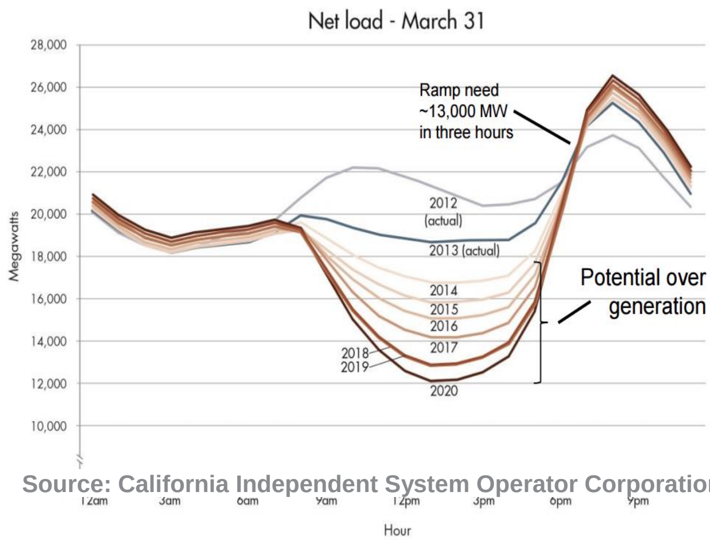
The Duck Curve

This document summarizes the duck curve and its implications on California's energy sector. The intent of this work is to further inform local government agency staff and their programs and projects about the pressing phenomenon of the duck curve.

What is the Duck Curve?

The duck curve is a visual representation of energy production over the course of a day. It shows the imbalance between when peak electricity consumption and peak solar production occur during a given day. In 2013, California's grid operator CAISO (California Independent System Operator) released a report that detailed how the expansion of solar energy would affect California's future energy loads, as represented by a distinct duck- shaped chart. The duck curve has since played a key role in California's evolving energy regulatory landscape and embodies the challenge of adapting to the rapidly increasing generation of renewable energy.



Source: California Independent System Operator Corporation

Why is it duck-shaped?

The duck-shape represents the midday drop in the net load of energy, driven by major solar flooding onto the grid, and a steep ramp-up starting in the late afternoon and extending into evening, as solar generation fades but electricity consumption goes up. For their report analysis CAISO chose a spring day as an example, as opposed to a summer or winter day, because at that time of the year solar generation is typically higher than energy demand. The lines on the graph represent various net loads. A load is the amount of electric power required to meet customers' use at any specific point in time; a net load is the difference between forecasted load and expected electricity production from various generation resources.

The "belly" of the duck denotes a deep midday drop in net load and is followed by a steep ramp-up starting in the late afternoon and evening. This is a challenge because mid-day when solar generation is highest and most efficient during the day, there is insufficient energy consumption to match solar production. Conversely, later in the day as denoted by the "head" of the duck, there is a rapid decline in solar generation placing a strain on the grid relative to the increasing energy demand that occurs in the evening. The chart forecasts that the drop will deepen and the ramp will steepen every consecutive year due to more adoption of renewable energy sources. This prediction has raised concerns over potential challenges with load-supply balancing between renewable and conventional energy.

Steep Ramps

A major concern that the duck curve presents is the ramp-up of energy needed in the late afternoon and evening. The existing conventional energy infrastructure includes many long-start resources such as solar and wind that need time to come on line before they can support upcoming sharp rises in energy demand. As exemplified in the chart, in the coming years, as California begins to rely more on solar energy there will be a sharper ramp up in megawatts (MW) needed to meet demand. The curve predicts that by 2020, between the hours of 6:00pm and 9:00pm, the independent system operator (ISO) must meet 13,000 MW demand within 3 hours. This is incredibly difficult given current resources.

Overgeneration

Another challenge of increased deployment of solar is the potential for solar to over-generate more energy than can be used by the grid system. When supply exceeds demand and energy sources cannot reduce in strength or output to accommodate the surplus of supply, technology connected to the grid can be damaged. This overgeneration potential is most obvious in the graph's mid-day drop period, when solar and other renewable sources may produce more energy than demanded. The technical solution to overgeneration is curtailment, in which an operator decreases output from solar and wind generation below usual levels. However, this reduces the economic and environmental benefits of these technologies, such as displacing fossil fuel. This reduction could potentially reach a point in which additional installations would not be worth the cost.

Where are we now?

In 2013, California exceeded the graph's predictions, with the real-world data being about two years ahead of schedule in terms of both minimum net load and ramp rates. One step that the state has taken to mitigate this problem was on September 30, 2017 when Governor Jerry Brown signed Senate Bill 338 into law; a bill that requires utilities to consider how carbon-free resources can meet peak power needs through the utilities' integrated resource plans (IRP). SB 338 directs utilities to plan for energy storage, demandside management and other non-emitting resources that will successfully meet peak demand needs. This step is one of several suggested solutions from CAISO that the organization believes will combat against the problems presented by the duck curve. Another suggested solution is more flexible ramping, which can be aided by targeting energy efficiency to the hours when the load ramps up sharply. Related to SB 338, CAISO also suggests increasing reliance on existing pumped storage while simultaneously expanding other kinds of energy storage such as battery storage power stations, solar thermal energy storage, storage tied to solar PV and storage implemented in targeted areas with abundant renewables. Additionally, CAISO recommends increasing load shifting and demand reduction via refined rate structures, such as time of use (TOU) and real-time-pricing (RTP).

Resources

https://www.greentechmedia.com/articles/read/the-california-duck-curve-is-real-and-bigger-than-expected
http://www.nrel.gov/docs/fy16osti/65023.pdf
http://reneweconomy.com/au/californias-duck-curve-has-arrived-earlier-than-expected-36106/
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