CRA Insights:
Energy
CRA Charles River Associates

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Utility resource implications for a 100% clean energy future

Background

Several states and utilities in the US have announced goals for a 100% carbon-free generation mix over the next two to three decades. The announcements provide broad guidance, but a utility's ability to meet such targets will be influenced by its individual load shape, the available technology options, and the market and regulatory environment in which the utility operates. In this paper, we present a case study that addresses resource planning considerations associated with a potential carbon-free future.

Planning considerations for utilities

Electric utilities in the US are far from homogenous, operating with differing load profiles, under different regulatory constructs, and in different market regions. All resource planning considerations, especially potentially transformational efforts related to deep de-carbonization, are expected to be highly dependent on the following factors:

- The utility's **load shape** may impact technology choice and the need and efficacy of renewables and storage. Electrification may increase the need for resources that are reliable during winter peaks.
- Access to an **open electricity market for energy and capacity** will drive considerations around plan feasibility and potential risks.
- **State and local regulators** will influence the timing of potential resource changes, eligible technologies, and how accounting of renewable or clean energy will be performed.[1]
- The utility's **individual strategy** will govern its pace of transition relative to the market, its appetite for market risk, and other considerations regarding future investment.

[1] For example, utilities operating in California, are expected to demonstrate compliance with the 2030 renewable energy mandate through an hourly emissions accounting methodology called Clean Net Short, which tracks the utility's resource mix versus its native load in every hour.

Intermittent renewables such as wind and solar have been contributing to reductions in carbon emissions in the US power sector over the last several years. It is expected that these technologies will continue to be the primary contributors to increasing de-carbonization efforts. However, as renewable penetration increases, battery storage resources will likely play an important enabling role by facilitating the alignment of renewable supply with hourly energy demand. Over the long term, longer duration and seasonal storage may also be necessary, and it is likely that a combination of complementary technologies will be necessary to integrate greater amounts of intermittent generation.

Evaluating your resource strategy

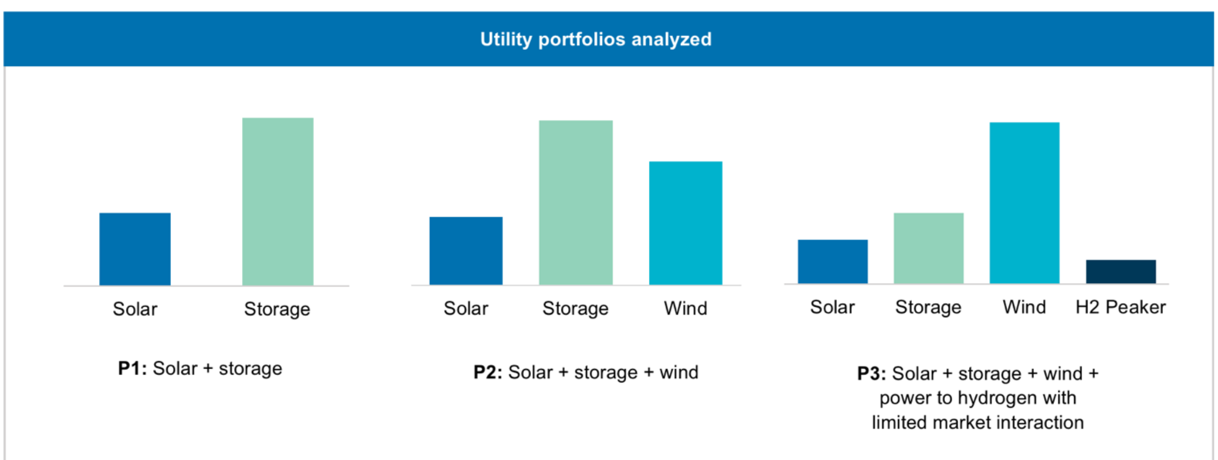
We have been evaluating potential 100% carbon-free energy strategies for utilities looking to achieve such a goal with varying levels of reliance on the market. Although solar and wind resources are likely able to provide cost effective energy to achieve renewable energy penetration levels over 50%, the ability to advance beyond such levels is dependent on the integration of a range of potential storage technologies or other firm renewable resources.

Case study

To evaluate the potential operational and cost outcomes associated with different strategies and address concerns about meeting daily and seasonal load shapes, we recently modeled three distinct strategies to achieve 100% carbon-free energy for a small, winter-peaking electric utility operating in a non-ISO[2] market. The analysis included a portfolio dispatch assessment and a full revenue requirements forecast, including generation production costs, plus all fixed costs associated with depreciation, return on capital, income taxes, and O&M expenses. The strategies were defined as follows (summarized in Figure 1):

- **Portfolio 1 (P1):** Solar + Battery Energy Storage
- **Portfolio 2 (P2):** Solar + Wind + Battery Energy Storage
- **Portfolio 3 (P3):** Solar + Wind + Battery Energy Storage + Power to Hydrogen Gas Conversion

Figure 1: Portfolio summary



2 An ISO refers to an Independent System Operator, which operates and controls dispatch in the open wholesale markets in the US. In this example, the utility does not operate in such a market and must rely on bilateral transactions with neighboring utilities to buy and sell energy when needed.

Each portfolio strategy was designed to provide insights on three key questions as utilities contemplate a future carbon-free generation mix:

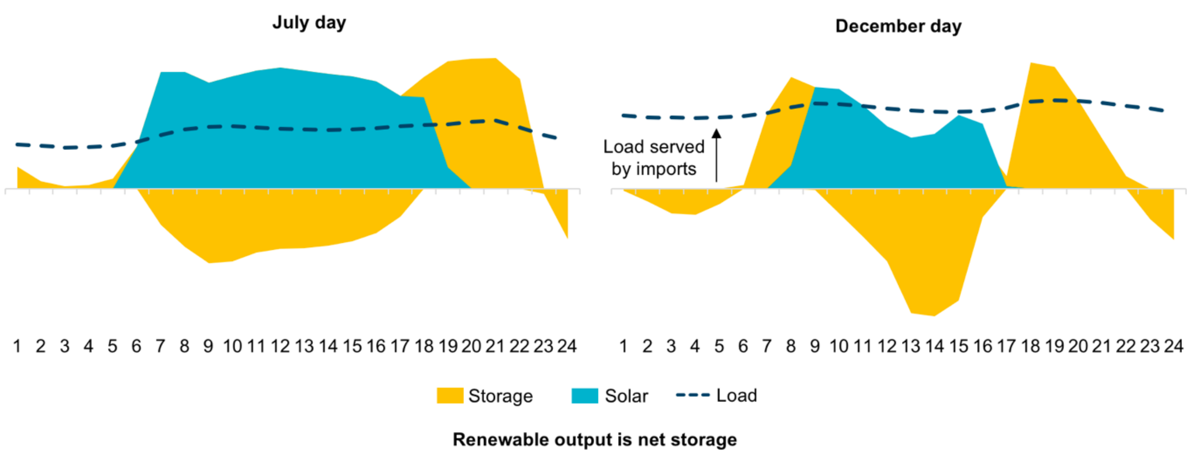
- **P1:** Is a pure Solar + Storage strategy feasible?
- **P2:** Is wind an effective resource to balance energy daily and seasonally?
- **P3:** Is deep de-carbonization possible with constrained market access?

P1: Is a pure solar + storage strategy feasible?

Portfolio 1 was found to be the lowest cost strategy, given the declining costs of solar and expected solar capacity factors above 30% in the utility's service territory. Both paired and stand-alone storage was included in this portfolio to meet winter reserve needs and to allow for operational flexibility with federal tax credits and charging and discharging patterns. Renewable curtailment was limited with abundant storage capacity, but the portfolio also relied on significant access to an external market to meet load needs at any given point in time and to sell excess solar energy. Given a significant reliance on market sales and purchases, this portfolio would only be able to achieve a 100% carbon-free energy goal when the broader market was also achieving such a level.

The hourly energy profiles in Figure 2 show that within this portfolio concept, storage would be expected to charge during the peak solar hours and discharge during the morning and evening hours when solar is not available. In July, load is lower for this winter-peaking utility, and solar generation is high; consequently a significant amount of solar generation is either stored or exported back to the grid as a market sale.[3] In December, load is higher and solar generation is lower; hence imports in the form of market purchases are needed to meet demand and help charge the standalone storage during certain times of the day.

Figure 2: P1 average daily and energy load profile



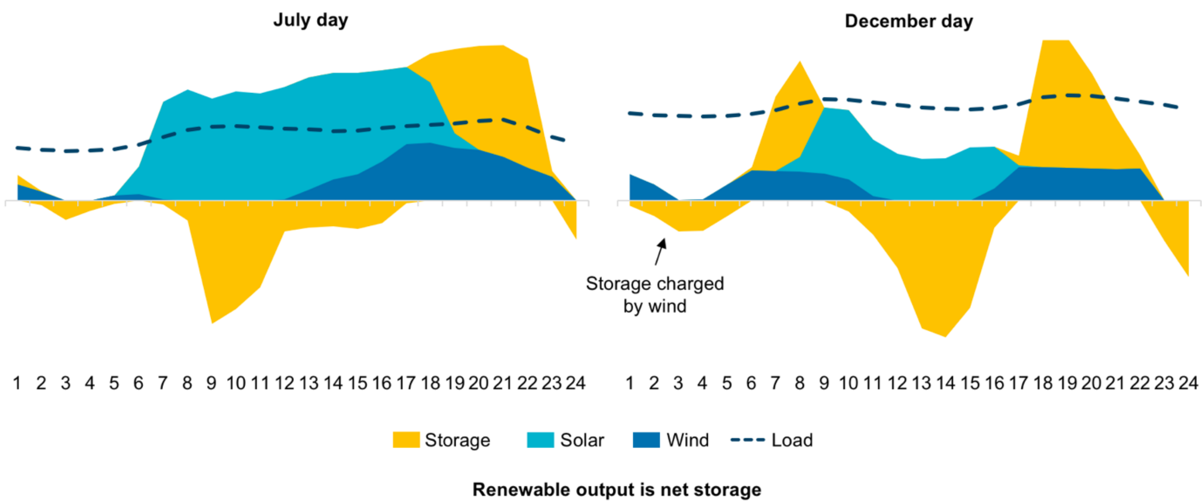
[3] Note that storage output is also sold back to the grid at times when market prices are expected to peak during the evening hours. Further note that some of the paired storage discharges during the morning hours, prior to the solar ramp up, to capture higher market prices and make room for charging from the paired solar.

P2: Is wind an effective resource to balance energy daily and seasonally?

Portfolio 2 tested a more diversified strategy, finding that wind can also achieve the carbon-free energy goals, but at a slightly higher cost. This is because wind is expected to be more expensive than solar on a levelized cost basis in the study region. Portfolio 2 included twice as much wind as solar, but with similar amounts of storage as in Portfolio 1 to meet the winter capacity need.

This portfolio has lower renewable curtailment and lower market exchanges relative to Portfolio 1, partly due to the temporal output diversity of wind and solar. The added wind results in fewer market purchases in the winter months, enabling achievement of the 100% carbon-free energy goal quicker. However, market reliance is still high. This is shown in Figure 3.

Figure 3: P2 average daily and energy load profile



P3: Is de-carbonization possible with limited market exchanges?

Portfolio 3 has the highest cost, but was designed to limit the ability to transact energy with the external market. As a result, the utility requires a larger portfolio of owned or contracted resources, including more wind and a gas peaker capable of burning hydrogen. Under this portfolio construct, excess renewable generation is seasonally stored in the form of "green" hydrogen produced through an electrolysis process.[4] This strategy allows for surplus renewable energy in the summer season to be used for electrolysis to create hydrogen that can be stored over long periods of time and consumed during the winter season when loads are higher and solar output is lower. This construct essentially introduces long-duration storage across days and seasons and minimizes potential curtailment risk and market exposure risk. Under this portfolio construct, adding more 4- or 6-hour battery energy storage is not effective, as energy must be stored over much longer periods of time.

[4] The analysis considers electrolysis costs, hydrogen storage costs, and the variable costs of hydrogen used in a peaking power plant that burns a maximum of 75% hydrogen. The electrolysis and storage costs are assumed to be fixed, with the incremental dispatch cost of hydrogen comprised of water consumption and hydrogen storage injection/withdrawal costs.

As shown in Figure 4, during the summer months a significant amount of surplus renewable output is converted to hydrogen for use during other periods of time, especially during the winter. Assuming energy for hydrogen production comes from avoided renewable curtailment, the hydrogen peaker is a low variable-cost option that could reasonably fill the supply gap during the winter.

Figure 4: P3 average daily and energy load profile

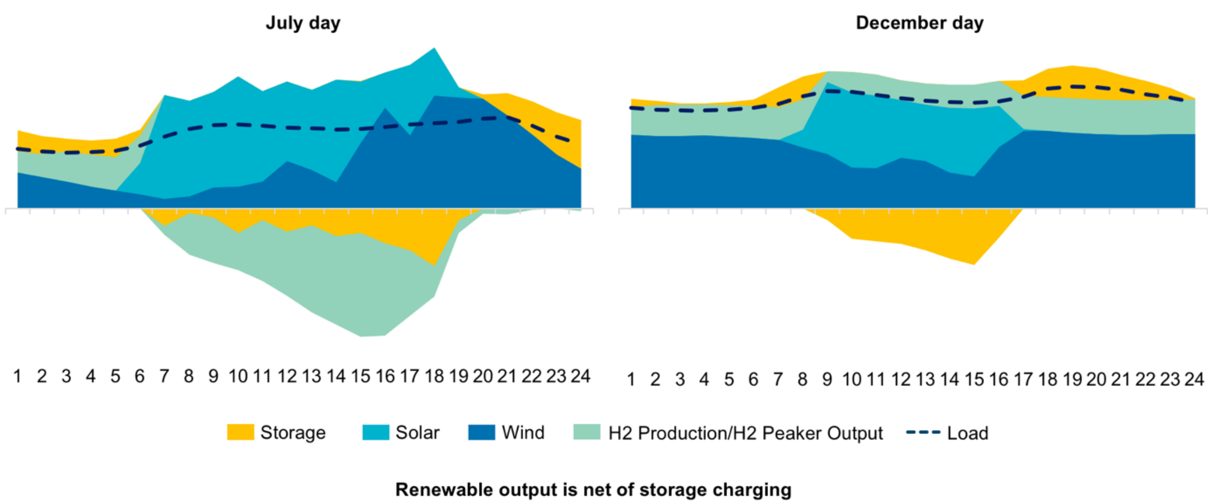
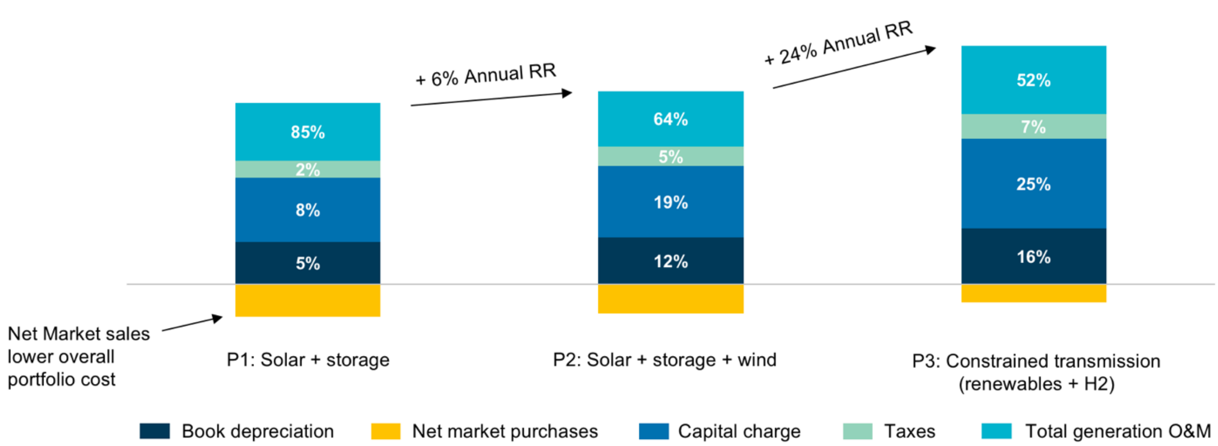


Figure 5 shows the projected revenue requirement for each portfolio by major component. Portfolio 1 is projected to have the lowest overall costs, even though it has the highest percentage of total costs from the generation operations and maintenance (O&M) component, due to a significant reliance on the external market. With wind (Portfolio 2), the overall costs increase, and the share of total portfolio costs coming from capital investment increases, as additional capacity is built and the reliance on the external market decreases. With even less reliance on the external market (Portfolio 3), the overall capital investment increases further, raising costs an additional 24%. However, this extra cost reduces risk associated with energy imports and exports and can achieve a carbon-free generation mix in a self-reliant fashion.

Figure 5: Revenue requirement by portfolio



Conclusion

In summary, the utility in this case study can achieve a carbon-free energy future using various technology mixes. However, there are a number of trade-offs that must be considered related to the timing of compliance, overall cost to customers, technology maturity and availability, and the level of reliance on the external market. These lessons can be applied more broadly to the sector, as utility resource planners consider how de-carbonization objectives fit within their operating environments. While a predominantly solar + storage strategy is likely to be cost effective in ISO market regions with limited renewable penetration, it faces market exposure risk and could necessitate significant storage installations to preserve reliability if the external market is not always available. Therefore, integration of other renewable technologies and seasonal storage may be required over the long-term, especially in a self-reliance situation or as the broader market becomes more concentrated with intermittent renewable resources.

About CRA's Energy Practice

Charles River Associates is a leading global consulting firm that offers strategic, economic, and financial expertise to major corporations and other businesses around the world. CRA's Energy Practice provides services to a wide range of industry clients, including utilities, ISOs, RTOs, large customers, and investors. The Energy Practice has offices in Boston, New York City, Washington, DC, Toronto, and London. Learn more at **www.crai.com/energy**.

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