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California Unplugged

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"If you live in California, you may want to keep a flashlight handy at all times; after nearly 10 years of tracking blackouts across the U.S., Eaton is crowning the Golden State the official Blackout Queen." [1]

We've been following the situation in California to see what lessons Governor Newsom, the California Energy Commission, the California Independent System Operator (CAISO), the California Public Utilities Commission (PUC), the Federal Energy Regulatory Commission (FERC), the North American Electric Reliability Corporation (NERC), and the rest of us might learn from the rolling blackouts that affected as many as two million Californians in mid-August. (This blog does not cover the fires that have caused so much devastation in parts of the state.)

In the meantime, we thought it might be helpful to summarize what we have learned from reporting mostly by *S&P Global Market Intelligence*, *The Economist*, *Los Angeles Times*, *New York Times*, *Wall Street Journal*, *Utility Dive*, *E&E News*, *Oil & Gas 360, and National Geographic*, and from CAISO's website, the Energy Information Administration, and a few data bases.

Background CAISO manages 80 percent of California's electricity flow and serves some 32 million consumers. Its five-member board is appointed by the governor. The grid operator's total electric generating capacity this year is approximately 62,600 megawatts (MW). The vast majority is natural gas, wind and solar power. In 2010, natural gas comprised 62 percent and wind/solar were 5 percent. This year, gas is 47 percent, solar 19 percent and wind 11 percent. (CAISO does not count 6,700 MW of "large hydro" as a renewable resource.) By 2030, solar and wind will be the largest source of CAISO's generating capacity at 43 percent. California's electricity prices are 71 percent higher than the national average and fourth highest in the country. In

[1] Eaton Corporation (NYSE: ETN) is a diversified power management company that does business in more than 175 countries.

June, the nationwide average retail price of electricity was 10.97 cents per kilowatt-hour (kWh). California's average electricity price was 18.78 cents/kWh.

In 2017, California's greenhouse gas (GHG) emissions totaled 424 million metric tons, making the state responsible for slightly more than 6 percent of U.S. GHG emissions and 0.8 percent of worldwide GHG emissions. Electricity generation was responsible for 15 percent of California's emissions (9 percent from in-state electricity sources plus 6 percent attributed to imports). Transportation (41 percent), industrial (24 percent), and agriculture (8 percent) were responsible for three-fourths of the state's GHG emissions.

California has been increasing its reliance on solar and wind and reducing the use of fossil fuels and nuclear power. In late 2018, California passed legislation which increased the state's renewable portfolio standard (RPS) to 60 percent by 2030. Then-Governor Jerry Brown also issued an executive order requiring the state to make its power sector carbon neutral by 2045.

In 2010, CAISO's gas, nuclear and coal fleets provided more than 43,000 MW of generating capacity; wind and solar provided less than 3,000 MW. By 2020, coal is essentially zero; gas/nuclear provide less than 32,000 MW; and solar/wind have increased to more than 18,000 MW.

CAISO has pointed out that increasing reliance on renewables will require "flexible resources to reliably manage the green grid." This means resources with ramping flexibility and the ability to start and stop multiple times during the day. Currently, natural gas-fired electricity resources and a very limited amount of battery storage (196 MW last year) are the only resources available to provide that flexibility.

Blackouts CAISO relies on solar power for roughly one-fifth of its electric generating capacity. According to CAISO, the sun starts setting around 4:00 pm on a typical spring day at the same time electricity demand begins building to a peak around 8:00 pm. On one typical day this month, solar served 5 percent of California's load at 7:00 am, 36 percent at noon, and negative 0.6 percent (minus 37 MW) by 7:30 pm.

As a consequence, "controllable" (CAISO terminology) electricity resources are needed to keep up with the late afternoon increase in electricity demand combined with the reduction in solar power. For California, this means calling on gas-fired electricity generators, hydro and electricity imports from other states. Then as demand ramps down later at night, CAISO decreases controllable generation until the sun rises around 7:00 am to start producing solar power again. (The up-and-down ramping of controllable resources during the day is called the "duck curve" because of the shape of the curve on a graph.) This pattern seems simple enough when everything goes according to plan … but it didn't in mid-August.

CAISO was forced to institute rolling blackouts because the grid operator did not have enough electricity starting in the late afternoon/early evening of August 14 (Friday) and 15 (Saturday). In addition to blackouts, power prices in some parts of the state reached $932/MWh (vs a low of $15/MWh the same day) on the 14th and

$879/MWh (vs a low of $19/MWh the same day) on the 15th. Moreover, the grid operator had to call for emergency energy conservation measures on August 17-19 to avoid more blackouts.

Why did the largest economy in the nation and the fifth largest economy in the world not have enough electricity? These are some, if not most, of the reasons that have been mentioned:

- Unusually hot weather in California and the surrounding states that California usually relies on for electricity imports. One location in southern California reached 130 degrees.
- Poor planning by and coordination between the California Energy Commission, CAISO and the PUC. In terms of accountability, it's hard to determine where the buck stops.
- A heavy reliance on wind and solar power and the retirement of conventional electricity sources (gas, nuclear and coal). California has essentially no coal-fired generation, and the last nuclear power plant — 2,200 MW Diablo Canyon — is scheduled to retire by 2025.
- Failure of gas-fired generating units to provide electricity when they were needed. During August 14 and 15, CAISO lost 870 MW of gas-fired generation at two facilities, but no one seems to know why the facilities were forced offline.
- Market manipulation because gas-fired units were unavailable at the very time they were needed the most.
- Overreaction by CAISO. The grid operator had enough generating capacity to serve load but decided on rolling blackouts to avoid the possibility of something much worse, i.e., a grid collapse.
- CAISO's 15 percent reserve margin was too small in light of the highly variable generation from renewables.
- Reliance on out-of-state resources. Each year, California relies on electricity imports for about one-fourth of its power. (During the two days of rolling blackouts, electricity imports ranged from 4,500 MW to 9,600 MW per hour.) However, neighboring states including Arizona, New Mexico, Nevada and Oregon which export power to California have either adopted or are adopting RPS targets that will reduce the amount of "controllable" resources.

So far, the reason seems to depend on who you ask, but no one will know for sure until reviews are completed. The most likely explanation for the screwup will probably be some combination of causes — a perfect storm of extreme weather plus other factors.

The Elephant and the Blind Men According to the Indian fable, six blind men each touched a different part of an elephant and, naturally, each one reached his own incorrect conclusion about what an elephant really looks like. It will be interesting to see what the California "elephant" ends up looking like. For the time being, here is our two cents worth.

Resilience A lot of discussion about resilience has focused on how a particular electricity grid performed during cold weather extremes, such as bomb cyclones and

polar vortexes, and whether that grid and its electricity resources are resilient. By replacing extremely cold with extremely hot, you have what happened to California in August. Was the CAISO grid resilient against extremely hot weather? Is it resilient against other extreme events? If not, what would it take to make it resilient? Are other grids resilient, not just to extreme weather, but to other major disturbances? How do we know?

Five days of rolling blackouts and emergency conservation measures do not seem like the characteristics of a resilient grid. This is where FERC could do a lot more to be helpful. The Commission opened a resilience docket more than two years ago and solicited comment on issues beginning with how to define the term resilience. However, FERC has done little since then. At the very least, the Commission should lay out a plan with milestones that would lead to defining resilience and establishing resilience criteria. That step by FERC might enable NERC to establish industry-wide resilience standards.

Transition The electricity grid is changing in ways which have huge implications for our economy, the environment, national security, and our lifestyles. In many ways, California is helping to lead this transition. For that very reason, California should also be a cautionary tale. It's not just that CAISO has increased its reliance on solar and wind by six-fold in 10 years, it's that it doesn't seem to have enough dispatchable resources to backstop solar and wind or to call on if something else goes wrong in the future. The blackouts show the need to be careful about moving away too quickly from dispatchable resources. They're not as popular right now as solar, wind and battery storage, but they are still essential to ensure reliability.

Decarbonization goals will also drive major changes to the grid. However, the pace of those changes needs to be deliberate and allow enough time to avoid mistakes — such as rolling blackouts and emergency conservation measures — and provide time to add infrastructure and take advantage of developing technologies. There also needs to be more thoughtful analysis of these goals. Last year, fossil fuels produced more than 60 percent of the U.S. electricity supply. Eliminating CO_2 emissions from the electricity sector by 2035 would require natural gas and coal to be replaced with more than 700,000 MW of renewables, battery storage, nuclear power and possibly other technologies. This equates to adding an average of more than 47,000 MW per year of non-CO_2 emitting technologies over the period 2021-2035 and retiring the same amount of coal and gas. (For perspective, that's like building each year the equivalent of Pennsylvania's entire electricity supply, not including transmission and other infrastructure.) Is this realistic and can it be done without causing major problems?

Let's hope that California's unfortunate experience turns out to be a valuable learning lesson for others.

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