WHITE PAPER / **FIRMING SOLAR GENERATION WITH NATURAL GAS**

EXPLORING ANOTHER VIABLE WAY TO FIRM RENEWABLE GENERATION

BY Adam Bernardi

As the nation's power generation mix continues its transformation away from coal and toward solar and other renewable sources, the need for fast-acting resources that can be dispatched quickly to firm renewable production is growing. While battery storage is often considered first, historically low natural gas prices could make gas-powered assets another viable alternative.

As solar and wind expand across the country and coal generation declines, one of the biggest challenges facing electric grid operators is accurately explained by the duck curve made famous by the large renewable build-out in California over the past decade.

Named for its resemblance to the waterfowl's profile, the duck curve illustrates the imbalance between peak energy demand and renewable energy production. It occurs because solar power floods the market when the sun is shining and demand trends lower (forming the belly of the duck), before dropping off at nightfall when electricity demand peaks (illustrated by the duck's head). Therefore, a grid operator's challenge is finding a way to fill in the gaps with dispatchable resources.

The duck curve also demonstrates why solar power must be "firmed," that is, supported by reliable energy sources that can be dispatched quickly to deliver power on demand. These dispatchable sources are typically needed during peak demand hours each day, as well as larger, multiday and seasonal gaps created by sustained low-sun conditions. They can also be required on a moment's notice when the wind stops blowing or a cloud appears overhead. The rolling brownouts and blackouts California experiences periodically highlight what can happen in extreme circumstances when there are not enough dispatchable resources available and grid operators have to reduce or restrict electrical power temporarily.

For example, a review of Midcontinent Independent System Operator (MISO) data on demand and renewable generation in select spring, summer and winter periods over a recent 18-month period found that the duck curve is greatest in the summer, when demand is 50% higher than cooler shoulder months. Winter averages produced a flatter demand curve.

In addition to considering seasonal differences, the MISO analysis drilled down to review daily and hourly demand fluctuations. Over an average 24-hour period in the summer, the duck curve reemerged, with peak demand rising and falling in the morning hours before rising again and peaking in evening hours. One way to address this issue is to size renewable generation to meet demand based on historical summer data and live with the resulting overgeneration in shoulder months. Dispatchable resources would then be sized to fill shortfalls on cloudy days and during peak demand. This approach creates opportunity for energy storage of any overgeneration that occurs in shoulder months. It is a potential win-win for both gas and storage resources.

Looking back at history, we used to have a lot of baseload resources, with a little bit of gas on tap with a fairly predictable demand curve. but as we've continued to add renewables we've created a duck curve.

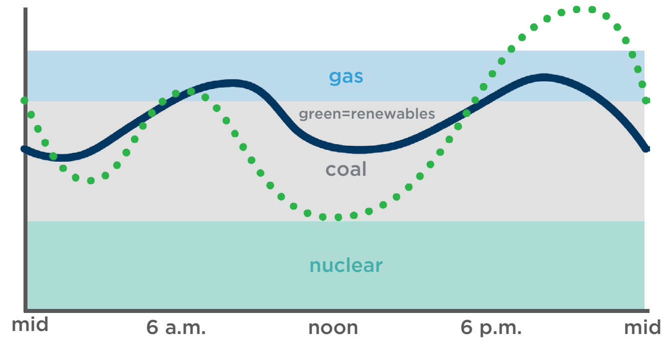

FIGURE 1: *The duck curve illustrates the difference between energy production before (the blue line) after renewable source (dotted green line) were added. This curve, first observed following the the large renewable energy build-out in California, demonstrates the necessity of "firming" renewable power with reliable, dispatchable energy sources.*

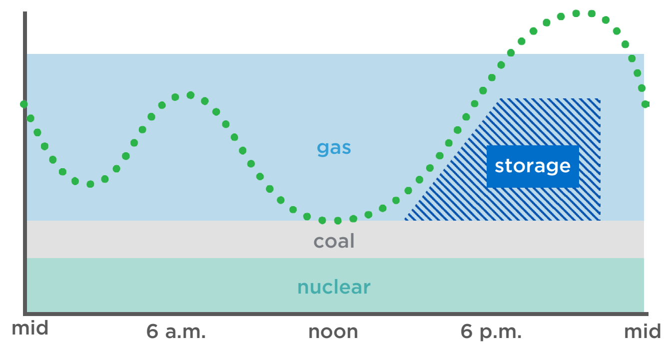

FIGURE 2: *As we add more solar and retire coal, the generation mix we have will have to change. This chart illustrates the need for more dispatchable resources and how batteries and natural gas fit into the picture.*

HYBRID POWER PLANT ALTERNATIVES

Many developers and utilities are beginning to evaluate hybrid power plants that pair renewable power with dispatchable sources. The firming source of choice in many cases has been battery storage. With this approach, large batteries store excess solar production or power purchased from the grid, which can then be discharged during peak periods.

But batteries may not be the right solution in all locations or situations. For one thing, batteries have a short duration capacity, typically four hours at the most. While that is sufficient to fill a supply shortfall during peak evening hours, it is of less help over days, weeks and seasons that experience less sunshine.

The economic feasibility of batteries also tends to be granular, fluctuating on a daily or hourly basis, rather than monthly. That can make them a reasonable option when the right arbitrage opportunities exist. But desirable arbitrage opportunities — where the spread between the rate paid to purchase electricity from the grid for storage is significantly lower than the peak rate collected when the battery is discharged — can be limited and unpredictable. Arbitrage also requires that a battery be charged and ready to take advantage of any opportunity the market presents. In addition, the ancillary services market for battery storage is still developing and evolving, and international trade status can affect battery pricing in unpredictable ways.

SOLAR-PLUS-GAS ALTERNATIVES

Increased solar penetration has created a need for a fixed power resource that is available 24/7 and can be dispatched quickly. Hybrid operations that firm solar with natural gas turbines or reciprocating internal combustion engines (RICE) — with or without batteries — meet these requirements. Solar-plus-gas also offers multiple benefits.

First, natural gas can be more economically feasible than batteries, especially in today's market of depressed gas prices. As with battery project opportunities, this economic feasibility depends largely on project location. Rather than rely on arbitrage, operators can hedge their exposure to price volatility by buying natural gas futures contracts, locking in revenues by hedging the power produced forward at a known price. The ancillary services market for natural gas is also well-developed.

While there are no investment tax credits (ITCs) for natural gas-fired projects, ITCs are becoming less impactful for renewable projects as the ITC continues to step down. Battery storage projects only qualify for ITCs if they are charged by solar power, and commercial hedging structures for batteries are in their infancy.

The pairing of natural gas with solar can be accomplished in multiple ways. One option is to repower current low-capacity or soon-to-be-retired coal-fired power plants with natural gas. This could involve reusing the existing electrical interconnection facilities or modifying an existing power plant to incorporate the new project through utilization of existing equipment. This approach could also have the benefit of further delaying remediation expenses; however, this would need to be evaluated on a project-specific basis.

Another alternative is greenfield development, where new or existing solar is paired with simple-cycle turbines or RICE. In fact, solar plus a simple-cycle gas plant may produce results similar to a large combined-cycle plant in certain regions of the country.

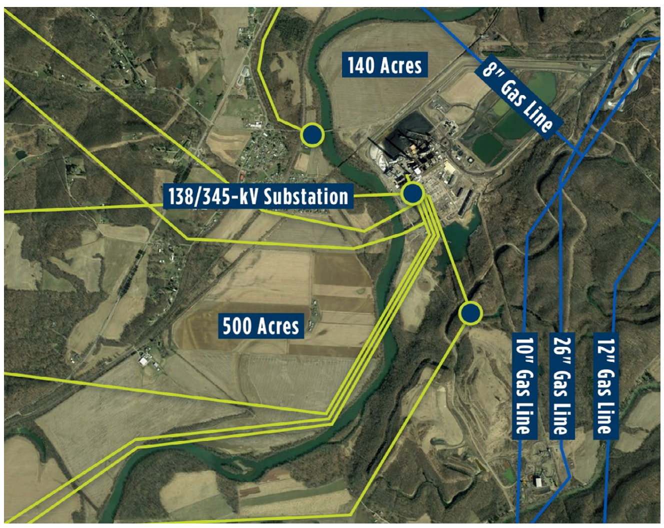

FIGURE 3: *Retired coal assets located near flat land and with access to gas lines often -- but not always -- are good candidates for repowering opportunities.*

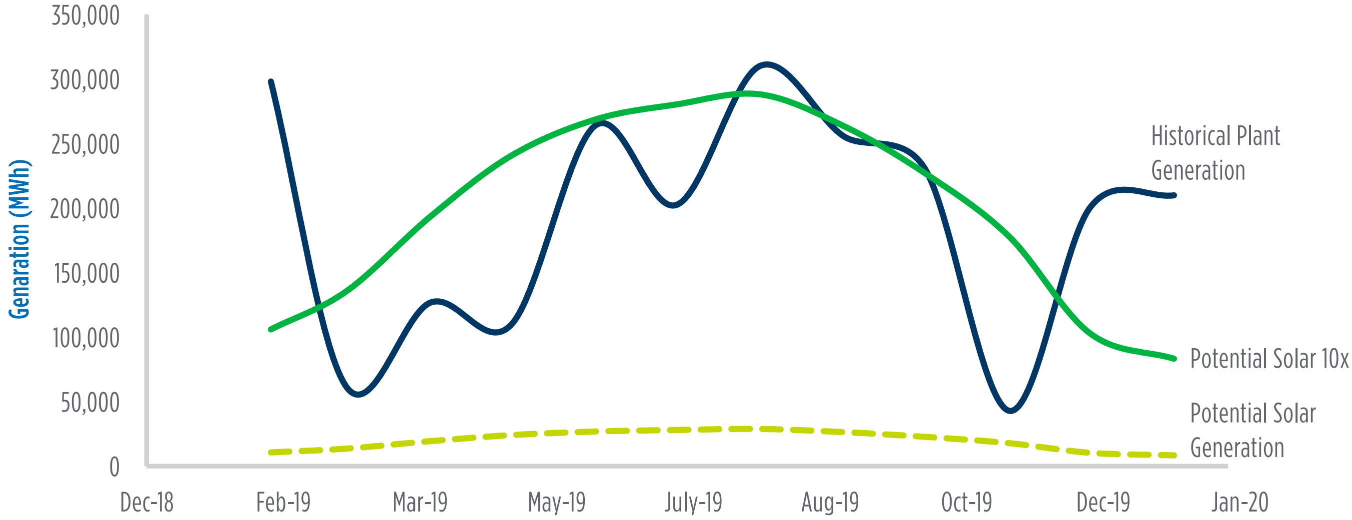

FIGURE 4: *Analysis of a retired 1,300-MW coal-fired power plant on a site capable of hosting 150 MW of solar power found that solar production would need to be increased tenfold to recover the peak generation from the plant's existing units. While solar can be used to target lower levels of baseload megawatts, it cannot alone replace peak generation of low-capacity generation.*

Many factors should be considered when choosing these alternatives, often relating to the potential project's location. Because natural gas is needed to operate turbines or RICE, for example, proximity to gas pipelines is key. Ready access to the transmission needed to move power from the generating site is another important consideration.

If a developer or utility wishes to repower a low-capacity or soon-to-be-retired asset, interconnection agreement status can affect the site selection decision. Whether repowering a coal-fired asset or converting an industrial site, planning should take into account the process used to bring back a lower-capacity asset at that location.

LOCATION MATTERS

Even a potential hybrid plant site that appears to check off all the important boxes may not deliver the anticipated results.

Consider, for example, the potential repowering of a six-unit, 1,300-MW coal-fired plant that sits adjacent to a flat, 600-acre site capable of hosting 150 MW of solar power. In this case, some units were already retired while others were running at lower-than-average capacity factors. Nearby gas lines could be used to power the plant following its gas conversion or to fuel the addition of a gas-fired asset.

Analysis showed that solar production at that particular site would need to be increased tenfold to recover the peak generation from the existing units. However, during shoulder months, the additional solar build-out would likely prove uneconomical, given that the hypothetical solar generation would exceed that of the historical plant.

The "lumpiness" of the historical plant generation indicates a need for production that varies greatly throughout the year, pointing to the opportunity for a dispatchable resource. The conclusion:

- Solar alone cannot replace peak generation of low-capacity generation, but it can be utilized to target lower levels of baseload megawatts.
- A solar-plus-gas combination provides a unique way to replace megawatts on the margin with those generated from solar, while still preserving the opportunity for a dispatchable peaking resource.

In today's world of hybrid power plants, most developers would first consider solar-plus-storage, rather than the solar-plus-gas combination. Given that battery economics can be driven by arbitrage opportunities, the research team therefore considered the economics of adding a 100-MW, 400-MWh battery installation to the same repower scenario.

For the purposes of this evaluation, the battery was assessed as a stand-alone asset and assumed to be AC-coupled (i.e., charged by the grid). Arbitrage at the project location was also evaluated based on historical energy pricing. On average, the spread between charging and discharging was found to be a little less than $26 per MWh.

Assuming an average spread at one cycle per day over 20 years with capacity payments between $1.00 and $3.00 per kW-month and an initial capital cost of $250 per kWh, the battery project is unable to clear almost all investment committee rate hurdles. And that is before operations and maintenance expense or the cost of augmentation are considered.

THE RISK OF OVERVALUING RENEWABLE CAPACITY

As renewable penetration increases, each new renewable deployment creates a false sense of security regarding the installed generation's capacity relative to the load that needs to be served. That is because current procedures for accrediting new installations and calculating capacity — the amount of generating capacity that a power resource can contribute — do not consider existing renewable penetration.

This false sense of security is what can lead to the real-life development of the duck curve. When renewable generation continues to be added to a given geographic area, capacity is not added as it might be contemplated. That is because the added renewable generation has the exact same profile as the resources that came before it. The result is oversaturation of generation when the sun shines the brightest and a large gap that has to be filled as the sun sets.

As a 2019 study conducted by Southwest Power Pool (SPP) illustrates, the question of whether ISOs should value solar capacity differently appears to be a good one. The study, which involved a review of solar data and SPP's effective load carrying capacity (ELCC) accreditation criteria, confirmed that as the total capacity available from solar resources increases with penetration, the accredited percentage of nameplate capacity of each individual resource decreases. If SPP continues to use its planning criteria for the accreditation of solar capacity, it will most certainty result in overvaluing solar's accredited capacity.

A 2019 ELCC review conducted by PJM Interconnection considered its procedure for calculating solar capacity credits. This ISO, too, found that its current 38% solar capacity credit is too high in some circumstances. This could signal PJM's plan to look at restructuring the credit curve and lowering the capacity credits issued as more solar generation is brought online.

These studies tend to raise more questions than answers. One question not yet discussed — especially in markets where energy margins are depressed and future renewable capacity payments could decrease — is whether this opens the window for peaking gas-fired assets to make a significant comeback. More important, does the correction to the ELCC in most markets help to build a case for solar-plus-gas?

The resulting conclusion showed that location matters. Solar-plus-storage is not always a default answer. This example demonstrates that repurposing an existing asset with solar-plus-gas can make economic sense. While other combinations of solar-plus-storage prove effective, solar-plus-gas can also work at this specific site.

The lesson is simple: As the renewable build-out continues — and that includes wind along with solar — each potential site should be evaluated on its own merits. A dispatchable power source that can firm renewable production needs to be part of that equation. Dispatchable power can become an increasingly valuable asset as the rest of the industry continues to pile on renewables.

RETHINKING THE POWER PLANNING PROCESS

As the solar build-out continues, developers will be wise to take a more holistic approach to long-term planning. Focus now may be on adding new solar resources to take advantage of remaining ITC opportunities, or to position for the potential Moving Forward Act from the U.S. Congress. But given the potential changes to the value of solar capacity, it is also necessary to plan now for the addition of dispatchable resources to fill in the opportunities created, or left behind, by intermittent renewable resources.

And the clock is ticking.

BIOGRAPHY

ADAM BERNARDI is a business development manager with nearly 15 years of experience in the power generation industry. He supports utilities and developers in the upfront development of renewable energy projects, from siting and commercialization strategies all the way through startup and commissioning.

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