Estimation of Electricity Production for a Moroccan Wind Farm

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Plan

- Present the wind speed data
- Model the wind speed distribution
- Estimate the available wind power density
- Estimate the usable wind power
- Summary

Studied parks

Wind speed data

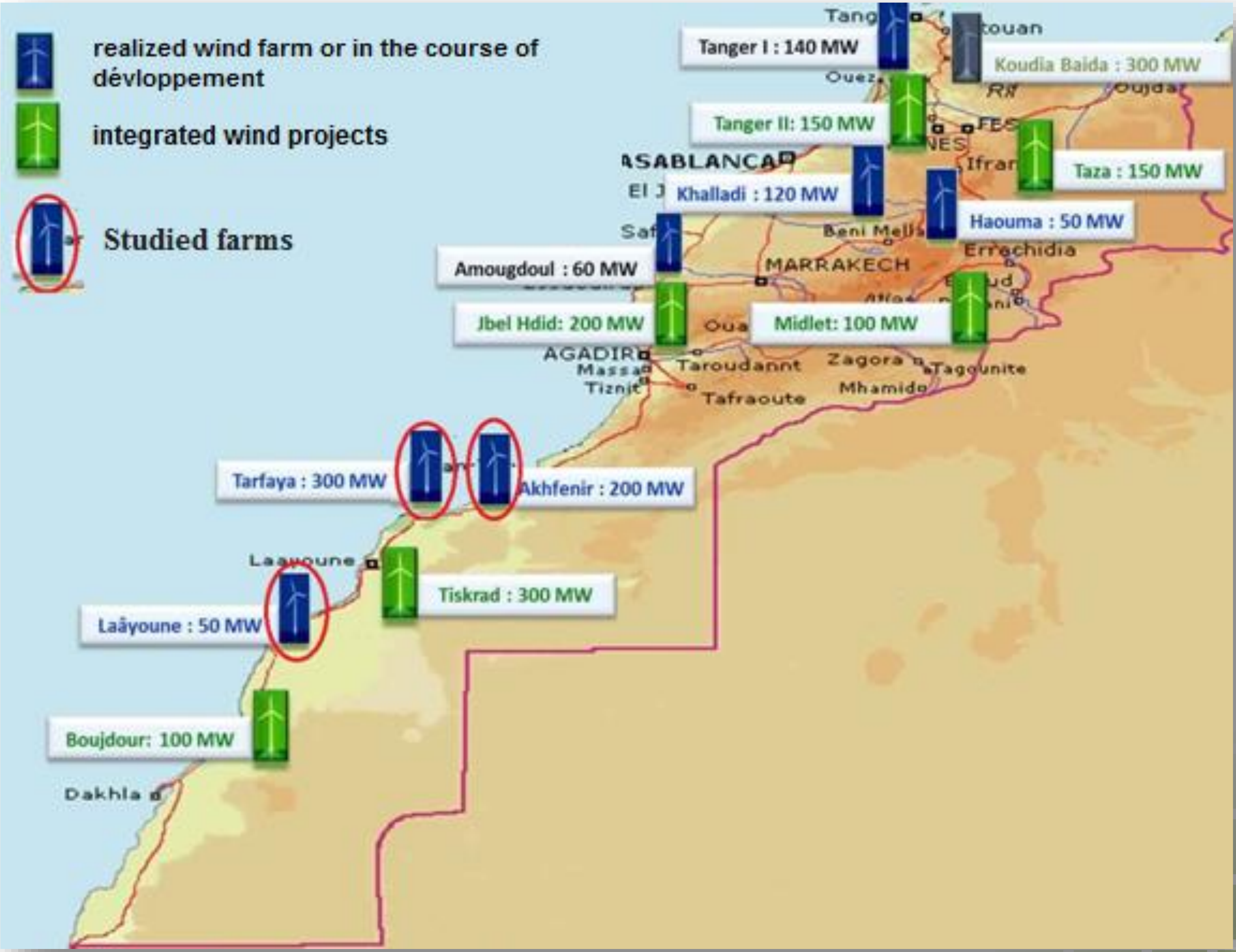
Wind speed data

Modeling the wind speed distribution

Estimation of available wind power density

Estimation of usable wind power

Summary



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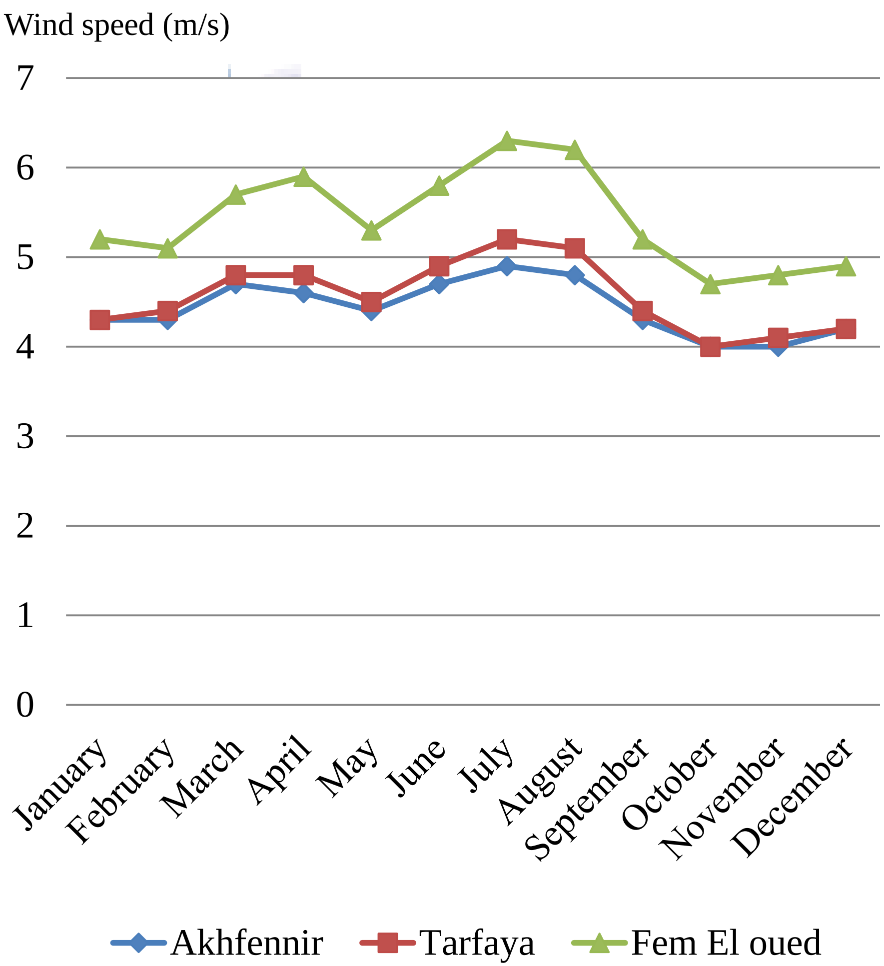
Wind speed data

Modeling the wind speed distribution

Estimation of Available wind power density

Estimation of Usable wind power

Summary



Month	Akhfennir	Tarfaya	Fem El Oued
January	4.3	4.3	5.2
February	4.3	4.4	5.1
March	4.7	4.8	5.7
April	4.6	4.8	5.9
May	4.4	4.5	5.3
June	4.7	4.9	5.8
July	4.9	5.2	6.3
August	4.8	5.1	6.2
September	4.3	4.4	5.2
October	4	4	4.7
November	4	4.1	4.8
December	4.2	4.2	4.9
Average	4 .4	4.6	5.4

https://eosweb.larc.nasa.gov/cgi-bin/sse/sse.cgi?rets@nrcan.gc.ca

- Weibull
- Rayleigh
- Lognormal …

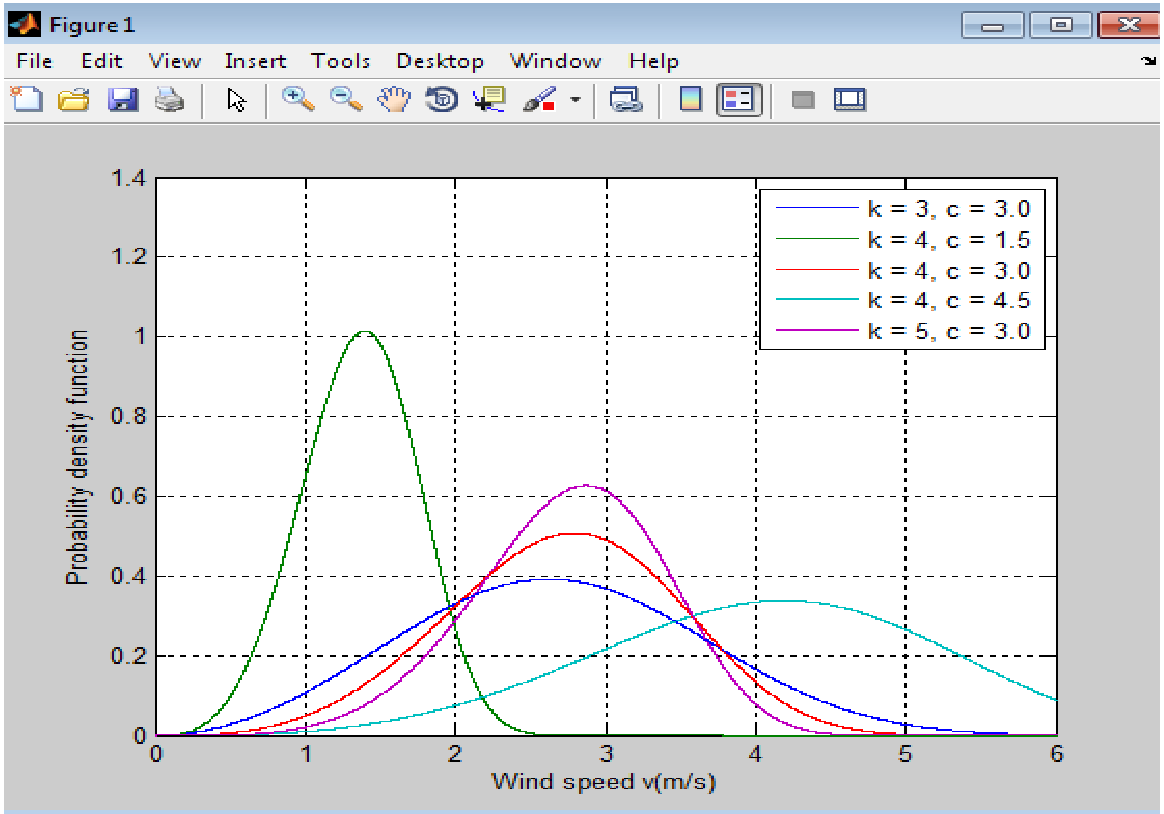
✓**Weibull** is widely used, accepted and recommended in the literature.

✓it gives a good agreement with the experimental data.

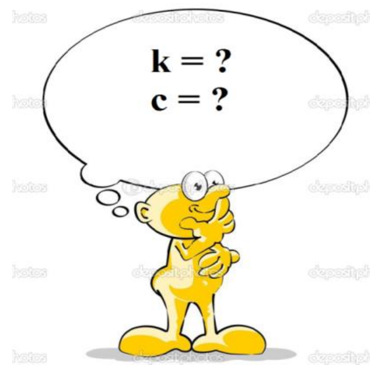
✓it allows determining quickly the average production of a wind turbine.

$$f(v) = \left(\frac{k}{c}\right)\left(\frac{v}{c}\right)^{k-1} \exp\left(-\left(\frac{v}{c}\right)^{k}\right)$$

- v : the wind speed (m/s)
- k : shape factor
- c : scale factor (m/s)



- The method proposed by Mabchour in 1999.



$$k = 1 + (0.483 * (\bar{v} - 2))^{0.51}$$

$$c = \frac{\bar{v}}{\Gamma\left(1 + \frac{1}{k}\right)}$$

Arithmetic mean of wind speed

Gamma function

Wind speed modelisation

Estimation of Weibull parameters at 10 m

Extrapolation of Weibull parameters at 80 m

Wind speed data

Modeling the wind speed distribution

Estimation of Available wind power

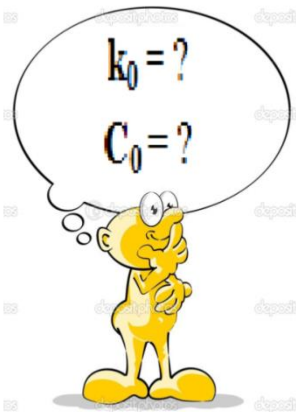
Estimation of Usable wind power

Summary

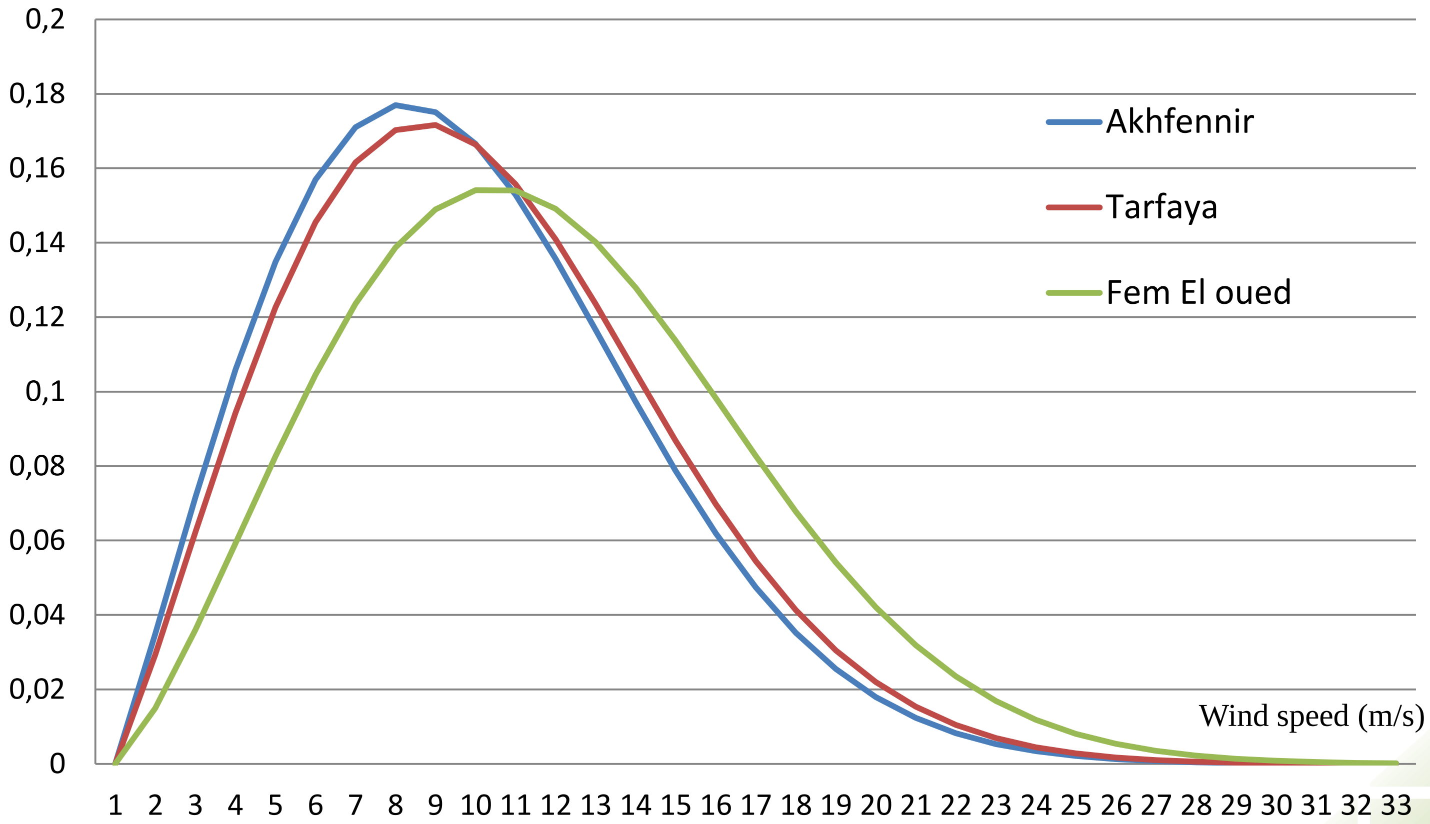
Month	Akhfennir		Tarfaya		Fem El Oued	
	C_0 (m/s)	k_0	C_0 (m/s)	k_0	C_0 (m/s)	k_0
January	4.85	2.06	4.86	2.06	5.87	2.25
February	4.85	2.06	4.97	2.08	5.76	2.23
March	5.31	2.15	5.42	2.17	6.43	2.34
April	5.19	2.12	5.42	2.17	6.66	2.38
May	4.97	2.08	5.08	2.1	5.98	2.27
June	5.31	2.15	5.53	2.19	6.55	2.36
July	5.53	2.19	5.87	2.25	7.11	2.45
August	5.42	2.17	5.76	2.23	7	2.43
September	4.85	2.06	4.97	2.08	5.87	2.25
October	4.52	1.98	4.52	1.98	5.31	2.15
November	4.52	1.98	4.63	2.01	5.42	2.17
December	4.74	2.03	4.74	2.03	5.53	2.19
Average	5.00	2.08	5.15	2.11	6.12	2.29

Fem El Oued is the **windiest** farm.

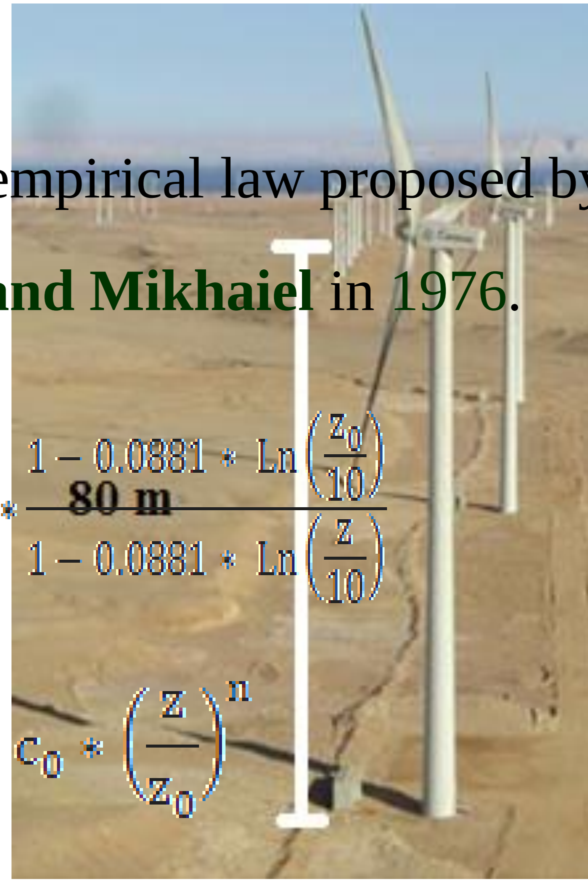
wind speed is more **uniform** in Fem El Oued



Adjustment of the Weibull law on the wind speed distribution of the three parks at height of 10 m.



- The empirical law proposed by **Justus and Mikhaiel** in 1976.



$$k_z = k_0 * \frac{1 - 0.0881 * \text{Ln}\left(\frac{z_0}{10}\right)}{1 - 0.0881 * \text{Ln}\left(\frac{z}{10}\right)}$$

$$c_z = c_0 * \left(\frac{z}{z_0}\right)^n$$

$$n = \frac{0.37 - 0.0881 * \text{Ln}c_0}{1 - 0.0881 * \text{Ln}\left(\frac{z_0}{10}\right)}$$

Month	Akhfennir		Tarfaya		Fem El Oued	
	C_{80} (m/s)	k_{80}	C_{80} (m/s)	k_{80}	C_{80} (m/s)	k_{80}
January	7.84	2.52	7.85	2.52	9.16	2.75
February	7.84	2.52	7.99	2.54	9.02	2.73
March	8.44	2.63	8.58	2.65	9.87	2.87
April	8.29	2.6	8.58	2.65	10.16	2.92
May	7.99	2.54	8.14	2.57	9.3	2.78
June	8.44	2.63	8.73	2.68	10.02	2.89
July	8.73	2.68	9.16	2.75	10.72	3
August	8.58	2.65	9.02	2.73	10.58	2.98
September	7.84	2.52	7.99	2.54	9.16	2.75
October	7.39	2.43	7.4	2.43	8.44	2.63
November	7.39	2.43	7.55	2.46	8.58	2.65
December	7.7	2.49	7.7	2.49	8.73	2.68

Available wind power density

Estimated Available wind power density

Wind speed data

Modeling the wind speed distribution

Estimation of Available wind power density

Estimation of Usable wind power

Summary

The average of available wind power density is given by:

$$P_{av} = \frac{1}{2} \rho \langle v^3 \rangle$$

Air density in (kg/m3)

$$\langle v^3 \rangle = c^3 . \Gamma\left(1 + \frac{3}{k}\right)$$

$$\rho = 3.485 \frac{P}{T}$$

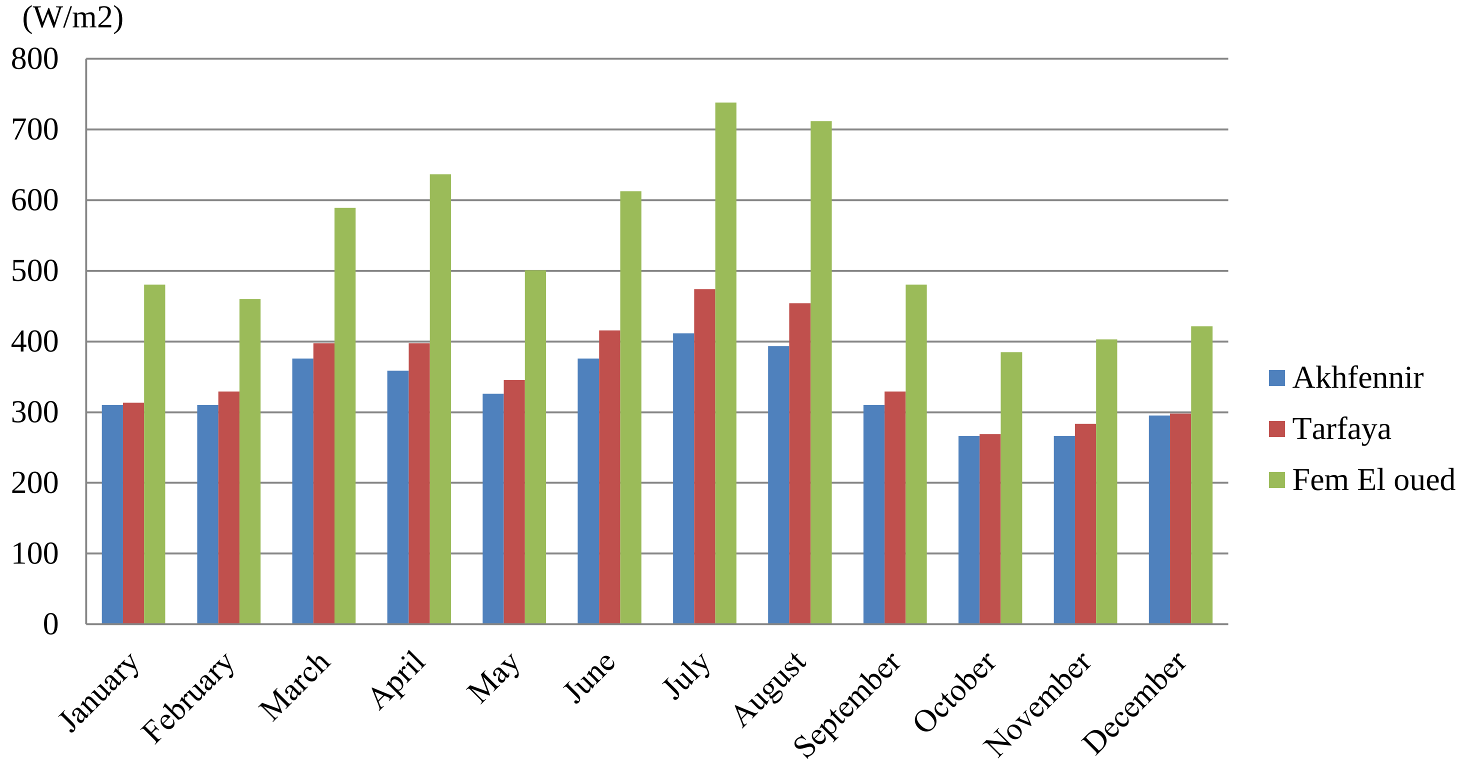
P → Pression en (k Pa)

T → Temperature (k)

	Akhfennir	Tarfaya	Fem El Oued
P: Pressure average (kPa)	99	100	101
T: Temperature average (K)	294.45	294.55	293.15
ρ: **Air density average (kg/m3)**	**1.17**	**1.18**	**1.20**

Available wind power density

Estimated available wind power density



The investment in Fem El Oued can be profitable

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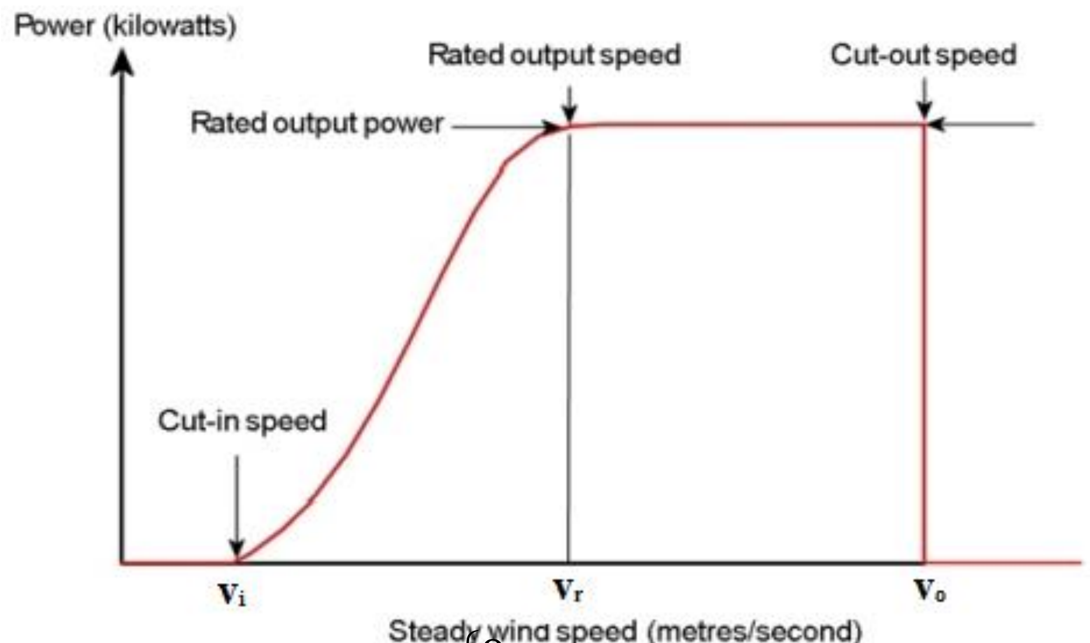
$$P_e = \eta \quad P_u$$

Usable wind power (P_e) — Machine efficiency (η) — Useful wind power (P_u)

$$\eta = 2 \times \frac{P_r}{\rho A \quad v_r^3}$$

P_r : rated power
A: swept area
v_r : rated wind speed

		P_r per unit (KW)	A (m2)	V_r (m/s)	Efficiency (%)
Akhfennir	Field 1	1670	11700	11	**11.09**
	Field 2	1700	7854	13	**27.76**
Tarfaya		2300	8012	12	**28.08**
Fem EL oued		2300	8012	12	**28.08**



$$P_u = \begin{cases} 0; v < v_i \\ \frac{1}{2}\rho \quad v^3 \quad ; v_i \le v \le v_r \\ \frac{1}{2}\rho \quad {v_r}^3 \quad ; v_r \le v \le v_o \\ 0; v \ge v_o \end{cases}$$

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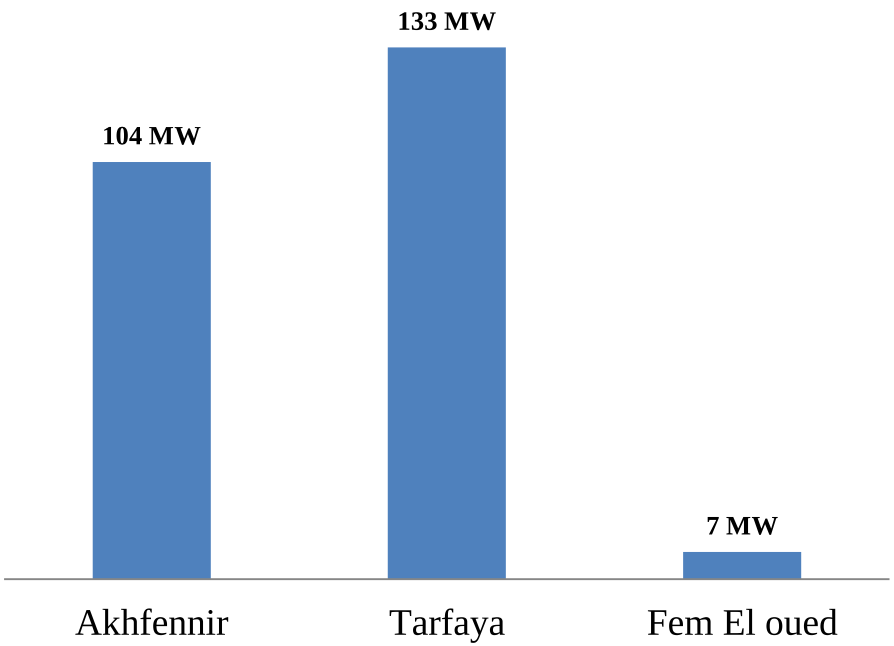
		Turbines manufacturer	Turbines model	Number of turbine	Cut-in speed (m/s)	Rated speed (m/s)	Cut-out speed (m/s)
Akhfennir	**Field 1**	General Electric	1.7-100	61	3.5	11	23
	Field 2	Alstom-Ecotècnia	ECO 74	56	3	13	25
Tarfaya		Siemens SWT-2.3-101	SWT-2.3-101	131	3	12	20
Fem El oued		Siemens SWT-2.3-101	SWT-2.3-101	22	3	12	20

http://eolienne.f4jr.org/

The estimated useful power is 537 MW in Akhfennir, 473 MW in Tarfaya and 25 MW in Fem El oued.



This result depends not only on the available power at each park, but also on the number of wind turbines and their characteristics, that is why Fem El Oued has the lowest production.

Summary

- ✓ Fem El Oued is the windiest park, and the wind speed is more uniform in this park.
- ✓ The wind potential is very important in Fem El Oued, so, the investment in this park can be profitable.
- ✓ Fem El Oued has the lowest production because there is a less number of turbines.


Thank You

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