Wind Turbine Power, Betz Limit and Annual Energy

Power in the wind through a rotor, the turbine output at a power coefficient (Betz limit 16/27), and annual energy from a capacity factor.

Method: P = ½ρAv³C_p; Betz (1920) limit C_p ≤ 16/27

Input parameters

Unit system: SI

Parameter	Value	Unit
Air density	1.2250	kg/m³
Rotor diameter	100.00	m
Wind speed at hub height	9.0000	m/s
Power coefficient (turbine and drive)	42.000	%
Capacity factor (for annual energy)	30.000	%

Calculated results

Parameter	Value	Unit
Swept area	7,854.0	m²
Power in the wind ½ρAv³	3.5069	MW
Betz-limit power (16/27)	2.0782	MW
Turbine output at C_p	1.4729	MW
Annual energy at the capacity factor	3,870.8	MWh

Notes for this case

• Annual energy here scales the output at this wind speed by the capacity factor; a proper estimate uses the power curve and the site's wind distribution.

Formula and method

$$P = \frac{1}{2}\rho A v^3 C_p, \quad C_{p,max} = \frac{16}{27}$$

Variables

ρ	Air density	kg/m³
D	Rotor diameter	m
v	Wind speed at hub height	m/s
C_p	Power coefficient (turbine and drive)	-
CF	Capacity factor (for annual energy)	-
A	Swept area	m²
P_w	Power in the wind ½ρAv³	W
P_{Betz}	Betz-limit power (16/27)	W
P	Turbine output at C_p	W
E	Annual energy at the capacity factor	J

Method and standards

Actuator disc.

Assumptions and limits

- Annual energy = P × CF × 8 760 h (a 365-day year): the output at one wind speed scaled by a capacity factor, not an integral over a power curve and wind distribution. The Weibull wind energy calculator does that, with a 365.25-day year, so its CF means the long-term average output over rated power.

- Steady uniform wind.

References

- P = ½ρAv³C_p; Betz (1920) limit C_p ≤ 16/27

Report details

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Release checks	2 reference cases of this calculator, computed independently, are checked on every release

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-turbine-power

Open this case on calc.firecad.com →

Reopens the calculator with the inputs of this report.