ENERGY GENERATION AND CONSUMPTION IN GHANA

Emmanuel A. Essah[1]
School of Construction Management and Engineering, University of Reading, Reading, RG6 6AW, UK

Electricity consumption in Ghana is estimated to be increasing by 10% per annum due to the demand from the growing population. However, current sources of production (hydro and thermal facilities) generate only 66% of the current demand. Considering current trends, it is difficult to substantiate these basic facts, because of the lack of information. As a result, research into the existing sources of generating electricity, electricity consumption and prospective projects has been performed. This was achieved using three key techniques; review of literature, empirical studies and modelling. The results presented suggest that, current annual installed capacity of energy generation (i.e. 1960 MW) must be increased to 9,405.59 MW, assuming 85% plant availability. This is then capable to coop with the growing demand and it would give access to the entire population as well as support commercial and industrial activities for the growth of the economy. The prospect of performing this research is with the expectation to present an academic research agenda for further exploration into the subject area, without which the growth of the country would be stagnant.

Keywords: energy, electricity generation, electricity consumption, Ghana.

INTRODUCTION

In today's world, the role of energy generation and consumption cannot be over emphasised. Energy consumption enhances productivity, economical growth, global networking as well as its adverse effects on climatic; climatic change. The need for additional installed capacity of energy source to meet the potential of a country has continued to be at the forefront of growing economies of many countries. However, these concepts and principles are yet to be fully harnessed in Ghana.

Electricity consumption in Ghana is estimated to be increasing by 10% per annum due to the demand from the growing population. However, current baseline production sources generate only 66% of the current demand. From this, an estimated 65% is used in the industrial and service sectors while the residential sector accounts for about 47% of total electricity consumed in the country. Though this does not add up (certainly there must be justified reason), this is what has been presented in the Energy Sector Strategy and Development Plan, 2010 (www.ghanaoilwatch.org). This lack of parity prompts research to enable the validation of available data.

Current data draws on the fact that electricity generation is primarily obtained from hydropower sources at Akosombo and Kpong Dam located in the Eastern Region of Ghana and another two thermal power plants using light crude oil at Aboadze near Second-Takoradi in the Western Region of Ghana (Gand, 2009). Additional infrastructure has been constructed to boost the capacity, bringing Ghana's installed

[1] e.a.essah@reading.ac.uk

Essah, E.A. (2011) Energy generation and consumption in Ghana *In:* Laryea, S., Leiringer, R. and Hughes, W. (Eds) *Procs West Africa Built Environment Research (WABER) Conference*, 19-21 July 2011, Accra, Ghana, 1-7.

capacity to 1960MW (i.e. 2009 figures) (www.ghanaoilwatch.org). Ghana's energy strategy and development plan by 2015 (www.ghanaoilwatch.org) predicts baseline production to rise to 80%, however it is not clear what percentage of the nation would have access to electricity. To achieve this increase, the sector raises the following challenges for additional energy generation sources:

- Developing infrastructure for the production and supply of adequate energy services to meet national requirements and for export.
- Developing the requisite infrastructure to ensure universal access as well as the efficient and reliable supply of energy services.
- Ensuring that energy is produced and supplied in a form that has no adverse health, safety and environmental impact.

These are interesting projections but current trends and statistics indicates that this may be farfetched within the 2015 targets set by the nation. This paper reviews existing data and develops detailed analysis that challenges for potential infrastructure development to meet growing energy demands. It also draws on the expectation to present an academic research agenda that is yet to be critically explored.

PROJECT RATIONALE

There is enormous potential for Ghana to address the "pressures" of its energy demand by investigating ways in which similar or other technologies could be viably adopted to supplement and provide energy to meet the needs of the growing population. However, without detailed research and commitment to implement its findings, this potential would not be realised The fact that there are variations in data regarding the current percentage of the population that has access to electricity raises concerns and debate regarding the authenticity of data available to the public. Depending on the source from which information is obtained, values of those who have access are quoted between 50-70% (www.ghanaoilwatch.org; http://www.modernghana.com). From this, it is estimated that the access to electricity in the urban areas is 70 % and that to rural areas is approximately 30% (http://www.modernghana.com). These figures are yet to be substantiated with facts backed by research.

Undoubtedly, it is clear from the constant *"blackouts"* that the current national grid lacks security because of the unpredictable variation in energy sources (www.ghanaoilwatch.org) or insufficient wholesale electricity supply (excluding indirect cost) eventually costing the nation between $320 million and $924 million annually or 2 - 6% of Gross Domestic Product (GDP) (www.adomonline.com). As a result, the current energy strategy policy of the country (2010) identifies the need for research to develop additional strategies to improve and modernise transmission and, distribution infrastructure. This is aimed at developing a non-congested transmission system by 2015 (www.ghanaoilwatch.org).

STUDY APPROACH

To understand the lapses in data presented and the challenges that face the Energy Sector, this paper present research that was performed using three effective stages:

Stage 1: Understanding the potential of the current grid infrastructure and its capability to meet the growing demands: a literature survey.

Stage 2: Empirical studies to investigate the countries energy requirements, installed capacity and energy consumption.

Stage 3: Modelling a photovoltaic system with grid integration as a possible source of energy generation.

Based on these stages, several recommendations are made with a view to initiate a rigorous research engagement into the subject area by leading researchers and academic institutions in Ghana.

IMPACT OF GROWTH: URBAN AND RURAL

Ghana's 2010 census reported a population of 24.3 million people out of which an estimated 29% of the population are identified to live in rural areas (http://unstats.un.org; Yanga and Di Sirio, 2011). Even though rural electrification has grown substantially (GRIDCo, 2010a), it goes without saying that the urban population consumes the most. Over the last decade, Ghana experienced annual growth in peak electricity demand of about 1.4%, from a baseline of 1,258 MW in 2000 to 1,960 MW in 2009, with a corresponding cumulative growth in energy demand of 3.3% annually from 7,539 GWh in 2000 to 10,116 GWh in 2010 (projected) (GRIDCo, 2010a).The growth rates have been driven largely by three trends (GRIDCo, 2010a):

- **Economic growth:** Ghana's GDP grew at an average of 5.5% per annum between 2000 and 2009.
- **Rapid urbanization:** Ghana's urban population share increased from 44% to 52% between 2000 and 2010.
- **VALCO's demand curtailment:** VALCO's operations have been interrupted several times over the last 10 years due to the unpredictable nature of the grid distribution.

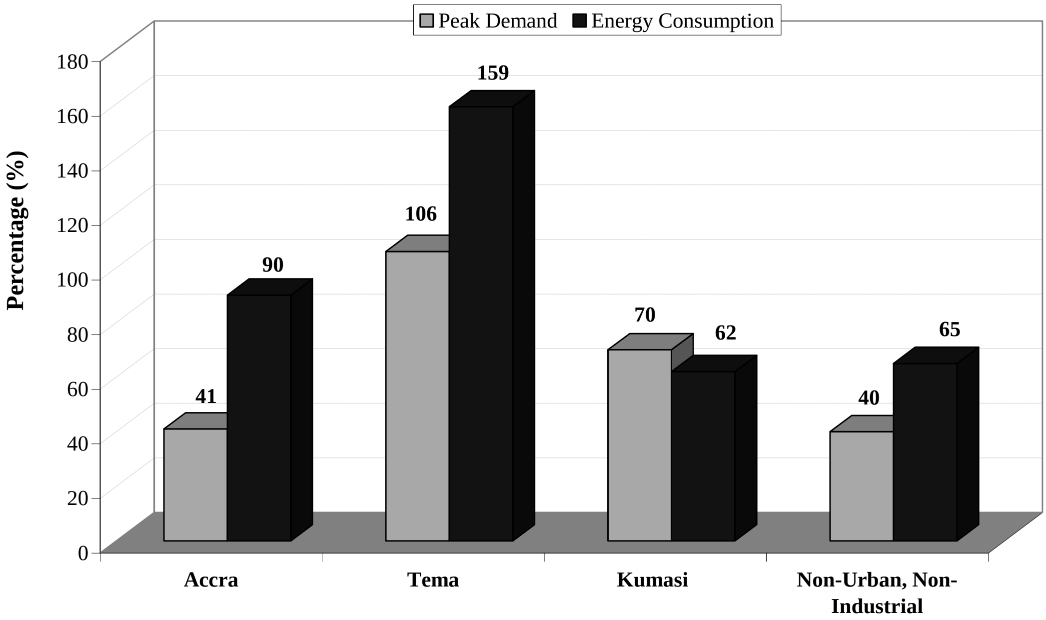

Figure 1. Peak Demand and Energy Consumption for key Urban areas; 2000-2009 *(Source:GRIDCo,2010a)*

Significantly, Ghana's three largest cities; Accra, Tema, and Kumasi, have been the key drivers in increased urban electricity usage, because of the impact of urbanisation. The total peak electricity demand for these cities rose from 48% in 2000 to 52% in 2009 with a corresponding steady growth of electricity consumption at just over 50%. The most significant growth was in Tema, where peak demand grew more than 106% over the 10 year period and energy consumption grew more than 159% (see Figure 1) (GRIDCo, 2010a; GRIDCo, 2010b).

To sustain this growth, significant development of additional infrastructure is required. Unless this is developed, the existing infrastructure would not be able to sustain and/or coop with the prospective demand, as a result the need for research and investment in this area.

EXISTING INFRASTRUCTURE

Statistics of electricity generation in Ghana as illustrated in Tables 1 and 2 shows the possible potential of electricity generation even though percentage availability varies significantly. Since 2007, five additional generation plants have been commissioned to boost the capacity of the existing structure. As stated earlier, despite this development, only between 50-70% of the population have access to electricity (www.ghanaoilwatch.org; http://www.modernghana.com). This is rather low, since the growth of any country depends on the availability and affordability of electricity to the entire population.

To meet the growing consumption rates, the projected yearly energy consumption is estimated by GRIDCo (2010) to be 10,305 GWh. It is anticipated that with the current construction of additional infrastructure (i.e. to be completed by 2014), hydro would contribute 6,360 GWh, with the remaining 3,945 GWh generated from thermal plants. This implies running almost five thermal plants continuously throughout the year. Hence, with the current low levels of units' availability (Table 1), a supply deficit of close to 1000 GWh is likely to be experienced (GRIDCo, 2010a).

Table 1: Electricity generated by plant (GWh)

	Hydro			Thermal								
Plant	AKOS	KPO	Total	TAPCO	TICO	TT1	TRPP	ERPP	KRPP	MRPP	Total	Total
2000	5557	1052	6610	345	268	-	-	-	-	-	613	7223
2001	5524	1085	6609	740	510	-	-	-	-	-	1251	7859
2002	4178	858	5036	874	1363	-	-	-	-	-	2237	7273
2003	3210	675	3885	1328	668	-	-	-	-	-	1997	5882
2004	4404	876	5281	536	222	-	-	-	-	-	758	6039
2005	4718	911	5629	831	328	-	-	-	-	-	1159	6788
2006	4690	929	5619	1416	1395	-	-	-	-	-	2810	8429
2007	3104	623	3727	1521	1417	-	162	80	33	38	3251	6978
2008	5254	941	6196	874	1063	-	85	45	16	46	2128	8323
2009	5842	1035	6877	453	1040	570	-	-	-	18	2081	8958
% availability	98.97	99.01	-	27.71	90.5	98.25	-	-	-	76	-	-

Where AKOS = Akosombo Hydro Power Plant
ERPP = Emergency Reserve Power Plant MRPP = Mines Reserve Power Plant TRPP = Tema Reserve Power Plant
KRPP = Kumasi Reserve Power Plant
KPO = Kpone Hydro Power Plant
TT1 = Tema Thermal 1 Plant
TICO = Aboadze Tico Thermal Power Plant
TAPCO = Takoradi Thermal Power Plant

Source: Energy Statistics (http://new.energycom.gov.gh)

From Table 3, there is a steady growth in electricity consumption by the residential sector while a corresponding decline is observed from the industrial sector. This is only possible because of the reduced activity of VALCO while the construction of residential properties connected to the grid is on the increase. Within the scheme of events, electricity exports are also on the increase (Table 3).

Table 2: Grid Electricity available for domestic sales (GWh)

Year	Electricity Generated (GWh)				Generation and Substation use	Transmission Loses	Export	Available for Domestic sale
	Hydro	Thermal	Import	Total				
2000	6610	613	864	8087	23	229	392	7835
2001	6608	1251	462	8321	32	259	302	8030
2002	5036	2260	1146	8442	45	368	612	8029
2003	3885	2015	940	6840	45	333	604	6462
2004	5281	758	878	6917	31	205	665	6681
2005	5629	1159	815	7603	42	249	639	7312
2006	5619	2810	629	9058	51	318	754	8689
2007	3727	3251	435	7413	47	230	246	7136
2008	6196	2128	275	8599	51	303	538	8245
2009	6877	2081	198	9156	25	339	752	8792

Source: http://new.energycom.gov.gh

To date, electricity exports have provided an important source of foreign exchange earnings for the country. Ghana exports power to the neighbouring countries including Togo, Benin, and Burkina Faso. It must be noted that when necessary, Ghana also imports power from La Cote D'Ivoire. Becoming a major exporter of electricity is a major objective to achieve the vision of the energy sector. In addition, the opportunity exists for Ghana to expand its electricity exports under the West African Power Pool (WAPP) Project (www.ghanaoilwatch.org). This is significant as it promotes investment in the sector.

Table 3: Electricity Consumption by Sector (GWh)*

Sector	Industrial	Non Residential	Residential	Total
2000	4306	536	1494	6336
2001	4335	579	1612	6526
2002	3900	602	1671	6173
2003	2205	620	1727	4552
2004	2085	661	1782	4528
2005	2543	698	1915	5156
2006	3593	791	2129	6513
2007	2697	803	2095	5594
2008	2966	928	2269	6163
2009	2943	878	2408	6229

**data does not include commercial and technical losses (Source: VRA, GRIDCo)*

ESTIMATED ELECTRICITY CONSUMPTION

Ideally, based on the population of a country, the basic energy needs of each individual must be met through the installed capacity of the generated sources. This forms the basic requirements of all developed countries; in fact, it must form the basis of any country that seeks development. From this analogue, this section develops simple equations to analyse the actual demand and deficit of electricity supply required to meet the needs of the current population of Ghana. Assuming all the electricity consumption requirements of Ghana are met,

Basic Equations

These equations are developed to assess the consumption of household appliances, assuming every individual has access to a range of basic appliances as would be in any home.

$$D_a P_W C_{ons}\ (Wh/day) = AR\ (W) \times quantity \times hours/day \qquad \textbf{(1)}$$

$$A_{nn} P_w C_{ons}\ (kWh/year) = \frac{D_a P_w C_{ons} \times Days\ of\ the\ year}{1000} \qquad \textbf{(2)}$$

Where $D_aP_wC_{ons}$ = Power Consumption/day; Wh/day
$A_{nn}P_wC_{ons}$ = Annual Power Consumption; kWh/year
AR = Appliance Ratings; W

Note:

These equations do not take into account losses due to inefficient appliances and or transmission losses.

From the carbon independent review of UK, annual average electricity consumption is 4,800 kWh per 4 person household. A smaller than average household (2 person household) is taken arbitrarily to be 3,000 kWh, and a larger than average household (5^+ person household) accounts for about 7,000 kWh (www.carbonindependent.org). Since similar statistics is not available through the statistics division of Ghana, a simple empirical study was carried out to estimate average energy consumption of a household (4 persons).

The study collates data within a domestic (residential) sector (Table 4) and non residential sector (using a virtual commercial office) as a case study (Table 5). Tables 4 and 5 were developed using Equations 1 and 2. From the study (Table 4) it was estimated that an average household of 4 persons consumes at least 1795.1 kWh/year of electricity. This is approximately $1/4^{th}$ the limits consumed in UK. It must be noted that most of the data used to generate the results in Table 4 were based on updates from general review appliances reported by Energy Foundation, Ghana (www. ghanaef.org) in comparison with the researcher's current domestic appliances and other relevant sites. Generally, comparing the yearly household (residential) values of 2408 GWh in 2009 (Table 3) the country requires additional electricity generation plants that would contribute to ~ 4.5 times more than the current annual average; 2408 GWh. This would then agree with the estimated residential electricity consumption of 10,771 GWh (Table 4).

The total energy required (estimated in Table 4 and 5) for the domestic and commercial sector is 94,036.1 GWh. From Table 3, the industrial sector requires an additional 35% (on average) of the residential sector. This implies that to address the electricity consumption required by the population and for economic growth, the annual total energy required is 97,805.76 GWh. This is ~ 11 times more than the current available electricity for domestic sale (Table 2) and ~ 9.5 times more than the projected electricity consumption estimated at 10,305 GWh.

Table 4: Estimated energy consumption for a domestic residence

Appliances	Rating (W)	Quantity	Hours (per day)	Power (kWh/year)
Hi-Fi radio	20	1	2	14.6
Mobile Phone(Charging 3 times/ week)*	-	1	3	0.7
Television (14 inch)	60	1	3	65.7
Computer with LCD screen	150	1	2	109.5
Ceiling Fan (max speed)	45	1	0.5	8.2
Telephone **	3.6	1	24	6.3
Refrig./freezer(22 cf***)	1200	1	-	292.0
Electric Stove	5500	1	-	876.0
Kettle	1200	1	0.2	73.1
Microwave	1000	1	0.2	73.0
Blender	700	1	0.1	25.6
Lights:				
11W compact fluorescent	11	3	2	24.1
Incandescent	40	4	3	175.2
Iron	1000	1	0.14	51.1
Total				1795.1
Total Demand (assume 4 person household of population) GWh				10,770.5

* *Mobile Phone Charger (http://www.willsmith.org/climatechange/domestic.html)*
** *Charges a DC researchable battery (6v 600mA)*
*** cf - cubic foot (*www.PVSyst.com*)

Table 5: Estimated energy consumption for a Commercial Offices (non residential)

Appliances	**Rating (W)**	**Quantity**	**Hours (per day)**	**Power (kWh/year)**
LCD Monitors(in Common areas)	90	3	6	591.3
Desk top computer (per Staff)	200	1	8	584.0
Telephone**	3.6	1	24	6.3
Refrig./freezer(22 cf***)	1200	1	-	292.0
Air Conditioning (efficient)****	1200	1	-	894.0
Toaster	800	1	0.15	43.8
Kettle	2200	1	0.15	120.5
microwave	700	1	0.25	63.9
Multifunctional printers - copiers	4500	1	24	2365.2
Lights:				
25W compact fluorescent	28	20	4	817.6
Fluorescent Lamps++	40	60	3	2628.0
Utility (security…)	500	6	0.08	87.6
Vacuum Cleaner	780	3	0.21	179.4
Total				**8673.5**
Total Demand***** **GWh**				**83,265.5**

**** *http://www.sust-it.net/energy_saving.php?id=75#nogo*
***** *assuming only 35% of the population work in commercial buildings based on facts from (www.theodora.com)*

To investigate the amount required to generate 97,805.76 GWh of electricity by plant, an empirical calculation based on the assumption that the required average transmission losses (*TLosses*), export and substation (*Sbs*) usage (Table 2) are known and accounted for.

Assuming 100% annual plant efficiency and yearly losses (Table 2),

then for the estimated available supply for domestic sale (DS)

$$
\begin{aligned}
Electricity\ available\ \ for\ DS\ (GWh) &= Estimated\ \ Value\,(GWh) - (TLosses + Export + Sbs)\,GWh \\
&= 97{,}805.76 - (284 + 550 + 39)\ GWh \\
&= 96{,}932.86\ GWh
\end{aligned}
\qquad (3)
$$

Therefore from the estimated demand assuming 85% plant efficiency (based on current efficiencies Table 1), the required plant power is

= 9,405.59 MW ***(4)***

That is if $1MW\ (plant\ \ power) = 8.76GWh\ (power\ \ produced)$

Considering the fact that to date Ghana has an installed capacity of 1960 MW (www.ghanaoilwatch.org), based on the estimated values in Equation 4, there is a deficit of ***6320.59 MW*** of plant power that is required to be installed (this does not include a possible 20% generation loss).

PROSPECTIVE INFRASTRUCTURE

There are several projects (Table 5) that are being built to meet the possible demand and strategic goal set out by the government to increase the existing facility to 5000 MW by 2015 (www.ghanaoilwatch.org). However, this is ~ 53 % less than the estimated capacity that is required to be installed, to enable every individual function and attain a substantial level of electricity usage.

Table 5: Summary of potential projects to meet the 2015 targets

Name of Project	**Unit Type**	**Installed Capacity (MW)**	**Time Frame**	**Investment Cost $/kW***
Bui	Hydropower	400	2013	1660
Hemang	Hydropower	60	-	1860
Juale	Hydropower	93	-	3300
Pwalugu	Hydropower	50	-	3600
Tema Thermal Power	Gas Turbine**	120	2010	-
Takoradi Thermal Power	Gas Turbine***	132	2013	-
Kpone Thermal Power	Gas Turbine***	220	2011	-
Wind Power Projects	Renewable	50	2014	-
Total (MW)		**1125**		
Deficit (MW)		**6320.59**		

** Karlsson,2006 (http://esa.un.org/un-energy/pdf/Ghana.pdf)*
*** Essandoh-Yeddu, 2010 (http://new.energycom.gov.gh)*
**** Energy Sector strategy plan (www.ghanaoilwatch.org)*

Amongst all these projects, the potential of photovoltaic systems is yet to be explored.

In this light it is envisaged that solar energy systems, will increase the national energy mix to ensure production and use. With an estimated 1.0MW of existing Photovoltaic (PV) installation (i.e. mainly standalone systems for rural electrification) supplying approximately 0.01% of the total electricity supply (http://www.areed.org), the potential of the sun through PV systems is still not harnessed.

Ghana, like all other countries in the sub-Saharan region, is blessed with year round intense and abundant sunshine with daily solar irradiation of between 4-6 kWh/m^2. While integrated photovoltaic (PV) technology is not new, the uptake of the technology has been slow and patchy. This can be attributed to a whole range of economical and technical reasons (Essah, 2010).

Using version 5.3 of PVSyst: a modelling software (*www.PVSyst.com*), the potential of using building integration photovoltaic (BIPV) technology to offset the deficit has been investigated, a summary of which is illustrated in Table 6. In this study only two types of PV technology was considered because of their relatively high efficiencies (η). These technologies are:

Polycrystalline Modules (η = 12 - 15%)

Monocrystalline Modules (η = 16 - 19%)

Table 6: Summary of possible electricity generation using photovoltaic modules

PARAMETERS	**POLYCRYSTALLINE MODULES**		**MONOCRYSTALLINE MODULES**	
Installed Capacity (MW)	5	10	5	10
Annual Energy Output (GWh)	6.72	13.55	6.72	13.55
Percentage of Demand (Eq. 3); %	0.007	0.014	0.007	0.014
Area required (m^2)	47,619	95,238	41,667	83,333
Percentage of Ghana's total area (%)	$2.00 * 10^{-5}$	$3.99 * 10^{-5}$	$1.75 * 10^{-5}$	$3.49 * 10^{-5}$
Cost on Investment ($)	41,100,378	81,466,248	40,053,320	79,367,932

From this study (Table 6), the potential of using PV to offset the demand for electricity generation sounds promising but comes with its own difficulties. Most of these short comings are the cost intensity and the vast land required (in this case roof space). For the percentage that would be offset, it is not currently viable, however with future reduction in PV module cost, this technology has a huge potential for the future. Payback time of the systems above was estimated at 20 years.

CONCLUSIONS

This paper has explored significant areas of energy generation and consumption. It is envisaged that the findings would stimulate debate and research in this field. The following deductions and suggestions are made:

From the estimates in Tables 3-5, the values of 50 -70% access to electricity consumption seems rather overstated. From this study, values presented indicate that it is rather < 30% and not as documented.

Though there are plans to increase the installed capacity, access to electricity would still be less than 40% of the population even though values quoted are above 70%.

Despite the abundance of yearly solar irradiance levels at present, the cost implications, payback periods and vast use of land, does not make the uptake of BIPV systems a viable source of generation and supplying electricity to the country.

It is rather interesting that one of the challenges proposed by the Energy Strategy Plans is *"Ensuring that energy is produced and supplied in a form that has no adverse health, safety and environmental impact"*. The constant generation of power, by thermal plants (that uses light crude oil for fuel) defeats this purpose as it contributes significantly to CO_2 emissions, and hence global warming.

It is evident that there is very little or no research, in this area hence the variation in information that has been made available through the net amongst others.

Suggestions

It would be beneficial if such statistics are made available to the public to ensure wider knowledge of the field.

Ideally data for domestic homes across the country must be made available. Possible investigation into the energy consumption of typical houses with 2, 4, 6 person household, throughout all regions.

Similar research and data collection for commercial buildings, educational establishments must also be considered.

Possible development of a carbon footprint for the country can be investigated.

The results presented in this research paper enhance the understanding of varying parameters associated with energy generation and consumption in Ghana. This study is designed to develop an essence of recognising the lack of information in this field to the general public and the need to research and invest in the subject area.

REFERENCES

Electrical Power in Ghana - Overview
Available at: http://www.mbendi.com/indy/powr/af/gh/p0005.htm
[Cited: May 2011]
Energy Foundation: Cost of Using Appliances
Available at: http://www.ghanaef.org/energyinghana/costofusingappliances.htm
[Cited: May 2011]
Energy Statistics (2000 – 2009)
Available at: http://new.energycom.gov.gh/downloads/statistics2000-2009.pdf
[Cited: May 2011]
Erratic electricity costs Ghana 924 million dollars (source Daily Graphic)
Available at:
http://adomonline.com/index.php?option=com_content&view=article&id=530:erratic-electricity-costs-ghana-924-million-dollars
[Cited: May 2011]
Essah, E.A. (2010) Building integration photovoltaic module with reference to Ghana: using triple junction amorphous silicon. Proceedings of the West Africa Built Environment Research (WABER) Conference, 27-28 July 2010, Accra, Ghana, 203-214.
Essandoh-Yeddu, J.K., (2010). Energy Commission, Ghana. 2010 Energy (Supply And Demand) Outlook for Ghana
Available at: http://new.energycom.gov.gh/downloads/2010Energy_Outlook.pdf
[Cited: January 2011]
Gand, E.K. (2009), Country profile for Ghana
Available at: http://www.setatwork.eu/downloads/SETatWork_Ghana_Profile_0910.pdf
[Cited: May 2011]
Ghana Overview
Available at: http://www.areed.org/country/ghana/ghana.pdf)
[Cited: November 2010]
Ghana People 2011
Source: 2011 CIA World Factbook and Other Sources
Available at: http://www.theodora.com/wfbcurrent/ghana/ghana_people.html
[Cited: November 2010]
Ghana wholesale power reliability assessment 2010 (GRIDCo), Final Report, March 2010b

Available at:
http://www.gridcogh.com/site/downloads/27a623e256c7d94a7dce43d5ef82d3e3GridCoReportFinal.pdf
[Cited: May 2011]
Home energy source
Available at: http://www.carbonindependent.org/sources_home_energy.htm
[Cited: May 2011]
Karlsson.M., (2006). Assessing Policy Options For Increasing the Use Of Renewable Energy for Sustainable Development: Modelling Energy Scenarios for Ghana (A UN-Energy Demonstration Study)
Available at: http://esa.un.org/un-energy/pdf/Ghana.pdf
[Cited: January 2011]
Ministry of Energy, National Energy Policy (2010), Republic of Ghana
Available at:
http://www.ghanaoilwatch.org/images/laws/national_energy_policy.pdf
[Cited: January 2011]
Ministry of Energy. Energy Sector Strategy and Development Plan, Republic Of Ghana
Available at: http://www.ghanaoilwatch.org/images/laws/energy_strategy.pdf
[Cited: January 2011]
PVsyst: Software for Photovoltaic Systems
Available at: www.PVsyst.com
[Cited: January 2011]
2010 Electricity Supply Plan, Ghana Grid Company Limited (GRIDCo), 2010a
Available at:
http://www.gridcogh.com/site/downloads/a22932efb1446463338be7d7f793dc6d2010-Electricity-Supply-Plan.pdf
[Cited: May 2011]
2010 Population and Housing Census. Provisional Results Ghana Statistical Service (February, 2011)
Available at:
http://unstats.un.org/unsd/demographic/sources/census/2010_PHC/Ghana/Provisional_results.pdf
[Cited: January 2011]
VRA to increase electricity supply
Available at: http://www.modernghana.com/news/326464/1/vra-to-increase-electricity-supply.html
[Cited: May 2011]
Yanga.T and Di Sirio. P.(2011). Draft Country Programme Ghana 200247 (2012–2016
Available at: http://one.wfp.org/eb/docs/2011/wfp234689~1.pdf
[Cited: May 2011]