

## European Solar and Energy Storage Solutions

# Wind power generation efficiency declines



## Overview

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This global decline in wind power density is particularly intense in specific areas: Quebec in Canada (40 %) and the Great Plains in the US (25 %). By contrast, increases in wind power density (~20 %) are anticipated in Hudson Bay and the Northern Passage - an extension of the general growth in wind resources in the polar regions.

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By accounting for individual site conditions we confirm that load factors do decline with age, at a similar rate to other rotating machinery. Wind turbines are found to lose  $1.6 \pm 0.2\%$  of their output per year, with average load factors declining from 28.5% when new to 21% at age 19.

Experts anticipate cost reductions of 17%–35% by 2035 and 37%–49% by 2050 under a median or best-guess scenario, driven by bigger and more efficient wind turbines, lower capital and operating costs, and other advancements. The findings are described in an article in Nature Energy, with further details on the Berkeley Lab website.

Then, we summarize how greenhouse-gas-induced climate change might impact wind power generation and the LCoE of wind-derived electricity via changes in wind resource magnitude.

Data from our Power Plant Operations Report show that U.S. wind generation in 2023 totaled 425,235 gigawatthours (GWh), 2.1% less than the 434,297 GWh generated in 2022. U.S. wind capacity increased steadily over the last several years, more than tripling from 47.0 GW in 2010 to 147.5 GW at the end of 2023. Do wind turbine load factors decline with age?

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How has wind power changed over the last year?

U.S. wind capacity increased steadily over the last several years, more than tripling from 47.0 GW in 2010 to 147.5 GW at the end of 2023. Electricity generation from wind turbines also grew steadily, at a similar rate to capacity, until 2023.

How much will wind energy cost reduce by 2035?

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Why do wind farms lose output a decade?

Onshore wind farm output falls 16% a decade, possibly due to availability and wear. Performance decline with age is seen in all farms and all generations of turbines. Decreasing output over a farm's life increases the levelised cost of electricity. Ageing is a fact of life.

What is the average decline rate of wind turbines?

This decline rate appears stable until 2002, after which it reduces for more recently commissioned turbines. Farms built before 2003 have an average decline rate of  $-0.49 \pm 0.05$  points per year, whereas those built afterwards average  $-0.16 \pm 0.08$ .

How much do wind turbines lose a year?

Wind turbines are found to lose  $1.6 \pm 0.2\%$  of their output per year, with average load factors declining from 28.5% when new to 21% at age 19. This trend is consistent for different generations of turbine design and individual wind farms.

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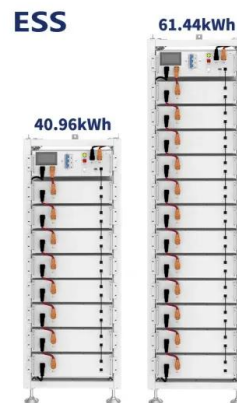
### Wind Energy Factsheet , Center for Sustainable Systems



Wind speeds are slower close to the Earth's surface and faster at higher altitudes. Average hub height is 98m for U.S. onshore wind turbines 7, and 116.6m for global offshore turbines 8.; ...

### Experts Predict 50% Lower Wind Costs Than They Did ...

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### Experts Predict 50% Lower Wind Costs Than They Did ...

Study shows expected cost declines of 37%-49% by 2050 . Technology and commercial advancements are expected to continue to drive down the cost of wind energy, according to a survey of the world's foremost ...

### Data-Driven Assessment of Wind Turbine Performance Decline ...

The discussion about the meaning of wind turbine performance decline with age, given that, as discussed in Section 4, the collected results indicate that it is questionable to pose that ...



## Inertia-based Fast Frequency Response from Wind Turbines

In large grids with significant penetration of wind (and solar PV) power: oModern variable speed wind turbine-generators do not contribute to system inertia oSystem inertia declines as wind ...

## The impact of environmental regulation on green investment efficiency ...

In terms of green investment focus, thermal power unit renovation has a more obvious role in boosting the green investment efficiency of thermal power enterprises than do ...

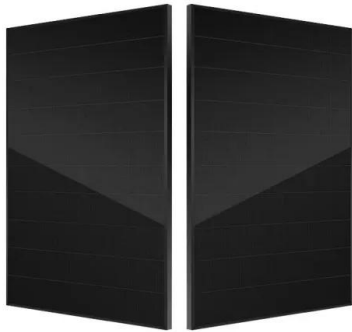


## Why did renewables become so cheap so fast?

Wind power - shown in blue - also follows a learning curve. The onshore wind industry achieved a learning rate of 23%. Every doubling of capacity was associated with a price decline of almost a quarter. Offshore ...

## Same-plant trends in capacity factor and heat rate for US power ...

Most notably, same-plant efficiency declines at US coal-fired power plants, rises at natural gas plants, and stays stable at nuclear plants during the analysis period. This result ...



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