A Comparison of the Levelized Cost of Energy (LCOE) of Various Generation Sources

by

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December 2025

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Introduction

The Levelized Cost of Energy (LCOE) is a widely accepted metric for comparing diverse sources of generation which may vary in size, efficiency, capital and operating cost, useful life and commercial operating date. It allows an "apples to apples" comparison of the all-in cost of the output to the ultimate customer, the electric ratepayer, on a $/MWH basis among renewable and fossil generating units.

In this study, we report the LCOE as calculated and cited in various recognized and available public sources. We compare solar, wind, battery storage, nuclear, gas and coal units with respect to their LCOE with and without currently available Federal tax credits. For intermittent sources we also include the cost of achieving equivalent reliability as dispatchable base load or peaking units by showing the added cost to back up these sources through capacity payments to the grid. Finally, we report the estimated cost to interconnect each source to the grid which adds to the total LCOE borne by ratepayers. Our focus is primarily on requirements of the PJM grid and in particular the need for power in the state of New Jersey.

Results

Table 1 shows the comparison of unit characteristics and LCOE ($/MWH) values.

	Capacity (MW)	Capacity Factor (%)	Economic Life (yrs)	**LCOE With Tax Credits**	**LCOE w/o Tax Credits**	**LCOE* with Grid Backup Cost**	**LCOE** With Interconnect Cost**
Utility Solar	150	25%	35	**51**	**74**	**122**	**121**
Onshore Wind	250	42%	30	**70**	**77**	**118**	**121**
Offshore Wind	1000	42%	30	**190**	**250**	**292**	**317**
Battery Storage (4 Hour)	100	14%	10-20	**142**	**185**	**185**	**204**
Large Nuclear	2200	95%	60	**130**	**180**	**180**	**181**
Small Modular Nuclear (SMR)	300	95%	60	**100**	**140**	**140**	**141**
Gas Peaker	150	15%	20	**200**	**200**	**200**	**201**
Combined Cycle Gas (CCG)	550	90%	20	**78**	**78**	**78**	**79**
CCG with Carbon Capture	550	90%	20	**88**	**118**	**118**	**119**
Coal	600	75%	40	**122**	**122**	**122**	**123**

*LCOE w/o Tax Credits plus Grid Backup **LCOE w/o Tax Credits plus Grid Backup and Interconnect Cost

Data Sources

LCOE values are available from a wide variety of sources including the US Energy Information Administration (EIA), National Renewable Energy Laboratory (NREL), International Energy Agency (IEA) and others. However, many of these sources are out of date, not representative of US market conditions or focused solely on specific technologies.

A recognized authoritative source is Lazard's annual LCOE report which has been issued and updated each year since 2008. We have used their 2025 report[1] as the basis for most of our reported LCOE values with adjustment or supplemental information as discussed below for each generating source.

Solar

For large utility sized (150 MW) solar photovoltaic (PV) installations, Lazard reports a range of $24-57/MWH with tax credits and $38-78/MWH without credits. We have taken Lazard's reported best estimates of the LCOE for solar as shown on Table 1 above.

Distributed rooftop residential solar installations are much more expensive, and Lazard reports a range of $122-284/MWH[2] with a midpoint of $203/MWH. These values are reduced to a range of $75-228/MWH and a midpoint of $151/MWH with tax credits. Additional behind the meter subsidies are available to homeowners, but these involve non-solar customers cross-subsidizing solar customers so provide no net benefit to ratepayers in total.

Onshore Wind

Similarly, for large (250 MW) onshore wind projects, Lazard's ranges are $0-62/MWH and $27-73/MWH with and without tax credits. Table 1 reports Lazard's best estimate within these ranges for onshore wind.

Offshore Wind

For offshore wind, Lazard uses estimates from its 2021 report adjusted for normal inflation. As such, the ranges reported for 2024 ($71-$123/MWH and $74-139/MWH) do not reflect the substantial increases in cost in the US offshore wind market which have occurred over the last four years, or the value of investment tax credits (ITCs) contained in the 2022 Inflation Reduction Act (IRA).

We have therefore relied on actual prices for Offshore Renewable Energy Credits (ORECs) awarded in competitive procurements in NY and NJ in 2024. These prices ranged from $140-165/MWH with provisions to increase these base OREC values by $15% based on inflation adjustment before commercial operation. As a result, we anticipate inflation adjusted offshore wind prices will be around $190/MWH in 2025 awards pending in NY, NJ and MA.

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[1] Levelized Cost of Energy (LCOE) Report, Lazard, June 2025.

[2] Levelized Cost of Energy (LCOE) Report, Lazard, June 2024.

These OREC award prices reflect ITCs of 30-40% of capital costs. Without these credits the developer would require an additional $50-60/MWH to cover their all-in costs and realize a minimum IRR of 12%. Thus, we estimate the offshore wind LCOE without tax credits at $250/MWH or more. These values are shown in Table 1.

Battery Electric Storage Systems (BESS)

The combination of intermittent solar or wind generation with battery storage has been proposed as a potential solution to provide around the clock power equivalent to base load capacity provided by nuclear and gas generation, and that such a combination could allow grids to become fossil free as envisioned by the NJ Energy Master Plan (EMP) by 2035. An examination of the demands of the grid reveals that battery storage on that scale is technically and economically not feasible.

The total fossil fuel generation in PJM is 130,000 MW of which 10,000 MW are in NJ. These units supply more than 50% of electric demand and NJ imports over 20% of its power from PJM. To replace that much capacity and energy with renewable/battery power would require almost double the capacity being displaced because the renewables when operating must serve the load while also charging the batteries for discharge when the sun goes down or wind is not blowing. Since such periods of low renewable generation occur regularly over periods of many hours or days, the battery capacity would have to be sufficient to meet demand for periods well beyond 24 hours. No such BESS units have been developed.

Studies have shown that battery capacity on that scale would cost trillions[3] and require enormous amounts of lithium and other critical materials[4]. The supply of much of those materials is controlled by China and reliance on them for such a vital strategic use would pose unacceptable national security risks not to mention the potential for tariffs which would drive costs even higher. Disposal of that much toxic material at the end of battery life (10-20 years) would also be prohibitive.

Beyond unacceptable cost and lack of availability of critical materials, siting that much battery capacity in NJ would not be feasible. Placing such installations in densely populated locations poses unacceptable fire risks which would be difficult to insure if not uninsurable.

While reliance on battery storage is not feasible to replace all fossil plants, short duration storage capacity can be used to support grid reliability, but this is costly. Lazard indicates that a 100 MW BESS with a 4 hour capacity has an LCOE range of $124-226/MWH with tax credits and $170-296/MWH without. The midpoints of these ranges are $175/MWH and $233/MWH as shown in Table 1. Lazard also indicates that such batteries degrade in capacity at 2.9%/yr, limiting their useful economic life to less than 20 years.

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[3] The $2.5 Trillion Reason We Can't Rely on Batteries to Clean up the Grid, MIT Technical Review, July 2018.

[4] The Hard Math of Materials, Mark Mills, Manhattan Institute, January 2022.

Nuclear

The only new nuclear plant constructed in the US in recent years are the combined 2200 MW Vogtle Units 3 and 4 in Georgia. The plant experienced significant cost overruns and schedule delays before going into operation in 2023 and 2024. Lazard reports the LCOE of these units at about $180/MWH. The Vogtle units were built as regulated utility assets without the ITC, which is estimated would reduce the LCOE by $50/MWH to $130/MWH. These values are reported in Table 1.

It is expected that few if any such large conventional nuclear units will be built after Vogtle due to their high capital cost (over $30 billion) and lengthy construction schedule. Alternatively, a number of small (60-300 MW) modular (SMR) nuclear designs are being developed, and it is anticipated that several such plants may be built in the coming decade at much lower capital cost/MW and LCOE than for large nuclear units. While no actual experience is yet available, based on estimates of capital and operating costs for such plants[5], we estimate that SMRs in 2035 could be built at an LCOE of about $140/MWH, and $100/MWH with a 30% ITC, as shown in Table 1.

Natural Gas Peakers

Simple cycle gas turbines are relatively easy to build and site in order to provide power under peak demand conditions. Because their fuel costs are relatively high, they are dispatched to operate only about 15% of the time when demand and grid prices are high. This low capacity factor raises their LCOE to $200/MWH, the midpoint of the Lazard range ($149-251/MWH) as reported in Table 1. No tax credits are available for fossil fueled units. Gas combustion turbines are extremely reliable and contribute significantly to grid reliability during peak demand conditions.

Combined Cycle Gas

Combined cycle gas plants combine a gas turbine with a steam turbine operating off the exhaust gas of the gas turbine. As a result they have a high thermal efficiency and low operating cost. They are dispatched as base load or load following units and so have a high capacity factor which lowers their LCOE to $78/MWH, the midpoint of the Lazard range ($48-109/MWH) as reported in Table 1.

Combined Cycle Gas with Carbon Capture

Capturing or sequestering greenhouse gas emissions from gas fired plants has been proposed as a means of rendering them carbon free and thus qualifying for IRA tax credits. It is estimated that adding carbon capture adds $30/MWH to the LCOE for a combined cycle gas unit[6] so the LCOE is $88/MWH with tax credits and $118/MWH

[5] Meta-Analysis of Advanced Nuclear Reactor Cost Estimations, Idaho National Laboratory, July 2024.

[6] CO2 Capture from Power Plants, CCL Community, 2025

without as shown in Table 1. The latter is about 36% higher than for a comparable unit without carbon capture.

Coal

There are very few remaining coal units in the PJM system and none in NJ and it is unlikely that any new ones will be built under current climate policies. However. Lazard has estimated the average LCOE of a new 600 MW unit at $122/MWH (midpoint of $71-173/MWH range). It would operate as a base load unit with 75% capacity factor.

Grid Backup Cost

In order to compare LCOE values among generating sources with widely varying capacity factors, it is necessary to adjust these values to reflect an equivalent source capable of providing the same MW capacity 100% of the time. Thus, intermittent sources such as solar and wind must be backed up by base load or dispatchable sources to provide replacement capacity when the sun is not shining or the wind not blowing. In Lazard's report this is called the Cost of Firming Intermittency (COFI) and is reported for solar and wind in the various regional grid areas.

Lazard has computed this cost for the PJM region based on the Electric Load Carrying Capability (ELCC) assigned to each source type. The ELCC reflects the capacity credit which PJM will count on to be available during peak demand conditions. For solar and wind, the current PJM ELCC values are 8% and 42% respectively. This means that of 1000 MW of capacity, only 80 MW of solar and 420 MW of wind can be counted on to be available during peak demand conditions.

To compare the LCOE of these sources with base load units such as nuclear which are given an ELCC of 95%, Lazard computes the additional cost which must be paid to units backing up the intermittent source based on the Cost of New Entry (CONE) dispatchable resource which would be needed to serve peak load when the intermittent source is unavailable. For PJM this is the net cost (capital and operating costs less expected market revenue) for a natural gas peaking unit at $10.29/kw-month[7].

Based on this assumption, for wind and solar, the COFI is $48/MWH for solar and $42/MWH for wind which as shown on Table 1 are added to the base LCOE for solar and wind units. No such cost is required by the fossil and nuclear units which are base loaded or dispatchable and thus available for peak demand.

As discussed above battery storage is not a viable solution as a grid backup supply as battery capacity capable of 24 hours or more backup would be prohibitively expensive.

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[7] $$\text{COFI} = \frac{\text{Nameplate Capacity (kw) x (1-ELCC *\%)) x Net CONE (\$/kw-month) x 12 months}}{\text{Nameplate Rating (MW) x Regional Capacity Factor (\%) x 8760 Hours}}$$

Interconnection Costs

An added cost which must be considered in comparing LCOEs for generating sources is the cost to interconnect those sources to the regional grid. This varies greatly based on technical requirements and siting considerations. Solar and land-based wind require relatively remote locations which may or may not have access to transmission corridors. Gas peakers can be installed at many existing generating or industrial sites while larger gas, nuclear or coal units could be placed at former generating sites with existing transmission capacity.

In January 2023 Berkeley Lab published a study[8] which estimated the cost of interconnecting various generating sources based on actual experience in the PJM region. The study estimated costs of $24/kw for natural gas units, $253/kw for solar. $136/kw for onshore wind and $335/kw for battery storage. Based on assumed cost recovery in rates and unit capacity factors, these values are the equivalent of $1/MWH for gas and nuclear, $9/MWH for solar, $3/MWH for onshore wind and $19/MWH for battery storage.

Offshore wind entails a unique and unprecedented interconnection challenge, requiring transmission through high voltage undersea cables from 10-40 miles offshore, to landfall locations to onshore substations and converters, then through new or upgraded transmission corridors to load centers far removed from the coast. Studies of interconnection costs for offshore wind in NJ[9] and NY[10] have estimated the cost at $1300/kw which translates into $25/MWH. These added costs are shown on Table 1 above.

Conclusions

The foregoing analysis indicates a wide range of costs among alternatives for supplying power to the PJM grid in New Jersey. Load forecasts in PJM indicate increasing demand for data centers which require continuous supply. The challenge will be to increase base load and peaking capacity to ensure this new load is served reliably at affordable rates to these new customers and the existing ratepayers.

While intermittent sources involving solar and onshore wind appear to have relatively low LCOEs, even with backup and transmission costs included, there are few sites available for large scale solar or wind facilities in the state.

Combined cycle and peaking gas plants are a proven and affordable resource for meeting future demand but conflict with the existing NJ Energy Master Plan (EMP) which calls for phase out of all existing fossil generation by 2035 and would prohibit construction of new gas units.

[8] Interconnection Cost Analysis in the PJM territory, Berkeley Lab, January 2023.

[9] NJ State Agreement Approach for Offshore Wind Transmission: evaluation Report, Bratelle Group, October 2023.

[10] NYISO MMU Evaluation of the Long Island Offshore Wind Export PPTP Report, Potomac Economics, May 2023.

The current policy relies heavily on offshore wind for meeting this goal but, as indicated, the LCOE of this source is far and away the highest and, in any case requires back up by other reliable base load and peak demand resources.

Another source of uncertainty for renewables is the potential for repeal of the IRA tax credits which are relied on to limit rate subsidies for wind and solar facilities. The incoming Trump administration has pledged to roll back those credits, particularly for offshore wind. Such as action, if achieved, would render the rate required to proceed with such projects unaffordable.

That leaves only nuclear power as the only realistic solution to increasing reliable supply while providing carbon free energy. However, its cost remains relatively high and its deployment involves uncertainty with respect to ability to meet demand growth in a timely manner. Small modular reactor (SMR) plants have the potential to lower these costs and shorten construction schedules. By 2035 it is expected that one or more demonstration plants will have been built and a domestic supply chain established that will provide confidence that such units could be deployed in NJ to provide affordable carbon free electricity.

The only conclusion that can be reached is that the entire EMP policy of relying on offshore wind and battery storage to achieve zero carbon electricity by 2035 must be reevaluated. It is neither affordable, nor achievable. Continued reliance must be placed on low carbon natural gas while we seek to bring nuclear plant costs down.

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The Author

Edward P. O'Donnell is a principal in Whitestrand Consulting LLC. He has spent 35 years in the nuclear power industry as an engineer, manager and executive with responsibilities for design and licensing of numerous plants in the US and abroad. He was also responsible for corporate planning and rate matters for a NJ nuclear utility and has testified in utility rate proceedings before the NJ BPU.

He was responsible for managing the successful sale of nuclear units in NJ and PA and as a consultant for advising clients on the sale and purchase of nuclear plants. In this role he forecasted future costs and performance of plants for re-financing as merchant power suppliers in a de-regulated electrical energy market and performed analyses of the economic viability of nuclear plants in comparison with alternative fossil and renewable energy facilities.

Mr. O'Donnell holds an M.S. in Nuclear Engineering from Columbia University and has been a licensed Professional Engineer in NJ. He is also a registered Enrolled Agent, authorized to represent individual and business entities before the IRS on tax matters.