Wind Energy from a Weibull Wind Distribution

Annual energy and capacity factor of a wind turbine from mean wind speed corrected to hub height, a Weibull shape factor and a simple power curve.

Method: Weibull wind statistics and power-law shear (Manwell, McGowan and Rogers, Wind Energy Explained, 2nd ed., ch. 2)

Input parameters

Unit system: SI

Parameter	Value	Unit
Mean wind speed at the reference height	6.0000	m/s
Reference height	10.000	m
Hub height	100.00	m
Shear exponent	0.14000	
Weibull shape factor	2.0000	
Rated power	2,000.0	kW
Cut-in speed	3.0000	m/s
Rated speed	12.000	m/s
Cut-out speed	25.000	m/s
Availability and other losses	10.000	%

Calculated results

Parameter	Value	Unit
Mean speed at hub height	8.2823	m/s
Weibull scale at hub height	9.3456	m/s
Mean wind power density	664.60	W/m²
Capacity factor	36.018	%
Annual energy	6,314.7	MWh

Notes for this case

- Simplified power curve: cubic between cut-in and rated speed, rated output to cut-out. Use the maker's power curve for a bankable estimate. Weibull k ≈ 2 (Rayleigh) for most inland sites; air density 1.225 kg/m³.

Formula and method

$$\bar{v}_h = \bar{v}_r \left(\frac{z_h}{z_r}\right)^{\alpha}, \quad c = \frac{\bar{v}_h}{\Gamma(1+1/k)}, \quad CF = (1-f_l)\int P(v) f(v)\, dv / P_r, \quad E = CF P_r t_a, \quad \frac{P}{A} = \frac{1}{2}\rho_0 c^3 \Gamma\left(1+\frac{3}{k}\right)$$

Variables

$\bar{v}_r$	Mean wind speed at the reference height	m/s
z_r	Reference height	m
z_h	Hub height	m
α	Shear exponent	-
k	Weibull shape factor	-
P_r	Rated power	W
v_{in}	Cut-in speed	m/s
v_r	Rated speed	m/s
v_{out}	Cut-out speed	m/s

f_l	Availability and other losses	-
$\bar{v}_h$	Mean speed at hub height	m/s
C	Weibull scale at hub height	m/s
P/A	Mean wind power density	W/m²
CF	Capacity factor	-
E	Annual energy	J
t_a	One year, 365.25 days (8 766 h)	s
ρ_0	Air density, fixed at 1.225 kg/m³	kg/m³

Method and standards

Weibull integration.

Assumptions and limits

- The year is 365.25 days (8 766 h), allowing for leap years; calculators that use 8 760 h give energy about 0.07 % lower.
- The power density uses a fixed air density of 1.225 kg/m³ (sea level, 15 °C); scale it by the site density for altitude or temperature. The capacity factor comes from the normalised power curve and does not depend on density.
- Weibull distribution; simplified power curve.

References

• Weibull wind statistics and power-law shear (Manwell, McGowan and Rogers, Wind Energy Explained, 2nd ed., ch. 2)

Report details

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Results are for engineering estimation. Verify critical designs against the referenced standards and your own data.

This calculator online

https://calc.firecad.com/environmental/carbon-energy/wind-energy-weibull

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Reopens the calculator with the inputs of this report.