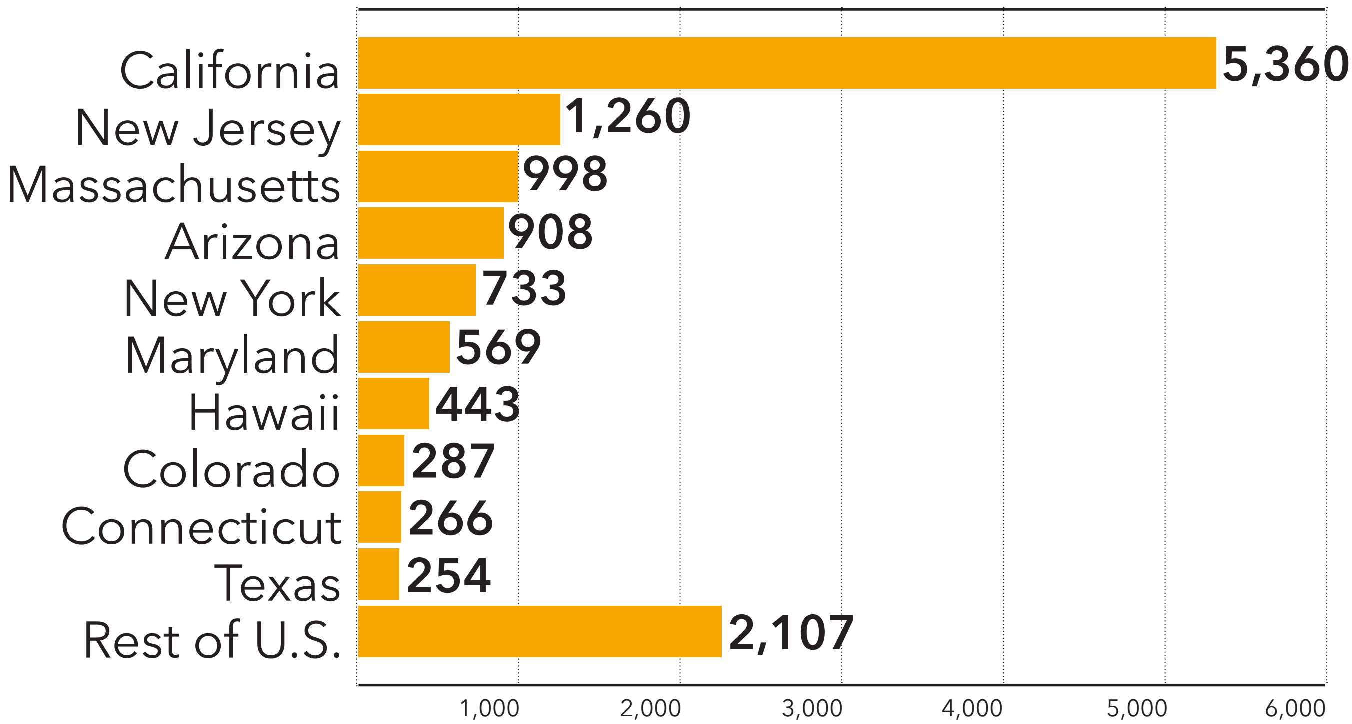
Flattening the duck curve through intelligent resource aggregation

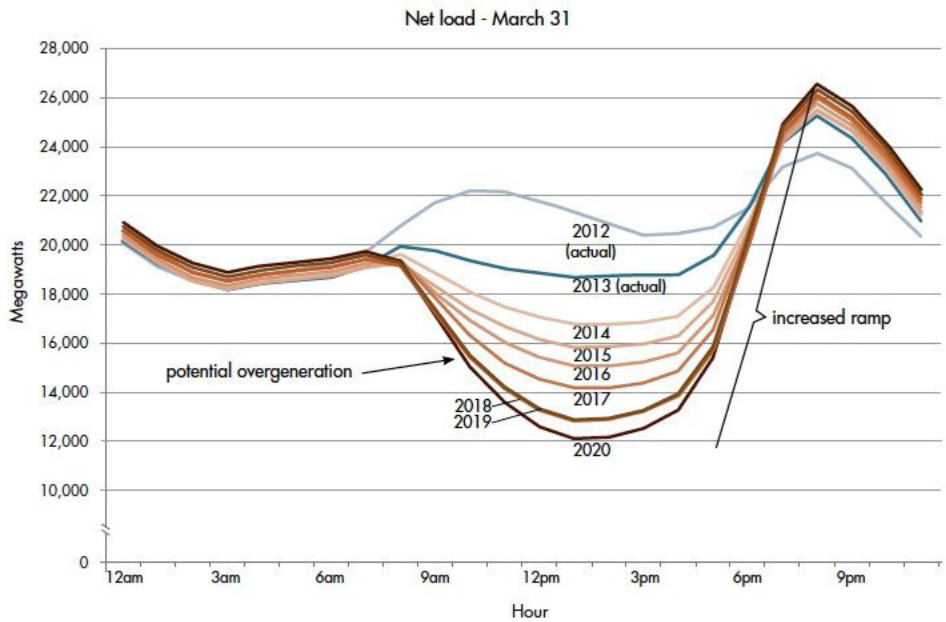
Over the past decade, residential solar installations have been growing at a rapid rate. This trend has been driven by the confluence of favorable regulatory environments, investment incentives at both the federal and state levels, and increasing cost-competitiveness of solar technology. In 2016 alone, 14.63 GW of capacity was installed, representing year-on-year growth of 95 percent[1], and increasing total installed capacity to 33 GW domestically. Distributed solar in particular is driving this trend, with 13.2 GW installed to-date driven by a number of states as shown in the graph below:

Distributed PV Installed Capacity, Top 10 States, as of Dec. 2016
Megawatts (MW_{AC})



Data courtesy of Q4 2016 / Q1 2017 Solar Industry Update, SunShot, US DOE

As a variable and intermittent generation resource, solar production is not tied or responsive to load consumption. Thus, the increasing penetration of solar presents a set of daily challenges for utility and power system operators whose primary concern is the continuous matching of the generation (supply) and consumption (demand) of electricity. Utilities and system operators must also focus on maintaining stability and service reliability throughout their service territory. Of particular issue to system operators, high levels of midday solar generation reduce net load on the system dramatically during sunlight hours – forcing many generators offline. As the sun sets, a steep net load ramp occurs, requiring flexible generation assets to quickly return online to meet the evening consumption peak. Expensive peaker plants and other inefficient thermal-based generating units are dispatched to respond to this ramp.



The combination of these two circumstances is commonly described as the "duck curve" phenomenon — with the belly of the duck characterizing the low net load period during the sunlight hours, and the neck of the duck as the net load ramp toward the evening peak. This phenomenon is well-documented at the system level in the case of the California Independent System Operator (CAISO). With increasing solar installations comes not only the risk of negative net load in the middle of the day, but also a significant ramp to meet the system's evening peak by 2020[2], as illustrated in the CAISO graphic above[3].

The duck curve phenomenon can manifest within a particular utility's service territory or localized at a particular substation or feeder. This can create the additional challenge of straining a utility's grid infrastructure, presenting undesirable grid operating conditions. For example, Pacific Gas & Electric's (PG&E) Huron substation is expected to reach its transformer's limitation twice a day by around 2022, initially due to forecasted reverse power flow during peak solar generating hours, and subsequently due to forecasted evening peak load conditions[4]. In the case of the Hawaiian Electric Company (HECO), many distribution circuits on the island of Oahu have been experiencing reverse power flow from excess solar generation[5] — and legacy safety and regulation equipment currently in place are not designed to support such voltage and power factor regulation conditions.

Though the challenges associated with the duck curve phenomenon have been discussed at length, what is less obvious is how to leverage customer-sited DERs to provide an effective solution. A utility's desire to flatten the net load curve can be solved by consuming more midday solar generation and reducing the evening ramp and peak.

Using grid-edge assets can address both the net load issue and reverse power flow conditions precisely where in the network they arise — from the system-level down to individual circuits. And the most cost-effective way for a utility to achieve this is by building a resource aggregation across a base of customer-sited DERs.

With these objectives in mind, EnergyHub's Mercury Distributed Energy Resource Management Software (DERMS) is designed to provide a flexible, intelligent resource aggregation across a diversity of DER device classes, device owners, and hardware manufacturers. Customers today are increasingly installing connected DERs behind the meter, such as connected thermostats, smart solar inverters, residential energy storage systems, grid-interactive water heaters, and electric vehicle supply equipment.

By leveraging these customer-sited DERs though the Mercury DERMS, utilities effectively solve the challenges the duck curve presents. Mercury performs automated analysis to inform a fleet-wide mitigation strategy and regularly optimizes the fleet's performance through ongoing, real-time analysis and dispatch control sequences, taking into account the respective technical and operating constraints of each DER class and customer device.

Each day, Mercury conducts feeder-level load and generation forecasts to determine the optimal timing and magnitude of load shift required. Using these forecasts alongside device-specific models and external data sources, Mercury translates the required load shift into optimal resource-specific control sequences.

One example of this mitigation strategy can be illustrated using a fleet comprised of grid-interactive water heaters and residential batteries. Typically, the initial solar ramp-up during the late morning hours triggers Mercury to signal the charging of the higher-capacity electrical storage units in residential batteries and electric vehicles. As midday peak solar generation approaches, the duty cycles of available grid-interactive water heaters – which have lower storage capacity on a per unit basis – are coordinated through Mercury such that the fleet consumption is maximized while the net load shape is maximally flattened.

To address the post-peak solar generation ramp down and immediate ramp toward the evening demand peak, Mercury achieves optimal coordinated discharge across the fleet by abstracting the unique consumption models of the available storage devices. Specifically, Mercury staggers the discharge cycles across the residential batteries while reducing the grid-interactive water heaters duty cycles in a similarly coordinated fashion.

The result is a minimized net load ramp, a reduction in evening peak consumption, and a flattened net load curve. Mercury's approach used for duck curve mitigation provides a number of benefits to a utility. Instead of procuring expensive thermal generation, utilities can rely on the cost-effective solution of leveraging DERs installed by their customers. In addition, utilities gain the benefit of reducing over-voltage incidents by optimally matching local supply and demand during the peak solar generation period. The active load shape management conducted by the Mercury DERMS at the fleet level ensures a flatter, more predictable net load shape for the utility throughout the day – from the initial solar ramp-up during the morning to the demand peak in the evening. This service to the utility is conducted while ensuring reliability, customer choice, and quality of service.

About EnergyHub

EnergyHub is the connected device and DER solution for utilities. EnergyHub's Mercury DERMS platform is the most widely used enterprise DERMS for managing grid-edge distributed energy resources into the grid. Utilities use EnergyHub's Mercury DERMS to manage customer-sited DERs and partner with customers to deliver more powerful demand response and grid service solutions using the industry's largest ecosystem of connected devices and distributed energy resources. EnergyHub is the leading provider of Bring Your Own Thermostat® services to utilities, having developed and popularized the concept in 2013. EnergyHub is an independent subsidiary of Alarm.com (NASDAQ: ALRM), the leading technology provider of connected home solutions. For more information, visit www.energyhub.com.

Endnotes

1 Munsell, Mike, "US Solar Market Grows 95% in 2016, Smashes Records." Greentech Media. February 15, 2017
2 California Independent System Operator, "Fast Facts." CAISO. 2016
3 Boff, Daniel; Feldman, David; Margolis, Robert, "Q4 2016 / Q1 2017 Solar Industry Update, SunShot, US DOE." U.S. Department of Energy. April 25, 2017
4 Pacific Gas & Electric, "2017 Distribution Resources Plan RFO." PG&E. 2017
5 St. John, Jeff, "Hawaii's Solar-Grid Landscape and the 'Nessie Curve.'" Greentech Media. February 10, 2014