Custo de Compensação da Intermitência (Firming Cost) de renováveis nos E.U.A e Comparação com Europa

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

NENUPHAR ADVISORS

Presented By

Raul Assuncao

www.nenupharadvisors.com

+971 54 486 1971
+34 602 453 375
+351 961 953 547

LCOE – Jul 2025 – v2_BESS

Disclaimer

NENUPHAR ADVISORS

This presentation is provided for informational purposes only and does not constitute an offer, invitation, or solicitation for the sale or purchase of securities, assets, or financing of the business described herein.

It is not intended to form the basis of, or act as an inducement to enter into, any contract or investment activity. **Nenuphar Advisors** and its affiliates, including **Nenuphar Advisors – FZCO**, **Nenuphar Frontier, Lda.** and **Nenuphar Advisors SL**, and **Nenuphar Advisors – FZCO** ("**Nenuphar Advisors**"), make no representation or warranty, express or implied, as to the accuracy, completeness, or reliability of the information provided.

The information contained herein, sourced from publicly available materials or provided to **Nenuphar Advisors**, has not been independently verified and should not be relied upon. **Nenuphar Advisors**, its directors, officers, employees, and advisers accept no liability for any errors, omissions, or misstatements, or for any direct, indirect, or consequential loss arising from reliance on this presentation.

Prospective investors or financiers are advised to perform their own independent investigation and analysis.

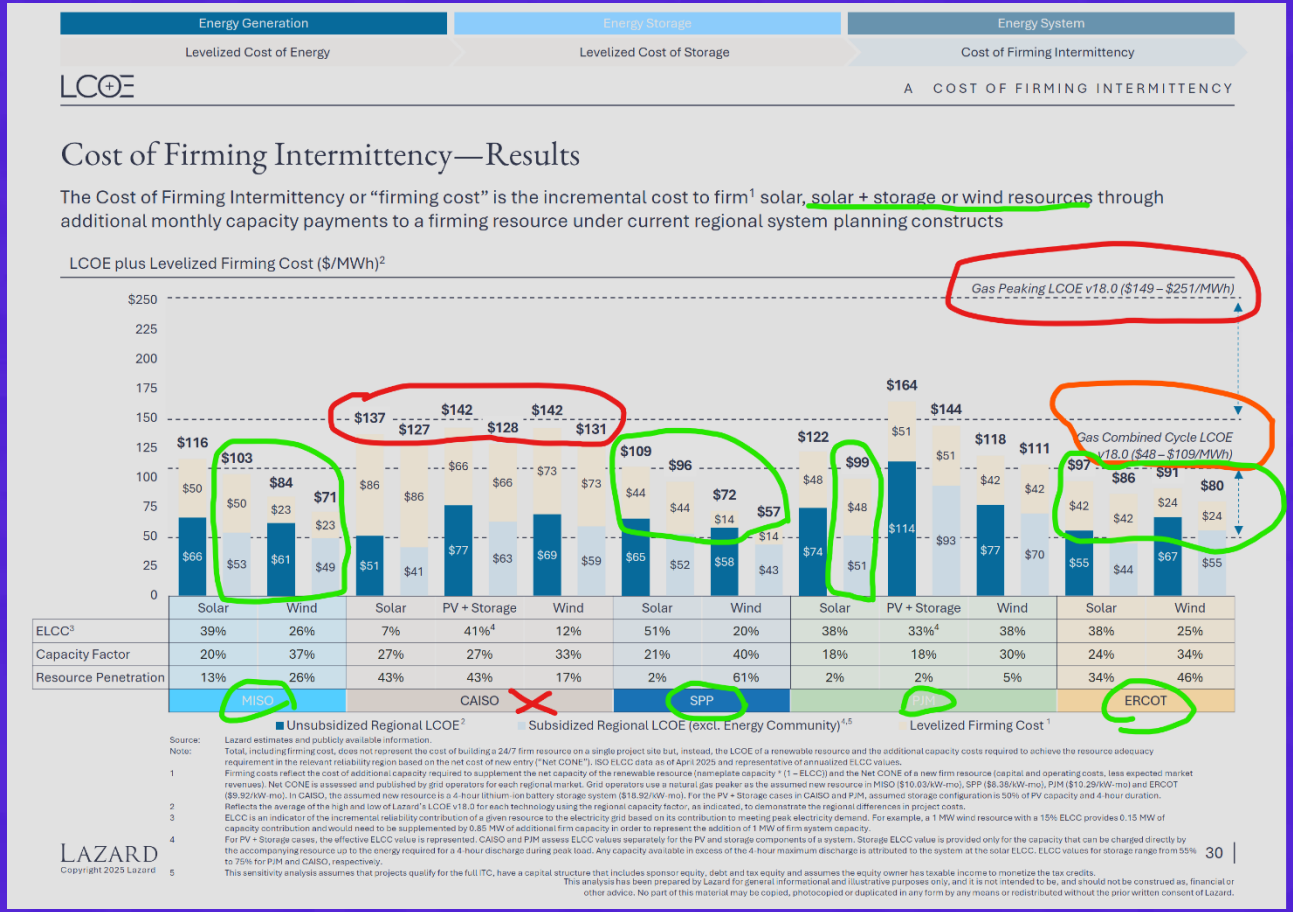
Nenuphar Advisors reserves the right to amend or terminate negotiations or procedures related to any transaction without prior notice or liability.

No obligation is undertaken to update this presentation or provide additional information.

Costs or expenses incurred by recipients in connection with the evaluation of this presentation are their sole responsibility.

Custo de Compensação da Intermitência (Firming Cost) de renováveis nos E.U.A e Comparação com Europa

NENUPHAR ADVISORS



Energy Generation | Energy Storage | Energy System

Levelized Cost of Energy | Levelized Cost of Storage | Cost of Firming Intermittency

LCOE

A COST OF FIRMING INTERMITTENCY

Cost of Firming Intermittency—Results

The Cost of Firming Intermittency or "firming cost" is the incremental cost to firm[1] 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]

Gas Peaking LCOE v18.0 ($149 – $251/MWh)

Gas Combined Cycle LCOE v18.0 ($48 – $109/MWh)

	MISO		CAISO			SPP		PJM			ERCOT	
	Solar	Wind	Solar	PV + Storage	Wind	Solar	Wind	Solar	PV + Storage	Wind	Solar	Wind
ELCC[3]	39%	26%	7%	41%[4]	12%	51%	20%	38%	33%[4]	38%	38%	25%
Capacity Factor	20%	37%	27%	27%	33%	21%	40%	18%	18%	30%	24%	34%
Resource Penetration	13%	26%	43%	43%	17%	2%	61%	2%	2%	5%	34%	46%

■ Unsubsidized Regional LCOE[5] ■ Subsidized Regional LCOE (excl. Energy Community)[4,5] ■ Levelized Firming Cost[1]

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 CONE"). 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 (nameplate capacity * (1 – ELCC)) and the Net CONE of a new firm resource (capital and operating costs, less expected market revenues). Net CONE 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 ($10.03/kW-mo), SPP ($8.38/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.

LAZARD

30

Custo de Compensação da Intermitência (Firming Cost) de renováveis nos E.U.A e Comparação com Europa

NENUPHAR ADVISORS

🎯 Objetivo do Gráfico

Mostrar quanto custa, em média, fornecer energia firme (despachável) com renováveis (solar, eólica, solar+armazenamento, eólica+armazenamento) com backup de capacidade, em comparação com Centrais a Gás de Ponta (Gas Peaking) e Ciclos Combinados a Gás (CCGT).

🟩 Conclusão Principal (Destacado em Verde):

✅ Em ERCOT, MISO, SPP e PJM:

Eólica + Armazenamento e Solar + Armazenamento:

- Apresentam sempre um LCOE + Custo de Compensação inferior ou competitivo com Centrais a Gás Peaking ($149–251/MWh) e frequentemente até com Ciclos Combinados a Gás (CCGT) ($48–109/MWh).

💡 **Não esquecer que o Gás Natural nos EUA é 3x mais barato do que na Europa, o que claramente elimina de uma vez por todas, até o Gás Natural da equação das melhores fontes de energia de Backup na Europa.**

Custo de Compensação da Intermitência (Firming Cost) de renováveis nos E.U.A e Comparação com Europa

NENUPHAR ADVISORS

🔍 ANÁLISE POR TECNOLOGIA:

1. Solar + Armazenamento:

LCOE + Firming no MISO: ~$86/MWh
SPP: ~$66
PJM: ~$66
ERCOT: ~$73
CAISO: ~$164
📌 **Conclusão: Excepto na CAISO, Solar+Storage já é claramente competitivo com CCGT e muito mais barato do que Gas Peaking.**

2. Eólica + Armazenamento:

LCOE + Firming no MISO: ~$71
SPP: ~$66
PJM: ~$73
ERCOT: ~$72
CAISO: ~$144
📌 **Conclusão: Eólica+Storage supera consistentemente o custo de Gas Peaking e CCGT em todos os mercados, exceto CAISO. MISO e SPP são os mais competitivos.**

3. Solar ou Eólica Isoladas (sem "Compensação")

Ainda mais baratas (ex: Eólica no MISO ≈ $61/MWh no total), mas sem despachabilidade total.
O custo para "Compensação" adiciona apenas um pequeno premium (≈ $20–$30/MWh).

Custo de Compensação da Intermitência (Firming Cost) de renováveis nos E.U.A e Comparação com Europa

NENUPHAR ADVISORS

🔥 COMPARAÇÃO COM GÁS:

🟥 Gás Peaking (Círculo Vermelho):

LCOE: $149–$251/MWh → Renováveis com armazenamento são sempre mais baratas, mesmo com Compensação.

🟧 Ciclo Combinado a Gás (CCGT) (Círculo Laranja):

LCOE: $48–$109/MWh

Apenas na CAISO e PJM, as renováveis com firming às vezes ultrapassam esse intervalo (devido aos maiores custos de Compensação).

⚙️ OUTROS DADOS IMPORTANTES:

Métrica	Observações
ELCC (Capacidade de Carga Efetiva)	Mais alta para sistemas híbridos (ex: Solar+Storage tem 33–38%)
Fator de Capacidade	Maior para Eólica (30–37%) do que Solar (20–27%)
Penetração de Recursos	MISO: 43%, SPP: 44%, ERCOT: 61% (quanto mais renováveis, mais credível o firming)

💡 Implicações Estratégicas

✅ MISO, SPP e ERCOT estão prontos para renováveis com armazenamento como nova base do sistema eléctrico — competitivas e limpas.

⚠️ CAISO enfrenta desafios de firming ("Compensação" devido à saturação e sobrepenetração, elevando custos.

🔄 Firming ("Compensação" não é mais um impeditivo — na maioria das regiões dos EUA, renováveis "Compensadas" superam térmicas a gás e estão no mesmo nível ou abaixo das CCGT.

NENUPHAR ADVISORS

📌 Conclusões Finais

Renováveis com "Compensação" (Firming) já são viáveis como base no MISO, SPP e ERCOT.

Centrais a Gás Peaking estão obsoletas economicamente na maioria das regiões.

CCGT ainda competitivo na PJM e CAISO, mas por pouco.

O armazenamento é o factor diferenciador — especialmente onde a penetração de renováveis é mais acentuada.

NENUPHAR ADVISORS

THANK YOU
FOR YOUR ATTENTION

Contact Us

www.nenupharadvisors.com
info@nenupharadvisors.com

Madrid, Spain
+34 602 453 375

Lisboa, Portugal
+351 961 953 547

Dubai, UAE
+971 54 486 1971

Nairobi, Kenya
+254 791 865 589