The Potential and Feasibility of Solar and Wind Energy Applications in Al-Ahli Hospital

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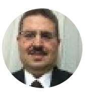

Radwan R. Tahboub
Palestine Polytechnic University

Imad Ibrik
An-Najah National University

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Radwan Tahboub
Electrical and Computer Engineering Dept,
Palestine Polytechnic University, PPU.
Hebron, Palestine
radwant@ppu.edu

Imad Ibrik
Energy Research Center (ERC),
An-Najah National University, NNU.
Nablus, Palestine
iibrik@yahoo.com

Mohammad Tamimi
Ahli Wind Energy Project, Al-Ahli Hospital, AWEP.
Hebron, Palestine
mohammad@awep.ps

***Abstract*—Ahli Hospital Wind Energy Project (AWEP) is an innovative pilot project that involves the design and implementation of an integrated low-cost, sustainable and reliable clean energy system, with very low environmental costs, and to create public awareness as to the enormous opportunities offered by the clean energy technologies. One of the main objectives of AWEP project was to reduce the Energy consumption of al Ahli hospital by (30-40) % by using a Wind Turbine with an approximate power of 750 KW. During the site assessment phase of the wind potential in al Ahli site, experts from the Centre For Renewable Energy Sources (CRES) recommended a 330 KW Wind Turbine. This site restriction leads to a saving of only 20% of the electricity consumption of the Hospital. AWEP team with cooperation partners from University of Twente searched the potential of finding an alternative solution to fulfill the 30%-40% Energy consumption objective. The suggested alternative was using a Solar System integrated with the suggested Wind Turbine. This Solar System is a Thermal Solar System that will be used to heat the water used in the hospital, heating the building at winter and for steam generation.**

In this paper we will discuss the potential and feasibility of using wind and solar energy in Al ahli Hospital project. We will discuss the idea of the project and the initial design, then the different site parameters and restrictions for wind system. Detailed analysis using latest technologies will be shown and discussed for both Wind and Solar systems. Then we will discuss the new design for the solar system and its calculations.

Keywords- Wind Turbine, Thermal Solar System

I. BACKGROUND

Wind and solar power provides sustainable and clean energy (a green energy source). Generating energy/electricity from the wind and solar does not require an input fuel; and hence removes the risk of electricity interruptions due to political interference or unaffordable fuel price rises. Further, there are no environmental costs, such as carbon emissions, in the generation process.

Hebron is about 850m above sea level and this mountain city can be considered as having a good wind/solar resource. Initial studies shows that the wind/solar regime are suitable for operating a wind turbine for wind power generation.

AWEP is an EU funded project for the benefit of the PFS/ Al-Ahli Hospital. EU Ref: EC project DCI-ENV-151707/ Wind Energy.

Al-Ahli Hospital is one of the largest hospitals in Palestine (~ 500 beds), serving more than 100,000 patients per year. It is located in the south-western part of Hebron at ~1000m above sea level on a site of 27500 m^2; the average wind speed at 10 m could be as high as 6.2m/s. This amounts to a rich resource of wind energy with great development potential.

In 2007, Al-Ahli Hospital spent €235,000 on buying in electricity plus €230,000 on fuel used to generate heat and steam and run standby electricity generators as shown in Table.1 and Fig.1. This figure shows the diesel consumption at Al-Ahli Hospital during the past three years, it is clear that annual consumption has decreased by ~100,000 liters since 2005 which reflects the hospital's policy of acclimatizing to rising fuel prices. To achieve this, the hospital mechanical engineering department has taken many actions to minimize the level of fuel consumption. Currently, fuel consumption is restricted to this level and any further constraints would affect the hospital's performance, services and quality

TABLE I. SUMMARY OF AL-AHLI ELECTRICITY INVOICES

Electricity Invoices 2008	
Month	Invoice
Jan	€ 15,738.91
Feb	€ 18,008.00
Mar	€ 18,008.00
Apr	€ 18,008.00
Total	€ 69,762.91

Total Electricity Invoices for 2006 = € 192,666.00
Total Electricity Invoices for 2007 = € 235,307.27

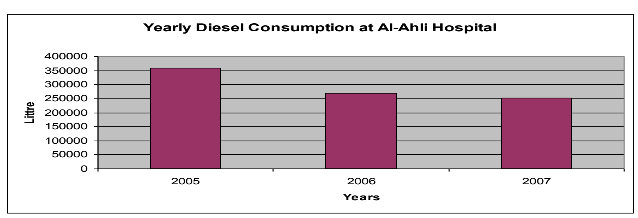

Figure 1. Diesel Consumption in litres (Current Price €1.0 per litre)

Two standby diesel-fuelled generators keep the hospital functioning to a certain extent during emergency situations when there is no grid supply. These two generators deliver only 50-60% of the required power and, due to technical and cost factors; they cannot operate for more than 15-20 hours per day.

II. AWEP Initial Design

AWEP initial design was aiming to study, design and implement a new wind power generation system at the premises of Al-Ahli Hospital that will be integrated with the existing power supply system provided by the local authorities in order to minimize the risks of power intermittencies, minimize costs and improve the efficiency of in-hospital power generation. A wind turbine system with a total rated power of ~700KW capacity was planned to be implemented at the premises of the Al-Ahli Hospital to help meet its energy needs and serve as a capacity building exercise to encourage and assist similar projects to be implemented in other similar organizations in Palestine. As important as the fuel savings, wind electricity generation will minimize the risk of damage to sensitive and costly equipment as a result of power interruptions.

A. Wind turbine(s) system with a rated power of ~700 KW.

Initial study showed that the proposed project will decrease the hospital's electricity and diesel consumption costs by 30-40% as shown in Fig.2, this projected amount is calculated by referring to the wind speed measurements obtained from the weather authority as shown in Fig.3 and the standard power curve of a 700 KW wind turbine shown in Fig.4, also in our study we did not increase the wind speed for hub-height where the speed is expected to be significantly higher or factor in the view of the weather authority that the hospital site is probably windier than the site of the wind measurement station.

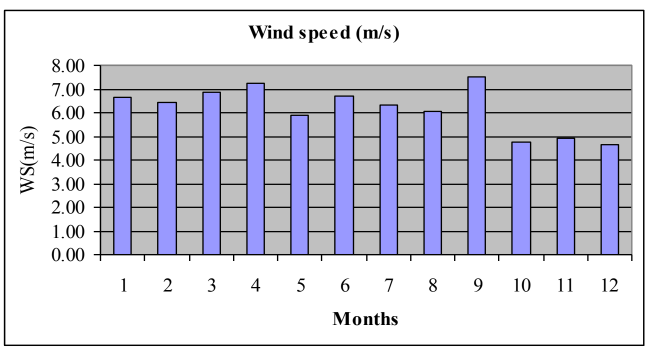

Figure 2. Wind speeds during 2007 as provided by the weather authority

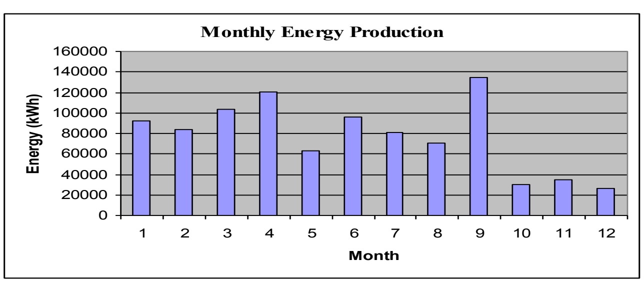

Figure 3. Estimated Annual Wind Energy Production (AWEP)

This saving was expected to reduce monthly electricity bills by 30-40% which can be reallocated for other hospital development projects and activities after having taken care of the maintenance and depreciation costs of the wind energy system.

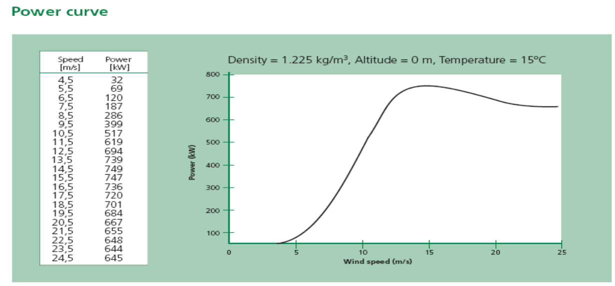

Figure 4. Power Production curve for the suggested turbine.

Accordingly, a power rating and specification of the expected wind turbine system was set to be as in Table II:

TABLE II. INITIAL WIND TURBINE SPECIFICATIONS.

Annual Wind Average	7-10 m/s
Max Cut-in Wind Speed	3 - 4 m/s
Cut-out Wind Speed for excessive wind	≈25 m/s
Hub Height	45 m- 55 m
Nominal Power	750 kW
Operating Atmospheric Temperature	From -10º to 40ºC
Lower Tower Diameter	2-5 m
Upper Tower Diameter	1.5-2 m

B. Increasing the expected reliability and availability of the hospital power towards 100%.

The supply from the municipal electricity provider is subject interruption with outages ranging from a few hours to a whole day. Since Hebron is a mountain city with high wind speeds in winter, we can expect the greatest wind energy contributions when they are most valuable. In periods of good wind resource, the Wind Turbine power output will be sufficient to meet the entire hospital's power requirements with diesel generation becoming the third choice after (i) wind and (ii) grid power when available. Theoretically, this combination should be able to guarantee 100 % availability through an integrated system.

III. AWEP Real SItuation analysis and findings

A. General issues.

Al-Ahli Hospital is located near Hebron, at a distance of 3km towards north-west direction. The hospital is erected on top of a hill (latitude 31o33'22.40'', longitude 35o04'58.63''), whereas the available land, owned by the hospital, for wind energy installations extends towards north-west.

A 1 year measurement data were supplied by Ahli Hospital, and regarded the measurements collected with a 10m meteorological mast during the period from 28/4/2009 – 8/4/2010. The 15-minutes statistics were used. The measuring system is erected on a 10m mast on top of the hospital roof, at a distance of 30 meters from the roof edge, towards the prevailing wind direction. For more accurate measurement of the wind potential of the site, a 40m high meteorological mast should have been used, positioned on the candidate location.

B. Analysis methodology

The collected data has been supplied to be analyzed in cooperation with the Center of Renewable Energy Sources and Saving (CRES). Data analysis is made using the software WindRose© developed in CRES[3] and comprises the calculation of mean wind speed, maximum ten-minute average wind speed and the "Wind rose" graphs. For the calculation and drawing of a wind rose, the horizontal direction is divided in 16 sectors, each 22.5^{o} wide. Each sector is "filled" to a level equal to the relative frequency of the times the wind blew from that particular direction during the one year period as shown in Fig.5 and Fig.6.

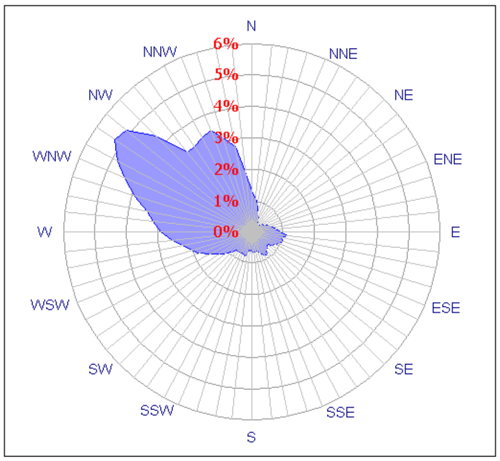

Figure 5. Al-Ahli site Wind Rose based on time.

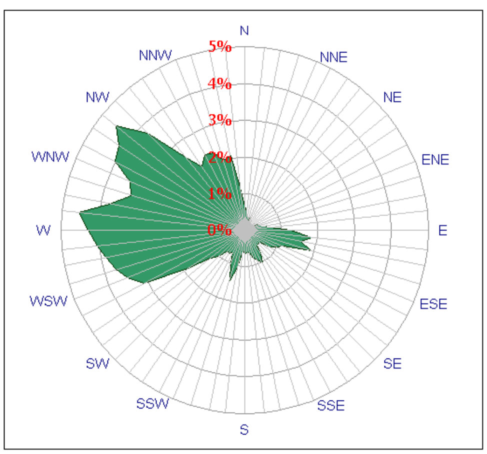

Figure 6. Al-Ahli site Wind Rose based on energy.

The analysis methodology can be summarized as:

- The used two parameter Weibull distribution is given by(1):
- $P(u) = (k/c)(u/c)^{k-1} e^{-(u/c)^{k}}$ (1)
- The scale parameter c is in m/s units and is directly proportional to the mean wind speed (c~u), while the k parameter is related to the shape of the distribution and is inversely proportional to the wind speed variance (k~1/σ2). For every measurement location the two parameters are calculated so that the Weibull distribution closely depicts the statistical distribution of the collected data [3].
- Wind speed cumulative probability curve. From this curve one can determine the percentage of time that the wind speed exceeds a certain value.
- Actual wind distribution (histogram) and the corresponding theoretical (fitted) Weibull distribution.
- Mean power density (wind energy per unit of time and area).
- Total wind energy (energy per unit area) Energy that would be produced by a WT, installed at that specific location, operating over the reported period exhibiting availability equal to the completeness of the data and also operating over one year exhibiting an availability of 100%.
- The number of ten-minute records used for the calculation of the results of the technical report.
- The number of records corresponding to periods of calm (low wind speed -i.e. <2m/s).
- The availability of the measurement system, given as a percentage of collected data against those expected for full availability during the measurement period.
- The diurnal wind speed variation.
- Accordingly, the collected data frequency of occurrence per wind speed bin (1m/s wide) and wind direction sector (22.5deg. wide), the mean Weibull shape and scale parameter values along with the mean wind speed value per wind direction sector (16 sectors) and the content of the time-based and energy-based wind roses on a monthly basis can be tabulated. as shown in Fig.7.

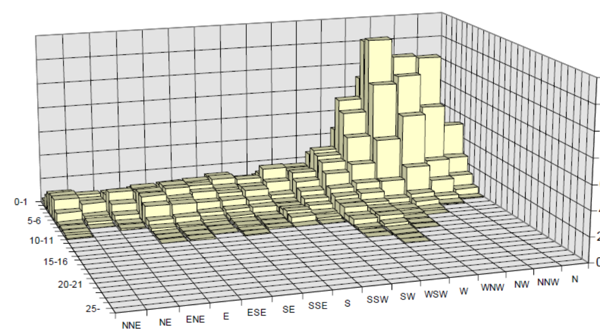

Figure 7. Data distribution vs Wind Speed & Wind Direction

C. Environmental issues

The main environmental concerns are the visual and noise impact upon the neighboring houses and primarily on the hospital itself. Evaluating the expected noise impact, the following technical characteristics should be taken into account:

- The noise level produced by a typical WT may reach 100db.
- At 50m downwind from the WT the expected noise level may be 57dB (±2dB); this regards the neighboring houses.
- At 90m downwind from the WT the expected noise level may be 52dB (±2dB); this regards the hospital.
- The above estimations regard the receptor to be at 10m a.g.l. where the wind speed is 8m/s.

D. Wind turbine sizing

Due to the limitations of the available area, the selection of a WT with rotor diameter greater than 35m is prohibitive. Safety issues may also be raised by the wind turbine manufacturer (even for smaller turbines). Based these limitations and on the manufactures data sheets, the expected energy yield from a WT position close to the hospital is not expected to yield more than 20% of the hospital total energy demand as shown in Table.III below.

TABLE III. WIND TURBINE POWER PRODUCION VALUES

Wind Turbine	Enercon E33-330kW	Enercon E44-900kW	Enercon E48-800kW	Enercon E53-800kW	Vestas V52-850kW	Gamesa G52-850kW
CASE	1	2	3	4	5	6
tower (m):	49	55	76	73	74	65
diameter(m):	33.4	44	48	53	52	52
control:	pitch	Pitch	Pitch	pitch	Pitch	pitch
U (m/s)	Power (kW)	Power (kW)	Power (kW)	Power (kW)	Power (kW)	Power (kW)
2	0	1.4	2	2	0	0
3	5	8	12	14	0	0
4	13.7	24.5	32	38	25.5	27.9
5	30	53	66	77	67.4	65.2
6	55	96	120	141	125	123.1
7	92	156	191	228	203	203
8	138	238	284	336	304	307
9	196	340	405	480	425	435.3
10	250	466	555	645	554	564.5
11	292.8	600	671	744	671	684.6
12	320	710	750	780	759	779.9
13	335	790	790	810	811	840.6
14	335	850	810	810	836	848
15	335	880	810	810	846	849
16	335	905	810	810	849	850
17	335	910	810	810	850	850
18	335	910	810	810	850	850
19	335	910	810	810	850	850
20	335	910	810	810	850	850
21	335	910	810	810	850	850
22	335	910	810	810	850	850
23	335	910	810	810	850	850
24	335	910	810	810	850	850
25	335	910	810	810	850	850
Capacity Factor	**14.1%**	**9.4%**	**12.7%**	**14.8%**	**11.8%**	**11.7%**
$\frac{\text{Annual Wind Energy Production}}{\text{Annual Wind Energy Demand}}$ (%)	**18.3 %**	**33.0%**	**39.8%**	**46.3%**	**38.9%**	**38.2%**

E. Wind turbine connection scheme

In the case of a wind turbine, installed in the area close to the hospital, the direct connection to the low voltage grid is the realistic solution. The connection point should be located after the power meter installed by the municipality (i.e. towards the hospital side). Thus:

- The hospital will exploit directly the available power produced by the wind turbine, the connection is the simplest possible, from the technical point of view.
- The market offers a variety of WT for direct grid connection to select from (in contrast to the stand alone systems).
- The WT operation and maintenance is kept simple and no change is required from the municipality grid infrastructure.

IV. SUGGESTED SOLAR SYSTEM ANALYSIS AND DESIGN

According to the previous limitations, the following electrical and thermal solar system issues are considered to post the total energy saving to 30-40 % limit:

A. Monthly Analysis of Electrical System for Al-Ahli Hospital

Table.IV and Fig.8 shows the electrical energy consumption for Al-Ahly hospital for 2009year.

TABLE IV. TOTAL ELECTRICAL ENERGY CONSUMPTIONS

Month	kWh
1	209867
2	202613
3	171787
4	160000
5	174507
6	230720
7	185613
8	216893
9	196040
10	207373
11	189240
12	187090
Total	**2331743**

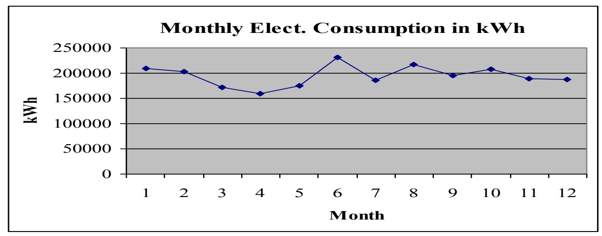

Figure 8. Monthly electrical consumption

B. Monthly Analysis of Current Solar Water Heater System

Since 2009, the Al-Ahli Hospital has been carrying out measurements of wind speed and solar radiation using modern meteorological station equipped with all necessary automatic data loggers, Table.V and Fig.9 illustrates a sample of solar radiation measurements in Al-Ahli site.

TABLE V. SOLAR ENERGY -KWH/M2-DAY-HEBRON-2009

Month	Solar Energy-kWh/m²
1	2.85
2	3.308
3	4.59
4	6.08
5	6.86
6	7.51
7	7.22
8	7.05
9	5.87
10	4.84
11	3.49
12	2.75

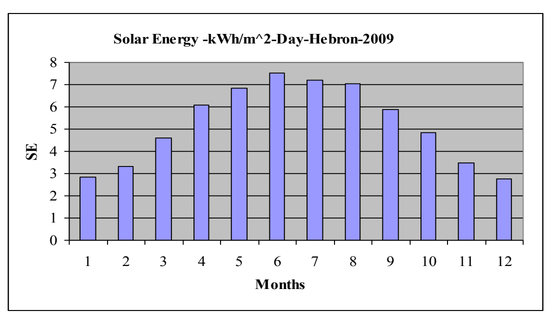

Figure 9. Solar Energy -kWh/m2-Day-Hebron-2009

The current thermal energy consumption in Al-Ahli hospital during 2009 is illustrated in Table.VI and Fig.10. The total yearly thermal energy consumptions are 2238545 kWh/year.

TABLE VI. THE MONTHLY THERMAL ENERGY CONSUMPTION

Month	liter	Eeq. (kWh)
1	43540	417679
2	34275	328800
3	30720	294697
4	20844	199957
5	7756	74403
6	8331	79919
7	10160	97465
8	7107	68177
9	9164	87910
10	15195	145766
11	20690	198479
12	25570	245293
Total	233352	2238546

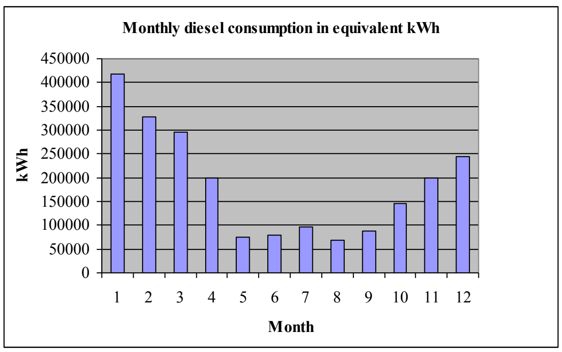

Figure 10. The monthly thermal energy consumption in kWh

C. *Design of the Thermal Solar System (SWHS)*

The hospital has buildings, which are very appropriate to be provided by solar heated water. The roofs of these buildings are totally not occupied and large enough for installation of large scale water heating systems, as well as there are no shadowing possibilities for the solar systems. A solar water heater system design will be capable to deliver the necessary hot water and to pre-heat the inlet water to feed the steam boilers as illustrated in the following points:

- Total daily energy required from the SWHS, 50% of the total thermal energy consumption, it means about 2.238.545X50% = 1.119.272
- So we will design our SWHS (Solar Water Heating System) as to save 1,200,000 Kwh/year, this is equivalent to a saving of 53.6% (3287Kwh/day.)
- Average solar radiation on horizontal surface in Palestine, 5400wh/m2/day.
- Area of solar collector: 2.55m2
- Number of necessary solar collectors= 355
- Provided each collector of this type has a production of (0.77 Kwh).
- Total area of the collectors: 905m2.
- Hot water storage tank capacity: 5X4 m3.
- Daily production of the SWHS= 23.0 m3 (at 70cº).
- Annual production of SWH= 8395.5m3.
- The SWHS systems should be built on buildings where enough places on the roofs are available.

The Monthly Energy producing (kWh) from suggested solar water heater system (SWH) are illustrated in Table.VII and Fig.11. Total Energy Producing = 1305082 kWh / year

TABLE VII. MONTHLY ENERGY PRODUCING FROM SWH

Months	Energy producing (kWh)
1	59532
2	69168
3	95977
4	127129
5	143438
6	157034
7	150968
8	147411
9	122742
10	101204
11	72976
12	57501

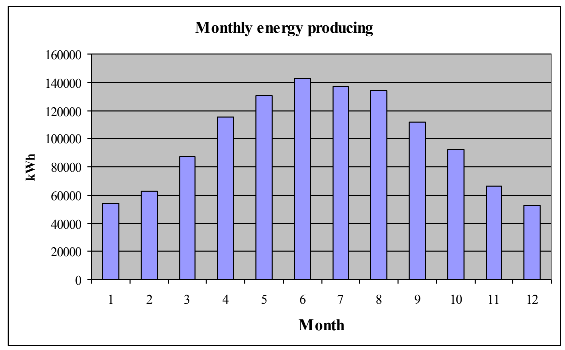

Figure 11. Monthly Energy producing from SWH in kWh

The balance of Thermal Energy consumption and producing from SWH are illustrated in Table.VIII and Fig.12.

D. *Summary of total energy saving*

- Thermal Energy Consumption before SWH=2238545 kWh/year.
- Thermal Energy consumption after installation of SWH= 1247184 kWh/year which equals to = 55.71%
- Energy Saving at using SWH = 44.29%.

TABLE VIII. ENERGY CONSUMPTION AND PRODUCTION BALANCE

Mon	Energy consumption (KWh)	Energy producing (KWh)	Energy balance - KWh
1	417679	59532	358147
2	328800	69168	259632
3	294697	95977	198720
4	199957	127129	72828
5	74403	143438	-69035
6	79919	157034	-77115
7	97465	150968	-53503
8	68177	147411	-79234
9	87910	122742	-34832
10	145766	101204	44562
11	198479	72976	125503
12	245293	57501	187792
Total	2238545	1305080	1247184

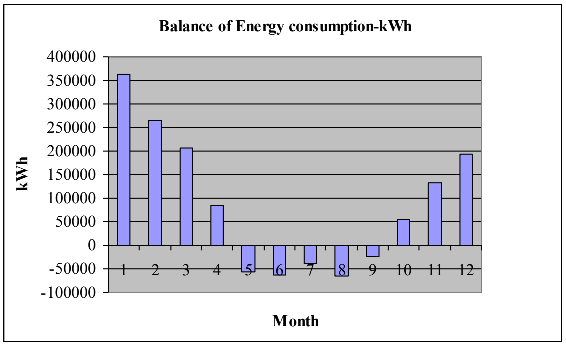

Figure 12. Energy Consumption and Production balance

V. CONCLUSIONS

The main objectives of this project was to reduce the Energy consumption of the hospital by 30%-40% by using a WT (Wind Turbine) with an approximate power of 750 KW, during the assessment of the site and wind potential in cooperation with CRES, a maximum of 330KW WT can be used at the site leading to a saving of only 20% of the electricity consumption of the Hospital. A suggested alternative was to install a Solar system. The alternative solar system suggested by the AWEP teams is a solar thermal system to heat the water used in the hospital for hot water, heating the building during winter and for steam generation. The overall energy saving would be as high as 40%.

ACKNOWLEDGMENT

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