Executive summary: Role of offshore wind in solving emerging electricity crises

February 10, 2026

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Summary of findings

The United States is entering a period of heightened reliability and affordability stress driven by electricity demand growth not seen for decades. The rapid expansion of data centers, increased electrification of heating and transportation, and renewed emphasis on domestic manufacturing are driving sustained upward pressure on electricity demand. At the same time, infrastructure and supply constraints are limiting the pace at which new generation can be added.

Of particular concern is resource adequacy, the ability to provide sufficient generation to meet electricity demand across all weather conditions, particularly stressed conditions. Increasingly, resource adequacy challenges reflect not only the quantity of installed capacity, but also fuel needs, seasonal availability, transmission limits, and performance during high-risk hours.

No single resource can resolve pressing reliability and affordability challenges. Resources that are most commonly selected as new electricity generators in recent years—natural gas, solar, onshore wind, and storage—face development headwinds that constrain both the scale and pace of new deployment, limiting their ability to close imminent resource adequacy gaps. These near-term stresses are prompting increased scrutiny of grid planning decisions. National discussion has shifted from an “**all-of-the-above**” framing toward a more operationally focused “**everything-that-works**” perspective—one that emphasizes performance, location, scalability, and speed to power in the race to meet growing demand.

Along with other technologies, offshore wind (OSW) has been considered as a potential contributor to meeting emerging reliability and infrastructure challenges. In a series of three white papers, consultants at Charles River Associates evaluated OSW’s reliability and cost contributions across US electricity markets (See Figure 1 for a summary). In our analysis, we combined quantitative and qualitative analysis, stakeholder engagement, and literature review to assess the potential benefits and limitations of OSW. We sought to identify regions where it is best positioned to provide incremental system value and evaluate its interactions with other resource types, particularly natural gas. Several themes emerged:

- **Reliability risks are real and shifting toward the winter:** Reliability risks are rising and increasingly shifting toward winter months as reserve margins tighten.
- **Energy infrastructure investment is essential:** Sustained infrastructure investment is required to mitigate accelerating risks.
- **New resource development is facing delays:** Despite growing needs, new generation development is increasingly constrained by interconnection, permitting, and supply-chain barriers as well as policy and market uncertainty.
- **OSW can play a measurable role in solving near-term risks:** OSW can provide resource adequacy value, particularly at low to moderate penetration levels, due to strong stress-aligned generation profiles on both coasts.

- **OSW bypasses coastal infrastructure constraints:** By generating power offshore, OSW can help bypass transmission congestion, fuel-delivery limits, and onshore siting challenges while delivering power directly to coastal load centers.
- **OSW costs are improving but remain sensitive to market conditions:** Global OSW costs have fallen substantially over the past decade due to technological improvements and economies of scale, though recent supply-chain pressures, inflation, and financing costs have slowed this trend, particularly domestically.
- **Domestic OSW development infrastructure has expanded but requires further investment:** While domestic investments in ports, wind turbine installation vessels (WTIVs), and supporting supply chains have grown, additional buildout may be needed to fully capture domestic economies of scale and further drive down domestic costs.
- **Levelized cost of energy (LCOE) alone does not capture OSW's full value:** LCOE alone does not capture OSW's reliability or system-level value. Broader planning frameworks show OSW delivers meaningful reliability contributions comparable to some thermal resources in certain regions.

***Figure 1**: Summary of White papers*[1,2,3]

Contribution of OSW to grid reliability & resource adequacy[1]	Contribution of OSW to reliability & affordability in NYISO & ISO-NE[2]	Synergies between OSW and Natural Gas[3]
• ELCC-based analysis shows OSW provides meaningful reliability benefits • **Higher capacity factors and more stable production** than onshore wind and solar • Strong **alignment with emerging high-risk hours**, enhancing resource adequacy • **Highest ELCC** among renewable resources across markets • **Competitive with certain thermal resources** in key markets (e.g., PJM), though ELCC declines at high penetration levels • **Locational value** near coastal load centers, where new generation siting is constrained	• IRP analysis shows OSW portfolios **improve reliability, affordability, and emissions outcomes** in NYISO and ISO-NE • Coastal siting and winter peak alignment **strengthen resource adequacy while reducing energy costs** • Versus onshore renewables, OSW delivers similar emissions and energy cost benefits with stronger reliability and lower required capacity • Versus natural gas, **OSW provides comparable reliability with lower energy prices and emissions**; cost competitiveness varies by market • No-build cases produce the weakest reliability and cost outcomes as demand grows	• Qualitative and quantitative analysis with stakeholder input assessed interactions between OSW and natural gas • OSW and natural gas address different system risks, showing **reliability synergies when deployed together** • Complementary performance across weather conditions and locations supports system resilience • Competitive interactions emerge in high reserve margin systems when reducing residual risks • **Shared challenges** identified, with infrastructure and policy pathways to accelerate net new supply and broader grid investment

1 Oliver Stover, Jesse Dakss, Dean Koujak, Ryan Chigogo, Abdul Mohammed, Ryan Israel, Charles Merrick, and Chloe Romero Guliak, *The Contribution of Offshore Wind to Grid Reliability & Resource Adequacy* (Boston: Charles River Associates, November 6, 2025), **https://media.crai.com/wp-content/uploads/2025/11/05132542/CRA-Report-Offshore-Winds-Contribution-to-Grid-Reliability-Resource-Adequacy-November-2025.pdf.**

2 Oliver Stover, Jesse Dakss, Dean Koujak, Abdul Mohammed, Chloe Romero Guliak, and Ryan Chigogo, *Impacts of Offshore Wind on Reliability and Affordability in ISO-NE and NYISO* (Boston: Charles River Associates, December 2, 2025), **https://media.crai.com/wp-content/uploads/2025/12/02163131/Impacts-of-offshore-wind-on-reliability-and-affordability-in-ISO-NE-and-NYISO-December2025.pdf**.

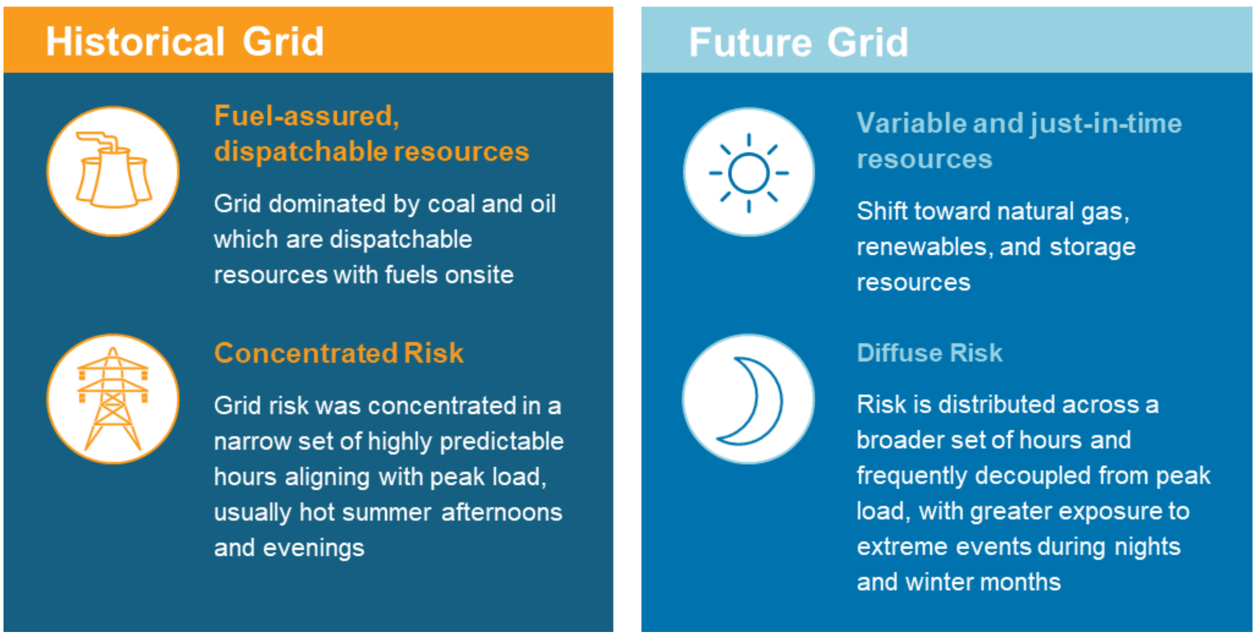
3 Dakss, Jesse, Oliver Stover, Ryan Chigogo, Ryan Israel, Charles Merrick, Chloe Romero Guliak, Dean Koujak, Abdul Mohammed, and Spencer Hurst. *Synergies between Offshore Wind and Natural Gas.* Charles River Associates, 2026. **https://www.crai.com/insights-events/publications/synergies-between-offshore-wind-and-natural-gas/**

Deep dive: The grid faces material near-term reliability pressures

Risk profiles are shifting

Even as reliability pressure increases in grids across the country, the **character of grid stress is shifting in fundamental ways**. Understanding the timing and drivers of growing reliability risk is critical to evaluating how different resources contribute to mitigating high-risk hours. The grid is increasingly stressed in new ways. These evolving dynamics are summarized in Figure 2.

Figure 2: Shifting Grid Conditions



Historically, electric system planning focused on meeting summer afternoon and evening peak demand, when air-conditioning loads were highest. Under those conditions, reliability risk was concentrated in a narrow set of hours, reserve margins were robust, and operators could rely on a largely dispatchable, fuel-assured[4] generation fleet to manage system stress.

These dynamics no longer drive risk profiles. Load growth is increasingly driven by hyperscale data centers and other industrial customers with round-the-clock electricity demand. At the same time, electrification of space heating and transportation is driving increased winter and evening demand in many regions.

An evolving generation supply mix further compounds these shifting dynamics. A significant share of fuel-assured thermal generation is retiring due to age, economics, and decarbonization goals, while much of the incremental capacity entering interconnection queues consists of non-

4 Fuel-assured means that generators had a high degree in confidence in accessing fuel because they stored it onsite.

dispatchable resources (solar and wind), energy-limited resources (storage), or just-in-time[5] fuel resources (natural gas).

These resources have delivered substantial cost and emissions reductions, but their reliability risk profiles differ from those of the resources that dominated historical conditions. Variable renewable generation is inherently weather-dependent and exhibits pronounced daily and seasonal patterns, reducing risk in some periods while shifting it to others. For example, solar mitigates risk during daylight hours and storage does so during early evening ramps (see Figure 3), shifting risk into evening hours. Simultaneously, common-cause outages have become more important, as demonstrated by Winter Storms Uri (2021) and Elliott (2022), which showed how grid stress can arise when natural gas supply is constrained by pipeline freezes, equipment failures, or competing heating demand.[6]

Reliability risk is no longer defined by a single peak hour but increasingly arises across multiple stressed grid conditions. Winter mornings and evenings are emerging as high-risk periods in many regions due to strong heating demand, limited solar output, energy-constrained storage, and strained natural gas fuel systems. As a result, **even summer-peaking systems are becoming winter-constrained**, underscoring the importance of resource performance during key risk hours, fuel availability under extreme conditions, and locational constraints rather than average annual performance.

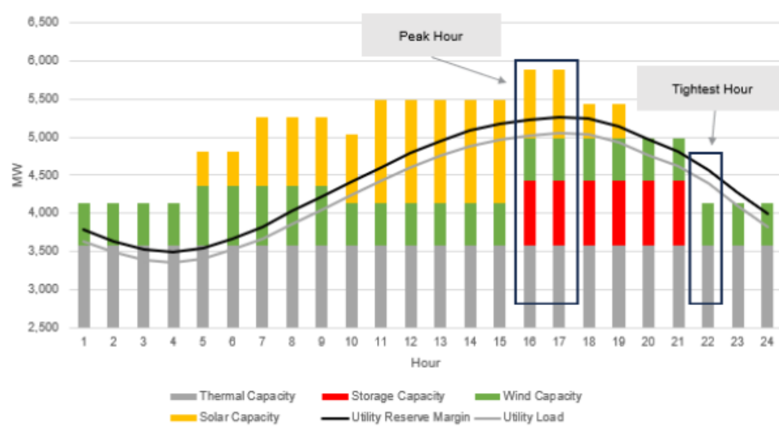
Figure 3: Shifting Risk Dynamics[7]

Risk dynamics are shifting

Renewables are becoming victims of their own success. By "solving" hours where their generation is strongest, they shift risk to low-generation hours. As a result, markets place less value on their resource adequacy contribution by lowering their ELCC values.

Increasing value for winter and night resources

Across the country, markets are placing greater value on winter and nighttime generation, as solar and storage mitigate daytime and summer risk while load grows during winter months.



5 This means that natural gas generators rely on pipelines to deliver fuel as they consume it to produce electricity.

6 Federal Energy Regulatory Commission (FERC) and North American Electric Reliability Corporation (NERC), Final Report on Lessons from Winter Storm Elliott, press release, Washington, D.C., Federal Energy Regulatory Commission, April 2024, https://www.ferc.gov/news-events/news/ferc-nerc-release-final-report-lessons-winter-storm-elliott.

7 PJM Interconnection, *2026/2027 Base Residual Auction Report* (Valley Forge, PA: PJM Interconnection, 2024), **https://www.pjm.com/-/media/DotCom/markets-ops/rpm/rpm-auction-info/2026-2027/2026-2027-bra-report.pdf**.

New generation additions have lagged load growth and retirements due to multiple development headwinds

In addition to shifting risk profiles, overall risk has increased. New generation additions have not kept pace with load growth and retirements in recent years. Across the country, interconnection timelines have lengthened, permitting complexity has increased, and supply-chain constraints impact the speed at which new resources can be deployed.[8] As a result, the reserve margins are tightening[9] and reliability risks are growing in markets across the country.[10] While industry stakeholders are seeking to accelerate new resource interconnections, wind, storage, solar, and natural gas projects continue to face development and siting barriers (see Table 1).

Table 1: Summary of Advantages and Challenges for Legacy Resources

Advantages and Challenges for Legacy Resources			
Onshore Wind	Strong winter performance can support reliability, but best sites are located **far from load pockets**	**Storage**	Moderate reliability impact, but net energy consumers and may be **limited during long-duration**, winter events
Solar	Increasingly cost competitive and leading resource in interconnection queues, but **lowest resource adequacy impact**	**Natural Gas**	Backbone of grid, but long lead time, **cold weather generator outages, and fuel constraints in Northeast are a concern**

For example, net new natural gas generation remains highly valuable from a reliability perspective, but additions are impacted by multiyear turbine backlogs,[11] permitting challenges,[12] and extended construction timelines. To understand these limitations, we interviewed five natural gas engineering, procurement, and construction (EPC) firms regarding their recent experiences

8 Joseph Rand, Nick Manderlink, Steven Zhang, Chris Talley, Will Gorman, Ryan H. Wiser, Joachim Seel, Julie Mulvaney Kemp, Seongeun Jeong, and Fredrich Kahrl, *Queued Up: 2025 Edition—Characteristics of Power Plants Seeking Transmission Interconnection as of the End of 2024* (Berkeley, CA: Lawrence Berkeley National Laboratory, December 2025), **https://emp.lbl.gov/sites/default/files/2025-12/Queued%20Up%202025%20Edition%20-%2012.15.2025.pdf**.

9 PJM Interconnection, Energy Transition in PJM: Resource Retirements, Replacements, and Risks, Valley Forge, PA: PJM, August 2023, Retrieved from the PJM website: Energy Transition in PJM: Resource Retirements, Replacements, and Risks (2023), **https://www.pjm.com/-/media/DotCom/library/reports-notices/special-reports/2023/energy-transition-in-pjm-resource-retirements-replacements-and-risks.ashx.**

10 U.S. Department of Energy, *Evaluating U.S. Grid Reliability and Security: Resource Adequacy Report* (Washington, DC: U.S. Department of Energy, July 7, 2025), **https://www.energy.gov/sites/default/files/2025-07/DOE%20Final%20EO%20Report%20%28FINAL%20JULY%207%29.pdf**.

11 Ibid.

12 Reuters Events | Renewables, "Rush for U.S. Gas Plants Drives Up Costs, Lead Times," July 21, 2025, **https://www.reutersevents.com/renewables/solar-pv/rush-us-gas-plants-drives-costs-lead-times**.

and challenges. These findings are summarized below. Their insights underscore that criticality of natural gas development but highlight that dynamics impacting development.

What natural gas developers are saying:

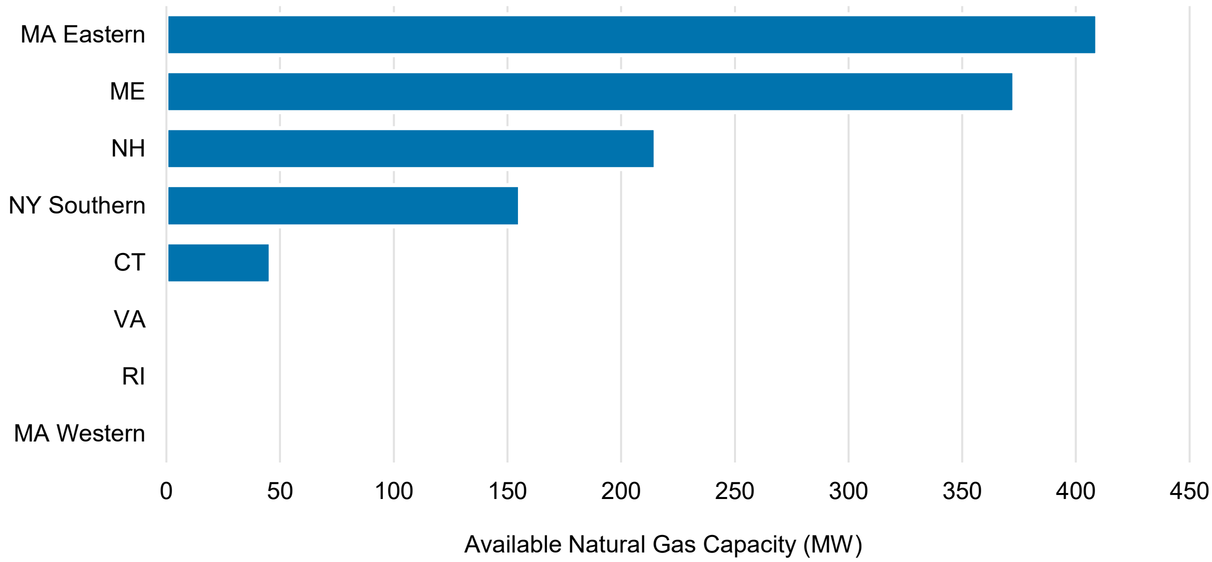
- **Competing demand for turbines:** Strong growth in hyperscaler and industrial load is driving competing demand for gas turbines as back-up power sources.
- **Supply chain bottleneck:** Turbines, transformers, and breakers remain highly constrained, with lead times extending to ~2029.
- **Workforce shortages:** Limited availability of skilled labor, especially electricians and field technicians, is creating project competition and execution risks.
- **Supplier investment dynamics:** Long-term gas demand uncertainty can deter manufacturing expansion; however, suppliers serving both gas and renewable projects show greater willingness to invest due to diversified demand.
- **Lengthy and complex permitting:** Interconnection processes and permitting remain major barriers, with delay of three to five years common.

In addition, many natural gas pipeline systems, particularly in the Northeast, are already operating near full utilization during winter conditions, without sufficient headroom to support incremental firm fuel contracts for new generation.[13, 14] Such constraints limit not only the pace of new natural gas development, but may also affect the fuel availability and resulting reliability contribution of existing plants during periods of peak system stress. Our analysis reiterates these concerns. As shown in Figure 4, we have found that the ability to add new natural gas generation under firm fuel arrangements in the Northeast is limited to a few hundred megawatts in many cases, while a single "hyperscaler" data center campus can exceed one gigawatt of average load.

13 Robert Walton, "Lack of Northeast Gas Pipeline Capacity Poses 'Severe Threats to Reliability' in Cold Weather: NERC," *Utility Dive*, 2025, accessed January 23, 2025, **https://www.utilitydive.com/news/northeast-gas-pipeline-capacity-reliability-NERC-NPCC/738100**.

14 Derrill Holly, "NERC Warns of Electricity Shortages in Winter Reliability Assessment," *Cooperative.com, 2023,* ***https://www.cooperative.com/news/Pages/NERC-Warns-of-Electricity-Shortages-in-Winter-Reliability-Assessment.aspx***.

Figure 4: Electricity generation headroom from natural gas generators by region



While urgent action is being taken to bring reliability-critical resources to the grid,[15, 16] resource adequacy concerns remain. The pace of load growth is still outstripping the ability to interconnect new resources with these legacy technologies alone. The resulting gap between growing demand and feasible supply additions is the key driver of the cost and reliability pressures now materializing across the grid.[17] As a result, increasing the speed and scale of investment in legacy resources—while identifying additional pathways for delivering net new energy and capacity—is becoming increasingly important.

Warning signs for both reliability and affordability are emerging as the grid faces tightening supply and demand conditions

Tightening supply-demand dynamics are increasingly reflected in market outcomes and system operations, directly affecting the grid's ability to accommodate growing electricity demand reliably and affordably. Capacity market prices have risen sharply in recent auctions, signaling tightening reserve margins and increased uncertainty around resource availability, as shown in

15 McGovern, Jason. "PJM Chooses 51 Generation Resource Projects to Address Near-Term Electricity Demand Growth." *PJM Inside Lines*, May 2, 2025. Accessed January 23, 2026. **https://insidelines.pjm.com/pjm-chooses-51-generation-resource-projects-to-address-near-term-electricity-demand-growth/**

16 Howland, Ethan. "FERC Upholds MISO, SPP Fast-Track Generator Reviews." *Utility Dive*, January 23, 2026. Accessed January 23, 2026. **https://www.utilitydive.com/news/ferc-miso-spp-fast-track-generator-eras/810343/**

17 U.S. Department of Energy, *Evaluating U.S. Grid Reliability and Security: Resource Adequacy Report* (Washington, DC: U.S. Department of Energy, July 7, 2025), **https://www.energy.gov/sites/default/files/2025-07/DOE%20Final%20EO%20Report%20%28FINAL%20JULY%207%29.pdf**.

Figure 5. For example, PJM's capacity auction has seen sharp spikes[18] and failed to clear sufficient capacity to maintain target reserve levels,[19] raising the possibility of power outages or load curtailment. In MISO's most recent capacity auction, held in April 2025, summer capacity prices rose to $666.50/MW-day, representing roughly a 22-fold increase across all zones.[20]

Figure 5: PJM Capacity Prices[21, 22]

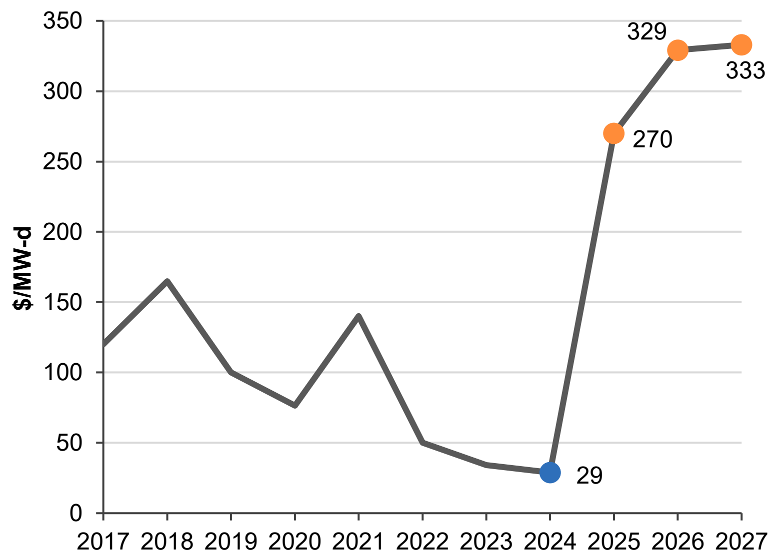
Capacity prices are spiking across the country, indicating tightening supply demand balance

What is a capacity price?

Capacity markets incentivize generators for meeting resource adequacy targets. Critically, they do not guarantee that sufficient generation is brought onto the grid. **Capacity markets spike when markets are tight, endangering resource adequacy and reliability.**

Key Metrics

PJM capacity prices for the 2026-2027 delivery year cleared at the $329/MW-day price cap, up 22% year-on-year. The 2027/2028 auction held in December 2025 cleared at $333/MW-day, again hitting the price cap.



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18 This auction was held for the June 1, 2026 through May 30, 2027 delivery period. See: PJM Interconnection, *2026/2027 Base Residual Auction Report* (Valley Forge, PA: PJM Interconnection, 2024), **https://www.pjm.com/-/media/DotCom/markets-ops/rpm/rpm-auction-info/2026-2027/2026-2027-bra-report.pdf**.

19 PJM Interconnection, *2027/2028 Base Residual Auction Report* (Valley Forge, PA: PJM Interconnection, published December 17, 2025), accessed January 12, 2026, **https://www.pjm.com/-/media/DotCom/markets-ops/rpm/rpm-auction-info/2027-2028/2027-2028-bra-report.pdf**.

20 Midcontinent Independent System Operator (MISO), "MISO's Planning Resource Auction Indicates Sufficient Resources," *MISO News Center*, April 28, 2025, **https://www.misoenergy.org/meet-miso/media-center/2025---news-releases/misos-planning-resource-auction-indicates-sufficient-resources/**.

21 PJM. *2026/2027 Base Residual Auction Report*. July 22, 2025. For public use. PJM. Accessed August 18, 2025. **https://www.pjm.com/-/media/DotCom/markets-ops/rpm/rpm-auction-info/2026-2027/2026-2027-bra-report.pdf**.

22 PJM Interconnection. *2027/2028 Base Residual Auction Report*. December 17, 2025. Accessed January 23, 2026. **https://www.pjm.com/-/media/DotCom/markets-ops/rpm/rpm-auction-info/2027-2028/2027-2028-bra-report.pdf**

Even as capacity costs have risen, adverse reliability outcomes are becoming more frequent.[23] Since 2011, five major winter storms have threatened the power grid, and heat waves caused summer rolling blackouts in Louisiana and California.

Key takeaway: Shifting resource mixes heighten exposure to extreme weather, shifting risk toward winter and nighttime hours. At the same time, reserve margins are tightening, and generator additions are facing delays. As a result, capacity prices are rising, and outage risk is growing.

- To see further discussion on the resource adequacy challenges facing markets and capacity price outcomes, see **Paper 1, section 4** and **Paper 2, section 3**.
- To see further discussions of resource adequacy and fuel limitations facing the Northeast, see **Paper 2**.
- To see further discussion into development headwinds for natural gas generators, see **Paper 3, sections 6.1.1 and 6.2**.

In the context of grid tightness, markets across the country are signaling the value of OSW

To address growing resource adequacy concerns and better align market signals with system needs, markets across the country are reforming how capacity is accredited.[24] Central to these reforms is the use of Effective Load Carrying Capability (ELCC), which measures the portion of a resource's nameplate capacity that can be reliably counted on during periods of highest system stress.

We apply the ELCC framework to evaluate the potential role of OSW in meeting evolving resource adequacy needs. This framework isolates OSW's contribution during periods of system stress, rather than including day-to-day and low-risk operations. Results of this analysis are summarized in Figure 6.

As shown in the figure, we find that OSW consistently achieves higher ELCC values than other renewable resources and, in some markets, is competitive with energy-limited storage and certain thermal resources, including in PJM (Figure 7) and ISO-NE (Figure 8 with ELCCs under three possible future grid outcomes, called scenarios). These outcomes are consistent with the stress-alignment and fuel-free nature of OSW.

We also evaluated the role OSW is currently playing in international power systems. In Northern Europe, OSW is a well-established component of resource adequacy planning and has been deployed at multi-gigawatt scale. Experience from European power systems offers evidence of

23 North American Electric Reliability Corporation (NERC), *2025 Summer Reliability Assessment* (Arlington, VA: NERC, May 2025), **https://www.electric.coop/wp-content/uploads/2025/05/NERC_SRA_2025.pdf**.

24 Energy & Environmental Economics, Inc. *Resource Adequacy for the Energy Transition: A Critical Periods Reliability Framework and its Applications in Planning and Markets*. August 2025. Accessed January 23, 2026. **https://www.ethree.com/wp-content/uploads/2025/08/E3_Critical-Periods-Reliability-Framework_White-Paper.pdf**.

OSW's operation impact in practice, beyond purely computational results. At the same time, European outcomes reinforce that OSW's resource adequacy impact is greatest at low to moderate penetration levels, with marginal contributions declining, but remaining non-trivial, as penetration increases, consistent with patterns observed for other variable resources.

Figure 6: Key Findings by Market

PJM	NYISO	ISO-NE
Challenges: Among the steepest load growth in the United States, driven by data centers. PJM projects that risk is now concentrated in winter months. Slow interconnection queues, dominated by solar and storage. **Role of OSW:** Scalable near-term option in coastal zones. ELCC = 69% in latest auction—higher than many storage and thermal resources.	**Challenges:** Transitioning to winter-peaking by late 2030s. Constrained natural gas infrastructure. Downstate congestion and retirement of peaker plants driving localized risk. **Role of OSW:** Highest accreditation of renewables (CAF ~32%). Delivers directly into downstate load pockets (NYC, Long Island).	**Challenges:** Winter peak growth 3x summer. Gas pipelines fully utilized in heating season. Storage vulnerable during prolonged cold snaps. **Role of OSW:** Accreditation projected at >90% in some studies, rivaling thermal resources. Most critically, OSW bypasses strained fuel systems.
CAISO	**ERCOT**	**International**
Challenges: Summer peaks remain binding. Aggressive decarbonization targets accelerate solar/storage buildout. Managing the "duck curve" as solar drops off in evenings. **Role of OSW:** Coastal winds strongest in late afternoons/evenings. Complements solar, reduces need for storage, scalable in-state resource.	**Challenges:** Peak demand projected to nearly double by 2044. Ongoing exposure to extreme weather and natural gas disruptions. **Role of Coastal Wind:** Offshore faces cost barriers, but coastal wind ELCC = 2-4x solar, the highest of all wind resources.	**Challenges:** Rising reliability and affordability crises due to age, economics, and policy driven retirements of coal and nuclear resources and geopolitical instability from the Russia-Ukraine war. **Role of OSW:** Mature, proven technology. Cornerstone of adequacy strategy in the U.K., Germany, and Denmark. Built at multi-GW scale with streamlined permitting and experienced developers. ELCC declines at higher penetration.

Figure 7: PJM ELCC Ratings[25]

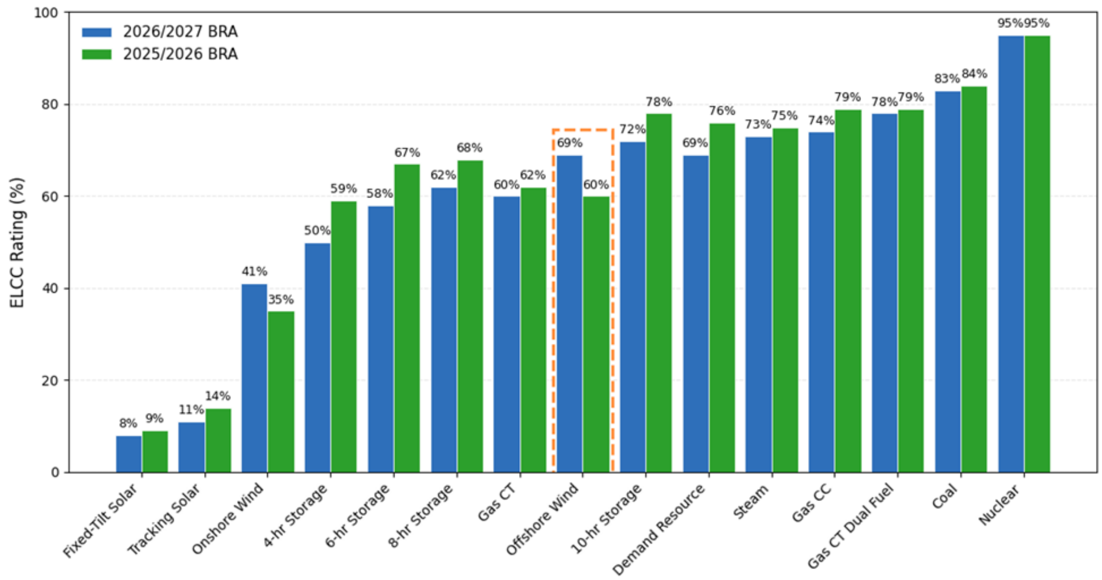
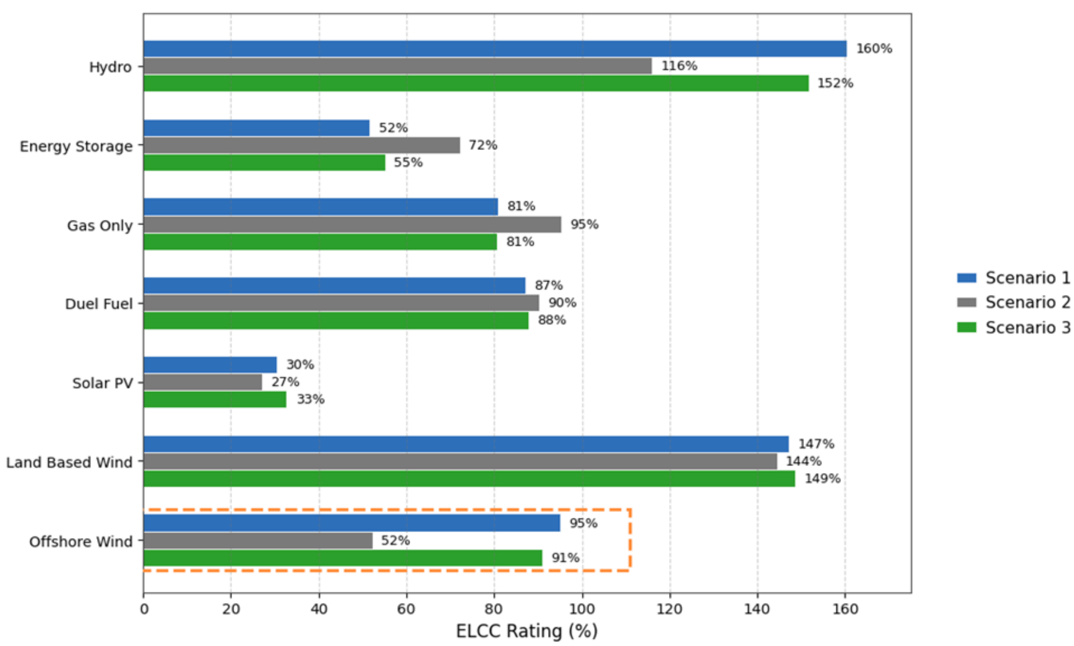


Figure 8: Average Capacity Rating Across Scenarios in ISO-NE[26]



25 PJM. *2025/2026 Base Residual Auction Report*. July 22, 2025. For public use. PJM. Accessed August 18, 2025. **https://www.pjm.com/-/media/DotCom/markets-ops/rpm/rpm-auction-info/2025-2026/2025-2026-base-residual-auction-report.pdf**.

26 ISO New England Inc., *Impact Analysis Sensitivity Results – May 2024* (Milford, MA: presentation to the NEPOOL Markets Committee, May 7–8, 2024), **https://www.iso-ne.com/static-assets/documents/100011/a02c_mc_2024_05_07_08_impact_analysis_sensitivity_results_may2024.pdf**.

Key takeaway: OSW demonstrates consistently strong ELCC performance across multiple markets, often leading other renewable resources and remaining competitive with thermal resources in several markets. However, its ELCC value will decline at higher penetration levels, in line with other renewable technologies.

- To see additional discussion around market-by-market analysis of current resource adequacy challenges and ELCC values, see **Paper 1, section 4**.
- To see additional modeling computing the resource adequacy impact of OSW and natural gas additions at varying levels of penetration in New York City, see **Paper 3, section 6.1.2**.

OSW exhibits reliability characteristics that differ from many other resources

When evaluating trends across markets, several consistent patterns emerge that help explain why OSW achieves relatively high ELCC values. In addition, our analysis identifies characteristics beyond those directly captured by ELCC that further support OSW's role as a resource adequacy contributor. Key characteristics underlying this performance include:

- **High capacity factors and steady outputs:** By accessing steady coastal winds at higher hub heights, OSW is projected to have a capacity factor around 46%[27] as compared to 37%[28] for the most recent onshore wind projects.[29] Both OSW and onshore wind have significantly higher capacity factors than solar generation (median capacity factor of 24% with a range from 7% to 35%)[30] and produce throughout the day, often peaking overnight. While wind output typically dips in summer, this effect is less pronounced offshore.
- **Stress-aligned generation:** PJM, NYISO, and ISO-NE increasingly face winter morning and evening risks, compounded by constrained natural gas supply. OSW's strongest output aligns with these periods. In contrast, California's risk occurs during summer evenings, when Pacific OSW output is strongest.
- **Efficient coastal siting and infrastructure relief:** OSW preserves scarce and costly onshore land in dense coastal and urban areas while helping alleviate natural gas and transmission constraints in key load pockets—such as New York City and Northern

27 Katie Segal and Henry Lee, *Offshore Wind in the Eastern United States: A Policy Brief* (Cambridge, MA: Belfer Center for Science and International Affairs, December 2021), **https://www.belfercenter.org/sites/default/files/pantheon_files/files/publication/Belfer%20Brief_Offshore%20Wind_20211216.pdf**.

28 U.S. Department of Energy, *Land-Based Wind Market Report: 2023 Edition* (Washington, DC: U.S. Department of Energy, 2023), **https://www.energy.gov/sites/default/files/2023-08/land-based-wind-market-report-2023-edition.pdf**.

29 *Ibid.*

30 Lawrence Berkeley National Laboratory, *Utility-Scale Solar, 2025 Edition: Analysis of Empirical Plant-Level Data from U.S. Ground-Mounted PV, PV+Battery, and CSP Plants (Exceeding 5 MWAC)* (Berkeley, CA: Energy Markets & Policy Group, Lawrence Berkeley National Laboratory, September 2025), **https://emp.lbl.gov/sites/default/files/2025-10/Utility%20Scale%20Solar%202025%20Edition%20Slides.pdf**.

Virginia—through direct interconnection[31] and its fuel-free nature, reducing fuel price exposure, energy costs, and emissions.[32] OSW bypasses aging and strained fuel systems, particularly in parts of New England.

- **Increasing fuel diversity:** Common-mode outages are increasingly shaping system risk. By relying on a distinct fuel source, OSW diversifies the generation mix, strengthening grid resilience against single-fuel disruptions.
- **Additional and complementary pathway to new generation:** Given supply chain constraints, OSW offers an alternative source of energy and capacity. Although OSW faces its own development and permitting challenges, advancing it alongside natural gas and other infrastructure can help hedge against supply chain and development risks.

OSW can be viewed as a complement, rather than an alternative, to natural gas

Another consistent finding across the modeling results is the synergy between OSW and natural gas. Even as these resources are often framed as alternatives, our analysis finds that this need not be the case. When deployed together, OSW and natural gas provide seasonally complementary reliability characteristics. Natural gas resources are well-suited to meeting summer peak demand, while OSW contributes more strongly during winter stress periods, particularly along the East Coast.

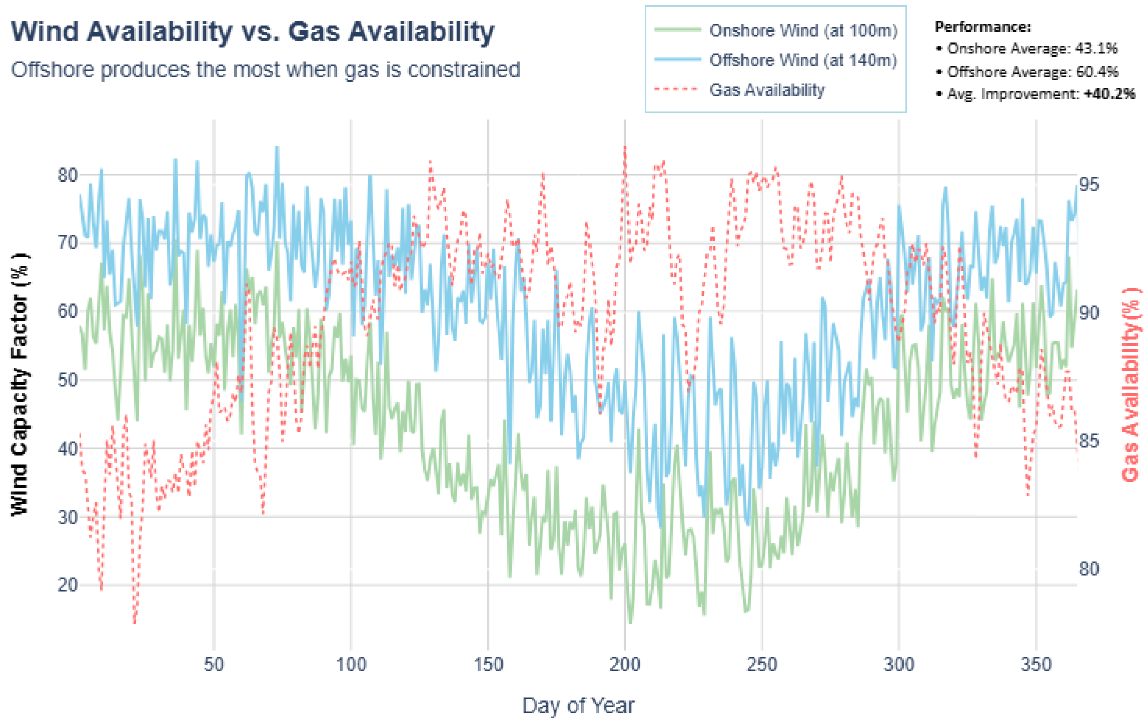
Figure 9 illustrates this interaction by comparing average daily availability from the offshore Revolution Wind installation, onshore wind, and a natural gas peaking plant. Wind output is highest in winter, when natural gas plants are most vulnerable to cold-weather outages, providing natural risk diversification. In summer, wind output generally declines on the east coast while natural gas availability improves. OSW further strengthens this balance by maintaining higher capacity factors than onshore wind, including during summer months while natural gas can hedge against lulls in wind generation. While both OSW and natural gas could play important roles across both seasons, their complementary profiles make both more effective at mitigating reliability risks when paired together. However, we also find the resources can have competitive interactions when both compete to reduce a limited number of remaining load shedding hours as sufficient resources are built to meet or exceed reserve margin targets.[33]

31 See “South Fork results” in *Synergies between OSW and Natural Gas*, and the “NYC Results” section of *Impacts of Offshore Wind on Reliability and Affordability in ISO-NE and NYISO.*

32 See IRP analysis results section.

33 CRA analysis

Figure 9: Generation Synergies Between OSW and Natural Gas



Modeling shows that OSW could further complement natural gas by easing localized reliability constraints, deferring transmission investments, and delivering new energy and capacity in gas-limited regions,[34] as illustrated by South Fork Wind (Case Study 1).[35,36,37,38,39] Placed into service in March 2024, South Fork Wind was the first utility-scale OSW project to deliver power to the American grid. Regulators identified reliability risks in the South Fork load pocket on Long Island due to local transmission and pipeline constraints. By adding a fuel-free resource directly within the transmission- and fuel-constrained South Fork load pocket, the project reduced dependence on a single fuel, bypassed constrained natural gas infrastructure, and deferred the need for select local transmission upgrades.

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34 This paper refers to the OSW project as 'South Fork Wind' and the region as 'South Fork region' or 'South Fork'.

35 "Welcome to South Fork Wind" n.d. Southforkwind.com. **https://southforkwind.com/**.

36 PSEG Long Island. *2015 South Fork Resources Request for Proposals*. June 24, 2015. **https://www.psegliny.com/aboutpseglongisland/proposalsandbids/2015southforkrfp**

37 "Celebrating One Year with South Fork Wind." 2025. LIPA. April 10, 2025. **https://www.lipower.org/blog/celebrating-one-year-with-south-fork-wind/**.

38 "New York Independent System Operator. *Power Trends 2025: A Balanced Path to a Reliable and Renewable Grid.* Rensselaer, NY: NYISO, 2025, 32. **https://www.nyiso.com/documents/20142/2223020/2025-Power-Trends.pdf**

39 Long Island Power Authority. "South Fork RFP: Board Materials for the LIPA Board of Trustees." January 25, 2017. **https://www.lipower.org/wp-content/uploads/2019/02/2017-01-South-Fork-Board-Material.pdf**

Case study 1: South Fork Offshore Wind

The South Fork Wind project was placed into service in March 2024. It is located 35 miles east of Montauk Point, New York, and consists of 15 turbines with 132 MW of capacity.

The problem

- The South Fork region of Long Island, NY faced rising peak demand, severe transmission constraints, and limited natural gas deliverability.
- South Fork's heavy existing reliance on gas-fired generation created reliability and price risks.

Procurement

- 2015 RFP sought up to 169 MW to defer costly local transmission upgrades.
- Only fuel-free or locally stored liquid-fuel resources with secure supply were eligible, due to local constraints on gas fuel delivery.

Why OSW won

- Best combination of scale, timing, and risk profile among 21 proposals.
- Direct delivery into a transmission-constrained load pocket.
- Strong production during winter and overnight hours when gas systems are most stressed.
- Fuel-free price certainty, hedging customers against natural gas price volatility.
- Fuel diversification explicitly valued.

How OSW and gas work together

- OSW complements, rather than replacing natural gas generation in South Fork
- Gas plants remain essential for dispatchability, reserves, and low-wind periods.
- OSW reduces marginal gas run hours, easing pipeline constraints.
- Provides near-term reliability while enabling longer-term infrastructure investments.

South Fork Wind shows how OSW may be used to strengthen wider grid investment by providing targeted solutions to constrained load pockets.

OSW may also be used to complement portfolio-level infrastructure investment strategies to meet high load growth. This dynamic is illustrated by Dominion's Coastal Virginia Offshore Wind (CVOW) project (Case Study 2).[40,41,42] Dominion serves the nation's largest data center market and is experiencing exceptionally strong demand growth. Dominion plans to build as much nuclear, onshore wind, solar, storage, and natural gas as it can support. But, even with these commitments, additional capacity is required. In this high load growth dynamic, OSW provides a

40 Dominion Energy. *Coastal Virginia Offshore Wind: The Project.* Accessed February 2025. **https://coastalvawind.com/about/the-project**

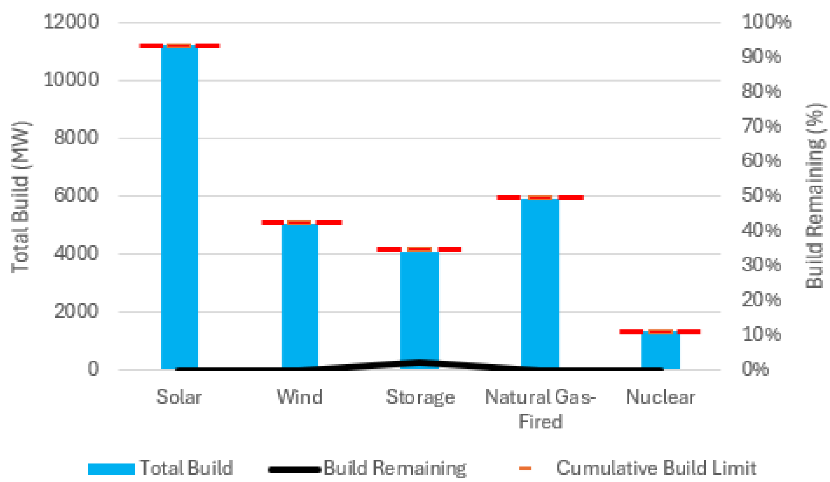
41 US Department of the Interior. 2025. "Trump Administration Protects US National Security by Pausing Offshore Wind Leases." Press release. Accessed December 28, 2025. **https://www.doi.gov/pressreleases/trump-administration-protects-us-national-security-pausing-offshore-wind-leases**

42 Virginia Electric and Power Company d/b/a Dominion Energy Virginia, 2018 Integrated Resource Plan, RD249, Reports to the General Assembly (Richmond, VA: Virginia General Assembly, May 1, 2018), **https://rga.lis.virginia.gov/Published/2018/RD249.**

necessary incremental source of net new energy and capacity to keep pace with demand growth.

Case study 2: Dominion Energy’s Coastal Virginia Offshore Wind

Dominion’s 2.6 GW Coastal Virginia Offshore Wind (CVOW) project, located roughly 27 miles off Virginia Beach, experienced a temporary federal stop-work order issued by the US Department of the Interior, introducing uncertainty around its previously expected 2026 completion timeline.



Dominion’s 2024 IRP does not choose between OSW and other resources. It needs every megawatt available—including OSW, nuclear, and natural gas—to keep up with very high demand growth.

Dominion Virginia supplies the largest data center market in the country. Dominion plans to build 5.9 GW of natural gas, 12 GW of solar, 1.3 GW of small modular nuclear reactors, 4.1 GW of energy storage, 60 MW of onshore wind, and 2.6 GW OSW in addition to its ongoing 2.6 GW CVOW project to keep up with rapidly growing demand.

Without OSW, Dominion would risk having to deny data center customer requests and slow the nation’s AI development and the region’s economic growth.

Key takeaway: OSW reliability value is supported by its fuel-free generation, stress-aligned production profile, and ability to avoid many onshore siting and buildability constraints.

- To see further discussion on OSW’s role in Dominion, see **Paper 3, section 6.3.1**.
- To see further discussion on OSW’s role in South Fork, see **Paper 3, section 6.3.2**
- To see further discussion on the characteristics that drive OSW’s potential reliability impacts, see **Paper 1, section 3**.
- To see further discussion on the synergies between OSW and natural gas, see **Paper 3**.

OSW's cost competitiveness using LCOE

One barrier to OSW adoption is cost pressure (see Figure 10). A commonly used metric for comparing generation technologies is the Levelized Cost of Energy (LCOE), which measures the average cost to build, operate, and retire a plant over its lifetime, normalized by the energy it produces. OSW currently lags other renewable technologies when evaluated solely on an LCOE basis [43]

OSW costs have declined substantially, with global LCOE falling 62% from 2010 to 2024, [44] though recent supply chain, financing, and inflationary pressures have slowed progress[45]—particularly in the US where development coincided with broader market disruptions. [46,47]

However, while LCOE provides useful cost context, it does not capture resource adequacy value because it reflects average annual energy costs rather than performance during high-risk grid conditions. To address this gap, we introduce LCOE-normalized ELCC (N-ELCC), which measures accredited capacity contribution per dollar of energy cost (shown in Figure 11)

Applying this metric using PJM ELCC values shows combined-cycle resources and OSW deliver strong reliability value alongside competitive energy costs, while technologies with weaker performance during system stress, such as solar, rank lower despite low LCOE values. These results highlight the limitations of relying on LCOE alone when evaluating resource value. Even this modest extension of LCOE results in materially different merit ranking of resources.

Key takeaway: OSW's LCOE has declined over time, although recent cost improvements have slowed and OSW continues to carry a cost premium relative to some other renewable technologies. Importantly, LCOE alone does not capture a resource's contribution to resource adequacy or its interactions with other technologies.

- To see further discussion on LCOE, see **Paper 1, section 3.6**.

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43 Levelized Cost of Energy+ (LCOE+).” 2025. Https://Www.lazard.com. 2025. https://www.lazard.com/research-insights/levelized-cost-of-energyplus-lcoeplus/.

44 Levelized Cost of Energy (LCOE) is the average cost of producing electricity from a given source over its entire lifetime, including building, operating, and fuel expenses spread out evenly across all lifetime plant production. For more information: Corporate Finance Institute, “Levelized Cost of Energy (LCOE),” accessed January 23, 2026, **https://corporatefinanceinstitute.com/resources/valuation/levelized-cost-of-energy-lcoe/**.

45 International Renewable Energy Agency (IRENA), *Renewable Power Generation Costs in 2024* (Abu Dhabi: IRENA, July 2025).

46 Tyler Stehly, Patrick Duffy, and Daniel Mulas Hernando, *Cost of Wind Energy Review: 2024 Edition*, NREL/TP-5000-91775 (Golden, CO: National Renewable Energy Laboratory, November 2024), **https://www.nrel.gov/docs/fy25osti/91775.pdf**.

47 Lazard, *Levelized Cost of Energy+ (LCOE+)* (New York: Lazard, 2025), **https://www.lazard.com/research-insights/levelized-cost-of-energyplus-lcoeplus/**.

Case study 3: Levelized Cost of Energy and Normalized ELCCs

While OSW shows cost premiums relative to other renewables when evaluated with LCOE, this metric does not capture contribution to high-stress hours. We develop a simple extension to LCOE—Normalized ELCC—that measures the ELCC per LCOE. OSW shows stronger performance on this metric

Figure 10: Levelized Cost of Energy (LCOE) comparison of various generation technologies[48]

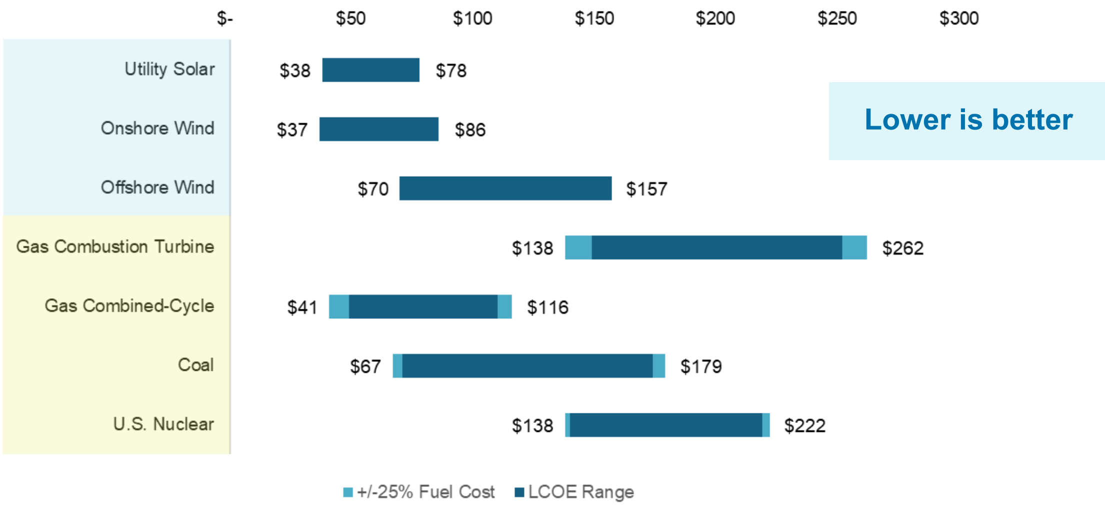
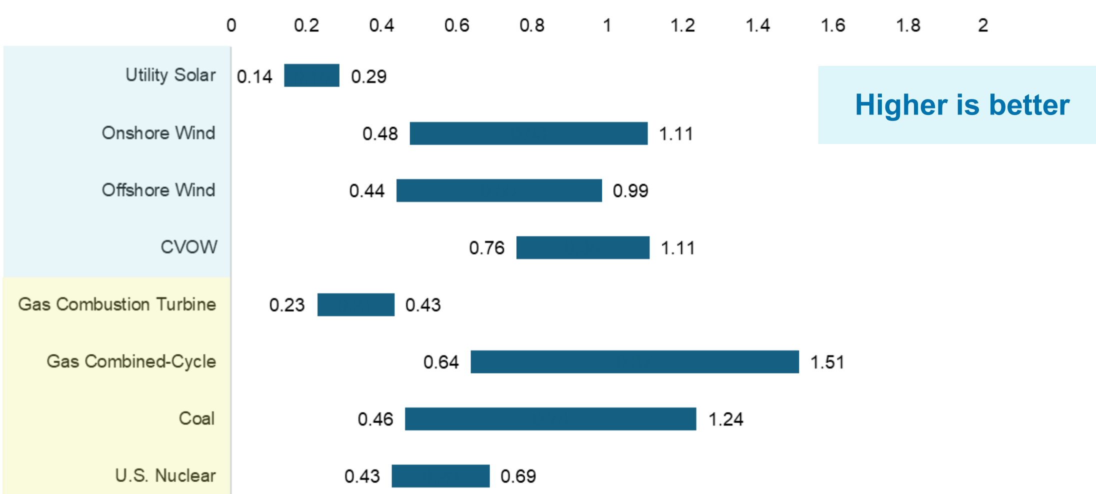


Figure 11: Normalized ELCCs across various generation technologies in PJM



LCOE alone can misrepresent resource value; for example, incorporating reliability impacts materially changes relative resource rankings and underscores the need for system-level evaluation.

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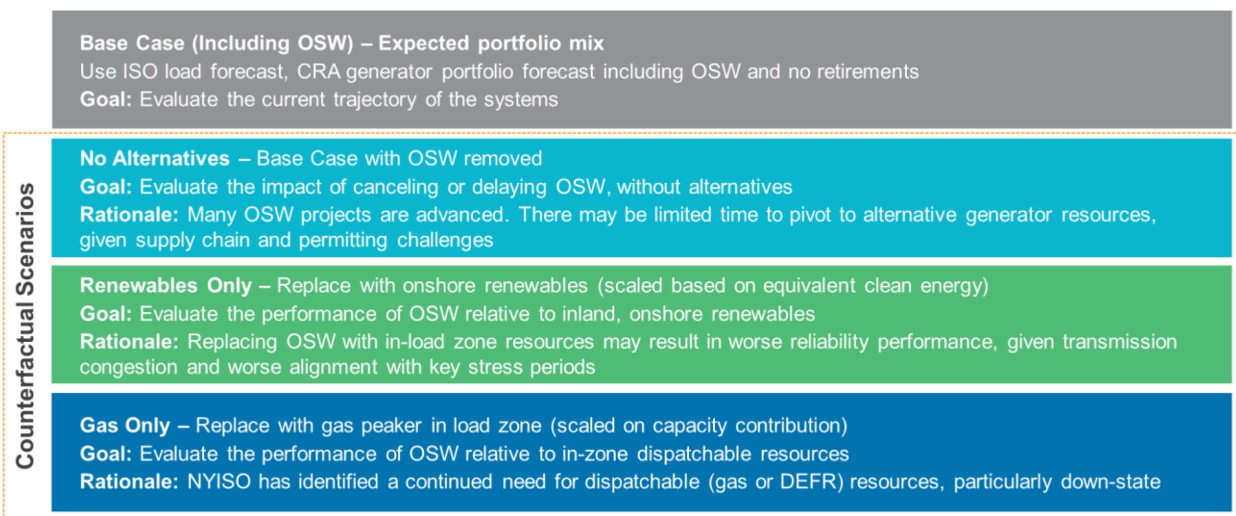
[48] Ibid.

When viewed in the context of wider portfolio investments, OSW's value and limitations become clearer

To address LCOE's limitations, we conducted an Integrated Resource Planning (IRP)-style analysis that fully capture interactions among technologies. The analysis compares portfolios across a range of outcomes using a unified scorecard covering energy and capital costs, reliability, emissions, and fuel infrastructure stress indicators. Results for NYISO and ISO-NE are summarized in Tables 2 and 3 with performance of a given technology scenario relative to the Base Case with OSW is shown in parentheses.

We applied this framework in ISO-NE and NYISO, comparing futures that include OSW with alternatives in which OSW is replaced by other resource options, including increased reliance on natural gas or additional onshore renewables (See Figure 12). While these alternative pathways may be feasible, each presents its own development, siting, and infrastructure risks, highlighting key factors planners must consider when evaluating the feasibility of resource alternatives.

Figure 12: Alternative Technology Scenarios



Portfolios that include OSW achieve energy price and emissions reductions comparable to those that replace OSW with onshore renewables, while delivering stronger reliability outcomes and lower net capital cost. These benefits reflect OSW's ability to generate during high-risk hours, deliver energy directly into constrained regions, and high ELCC values.

Portfolios that replace OSW with additional natural gas also maintain strong reliability but result in higher energy prices, emissions, and increased stress on fuel delivery systems. Across both regions, scenarios that delay net new resource additions produce the weakest energy and reliability outcomes, highlighting risks associated with deferred investment in tight markets. Capital cost outcomes vary by region and investment level. The analysis also shows OSW delivers the greatest marginal value at low to moderate penetration levels and in systems with elevated resource adequacy risks. It shows diminishing but non-trivial benefits at higher deployments; these declines might be muted by balanced portfolio investment.

OSW provides particularly strong value in NYISO by adding generation directly into the New York City load pocket and improving reliability during emerging winter and summer stress periods. Case Study 4 shows OSW reduces reliance on backup fuel oil at dual-fuel gas units, lowering emissions, energy costs, and operational strain, with reductions continuing through approximately 5 GW of OSW and potentially increasing when paired with storage.

Table 2: ISO-NE Metric Scorecard

Metric	Base case (with OSW)	No alternatives	Renewables only	Gas only
EUE (ppm) 2032 w/ HQ Imports	0.0	0.02 (0%)	0.02 (0%)	0.0 (0%)
EUE (ppm) 2032 without HQ Imports	0.0	0.0 (0%)	0.01	0.0 (0%)
Net Capital Cost	$62.0B	$23B (-62%)	$92B (48%)	$42.0B (-32%)
Power Price	$62.0B	$68.2 (+10%)	$55.9 (-9.8%)	$67.3 (+8.5%)
Emissions	211M Tons CO2	262M Tons CO2 (+72%)	219 M Tons CO2 (+4%)	274M Tons CO2 (+77%)

Table 3: NYISO Metric Scorecard

Metric	Base case (with OSW)	No alternatives	Renewables only	Gas only
EUE (ppm) 2032	69	99 (+43%)	75 (+9%)	77 (+12%)
EUE (ppm) 2036	2.5	4.5 (+76%)	6 (+146%)	11 (+327%)
Net Capital Cost	$63.1B	$43.9B (-31%)	$77.5B (+22%)	$60.8 (-4%)
Energy Price	$67B	$72B (6.6%)	$67B (-0.3%)	$72B (6.3%)
Emissions	335M Tons CO2	424M Tons CO2 (+27%)	371 M Tons CO2 (+10%)	428M Tons CO2 (+27%)

Case study 4: Back-Up Fuel Usage in NYISO

This case study explores the impact of adopting OSW on fuel oil usage. In NYISO, dual-fuel natural gas, using back-up fuel, and oil-fired generation are dispatched when winter load is high.

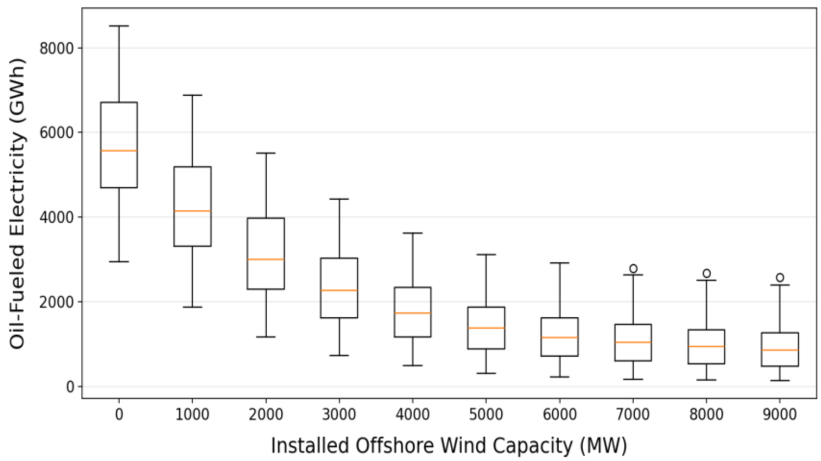
Why increased back-up, fuel oil usage creates challenges?

- Fuel oil is expensive relative to natural gas or fuel-free generation. Using it drives up energy prices
- When dual-fuel natural gas generators switch to back-up fuel, it increases maintenance strain on the generators
- Fuel oil drives up emissions

Why OSW drives down fuel oil usage?

- OSW is fuel-free, bypassing strained fuel systems
- OSW has its greatest output on the coldest days
- OSW is directly linked to the highest load, urban load pockets

Total Winter Oil-Fired Generation at Varying Level of OSW in NYISO (Study Year 2036)



Electrification drives load growth in the winter months. Without commensurate growth in fuel-free, winter generation, this load growth would drive increasing strain on dual-fuel generators and the use of back-up fuel oil.

Key takeaway: Portfolio-wide modeling is better able to capture the potential role of OSW by capturing reliability impact and portfolio interactions. Such modeling in ISO-NE and NYISO shows that OSW can reduce emissions and energy costs similar to onshore renewables while also lowering overall capital investment needs. OSW can deliver reliability benefits comparable to natural gas depending on technology sizing and portfolio composition. The most capital cost-effective pathway varies depending on broader market conditions.

- To see further discussion on portfolio-wide modeling and results, see **Paper 2**.
- To see further discussion on the detailed simulation of back-up fuel usage in NYISO, see **Paper 2, section 5.1.3**.

A path forward with shared solutions across the energy space

OSW faces development headwinds, including market and policy uncertainty, limited port and shipyard capacity, a shortage of Jones Act–compliant wind turbine installation vessels (WTIVs), permitting complexity, supply-chain constraints, and limited skilled labor. Constraints on domestic infrastructure and workforce capacity have also affected timelines and costs, particularly as projects advanced during broader supply-chain disruptions.

However, these challenges are not unique to OSW. Other infrastructure investments, particularly natural gas pipelines and generation, face similar development barriers. Targeted interventions, as summarized in Figure 13, can accelerate resource development to support grid reliability and affordability. For domestic OSW technology, investment in wider development infrastructure could drive down the domestic cost of this technology by leveraging economies of scale.

Figure 13: Shared Solutions to ease barriers to adding new generation across the energy space

Coordinated infrastructure investment	Targeted transmission, pipeline, and port upgrades directed toward the most critical regions and most constrained resources
Streamline permitting and interconnection processes	Reduce wait times, complexity, and policy reversals, enabling developers to bring new resources online faster and with fewer risks
Expand domestic manufacturing	Expand domestic manufacturing of critical components and cut supply-chain bottlenecks affecting all large-scale energy resources
Invest in skilled labor	Develop workforce and EPC capacity; emphasize transferable skills across technologies in engineering, construction, and operations
Explore alternative market designs	Continue to design markets with leading, clear, durable market signals; find new mechanisms to develop high-ELCC resources

Key takeaway: Along with a number of other technologies, OSW faces development headwinds. Target investments could help improve the speed, pace, and cost at which all energy resources and associated infrastructure can be brought onto the market.

- To see further discussion on synergies between OSW and natural gas, see **Paper 3**.
- To see further discussion on the shared headwinds and potential solutions across all generator technologies, see **Paper 3, section 8**.

Conclusion

Across the three white papers, our analysis indicates the American power system is entering a period of heightened stress. Maintaining reliability and affordability will require timely investment in new infrastructure, yet development timelines remain long while resource options are constrained by supply chain, fuel delivery, interconnection, permitting, and market uncertainty.

OSW has potential to help address reliability and affordability pressures. While not a substitute for broader infrastructure investment, OSW provides an additional pathway for delivering net new energy and capacity and brings stress-aligned characteristics. Across adequacy modeling, IRP-style portfolio analysis, and evaluations of interactions with natural gas, OSW performs strongly during emerging high-risk periods—particularly in winter-constrained regions along the Atlantic coast—and could provide locational value where onshore expansion is limited by fuel or land constraints. In these regions, the feasibility of alternative resource pathways often depends on supporting infrastructure such as natural gas fuel delivery and transmission expansion. OSW can provide reliability benefits by bypassing these constraints and expanding the total amount of resources that can be added to a system. Although this analysis emphasizes the Northeast, similar insights apply in other regions experiencing rapid demand growth, including the Dominion Virginia case study.

Across modeled scenarios, OSW consistently improved reliability outcomes, including reductions in expected unserved energy and improved performance during high-risk conditions. While reliability contributions decline at higher deployment levels, they remain positive and can enhance the effectiveness of complementary resources such as natural gas and storage.

OSW may be cost competitive in certain market conditions and can reduce overall system costs when deployed alongside complementary infrastructure, but these outcomes depend on overall system conditions. In scenarios where reserve margins can be achieved through alternative resources or OSW deployment levels are high, OSW may carry a capital cost premium, though costs may decline as domestic supply chains mature

Overall, these findings highlight the importance of evaluating OSW within integrated planning frameworks that consider system scale, infrastructure feasibility, and technology interactions. While not a universal least-cost solution, OSW represents a viable pathway for delivering net new resources that improves modeled reliability outcomes and can be cost competitive under evolving grid conditions.

Disclaimers and acknowledgements

This study was commissioned by Turn Forward. The conclusions set forth herein are based on independent research and publicly available material. The views expressed herein are the views and opinions of the authors and do not reflect or represent the views of Charles River Associates or any of the organizations with which the authors are affiliated. Any opinion expressed herein shall not amount to any form of guarantee that the authors or Charles River Associates has determined or predicted future events or circumstances and no such reliance may be inferred or implied. The authors and Charles River Associates accept no duty of care or liability of any kind whatsoever to any party, and no responsibility for damages, if any, suffered by any party as a result of decisions made, or not made, or actions taken, or not taken, based on this paper. Detailed information about Charles River Associates, a trademark of CRA International, Inc., is available at **www.crai.com**.