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Max-Planck-Institut für Biogeochemie

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Wind energy supplies almost three quarters of expected electrical energy

Ageing and slipstream effects restrict the actual yield – 20 percent of the difference remains unclear.

The energy transformation in Germany has just reached a new record. In 2018, almost 40 percent of the generated energy came from renewable sources, 17 percent of which came from wind energy. Thus, wind energy contributes to the energy mix in about the same proportion as is to be expected under the wind conditions in Germany. This was determined by researchers of the Max Planck Institute for Biogeochemistry, who compared the potential and the actually obtained energy output of the wind turbines.

Even just looking at some wind parks can give cause for skepticism: Individual turbines are often at a standstill. This impression doesn't line up with the notion that wind energy must be used intensively in order to meet the needs of the energy transformation. It is against this background that scientists have been increasingly questioning in recent years whether the anticipated contribution of wind energy to the energy mix may perhaps be overestimated. Sonja Germer and Axel Kleidon, who conduct research at the Max Planck Institute for Biogeochemistry in Jena, have determined that wind turbines in Germany supply about 73 percent of the theoretically attainable energy. "Based on our studies, the turbines largely make effective use of the wind and thus contribute to the success of the energy transformation," says Axel Kleidon.

In their study, which covers the period from 2000 to 2014, the researchers combined data from the German Meteorological Service (DWD) regarding wind fields and information about the sites and technical properties of the wind turbines. They were able to determine how much power the turbines can ideally generate given the prevailing wind conditions. Accordingly, the efficiency of wind turbines that is to be expected under ideal conditions, i.e. the ratio of actual power output to the ability of the generators to generate electrical power, is about 25 percent or around 2300 full load hours per year. "This expected efficiency seems comparatively low," says Axel Kleidon. "However, it is the result of the uneven distribution of wind speeds." Half the time, winds in Germany are less than 20 kilometres per hour, so that turbines during this time can only use 10 percent of their capacity or less.

In 2014, the share of wind energy in electricity generation was 9.1 percent.

The researchers compared the anticipated electricity yield under these conditions for about a quarter of the wind turbines for which data was available with the actual power output. The researchers also examined which factors reduce the power output actually generated by the wind turbines. According to this, the ageing of the wind turbines reduced the yield in 2014 by close to seven percent. This is also due to the fact that the average age of wind turbines in Germany rose from 3.8 years to 10.8 years in the period from 2000 to 2014. Since turbines in wind parks are often located in the wake of other turbines, the yield is reduced by about two percent. However, the scientists also ob-

P.B. 10 01 64
07701 Jena, Germany

Hans-Knöll-Straße 10
07745 Jena, Germany

Phone.: +49 (0)3641 57-60
Fax: +49 (0)3641 57-70
www.bgc-jena.mpg.de

Directors

Prof Susan Trumbore, PhD
Phone: +49 (0)3641 57-6110
susan.trumbore@bgc-jena.mpg.de

Prof. Dr. Markus Reichstein (Managing Dir.)
Phone: +49 (0)3641 57-6273
mreichstein@bgc-jena.mpg.de

Research Coordination & Press

Dr. Eberhard Fritz
Phone: +49 (0)3641 57-6800
efritz@bgc-jena.mpg.de

Public Relations

Susanne Héjja
Phone: +49 (0)3641 57 6801
shejja@bgc-jena.mpg.de

served a constant difference between the actual and ideal yields of up to 20 percent that they cannot explain. The different contributions with which the scientists explain the discrepancy cannot, however, simply be summed up as the relationship between the factors is non-linear.

The difference between expected and actual yield was then used by the researchers to determine the actual yield of all wind turbines in Germany. The generated yield has risen from 9.1 to 58.9 terawatt hours between 2000 and 2014. This corresponds to a share of 1.6 percent of the electricity generation in Germany in 2000 and 9.1 percent in 2014. These numbers line up very well with the data that the Federal Minister of Economics and Energy has published regarding the performance of wind energy systems in Germany.

The influence of reduced wind speeds is not yet noticeable.

In earlier studies, the scientists calculated that as more turbines are installed in an area, the efficiency of wind turbines would drop. Given such intensive use, the wind speeds should drop, because every turbine removes part of the wind's energy. "We expected that we should already be able to find such a trend in some regions of Germany," says Axel Kleidon, group leader at the Max Planck Institute for Biogeochemistry in Jena.

That is why, for their new study, the researchers examined the years 2000 to 2014 as it was a period during which the number of wind turbines in Germany increased from almost 9,000 to more than 25,000. Since the turbines during the same period clearly improved in capacity – for example, the rotor diameter on average increased from 42 to 66 meter – the average capacity increased from 611 to 1453 kilowatt. The installed capacity increased from 5.7 gigawatt to 37.6 gigawatt. "The difference between the expected and the actual power yield has remained relatively constant over the years," says Sonja Germer, scientific researcher in the task group. The researchers did not find any drop in efficiency linked to the increased number of turbines. "We probably don't use enough wind energy yet to be able to see the influence of reduced wind speeds clearly enough," says Sonja Germer.

Wind turbines are getting more and bigger. This is another reason why their share of generating electricity in Germany has risen to 9.1 percent by 2014 - equivalent to 58.9 terawatt hours. Wind turbines near Coppanz, Thuringia (© Axel Kleidon)

Original publication

Sonja Germer and Axel Kleidon (2019) Have wind turbines in Germany generated electricity as would be expected from the prevailing wind conditions in 2000-2014? PLOS ONE. doi:10.1371/journal.pone.0211028

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Contact

Axel Kleidon
Max Planck Institute for Biogeochemistry
Jena, Germany
Telephone: +49 3641 57 6217
Mobile: +49 170-9260144
e-mail: akleidon@bgc-jena.mpg.de