

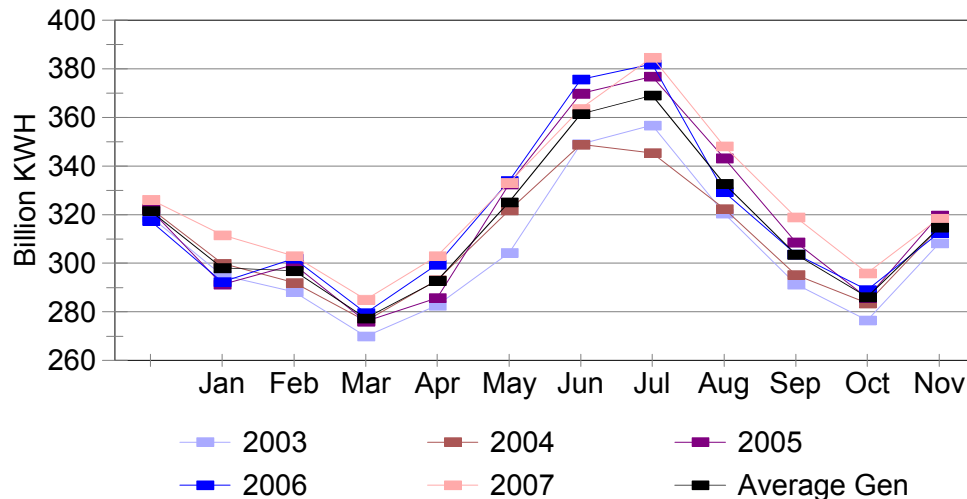
## Solar Energy, Wind Power, Intermittency, and Storage

In ordinary conversations about renewable energy, the issue of energy storage is often overlooked. Renewable sources generate energy on their own schedules, not customers' schedules. The difference must be met either by backup energy supplies or by energy storage. This article describes some storage calculations in the absence of fossil-fired or nuclear sources. The calculations can be downloaded from <[http://gwperplexed.niof.org/elec\\_gen.xls](http://gwperplexed.niof.org/elec_gen.xls)>.

This is a plot of electricity generation for the US. This writer doesn't have data for any other countries and wouldn't presume to offer advice if he did.

<[http://tonto.eia.doe.gov/merquery/mer\\_data\\_ascii\\_display.asp?table=T07.01](http://tonto.eia.doe.gov/merquery/mer_data_ascii_display.asp?table=T07.01)>

### US Electricity Generation

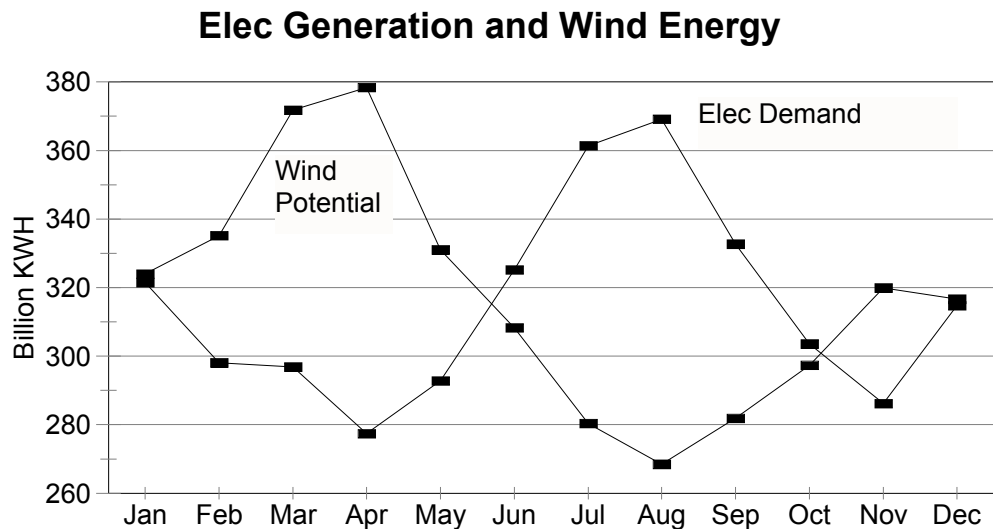


For the rest of this analysis, the average generation for the years 2003-2007 will constitute the model year.

First, compare the demand curve with the availability of wind energy. Wind energy is approximately proportional to the cube of wind speed. Density is also a factor, and there is considerable mismatch at very high and very low wind speeds, but those differences won't change the conclusions. This analysis is based on wind-speed cubed.

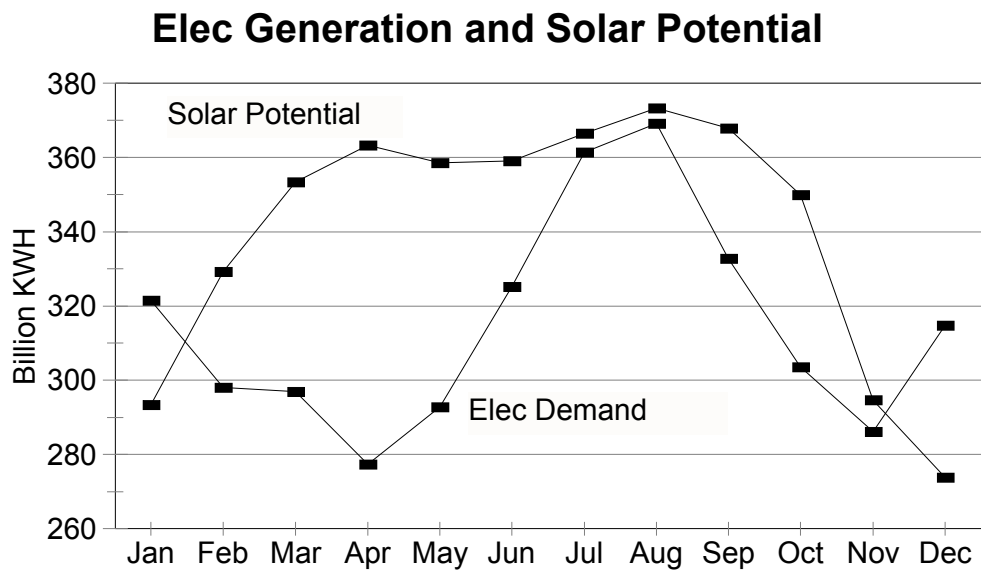
The data show wind speeds for 265 cities. We have deleted cities with low winds or high differences between high-wind and low-wind months. We also have deleted Alaska cities, owing to their unique characteristics and their separation from the US power grid. 244 cities are left.

<<http://lwf.ncdc.noaa.gov/oa/climate/online/ccd/avgwind.html>>



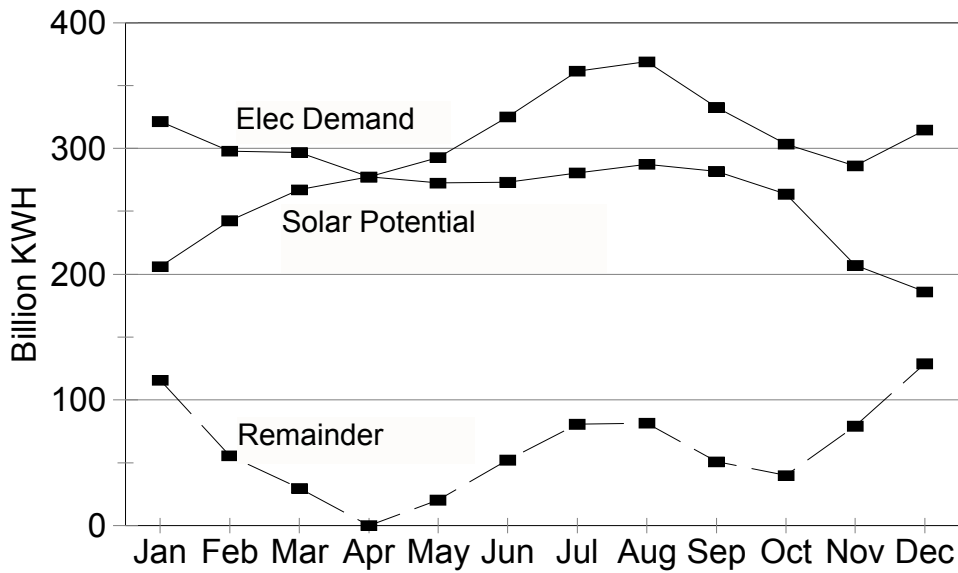
Clearly, wind energy doesn't match electricity demand well. Next, compare electricity generation with solar potential. Cities with poor solar characteristics were deleted from the data, leaving 221 out of 238.

<[http://rredc.nrel.gov/solar/old\\_data/nsrdb/redbook/](http://rredc.nrel.gov/solar/old_data/nsrdb/redbook/)>



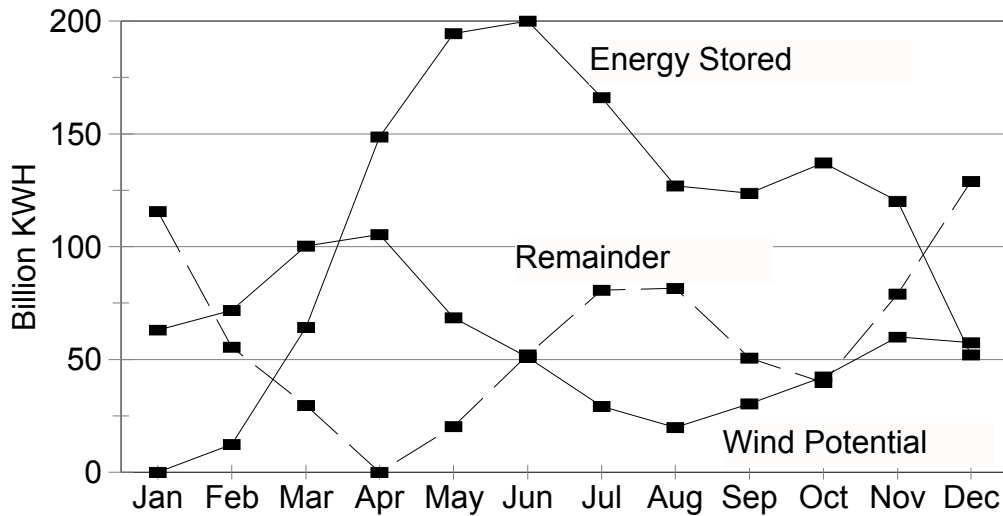
So we see that solar energy matches the electricity demand somewhat better. Accordingly, for our first cut we shall calculate the maximum amount of solar energy that can be used without creating a surplus that has to be stored, and we find that 80.6% of the yearly demand can be met with solar energy on these terms. Now we can consider the remaining demand after all that solar energy is accounted for.

## Elec Demand Reduced by Solar



Now we can compare the remaining demand with available wind energy.

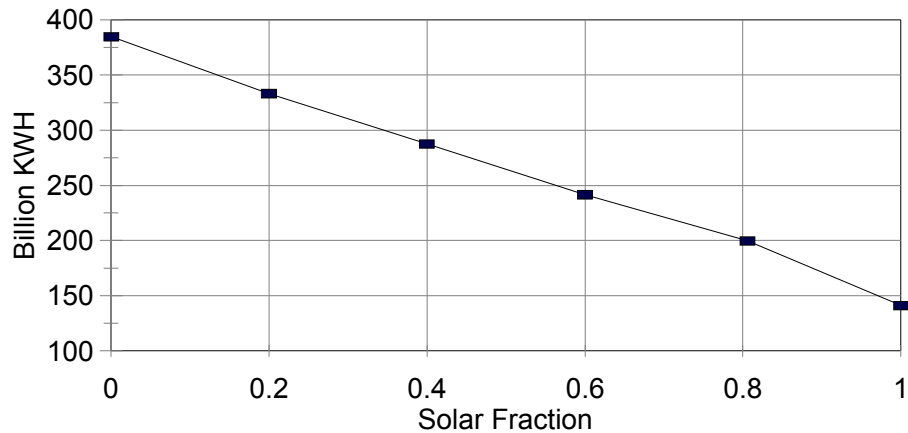
## Wind Compared to Ex-Solar Demand



The calculations show that 200 billion KWH of storage is required.

We can do the same calculations for other shares of supply from solar energy, with the results shown here:

## Energy Storage Required



Our calculations show that the storage requirement ranges from 141 to 386 billion KWH.

There is no way to store that amount of energy. In fact, we'll have to devise a fictional example to illustrate the problem.

Imagine that a lake exists, named Upper Lake Fead, which is equal in size to Lake Mead. Lower Lake Fead is the same size and is located at the bottom of Foover Dam, which is identical to Hoover Dam. However, all the water in Upper Lake Fead can drain through the water turbines.

Lake Volume = 30,000,000 acre-feet

<<http://www.crwua.org/coloradoriver/riveruses/index.cfm?action=reclamation>>

Average head at dam = 520 feet <<http://www.usbr.gov/lc/hooverdam/faqs/powerfaq.html>>

If the efficiency were 100%, then

Energy = volume x pressure = volume x head x weight-density

= 30,000,000 acre-feet x 43560 sq-ft/acre x 520 feet x 62.4 lb/cu-ft

= 4.24 x 10<sup>16</sup> ft-lb

= 16 billion KWH

We'll set the turbine efficiency at 85% and account for pump inefficiency by upsizing where necessary. Thus, Upper Lake Fead is good for 13.6 billion KWH.

So we have calculated that the US would need between 10 and 28 Foover Dams, each with Upper and Lower Lake Feads, depending on how much electricity is generated with solar energy. There are, in fact, no Foover Dams and no locations for building any.