Central Coast Climate Science Education

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A Visit to Cal-ISO:
Where Does California's Electricity Come From and How it is Managed?

(Last edit: September 1, 2015)

When California suffers from a severe heat wave, you may hear an announcement on the radio something like "Cal-ISO has issued an alert asking people to reduce their electricity usage during the afternoon and early evening hours."

Not long ago, I, along with three interested friends, was given a wonderful tour of the Cal-ISO headquarters in Folsom, California. The following account of the visit is from notes I took during the visit, supplemented from material on the excellent Cal-ISO website: www.caiso.com and responses from personnel at Cal-ISO, but any errors of fact are strictly mine.

So what is Cal-ISO (or CAISO) and what does it do? CAISO manages the distribution of electricity on a large interconnected "grid" of transmission lines so that the supply of electricity from various public and private producers of electricity matches very closely the demand for electricity from all the consumers served by the grid. CAISO is thus sometimes referred to as a "balancing authority."

Most California consumers and the major utilities supplying them are on this grid, but not all. Notably, the Los Angeles Department of Water and Power is a separate balancing authority, but 80% of the electricity flowing to California consumers is on the grid managed by CAISO. This includes consumers served by PG&E, which supplies electricity to most of Central and Northern California, and like other utilities, owns and maintains the actual transmission lines.

The balancing referred to must be very precise and is done over very short time scales. At intervals as short as 15 minutes the CAISO operators can "tweak" scheduled delivery of power from suppliers, but a modern computerized energy management system reads the power grid every 33 milliseconds (rather than using the former industry standard of every four seconds) to check the balance and health of the grid. If this were not done, consumers would not have the proper voltage and frequency for their needs. Also, damage to some components of the vast transmission network of the CAISO grid could occur. CAISO is not an island unto itself though, and interacts with a larger distribution system covering parts of the western U.S. and Canada, under the guidance of the Western Electricity Coordinating Council—WECC. The WECC in turn is overseen by the Federal Energy Regulatory Commission (FERC). These inter-connecting grids will likely be playing an increasingly larger role to facilitate managing California's electricity consumers and producers. In particular, there have been recent discussions to have PacifiCorp join the CAISO-managed grid. (See: http://www.pacificorp.com/about/newsroom/2015nrl/study-joining-california-iso.html) PacifiCorp involves utilities generating electricity over Oregon, Washington, Utah, Idaho and Wyoming.

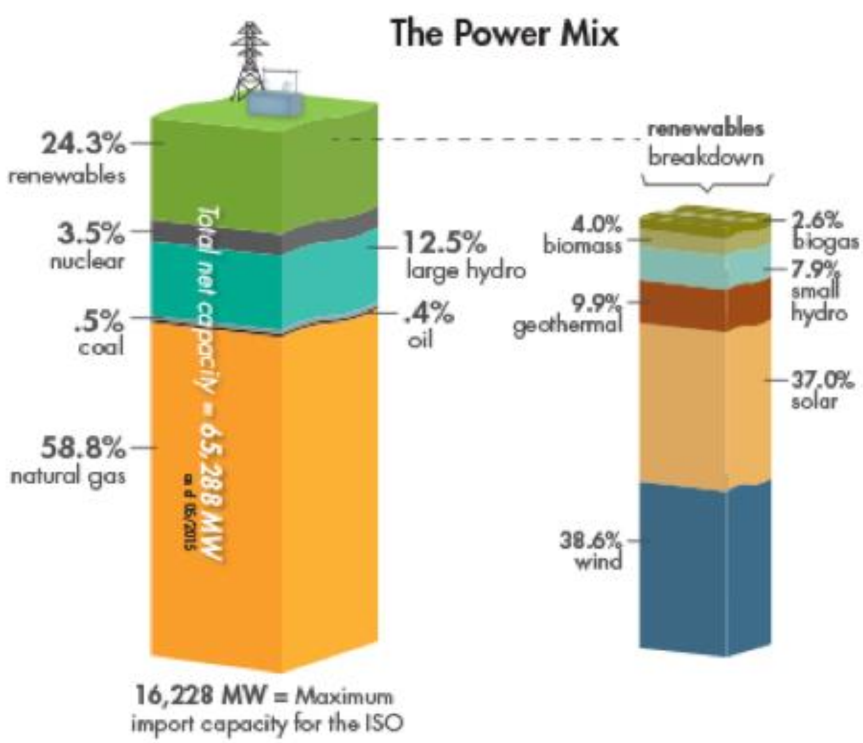
But “balancing” is only one part of CAISO’s job. It also acts as a sort of electricity “commodity market.” This market operates on various time scales--e.g. the “day ahead” market and the “real time” or “spot” market that operates at periods as short as 5 minute intervals. The CAISO market responsibility is to ensure the least costly yet reliable power for every consumer on its grid. For details abut their market operations see:
https://www.caiso.com/market/Pages/MarketProcesses.aspx
Funding for the CAISO operation comes from fees charged to utilities on the CAISO grid.

All of this activity is housed in a large modern building that is itself a model of energy efficiency, and the activity is centered in a huge room as impressive as a NASA “mission control” center. But they do still more, by participating in advanced planning for improvements in the entire western grid system.

One thing they are not, however, is a policy-setting organization. Energy policy in California is set, ultimately, by the Governor and the State Legislature, but more immediately by the California Energy Commission whose mandate is “Promoting Efficiency and Conservation, Supporting Cutting Edge Research and Developing Our Renewable Energy Resources”. The other major energy policy entity is the California Public Utilities Commission that, among other things, sets the pricing structure that utilities charge their customers.

Nevertheless, since the Governor and Legislature have set very ambitious goals for reducing greenhouse gas emissions, CAISO tries to advance these goals by working to integrate renewable resources across the larger inter-state grid described above.
The specific goal for 2020 is to generate 1/3 of California’s electricity from renewables sources.

So much for the general picture. What are some specifics in terms of numbers? The mix of power sources and, specifically, what is available in terms of the renewables—mainly sun and wind—is of course highly variable from hour to hour and day to day, and depends upon the particular public or private utility. Here is a graph taken from the CAISO website showing the average mix:

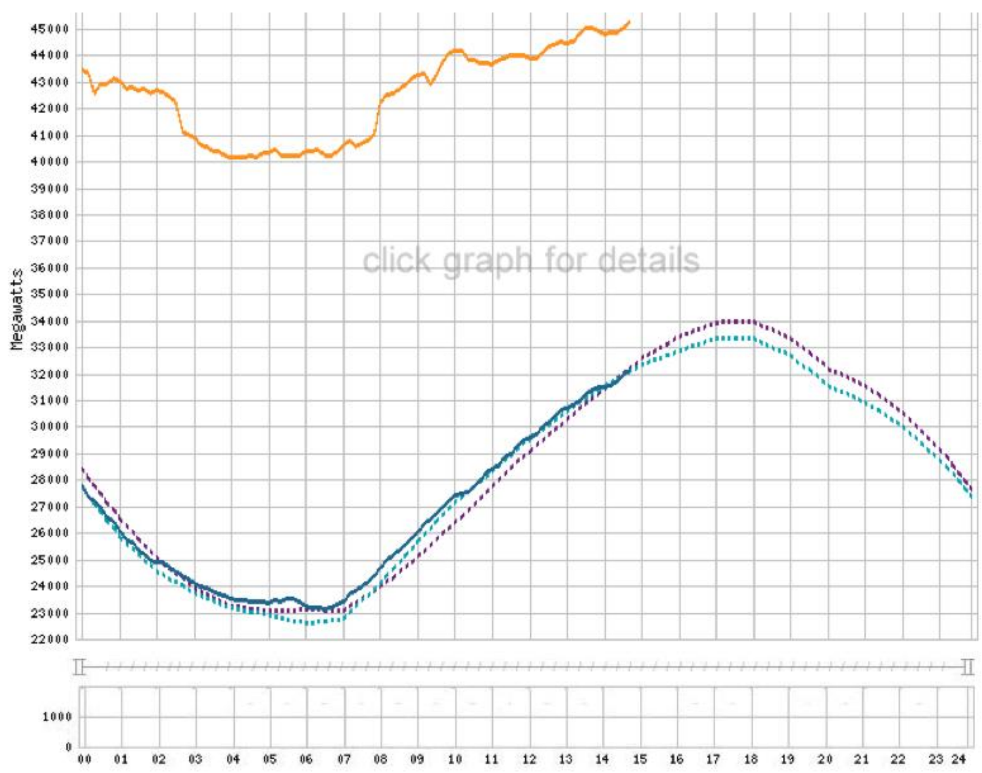


(The 16,228 Mw limitation shown above for imports into California is set by transmission line capacities, subject to the need to maintain the appropriate voltage and frequency on the CAISO grid.)

You can see that almost no electricity is produced by coal or oil, and in fact I was interested to learn that, in response to Legislative action (SB 1369), CAISO imports no electricity from coal generation. The Los Angeles Department of Water and Power still does, but is in the process of eliminating all imports of coal-generated electricity as well.

Thus, the main source of greenhouse gas emissions is the nearly 60% from natural gas with “renewables”, nuclear and “large hydro” accounting for most of the rest. (“Large” hydro is defined to be power generation greater than 30MW, and “small hydro” is less than this.) The right-hand portion of the illustration above gives the breakdown of renewables: Biomass makes a small contribution, with “small hydro” and geothermal adding somewhat more, while wind and solar each contribute about equally—roughly 38% each. With the rapid increase in wind energy, and especially solar energy, in California, I personally came away optimistic that California really can meet its 2020 goal of 1/3 of its electrical generation from renewables.

It is interesting to observe the daily variation of demand and supply of electricity and its sources. Here is a plot that you can get daily from the CAISO website. It represents “daily demand”, both the forecast demand and the actual demand:



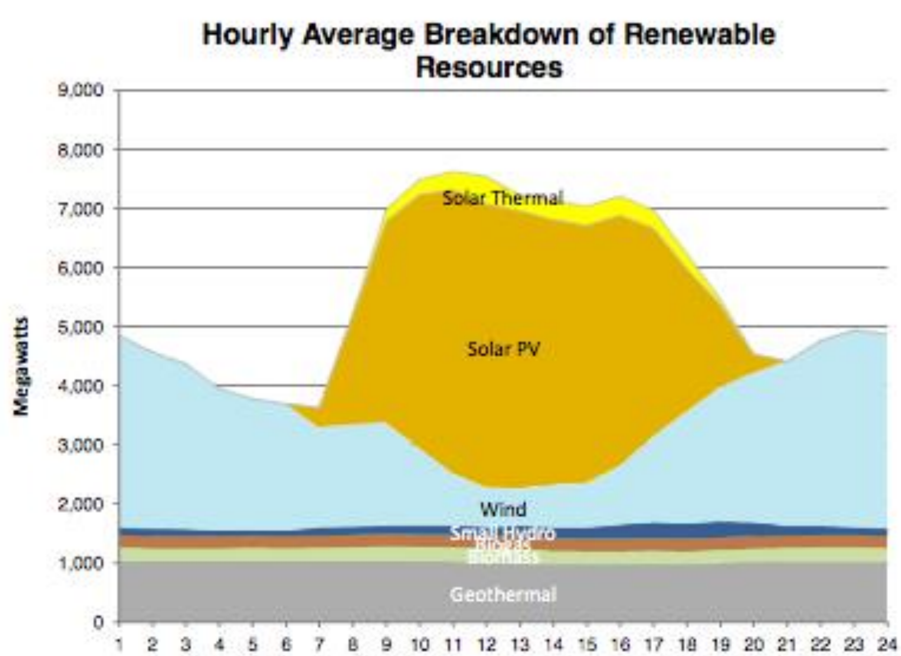
The vertical scale (too small to read I’m afraid) is the amount of power, measured in megawatts, while the horizontal scale is the time, starting at midnight. Dotted lines represent two forecasts: “day ahead” and “hour ahead”, while the solid blue line is the actual demand. This particular graph was made at 3 PM on July 4th (and the demand at that instant was still below the peak, which was forecast to occur around 6 PM.) The minimum demand for July 4th occurred around 6 AM, though I have noticed that on other days, it has frequently occurred earlier—3 to 4 AM.

I was surprised that there is so much demand at these early hours--about 23,000 megawatts (or 23 gigawatts, GW.) We learned that some of this comes from pumping water for irrigation, which will require more and more energy as water tables drop but some may come from industrial uses that shift their usage to the lower priced power at off-hours. The peak demand for July 4th was forecast to be about 34 GW. The top orange curve represents "available resources": these are sources that can be called upon to provide additional power within an hour after being asked to do so. Some sources take much longer to "ramp up" than others. You can see that there was ample excess on July 4th, but a few days previous to this, during the worst of a heat wave, the peak demand was well over 40 GW. The difference between peak demand and available resources was sufficiently small that CAISO issued one of the alerts mentioned at the beginning of this commentary. In fact, during a past very severe heat wave peak demand exceeded 50 GW.

A separate graph (not shown here) allows you to see the moment-by-moment amount of renewables. Wind typically peaks in the late evening/early morning hours (at just after midnight on July 4th,) and 3.2 GW of wind power was being produced. On clear days solar generation of course peaks in the late morning –early afternoon hours. On July 4th solar output peaked at about 5.5 GW around 1:30 pm.

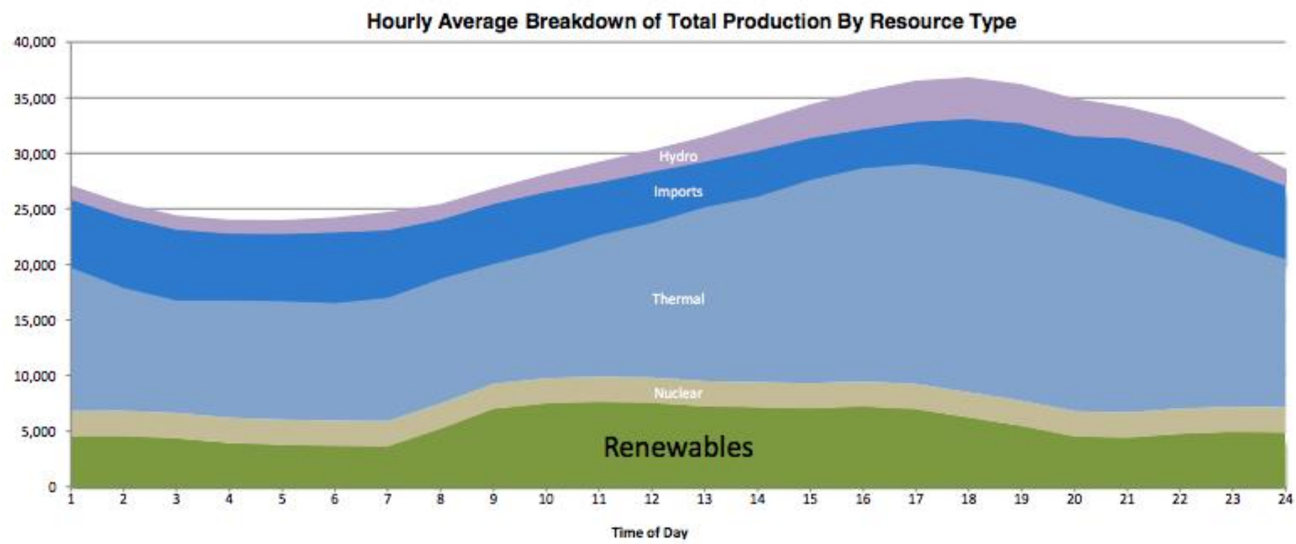
It should be noted that CAISO does not, and cannot, keep track of "behind the meter" solar generation by residential and small business installations. (Though they could eventually; my solar rooftop panels came with sensors that record my solar output and I can look at my hourly, daily, and monthly output. This could be reported daily to the utilities and thence to CAISO.) The best estimate though, (available from the California Utilities Commission here http://www.gosolarcalifornia.ca.gov/) is that these small-scale installations currently have a peak output of about 3.2 GW (as of August 31, 2015), but this is increasing rapidly. The total capacity of utility-scale solar "farms" available to CAISO is now nearly 6.5 GW and is also increasing.

Here is a nice graphic depicting the hourly variation in renewables (for the previous day, July 3rd):



The top yellow sliver is “concentrated solar thermal”. Concentrated solar thermal does not directly produce electricity, but rather heat, which in turn drives turbines producing electricity. An advantage of concentrated solar thermal is that the heat can be stored for evening generation of electricity. The orange is the direct photo-voltaic generation of electricity by utility-scale solar farms, and the light blue is the wind energy, which, as noted above, peaks in late evening and early morning. Geothermal sources chug along at a steady 1 GW rate.

While this looks promising (and I think it is), still, when compared to the generation from all sources, there is still a long way to go before the carbon dioxide-producing natural gas source is mostly supplanted. The following graph shows the hourly sources of all the electrical power on July 3rd.



The renewables are shown as the bottom green segment, while nuclear-generated electricity (from Diablo Canyon) chugs along at a steady 2.2 GW (in brown), hydro (in purple) contributed a little less than nuclear (and the current California drought doesn’t help!) The light blue—the largest contributor--is essentially all from natural gas. “Imports” are shown in dark blue. CAISO does not know the exact mix of the imported sources, but a significant source is probably hydro—as noted above, no CAISO imports are derived from coal.

One complexity in future energy generation planning is that some gas-powered plants using ocean water for “once-through” cooling have yet to be either shut down or retrofitted by 2018-2020 in order to comply with environmental regulations. This involves about 10 GW of power.

We also learned a surprising issue that CAISO has to deal with. From the discussion so far, you might think, “if only we could just generate more solar energy”.

It isn’t that simple. Surprisingly, CAISO is often faced with the problem of having *too much* solar energy. The problem is not just a technical one but also an administrative and contractual one. If large amounts of money are invested in solar farms, then if, for example, a utility like PG&E has contracted to buy this electricity, they will want to be able to use it, and so contractually will be authorized to sell it. Only if the over-supply during the afternoon becomes a severe problem is CAISO authorized to insist that supply be turned down.

An obvious issue that will occur to readers regarding future electricity generation, as California tries to meet its goals of 2020 and beyond, is the “intermittency” of wind and solar energy. They can only be approximately predicted and will fluctuate during any 24 hour period. One step in dealing with this is to expand the geographical area over which these intermittent sources can be exchanged, which will help to “smooth” some of the variability. The possible incorporation of PacifCorp in the CAISO grid mentioned above is an example of this. Another key aspect of dealing with intermittency is the need to be able to store electrical energy from wind and solar. I will discuss this storage of electricity as well as my own perspective on “California’s Energy Future” in a future commentary.

On behalf of my companions and myself, I wish to express our appreciation to our CAISO tour guide, Mr. Steve Greenlee, for an excellent tour and his patience in answering our many questions. But I need to repeat that any errors in this commentary are strictly my own. I also thank John Lindsey & Walter Reil of PG&E for comments and corrections.