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Prospect of wind energy as a resource for water pumping in Ngaoundere

Presented by:

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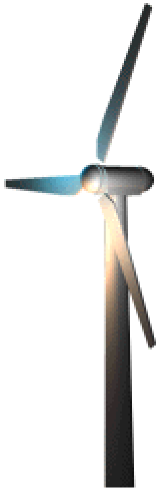
Outline

- Problem statement
- Aim of the study
- Methodology
- Results
- Conclusion



How can we help them to solve the problem about access to water?

Beka-Hosséré

3000 people

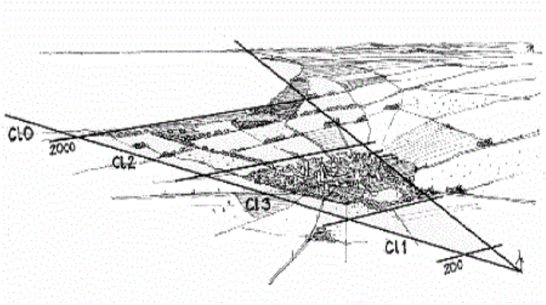
Main activities: Agriculture and cattle farming

Problem: lack of electricity supply and water distribution system

Aim of the study

- Assess the wind potential of our site;
- Compute the amount of water that could be provided for each pump model;
- Select the pump model that can cover the water needs of Beka Hossere's people.

Collection and processing of data



Wind

Roughness

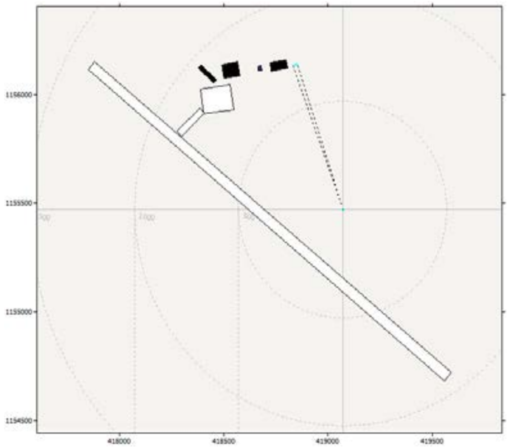
Data

Topography

Obstacle

1h measurement

- Speed (m/s)
- Direction (°)



SRTM Data

1 Arc-second

Jet Propulsion Laboratory
California Institute of Technology

Modelling of the observed wind speed distribution

Weibull's Probability Density Function

$$f(v) = \frac{k}{C}\left(\frac{v}{C}\right)^{k-1} exp\left[-\left(\frac{v}{C}\right)^{k}\right] \quad (1)$$

Modified Maximum Likelihood Method (*Seguro and Lambert, 2000*)

$$k = \left(\frac{\sum_{i=1}^{n} v_i^k Ln(v_i) f(v_i)}{\sum_{i=1}^{n} v_i^k f(v_i)} - \frac{\sum_{i=1}^{n} Ln(v_i) f(v_i)}{F(v \geq 0)}\right)^{-1} \quad (2)$$

$$C = \left(\frac{1}{F(v \geq 0)} \sum_{i=1}^{n} v_i^k f(v_i)\right)^{\frac{1}{k}} \quad (3)$$

Mean wind speed and Energy density (*Boudia et al., 2015*)

$$\bar{V} = C\,\Gamma\left(1 + \frac{1}{k}\right) \quad (4)$$

$$E_D = \frac{1}{2}\rho C^3 \Gamma\left(1 + \frac{3}{k}\right) \quad (5)$$

Extrapolation of the Weibull parameters:

Justus and Mikhail Law (1978, 2011):

$$k_h = k_a\left[1 - 0.0881 Ln\left(\frac{Z_h}{10}\right)\right]^{-1} \quad (6)$$

$$C_h = C_a\left(\frac{Z_h}{Z_a}\right)^{n} \quad (7)$$

$$n = 0.37 - 0.0881 Ln C_a \quad (8)$$

Modelling of the power curve

$$P_T(v) = \frac{P_{i+1} - P_i}{v_{i+1} - v_i}(v - v_i) + P_i \quad (9)$$

$$P_{EL} = \int_{V_d}^{V_n} P_T(v)\, f(v) dv + P_n \int_{V_n}^{V_a} f(v) dv \quad (10)$$

$$E_{EL} = P_{EL} * N_H \quad (11)$$

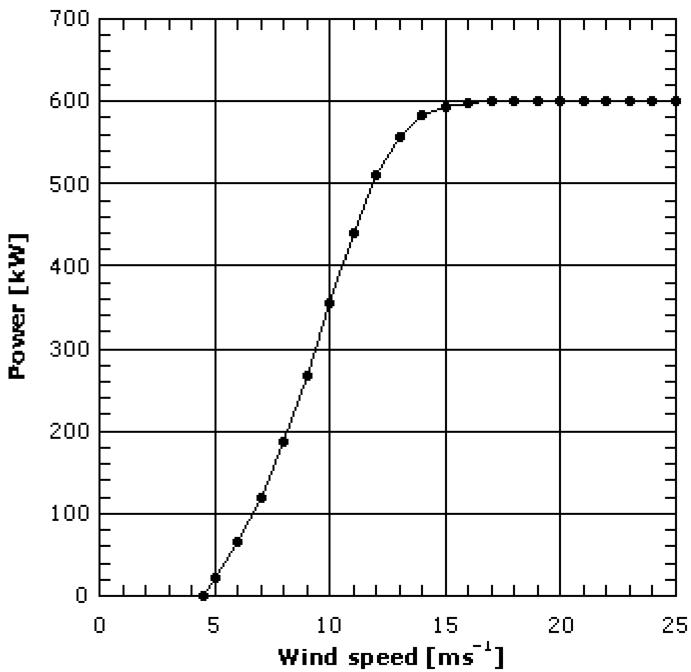


Fig. 1 Actual power curve is approximated by a piece-wise linear function with few nodes. (*Carta et al., 2008*)

Modelling of the water output discharges

Piston pump :

$$Q_P = T \int_{V_I}^{V_O} Q_{VP}(V) f(V) dV \qquad (12)$$

$$\boldsymbol{Q_P = 2C_{Pd}\eta(T,P)\frac{\rho_a}{\rho_W}\frac{\pi D_T^2}{4gH}T\int_{V_I}^{V_O} V^3\left[1-K_O\left(\frac{V_I}{V}\right)^2\right]K_O\left(\frac{V_I}{V}\right)^2\left(\frac{k}{C}\right)\left(\frac{V}{C}\right)^{k-1} exp\left[-\left(\frac{V}{C}\right)^k\right]dV} \qquad (13)$$

Roto-dynamic pump :

$$Q_R = T \int_{V_I}^{V_O} Q_{VR}(V) f(V) dV \qquad (14)$$

$$\boldsymbol{Q_R = \frac{1}{8}kC_{Pd}\eta_{Pd}D_T\frac{\rho_a}{\rho_w}\frac{V_d^3}{gH}\frac{G\lambda_d}{N_{Pd}}T\int_{V_I}^{V_O}\left(\frac{V}{C}\right)^k exp\left[-\left(\frac{V}{C}\right)^k\right]dV} \qquad (15)$$

Electric pump :

$$Q_E = \frac{\eta T}{\rho_w g H}\int_{V_I}^{V_O} P(V) f(V) dV \qquad (16)$$

$$\boldsymbol{Q_E = \frac{\eta T}{\rho_w g H}\left\{\int_{V_I}^{V_R}\left[\frac{P_{i+1}-P_i}{V_{i+1}-V_i}(V-V_i)+P_i\right]\left(\frac{k}{C}\right)\left(\frac{V}{C}\right)^{k-1} exp\left[-\left(\frac{V}{C}\right)^k\right]dV + P_R\int_{V_R}^{V_O}\left(\frac{k}{C}\right)\left(\frac{V}{C}\right)^{k-1} exp\left[-\left(\frac{V}{C}\right)^k\right]dV\right\}} \qquad (17)$$

Table 1: Specifications of water pump models

Pump specifications	Piston	Roto-dynamic	Electric
Wind turbine			V29
Coefficient K	0.25	-	
Cut-in wind speed (m/s)	2.5	2.5	3
Cut-out wind speed (m/s)	10	10	20
Design power coefficient	0.3	0.38	
Design tip speed ratio	-	2	
Design wind velocity	-	6	
Efficiency (pump + transmission)	0.95	0.558	
Gear ratio	-	19.8	
Rated power			255 kW
Rated wind speed			14 m/s
Pump speed at design point (rps)	-	40	-

Collection and processing of data

Table 2: Wind speed statistics in frequency

Wind speed (m/s)	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10
Frequency (%)	51.0	16.3	14.8	12.0	4.8	0.9	0.1	0.1	0.0	0.0

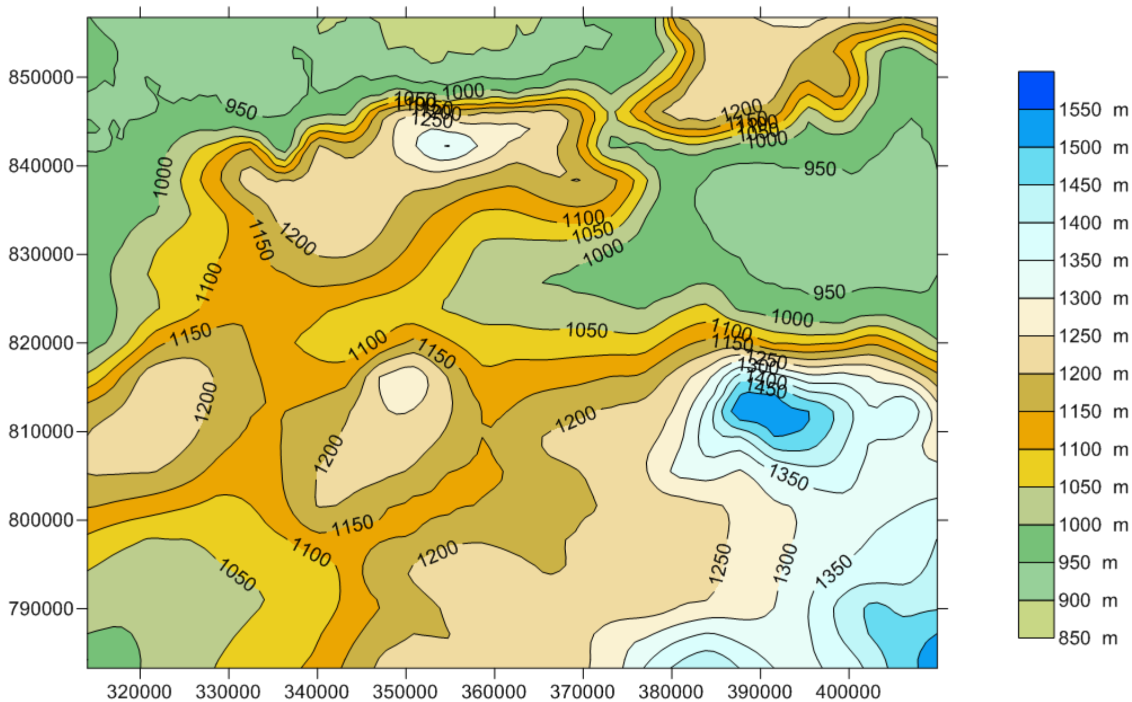


Fig. 2 Topographic map of our site

Modelling of the observed wind speed distribution

Table 3: Wind parameters at 10 m agl

	k -	C (m/s)	$\bar{V}^{10\ m}$ (m/s)	E_D^{10m} (W/m²)
Our results	1.236274	1.690723	1.578156	7.593257
From WasP	1.230	1.700	1.570	8.00

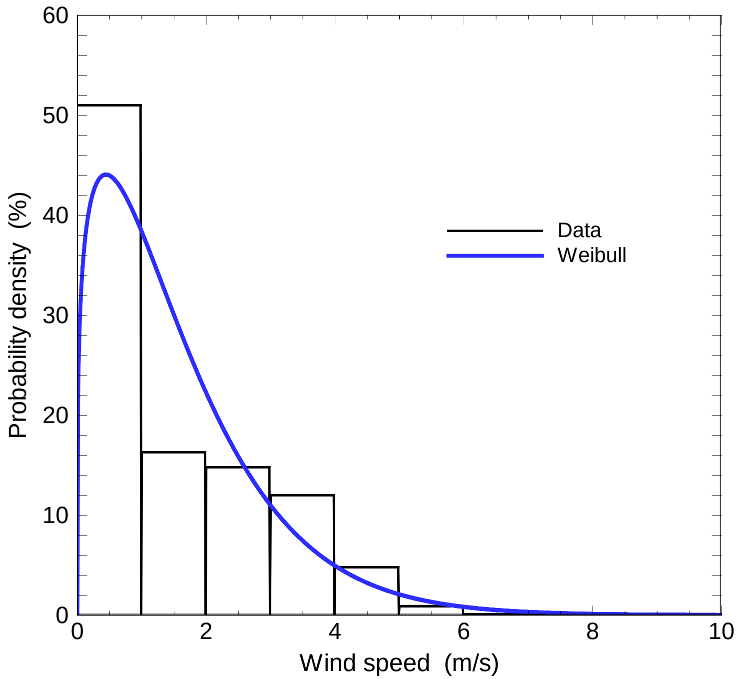


Fig. 3 Wind speed histogram fitted by the Weibull PDF

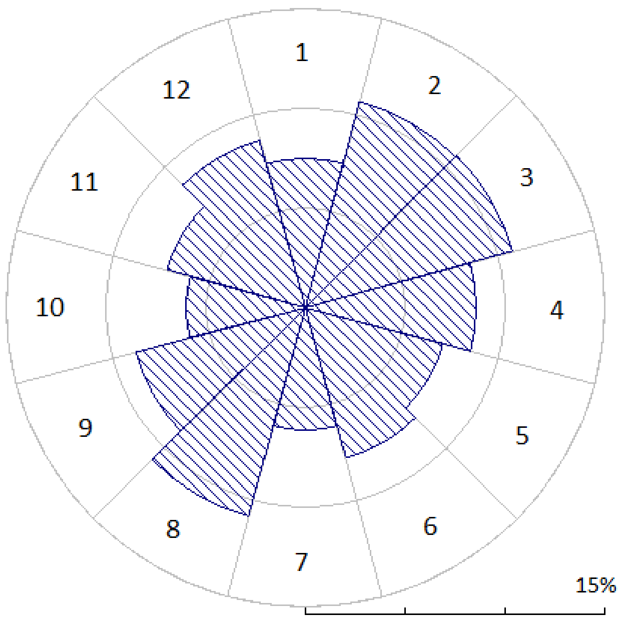


Fig. 4 The wind rose of our site

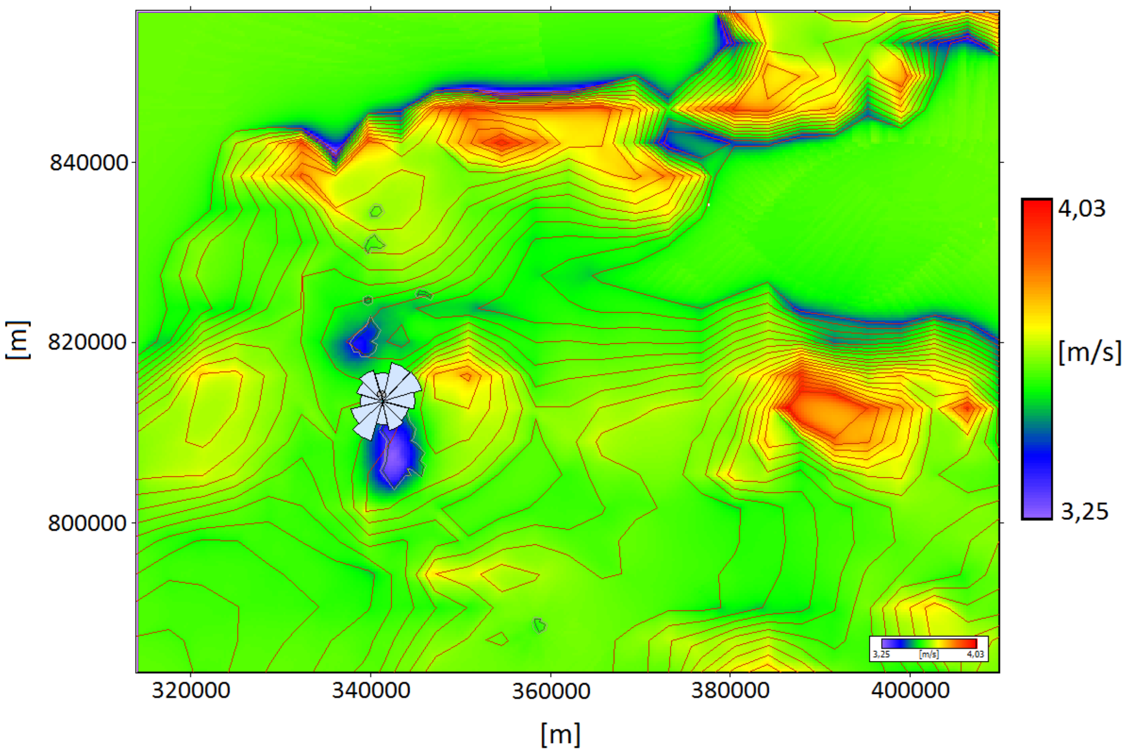


Fig. 5 The wind speed map based on the topographic map generated

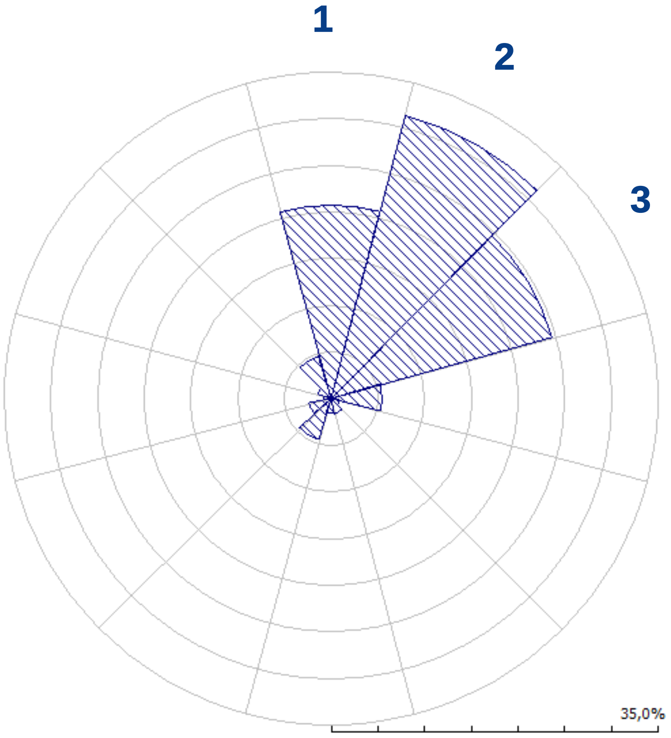


Fig. 6 The wind energy distribution per sector

Computations with Eclipse Juno

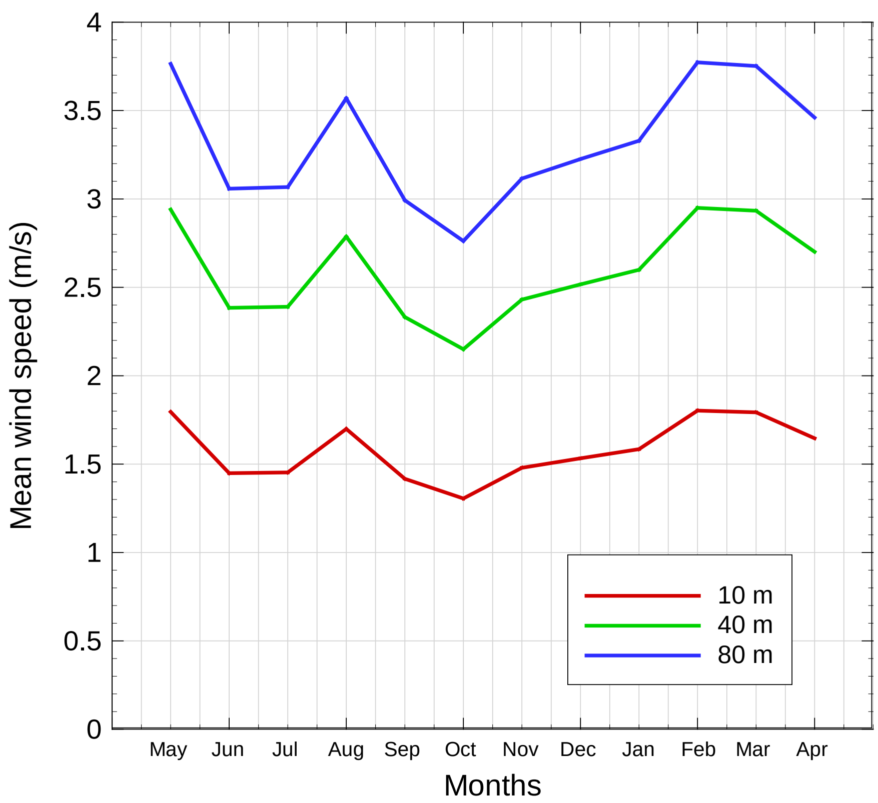


Fig. 7 Vertical wind profile at different heights

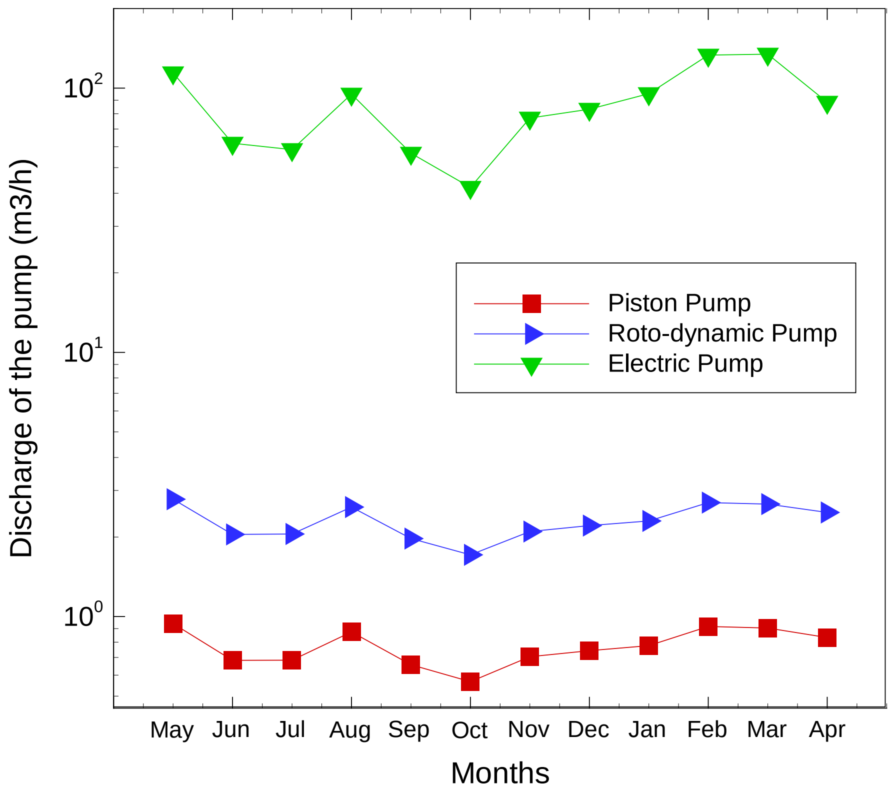


Fig. 8 Monthly water discharge for different type of pump used

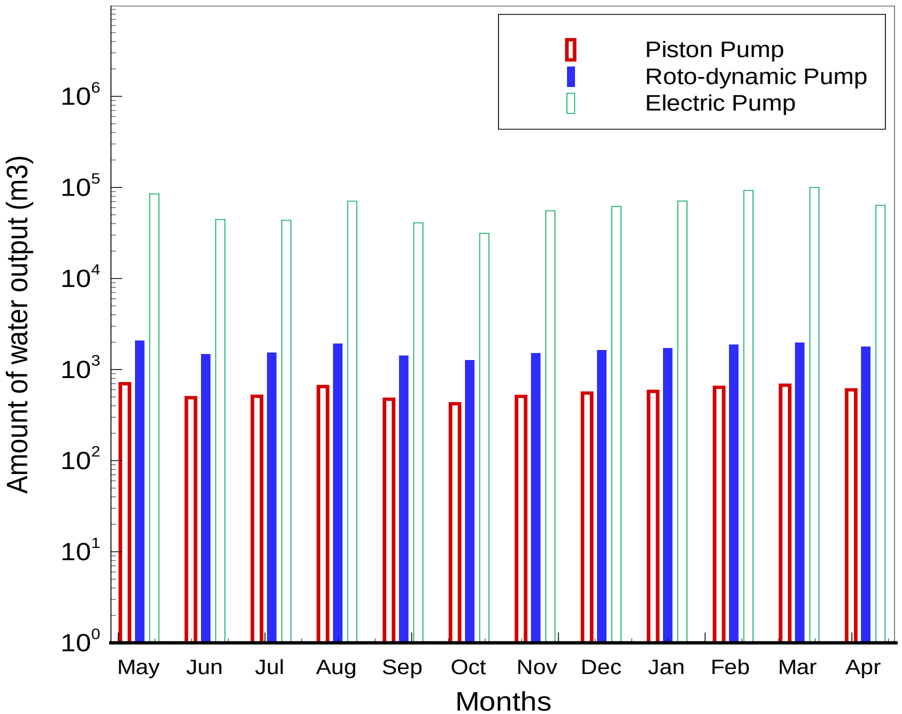


Fig. 9 Monthly water volume provided by each type of pump

Electric water pump

$Q = 754\ 000\ M^3$

3000 Families
15000 people

CO_2 Emissions saved:
16 tons/year

Table 4: Water volume in (m^3) after computations

	may-11	juin-11	july-11	aug-11	sept-11	oct-11	nov-11	dec-11	janv-12	feb-12	mars-12	apr-12	**Annual**
Piston	700	492	509	651	473	422	507	553	577	638	674	600	**6839**
Roto-d.	2069	1473	1528	1932	1421	1275	1510	1644	1711	1879	1982	1784	**20324**
Electric	85016	44542	43550	70615	40829	31334	55467	61899	70901	92820	100042	63670	**753905**

From Research – 2 - Practice

Conclusion

The wind potential of our site is favourable for an electricity generation from wind power;

Between the 03 models of wind pumps considered, the electric pump is the one that gives the best performance;

The volume of water is expected to yield 754 000 M^3 per year. It is five times higher than the needs of Beka-Hossere's people;

Expectations about collaborations

- Deep studies of the project
- Realization of the project in the future

INFRASTRUCTURES AND EQUIPMENTS IN OUR ENERGY ENGINEERING DEPARTMENT

Renewable Energies

- Weather station Vantage Pro 2 for a practical works on renewable energies.
- 1.5 meter wind power plant
- 5 kW solar plant




INFRASTRUCTURES AND EQUIPMENTS IN OUR ENERGY ENGINEERING DEPARTMENT

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Thank you for your kind attention !