International Journal of Sustainable and Green Energy
2017; 6(3-1): 8-13
http://www.sciencepublishinggroup.com/j/ijsge
doi: 10.11648/j.ijrse.s.2017060301.12

An Open-door Immature Policy for Rural Electrification: A Case Study of Afghanistan

Mir Sayed Shah Danish[1, *], Najib Rahman Sabory[1], Sayed Mir Shah Danish[2], Gul Ahmad Ludin[3], Atsushi Yona[3], Tomonobu Senjyu[3]

[1]Energy Engineering Department, Kabul University, Kabul, Afghanistan

[2]Electrical Department, Technical Teachers Training Academy (TTTA), Kabul, Afghanistan

[3]Electrical and Electronics Department, University of the Ryukyus, Okinawa, Japan

Email address:

mdanish@ku.edu.af (M. S. S. Danish)

To cite this article:

Mir Sayed Shah Danish, Najib Rahman Sabory, Sayed Mir Shah Danish, Gul Ahmad Ludin, Atsushi Yona, Tomonobu Senjyu. An Open-door Immature Policy for Rural Electrification: A Case Study of Afghanistan. *International Journal of Sustainable and Green Energy.* Special Issue: Sustainable Energy Design and Exploitation. Vol. 6, No. 3-1, 2017, pp. 8-13. doi: 10.11648/j.ijrse.s.2017060301.12

Received: June 9, 2016; **Accepted**: June 16, 2016; **Published**: November 22, 2016

Abstract: Electricity policy as a tool for enhancing the persistent of energy resources' appropriate exploitation and deployment are known essential. Conversely, an open-door immature energy policy can lead a nation to an irrecoverable consequences. In this paper, electrification policy-related gaps and their worst-case scenarios and reasons behind the dominant increasing trend for decentralized PV system application are addressed in form of a case study. Over the last 13 years, numbers of PV rooftop projects have been inaugurated around the country but due to immature energy policy for ensuring the PV project life-span; excluding few, all the PV systems in medium and large scales villages are failed due to poor maintenance and operation. In the present approach, techno-economic analysis of customary implementation of PV systems are developed. The methodology is first conducted to develop cost-effective centralized PV system. Then, a comparative analysis of techno-economical approach of both centralized and decentralized PV systems are discussed, which is associated with systems' advantages, disadvantages, practicability studies, and barriers.

Keywords: Electricity Policy, PV Systems, Rural Electrification, Techno-economic Analysis

1. Introduction

Solar energy as a source of renewable energy for electric power production has tremendous gratis potential in the world. The nowadays technology continues to improve noteworthy prosperous experience is gained on the best approaches in order to planning and design the PV power systems. PV is now, after hydro and wind power, the third most important renewable energy source in terms of globally installed capacity. The PV modules have undergone significant price decreases, further increasing their attractiveness to investors and accelerating the technology's drive toward competitiveness with conventional electricity sources [1]. The percentage of the population whose access to electricity in Afghanistan, is among the lowest in the world [3]. Near 4% of rural households have access to electricity and over 20.4% of the rural population cannot meet the minimum level energy required to sustain a healthy life [4]. Without access to modern, commercial energy, poor countries can be trapped in a vicious circle of poverty, social instability, and underdevelopment [5]. Currently, 28% of the Afghan house-holds are connected to the electric power supply systems. The connection rate within the provinces differs in a wide range from zero in the rural areas to near 100% in urban regions [6]. With consider growing electricity demand and at the same time air pollution problem in Afghanistan, it proves the overwhelming need for renewable energy development. By ensuring the relative security over the last 13 years in Afghanistan, the trend of electricity generation and consumption was flourished dramatically. Which, the solar energy can be counted a negligible share of this trend.

Over the last 13 years, numbers of PV projects have been inaugurated around the country. Excluding few projects, all the PV systems are in form of decentralized (individual household) installation. So, the aim of this paper is to assess the overall aspects of centralized and decentralized PV systems based on the implemented decentralized rooftop projects (case study: Kulangar Village in Logar province), and new proposed approach for centralized PV system. Besides, the lack of sufficient policy for rural electrification is pointed out. For this purpose, the centralized PV system planning for rural communities are developed in coordination with real-world feasible load demand forecasting and Afghanistan's real marketplace rates estimation. Afterward, study is laid on a techno-economic comparative analysis of centralized and decentralized PV systems to find out a reasonable solution for rural communities electrification in Afghanistan.

The rest of the paper is organized as follows; in section II, a concise outlook of renewable energy and its history, barriers on the way of renewable energy deployment in Afghanistan are presented. Section III develops a cost-effective planning of centralized PV system including technical and economic assessments, and also focused on load demand forecasting, proper sizing of PV system, and correct selection of BOS (Balance of System) components. Section IV investigates on 32 individual households' rooftop decentralized PV systems in Sayed Noor Village in Logar province. Section V deals with comparative analysis assessment between centralized and decentralized PV systems implementation in rural and remote communities with consideration of techno-economic study. Finally, section VI concludes the preference of the centralized PV system and introduces the significance of proposed approach for rural communities' electrification in Afghanistan.

2. Background

Renewable energy especially solar and wind resources have continuously attempted to perch places among the other energy sources in order to play an important role as the main contributor for achieving environment friendly energy. For the first time in 1986, directorate of new energy project started solar hot water system producing and installation in Afghanistan that was inaugurated in different governmental offices [7]. According to the NSP (The National Solidarity Program), as of 2007, 42000 villages are referred as rural settlements in Afghanistan [12].

The ERDA (Energy for Rural Development Afghanistan) program was established by MRRD (Ministry of Rural Rehabilitation Development) for the purpose of sustainable livelihoods through rural infrastructure services. The main goal of the REnD (Rural Energy Department) is to develop renewable energy projects in the rural areas of Afghanistan to promote the sustainable development of the country. Solar energy system is a part of these projects, which widely implemented in rural areas. The prerequisite for proposal has been at least 10 households in as settlement, which the SHS (Solar Home System) sizing is proposed individual household from 20–100 W_P. For system operation, monitoring, and management system, 5% of the total subsidy is considered [8].

Due to understanding the importance of empowering the rural sustainability, MRRD had implemented over 100,000 individual household photovoltaic systems [13]. Almost a lion share of these photovoltaic systems are failed or running under poor performance of reliability. That based on our observation from Sayed Noor Village, due to lack of proper maintenance and poor maintenance; less than 20% of decentralized photovoltaic systems have utilized respectively in adapt with desired installed capacity (with considering utilization and lifetime factors). There are numbers of reasons to cause expensive project investment with poor performance short time life-spam.

Overall difficulties in photovoltaic in rural areas in Afghanistan have been due to an open-door personalized policy that causes poor engineering such as photovoltaic system design and planning (sizing, orientation and tilt, equipments and etc.), improper implementation, lack of technical staff, and mainly lack of coordination between the technical and economic analysis in regional contexts. This open-door policy not only waste the resources (budget and time), but also create a distrust environment among citizens and government.

3. Centralized PV System Planning for Rural Facilities

For scaling and planning of a PV system, the most primary concern is the system power balance (power production must meet the load demand). Availability of the energy source, variety of performance, technical, safety, environmental, legal, cost and applicability consideration are other factors can influence the design of a PV system.

3.1. Load Demand

The 24 hours load estimation for a 30 households' medium size village is supposed, which it is typically a central focus of decision on capital investment. Initial investment is the primary determinant of costs for power supply sizing and operation. Type of consumer load (AC) (residential/domestics, public services, and industrial), and load operation time (day time, night time and also seasons) are considered. The basic electric power for residential houses are (a) lighting load and (b) general small appliances load such as radio, TV, fan, computer, refrigerator and other miscellaneous small loads.

$$E_R = \sum_{i=1}^{n} P_{Li}\, T_{Li} + \sum_{i=1}^{n} P_{Si}\, T_{Si} \quad (1)$$

$$P_R = P_L + P_S \quad (2)$$

Where, E_R is the whole community total residential electric energy demand in kWh, $P_R, P_L,\ P_S$ are total residential load demand, lighting load and general small power load demand respectively. T_{Li} and T_{Si} are the operation times segments related to lighting and general small power loads, and n is the numbers of the residential houses in rural or remote community.

Meanwhile, beside of the residential load, for the rural community a solar water pumping systems load to provide drinking water, rural health centers load, small industry load (for rural development) and other public service load (for education and religious purposes) are supposed as well. Later each load classes are illustrated with detail within case study.

$$E_{NR} = P_W T_W + P_H T_H + P_I T_I + P_P T_P \quad (3)$$

$$P_{NR} = P_W + P_H + P_I + P_P \quad (4)$$

$$E_T = E_R + E_{NR} \quad (5)$$

Where, E_T is the total demand load and E_{NR} is the whole community total nonresidential electric energy demand in kWh. P_W, P_H, P_I, P_P are water pump load, rural health center load, small industry load and public services load respectively. T_W, T_H, T_I and T_P are the operation time segments related to foresaid loads. The result of calculations and 24 hours load demand shows in Table 1, and Figure. 1, respectively.

Table 1. *The village 24 hours energy demand estimation.*

Type of Load	Description	Nominal Power (W)	Load Factor	Quantity	Working Hours/ Day	Total Energy (Wh/day)
P_L	Light	18	1.25	2	5	225
P_S	Fan	88	1	1	6	528
	Radio	15	1	1	8	120
	TV	70	1	1	6	420
	Computer	120	1	1	6	720
	Refrigerator	1200	1	1	-	1200
	Miscellaneous (Mobile phone charger and etc.)	30	1	1	24	720
P_R	Appliances nominal powers are consider as [16] [17]					117990
P_W	Water Pump	2200	1	1	4	8800
P_H	Rural Health Center	800	1	1	8	6400
P_I	Small Industry	1200	1	1	6	7200
P_P	Public Services	200	1	2	12	4800
P_{NR}	The load demand and working hours are proposed based on present most real need of the rural communities in Afghanistan [15].					27200
E_T						145.19 (kWh/ day)

Note: Appliances nominal powers are consider as [16] [17].

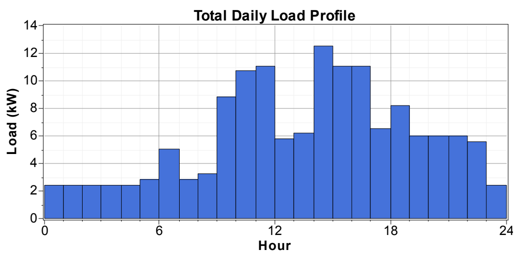

Figure 1. *24 hours load profile.*

Afghanistan is a mountainous country in the heart of Asia with extreme change of seasonal weather and climate. In the most areas of Afghanistan, the cold weather runs from the early autumn through late winter. So, the domestic load calculation for fan and refrigerator directly affect from the seasonal weather extreme changes. Therefore, it is assumed that the fan and refrigerator should be switched off during the cold climate and the resulting excess capacity should compensate the cloudy days' production and other seasonal defects.

The water pump load is considered as daytime load with 3 hours pause at 6am, 10am, 2pm, and 6pm, and also a small industry load is proposed in two shift morning and afternoon for 6 hours. The distinguish between controllable and non-controllable load is essential for load forecasting which the non-controllable domestic appliances have the capability of on/off action such as TV, lights and so on [21].

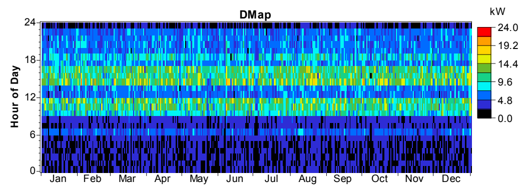

Figure 2. *Data map.*

The Data Map (Figure. 2) is typical shows one year of time series data which can observe the daily and seasonal patterns of load.

3.2. BOS Components

The numbers of required solar panels and BOS (Balance of System) components are calculated within observance of PV pre-design and estimation norms [18-20]. The main aims to offer a cost-effective PV system with consider to meet sufficiently the load demand.

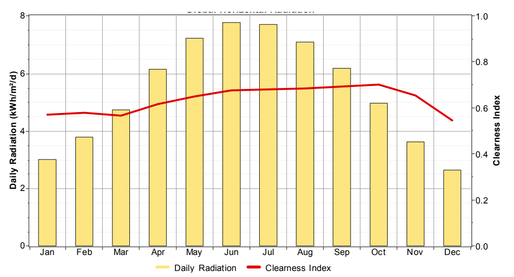

Figure 3. *3 days radiation and clearness index.*

The ESH (Equivalent Sun Hours) for the case is obtained 5.41 kWh/dm^2 by using the HOMER Software [22] at 34° 2' N, 69° 1' E of geographic coordinate. It is noteworthy that the HOMER Software [22] is employed for obtaining the average solar radiation for proposed project, Figure. 3. The efficiency factor is assumed 0.73 (0.95, 0.9, 0.95, 0.98, 0.92 shading de-rate factor, temperature de-rating factor, inverter efficiency, wiring losses, and protection devices and utilization performance respectively).

$$\text{Minimum } W_p = \frac{\text{Total Energy Demand}}{\text{ESH} \times \text{Efficiency Factor}} \quad (6)$$

$$\text{Number of Panels} = \frac{\text{Minimum } W_p}{\text{PV } (W_P)} \quad (7)$$

Parallel configuration:

$$I_{max} = I_{SC} \times \text{Number of Panels} \quad (8)$$

Series configuration:

$$V_{max} = V_{OC} \times \text{Number of Panels} \quad (9)$$

$$\text{Efficiency} = \text{Module Efficiency} + \text{BOS efficiency} \quad (10)$$

Nomenclature:
BOS: Balance of System
ESH: Equivalent Sun Hours
I_{max}: Maximum current
I_{SC}: Short Circuit Current
V_{max}: Maximum Voltage
V_{OC}: Open Circuit Voltage
W_P: Power Output

Optimum tilt of solar panels is various in different seasons, approximately in winter, spring and summer are $32^{\circ}, 56^{\circ}$ and 80° respectively. Therefore, we supposed the correction angle for the PV system based on the winter best performance (40°) because in this season the sun hours steadily decrease.

Storage devices in the system improve efficiency and reliability of renewable energy resource utilities and the flexibility of time of use electricity prices [9, 14]. To define the battery bank capacity, the desired/required storage day is considered one day with 0.8 allowable depth-of-discharge limit. The relation between lifetime and the DoD of the battery is linear function, with use of the battery in high value of the DoD the battery lifetime is decreasing [24].

$$\text{Minimum } C_b = \frac{\text{Total Energy Demand}}{\text{DoD} \times \text{OVS}} \times \text{DA} \quad (11)$$

$$\text{NBS} = \frac{\text{OVS}}{\text{Battery Nominal Voltage}} \quad (12)$$

$$\text{NBP} = \frac{\text{Minimum } C_b}{\text{Battery Rated Capacity}} \quad (13)$$

$$\text{Battery Bank} = \text{NBS} \times \text{NBP} \quad (14)$$

Nomenclature:
C_b: Battery bank capacity
DA: Days of Autonomy
DoD: Depth of Discharge
NBP: Number of Batteries in Parallel
NBS: Number of Batteries in Series
OVS: Operational Voltage of the System

Admittedly, the next step in planning a PV system is to understand the elements of BOS that compose it. So, the central inverter is supposed for this approach which the rest of BOS components are calculated in Table 2.

Table 2. *Proposed PV system cost estimation.*

PV Components	Quantity	Unit	Unit Price		Subtotal	
			AFN	USD	AFN	USD
PV panel and Accessories (1)	122	Set	23,940	435	2,920,680	53,103
Mounting hardware (2)	2	Set	41,040	746	82,080	1,492
Wiring and installation	1	Set	46,740	850	46,740	850
Battery (3)	104	Set	12,255	223	1,274,520	23,173
Central inverter	1	Set	68,400	1,244	68,400	1,244
Distribution Panel, Safety, and electrical control circuits accessories	1	Set	91,200	1,658	91,200	1,658
Training	20	Hour	4,275	78	85,500	1,555
Maintenance	15	Year	50,160	912	752,400	13,680
Technical staff	180	Month	12,540	228	2,257,200	41,040
Initial Capital Cost				4,569,120		83,075
Operating Cost for 15 Years				3,009,600		54,720
Total Project Cost within 15 Years				7,578,720		137,795

(1) Including charge controllers, and other accessories but tracking system and control system (maximum power point tracker) are not included. The solar panels sizes are taking into account 300 W_p.

(2) There is two mounting structure is supposed to be installed in two direction in order to increase the system productivity.

(3) Desired days of storage is one day with 0.8 DoD of 200 Ah battery.

NSP alike various project under the MRRD have established to empower the rural communities. Logar province with 7900 urban and 324500 rural population is one on the 34 province of Afghanistan that is located approximately 60 km at the vicinity of Kabul [10].

For comparative purpose of centralized and decentralized PV systems analysis, we recall the decentralized individual household rooftop PV project which was implemented in 2005 in Sayed Noor village. The project is implemented by NSP and local government support with including 10% of villagers share. This project had comprised from 32 individual household families rooftop PV systems (including 100 W_P solar panel, charge controller, 100 Ah battery, 2 fluorescent lamp, and other accessories). Recently reported, that less than

20% of this project is running in adapt with desires installed capacity (with considering utilization and lifetime factors) and the rest 80% of decentralized PV system are failed or operating under very low performance. The aim of this case study is to investigate on the existing issues. It covers technically and economical aspects of the present condition of this project after near nine years. The project under study is located in the Sayed Noor village in Kulangar with approximate latitude and longitude of 34°02'44.5"N and 69°01'0.7"E.

Beside, of the mentioned technical problems, there some non-affordable operational cost estimation mismatches. The cost estimation for this sample project (decentralized PV system) in order to economic comparative analysis (with the centralized PV system), performed based on the present Afghanistan's marketplaces rate in Afghanistan currency (55AFN ≅ 1USD). Whole project cost are lumped as 32 households' individual rooftop PV systems that shown in Table 3.

4. Comparative Assessment of the Scenarios

The case study include scenarios that apply comparative analysis of cost-effectiveness assessment of both centralized and decentralized PV systems to meet the load demand of the rural medium size village. Estimations show that in Afghanistan solar radiation averages about 6.5 kWh per square meter per day with 300 sunny days a year [11]. PV technology normally seems expensive because of its upfront initial cost. However, it the recent, rural and remote areas of Afghanistan have been the best market for PV system distribution. These markets continue to develop simultaneously at the end of the conflict in 2001 that has experienced many ups and downs of transitions from 2001 to now.

1. The efficiency of the overall system is measured an important factor for total costs estimation. The capital cost of the project affects from:
2. Improvements of solar cell efficiencies;
3. Lower cost materials and application methods; (array modules mounting structure to benefit the maximum radiation;
4. Life cycle of the used materials; and
5. PV's system isolation.

Across the entire study of cost reduction mainly focused on technical reliability more than economic feasibility.

Table 3. *Cost estimation of present decentralized PV system (Sayed Noor village in Logar province).*

PV Components	Quantity	Unit	Unit Price		Subtotal		Remarks
			AFN	USD	AFN	USD	
PV panel and Accessories	32	Set	13,395	244	428,640	7,793	100 W_P, including change controller and etc.
Mounting hardware	32	Unit	3,705	67	118,560	2,156	Roof top frame
Wiring and installation	32	Set	4,845	88	155,040	2,819	
Battery (2)	32	Set	7,410	135	237,120	4,311	100 Ah
Spare parts & maintenance	15	Year	4,250	77	63,750	1,159	
Initial Capital Cost					1,003,110 AFN ≅ 18,238 USD		

There two approaches are investigated; for price comparison the installed capacity of each scenario are supposed as benchmark. So the existing decentralized PV system (with efficiency of 0.76) in Sayed Noor village (in the case study) with total installed capacity of 32 (100 W_P) solar panels is compared with new proposed centralized PV system (with efficiency of 0.73), based on each methodology total investment within 15 years. The analysis result shows that the cost for centralized and decentralized PV systems are $283.656\ \mathrm{AFN}/W_p$ and $412.463\ \mathrm{AFN}/W_p$ respectively. Not only the implementation of centralized PV system in rural communities in Afghanistan is 31% cost-effective but also there are other advantages are associated as well. Such as a small number of technical staff requirement with easy and always access to the system, facilitate the maintenance, monitoring and control, ensure the quality and reliability of supply with coherent decision-making and better load management. The standards and norms are crucial for ensuring the reliability and quality, it should be impracticable for each decentralized household photovoltaic systems which are not easily accessible for the technical team. Therefore, centralized PV system can prefer through its economic and technical advantages. The finding can implicate for having and applying an adequate electricity policy in order to prevent such issues for rural communities' electrification.

5. Conclusion

The purpose of rural and remote communities' electrification by using PV should not just be to electrify the communities, but also there are other reasons behind PV implementation to be seized. The noticeable result to ensure a clean environment, reduce poverty, and promote the literacy level in these communities must be associated with electrification concept. Generally, the difficulties in the way of renewable energy projects in Afghanistan have been the lack of sufficient policy for long-term monitoring and support, improperly use of the equipments with short life-span, lack of quality control and assurance, mismatch application of norms, and overall mismanagement in the village level. This study reveals that the implementation of individual household decentralized PV systems is not cost-effective, and pursuing such decentralized method may have worst outcome. While, the centralized PV system is competitively 31% cost-effective than decentralized PV system. In addition, of the comparative study of PV's centralized and decentralized systems, we seek to address feasible cost-effective solution with real time/real cost analysis for rural and remote communities in Afghanistan to offer the best alternative option. The proposed approach can be applied to the real world rural project in Afghanistan with developing of detailed design with on-site compatibility. Through implementation of the proposed approach in practice, it should increase the system efficiency to ensure the desired high performance of centralized PV system with cost-effective investment.

Acknowledgement

This work is part of a research study, which is financially and technically supported by the JSPS (Japan Society for the Promotion of Science) under RONPAKU PhD. Fellowship for FY 2015 (JSPS/OF/214090), and Energy Engineering Department in Kabul University, respectively; with the aim of eminent researchers' empowerment.

References

[1] EPIA Sees Solar Power at the Crossroads | photovoltaic production, http://www.photovoltaicproduction.com/3365/epia-solar-power-at-the-crossroads (accessed Feb 12, 2014).

[2] Qing-Shan Jia, Jian-Xiang Shen, Zhan-Bo Xu, and Xiao-Hong Guan.: 'Simulation-Based Policy Improvement for Energy Management in Commercial Office Buildings', Smart Grid, IEEE Transactions, Volume:3, Issue: 4., 2012, pp. 2211 - 2223, doi: 10.1109/TSG.2012.2214069

[3] The World Bank. (2013, Nov). Afghanistan Overview. The World Bank. Kabul, Afghanistan. Available: http://www.worldbank.org/en/country/afghanistan/overview.

[4] Afghanistan National Development Strategy (ANDS), Islamic Republic of Afghanistan.: 'Energy Infrastructure' (Volume 2, Pillar 3, 2008).

[5] Terry Mohn.: 'It Takes a Village: Rural Electrification in East Africa', Power and Energy Magazine, IEEE, Volume: 11, Issue: 4., 2013, pp. 46-51, doi: 10.1109/MPE.2013.2258281

[6] Asia Developing Bank (ADB), "Technical Assistance Consultant's Report," Islamic Republic of Afghanistan, Ministry of Energy and Water (MEW): Power Sector Master Plan, ADB., Kabul, Rep. P. No 43497, May, 2013.

[7] Wahiddullah Sabavon, Gardizi, "Electricity In Afghanistan," in Madina Printing Press, 1st ed. Kabul, Afghanistan, 2008. pp. 1–24.

[8] MRRD, Ministry of Rural Rehabilitation and Development. "Rural Electrical Implementation Guidelines." http://mrrd.gov.af/Content/files/Rural%20Electrical%20Implementation%20Guidelines.pdf (accessed April 6, 2014).

[9] Zhanbo Xu., Xiaohong Guan, Qing-Shan Jia, Jiang Wu, Dai Wang, and Siyun Chen: 'Performance Analysis and Comparison on Energy Storage Devices for Smart Building Energy Management', Smart Grid, IEEE Transactions, Volume:3, Issue: 4., 2012, pp. 2136 - 2147, doi: 10.1109/TSG.2012.2218836

[10] Program for Culture and Conflict Studies. http://www.nps.edu/programs/CCS/Docs/Executive%20Summaries/Logar.pdf (accessed April 17, 2014).

[11] Nadeem Malik, "Energy Resources in Afghanistan and Measures to Improve for Sustainable Development," Journal of Sustainable Energy, vol. JSE-2, no. 4. Dec, 2011.

[12] Ministry of Rural Rehabilitation and Development. "National Solidarity Programme." http://www.nspafghanistan.org (accessed May 4, 2014).

[13] MRRD, Ministry of Rural Rehabilitation and Development. "Ministry Archive.". March, 2014.

[14] Dan Wang, and Fang Zheng Peng.: 'Smart Gateway Grid: A DG-Based Residential Electric Power Supply System', Smart Grid, IEEE Transactions, Volume: 3, Issue: 4., 2012, pp. 2232 - 2239, doi: 10.1109/TSG.2012.2214070

[15] MUDA, Ministry of Urban Development Affairs. "Strategic Development Plan, Database.". March, 2014.

[16] "OkSolar.". http://www.oksolar.com (accessed April 12, 2014).

[17] Welcome to Wholesale Solar. "Welcome to Wholesale Solar.". http://www.wholesalesolar.com (accessed February 18, 2014).

[18] Maeda, Martha. How to Solar Power Your Home. Florida: Atlantic Publishing Group, Inc., 2011.

[19] Hoff, T.E. "Photovoltaic Incentive Design Handbook." In. Battelle: Clean Power Research Napa, California, 2006..

[20] "Solar Electric System Design, Operation and Installation." In. Olympia: Washington State University Extension Energy Program, 2009.

[21] Hubert, T., and Grijalva, S.: 'Modeling for Residential Electricity Optimization in Dynamic Pricing Environments', Smart Grid, IEEE Transactions, Volume:3, Issue: 4., 2012, pp. 2224-2231, doi: 10.1109/TSG.2012.2220385

[22] Homer Energy Software. "HOMER ENERGY." http://homerenergy.com (accessed January 14, 2014).