PSE Healthy Energy

SCIENCE SUMMARY

MAR 2014

Powering the grid with intermittent renewables

Strategies for Building a Reliable Electric Grid Using Wind, Solar and Other Renewables

Many studies have demonstrated the technical feasibility of meeting the majority[1,2] or even all[3,4] electricity demand with renewable energy resources. However, renewable energy generators, such as wind turbines and solar photo-voltaics, introduce different grid management challenges than power generated with nuclear and fossil fuels. Currently, the grid currently must be sufficiently flexible to respond to unexpected fluctuations in energy demand. Using wind and solar based energy technologies, however, requires that the grid be flexible enough to respond to variability in energy supply because we cannot choose when they generate electricity. Some of this variability is predictable and some more uncertain, as described below.

Seasonal variability

Some renewable energy resources have seasonal peaks. Solar, for example, produces the most electricity in the summer, while hydro-electric power peaks with the spring snow melt.[5]

Daily variability

Solar photovoltaics produce electricity on a predictable daily cycle during daylight hours. Wind energy often also follows certain daily patterns, but these are much less predictable.

Short-term variability

Wind turbine output, based on wind speed, can change rapidly over seconds or more slowly over the course of hours. Solar panel generation can also unpredictably drop in seconds if a cloud passes overhead.

Solar variability and ramp rates

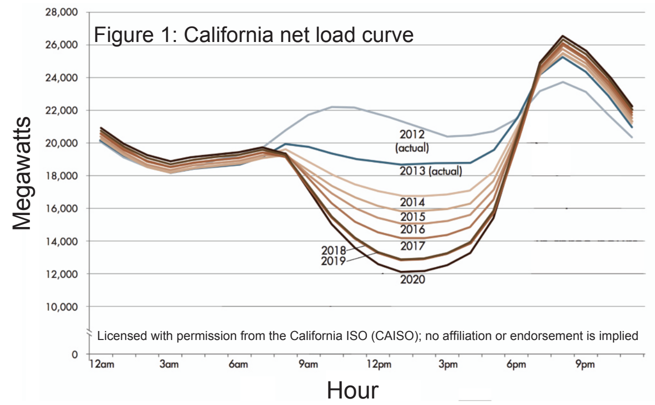


Figure 1: California net load curve

Changes in electricity output from variable renewables may result in a need for rapid ramping of dispatchable resources. For example, when the sun sets, generation must ramp up quickly to replace solar power that moves offline. Figure 1 shows the daily net load curve for California - the amount of generation required to meet demand. The plot illustrates the impact of increasing rates of rooftop solar: additional daytime generation requirements drop as rooftop solar increases, and thus, the ramp rate at sunset increases. High levels of solar penetration have resulted in a duck-shaped net load in some areas, nicknamed "the duck curve".[6]

Strategies for integration

In this section we describe a few strategies for ensuring that variable renewables resources can reliably meet demand.

Energy storage

Energy storage, like batteries or pumped hydropower, can help to mitigate the variability of renewables by storing electricity when there is too much - such as during the midday peak in solar - and discharging the energy when the demand is greater than electricity generated (**Figure 2**). Storage can be used to smooth shorter fluctuations in output caused by passing clouds or sudden changes in wind and smooth ramp rates as well.[7,8]

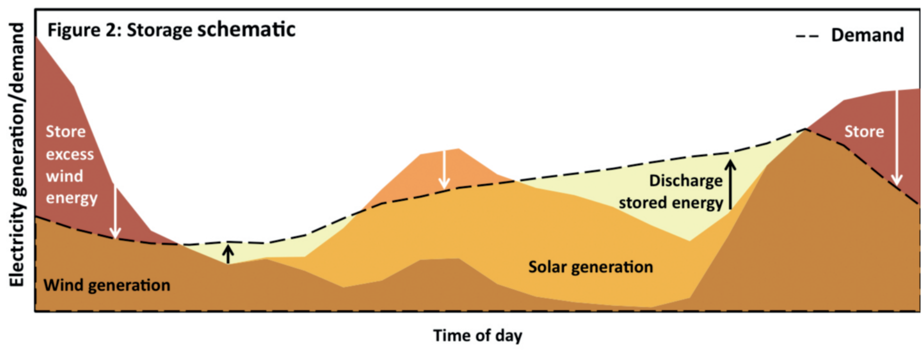
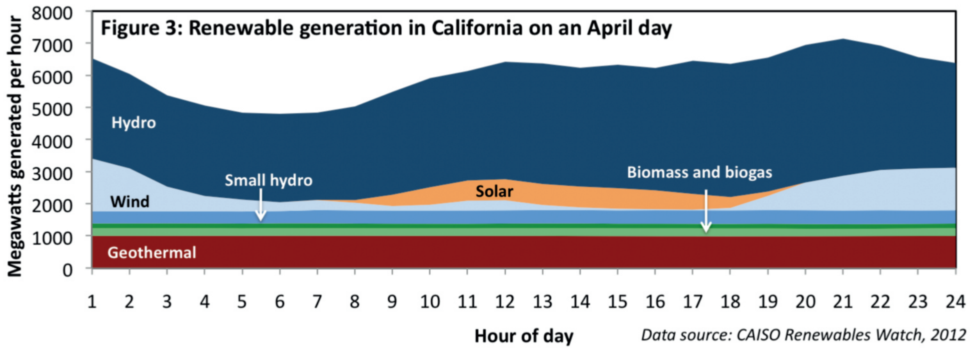


Figure 2: Storage schematic

Integration of many types of renewable resources

The integration of different types of renewables can help to smooth out the variability from a single source.[9] As an example, **Figure 3** shows the different roles played by renewables on a California day in April 2012. Geothermal and biomass resources provide constant baseload generation. Solar and wind each peak at different parts of the day (and year[5]), but hydropower can be dispatched at different rates to compensate for some of these changes in output. Meeting all demand may also require an excess of installed renewable capacity.[11]



Integration across a wide geographic area

Numerous studies have illustrated that connecting generation distributed across a large geographical area reduces the variability of generation from wind[12,13] and solar.[14,15]

Demand response

Demand response programs allow grid operators to control certain types of customer electricity use, like air conditioning, to better match generation and demand. If variability from renewables causes a drop in generation, demand response lets some demand to be lifted until generation increases again.

The integration of many types of renewable energy resources with energy storage and demand response in a smart grid can provide the flexibility needed to create a reliable low-carbon power supply.

References

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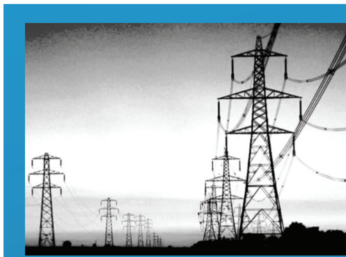

The smart grid

Grid **flexibility -** the ability for components of electricity generation, transmission and load to respond rapidly to new information - is critical for integrating renewable resources. The term **smart grid** is typically used to describe such a system, where both generation and demand can respond dynamically to evolving conditions by in-creasing supply or decreasing load to optimize system efficiency and reliability.

A common example of a component of the smart grid is called **vehicle-to-grid:** electric cars are charged when there is an oversupply in electricity and stop charging or even supply electricity when demand is high. Vehicle-to-grid technology incorporates both energy storage and demand response.

Being able to respond on much **faster** time scales is also important: by using detailed weather forecasting, for example, grid operators can improve planning for generation and increase efficiency, reducing the need for curtailment of renew-ables[16]. The smart grid and renewables integration will necessitate an upgrade to our **transmission** infrastructure, but the electric grid in the US is greatly out of date[17] and such upgrades will improve overall efficiency and performance.