Wind Turbie Economics

Energy Calculation for Wind Turbine

specification

Manufacturer:	NEG Micon	NEG Micon	NEG Micon	Vestas	Whisper	Wind World	Nordex	Bonus
Rated Power (kW):	1000	1000	1500	600	0.9	250	1300	300
Diameter (m):	60	54	64	42	2.13	29.2	60	33.4
Windspeed								
v (m/s)	kW	kW	kW	kW	kW	kW	kW	kW
0	0	0	0	0	0.00	0	0	0
1	0	0	0	0	0.00	0	0	0
2	0	0	0	0	0.00	0	0	0
3	0	0	0	0	0.03	0	0	4
4	33	10	9	0	0.08	0	25	15
5	86	51	63	22	0.17	12	78	32
6	150	104	159	65	0.25	33	150	52
7	248	186	285	120	0.35	60	234	87
8	385	291	438	188	0.45	92	381	129
9	535	412	615	268	0.62	124	557	172
10	670	529	812	356	0.78	153	752	212
11	780	655	1012	440	0.90	180	926	251
12	864	794	1197	510	1.02	205	1050	281
13	924	911	1340	556	1.05	224	1159	297
14	964	986	1437	582	1.08	238	1249	305
15	989	1006	1490	594	1.04	247	1301	300
16	1000	998	1497	598	1.01	253	1306	281
17	998	984	1491	600	1.00	258	1292	271
18	987	971	1449	600	0.99	260	1283	259
19	968	960	1413	600	0.97	259	1282	255
20	944	962	1389	600	0.95	256	1288	253
21	917	967	1359	600	0.00	250	1292	254
22	889	974	1329	600	0.00	243	1300	255
23	863	980	1307	600	0.00	236	1313	256
24	840	985	1288	600	0.00	230	1328	257
25	822	991	1271	600	0.00	224	1344	258
26	0	0	0	0	0.00	0	0	0

Source: Mostly based on data in www.windpower.dk.

Energy Production Calculation

(a) Using the Specification
    (provided by manufacturers)
(b) Using Capacity Factor (CF)

Energy Calculation from Specification

- Suppose that a NEG Micon 60-m diameter wind turbine having a rated power of 1000 kW (often expressed as 1000/60) is installed at a site having Rayleigh wind statistics with an average wind speed of 7 m/s at the hub height.
  - (a) Find the annual energy generated,
  - (b) From the result, find the overall average efficiency of this turbine in these winds,
  - (c) Find the productivity in terms of kWh/yr per m^2 of swept area.

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18	987
19	968
20	944
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23	863
24	840
25	822
26	0

Operation hours extraction from Rayleigh Distribution

- If average wind speed is given, probability of any wind speed can be found

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3	0
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Program – Excel Spreadsheet

Example Calculation by Spec

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- Total Electric Energy Production per year

- Total Energy in the Wind per year

- Average Efficiency of the Wind Turbine

- Productivity by the swept area

Energy Calculation for Wind Turbine – with CF

- **Calculation with Turbine Specification is complex**

  every possible wind speed is considered

- Easier approach – Use of the **Rated Power (P_R)** of Wind Turbine & **CF** (Capacity Factor)

  - Capacity Factor (CF): Actual energy generation expressed as percentage of the maximum possible energy generation with the rated power (P_R*8760)

  - **Actual Energy by CF**

$$\text{CF} = \frac{\text{Actual energy delivered}}{P_R \times 8760}$$

$$\text{Annual energy (kWh/yr)} = P_R \text{ (kW)} \times 8760 \text{ (h/yr)} \times \text{CF}$$

Capacity Factor

- What is the CF of Micon 1000/60 In the previous example?

Total Energy produced 2.85×10^6 kWh/yr.

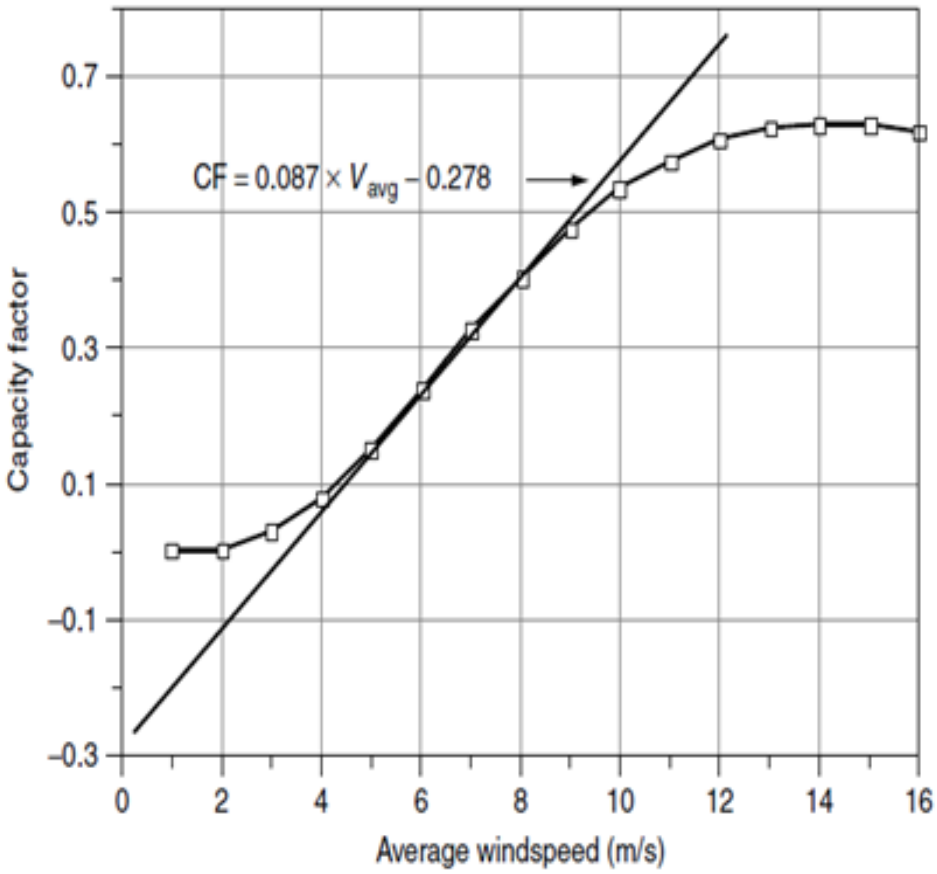
Rated Power (P_R) = 1000 kW

$$CF = \frac{\text{Actual energy delivered}}{P_R \times 8760} = \frac{2.851 \times 10^6 \text{ kWh/yr}}{1000 \text{ kW} \times 8760 \text{ h/yr}} = 0.325$$

- **Is this CF (0.325) the same at all average wind speeds?**

325_Ch6_3_CF by AVG Wind Speed.xlsx

Capacity Factor Determination – Approximation



Energy Estimate using CF

- Question: The Whisper H900 wind turbine has a 900-W generator with 2.13 m blade diameter. In an area with 6 m/s average wind speed, estimate the energy delivered.

Wind Turbine Economics

60 MW Wind farm
1.5 MW turbines (x 40)

Capital Costs	Amount ($)	Percentage
40 1.5-MW turbines @ $1.1 M, spare parts	46,640,000	76.6
Site prep, grid connections	9,148,000	15.0
Interest during construction, contingencies	3,514,000	5.8
Project development, feasibility study	965,000	1.6
Engineering	611,000	1.0
Total Capital Cost	60,878,000	100.0

Annual Costs	Amount ($/yr)	Percentage
Parts and labor	1,381,000	70.3
Insurance	135,000	6.9
Contingencies	100,000	5.1
Land lease	90,000	4.6
Property taxes	68,000	3.5
Transmission line maintenance	80,000	4.1
General and miscellaneous	111,000	5.6
Total Annual Costs	1,965,000	100.0

Source: Ministry of Natural Resources, Canada.

Annualized Cost

- Annualized Fixed Cost [$/yr]

$$FCR = \left[\frac{i(1+i)^n}{(1+i)^n - 1} \right]$$

- Annual (O&M) Cost

- **Annual Cost = Annual Payment (A) + Annual O&M Cost**

- Cost of Energy ($/kWh)

Electric Energy Cost - Example

- Suppose that a 900-W Whisper H900 wind turbine with 7-ft (2.13 m) blade costs $1600. By the time the system is installed and operational, it costs a total of $2500, which is to be paid from with a 15-yr, 7% interest loan. Assume O&M costs of $100/yr. **Question:** Estimate the energy cost [$/kWh] over the 15-year period if average wind speed at the hub height is 6.7 m/s.