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MEETING THE RENEWABLES INTERMITTENCY CHALLENGE

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Environmental and other drivers have increased the focus on renewable sources of energy – in particular, wind and solar – over the past few decades. While these systems have many benefits, one downside is that they produce electricity only when nature cooperates. The intermittent nature of these energy sources means that the amount of electricity generated varies from zero to full capacity depending on conditions that are often beyond human control.

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What are the costs of this intermittency? Can these costs be reduced through grid management practices, policy solutions or technological innovation? How can we best incorporate more renewables into our electric grid while assuring uninterrupted power delivery? To address these issues, the UNC Energy Center and the Kenan Institute of Private Enterprise hosted a conference on Meeting the Renewables Intermittency Challenge on April 13-14, 2018.

The conference brought together senior executives from major utilities and renewable energy companies, consultants and academic researchers to examine the true cost of integrating renewable energy generation into the electric grid and explore ways to address the challenges posed by wind and solar energy intermittency. This report, based on conference presentations and discussions, highlights key issues and ideas for moving the field forward.

CONFERENCE CONTEXT AND GOALS

To reduce carbon emissions, the public, policy makers and utilities have focused on ways to increase the portion of our electricity that is supplied by renewables. These efforts have largely emphasized wind and solar power, which represent zero carbon, non-depletable power sources with arguably less environmental risk than fossil fuels. Increased wind and solar energy generation has been encouraged through federal tax credits and Renewable Portfolio Standards — mandates, usually at the state level, that require power companies to reach a defined percentage of generating capacity provided from renewable sources in a given time period. Over just the past decade or so, these policies have achieved many of their targets. Renewable energy sources now provide considerable portions of the electricity-generating capacity in many states; in California, for example, renewables can represent two-thirds of electricity generation in the middle of the day.

The cost of wind and solar projects has decreased thanks to manufacturing economies of scale and more efficient project design and installation. This has led some to speculate that wind and solar energy generation will soon be more cost effective than fossil fuel plants. Reports by the U.S. Department of Energy's Energy Information Administration and Lazard bank appear to support these claims. However, these reports disregard costs associated with the intermittent nature of wind and solar generation, overlooking the fact that a heavy reliance on intermittent sources of energy necessitates supporting infrastructure, such as energy storage systems and backup generators, to assure customers receive uninterrupted, high quality power.

Accounting for intermittency in the total, or "all-in," costs of integrating wind and solar power into the electric grid is important to informing future investments in and incentives for renewable power generation. The conference had three specific objectives: 1) to measure accurately the all-in costs of wind and solar power, 2) to identify the lowest cost path for integrating more renewable generation into the electric grid, and 3) to determine whether technology innovations on the horizon will materially alter this outlook.

UNDERSTANDING THE ALL-IN COST OF WIND AND SOLAR POWER WITH STORAGE

Wind and solar power have achieved impressive reductions in terms of installation cost and have the potential to become even more inexpensive. Adding to their appeal, solar and wind energy projects provide power with almost no additional costs and no carbon emissions after their initial installation. At the same time, storage technologies are advancing, improving the ability to harness the power of wind and sunlight when it is available and use the energy at a later point in time. In specific situations and locations, systems that combine wind and solar generation with energy storage have been able to displace natural gas plants.

Despite these trends, the popular impression that the U.S. is on the brink of achieving a wind and solar-dominated electric grid is misleading. Critically, this impression fails to adequately account for the costs associated with intermittency and grid integration. This omission has led to an incomplete and inaccurate impression of the potential role and costs of renewables in providing power and reducing carbon emissions.

ACCOUNTING FOR THE COSTS OF INTERMITTENCY & INTEGRATION

The intermittency and integration costs associated with renewables come in several forms. In addition to the overarching challenge of using energy sources that are impacted by time of day, weather and seasonality, electric utility managers must deal with temporary variations in voltage and frequency that affect power quality, anticipate and respond to changing electricity demands and store surplus power when demand is down.

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To accommodate these issues, utilities and grid operators incur costs that can be hard to quantify. Some costs are tied to the way existing plants must be operated to accommodate fluctuations in wind or solar power. Today's electric grid was designed around large-scale coal, gas and nuclear plants that produce electricity at an essentially constant rate, run continuously and are often costly to stop and restart. Idling conventional power plants when wind and solar generation is high and then restarting them when renewable generation is reduced can introduce significant inefficiencies and shorten the lifespan of conventional plants, including zero-carbon nuclear facilities.

Other costs stem from new investments that would be needed to facilitate a heavier reliance on renewables, such as investments in battery storage, substation upgrades, fast-start natural gas plants and transmission infrastructure to integrate wind and solar generation capacity from locations that are less optimal for connecting to the grid.

Conceivably, a grid built to anticipate renewables intermittency by featuring more storage capacity would lower the cost of further increases in wind and solar power generation but would also likely have higher average electricity costs. Although the indirect nature of renewables' intermittency costs impedes an accurate assessment of their impact, one utility estimates this cost to be $11 per megawatt hour when 20 percent of the electricity-generating capacity is wind and solar. However, there is not a consensus on the cost of integrating renewables or how this cost would change over time, and different analysts may have different perspectives on the feasibility or level of risk associated with changing grid management practices. Still, there is little doubt that intermittency and integration costs exist and are likely to increase as more wind and solar energy is incorporated. These costs are likely to be borne by the power rate structure because they are not captured in the Renewable Power Purchase Agreements used to sell renewable energy to commercial and industrial organizations.

APPROACHES TO MODELING ALL-IN COSTS

The Kenan Institute of Private Enterprise sponsored a research project into the all-in costs of using wind and solar energy plus storage capacity to meet all electricity demand all day, every day with a reserve capacity to address planned and unplanned outages. As its reference case, the project used a 650-megawatt combined cycle natural gas plant, a high-efficiency type of fossil fuel-based power plant. The project sought to quantify what it would cost to reliably replace such a plant's yearly output with a combination of wind and solar energy generation with storage capacity.

The results, which focus solely on costs and not on technical feasibility, revealed that intermittency is likely to make integrating renewables quite expensive over the long run. In particular, the study points to a high cost of using renewable sources plus storage for base load, the portion of electricity demand that is relatively constant. The study modeled these costs in terms of the carbon tax that would provide renewable projects with wholesale prices sufficient to generate a 10.5 percent leveraged Return on Equity (a threshold that would make them sufficiently appealing to investors). The models estimated the carbon tax for a wind/solar combination plus storage at $151/ton and the carbon tax for solar plus storage at more than $300/ton, markedly more expensive than the natural gas reference case.

Studies to quantify the average cost of electricity produced by a given energy-generating source over its lifetime, an approach known as "Levelized Cost of Energy" (LCOE), are particularly challenging when applied to renewables. In addition to frequently leaving out intermittency costs, these studies often fail to adequately or consistently account for factors such as the location of wind and solar generation resources; the transmission costs of moving generated electricity to the places where it will be used; the efficiency gains associated with extremely large scale wind and solar projects; and factors that affect capital costs, such as tax credits and artificially low interest rates, which may not apply to future projects to the same degree as past ones. As a result, LCOEs are often inaccurate and misleading when it comes to renewables.

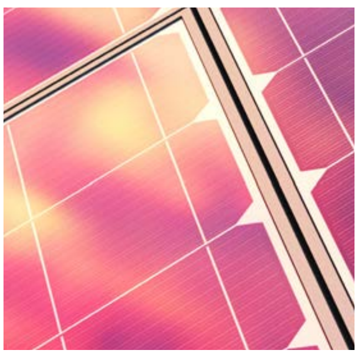
One additional complication is that the price of wind and solar assets, such as turbines and solar panels, can be difficult to predict. For example, while overcapacity in Chinese manufacturing has in recent years driven down the cost of solar panels, recent tariffs have interrupted this steady decline. At the same time, new changes in Chinese domestic support have reorganized the industry in ways that suggest prices may again resume dropping. The direction and pace of future wind and solar costs are uncertain and will reflect the tug and pull of technology advances, manufacturing economies and diminishing returns.

THE LOWEST COST PATHWAY FOR RENEWABLES INTEGRATION

While the conference was not designed to comprehensively analyze integration options, participants ranked the cost and feasibility of various options and outlined a rough plan for a low-cost integration pathway. The pathway that emerged from the discussions emphasizes wide-area energy markets, compressed air and pumped hydroelectric storage, power curtailment, time-of-use pricing and diversification.

LOWEST COST OPTIONS

Perhaps the most promising option for low-cost renewables integration is to expand grid management through an organizational mechanism known as wide-area energy markets. Wide-area energy markets integrate electricity markets across states and utilities in order to reduce power volatility by diversifying supply sources, transmission options and sources of demand. This organizational step involves little new capital and uses existing assets and infrastructure, bringing enhanced forecasting, planning and coordination. Typically, the expanded area also brings different mixes of wind and solar energy with storage under a new coordinating body. This type of organization can also help address long-term intermittency issues by calibrating the amount of constant base power generation needed to address variation in renewable generation due to weather and seasonality.



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Among storage solutions, compressed air and pumped hydroelectric storage are the strongest options. With the compressed air approach, excess electricity is used to compress air into a defined space. The pressurized air can then be used later to drive a turbine that generates electricity to meet demand. Pumped hydroelectric storage stows energy in the form of gravitational potential energy of water, pumped from a lower elevation reservoir to one at a higher elevation. Both storage methods are much more economical than battery storage for high capacity, long duration applications. Moreover, because they retain the potential to generate electricity for longer periods without material losses, they are well suited to address intermittency that occurs over the course of days, weeks, or seasons. These storage approaches are a slightly higher-cost option than wide-area energy markets, however, because they involve capital expenditures and some environmental risks.

A readily available option for addressing surplus power with negligible marginal cost is power curtailment, which involves taking deliberate action not to produce power that would otherwise be available. Planned curtailment can create a reserve of renewable power that, with planning and forecasting, can be used to address variable demand. However, this comes at the cost of denying the underlying renewables project a portion of its potential return. Curtailment has been less studied and should receive more consideration going forward.

Time-of-use pricing is another low-cost option that can be used when a utility has customers — typically commercial and industrial — who respond to pricing and incentives. With this approach, the utility offers electricity prices that vary by time of day to provide incentives for customers to use power in periods of low demand and to conserve electricity during high-demand times. Sophisticated commercial and industrial customers could identify processes that take advantage of the low-cost power created by high-generation, low-usage conditions. However, such win-win situations may be limited in scope and scale.

Finally, diversification of the types of renewable energy used can be an attractive option if both wind and solar projects show economic returns. Using a combination of energy sources somewhat diminishes the mismatches between a power source and variable demands. However, this gain can be offset by the fact that adding a diversified pool of renewable resources intensifies other, longer-term intermittency issues.

HIGHER COST OPTIONS

Despite noteworthy cost improvements and prospects for large capacity, battery storage does not appear to provide a remedy for longer-duration intermittency issues. While today's lithium ion battery storage technologies can effectively compensate for intermittency on the scale of seconds to hours, they are not cost effective for day-to-day, weekly, or seasonal intermittency.

Other options, including mandates for storage, micro-grids and distributed energy resources, are likely to be costly because they create unintended consequences and impede the integrating ability of utilities and coordinating bodies who work to manage supply, demand and power quality across multiple utilities and jurisdictions.

LESSONS FOR COMBINING OPTIONS

Combining options is important because no one solution is applicable to every location or utility. While outcomes from California's aggressive mandates for low-carbon electrification will provide useful lessons for other localities, in many cases the optimal mix will depend on local circumstances. The fact that many integration options exist is itself a boon for wind and solar energy, because it suggests that a given location is likely to be able to find some mix that is cost effective to some degree. As utilities and coordinating bodies learn more, and as technology progresses, wind and solar energy production can be increased where it is cost effective to do so.

PROSPECTS AND RECOMMENDATIONS

Conference participants pointed to a number of factors that are likely to affect the cost and adoption of renewable energy sources in the coming years. Attendees explored what next steps would be useful to advance a hybrid approach to electricity generation that continues to reduce carbon emissions while minimizing the costs and risks related to intermittency and renewables integration.

PROSPECTS FOR THE RENEWABLES MARKET

For the near term, growth in wind and solar energy is likely to continue at a robust pace because of competitive costs, customer demand, remaining mandates, favorable capital market conditions and the desire to grandfather projects as tax subsidies are phased down. In the next few years, the costs for renewables face three potential headwinds: 1) phasedown of federal tax credits, 2) lower tax rates from recent tax reforms, which reduce the value of tax credits and 3) a rising interest rate environment. Despite those forces, financing for renewables projects is now a mature market that attracts significant investments. Major utilities are also emerging as important renewables project investors, and utilities' interest in buying out existing projects will likely grow as initial Power Purchase Agreements begin to expire.

Because today's wind and solar energy with storage technology cannot by themselves greatly reduce or eliminate carbon emissions in electricity production at an acceptable cost, policy should embrace hybrid solutions optimized by location.

After 2020, growth prospects for wind and solar energy are less clear. The use of these energy sources will continue to grow, but how quickly this growth will take place and the ultimate amount of penetration are unknown. The costs of intermittency are becoming more apparent, as is the unsuitability of wind and solar with storage to fully replace other sources of energy for meeting constant electricity demands. Diminishing returns, tariffs, rising interest rates and subsidy reductions raise questions about whether costs for wind and solar energy generation with storage will continue to decline, and if so, at what rate.

ADVANCING A HYBRID APPROACH

Because today's wind and solar energy with storage technology cannot by themselves greatly reduce or eliminate carbon emissions in electricity production at an acceptable cost, policy should embrace hybrid solutions optimized by location. Successful implementation of a hybrid approach will require technology advances and policies that encourage a broad mix of electricity generation, including roles for renewables, natural gas, storage and nuclear energy.

Natural gas is likely to play a particularly important role in this hybrid approach because it can compensate for the intermittency of wind and solar energy, as exemplified by California's use of natural gas to stabilize its grid. Serious efforts should be made to lower carbon emissions involved in natural gas production and use, such as through adoption of carbon capture and sequestration technology.

Quick-starting natural gas plants have emerged as the natural companion of wind and solar energy. These plants not only compensate for short- and medium-term renewables intermittency but can also provide a constant flow of power to meet demands under extreme conditions. Cost-effective natural gas supplies for these plants are an essential ingredient of hybrid approaches to lowering carbon emissions.

Compressed air and pumped hydroelectric storage could show great synergy with wind and solar generation and offer specific customers fully renewable power. However, environmental regulations may be unduly hindering the development of such facilities. Because current siting regulations were adopted before the climate change issue was well defined, they may have tilted excessively in the direction of safety. Improved compressed air and pumped hydroelectric storage technologies may also address some of the concerns that shaped existing regulations.

Care should be taken before allowing efforts to increase the percentage of electricity made by renewables to force the retirement of existing nuclear power plants. Carbon taxes, capacity credits and other pricing mechanisms are warranted to put appropriate value on these facilities for their reliable ability to provide constant power with zero carbon production.

Finally, in the context of facilitating hybrid approaches optimized for each location, the need for continued Renewable Portfolio Standards should be reconsidered. These mandates were implemented to enable renewables technology and manufacturing to be proven at scale, which has been accomplished. With intermittency and integration costs now evident and increasing, and with unanticipated consequences evident, the moment may have arrived for allowing projects involving wind and solar energy with storage to stand on their own economic feet. Doing so will also allow those responsible for power quality and grid stability to weigh all factors before promoting further use of solar and wind energy in the electric grid.

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