# Renewable Energy Systems for Rural Health Clinics in Algeria: Homer Application

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**Abstract:**
The solar potential of Algeria ranks among the highest in the world. The annual sunshine duration reaches 2000hrs all over the territory and 3900hrs in the Sahara. The received energy is 1.7kWh/m$^2$/year in the north, 1.9kWh/m$^2$/year in high plains and 2.650kWh/m$^2$/year in the Sahara. The wind is characterized by a moderated speed (2 to 6 m/s) ideal for water pumping especially in high plains. The southern Algerian population is concentrated in small villages where electricity is supplied by isolated networks that are fed by diesel plants. These plants are very expensive due to maintenance costs and fuel supply transported by trucks on desert roads exceeding 1000 km. The study concerns the optimization and the cost analysis of RE hybrid systems for electricity production using HOMER. These systems have to supply rural health clinics situated in coastal, high plains and desert regions of Algeria, represented by Algiers, Ghardaia and Djanet. Regarding the cost of fuel in different regions of Algeria, optimized RE systems found for Algiers and Ghardaia are composed of PV systems, Wind generators and Batteries, while for Djanet it is a PV system and Batteries. The implementation of RE systems to supply Rural Health Clinics will contribute to reduce electricity both production cost and $CO_2$ emissions while improving health care and quality of life in isolated regions.
Key words: Renewable energy systems, Wind energy, PV, Diesel generator, hybrid system, Rural health clinic, HOMER

## I - Introduction

An important challenge for Algeria to take up, is the implementation of health care services in isolated coastal and mountainous regions of the north, high plains and desert regions of the south. Communities living there lack electricity for water sterilization, domestic use, medical services, education and irrigation. These remote areas are not supplied by power lines. The important infant and maternal mortality rate in these regions is due essentially to transmissible diseases, scorpion poisoning and malnutrition. The sub-saharan localities are also threatened by the extension of sexually transmissible diseases [1]. The construction of health clinics electrified by local resources such as solar and wind energy become the most suitable alternative.
Algeria is divided in three main climatic regions: the temperate mediteranean coastline and the Atlas mountainous regions where the global solar radiation ranges form 3.5 to 4.5 kwh/m$^2$/day , fig. 1, the sparsely populated high plains that look as two sub-climate zones, the northern and the southern slopes semi-arid Saharan Atlas where global solar energy is around 6kw/m$^2$/day and finally the Sahara where the global solar radiation is higher than 6kw/m$^2$/day. The solar potential of Algeria is one of the highest in the world. The annual sunshine duration reaches 2000hrs all over the territory and 3900hrs in the Sahara. The received energy is 1.7kWh/m$^2$/year in the north, 1.9kWh/m$^2$/year in high plains and 2.650kWh/m$^2$/year in the Sahara. The wind is characterized by a moderated speed (2 to 6 m/s) ideal for water pumping especially in high plains. The wind chart of Algeria, fig. 2, is provided by [2].
The southern Algerian population is concentrated in small villages where electricity is supplied by isolated networks that are fed by diesel plants. These plants are very expensive due to maintenance costs and fuel supply transported by trucks on desert roads exceeding1000 km.

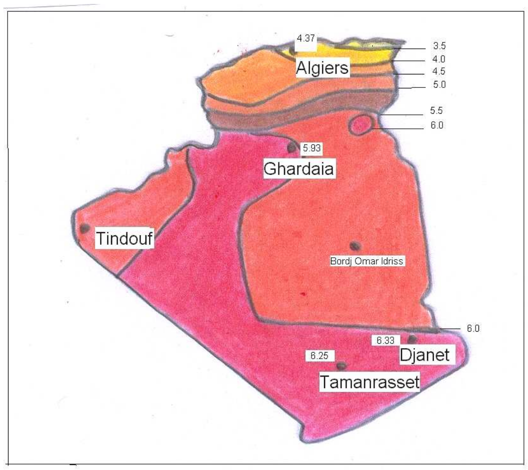



Fig.1 Global solar radiation in kwh/m$^2$/day over Algeria

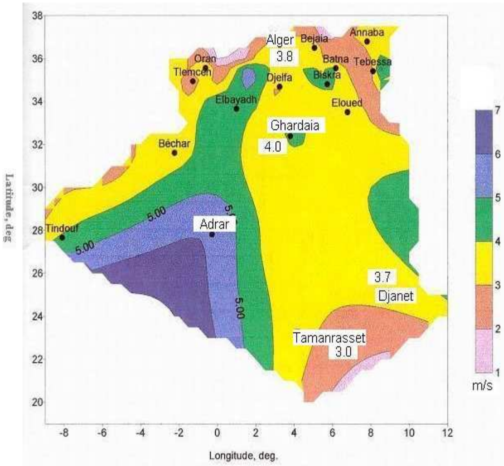



Fig.2 Wind chart of Algeria

The study concerns the optimization and the cost analysis of RE hybrid systems for electricity production using the free software HOMER (Hybrid Optimization Model for Electric Renewable) [3]. These systems have to supply rural health clinics situated in coastal, high plains and desert regions of Algeria, represented by Algiers, Ghardaia and Djanet.

## II- Methods and material

'Homer simulates and optimizes hybrid power systems, which are stand alone power plants that employ some combination of wind turbine, photovoltaic panels, or diesel generators to produce electricity' [3].

The simulation concerns a typical health clinic described in the guide of NREL's Village Power Group: RE for Rural health clinic [4]. The common health clinic, require electricity for lighting, refrigeration, medical tools, communication equipment, water pumping, sterilization, ceiling fan, medical and familial planning education.

Simulations are based on a specific search space and certain sensitivities defining the optimum configuration of the RE system. The load size of 7 kwh/m$^2$/day was determined using mean approximations of remote clinics and the simulations are performed for the levelised load of 6 kwh/kwh/m$^2$/day. The regions of Algiers in the north, Ghardaia in the middle south and Djanet in the deeper south are chosen.

Monthly average local data regarding solar radiation and wind speed are taken from [5,6]. The power systems are composed of PV panel, wind turbine, Diesel generator, battery, and inverter. Standard market prices and power generation statistics of each component provide the base input data for the optimization process.

The input parameter for each component is specified under the categories: PV, Turbine Diesel, Battery and converter. PV input are the size range (0, 0.4, 0.8, 1.5, 3, 4)kw. From 0 to 3 wind turbine of 1kw and only Diesel generators of 1 and 2kw capacity are allowed. The size of the inverter is 2kw. The input battery parameter is the number of batteries of 250Ah each, necessary to optimize the power output. The fuel price is fixed to 0.4$/L for Algiers, 0.8 $/L for Ghardaia and 1$/L for Djanet.

Once these standard data were input, HOMER was run for each region. " HOMER then ranked each of the simulations according to Net Present Cost (NPC), which is the total cost over the lifetime of the system using current monetary value"[7].

In this investigation we attempt to determine for each region and regarding the selected components, which of the RE hybrid system PV/Batt or PV/Wind/Batt is the optimal power system.

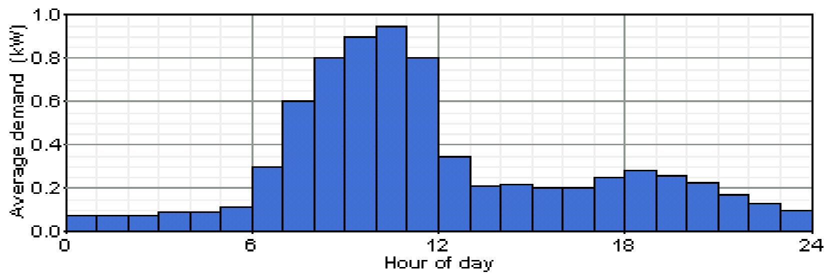
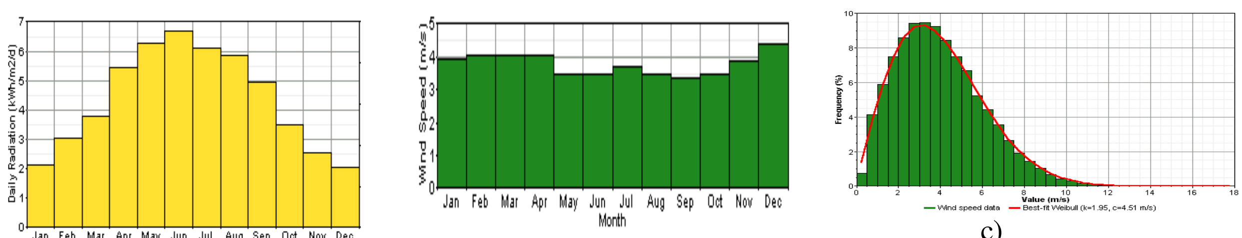



Figure 3. Daily load profile of the health clinic

## III- Results

### *1-Algiers*

The annual average global solar insolation and annual wind speed of Algiers (36.72 N latitude) are respectively 4.37kwh/$m^2$/day and 3.78m/s, [fig.4]. The optimal system found using HOMER is a hybrid PV(0.8 kw), wind turbine(1kw), diesel generator(1kw), 12 batteries and inverter(2kw) system for the capital cost of $12920 and the net present cost (NPC) which is a the capital cost and the total cost to maintain this system with these components, would be $18768.




a) b) c)

Fig. 4 Average global solar radiation (kw/$m^2$/day), b) Wind speed (m/s), c) Wind speed probability distribution of Algiers

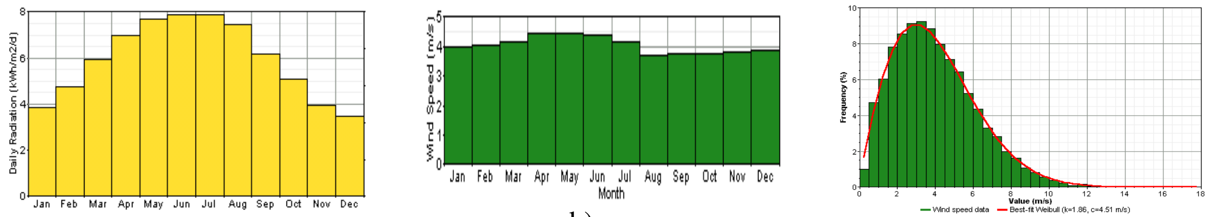
Renewable energy represents 82% of the total energy production, the generator will be running about 565 hours per year corresponding to 176 diesel liters consumption.

The first system without a wind turbine incorporate 0.8kw of PV along with a 1kw generator, 12 batteries and an inverter capacity of 2kw for an initial cost of $9920. The NPC over the lifetime of the system is $19429.

Table 2

| PV (kW) | XL1 | Gen1 (kW) | Batt. | Conv. (kW) | Disp. Strg | Total Capital | Total NPC | COE ($/kWh) | Ren. Frac. | Diesel (L) | Gen1 (hrs) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.8 | 1 | 1 | 12 | 2 | CC | $ 12,920 | $ 18,768 | 0.803 | 0.82 | 176 | 565 |
| 0.8 | | 1 | 12 | 2 | CC | $ 9,920 | $ 19,429 | 0.831 | 0.47 | 497 | 1,551 |
| | 1 | 1 | 12 | 2 | CC | $ 7,320 | $ 19,558 | 0.837 | 0.36 | 628 | 1,918 |
| | | 1 | 12 | 2 | CC | $ 4,320 | $ 20,800 | 0.890 | 0.00 | 1,000 | 3,029 |
| 1.5 | 1 | | 30 | 2 | CC | $ 18,800 | $ 24,618 | 1.053 | 1.00 | | |
| 3.0 | | | 24 | 2 | CC | $ 25,640 | $ 30,706 | 1.313 | 1.00 | | |
| | | 1 | | | CC | $ 1,000 | $ 35,038 | 1.499 | 0.00 | 1,362 | 8,760 |
| | 1 | 1 | | 2 | CC | $ 6,000 | $ 36,747 | 1.572 | 0.33 | 1,135 | 7,421 |
| 0.4 | 1 | 1 | | 2 | CC | $ 8,800 | $ 38,959 | 1.666 | 0.48 | 1,047 | 7,267 |
| 0.4 | | 1 | | 2 | CC | $ 5,800 | $ 40,530 | 1.734 | 0.22 | 1,282 | 8,758 |

***2-Ghardaia***




a) b) c)

Fig. 5 Average global solar radiation (kw/$m^2$/day), b) Wind speed (m/s), c) Wind speed probability distribution of Ghardaia.

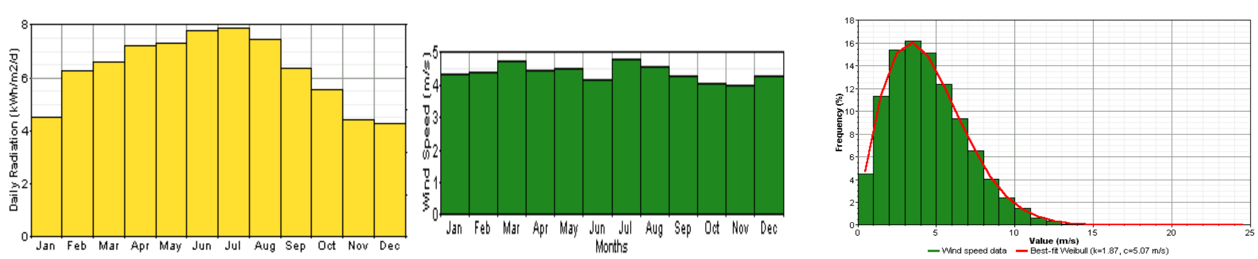
The annual global solar radiation average of Ghardaia (32.38 N latitude) is 5.934 kwh/$m^2$/day and the annual wind speed average is 4m/s, [fig.5]. The optimal hybrid power system proposed by HOMER includes PV, wind turbine, battery, and inverter. The components needed to satisfy the annual load of 2190kwh are 0.8 kw of PV, 1 kw rated power wind turbine, 1kw capacity generator, 12 batteries and 2kw inverter. The capital cost of this system is $12920 and the NPC is $17577. The RE fraction represents 99% of the energy production. The generator will be running 87 hours and will use 12L/yr of diesel fuel. The least cost system without wind turbine consists of 1.5kw of PV, 16 batteries and 2kw inverter capacity for an initial capital cost of $14260 and a net capital cost of $17699. Three power systems representing the optimal configuration were considered and the results are summarized in table 3.

Table3:

| PV (kW) | XL1 | Gen (kW) | Batt. | Conv. (kW) | Disp. Strgy | Total Capital | Total NPC | COE ($/kWh) | Ren. Frac. | Diesel (L) | Gen (hrs) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.8 | 1 | 1 | 12 | 2 | LF | $ 12,920 | $ 17,577 | 0.752 | 0.99 | 12 | 87 |
| 1.5 | | | 16 | 2 | CC | $ 14,260 | $ 17,699 | 0.757 | 1.00 | | |
| 1.5 | | 1 | 12 | 2 | LF | $ 14,820 | $ 17,958 | 0.768 | 1.00 | 4 | 27 |
| 0.8 | 1 | | 24 | 2 | CC | $ 13,240 | $ 18,442 | 0.789 | 1.00 | | |
| | 3 | 1 | 30 | 2 | LF | $ 15,300 | $ 24,157 | 1.033 | 0.99 | 15 | 93 |
| | 3 | | 46 | 2 | CC | $ 16,060 | $ 25,821 | 1.105 | 1.00 | | |
| | | 1 | 12 | 2 | CC | $ 4,320 | $ 49,185 | 2.105 | 0.00 | 1,006 | 3,138 |
| 1.5 | 3 | 1 | | 2 | CC | $ 22,500 | $ 76,588 | 3.276 | 0.90 | 542 | 4,121 |
| | 3 | 1 | | 2 | CC | $ 12,000 | $ 76,824 | 3.287 | 0.75 | 772 | 5,025 |
| 1.5 | | 1 | | 2 | CC | $ 13,500 | $ 103,574 | 4.430 | 0.68 | 987 | 7,484 |
| | | 1 | | | CC | $ 1,000 | $ 106,311 | 4.550 | 0.00 | 1,362 | 8,760 |

***3-Djanet***

The global solar radiation average of Djanet (24.55 N latitude) is 6.3kwh/$m^2$/day and the annual wind speed average is 4.38m/s, fig.6.




a) b) c)

Fig. 6 Average global solar radiation (kw/$m^2$/day), b) Wind speed (m/s), c) Wind speed probability distribution of Djanet.

The optimal power system found by HOMER is a 1.5kw of PV, 1kw capacity generator, 10 batteries and an inverter of 2kw for an initial capital cost of $14600 and NPC of $17323. Renewable energy represent 100% of the total energy production, the generator will be running about 38 hours per year corresponding to 5 diesel liters consumption.
The table 4 summarizes systems corresponding to the best configurations.

Table4:

| PV (kW) | XL1 | Gen1 (kW) | Batt. | Conv. (kW) | Disp. Strgy | Total Capital | Total NPC | COE ($/kWh) | Ren. Frac. | Diesel (L) | Gen1 (hrs) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.5 | | 1 | 10 | 2 | LF | $ 14,600 | $ 17,323 | 0.806 | 1.00 | 5 | 38 |
| 0.8 | 1 | 1 | 16 | 2 | LF | $ 13,360 | $ 17,437 | 0.811 | 1.00 | 5 | 35 |
| 1.5 | | | 18 | 2 | CC | $ 14,480 | $ 17,615 | 0.819 | 1.00 | | |
| 0.8 | 1 | | 24 | 2 | CC | $ 13,240 | $ 17,829 | 0.829 | 1.00 | | |
| | 2 | 1 | 32 | 2 | CC | $ 12,520 | $ 23,205 | 1.079 | 0.90 | 106 | 332 |
| | 3 | | 46 | 2 | CC | $ 16,060 | $ 24,519 | 1.141 | 1.00 | | |
| | | 1 | 24 | 2 | CC | $ 5,640 | $ 55,414 | 2.578 | 0.00 | 1,007 | 3,116 |
| 1.5 | 4 | 1 | | 2 | CC | $ 25,500 | $ 79,933 | 3.718 | 0.92 | 496 | 3,771 |
| | 5 | 1 | | 2 | CC | $ 18,000 | $ 81,346 | 3.784 | 0.86 | 660 | 4,317 |
| 4.0 | | 1 | | 2 | CC | $ 31,000 | $ 112,350 | 5.225 | 0.88 | 800 | 6,100 |
| | | 1 | | | CC | $ 1,000 | $ 117,655 | 5.474 | 0.00 | 1,362 | 8,760 |

## VI-Discussion

Algiers, as shown in table2, and Ghardaia, in table 3, need the same PV/wind/generator/batt optimal combination but Ghardaia has more favorable meteorological conditions. That implies relying less the diesel generator, 87 hours/year versus 586 hours for Algiers.
As shown in table 3 the three optimal systems can be used even if the PV-only system use more batteries than the PV-generator configuration. In Djanet, table 4 the PV-generator optimal configuration use 8 batteries less than the PV-only system. Finally the optimal power systems found for Ghardaia and Djanet do not depend on diesel price.
The generator-only configuration cost, in Ghardaia (NPC= $49185) and in Djanet (NPC=$55414), is very expensive compared to the RE hybrid systems. For Algiers, the NPC of the generator-only system is equivalent to the NPC of hybrid optimal system but use 824 liters of fuel more.

## V-Conclusions

PV/wind/generator is the best configuration for Algiers in terms of net present cost and carbon emissions, while for Ghardaia and Djanet PV/wind/generator configuration and PV-only solution are very close. For both regions the hybrid electrical system incorporating wind technology is not influenced by the fuel price. These power systems are very well suited to supply the specific load demand of the rural health clinic that present a peak in the morning when the solar radiation is maximum. The implementation of RE hybrid systems to supply Rural Health Clinics will contribute to reduce electricity production cost, the annual 72 tones of $CO_2$ emissions of generator-only systems and will improve the health care and the quality of life in isolated regions.

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*References*
[1] Ministere de la sante, de la population et de la reforme hospitaliere: http://www.ands.dz/
[2] http://www.mem-algeria.org/
[3] T. Lambert: HOMER : The Hybrid Optimization Model for Electric Renewables. Available:http://www.nrel.gov/internationa/tools/homer/homer.html.
[4] NREL's Village Power Group: Renewable Energy for Rural Health Clinics- Web site: http://www.rsvp.nrel.gov
[5] NASA Surface meteorology and Solar Energy- http://eosweb.larc.nasa.gov/
[6] http://energy.caeds.eng.uml.edu
[7] W. Jennings: Optimization of electric power systems for off-grid domestic applications: An Argument for Wind/Photovoltaic Hybrids. NREL