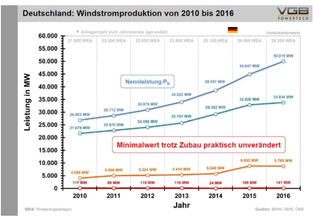
« Wind and Solar: Intermittency, storage and backup (part 1).
So what happened to the science? »

Wind and Solar: Intermittency, backup and storage (part 2)

In the first part of this comment I wrote that the study of F. Wagner on the 100% renewables aim of Germany's Energiewende showed that this would need a massive blowup of the electrical power structure (about 4 times more capacity than the needed load has to be installed), and a non avoidable production of surplus electricity, which might become more a liability than an asset.
In this second part I will discuss some points of the second study by Linnemann & Vallana "Windenergie in Deutschland und Europa, Teil 1" published in the June 2017 issue of the VGB Powertech Journal (link1 to paper, link2 to additional slides). This interesting study looks at wind power, insists on what is needed to guarantee reliability and what has been achieved during the tremendous increase in German wind power from 2010 to 2016.

1. **Big increase in installed capacity, none in minimum.**

The following slide shows the big increase in installed capacity during one decade: from approx. 27 GW to 50 GW:

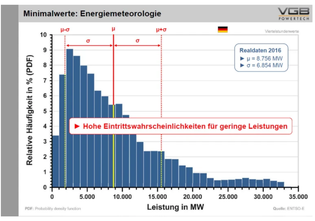


Two facts are sobering:

a. the maximum produced power (during a short annual time-period) decreases from 81% to 68%, in spite of the nearly double installed capacity, and the more modern wind turbines (see blue curves).

b. the minimum power delivered remains constant at less than 1% of the installed capacity. In other words the guaranteed power available at every moment of the year is less than 1% of the installed capacity.

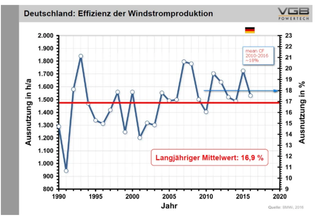
If one makes a statistical analysis, the distribution of the delivered power is very asymmetric and far from normal :



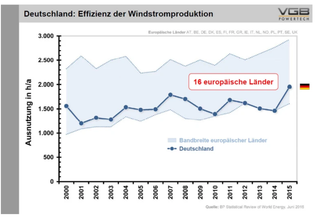
This histogram gives the percentage part of a certain delivered power during 2016 where the mean **u** is about 8.7 GW. The sum of all relative frequencies left to that mean (i.e. the blue area **left** to the vertical u) is high, and corresponds to a 60% probability that the delivered power is low.

2. The capacity factor of the installed wind turbines.

Despite the doubling in installed capacity, the change to more modern and powerful wind turbines, and the increase in offshore wind parks (which in 2016 delivered 12 TWh out of a total of 77 TWh), the overall capacity factor remains depressingly low, and also low when compared to other European countries:



The large variations are essentially due to changing weather patterns: 2010 was a very low wind year for most of Europe. The long-time mean of the CF from 1990 to 2016 did increase by no more than 1% for the 2010-2016 period.



Compared to other European countries Germany's wind turbines do a disappointing job (note that CF% = [Ausnutzung/8760]*100); the CF always lies close to the lower range.

3. How much backup power?

The VGB report is very clear: **you need 100% of the installed renewable wind capacity as backup**. The cause is that the minimum guaranteed power ("Gesicherte Leistung") is close to zero; the next table shows that this is the case for practically all countries, even those like Ireland or Denmark which are geographically privileged:

Land	Ausnutzung $\eta_{A,\varnothing}$	Gesicherte Leistung P_P
Deutschland	**1.531 h/a**	**0,3 % P_N**
Irland	2.264 h/a	0,0 % P_N
Großbritannien	2.200 h/a	0,0 % P_N
Danemark	2.195 h/a	0,3 % P_N
Spanien	2.060 h/a	1,1 % P_N
Portugal	1.996 h/a	0,3 % P_N
Schweden	1.856 h/a	0,3 % P_N
Niederlande	1.836 h/a	0,0 % P_N
Polen	1.766 h/a	0,3 % P_N

As the best windy places are mostly used, a bettering could theoretically be reached by modernization ("re-powering") and smoothing by including all European producers in one big grid. The real data suggest that neither of these solutions is very effective; low wind areas often extend over a large part of Europe (wind is often strongly correlated over much of Europe).

4. Conclusion

The minimum delivered power during the 2010-2016 period is about 0.15 GW, which represents the displacing of conventional (fossil/nuclear) producers by the newly installed wind turbines. In other words, the doubling to 50 GW installed wind capacity has made only a ridicule low amount of 0.15 GW conventional electricity generators superfluous!

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