Renewable Energy and Electricity Demand

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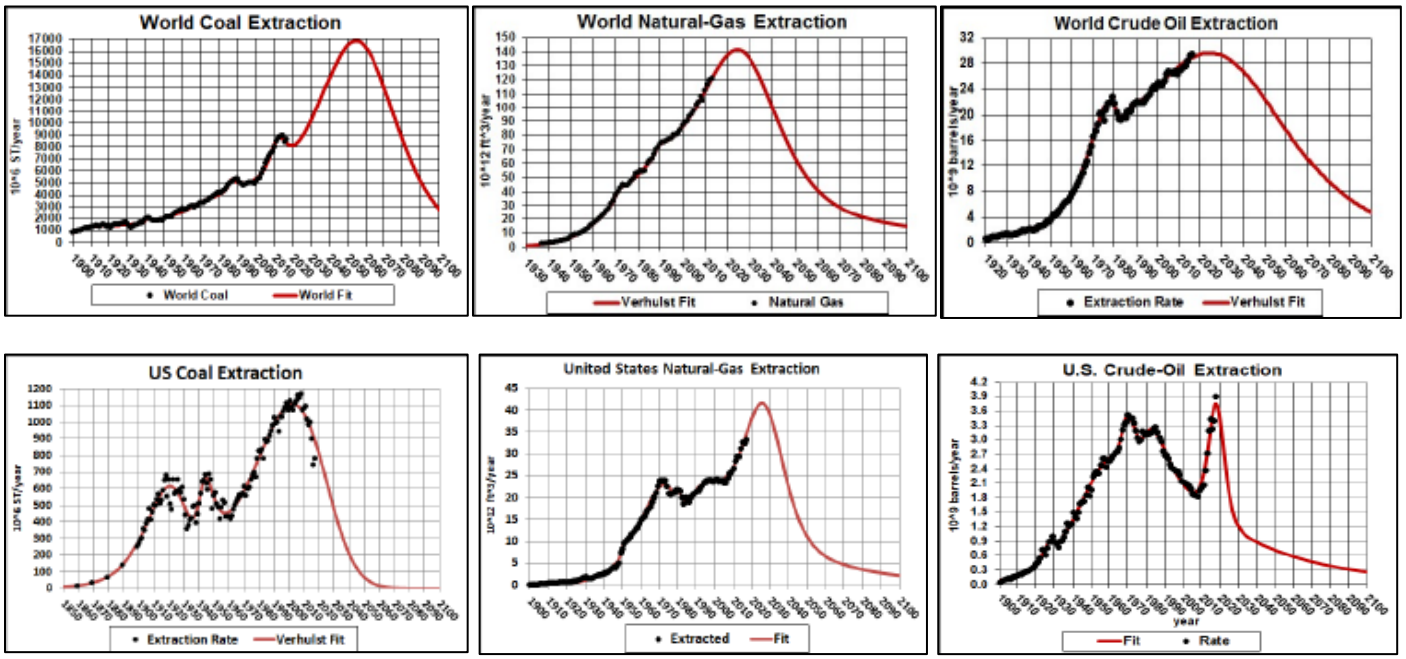
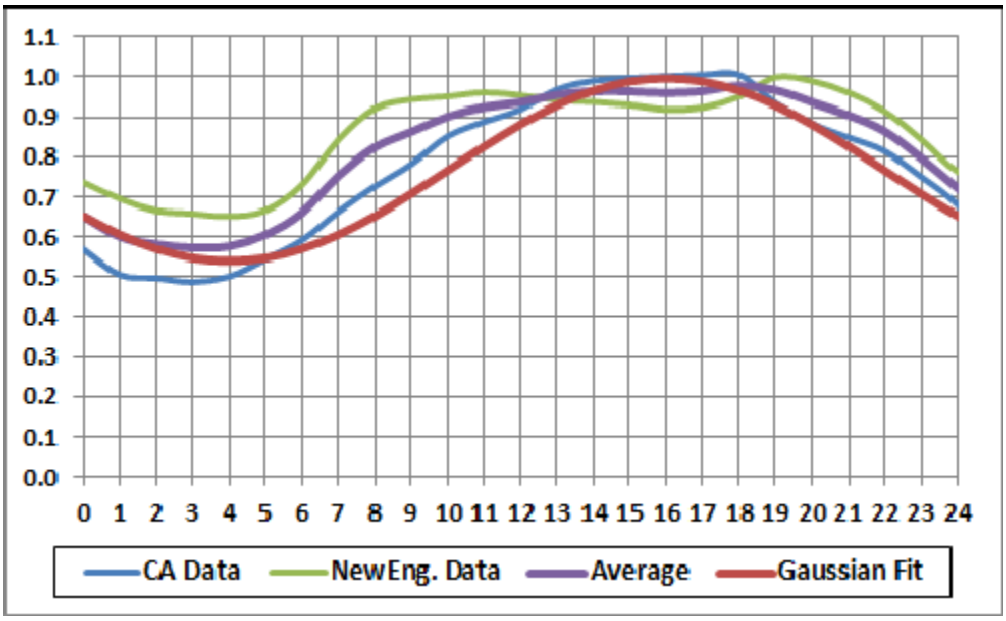
Introduction

As humans quit burning coal to produce energy because of global warming and crude oil and natural gas decline, all energy must be renewable in the near future. This document uses, for the United States, current demand versus time-of-day (TOD) and availability of solar and wind energy versus TOD to see how well solar and wind energy can satisfy the demand.



Demand Data

Demand data for California and New England are averaged to get an approximate curve for the U.S. demand:

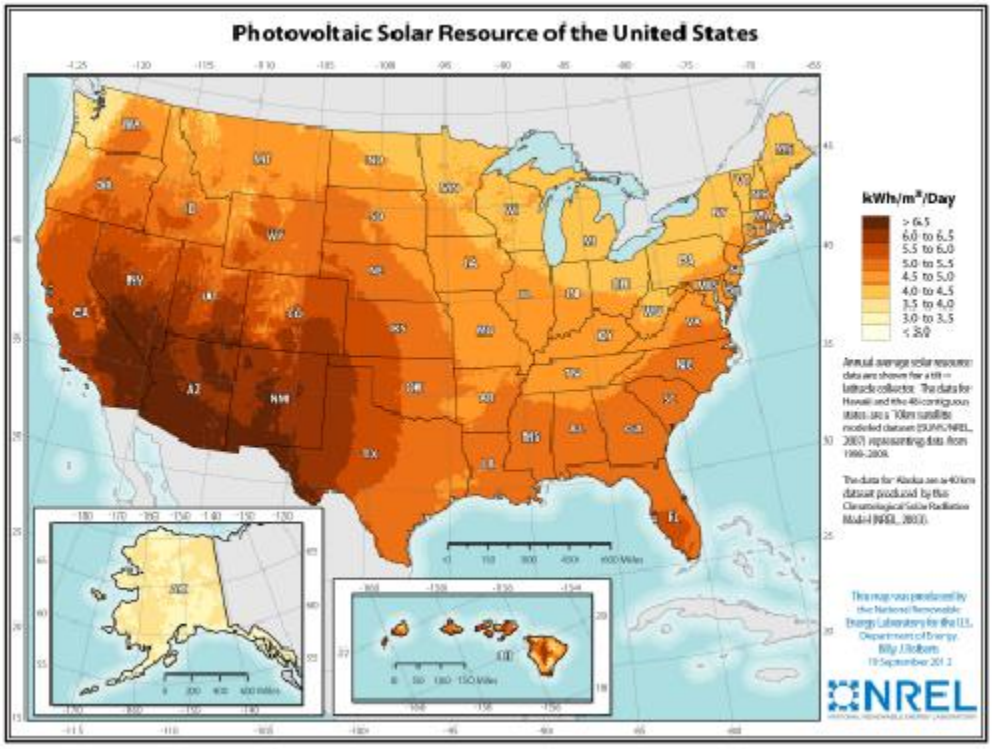


A Gaussian function (**red curve**) was fitted to the average demand as an approximation of the demand.
For the curve above σ = 7.453 hours and x = 16.00 with a factor of 18.424 in order to fit the average data.

The hours for this curve and the following curves are for EST. This Gaussian fit is for a Gaussian curve normalized to an area of 1. Later the solar and wind curves will be fitted to the demand by varying factors.

The Gaussian function is: $$g(t)=\frac{1}{\sigma\sqrt{2\pi}}\exp\left(-\frac{1}{2}\left(\frac{x-x_0}{\sigma}\right)^2\right)$$ It is used for all fits in this document.

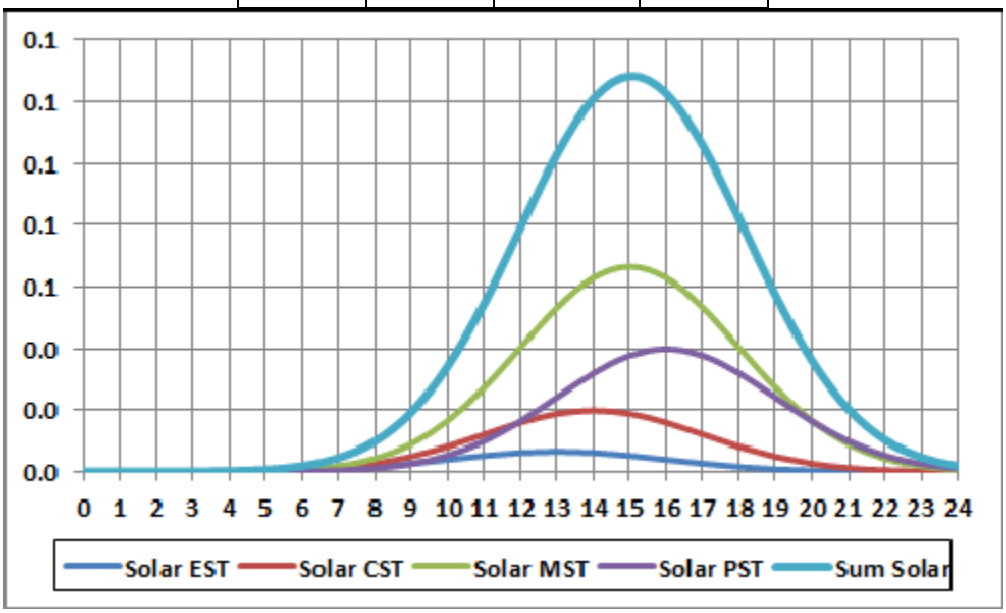
Solar Energy Availability



https://www.nrel.gov/gis/images/eere_pv/national_photovoltaic_2012-01.jpg

The following graph shows the TOD availability curve and a Gaussian fit to it for the four U.S. time zones with the weight factors

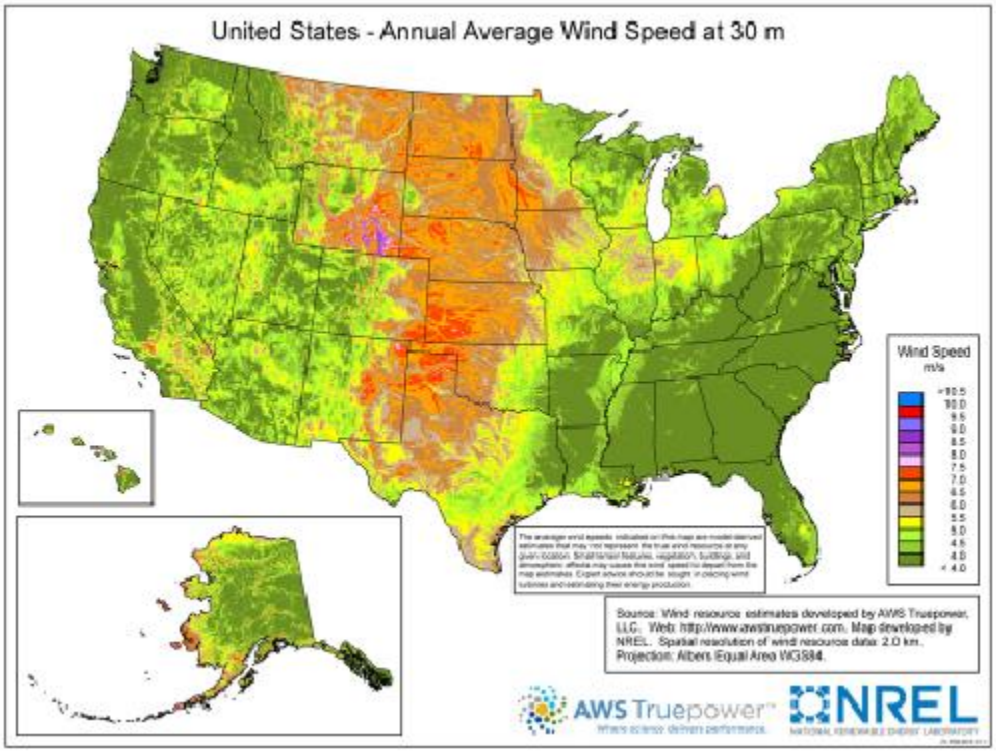
EST	CST	MST	PST
0.050	0.150	0.500	0.300



The Gaussian width is σ =3 hours.

The shape of the solar-availability curve is taken from https://cleantechnica.com/2012/06/26/offshore-wind-solar-combined/.

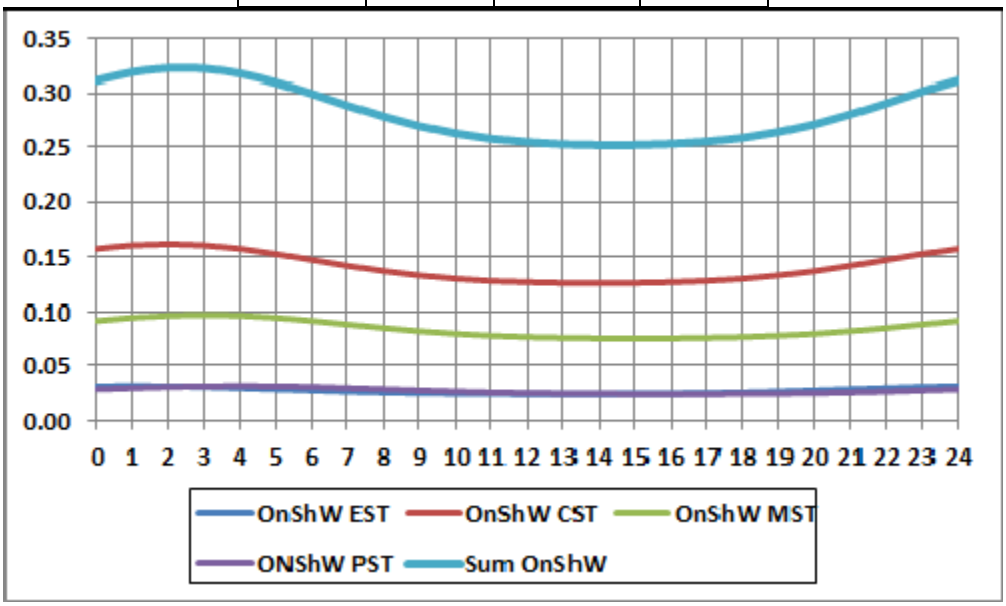
Onshore Wind Availability



https://www.nrel.gov/gis/images/30m_US_Wind.jpg

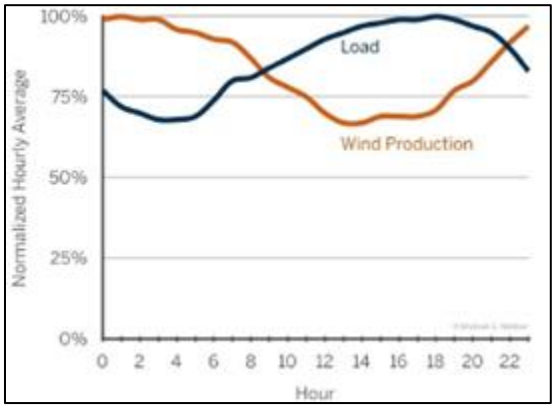
The following graph shows the TOD availability curve and a Gaussian fit to it for the four U.S. time zones with the weight factors:

EST	CST	MST	PST
0.10	0.500	0.300	0.100



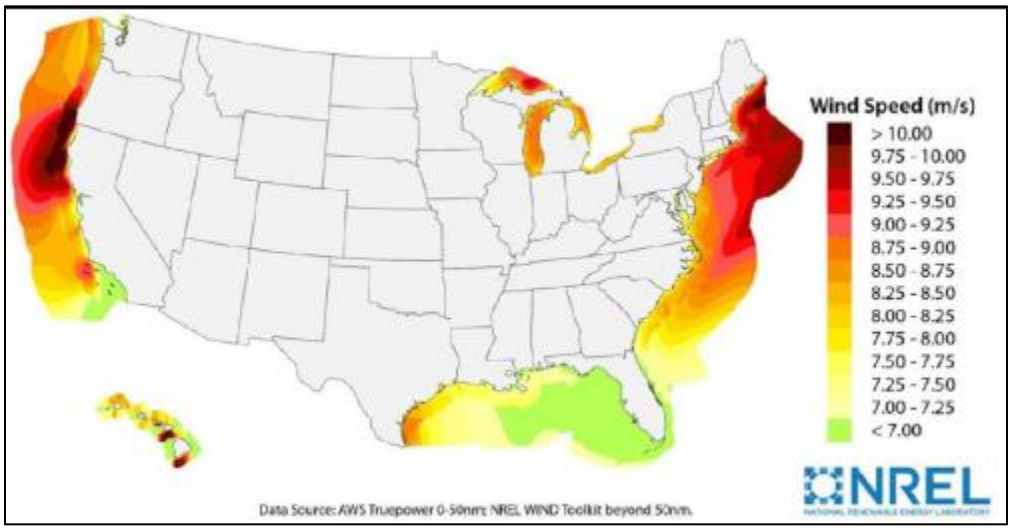
The Gaussian width is σ =4 hours.

The shape of the onshore-wind-availability curve is taken from



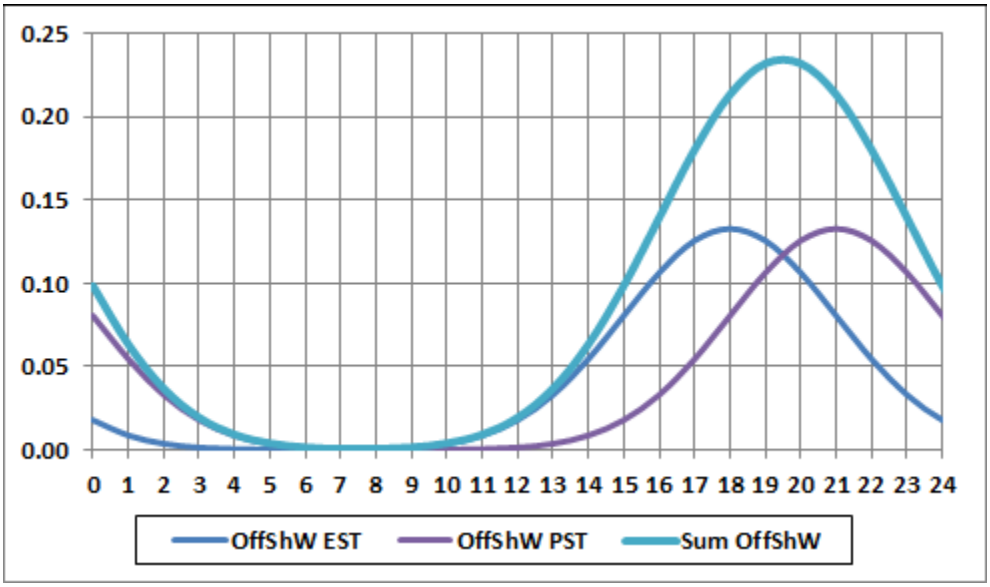
https://www.quora.com/Is-there-more-wind-power-at-night-Or-does-lower-usage-increase-the-of-power-from-wind

Offshore Wind Availability



https://www.boem.gov/uploadedImages/BOEM/Renewable_Energy_Program/Renewable_Energy_Guide/Wind-Resource-Data2.jpg

The following graph shows the TOD availability curve and a Gaussian fit to it for the four U.S. time zones with identical weight factors for both the east coast and the west coast:



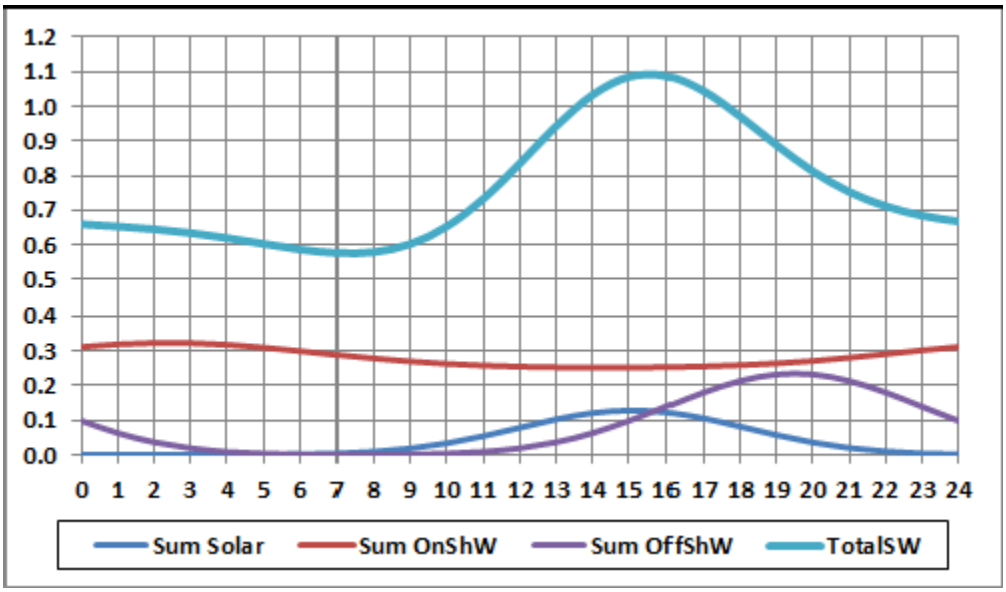
The Gaussian width is σ =3 hours.

The shape of the solar-availability curve is taken from https://cleantechnica.com/2012/06/26/offshore-wind-solar-combined/.

No offshore wind is assumed for the Gulf-of-Mexico coast.

Fitting Solar and Wind Energy to Demand

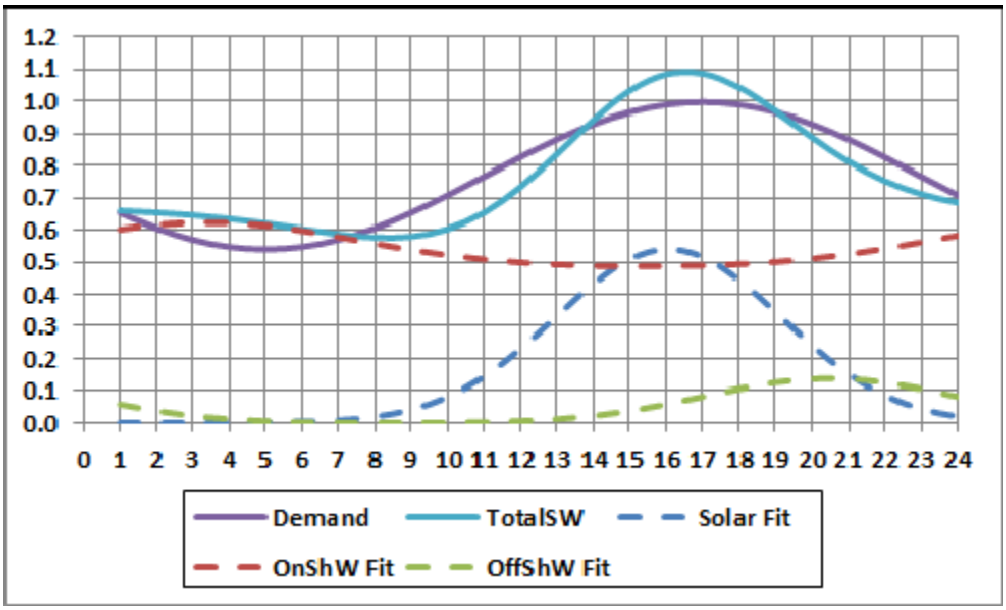
The sum of the total U.S. solar, onshore-wind and offshore-wind energy curves given above is:



The ratio of the three energies as shown is arbitrary. Those ratios need to be varied to fit the demand curve given above. Doing so yields these fit parameters:

Solar Energy	Onshore-Wind Energy	Offshore-Wind Energy
4.205	1.931	0.5886

The fit is:



Modest energy storage could allow time movement of energy from where the TotalSW curve exceeds the Demand curve to times when it is less than the Demand curve.

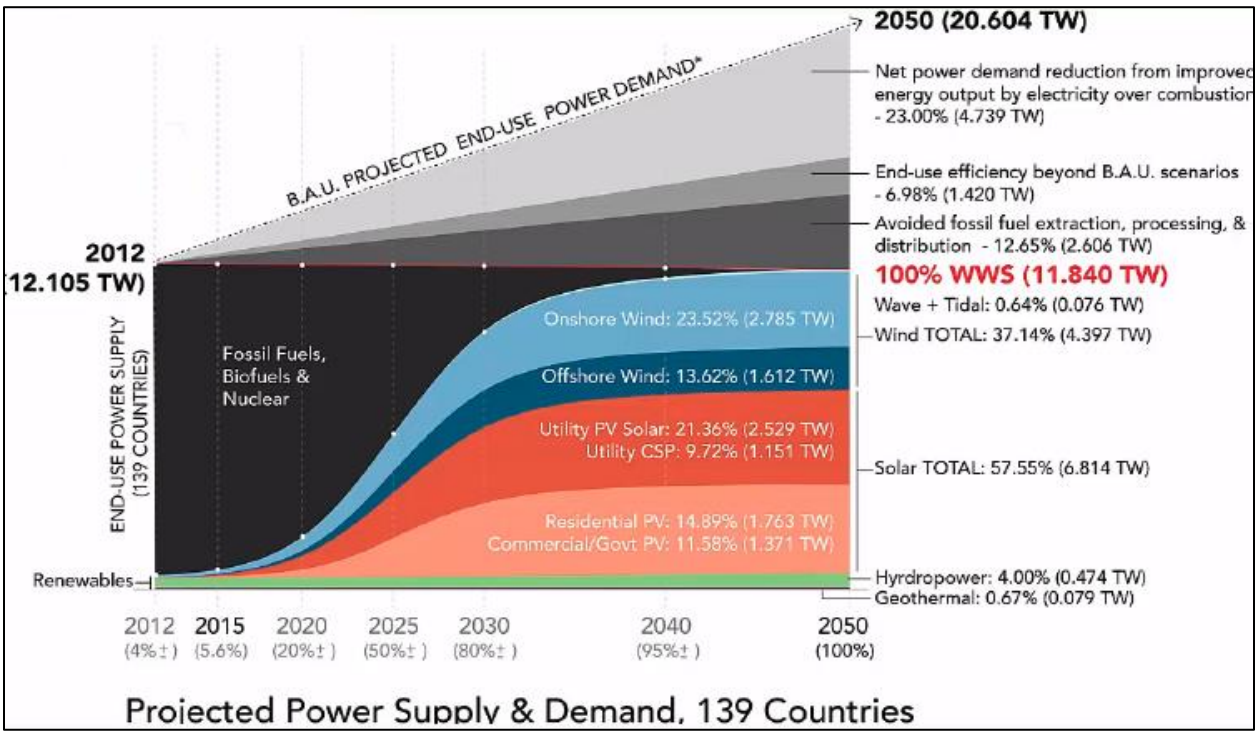
Other renewable energies (geothermal, biowaste combustion, etc.) will help to meet Demand.

Conclusion

This approximate calculation shows that it is possible for massive solar energy, modest onshore-wind energy and even-more modest offshore-wind energy to meet the electricity-energy demands of the United States.

A resilient modern electricity grid needs to be built, including nanogrids in buildings, microgrids in neighborhoods and regional grids, all connected with smart electronics. Some storage will be necessary at the lower grid levels to assure resiliency and meeting demand, mostly modern battery storage.

World Energy



The ratios of solar, onshore-wind and offshore wind are similar for this world case as for the U.S. case above.

References

- http://web.stanford.edu/group/efmh/jacobson/Articles/I/CountriesWWS.pdf
- http://web.stanford.edu/group/efmh/jacobson/Articles/I/WWS-50-USState-plans.html
- http://web.stanford.edu/group/efmh/jacobson/Articles/I/CountryGraphs/139-CountryTimeline.mp4