Exercise : *Wind Energy*

Let us consider a wind turbine with a rotor diameter of **8 m** and **3 blades**.

The performance measurements according to the wind speed are given in the table below:

Wind speed m/s	**Mean Power (W)**	**% of time in one year**
1	0	0.9%
2	0	2.6%
3	231	7.7%
4	709	10.9%
5	1535	14.4%
6	2873	16.2%
7	4384	14.0%
8	5952	10.9%
9	8015	7.9%
10	9823	5.5%
11	10112	3.7%
12	10304	2.6%
13	10512	1.1%
14	10305	0.9%
15	10096	0.7%

1) The manufacturer displays a rated power of **10 KW for 10m/s**. is it exact?

2) Deduce the efficiency coefficient ***Cp*** of the wind turbine **at 10m/s.**

The density of air **ρ = 1.225kg /m3.**

3) **Calculate the annual operating time *D*:**

The annual operating time is defined as the quotient of the energy bought back **during a year (365 days)** of operation of the installation by the maximum active power of the same installation (**10 kW**).

4) The investment cost of this wind turbine is **26.500 euros**. operation and maintenance costs are estimated at **500 euros / year**. In order to evaluate the return on investment and given EDF's electricity purchase price as defined below. calculate the **payback period PBT** of the installation (time for which the wind turbine is reporting as much as it has cost).

Annual reference operating time D	Price for **the first 10 years** (€/kWh)	Price **for the following 5** years (€/kWh)
3600 h and more	**0.082**	**0.028**

Correction

1) According to table. the mean power is 9823 W. It is **a mean value** near 10000 W.

Therefore. we can admit the **rated power** displayed by the manufacturer. It is exact.

2) $C_p = \frac{P_{eol}}{0.5\times\rho\times\pi\times R^2\times V^3} = \frac{9823}{0.5\times1.225\times\pi\times4^2\times10^3} = 0.31$

3) Annual operating time $D = \frac{Total\ Energy\ per\ year\ produced}{maximum\ active\ power\ 10\ KW}$

Wind speed m/s	Mean Power (W)	% of time in one year	Duration (h) in one year	Produced energy (Kwh)
1	0	0.9%	76.6	0
2	0	2.6%	229.8	0
3	231	7.7%	670.3	155
4	709	10.9%	957.6	679
5	1535	14.4%	1264.0	1940
6	2873	16.2%	1417.2	4072
7	4384	14.0%	1229.5	5390
8	5952	10.9%	957.6	5700
9	8015	7.9%	689.5	5526
10	9823	5.5%	478.8	4703
11	10112	3.7%	325.6	3292
12	10304	2.6%	229.8	2368
13	10512	1.1%	99.6	1047
14	10305	0.9%	76.6	789
15	10096	0.7%	57.5	580
Total Energy per year produced				**36242**

$$D = \frac{Total\ Energy\ per\ year\ produced}{maximum\ active\ power\ 10\ KW} = \frac{36242kWh}{10kW} = 3624h.$$

4) Expected revenues for the first 10 years:

$$R = 36242 \times 0.082 - 500 = 2472\ euros/year$$

Expected revenues for the following 5 years:

$$R = 36242 \times 0.028 - 500 = 515\ euros/year$$

Depreciation period:

$$PBT = 13.5\ \text{years as}: 26500 \cong 10\ \text{years} \times 2472€ + 3.5\ \text{years} \times 515\ € = 13.5\ years$$