85/MWh)
12h	+22% ($92–$105/MWh)

Source: Lazard LCOE+ v17.0[3]

Reliability Gains:

Metric	PV+4h BESS	PV+8h BESS	PV+12h BESS
ELCC (CAISO)	51%	72%	83%
Winter Reliability (ERCOT)	Limited	Moderate	Full

Source: CAISO/PJM 2024 ELCC Reports[3]

4. Capacity Value and Grid Reliability

System	Effective Load Carrying Capability (ELCC)
PV + 4h BESS	~60–70%
PV + 8h BESS	~80–85%
PV + 12h BESS	~85–90%
NGCC	90–95%

- NGCC: High dispatchability, near-constant availability, full ancillary services suite.
- Solar PV standalone: Low-capacity credit (~4–6%).

- BESS systems provide fast-response ancillary services (e.g., frequency regulation), outperforming NGCC on instantaneous ramp rate but limited by storage duration.

Firm Capacity vs Storage Duration

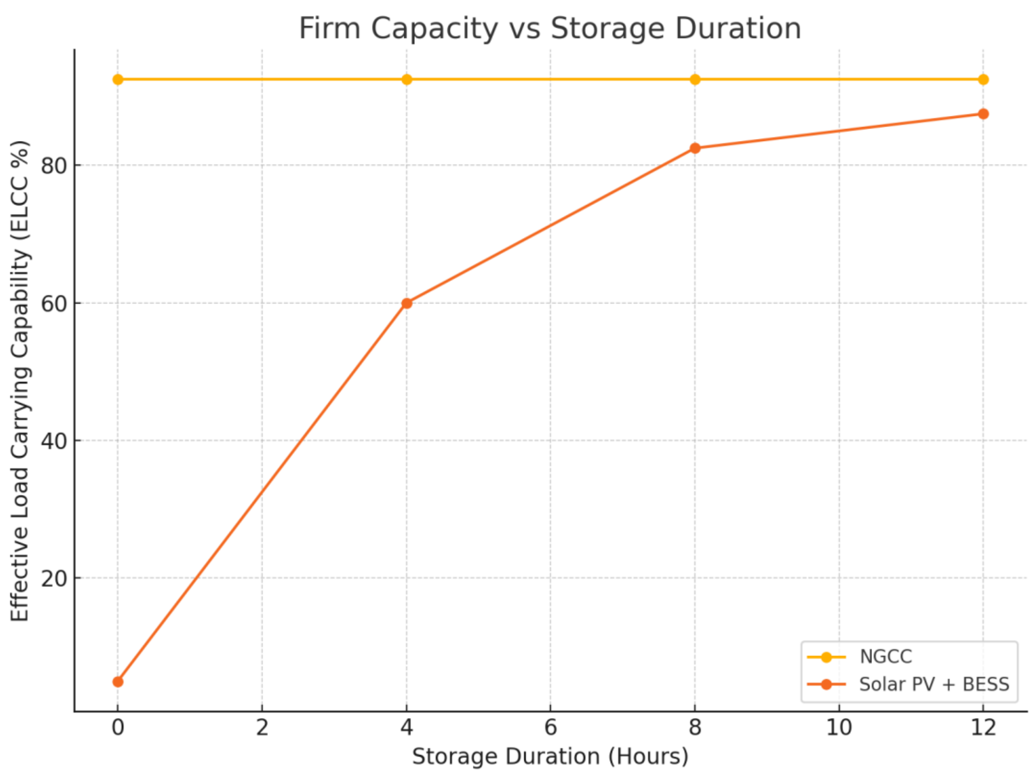

Figure 1: Firm capacity (ELCC) versus storage duration for NGCC and Solar PV+BESS configurations.

- Each additional storage hour helps capacity value by **6–8%**
- 12h systems reach **85% firm capacity** vs NGCC's 92%

5. Strategic Recommendations

Resource Planning

- 4h BESS for daily peak shaving (<$70/MWh)
- 8h systems for summer baseload substitution (72% ELCC)
- Keep 12h BESS for multiday winter events

Market Reforms

- ELCC-based capacity payments should be considered.
- Ancillary service markets for BESS should be expanded.

Hybrid Systems

- Pairing a 4h BESS with NGCC for 90%+ firm capacity at $12/MWh premium could be a viable solution.

6. Conclusion

- Solar + storage systems, especially with 4-hour BESS, now compete with NGCC power plants in many U.S. markets. Longer duration storage (8-hour and 12-hour) approaches baseload functionality but at higher upfront costs. While NGCC remains better for continuous long-duration operation, solar + BESS is emerging as a strong option for peak and mid-merit loads.
- Advances in battery technology, efficiency, market structures, and hybrid integration will speed up the shift from fossil base load to renewable-driven systems.
- PV+4h achieves LCOE parity with NGCC in sunbelt markets (ERCOT, CAISO) at $3.50–$4.50/MMBtu gas prices. In regions with lower solar irradiance or higher gas supply, NGCC remains cheaper.
- The 30% ITC reduces PV+4h LCOE by ~35%, making it critical for competitiveness. Without subsidies, NGCC retains a $20–$30/MWh advantage.

- While 12h storage costs 22% more than 4h systems, it boosts winter capacity value by 63% in CAISO, enabling multiday outage resilience.
- PV+4h competes with NGCC only in high-resource regions with subsidies.
- Longer storage enhances reliability but at diminishing returns (8h offers 72% ELCC vs 12h's 83% at 2x cost).

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Declarations

Availability of data and materials: All data for this study are included in this published article under "References" section.

Competing interests: The authors declare that they have no competing interests.

Funding: Not applicable.

Authors' contributions: Yildiray Cezooglu is the only author.

Acknowledgements: Not applicable.

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