October 25, 2021

#39 Decarbonizing California can be simple and affordable

California's low-cost optimum appears to be >50% nuclear, < 50% PV+ storage

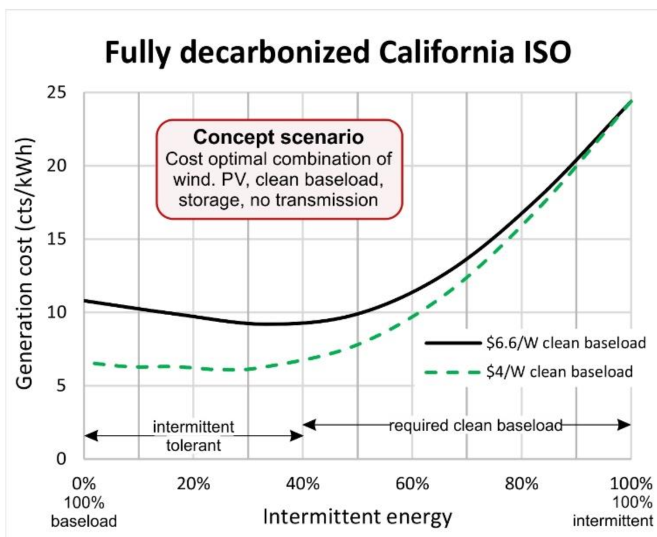
Worldwide decarbonization of electric power is the keystone to mitigating climate disruptions. Without clean electric power, the electrification of other energy sectors is ineffective. Decarbonizing California can be simple, affordable, and expeditious, but only if the public accepts some baseload nuclear.

Imagine that the only resources available are intermittent generators, baseload generators and storage. How can these resources fit together as a reliable system? What does it cost? The performance metric is simply the cost of simply producing clean reliable power. In 2019, California's cost of generating electric power was about 5 cts/kWh; while its average annual retail price was 17 cts/kWh. Retail price includes the cost of transmission, distribution and various social charges which are unimportant here.

The CAlifornia Independent System Operator (CAISO) publishes historical hourly demand data plus concurrent hourly data for wind and solar for the years 2018-2020. There is no ambiguity. No generator performance modeling is required. To estimate system costs, we need estimates of technology unit cost. For this we turn to the National Renewable Energy Laboratory (NREL) ATB database. Here we find assumptions and biases galore. Nth of a kind estimates for nuclear power are too high. But that is not important now. What is very important now is that we accurately represent resource variability.

Wind + solar only is not a credible scenario. CAISO wide production of both wind and solar simultaneously dropped below 2% of nameplate power for a total of 201 hours over the 3-year period. Something else needs to provide power when there is no wind and/or sun. The only options are baseload and storage. A 100% intermittent + storage scenario may seem credible but, using NEL-ATB numbers, the system cost for reliable power would be 27 cts/kWh (vs CAISO's current 5 cts/kWh).

A foundational paper by Sepulveda et.al observes that practical least-cost systems need baseload generators to cost effectively maintain reliability. But how much baseload is required? The cost relationship between baseload and intermittent generation for CAISO resources with NREL-ATB technology costs is presented in the adjacent chart; 100% baseload on the left, 100% intermittent on the right, and different combinations of baseload and intermittent power fall in between. All the systems represented by this curve are 100% clean.



The dashed curve is cost sensitivity using what we regard to be more realistic $4/W baseload, the high end of CAPEX for nuclear installations in Japan and South Korea, both of which have mature nuclear industries. The solid curve is based on the NREL-ATB 2033 estimate of $6.6/W.

Dr. Alex Pavlak; Future of Energy Initiative; www.pavlak.net; www.FutureOfEnergyInitiative.org
315 Dunham Ct., Severna Park, MD 21146; (410) 647-7334; (443) 603-3279(c); alex@pavlak.net

The main conclusion is an unavoidable threshold beyond which the system generation cost increases rapidly with increasing intermittent generation. All the low-cost system options are on the left at less than 50% intermittent generation.

The existence of a threshold is consistent with what we see when we look at real utilities around the world. Those that are isolated (little electricity import/exports) all exhibit capacity & stability problems beginning at about 20% intermittent generation. These problems can be partially mitigated with additional storage, transmission, and reserves. All of this comes at additional cost, a threshold.

isolated grid	intermittent energy	retail cts/kWh
Hawaii	16%	30
Texas	20%	12
Australia	14%	23
California	22%	19

Also apparent from the chart is that anything clean will be more costly than today's cost with fossil fuel (5 cts/kWh).

Physics and economics will eventually trump politics. The inconvenient fact is that an affordable 100% clean system for California requires more than half the energy needs to come from dependable baseload generation. Historically the world's big clean grids have been dominated by hydro and nuclear. For California, the practical option is to preserve existing nuclear and develop Gen-4 nuclear technologies. Both France and Ontario have used nuclear power to successfully decarbonize in less than 15 years.

Dr. Alex Pavlak; Future of Energy Initiative; www.pavlak.net; www.FutureOfEnergyInitiative.org
315 Dunham Ct., Severna Park, MD 21146; (410) 647-7334; (443) 603-3279(c); alex@pavlak.net