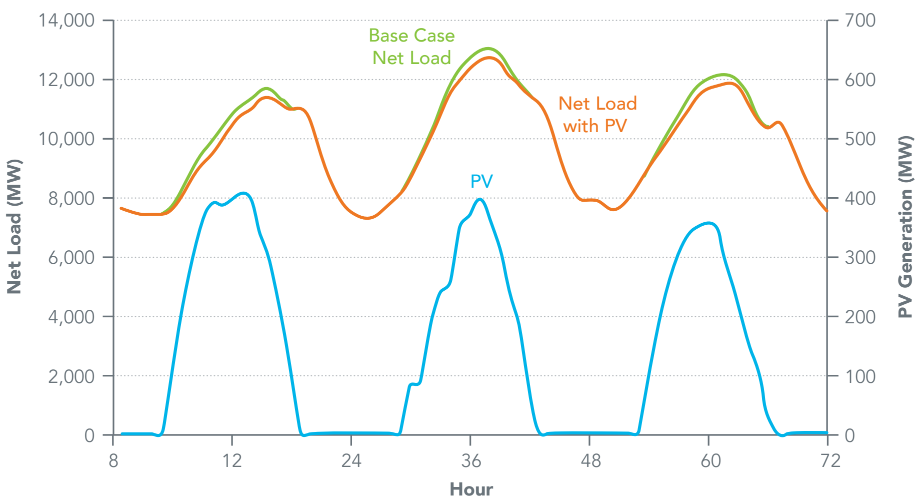
USING WIND AND SOLAR TO RELIABLY MEET ELECTRICITY DEMAND

GREENING THE GRID



Wind and solar energy can provide capacity value by reducing the demand that must be met by conventional generators during periods of high demand. This figure shows solar photovoltaic (PV) generation, the total load, and the net load (load minus solar's contribution). In systems where peak loads are relatively coincident with PV generation, solar can help meet peak demand and provide capacity value to the system.

LEVERAGING RENEWABLE ENERGY TO ACHIEVE LONG-TERM ADEQUACY

An important aspect of power system planning is ensuring that adequate generation capacity exists to meet electricity demand during all hours of the year. Mechanical failures, planned maintenance, or lack of on-demand generating resources (especially for variable renewable resources) may leave a power system with insufficient capacity to meet demand. Grid planners project future peak demand patterns and estimate the relative contribution of each generator towards achieving a reliable supply of energy. When generating during peak demand periods, variable renewable energy (VRE) such as wind or solar PV provides capacity value to the system. By providing capacity value, VRE can help to defer capital investments in traditional generation and transmission infrastructure.

CALCULATING CAPACITY VALUE

Determining the capacity value of VRE is more complex than it is for conventional generation technologies due to the inherent variability of these resources. The simplest way to calculate capacity value of a renewable generator is to examine how well VRE generation aligns with regional demand patterns. This approach considers the output of a generator over a subset of periods during which the system faces a high risk of an outage, such as the 10 to 100 hours of highest net load in a year [1]. The result is expressed as either a capacity value (kW, MW) or as the fraction of the renewable generator's capacity that adds to system reliability or can offset conventional capacity (see sidebar).

More accurate approaches used by utilities and system planners employ detailed reliability-based metrics to assess capacity value. One widely used statistical approach calculates the effective load-carrying capacity (ELCC) of additional generation. The ELCC of a generator is defined as the amount by which the system's loads can increase when the generator is added to the system while maintaining the same system reliability. In this case, system reliability can be described using two metrics: loss of load probability (LOLP) and loss of load expectation (LOLE). The LOLP is defined as the probability of a loss-of-load event in which the demand is greater than available generating capacity during a given period [2]. The LOLE is the sum of the LOLPs during a planning period—typically 1 year. LOLE gives the expected number of periods in which a loss-of-load event occurs. Power system planners aim for a certain LOLE target, such as 0.1 days/year or 0.1 events/year [3]. Figure 2 illustrates the steps used to calculate the full ELCC of an added renewable generator.

DEFINING CAPACITY-RELATED TERMS

Capacity: the maximum output (generation) of a generator or power plant. Capacity is typically measured in a kilowatt (kW), megawatt (MW), or gigawatt (GW) rating. Rated capacity may also be referred to as "**nameplate capacity**" or "**peak capacity**." This may be further distinguished as the "net capacity" of the plant after plant parasitic loads have been considered, which are subtracted from "gross capacity."

Capacity factor: a measure of how much energy is produced by a plant compared with its maximum output. Capacity factor is measured as a percentage, generally by dividing the total energy produced during some period of time by the amount of energy the plant would have produced if it ran at full output during that time. Typical capacity factors for wind and solar photovoltaics (PV) in regions with good resources are about 30–50% and 15–20%, respectively.

Capacity value (also known as **capacity credit**)**:** the contribution of a power plant to reliably meet demand. Capacity value is measured either in terms of physical capacity (kW, MW, or GW) or the fraction of the power plant's nameplate capacity (%). For example, a plant with a nameplate capacity of 150 MW and a capacity value of 50% could reduce the need for conventional capacity by 75 MW.

Demand (or **load**)**:** the total demand for electricity by one or more set of consumers and met by a utility or power system operator. Demand can be measured both by the instantaneous power (kW, MW, or GW) or total energy during some period (kWh, MWh, GWh). **Peak demand** is the maximum demand for electricity. **Net demand** (or **net load**) is sometimes used to estimate the demand for electricity after the contribution from wind and solar, or the demand which is met by "conventional" (non-VRE) generators.

Studies have found a large range in capacity values, ranging from 5% to 40% for wind and 5% to 75% or higher for solar PV [2], [4], [5]. Once capacity value is known, a monetary value per unit of installed VRE capacity can be calculated using a variety of approaches [1].

IMPACT OF HIGH PENETRATION AND THE ROLE OF ENABLING TECHNOLOGIES

The capacity value of VRE is dependent on the extent to which wind and solar generation align with demand patterns. A challenge occurs when increased grid-tied VRE generation (particularly solar) actually changes the net load patterns. For example as solar is added to the grid, it offsets the demand for electricity in the middle part of the day and shifts the time of greatest need to the evening. As a result, the capacity value of solar can decline significantly as penetration increases [2]. The capacity value of wind also declines as a function of penetration, although at a much lower rate than solar.

At high penetrations of solar, new techniques could help maintain high capacity values for solar and wind generation technologies. A variety of approaches can be deployed, including demand response, which can be used to shift demand to periods of greater renewable output, and energy storage, such as the use of thermal energy storage in concentrating solar power plants.

Overall, application of standard capacity value tools can help determine the potential contribution of wind and solar to maintain a reliable grid. Capacity credit analysis can aid in assessing both the type and location of renewable deployment for maximum system benefit and determine potential need for complementary technologies to decrease outage frequency and accommodate load growth.

REFERENCES

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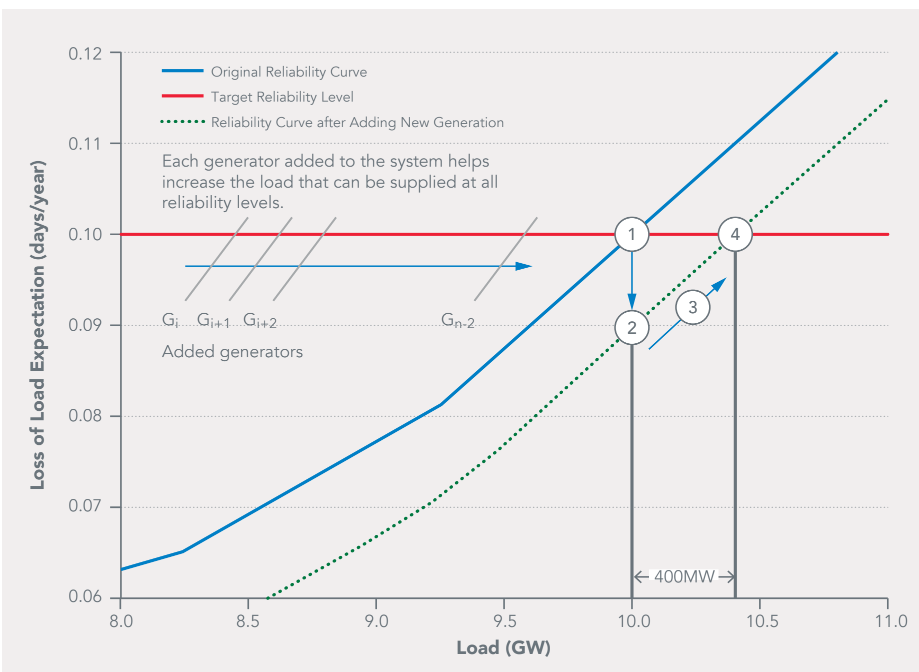
Written by P. Denholm and J. Katz, National Renewable Energy Laboratory.



This figure illustrates the process for calculating the ELCC of an added renewable generator: 1) For a given set of generators (excluding the new renewable generator), calculate the base LOLE using loads, capacities, and outage rates (illustrated by the blue curve). Determine the system load that can be supplied while meeting the target reliability level (i.e., the intersection of the blue and red lines); 2) Add the new renewable generator and recalculate LOLE for the load at which the base system meets the target reliability level. For the same load, the new LOLE value will be less than or equal to the LOLE of the base system; 3) Keeping the renewable generator in the system, add a constant load in each hour and recalculate LOLE. Additional load is added incrementally (moving along the green dotted curve) until the LOLE of the system with the added generator reaches the target reliability level. The green dotted curve represents the new reliability curve (i.e., the blue curve shifts to the right when the new generator is added); and 4) The difference between the new and base load at a constant LOLE is the ELCC of the added renewable generator. In this example, 2000 MW of wind with a 20% capacity credit provides an ELCC of 400MW. Source: [1], [4], [5]

Greening the Grid provides technical assistance to energy system planners, regulators, and grid operators to overcome challenges associated with integrating variable renewable energy into the grid.

FOR MORE INFORMATION

Jennifer Leisch
USAID Office of Global Climate Change
Tel: +1-202-712-0760
Email: jleisch@usaid.gov

Jaquelin Cochran
National Renewable Energy Laboratory
Tel: +1-303-275-3766
Email: jaquelin.cochran@nrel.gov

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