academicJournals

Vol. 9(22), pp. 959-965, 30 November, 2014
DOI: 10.5897/SRE11.528
Article Number: 3AAD50E48778
ISSN 1992-2248 © 2014
Copyright©2014
Author(s) retain the copyright of this article
http://www.academicjournals.org/SRE

Scientific Research and Essays

Full Length Research Paper

Design considerations for a sustainablepower energy system in Khartoum

Abdallah Z. M. E.[1,2]*, M. F. M. Zain[1] and Sopin K.[3]

[1]Department of Architecture Engineering,Faculty of Engineering and Built of Environment, Universiti Kebangsaan Malaysia, 43600, UKM, Bangi, Selangor D. E., Malaysia.
[2]Department of Architecture, Faculty of Engineering Science, Omaurman Islamic University, Sudan.
[3]Solar Institute (SERI), Universiti Kebangsaan Malaysia, 43600, UKM, Bangi, Selangor D. E., Malaysia.

Received 11 March, 2011; Accepted 11 November, 2014

Application of renewable energy in Sudan is a major issue in strategic planning for alternatives fossil fuels to provide part of local energy demand. Sudan is an important case study in the context of renewable energy because Sudan possesses relatively high profusion of solar radiation, moderate wind speeds. This paper discussed the efficient system of sustainable renewable energy for domestic used and its total cost. The method of this paper was collection of the basic data of solar radiation, wind speed, others required input data, and then hybrid optimization simulation model was developed using the electric renewable energy software Hybrid Optimization Model for Electric Renewable (HOMER). The simulation model has been used to find out the best technically viable renewable based energy efficient system for different numbers of household. It finds as the result some topologies of hybrid power. The simulation results have been presented the most efficient achievement and economic way for different numbers of household. The overall cost of energy would be low if the turbine cost decreases in Khartoum. The project lifetime has been considered for 25 years and the annual real interest rate has been taken as 4%.

Key words: HOMER, Khartoum- renewable energy, power system, domestic.

INTRODUCTION

A hybrid energy system generally consists of a primary energy sources working in parallel with standby secondary energy storage units. Hybrid Optimization Model for Electric Renewable (HOMER) has been used to optimize the best energy efficient system for Khartoum considering different load and wind-PV combination. Figure 1 reflects the propose scheme as implemented in HOMER simulation tool. HOMER software developed by National Renewable Energy Laboratory (NREL), USA for micro-power optimization model, has been used to find out the best energy efficient renewable based hybrid system options for Khartoum. It contains a number of energy component models and evaluates suitable technology options based on cost and availability of resources (HOMER, 2005).

HOMER optimum configurations of appropriate power

*Correspondence author. E-mail: zeinab3007@yahoo.com. Tel: +6143296490.

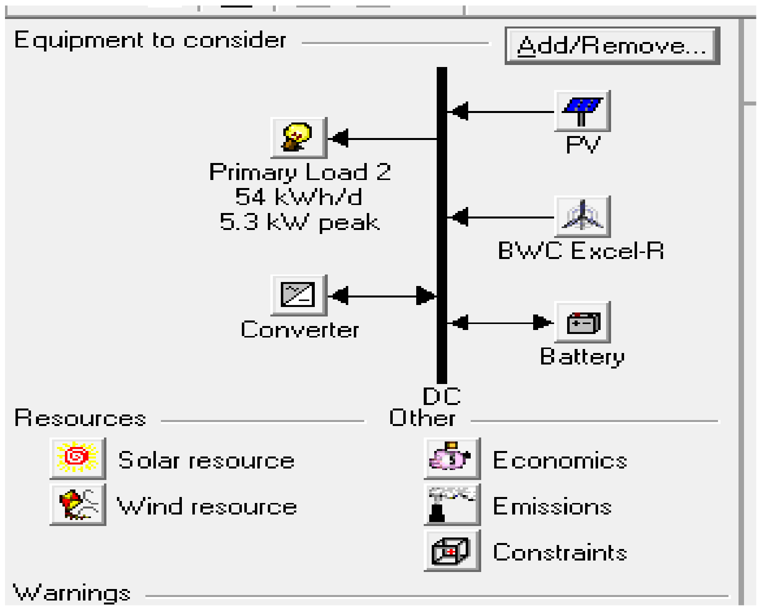

Figure 1. Schematic diagram of hybrid power system.

stations were suggested in the Plan depending on energy resources available in specific locations (Indradip and Chaudhuri, 2008). Analysis has been done for single home user as well as combination of 10 and 50 home users to get the most economic and technical viable options (James and James, 2005). HOMER models each individual system configuration by performing an hourly time-step simulation of its operation for a one year duration. The available renewable power is calculated and is compared to the required electrical load (Dalton et al., 2009).

Sudan lies between latitude 3° N 23°N and longitude 21°.45/E and 39°E. This large area enjoys a variety of climates, from desert regions in the north to tropical in the south, and makes it a favourable environment for all activities of the integrated agricultural investment from production to processing industries. Sudan is a relatively sparsely populated country (UN.UONISCO, 2004) and Alnaser et al. (2007). Khartoum climate region in the summers are invariably hot (mean maximum, 41°C and mean minimum 25°C) with large variation; low relative humidity averages (25%). Winters can be quite cool. Sunshine is very prevalent. Climate is a typical desert and rain is infrequent and annual variation in temperature is large. The fluctuations are due the dry and rainy seasons. Two main air movements determine the general nature of the climate. First, a very dry air movement from the north that prevails throughout the year.

Khartoum is located at 15.38 latitude and 32.28 longitudes. Energy planners have long envisioned large utility-scale solar power plants covering large expanses of desert (Alnaser et al., 2004). While this vision has many favorable attributes, the economics require careful investigation. Ground-mounted PV systems require the allocation of land, which must be acquired and prepared to accept the PV system. The cost of land and the cost of site work can be considerable (Anonymous, 1996). In Sudan and many others countries, the lack of available large open tracts of land has effectively precluded the grid connected PV option as afforded to develop in Sudan. As interest in solar electricity increases, there is a growing consensus that spread PV systems that provide electricity at or near the point of use will be the first to reach prevalent commercialization (IEA, 2002) and Sasitharanuwat and Rakwichian (2007). This study find that HOMER is Hybrid Optimization Model for Electric Renewable (HOMER) is design optimization model that determines the configuration, dispatch, and load management strategy that minimizes life-cycle costs (Steven,2005) and Sasitharanuwat et al. (2007).

This paper describes the designing and implementation process for hybrid system in Khartoum capital of republic of Sudan that took about 12 months, starting from January 2009 and HOMER. Simulation tool has been at length used in order to compare and optimize the electrical demand to the electrical energy that the system is bright to supply, on an hourly base.

DESIGN PROCEDURE

Hybrid power system

HOMER simulates the operation of a system by making energy balance calculations for each of the 8,760 h in a year. For each

Table 1. Appliances for single home user.

Appliance	Quantity	Capacity (W)	Maximum use hour / day
Florescence light	4.2	10	4
B / W TV	1.5	15	4
Radio / cassette	1	5.5	5

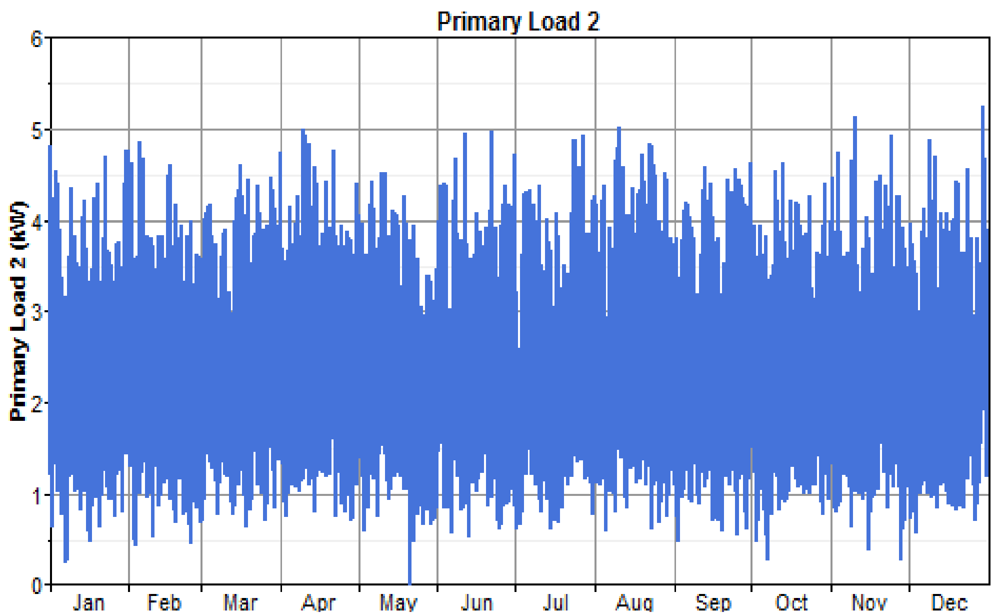

Figure 2. Primary load 2.

hour, and compares the electric and thermal demand in the hour to the energy that the system can supply in that hour, and calculates the flows of energy to and from each component of the system. For systems that include batteries or fuel-powered generators. HOMER also decides for each hour how to control the generators and whether to charge or discharge the batteries. HOMER performs these energy balance calculations for each system configuration. It determines whether a configuration is feasible. The system cost calculations account for costs such as capital, replacement, operation and maintenance, fuel, and interest. System in HOMER Information about the load, resources, economic, constrains, controls and other component that have been used in HOMER are in Figure 1.

Electric load material

A typical load system, shown in the Table 1 for single home in the remote areas has been considered for the analysis. Monthly average hourly load demand (Sudanese perspective) has been given as an input of HOMER and then it generates daily and 2.3 kW/day monthly load profile for a year as get in Figure 2. It has been found that for this system each home user consumes energy around (338 W/day of Wh/day). The system also gives the opportunity for expanding its capacity in order to cope with the increasing demand in the future. This can be done by increasing either the rated power of diesel generator, renewable generator or both of them (Nayar et al., 1993; IEA, (2002).

RESULTS AND DISCUSSION

Renewable resources

As hourly data is not available therefore monthly averaged global radiation data has been taken from (NASA, 2008). HOMER introduces clearness index from the latitude information of the selected site and this index values are shown in Figure 3. HOMER creates the synthesized 8760 hourly values for a year using the Graham algorithm (Graham and Holland, 1990) which results in a data sequence that has realistic day-to-day and hour-to-hour variability and autocorrelation (HOMER, 2005). For wind monthly averaged (1999 - 2007) and Graham and Holland, (1990) measured data from (SEI) have been used along with the information of height = 30 m, elevation = 3 m ASL, surface roughness = 0.01 m (Benemann and Chehab, 2000; Benemann et al., 2001). HOMER create these monthly average data based on the other parameters such as Weibull factor "k" = 1.8, autocorrelation factor (randomness in wind speed) = 0.90, diurnal pattern strength (wind speed variation over a day) = 0.25, hour of peak wind speed = 22 m/s to generate hourly data for a year as shown in Figure 4

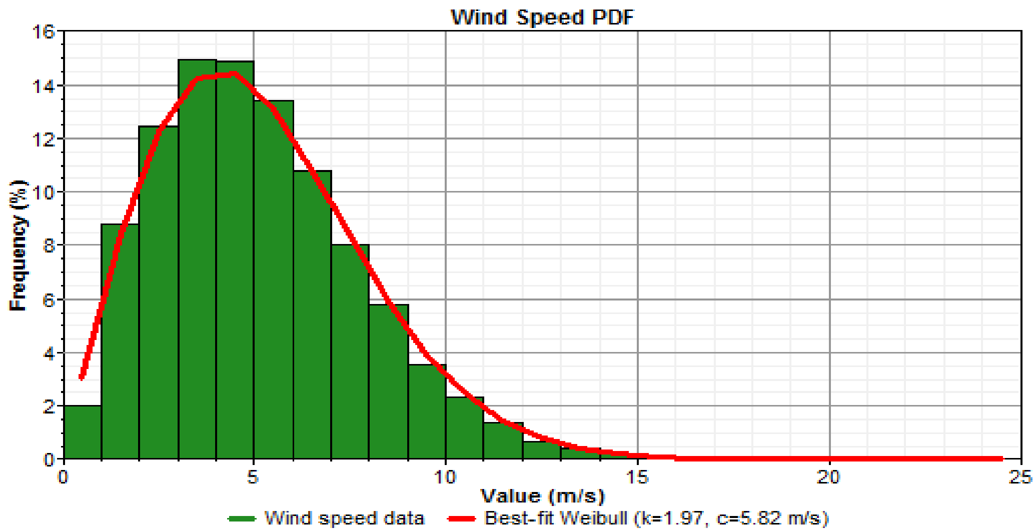

Figure 3. Solar analysis diagrams.

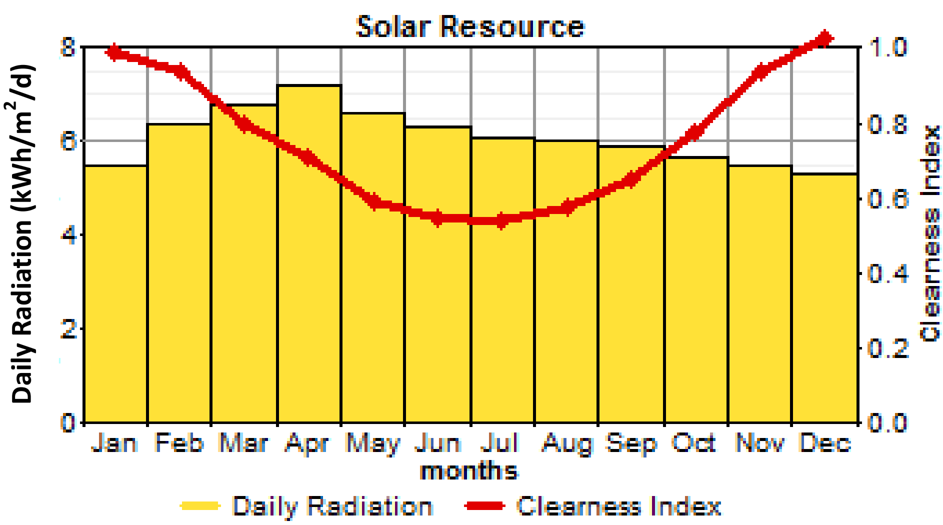

Figure 4. Daily wind speed.

(Ahmad and Nayar, 2004); certain of systematic result depend on different location to get the analysis Combining the renewable energy generation with conventional wind and PV power generation will enable the power generated from renewable energy sources to be more reliable and affordable (Rohinton, 2009).

Photovoltaic module

The cost of PV module including installation has been considered as 220 SP / W for Sudan (Anonymous, 1998). Life time of the modules has been taken as 25 years and these are tilted at 21° with no tracking mode (ISE, 2008). As of this analysis we get the continuous of energy depend on the lifetime of a hybrid power system which has an ability to provide 24-hour grid quality electricity to the load. This system offers a better efficiency, flexibility of planning and environmental benefits compared to non renewable energy. Steven (2005) and Ahmed (2008) found that PV calculates the electric behavior of large and in homogeneously light up PV arrays that obtained the scale of photovoltaic module should become more gorgeous as costs of usual supplies increase (Dalton et al., 2009). Capacity shortage and fraction of excess electricity, cost of useful energy varies from 24 to 39 /kWh which is comparable to solar home system (Shafiuzzaman, 2005) that mean

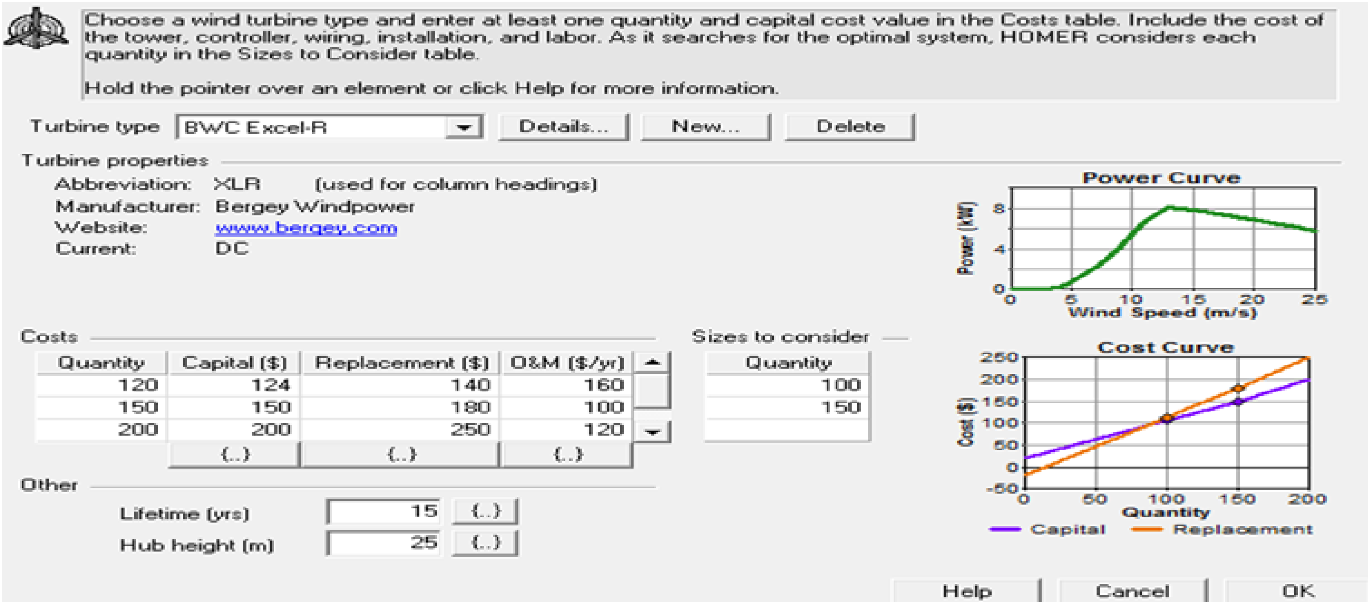

Figure 5. Wind turbine input.

the scale of solar system the one of the main factor of design the hybrid system.

Wind generator

The load demand is very low for a single home system and the price per kW turbine cost is very high for low capacity wind turbine compare to that of high capacity ones. Low capacity wind turbine is not much available (Awea, 1999); research and development are going on to improve the technology and designing low capacity turbine with low cut-in speed at around 2.5 m/s. Turbine with a capacity of 0.5 kW has been considered (Figure 5). The cost of the turbine with tower and installation has been considered as 96000 SP/turbine. For the load higher than 1 kW, turbine from Southwest Wind power, (model: W175, capacity, 3 KW) has been considered at the cost of 200000 SP/ turbine with tower and installation. Options analysis was done for only PV and wind that acquired after 2007-power demand including reverse system is supplied by using mini-grid connected hybrid power system with quite a few power options: PV/wind. HOMER Optimum configurations of appropriate power stations were suggested in the Plan depending on energy resources available in specific locations. Total 35 power stations have been proposed in the Plan. All of them are of hybrid types with Wind and battery bank (Indradip and Chaudhuri, 2008) for a 400 W capacity of Wind Home System (three home users) in coastal areas at a speed of 5 m/s the IRR, payback period and benefit-cost ratio are found to be around 16%, 8 years and 2 respectively. Results show that considering energy consumption, environmental effects and remote accessibility most of the coastal regions are viable for wind home system (Shafiuzzaman, 2005) that obtained to the scale of project depending on the suitability for individual locations of the project of wind type of hybrid system.

Battery with control

As the system considered the DC load only, battery and controller were also form as a main part of the performance evaluation of 10 kW PV power system (Sasitharanuwat and Rakwichian, 2007). Isolated battery from Trojan Company (Model: Trojan T- 105, nominal V: 6v, nominal capacity: 225 Ah) has been used at a cost of 10,000.00 SP/battery with charge controller. Optimized HOMER found for Algiers are composed of PV systems, wind generators and batteries (Malika, 2009). On the basis of local inspections and analysis with the HOMER model, the following design specifications were found to be optimal for a solar penetration of about 25%: PV capacity of 12 kWp, battery capacity of 108 kWh (50 batteries, 360 Ah, 6 V), and 12 kWp converter at Maldives (van Sark et al., 2004).

Constraints and economics

The project life time has been considered to be 25 years and the annual real interest rate has been taken as 4% (IEA, 2002). As the system has been designed for single

Table 2. HOMER details results.

Home	Load	PV module (KW)	Wind generator (quantity)	Battery (quantity)	Initial Cost SP	Total NPC	COE (SP/ Wh)
Single	338 Wh/day 115 KW Peak	0.15	0	2	61,890	98,470	49.5
20	6.8 KWh/day 2.3 KW peak	1.0	1	16	780,000	841,480	25.8
30	10.1 KWh/day 3.5 KW	2.0	1	24	978,890	1,463,300	23.8
40	13.5 KWh/day 4.6 KW	2.5	2	24	2,188,330	1,999,590	24.7
50	16.9 KWh/day 5.8 KW	3.5	2	8	1,567,220	1,940,985	20.1

and for multiple home users like 10 to 50, but the load consumed by the user is low so operation and maintenance cost has been taken 500 SP/year. There is no capacity shortage for the system and operating reserve is 10% of hourly load. Analysis shows that the cost of energy (KWH) is low for the system that is the combination of 50 homes (Roaf and Fuentes, 1999). Table 2 shows the load demand for each combination of homes with system architecture and financial summary.

Dalton et al. (2009) found that as the result of optimization a modeling for design a hybrid system using HOMER software demonstrated that, at 2004 prices, the NPC of the grid/RES hybrid configuration is comparable with the grid-only supply and resulted in a RF of 73%, a payback time of 14 years and a reduction in greenhouse gas emissions of 65%. Optimization modeling also showed that whilst a RES-only configuration can potentially supply 100% of power demand, at present electricity prices, which have nearly quadrupled since 2004, and predicts that a configuration of 3 Vests WECS (1.8 MW), an 800 kW converter and 3500 batteries provides the lowest NPC after 20 years at $19.1 M and Shafiuzzaman (2005) found as result that payback period and benefit-cost ratio are found to be around 16%, 8 years and 2 respectively. Results show that considering energy consumption, environmental effects and remote accessibility most of the coastal regions are viable for wind home system.

van Sark et al. (2004) and van Roosmalen et al. (2004) found the system simulations showed that with a daily load of 207 kWh/day, the combination of a 12 KWp, PV system with a battery backup capacity of 108 kWh would be optimum, given the most suitable strategy for the use of two differently sized diesel generators now present. Reducing solar radiation and wind power also means less emission from the system as shown by the PV/wind system. In addition, the hybrid system reward able also consider providing enough electricity for domestic using as needed by people in this particular remote area.

Conclusions

This paper could be summarized from the analysis that the project life time has been considered to be 25 years and the annual real interest rate has been taken as 4% as the system has been designed for single and also for multiple home users like 10 to 50, but the load consumed by the user is low operation and maintenance cost.

It will be better to use wind-PV combination system for 50 homes instead of single home system. The overall cost of energy would be low if the turbine cost decreases in Khartoum. The simulation results display that utilizing renewable generators such as PV and wind generator reduces the operating costs of using third class housing at Khartoum State.

Conflict of Interests

The authors have not declared any conflict of interests.

REFERENCES

Ahmed AZ, Nayar CV (2008). Integrating Sustainable Energy in Buildings: A Case Study in Malaysia. Copenhagen: FAU Conference, May.

Ahmad AS, Nayar CV (2004). Department of electrical and computer Engineering Curtin University of Technology-article from article from Homer Energy.

Alnaser WE, Trieb F, Knies G (2007). Solar energy technology in the Middle East and North Africa (MENA) for sustainable energy, water and environment. Adv. Solar Energy: An. Annu. Rev. Res. Dev. 17:261-304.

Alnaser WE, Eliagoubi B, Al-Kalak A, Trabelsi H, Al-Maalej M, El-Sayed HM, Alloush M (2004). First solar radiation atlas for the Arab world.

Renew. Energy 29:1085-1107. http://dx.doi.org/10.1016/j.renene.2003.10.007

Alnaser WE, Eliagoubi B, Al-Kalak A, Trabelsi H, Al-Maalej M, El-Sayed HM (2004). First solar radiation atlas for the Arab world. Renew. Energy 29(7):1085-1107. http://dx.doi.org/10.1016/j.renene.2003.10.007

Anonymous (1996). Review of ultra-low energy homes. Information Report.

Anonymous (1998). European Countries Set to Agree on Greenhouse Targets. Nature 393:616. http://dx.doi.org/10.1038/31316

AWEA (1999). Global Wind Energy. The Wind Energy Production Tax Credit. http://www.awea.org/pubs/documents/globalmarket1999.html

Benemann J, Chehab.O (2000). Building-Integrated PV Modules. Building-Integrated PV Modules, Solar International Gmbh, Muehlengasse 7, D-50667 Cologne, Germany November 2000 Ministry Energy (a).

Benemann J, Chehab O, Schaar-Gabriel E (2001). Building-integrated PV modules. Solar Energy Mater. Solar Cells 67(1-4):345-354. http://dx.doi.org/10.1016/S0927-0248(00)00302-0

Graham VA, Hollands KGT (1990). A method to generate synthetic hourly solar radiation globally. Solar Energy. Blackwell. Nayar CV, Phillips SJ, James WL, Pryor TL Remmer D (1993). Novel wind/diesel/battery hybrid energy system, Solar Energy 51(1):65-78.

HOMER (2005). Homer version history. Version 2.14.

IEA (International Energy Agency) (2002). Trends in photovoltaic applications, survey report of selected IEA countries between 1992 and 2002. Report IEA-PVPS T1-12:2003.

Indradip M, GonChaudhuri SP (2008). Remote Village Electrification Plan Through Renewable Energy in the Islands of Indian Sundarbans. The Energy and Resources Institute, IHC Complex, Lodhi Road, New Delhi, India. Article from Homer energy.

ISE (2008). Solar Photovoltaic Energy. Solar Radiation in Khartoum, Khartoum Final Report of Solar Energy, pp. 29-32.

James & James (2005). Planning and Installing Photovoltaic Systems Guide for-Installers, Architects and Engineers. SciTech Book News, Earthscan Publications, London, pp. 88-89.

Malika A (2009). Renewable energy systems for rural health clinics in Algeria: Homer application. Renewable Energy Research Centre Algeria.http://homerenergy.com/webcast-downloads/Malika_Amini/health.pdf

NASA (2008).Surface meteorology and solar energy, released. 5.1

Roaf S, Fuentes M (1999). Demonstration project for a 4 KW domestic photovoltaic roof in Oxford, p. 1.

Rohinton EM (2009). An Urban Approach to Climate-Sensitive Design. SPON Press, Taylor and Francis Group, London.

Sasitharanuwat A, Rakwichian W (2007). Performance Evaluation Of A 10 KW P PV Power System Prototype For Isolated Building In Thailand. Renew. Energy 32:1288-1300. http://dx.doi.org/10.1016/j.renene.2006.05.002

Sasitharanuwat A, Rakwichian W, Ketjoy N, Yammen S (2007). Performance evaluation of a 10 kWp PV power system prototype for isolated building in Thailand. Renew. Energy 32(8):1288-1300. http://dx.doi.org/10.1016/j.renene.2006.05.002

Shafiuzzaman KK (2005). Feasibility Study of Wind Home System in Coastal Region of Bangladesh. Renewable Energy Research Centre, University Of Dhaka, Dhaka – 1000, Bangladesh. Article from Homer energy website.

Steven S (2005). Building integrated photovoltaic. A White Paper on its Principles and Applications. Solar Design Associates. http://www.solardesign.com/library/pdf/Building-Integrated-Photovoltaics-Steven-Strong-2005.pdf.

van Roosmalen JAM, Lysen EH (2004). Modeling improvement of spectral response of solar cells by deployment of spectral converters containing semiconductor nanocrystals. Semiconductors 38:962-969. http://dx.doi.org/10.1134/1.1787120

van Sark WGJHM, Meijerink A, Schropp REI, van Roosmalen JAM, Lysen EH (2004). Modeling improvement of spectral response of solar cells by deployment of spectral converters containing semiconductor nanocrystals. Semiconductors 38:962. Available at: http://www.springerlink.com/content/11371u7541785v61, http://dx.doi.org/10.1134/1.1787120