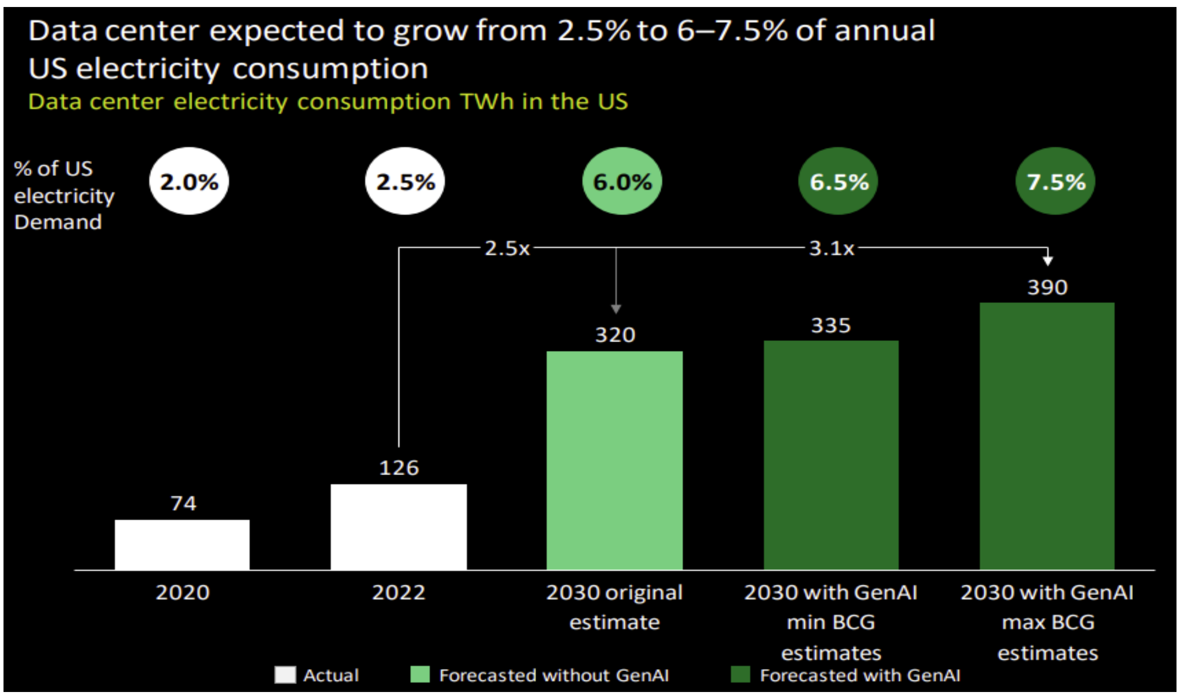
The True Cost of Renewable Energy

May 2024

Executive Summary

The United States is experiencing an unprecedented increase in the construction of new Artificial Intelligence (AI) driven data centers that will have a considerable amount of associated electricity demand[1]. Many of the clients and developers of these new data centers are insisting that the electricity for these facilities be supplied by “green” or renewable power generation[2].



When this new AI driven electricity demand attempts to only utilize renewable generation, it will face significant challenges such as:

1. **Renewable Generation Intermittency and Demand Load Factor**

   a) Nameplate ≠ Output: Power generation nameplate capacity is the maximum electricity output of a generation asset at a theoretical point in time. With renewable generation there can be a significant difference on an hourly and daily basis between nameplate capacity and electricity generated.

b) P-95 Demand Load Factor vs P-50 Renewable Generation: P-95 is defined as the probability of an event occurring ninety five percent of the time; data centers need reliable electricity at the P-95 levels to be able to meet their forecasted operations. Renewable generation is historically forecasted to only generate electricity at a P-50 level (50% of the time) over an average 24 hour period which means there will need to be significant additional back-up generation or battery storage capacity to meet the daily demand of the data center.

c) Wind + Solar output: The two most common sources of renewable generation are wind and solar. These types of generation utilize wind and sun as their energy sources and do not have the ability to directly offset each other's output in a meaningful way that increases their overall dispatchable electricity generation capacity.

2. **Additional Power Assets**

   a) Load Balancing: To address renewable generation output intermittency, data centers will need additional generation capacity and/or electricity storage. One option could involve having to build more wind and solar facilities, coupled with battery storage.

   b) Peaking Generation Power Plants: When focused solely on capital efficiency, the addition of natural gas peaking plants to a renewable generation asset mix would be the logical choice to make when the objective is to meet 100 % of a data center's daily power demand. These type of peaking plants are fully dispatchable and can quickly ramp up and down their electricity output to meet fluctuating demand. These assets will also have additional emissions associated with them.

   c) Additional Costs: Capital costs and operating costs associated with the potential combination of additional renewable generation, battery storage, and peaking generation plants will substantially increase the overall cost of power for data centers.

3. **Additional Cost Considerations**

   a) Carbon Emissions: With delivered "green" electricity supply as the ultimate goal, renewable generation assets will need incremental peaking generation and the associated carbon allowances.

b) Transmission Upgrades: Integrating large-scale renewable sources often requires significant upgrades to the existing transmission grid to handle the incremental distances necessary to get the additional electricity from renewable generation facilities to the data centers.

Renewable Generation Intermittency and Demand Load Factor

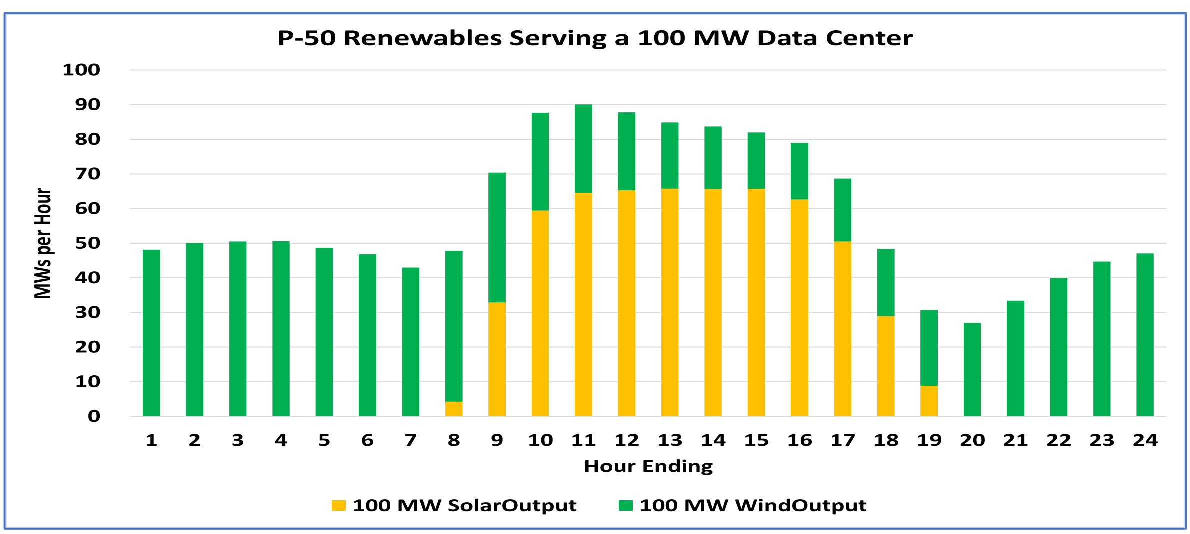
Nameplate ≠ Output

Traditional fossil fuel generation plants are designed and constructed to generate electricity at or near their nameplate capacity except during times of repairs or scheduled maintenance. However, renewable generation is quite different due to factors such as physical location, time of day, and weather patterns that include but are not limited to changing winds and/or cloud cover. Because of these variables and their impact on renewable generation energy sources, renewable generation assets are not able to perform at nameplate capacity for sustained periods of time.

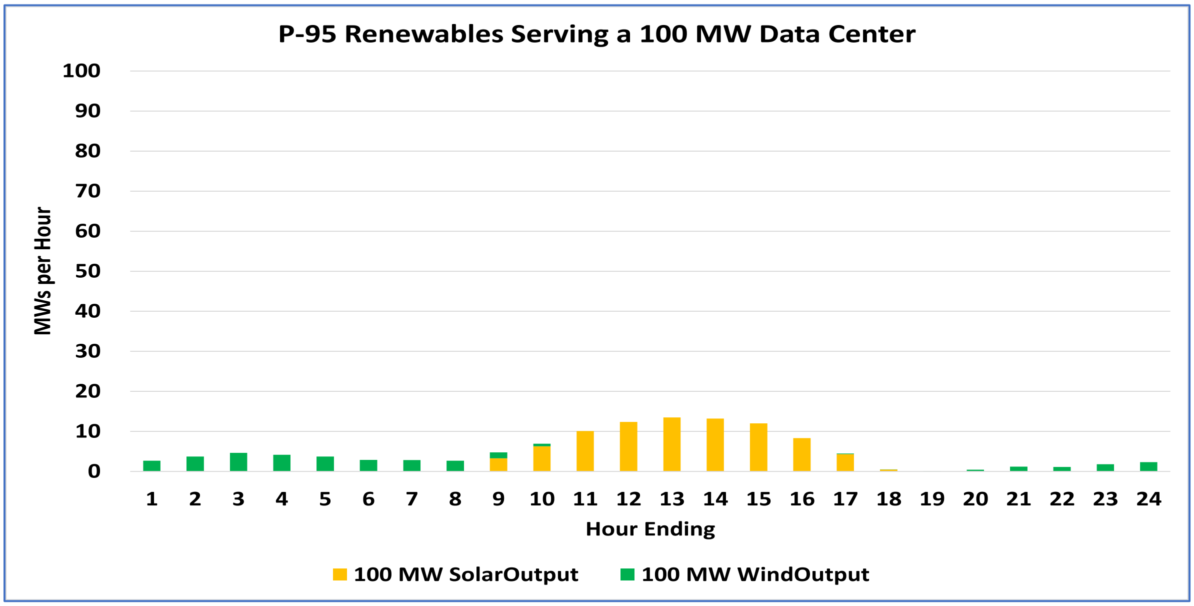
P95 Demand Load Factor vs P50 Renewable Generation

Renewable energy developers conduct detailed location analysis with wind studies that generate data on wind intensity, duration, and intermittency, and solar studies that provide average daily sun hours, radiance, and optimal sun angle.

The collected data is input into a P-value probability based model to determine the expected electricity output of a specific or a combined group of renewable generation assets. With these calculations, asset developers can determine how much electricity can be expected on an average 24 hour period from a specific or a combined group of renewable generation assets 50% of the time (P-50) or 95% of the time (P-95). In this model a higher P-factor number means the asset(s) will generate a lower amount of actual electricity when compared to nameplate capacity. The inverse is true with a lower P-factor number meaning the asset(s) generate a higher amount of electricity when compared to nameplate capacity.



The True Cost of Renewable Energy



These P-50 and P-95 charts use actual historical data from a 100 MW wind facility and a 100 MW solar farm in Texas. On a P-50 basis, the 24 hour average combined output from the 100 MW wind facility and the 100 MW solar facility (200 MW total capacity) does not meet the continuous 24 hour demand of a 100 MW data center. On a P-95 basis, the combined average 24 hour period of expected electricity generated is calculated to be a maximum 25 MWs compared to the 100 MW demand of the data center.

Additional Power Assets

Load Balancing

To address renewable generation's inability to produce nameplate capacity continuously during an average 24 hour period, batteries are normally added to the generation mix. Commercial-scale industrial sized batteries are typically constructed in 100 MW "blocks" and are capable of producing up to 100 MWs of electricity for a four hour consecutive time period at full charge.

Below is a graph illustrating the amount of electricity that a 100 MW capacity wind farm, a 100 MW capacity solar farm, and a 100 MW 4-hour battery combined would generate on a P-50 basis for a 24 hour period compared to a 100 MW demand data center.

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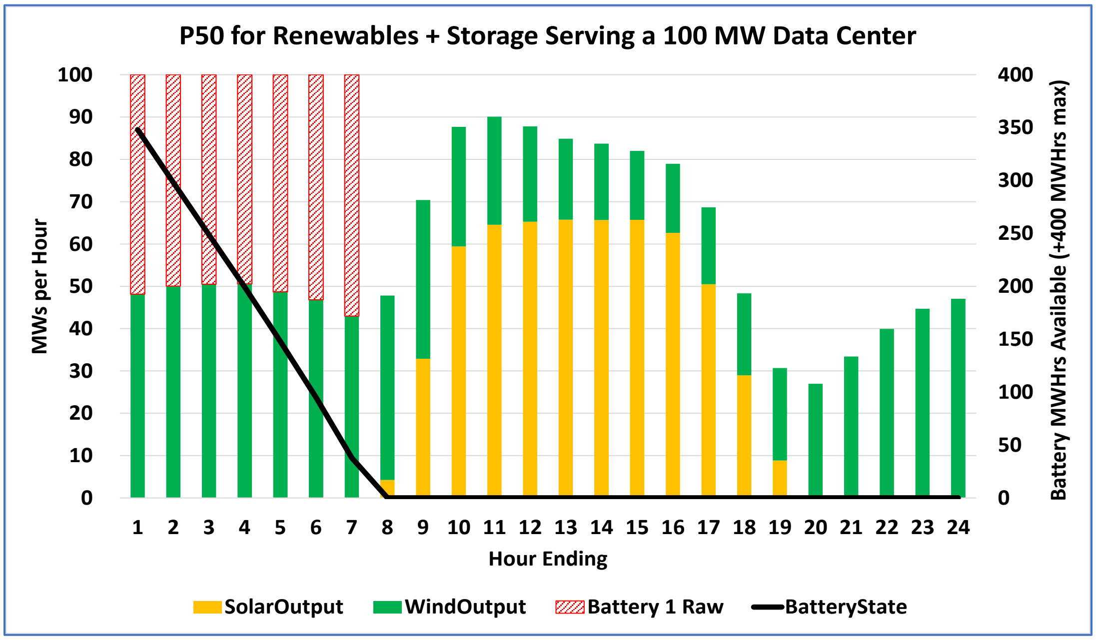
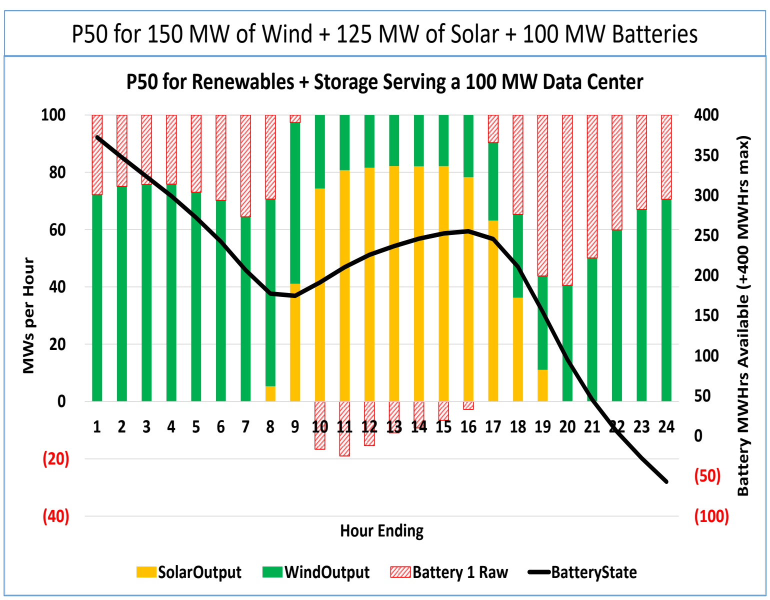
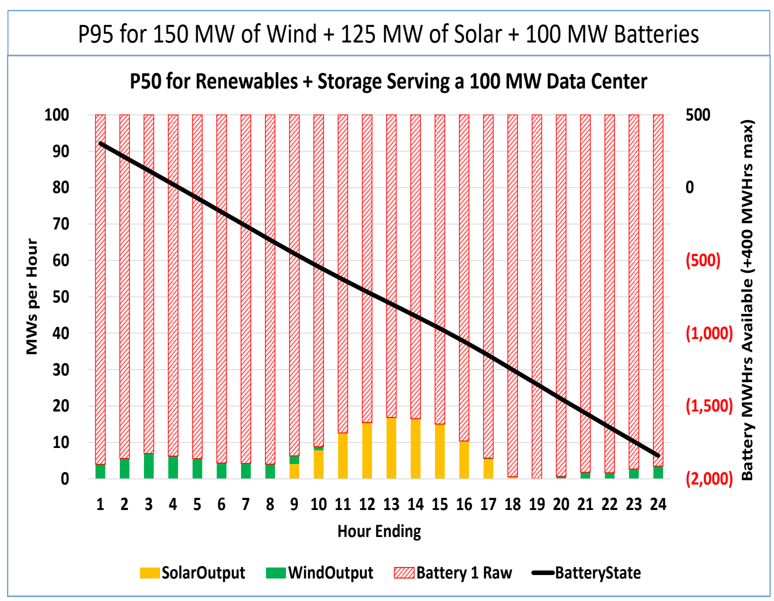


To fully cover the daily electricity demand of a 100 MW data center on a P-50 basis, the optimal generation mix would be 150 MW wind, 125 MW solar, and a 100 MW 4-hour battery. This combination is modeled to work on a P-50 basis and would be insufficient on a P-95 basis for an average 24 hour period to meet the demand of a 100 MW data center.





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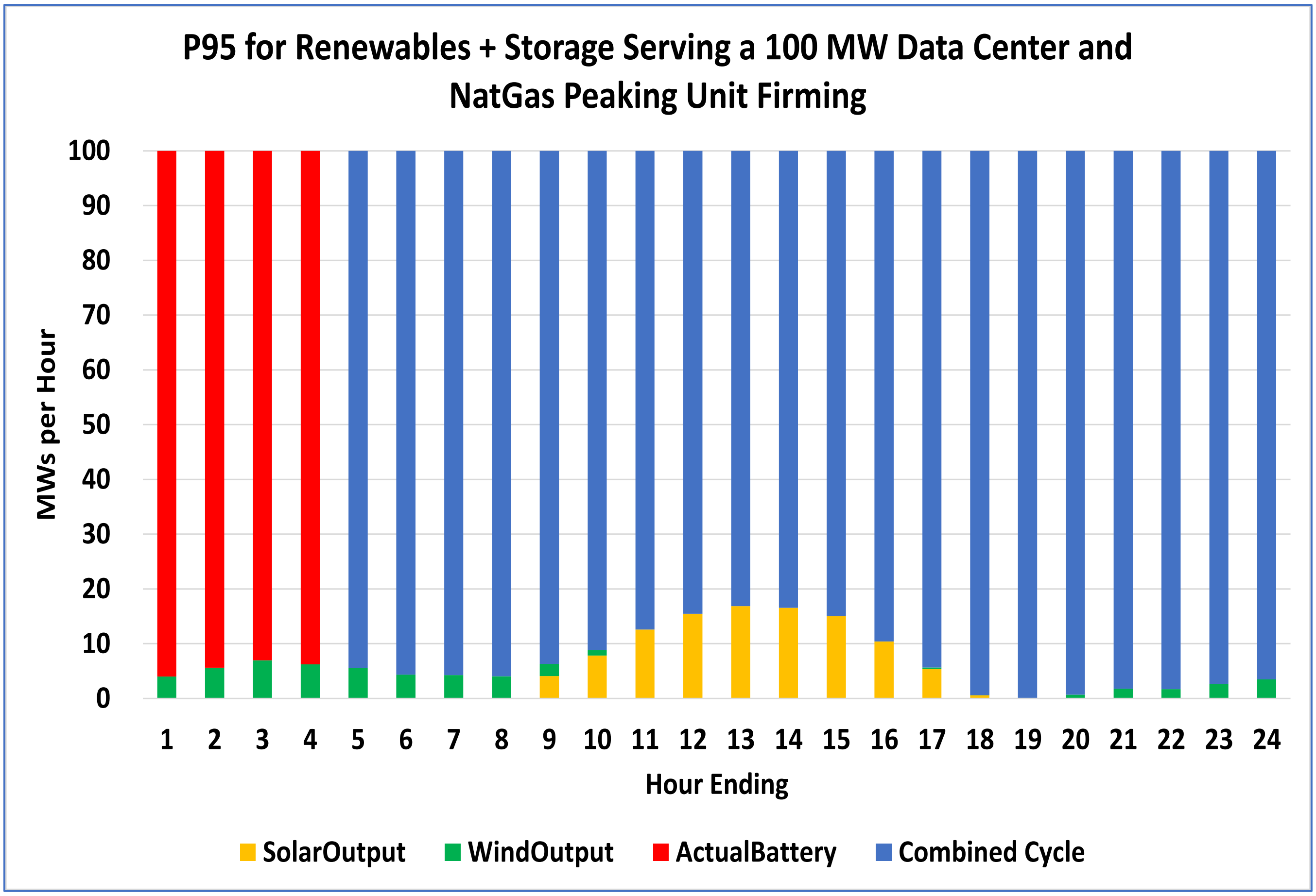
Peaking Generation Power Plants

The most capital efficient way to reliably serve the continuous demand of a 100 MW data center utilizing the optimum amount of renewable generation for an average 24 hour day would be to add an additional source of dispatchable electricity to the power generation mix. Currently technology presents two options; 1) a battery farm, or 2) a natural gas peaking generation unit (“peaker”).



Additional Costs

To serve a 100 MW data center with P-95 reliability requires a 100 MW peaking plant be added to the generation mix to provide 100 % reliable back up renewable generation and batteries. Peaking generation costs are driven mainly by the initial capital expenditure and annual operating expenses.[3] The all-in costs associated with 100 MW peaking generation is more economical and reliable than additional battery packs are for the same amount type of electricity capacity.

The True Cost of Renewable Energy

To supply a 100 MW data center with green electricity, there would need to be incremental renewable generation capacity and back up battery facilities added to an existing 100 MW renewable generation asset to be able to reliably supply the data center on a continuous daily basis. These renewable asset additions would increase the cost of supplied electricity by as much as 2 to 3 times the cost of supplied electricity from stand-alone fossil-fuel generation.

FIRMING COST COMPARISON OF NATURAL GAS PEAKER vs 4-HR BATTERY

Feature	4-Hour Batteries	Natual Gas Peaking Units
CapEx	$1,000 - $2,000 per kW	$500 - $1,000 per kW
OpEx Estimated Annual Cost (Leveli	$1.25/MWHr	$5.00/MWHr
Fuel Costs (Charging Costs)	$61 per MWHr	$30 per MWHr
Estimated Annual Cost (Levelized)	$175 - $250 per MWHr	$60 - $150 per MWHr

Sources: BNEF; Lazard; EIA

Additional Cost Considerations:

Carbon Emissions

To generate "green" power and meet the continuous daily demand of a data center, renewable generation assets will need natural gas peaking generation. It will be necessary for natural gas fired generators to have carbon allowances to offset their CO2 emissions. With the forecasted demand of carbon allowances expected to increase dramatically over time, the costs of these allowances are estimated to be as much as $185 per ton. This is considerably higher than the today's market price range of $20 - $40 per ton[4]. This forecasted increase in demand and price is being driven by various state and federal emission mandates. This potential increased carbon allowance cost could add an incremental $20.00 per MWh to the generated electricity price[5].

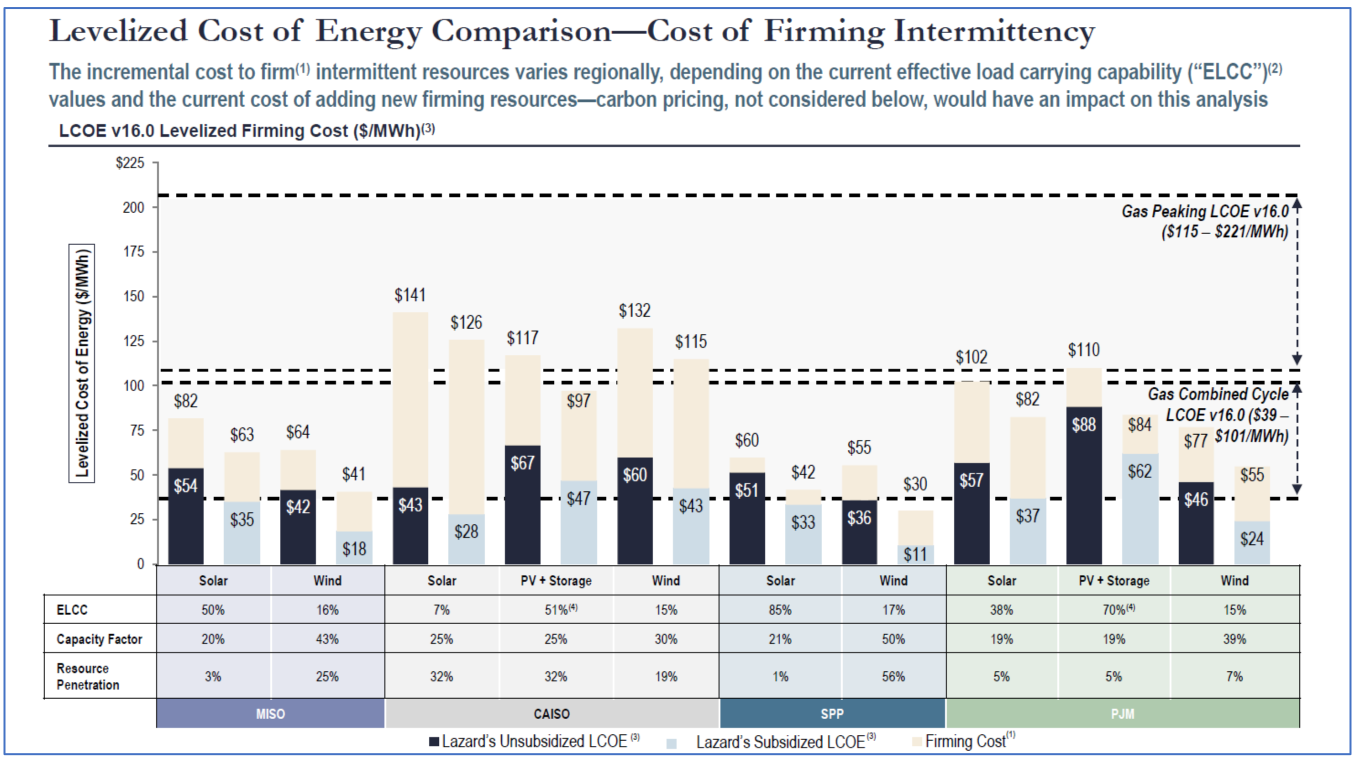
Transmission Upgrades:

Transmission upgrades will be needed 1) to deliver electricity from renewable generation that is located a significant distance from the new AI data centers, and 2) to transport the peak electricity from the considerable amount of incremental renewable generation capacity that will be needed to produce enough carbon-free electricity during an average 24 hour period to meet the forecasted load[6]. This incremental generation capacity will need additional transmission capacity to meet the high load factor demand of the data centers. The costs for this type of incremental transmission are being forecasted to increase the costs of delivered electricity by as much as an incremental $12 to $20 per MWh[7].

The True Cost of Renewable Energy

<u>The "True Cost" of Renewable Electricity</u>

If natural peaking generation units are used to assist renewable generation to reliably meet demand center load requirements the overall costs of delivered green electricity will increase. Today renewable electricity generators have not had to be concerned about back up electricity or capacity and the associated costs to supply these new demand centers, but these market conditions will change quickly as a considerable amount of fossil fuel generation capacity is being retired in the near future and wholesale commercial battery electricity storage is not yet viable. Without a significant change to the current regulatory scheme, there will be a market based reconciliation of the incremental costs to the power grid from this new data center demand, and that is before taking into consideration of the new incremental demand has a publicly stated goal of being supplied 100% with green electricity.



[1] Boston Consulting Group "The Impact of GenAI on Electricity" https://media.licdn.com/dms/document/media/D561FAQFrYAXZXiTYbQ/feedshare-document-pdf-analyzed/0/1712748521797?e=1714608000&v=beta&t=oxsHZdRonPkSB-22r63obdJa_yR5NKSwH2IdtXfnKFU

[2] WSJ "AI's Power-Guzzling Habits Drive Search for Alternative Energy Sources" https://www.wsj.com/articles/ais-power-guzzling-habits-drive-search-for-alternative-energy-sources-5987a33a

[3] Lazard "Levelized Cost of Energy" https://www.lazard.com/research-insights/2023-levelized-cost-of-energyplus/

[4] Social Cost of Carbon More Than Triple the Current Federal Estimate - https://www.rff.org/news/press-releases/social-cost-of-carbon-more-than-triple-the-current-federal-estimate-new-study-finds/#:~:text=A%20multi%2Dyear%20study%20of,estimate%20of%20%2451%20per%20ton.

[5] BNEF "Carbon Price To Triple by 2035 As Supply Wanes" EU Carbon Price to Triple to €194 by 2035 as Supply Wanes | BloombergNEF (bnef.com)

[6] UtilityDive "Reserve Margins May Need To Rise To 300% by 2040 As More Renewables Added to Grid: ISO New England" Reserve margin may need to rise to 300% by 2040 as more renewables added to grid: ISO New England | Utility Dive

[7] BNEF "New US Power Lines Cost $2.7mm per Kilometer" https://www.bnef.com/shorts/sc557adwrgg000