Techno-Economic Feasibility of Energy Supply of Remote Zone Family House in Jordan Badia by Photovoltaic System and Diesel Generators

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Abstract—**In the development of energy sources in remote regions in Jordan at the brink of the 21st century, it is necessary to view the use of solar energy in all applications as one of the most promising new and renewable energy sources. As a contribution to the development program of remote areas in Jordan Badia, this paper presents two energy supply alternatives for a remote house represented in photovoltaic system and diesel generator for providing the electrical loads in a family house according to their energy requirements. The result of this study shows that remote households in Jordan Badia will require 3.22kWh/day or 1175kWh/yr to meet their basic power requirements for such loads as lighting and electronic appliances-radios and televisions. It is found that providing electricity to a family house in a remote zone using photovoltaic systems is very beneficial and competitive with the other types of conventional energy sources, especially considering the decreasing prices of these systems and their increasing efficiencies and reliability. They have also the advantage of maintaining a clean environment. It is recommended that solar photovoltaic-based rural home electrification application should be encouraged by the government, especially for those rural households without access to a grid supply.**

***Index Terms*—Badia, Jordan, photovoltaic, remote**

I. INTRODUCTION

The rapid depletion of fossil-fuel resources, the limited reserves and their unstable prices on a worldwide basis have necessitated an urgent search for alternative energy and significantly increased the interest in renewable energy sources. Of the many alternatives, photovoltaic energy has been considered as promising toward meeting the continually increasing demand for energy [1], [2]. Since the oil crises of the early 1970s, utilization of solar power has been increasingly significant, attractive and cost effective [3], [4]. In numerous remote and rural areas in the world, a noteworthy number of domestic consumers, farms and small business are not connected to main electrical grid system. This is especially in the developing countries, where large distances and the lack of capital are some of the obstacles to the development of a grid system. Therefore, a growing interest in renewable energy resources has been observed for several years, renewable energy is expected to play a major role in the 21st century [3]-[6].

Solar energy, one of the potential renewable energy sources, which is being harnessed in a commercial scale today. Solar energy is non-depletable source, non-polluting, low operating cost, high reliability and cost free in its original radiation form. Therefore, solar energy will represents a suitable solution for energy requirements especially in rural areas. These facts make the alternative resources attractive for many applications. Today, photovoltaic generators are utilized in such applications as water pumping, lighting, electrification of remote areas and telecommunications [1], [3], [4], [6]-[8].

Al-Smairan *et al.* in [9] shows that photovoltaic solar energy systems is the best choice for electrification in Northeast Badia of Jordan in terms of technical and economical point of view.

Photovoltaic systems have made a significance contribution to daily life in developing countries where one third of the world's people live without electricity. One of the problems is in the remote areas there are fewer users per kilometer of high, medium and low voltage line than in urban zones. Also, average consumption is generally much lower than for urban or industrial customers. The second problem is the feasibility of rural electrification via a distribution grid is much lower than that of urban or industrial electrification; since the investment is higher, the costs are greater and the revenue received by utilities is lower [10], [11]. Therefore, even though they generate little power in comparison to central power plants, photovoltaic energy systems could meet the modest needs of remote areas in the Third World villages. Low per capita consumption magnifies the renewable systems benefits because so little electricity is needed to raise the quality of life [10].

In Jordan, there are many new projects such as those carried out in the eastern desert of Jordan and those on the southern part of Jordan, which will be accompanied by people who require energy for principal life requirements. From this point of view, it is very important to introduce a model for a family house that depends mainly on solar energy to run the electrical appliances according to Table I. Rawthat Al-Bandan

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village in the eastern part of Jordan was selected as the site under consideration in this work since it is located far from the utility grid. The average daily solar energy incident on the horizontal plane in the village is about 5.6kWh/m^2/day which is considered to be a high solar energy input.

TABLE I. THE DAILY LOAD ENERGY REQUIREMENTS FOR A TYPICAL FAMILY HOUSE IN RURAL ZONES

Appliances	**No. of units**	**Appliance power (W)**	**Expected daily use (hrs)**	**Electrical energy requirements (kWh.day^{-1})**
Fluorescent tube 20W each	5	100	5	0.5
Color TV	1	90	6	0.54
Cassette player	1	10	4	0.04
Cooling fan	1	50	8	0.40
Washing machine	1	100	1	0.10
Refrigerator	1	150	11	1.65
Total energy (kWh/m^2/day)				**3.22**

II. ENVIRONMENTAL DATA

To get an optimum design for a family house in a remote area, it is very important to collect the meteorological data for the site under consideration. The solar radiation data has a great effect on the performance of photovoltaic systems.

Fig. 1 shows the monthly average values of solar energy incident on the horizontal surfaces in the Rawthat Al-Bandan village [12]. It is clear from the figure that solar energy incident in this region is high especially during summer months, where it exceeds 8 and 7 kWh/m^2/day on horizontal and tilted planes respectively.

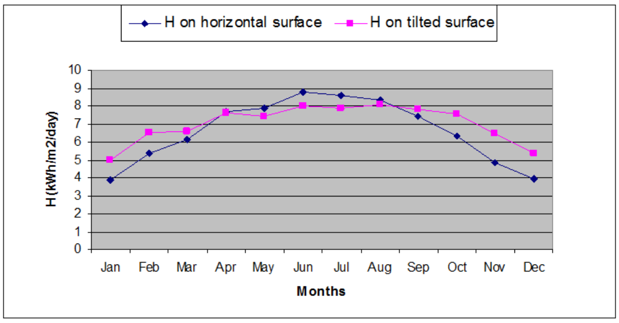

Figure 1. The monthly average values of daily solar energy (kWh/m^2/day) in the Rawthat Al-Bandan village incident on horizontal and tilted surfaces with the latitude (ϕ=30 °).

III. ENERGY REQUIREMENTS OF A TYPICAL HOUSE IN RURAL ZONES

The load profile to be met in a renewable system is of the same importance as the weather data. In general, the demand to be met by a power system is time dependent. Therefore, for correct system sizing, the general non-constant load demand pattern must be considered [13].

The electrical load in the village is mainly concentrated on the night period since the population work during the day. The domestic load demand of any given household is equal to the sum of all the energy requirements. The appliances considered were those having the highest identified probability of use, and consequently satisfying part of the basic energy needs. Household power requirement data did not include such uses as hot plates, electric irons or other large appliances. The family houses in the selected site are expected to be very simple and do not need large quantities of electrical energy for lighting or operating electric appliances. The main electrical loads necessary for improving living conditions in the village are: household appliances (lighting, TV, refrigerator, radio, washing machine and fan). It is expected that most of these houses will have electrical loads as shown in Table I.

The hourly load demand for a typical family house in the village for a complete typical day's energy consumption is shown in Fig. 2. It is noticed that the largest amount of energy consumption is concentrated in the evening, when the family is sitting down in the house and lighting, TV and refrigerator are working.

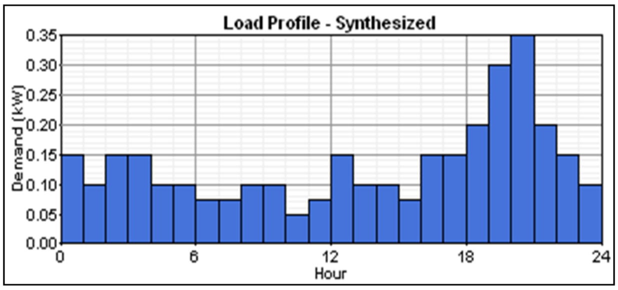

Figure 2. The load curve of a typical complete day's consumption for a typical family house in the Jordan Badia.

IV. THE SYSTEM DESIGN

In sunny parts of the world, stand-alone photovoltaic systems are becoming cost-effective for the rural electrification of widely scattered homes and villages. For the majority of the population living in remote, rural and isolated locations, stand-alone photovoltaic systems can be considered a promising option and a very reliable power source, with the minimum attention and maintenance [14], [15]. In order to size a system acknowledgement of the solar radiation data for the site, the load demand profile, and the importance of supply continuity are required [11], [15], [16]. The first problem of sizing a stand-alone photovoltaic power system and battery storage is to find the optimum combination of array size and storage battery capacity that will meet the load requirements, which minimize energy cost for a chosen reliability. The solar photovoltaic array is sized to replace the load on a daily basis for average weather conditions. By using the daily requirement of appliances and the daily output from one module, the number of modules can be calculated [17]-[20].

To design a PV system for a family house in rural zones, the following steps are carried out.

A. *Calculating the Average Daily Load Energy Requirements*

Using Table I, it is found that the average daily load energy (E_L) for a typical house in Rawthat Al-Bandan village in Jordan is about 3.22kWh/day. For this study the total energy consumption is 1175kWh/year.

B. PV Array Sizing

14 modules of polycrystalline, each one has 53Wp are used to supply the house with the required energy. The modules can be connected to give the desired voltage according to the design of the other parts of the PV system and the load specifications.

C. Design of the Storage System

Stand-alone home power systems often store energy generated during the day in a battery bank for use at night. Therefore, the photovoltaic system is equipped with a storage battery, in order to meet the demand requirements during the cloudy days in the application period [18], [21].

The storage capacity of battery block for such systems is considerably large. Therefore, special lead-acid battery cells (block type) of long life time (greater than 10 years), high cycling stability-rate (greater than 1000 times) and capability of standing very deep discharge should be selected [22], [23]. 12 battery cells (2V, 700Ah) have to be connected in series to build a battery block of an output rated at $24V_{DC}$/700Ah. This battery bank can drive the loads for 3 days without any sunshine.

D. The Battery Charge Controller

Measurements must be taken to prevent excessive discharge or overcharge of batteries. Therefore, system or charge controllers are required in renewable systems to regulate the battery charge and to control the operation of the load [15]. In this case the appropriate rated power of charge regulator is 800W and to maintain the system voltage in the range of 24V.

E. DC/AC Inverter

An inverter is a standard item of electronic equipment, which is used in many different applications. Inverters convert Direct Current (DC) voltage to Alternating Current (AC). Therefore, the input power is the DC power from the renewable energy system or battery, and the output is AC power used to run AC appliances or fed into the utility grid [15]. The inverter [7] has to be capable of handling the maximum expected power of AC loads. Thus, it can be chosen 20% higher than the rated power of the summation of AC loads according to Table I.

The specifications of inverter will be 600W, $24V_{DC}$, and $220V_{AC}$.

V. The Diesel Electric Generator

Diesel generators are not widely used in Jordan to provide remote villages with electric power. These have the advantage of being able to deliver the required power on demand. However, they also suffer from a number of drawbacks. Diesel generator engines are inherently noisy and expensive to run, especially for consumers in rural areas where fuel delivery costs may be high. Also, installing diesel generators in these villages is very restricted for many reasons. Fuel buying around the year, and operation and maintenance of these generators are the most significant factors against the economic deployment of diesel generators. In addition, small consumers always have a low load factor; this in turn reduces the overall efficiency and increases percentage maintenance costs and they pollute the environment [22], [24].

VI. Economic Estimation

A. The PV System Economics

For many remote applications, stand-alone solar photovoltaic energy systems are presently economical, where the cost of other energy resources, such as extending utility power lines or transporting fuel, is very high [25]. At present, photovoltaic energy is most competitive where small amounts of energy are required far from the grid [15]. The price of the PV system and its installation are important factors in the economics of PV systems. These include the prices of PV modules, storage batteries, the control unit, the inverter, and all other auxiliaries. From the economical viewpoint, photovoltaic energy systems differ from conventional energy systems in that they have slightly high initial cost, low operating costs, there is no fuel cost, and reliability is high so replacement costs are low [7], [15].

For the present PV system, the life cycle cost will be estimated as follows. The lifecycle of the system components will be considered as 25 years except for the batteries, which will be considered to have a lifetime of 8 years. Also, the annual inflation rate in batteries prices is considered to be 0% and the market discount rate as 10%.

The cost of the first group of batteries (A) [7]=No. of batteries × cost of battery=12×100$=1200$ (1)

The present worth [7] of the second group of batteries (after 8 years):

$$= \frac{A(1+i)^{N-1}}{(1+d)^{N}} \tag{2}$$

$$= \frac{1200(1+0)^{7}}{(1+0.1)^{8}} = 560\$$$

The present worth of the third group of batteries (after 16 years):

$$= \frac{1200(1+0)^{15}}{(1+0.1)^{16}} = 260\$$$

The initial cost of the PV system [7]=PV array cost + first group of batteries cost + battery charge cost + inverter cost + auxiliaries cos = (740$ ×1.2) + 1200$ + 800$ + 900$ + (888$×0.05) = 3833$ (3)

where the auxiliaries cost=5% of the PV array cost [7]. The PV system installation cost can be estimated as 10% of the initial cost. Also, the annual maintenance and operation cost is about 2% of the initial cost [7], [15].

Life cycle cost [7], [25]=initial cost of PV system + installation cost + cost of second and third groups of batteries + maintenance and operation cost = 3833 + (0.1×3833)+(560+260)+(0.02×25×3833)=6952.5$ (4)

The life cycle output energy [7], [15]

$=E_L\times 365\times 25=3.22\times 365\times 25=29382.5\text{kWh}$ (5)

The cost of 1kWh from the PV generator [7]:

$$=\frac{6952.5}{29382.5}=0.236\$/kWh$$

A common and simple way to evaluate the economic merit of an investment is to calculate its payback period, or break-even time. The payback period is the number of years of energy-cost saving it takes to recover an investment's initial cost. In this way, the payback period in years is given by [13], [26], [27].

$$PBP=\frac{C_{tot}}{(Q_D.e)} \quad (6)$$

where, C_{tot}: total system costs; Q_D: the annual energy production (kWh/year); e: the cost of the conventional electricity per energy unit ($/kWh).

$$PBP=\frac{6952.5}{29382.5\times 0.0436}=5.4\,\text{year}$$

B. The Diesel Generator System Economics

If a diesel generator is used to feed the house in question with its energy requirements, then it's important to estimate its life cycle cost. This will give an indication of the difference in energy cost between PV systems and diesel generator systems [7].

To estimate the diesel generator life cycle cost, there are some assumptions:

1. Two diesel generators will be used, each with a power capacity of 1.0kW.
2. The diesel generators need reviving every 4 years. The cost of reviving is about 20% of their initial price [7].
3. The cost of annual maintenance, operation and oil changing is about 5% of the initial price [7].
4. Fuel consumption is about 4 l/day.
5. The inflation rate in prices is about 0%, while the market discount rate is about 10%.

The life cycle cost of diesel generator system [7] = Initial cost + (present worth of 20% from the initial cost × 6 times reviving) + (present worth of 5% from the initial cost for maintenance, operation and *oil changing) + (present worth of fuel consumption for 25 years)* (7)

The cost of commercially available diesel generator may vary from $250 to $1000/kW [7], [28]. For larger units per kW cost is lower and smaller units cost more. Since the peak power demand is less than 5kW, in this analysis diesel generator cost is taken as $1000/kW. At present, diesel price is around $0.70/l.

Initial cost (according to the market price)
$=2\times 1000\$/\text{unit}=2000\$$

Present worth of reviving = $\frac{A(1+i)^{N-1}}{(1+d)^N}$ for N = 4, 8, 12, 16, 20, 24.

where in this equation, A = 20% from the initial cost.

Present worth of reviving=(0.2×2000)

$$\left\{\frac{(1+0)^3}{(1+0.1)^4}+\frac{(1+0)^7}{(1+0.1)^8}+\frac{(1+0)^{11}}{(1+0.1)^{12}}+\frac{(1+0)^{15}}{(1+0.1)^{16}}+\frac{(1+0)^{19}}{(1+0.1)^{20}}+\frac{(1+0)^{23}}{(1+0.1)^{24}}\right\}$$

=786$

Present worth of maintenance, operation and oil changing [7]:

$$=\sum_{N=1}^{N=25}\frac{A(1+i)^{N-1}}{(1+d)^N} \quad (8)$$

where in this equation, A = 5% from the initial cost.

Present worth of maintenance, operation and oil changing = $\sum_{N=1}^{N=25}\frac{(0.05*2000)(1+0)^{N-1}}{(1+0.1)^N}=909.5\$$.

Present worth of fuel consumption [7] for 25 years:

$$=\sum_{N=1}^{N=25}\frac{A(1+i)^{N-1}}{(1+d)^N} \quad (9)$$

where in this equation, A = first year fuel cost = 4 l/day × 365 × 0.70$/l = 1022$.

Present worth of fuel consumption for 25 years = $\sum_{N=1}^{N=25}\frac{1022(1+0)^{N-1}}{(1+0.1)^N}=9249\$$.

The life cycle cost of diesel generator system = 2000 + 786 + 909.5 + 9249 = 12945$.

The life cycle output energy = 3.22×365×25 = 29382.5kWh.

The cost of 1kWh from the diesel generator = $\frac{12945}{29382.5}=0.44\$/kWh$.

$$PBP=\frac{12945}{29382.5\times 0.0436}=10.1\,\text{year}$$

This study shows that the life cycle cost, the cost of energy and the payback period of the PV system is less than that of the diesel generator system for providing a rural zone family house with energy.

In any case, PV systems are clean and renewable sources of energy; they do not cause pollution of any type during their use. On the other hand, diesel generators cause noise and produce gases and smoke.

TABLE II. EVALUATION RESULTS OF THE DYNAMIC METHODS APPLIED ON THE TWO ENERGY SUPPLY SYSTEMS

Dynamic method (indicator)	PV-system	Diesel generator system
Life cycle cost ($)	6952.5	12945
Cost of kWh production ($)	0.236	0.44
Pay-back period (year)	5.4	10.1

VII. EVALUATION RESULTS, CONCLUSIONS AND POLICY RECOMMENDATIONS

A. Evaluation Results

Table II illustrates the above three dynamic economic methods on the two energy supply systems of the rural zone family house, and the obtained evaluation results for the three dynamic methods.

VIII. Conclusions

The availability of energy is an important pre-condition for developing the national economy and improving people’s living standards. From an economical point of view using PV systems in feeding rural zones is very important, especially when their life cycle costs are competitive with the other types of conventional energy sources. The study has shown that, for rural areas of Jordan, the domestic load demand for light-duty applications represents 3.22kWh/day or 1175kWh/year.

The results shows that the best choice of a family remote house in Jordan Badia is the stand-alone photovoltaic system as compared with the diesel generator, where, the three dynamic indictors for comparison (the life cycle cost, the cost of energy production and the pay-back period) for the photovoltaic system is better than for diesel generator as a power supply in Jordan Badia. The life cycle cost is 6952.5US$ and 12945US$ for the photovoltaic system and diesel generator respectively. While, the cost of energy for the two systems are: 0.236US$/kWh and 0.44US$/kWh respectively. Meanwhile, the payback period for the two systems are: 5.4 and 10.1 year respectively.

Therefore, utilizing of photovoltaic systems is more economic feasible for electrification of remote villages of geographic, climate and load conditions similar to Rawthat Al-Bandan village in Jordan. Also, PV-systems do not pollute the environment as the case of using diesel generator systems. This study could serve as a guide to building an appropriate PV-based rural home electrification project in Jordan and also assist government in its Rural Electrification Project.

A. Policy Recommendations

It is recommended that rural PV-based home electrification application should be encouraged by government, by committing additional political and financial support, and establishing pilot projects in each of the remote areas of Jordan to assist in household adoption and diffusion. It is a known fact that the application of PV-systems will offer a quick, economic and reliable answer to the remote household's need for power, especially for those of light-duty appliances. Also, the application and diffusion of PV-systems in rural and remote areas will enhance the quality of life in those areas, which will in turn, help to reduce the pressure caused by the unsustainable use of rural and remote-based natural resources and also reduce rural and remote-urban migration.

References

[1] G. E. Ahmed, “Photovoltaic-Powered rural zone family house in Egypt,” *Renewable Energy*, vol. 26, pp. 379-390, 2002.

[2] A. Al-Mehaidat, “Sizing and designing of a PV power system to operate electrical load,” Internal report, National Energy Research Center, Amman, Jordan, 2003.

[3] M. A. Elhadidy and S. M. Shaahid, “Parametric study of hybrid (wind+solar+diesel) power generating systems,” *Renewable Energy*, vol. 21, pp. 129-139, 2000.

[4] M. A. Elhadidy, “Performance evaluation of hybrid (wind/solar/diesel) power systems,” *Renewable Energy*, vol. 26, pp. 401-413, 2002.

[5] N. Toshihiko, K. Kazuo, and L. Alan. Design for renewable energy systems with application to rural area in Japan. [Online]. Available: http://www.earth.tohoku.ac.jp/Geoth21/EImy_Nakata.pdf

[6] L. H. Tay, W. W. L Keerthipala, and L. J. Borle. Performance analysis of a wind/diesel/battery hybrid power system. [Online]. Available: http://www.itee.uq.edu.au/~aupec/aupec01/129_TAY_AUPEC01paper%20revised.pdf

[7] G. E. Ahmed, “Photovoltaic-Powered rural zone family house in Egypt,” *Renewable Energy*, vol. 26, pp. 379-390, 2002.

[8] B. S. Borowy and Z. M. Salameh, “Optimum photovoltaic array size for a hybrid wind/PV system,” *IEEE Transactions on Energy Conversion*, vol. 9, no. 3, pp. 482-488, 1994.

[9] A. Mohammad, A. Rida, and A. Omer, “Techno-Economic feasibility of energy supply of remote zone family house in Jordan Badia by photovoltaic system and diesel generators,” *Research Journal of Applied Sciences, Engineering and Technology*, vol. 4, pp. 1073-1081, 2012.

[10] A. N. Celik, “The system performance and sizing of autonomous photovoltaic, wind and the hybrid energy systems,” PhD thesis, Division of Mechanical Engineering and Energy Studies, University of Wales, Cardiff, 1998.

[11] X. Vallve and J. Serrasolses, “Design and operation of a 50kWp PV rural electrification project for remote sites in Spain,” *Solar Energy*, vol. 59, no. 1-3, pp. 111-119, 1997.

[12] Jordan Meteorological Department, “Monthly average values of daily solar radiation for Jordan Badia,” Internal report, Amman, Jordan, 1998.

[13] C. Protogeropoulos, “Autonomous wind/solar power systems with battery storage,” PhD thesis, University of Wales College of Cardiff, 1992.

[14] J. M. Gordon, “Optimal sizing of stand-alone photovoltaic solar power systems,” *Solar Cells*, vol. 20, pp. 295-313, 1987.

[15] M. Tomas, *Solar Electricity*, Baffins Lane, Chichester: John Wiley and Sons, 1997.

[16] A. H. Arab, B. A. Driss, R. Amimeur, and E. Lorenzo, “Photovoltaic systems sizing for Algeria,” *Solar Energy*, vol. 54, no. 2, pp. 99-104, 1995.

[17] R. Chedid, H. Akiki, and R. Saifur, “A decision support technique for the design of hybrid solar-wind power systems,” *IEEE Transactions on Energy Conversion*, vol. 13, no. 1, pp. 76-82, 1997.

[18] M. Bhuiyan and M. Asgar, “Sizing of a stand-alone photovoltaic power system at Dhaka,” *Renewable Energy*, vol. 28, pp. 929-938, 2003.

[19] W. Grainger, “Wind and solar data for sizing small wind turbine and photovoltaic power plants,” *Solar and Wind Technology*, vol. 7, no. 1, pp. 63-66, 1990.

[20] R. Simon, *Solar Electricity, a Practical Guide to Designing and Installing Small Photovoltaic Systems*, Prentice Hall International (UK) Ltd., 1991.

[21] J. Samimi, E. A Soleimani, and M. S. Zabihi, “Optimal sizing of photovoltaic systems in varied climates,” *Solar Energy*, vol. 60, no. 2, pp. 97-107, 1997.

[22] M. Mahmoud and I. Ibrik, “Techno-Economic feasibility of energy supply of remote villages in Palestine by PV-systems, diesel generators and electric grid,” *Renewable and Sustainable Energy Reviews*, vol. 10, pp. 128-138, 2006.

[23] M. Mahmoud, A. Muhaidat, J. Jaeeussi, M. El-Kabariti, F. Samareh, and I. Odeh, “Design the generating energy systems for pumping water, heating and air conditioning,” Internal report, Royal Scientific Society, Amman, Jordan, 1991.

[24] M. A. Mousa, I. M. S. Ibrahim and I. M. Molokhia, “Comparative study in supplying electrical energy to small remote loads in Libya,” *Renewable Energy*, vol. 14, no. 1-4, pp. 135-140, 1998.

[25] M. Kolhe, S. Kolhe, and J. C. Joshi, “Economic viability of stand-alone solar photovoltaic system in comparison with diesel-powered system for India,” *Energy Economics*, vol. 24, pp. 155-165, 2002.

[26] D. Yang. Local photovoltaic (PV)-wind hybrid systems with battery storage or grid connection. [Online]. Available: http://www.chem.jyu.fi/ue/frame_left/UESem 2005-Yang.pdf
[27] J. F. Manwell, J. G. McGowan, and A. L. Rogers, *Wind Energy Explained, Theory, Design and Application*, Baffins Lane, Chichester: John Wiley & Sons Ltd., 2002.
[28] M. J. Khan and M. T. Iqbal, "Pre-Feasibility study of stand-alone hybrid energy systems for applications in Newfoundland," *Renewable Energy*, vol. 30, no. 6, pp. 835-854, 2005.

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