ENERGY ACCESS AND RURAL DEVELOPMENT IN GHANA: PROSPECTS FOR DECENTRALISED ENERGY AND APPROPRIATE TECHNOLOGY OPTIONS

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Abstract: The actual structure and magnitude of domestic, production and community access to energy of remote rural communities are often concealed by national aggregates. Two models – the Energy Development Framework and the Total Energy Access – were used to examine the levels of access in 10 rural communities in three rural districts in the northern part and the middle belt of Ghana. The study also sought to identify possible local potentials that could be harnessed for community specific energy needs. The mixed methods approach was used to carry out the study. Access to energy in these communities was found to be woefully low. Solar energy was identified as the most abundant energy resource for decentralised energy. Even though the potential for biogas existed in northern Ghana, rural energy decision-making was identified to follow procedural rationality, resisting its adoption. It is recommended that new market models are explored, giving equal priority to both decentralised energy systems and appropriate technology to ensure both growth and development in rural communities.

Author keywords: appropriate technology, decentralised energy, development, energy access, Ghana

INTRODUCTION

Access to modern energy is fundamental to reducing poverty, increasing productivity, enhancing competitiveness, improving mobility and promoting economic growth (IEA, 2013). Without appropriate access to modern energy, people are deprived of basic energy services such as lighting, cooking, water heating, space heating and cooling, and cold storage; access to a range of services supporting human development particularly modern medical care, transportation, information and communications services, and mechanical power for agriculture is also hindered (UNDP, 2011). Yet, access to energy in the sub-Saharan African region is woefully low. The sub-region has an electrification rate of 24% as compared to 40% in the other low income regions, and more than 80% of people in the region depend on traditional biomass for cooking (IEA, 2010). Rural communities in the sub-region are the worst affected: in addition to inadequate energy supply to meet basic human needs, there is also

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Citation: Akosua B. K. Amaka-Otchere (2016) Energy access and rural development in Ghana: prospects for decentralised energy and appropriate technology options, *African Journal of Built Environment Research,* Vol. 1, Iss. 1, pp. 29-58.

inadequate supply of energy for livelihood activities and for community development infrastructure for health, education and trading.

In the West African corridor, energy supply ratios in Ghana appear to be high compared to other countries in the sub-region. The rate of electrification is estimated as 72% and dependence on traditional biomass for cooking is estimated as 60%. The corresponding rural electrification rate is recorded as 49%, however effective electrification is feared to be lower (Energy Commission, 2012). Close to 80% of rural households in Ghana depend on traditional biomass for cooking and sometimes, for rural cottage industrial energy needs. The main strategy of the government for addressing energy supply in the rural communities has been the expansion of the national grid and improving modern fuel supply. The strategic national energy goal is to reach universal access to electricity by 2020 and to achieve 50% access to liquefied petroleum gas (LPG) by 2015 (Ministry of Energy, 2010; Energy Commission, 2012). However, the electricity sub-sector of Ghana is bedevilled with numerous challenges: the country as a whole has been subjected to inadequate power supply since 2007 with frequent power cuts, brown-outs, and load-shedding programmes. Anticipated economic growth with the expansion of national grid has not been achieved (Energy Commission, 2012). With regards to modern fuel, frequent shortages are often recorded with insufficient supply even for urban users. Therefore, Barnes and Floor (1996) assert that on the one hand, simply expanding supplies of modern fuel will not address poor access to fuel because even under the most optimistic growth scenarios, many rural areas in the developing world are likely to depend on traditional fuels for the next 20-30 years. On the other hand, within the short to the immediate future, income levels of rural communities are not likely to improve significantly (nor will supply prices go down sufficiently) for them to be able to embrace conventional energy. Therefore, for rural communities that are far away from the grid, current development practice suggests that decentralised energy options are the least cost options ((Practical Action (2012); Salire and Calixto-Muhi (2010); Deichman et al. (2010)) and appropriate technology for cooking is recommended to address cooking and heating energy needs. This paper aims to examine the actual disparities in the structure and magnitude of domestic and production energy needs of rural communities in Ghana beyond aggregated national estimates, and to identify local energy resources which could be harnessed as decentralised energy or appropriate technology solutions.

Conceptual development

Decentralised energy systems and appropriate technology

Decentralised energy (DE) systems are characterised by locating energy production facilities close to the site of energy consumption. They are mainly derived from renewable energy resources. The energy systems can exit at different levels. At the village level, the focus of a DE system is on providing electricity to meet the rural needs (Subhes, 2013). They can be grid-connected or off-grid (stand-alone), and individual systems or collective systems. The individual systems include small ready-to-use kitbased systems such as solar home systems (SHS), solar lamps, and battery-operated systems. Collective systems are either stand-alone systems or local grid systems. Their small-scale nature favours the active involvement of local stakeholders and may be custom-designed to the local context of the community. DE systems save wastage associated with the transmission and distribution of centralised conventional electrical energy. Closely related to DE systems are appropriate technologies for heating and cooking which are also small-scale and often designed to suit the users.

Energy Access

The IEA (2012) and Practical Action (2012) define energy access with two models respectively – the Energy Development Framework (EDF) and the Total Energy Access (TEA) models. Both models suggest that energy access comprises addressing domestic, productive, and community service energy needs. The EDF is a multi-dimensional indicator that tracks energy development at the country level. The TEA is acknowledged as a practical tool for measuring the status and progress of energy access at the household level. A list of indicators is drawn from both models which are matched with study findings to assess the level of energy access in the study communities.

Energy use and supply in Ghana

Woodfuels, i.e. firewood and charcoal, account for over 70% of total primary energy supply in Ghana. Close to 90% of the supply is directly from the natural forest. This rate of supply is deemed unsustainable due to unsustainable logging practices adopted. It is estimated that the rate of deforestation is 2% per annum (Ministry of Lands and Natural Resources, 2012). Communities in the transitional ecological zone [which are the main charcoal producers in the country], and the savannah ecological zones, are showing signs of forest depletion causing users and producers of woodfuel to travel further in search of wood resources. Woodfuel use is split between urban and rural users. The rural communities simply gather fuelwood from their farms or the natural environment. Charcoal on the other hand is produced in the hinterlands but mainly for urban consumption. It is perceived that under these supply conditions, woodfuel will remain a dominant and an important source of energy for next few years just as pertains in other Sub-Saharan African countries (UNDP, 2009; Practical Action, 2012; IEA, 2010).

With regards to access to modern cooking fuels, urban and rural access to liquefied petroleum gas (LPG) is estimated to be 17.2% and 1.2% respectively of total national consumption (Kemausuor et al., 2012). In 1989, the country launched an LPG improvement programme but targeted urban consumers. In 2004, the programme was re-launched as the LPG Rural Challenge programme to encourage a switch from usage of woodfuels to LPG (National Petroleum Authority, undated) but the rural ratio remained low. LPG is produced by the nation's single oil refinery, the Tema Oil Refinery. Production levels have fluctuated over the years, falling from 75,300 tonnes in 2005 to 31,600 tonnes in 2010 (Energy Commission, 2012). The gap in supply is compensated for through imports.

The country also instituted the Rural Kerosene Distribution Improvement Project to improve rural access to kerosene for lighting. The targeted was to establish over 2,400 kerosene rural retailer outlets by the year 2010. A total 1200 surface tanks were fabricated and distributed, but there is no data on the success of actual supply to retailers.

Ghana's strategy for improving electricity access has mainly been on-grid electrification. The country has since 1989 implemented a National Electrification Agenda that is expected to have the whole country connected to the grid by the year 2020. Over the last two decades, the national access rate has risen from under 35% to over 72% (Energy Commission, 2012). The current rate splits into a ratio of 100%:49% between the urban and the rural areas (The Energy Centre, 2011). However, power supply is intermittent, barely able to support itself with frequent load-shedding exercises. It is currently estimated that the cost of electrification per household is USD2000 (Amadu, 2012). The costs keep rising due to reducing customer density and longer transmission and distribution lines required for connecting the hinterlands (Amadu, 2012; World Bank, 2010). Consequently, profit-oriented service providers are reluctant to extend the services.

Renewable energy sources play a limited role in energy supply in Ghana notwithstanding the government's energy policy goal that renewable energy will constitute 10% proportion of the total energy mix by 2020 (Energy Commission, 2012). Ghana's renewable energy resource constitutes solar, wind and water. The country receives averagely 4.0 – 6.5kWh/m2/day of solar radiation; wind measurements taken at 12m height along the coast and island regions give wind speeds varying from 3.33 m/s to about 6.08 m/s; and over 70 potential small hydro resources are identified nationwide though none has been developed. Rural Ghana has the locational advantage of being endowed with abundant renewable energy potentials.

RESEARCH DESIGN AND METHODOLOGY

A multi-design method that combines both quantitative and qualitative methods and techniques using the case study approach was adopted. The combination gave the advantage of access to richer and stronger array of evidence through the collection of complementary data, allowed for triangulation, and the weaknesses of both the quantitative and qualitative methods were compensated for. The quantitative aspect involved household survey and other specific technical enquiries such as economic activity survey. The qualitative techniques used were in-depth interviews, key informant interviews from the national to the community level, and observation. The study was undertaken in three rural districts - the Builsa and Kassena-Nankana East Districts in the Upper East Region (UER), and the Atebubu-Amantin District in the Brong Ahafo Region (BAR).

Using the sampling formula n=N/ (1+ (N*10%2), a total of 199 household questionnaire interviews out of a total of 11,759 households were conducted. These distributed as 49, 76, and 74 interviews in the Builsa, Kassena-Nankana East, and Atebubu-Amantin Districts respectively. In addition, 40 in-depth interviews were conducted. The research adopted a pragmatic worldview to understanding the problem and in the analysis of the data gathered.

Overview of study districts - Builsa, Kassena-Nankana East, and Atebubu-Amantin districts

Figure 1 shows the geographical location of the study Districts in the national and regional contexts.

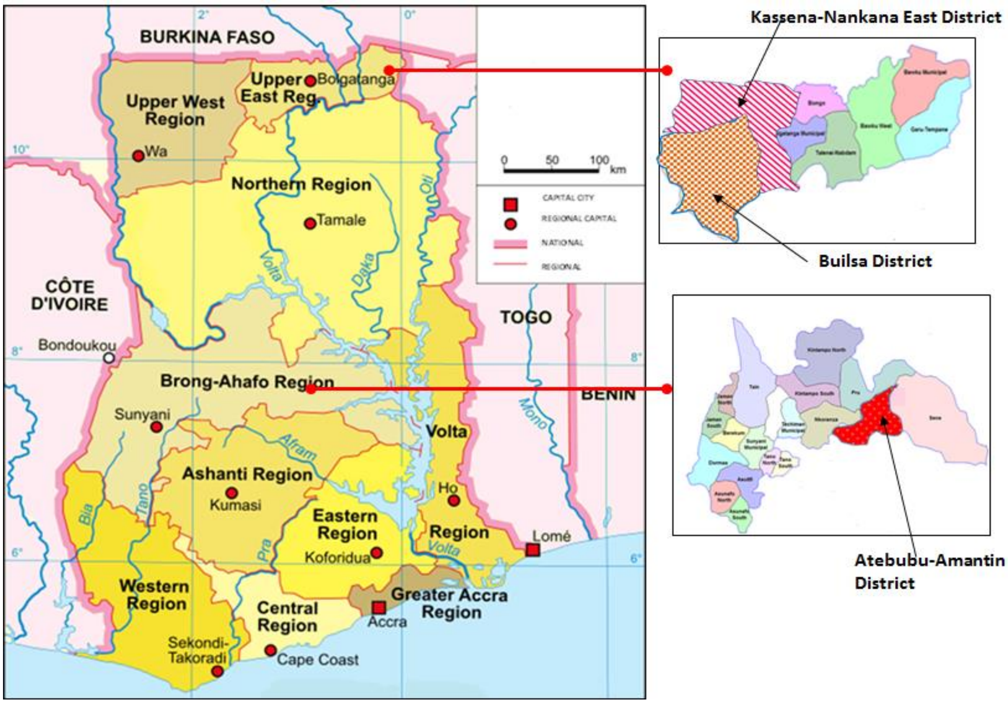

Figure 1: Study Districts in national and regional contexts
Source: Modified based on internet maps[2]

The Builsa District3 is located in the UER. It lies between longitudes 1° 05' and 1° 35' W, and latitudes 10° 20' and 10° 50' N. The administrative capital of the District is Sandema. The District lies in the Guinea Savannah ecological zone and within the Volta River basin. The alluvial soils of the River and its tributaries are major resource potentials for the District. The principal economic activity is subsistence farming. Mean

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[2] http://de.wikipedia.org/w/index.php?title=Kultur_in_Ghana&oldid=133293564; http://en.wikipedia.org/w/index.php?title=Brong-Ahafo_Region&oldid=639720376; http://de.wikipedia.org/w/index.php?title=Upper_East_Region&oldid=135814427 – All accessed 01/11/2014

[3] Since 2012, the Builsa District has been split into Builsa North and Builsa South Districts. However the administrative and logistical machinery that should accompany the division is not completed and therefore both Districts follow the original development framework of the former Builsa District

monthly temperature ranges between 22°C and 34°C. Rainfall pattern is single maxima, starting from April and ending in September. The wet season is interspersed with irregular dry spells between June and July. The District has 155 communities with a peculiar community clustering system: the 155 communities have been clustered into eight zones. The zones are represented by the bigger communities. Three communities were studied in this District. These were Balansa, Kori-Alamyeri, and Kandema. The communities were within the Sandema zone. They were 4km, 5km, and 6km respectively from the national grid.

The Kassena-Nankana East (KNE) District also lies within the Guinea Savannah woodlands of the UER, between 10° 53' and 10° 88' W and 1°05' and 1°09' N. It exhibits similar climatic conditions as the Builsa District. The District capital is Navrongo. Similar to the Builsa District, the principal economic activity is farming. The tributaries of the White Volta – the Sissili, Asibelika, Afumbeli, Bukpegi and Beeyi - form the drainage system of the District. Four rural communities were studied in the District. These were Akurugu Daboo, Azaasi, Nagalikenia, and Wuru. These communities are within a radius of 3km from the national grid.

The Atebubu-Amantin District is in the transitional ecological zone in the BAR. It is located between 7°23' and 8°22' N and 0°30' and 1°26'W. Atebubu is the District capital. The vegetation type is the interior wooded savannah. The District lies between the tropical semi-deciduous forest and the Guinea savannah ecological zones and therefore exhibits vegetative characteristics of both zones. The BAR is known as the food basket of the country. The Atebubu-Amantin District is one of the leading food producing Districts in the Region. It is also one of the largest charcoal producing Districts in the country. Three communities were studied: these were Fakwesi, Kumfia and Sabidi which are 37km, 28km, and 20km respectively from the national grid.

FINDINGS

From Table 1, the average household size for all communities studied is 5. Variations existed among the Districts. The community averages compared favourably with the Districts averages recorded during the 2010 Population and Housing Census (PHC) with the exception of the KNE District where a high variation is recorded.

Table 1: Demographic characteristics

Average household size - study communities	District	Average household size	
		Field study	2010 Census
5.0	Atebubu-Amantin	6.0	5.1
	Builsa	5.0	5.5
	Kassena-Nankana East	8.0	5.4

Source: Author's field study, 2012 and Ghana Statistical Service (2012)

Energy as a domestic necessity

The pattern of domestic energy consumption is shown in Table 2. Energy needs identified were cooking and water heating, lighting, learning, and operating domestic appliances. The energy options identified for cooking were firewood, charcoal, crop residues and liquefied petroleum gas (LPG). The principal cooking fuel was firewood used by 83.9% of respondents. 14.8%, 0.7%, and 0.7% of respondents used charcoal, crop residue and LPG respectively. The principal energy for lighting identified was dry cells (with LED flashlights), used by 79.3% of respondents; 7.6% of respondents depended on paraffin, and 6.9% used solar lighting resources. The remaining 2.1% used other sources of lighting.

Energy for learning was examined to observe the role energy played in human capital development. 73% of respondents had an energy option for learning for school children. The main source of energy was dry cells (with LED flashlights); others depended on paraffin, solar and electric rechargeable lamps. Other domestic energy activities identified was the operation of appliances, i.e. radio and TV, and in addition, the charging of mobile phones which has become an important component of the rural energy profile. Almost 90% of respondents had an energy option for these other domestic activities. The respondents used dry cells for radio, patronised commercial phone charging services, and used rechargeable batteries to operate their TVs.

Table 2: Domestic access to energy

Energy activity	% of respondents, N=199
Cooking and heating	100
Lighting	100
Learning	73.0
Others – TV, radio, phone charging	89.9

Source: Author's field study, 2012

Energy needs for economic productivity

Table 3 shows the economic sector distribution among the communities. The agricultural sector employed almost 83% of respondents, industry engaged 3%, and service and commerce employed 14%.

Table 3: Economic sector

Economic sector	% of respondents, N=199
Agriculture	82.6
Industry	3.4
Service and commerce	14.0
Total	100

Source: Author's field study, 2012

Only 18% (36 households) of respondents were engaged in productive activities that were energy-dependent (Table 4). Only seven out of the 36 households were in the agricultural sector, practicing mechanised farming. Evidently, almost 83% of all respondents were farmer-households which depended on human mechanical energy and simple agricultural implements such hoes and cutlasses and (rarely) animal power for their agricultural activities.

Table 4: Household energy-based economic activities

Economic activity	No. of respondents, N=36
Service and commerce – petty trading, solar phone charging	13
Agriculture – farming	5
Agriculture and commerce	2
Agriculture processing - shea butter, dawadawa[4]	5
Food processing and vending	5
Light industry – tailoring	4
Cottage industry – milling	1
Commerce and agricultural processing	1
Total	36

Source: Author's field study, 2012

Figure 2 shows the energy use for the economic activities identified. Principal among them were firewood and charcoal, followed by fossils. Grid electricity was accessed from neighbouring communities for charging rechargeable lamps and milling cereals for retailing.

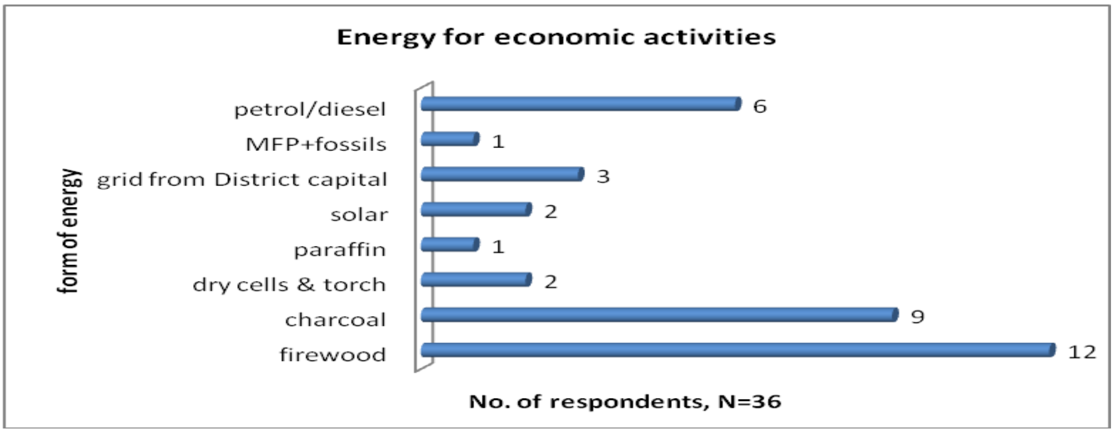

Figure 2: Energy for economic activities
Source: Author's field survey, May-July 2012

It is worth noting that even though agriculture in these rural communities was generally not modern energy intensive, it involved a series of energy intensive processes. Land clearing and preparation, planting, harvesting, drying, storage, and processing were activities which employed human energy and 'non-technicalised' forms of energy. Hoes, cutlasses, and oxen were employed for clearing the land. The farming practice was slash-and-burn, thus, the land was burnt after clearing. Farmers relied on direct heat energy from the sun for harvesting and drying. Wind was an important drying agent particularly for cereals; vegetables such as pepper were cooked, dried in the sun and bagged. For communities without

[4] Soumbala balls, a local spice

grinding mills, the processing of cereals entailed winnowing, pounding and sifting using human mechanical energy. [Alternatively, respondents waited for market days which occurred every third day and travelled not less than 5km on foot to the market centres to mill their cereals.] Legumes such as beans and peanuts were beaten with sticks to release the beans/nuts from the pods and subsequently, hand-sorted. Food stuffs were usually head-carried from the farms to the homes and market-centres, or drawn by animal-drawn carts in the case of the study communities in the UER.

Anticipated improvement in economic activities with improved energy supply

Respondents anticipated improvement and increase in economic activities and subsequent growth in the rural economy with improved supply of energy (Table 5). Dressmakers foresaw that they would be smarter, faster, and improve their productivity if they operated with electric sewing machines. Similarly, fishmongers would operate cold stores to keep their fish fresh instead of frying, salting or smoking them to preserve them. For agricultural processing activities such as shea and dawadawa (soumbala balls) processing, manual activities in the process such as pounding and hand-turning the paste would be replaced with mechanised processes which would release seven extra days for other activities. Other respondents identified new economic opportunities such as barbering, baking, welding, and electrical work services. Longer working hours were anticipated by petty traders and convenient shop operators. It was observed that the respondents in the UER were generally unconscious of productive potentials and economic opportunities. Most of the respondents could not anticipate beyond subsistence farming. However, respondents in the AAD were quick to identify business opportunities and how they could diversify what they were already engaged in.

Table 5: Anticipated economic activities with improved supply of energy

Builsa and Kassena-Nankana East Districts	Atebubu-Amantin District
Large-scale farming	Commercial mobile phone charging
Hair barbering	Operate a cold store to sell fish
Operate a convenient shop	Sale of cold water, drinks, operate a bar
Sale of cold water and drinks	Baking
Work late into the night	Operate a corn mill
Expand shea butter production	Expand and improve functions of MFP
Operate corn mill	Welding
Open an electrical works shop	Irrigation farming
Operate a poultry farm	Petty trading
	Sale of appliances
	Rent out musical instruments
	Large scale food vending
	Expand tailoring business
	Work late into the night

Source: Author’s field study, 2012

Furthermore, in community key informant interviews, the Tono Irrigation Project in the Kassena-Nankana East (KNE) District was identified as an important source of water for dry season farming. There was high market demand for the vegetables cultivated during the dry season, so farmers in the threshold were occupied both during the wet and dry seasons. The irrigation facility also supported rice farming. However, not all communities had this economic advantage due to the limited threshold of the irrigation facility albeit both the Builsa and Kassena-Nankana East Districts were located in the Volta Basin. Mechanising irrigation could extend the threshold of the facility to capture more communities.

Energy needs for community development

Energy as a community necessity is reflected in how efficient and effective community services are delivered through the availability of energy. Community services include hospitals, schools, street lighting, markets, as well as community communication system due to its peculiar significance in rural information dissemination.

Table 6: Energy needs for community services

Basic community facility	No. of communities with facility, N=10	No. of communities having facility with modern energy, N=10	Type of modern energy
Health Centre	4	4	Solar PV
Streetlight	1	1	Solar PV
School	6	2	Solar PV
Water	6	0	None – human power
Community communication system	2	2	Diesel generators
Market	0	0	None

Source: Author's field survey, 2012

Table 6 depicts that with the exception of school and water, most communities lacked the basic community facilities. None of the communities had a market and only one had a streetlight. Four communities had health centres which operated on solar PV. Two communities had schools with solar PV installed. The remaining four depended on natural light which impeded studying in the evening and on cloudy rainy days. In the Kumfia and Fakwesi communities, teachers posted to the communities would rather commute from the District capital to the communities everyday rather than staying in the community teachers' bungalows due to the unavailability of electricity. Consequently, teachers reported late to school and closed before the official closing time and pupils developed low interest in education and their academic performance was poor.

Water supply in the communities visited was a manual activity. Six communities had boreholes. The remaining four communities without boreholes depended on streams, rivers, and dugouts. While the borehole is an improved water supply system, the supply could be enhanced to the extent of serving as a livelihood activity if it was mechanised. A related discussion during an expert interview showed that a similar system installed with a solar pump in a rural community in the Northern Region was able to pump 15m3 of water per hour, equivalent to about 200 times what the manual borehole produced. Community members enjoyed an alternative livelihood activity from the sale of water.

The community communication system is an important service for public announcement and information dissemination from the traditional authorities to the people. Two communities used the public address system powered by a diesel generator. The remaining communities used the traditional manual gong-gong system which required the chief linguists to travel on foot across the length and breadth of the communities.

None of the communities had a constructed market even though Kumfia and Fakwesi hosted two of the busiest weekly markets in the Atebubu-Amantin District, which attracted traders from neighbouring Districts. Make-shift stalls were constructed on market days; retailers either displayed their wares on the floor, or hawked them. Traders who wished to arrive the evening prior to the market day could not do so due to lighting and security challenges. Furthermore, traders were limited in the quantum of fish that could be traded and in the provision of other electricity-dependent ancillary services due to the unavailability of power.

Energy resources identified

The biggest energy resource identified is solar. The UER receives daily solar radiation of 4-6kWh/m2 with very low diffuse rate of about 32%. The Atebubu-Amantin District (AAD) experiences daily radiation levels between 3.1-5.8kWh/m2 (Omane Frimpong, 2013), with relatively high diffuse radiation rate between 36 – 40%. Thus, solar applications such as solar PVs have very high potentials in the communities studied. It is also possible to install solar water pumping to address the agricultural irrigation needs and community water supply improvement needs. For solar pumping, a minimum of 6 Peak Sunlight Hours (PSH) is required in addition to the favourable radiation rates. The average PSH of the Atebubu-Amantin District was calculated to be 6.7 sunlight hours per day. The Builsa and KNE Districts have a PSH average of 8 sunlight hours per day. This is able to sustain a solar water pump for a lifetime of 20-25 years.

Biogas resources were identified in the study communities in the UER. One cubic metre of biogas is shown to be equivalent to 1.50kilograms of firewood (Bates, 2007). Thus the biogas option could reduce significantly the time spent in gathering woodfuel and release time for other productive activities, reduce the pressure on natural wood resources, and the slurry by-product could be used as fertiliser to improve agricultural productivity. The technical input requirements of a biogas digester are (i) the availability of feedstock - either animal or human waste, (ii) high temperatures ranging between 30°C and 40°C for the anaerobic process, and (iii) water to dilute the waste into slurry (Bates, 2007). In a study in rural Uganda, it was estimated that with five to ten cows, a household could produce a minimum of 2.5m3 of gas adequate for lighting and cooking for an average household size of six (Otim et al., undated). Using this as a proxy for Ghana, a situational analysis was conducted to check for feasibility in the study communities.

Situational analysis

- The predominant animal husbandry activity in the UER is cattle-rearing. The following estimation is based on Builsa District [the cattle population the Kassena-Nankana East District were concentrated in other sections of the District other than the study communities]. Cattle population data was obtained from the District Agricultural Department; the total human population was obtained from the 2010 Population and Housing Census. Given these parameters, the number of cows per household was estimated to be 6.6 (Estimation 1).

Estimation 1: Number of cows per household

$Ps_{(2010)}$ = Total population Sandema (2010) = 5,955

Hhs = Average household size Sandema = 4.5

$Pc_{(2009)}$ = Total cattle population Sandema (2009) = 8770

Average number of cows per household $= \frac{Pc_{(2009)} \times Hhs}{Ps_{(2010)}}$

= 6.6 cows

Source: Author's estimation

However, the average number of cows per household in the study communities was three. Moreover, the pastoral type of animal husbandry was practiced, thus adequate dung could not be collected from the kraals and had to be supplemented from the field.

- The Region records the highest temperatures in the country with an average of 31°C; a maximum 41°C is recorded during the dry season.

- Access to water was a major challenge for the District due to its ecological location. To ameliorate such conditions, The Central Institute of Agriculture Engineering in Bhopal, India, has modified the design of the fixed-dome biogas digester (Bates, 2007). The design modifications are an increase in the bore of the inlet feed, a greater reinforcement of the chamber to withstand the high gas pressure, an enlarged slurry chamber outlet, and a smooth widened outlet channel to streamline the flow of the slurry. This design allows undiluted cow dung to be used. It generates 50% more biogas for each kilogram of dung loaded into the system and does not require slurry drying time before it can be used as a fertilizer.

- Socio-cultural constraints were identified:

  Cow dung was used as binding material and for plastering local houses, and as feedstock for generating local poultry feed.

  The use of any form of faecal matter for cooking was completely unacceptable in some communities.

Due to the impoverished nature of the farmlands, the farmer-households would rather use cow dung collected from both the kraals and from the fields as manure for their farms in spite of the potential slurry by-product from biogas.

Conclusively, even though biogas is perceived as energy option for communities in the UER, other factors may militate against its development. A more detailed feasibility study may be necessary to conclude on this resource potential.

The third potential, the multifunctional platform (MFP), comprises of a diesel engine mounted on a chassis which powers a variety of end-use equipment such as grinding mills, de-huskers, battery chargers, and water pumps. The technical feasibility and potential capacity of the MFP has been proven after the implementation of pilot projects by KITE under the UNDP Regional Energy and Poverty Program in a number of rural communities in the Brong Ahafo and Northern Regions of Ghana. Two of the study communities of this research - Fakwesi and Kumfia - were among the pilot communities. The MFP has promoted agriculture and agricultural processing activities especially cassava processing and even served as social capital for the communities (Inkoom, 2009; Amaka-Otchere, 2014). There may be the possibility of up-scaling the concept to the study communities in the UER. Again, by its original design for Ghana, the MFP operates on fossil fuels. There is however a recent research Jana, a community in the Northern Region of Ghana, exploring the possibility of gasifying rice husk or groundnut shells as alternative fuel for the MFP. When proven feasible, the communities in the UER could also consider this alternative fuel given that the UER produces large volumes of rice (Amanor-Boadu, 2012). It would be more useful when its complementary components such as the blade sharpener, rice de-husker, and grinder are installed. In addition, the feasibility of gasifying wet biodegradable waste can be explored as alternative fuel for the MFP for communities BAR.

DISCUSSION

The structure and magnitude of domestic and production rural energy needs and how these are being met

The statistics on energy use structure and magnitude compares generally with national and Sub-Saharan African regional energy statistics. One outstanding emerging phenomenon was the extensive use of dry cells and

LED flashlights and lamps by a significantly high proportion of 79% of respondents, contrasting previous national statistics where paraffin was the main energy for lighting for 72% of rural communities (Ghana Statistical Service, 2008), and exceeding estimates of recent national statistics – the Population and Housing Census 2010 – which estimates the use of LED as the main source of lighting for 29% of rural households. The rural households have rationalised the necessity of a less risky source of lighting (as against the paraffin lamps) with the need for better illumination, which the dry cell LED flashlights and lamps provide in the absence of grid electricity or affordable renewable energy alternatives. It can be inferred that communities studied did not fall within the 49% rural electrification coverage of the country.

Solar phone charging was an emerging business identified. In the UER, this was done on small-scale individual home-based basis. Though the service was paid for, the domestic 'service providers' sometimes refused to offer the service. On the contrary, in the AAD, it was a commercialized charged service, ran as part of a local convenience shop. This buttresses the finding that the rural communities in the BAR had more business inclination and agility to identifying business opportunities than those in the UER.

The study was undertaken within the conceptual definitions of energy access advanced by the Energy Development Framework (EDF) and the Total Energy Access (TEA). Measuring by the energy access indicators shown in Table 7, energy access in the study communities fell woefully below international minimum standards with the exception of the provision for cooking and water heating in the study communities in the AAD. For lighting, as against the IEA minimum of 250 kilowatt-hour (kWh) per year for a household of 5 persons, the study respondents who used solar home systems or had access to grid resources in neighbouring communities had access to approximately 77kWh per year for an average household size of 5 persons. However, when a comparison is made with the minimum standards of the TEA of 300 lumens per household, the solar users compared favourably with 1500 lumens per household (See Table 7). It is obvious that the two models had different measurements, that is, the EDF measured energy consumption while the TEA measured illumination. Further research may be necessary to establish a common parameter that provides a clear conceptual definition as to the minimum requirements for acceptable rural lighting.

For cooking, the efficiency of cook stoves recorded was less than 9% as against the minimum efficiency of 40% required. For productive use purposes, access to energy was generally inadequate for enterprises which were energy dependent.

Table 7: Indications of energy access in study communities

Energy service	Minimum standard/ potential indicator	Results from study
Lighting	250kWh per year for household of 5	77kWh per year for a household of 5
	300 lumens at household level	1500 lumens per household recorded for solar users using two 5W lamps (LED produced 150 lumens per watt (Amogpai, 2011)).
Clean cooking	% households having an efficient stove with minimum indoor air quality	0.7% used LPG stoves
	% households that cooks with modern fuels	0.7%
Cooking and water heating	1kg woodfuel or 0.3kg charcoal or 0.04kg LPG or 0.2litres of kerosene or ethanol per person per day, taking less than 30 minutes per household per day to obtain	In the UER, average woodfuel use per person per day was 0.34kg. Average access distance was 9miles, an equivalent of 2 hours 15 minutes.
		In BAR, woodfuel use was beyond the minimum standard of woodfuel and charcoal. Woodfuel was relatively available and collected as part of daily farming activity
	Minimum efficiency of improved wood and charcoal stoves to be 40% greater than a three-stone fire in terms of fuel use	None was identified. The traditional three-stone fireplace and coal pots (very rare) had efficiencies of ≤9% and (8-15%) respectively.
Cooling	Food processors, retailers and households have facilities to extend life of perishable products by minimum of 50% over that allowed by ambient storage.	Local preservation methods used were drying, boiling and frying. No cooling facility was available
	All health facilities have refrigeration adequate for the blood, vaccine and medicinal needs of local populations	The health centres only handled minor health issues in additional to maternal delivery. They were not capacitated to keep a blood bank. Vaccines could be preserved for a maximum of two days in an ice chest.
Information and communication	People can communicate electronic information beyond the locality in which they live	32.1% of respondents used personal mobile phones and 67.9% used commercial mobile phones
	People can access electronic media relevant to their lives and livelihoods	All respondents had radio
Productive use	Access to energy is sufficient for the start-up of any enterprise	Access to energy was insufficient within the communities.

Source: Adapted from IEA (2012), Practical Action (2010; 2012) and Author's data analysis, 2014

Energy resources

The high solar energy potential identified in the study communities is typical of the solar resource potential in Ghana. Nonetheless, it is least exploited. It contributes only 0.3% to total national energy supply for lighting, and its other applications such as solar drying and solar water pumping is almost negligible.

In the case of biogas, the three Northern regions of Ghana, including the UER are particularly tipped for domestic biogas potential due to the predominance of cattle husbandry in these Regions. Yet similar to the results of the study, the implementation of biogas has often been met with socio-cultural and technical (water availability) challenges and the option is poorly exploited.

By the original design, the MFP runs on fossil fuels. With world oil price fluctuations, renewable sustainable fuel stock could be an optimum fuel option. Furthermore, the viability of agricultural or productive activity that supports its maximum capacity output is a necessary feasibility condition.

CONCLUSIONS AND RECOMMENDATIONS

The communities studied satisfied the conditions appropriate for decentralised energy and appropriate technology solutions. For rural economic growth and development purposes, these options reduce the unproductive time of waiting for conventional and centralised energy supply. The rural energy needs identified are not sophisticated and may be addressed by these simple energy technologies. It remains important that all three facets of access are satisfied – domestic, production and community service energy needs. Again, the energy needs can be broadly categorised into consumption and production needs. It is crucial that energy supply-and-demand cycle is self-sustaining if the anticipated development is to be achieved and sustained: when energy catalyses production, it creates energy demand for production as well as for consumption.

Time and time again, the relative under-development of the UER has been moaned. Following from the relationship established between energy supply and development, it is imperative to stress that decentralised energy cannot stimulate growth and development when labour productivity of rural communities especially in the UER remains business-as-usual. Without their ability to uncover enterprise potentials, energy access may do little to improve and/or the economic growth and development of the communities.

Out of the energy resources identified, solar and the MFP appears to have higher leverage in addressing the energy needs identified. The typicality of the energy resources identified particularly solar is significant proof that the search for DE resources may not uncover different resource potentials. However, beyond identifying energy resources, it is recommended that new business models specifically for rural energy supply are identified for effective promotion, implementation and sustainability. In the past, the fee-for-service model failed. An investigation into the output-based approach which demands quality supplier service delivery before imbursement, modified to suit the local context may be worth considering.

The biogas option has both the capacities of DE systems and appropriate technology. Biogas development is constrained and further research will be necessary to ascertain its viability. Respondents' non-preference for the option is indicative that energy decision-making by rural folks follows procedural rationality and may not be predicted. It will be an important research question to consider in designing feasibility studies to promote decentralised energy options at the rural level.

It is highly recommended that the two major components of domestic energy needs are given equal attention. It is often the case that rural energy development concentrates much effort on supplying electrical power than cooking fuel even though statistics and analysis establishing the nexus between energy poverty and poor development often put more emphasis on the dependence of deprived communities on traditional biomass. Literature argues that access to electricity has more ripple effects on development in general including improving access to better forms of energy for cooking. This is however a critical assumption given that the growth anticipated with the extension of the national grid to the rural communities has not been achieved. Total energy access must seek to address the individual energy needs.

REFERENCES

AfDB (2011): Draft Energy Strategy – Technical Annexes. Tunis: AfDB

Amadu, M. (2012): 2012 international year for sustainable energy for all – Africa frontrunnership in rural electrification. Energy Policy Volume 48, September 2012, Pages 76–82

Amaka-Otchere, A.B.K. (2014): Decentralised Options for Energy Supply for Sustainable Economic Development in Rural Ghana. Dortmund: TU Dortmund.

Amanor-Boadu, V. (2012): Rice Price Trends in Ghana (2006-2011). USAID Monitoring, Evaluation and Technical Support Services (METSS)- Ghana Research and Issue Paper Series No. 02-2012, June 2012

Amigun et al. (2008): Commercialisation of Biofuel Industry in Africa: A Review. Renewable and Sustainable Energy Reviews 12

Barnes, D. and W.M. Floor (1996): "Rural Energy in Developing Countries: A Challenge for Economic Development", Annual Review of Energy and Environment 1996. 21: 497–530.

Bates, L. (2007): Biogas. Rugby: Practical Action

Christensen, C.M. (1997): The Innovator's Dilemma – When New Technologies cause Great Firms to fail. Massachusetts: Harvard Business School Press

Deichman et al. (2010): The Economics of Renewal Energy Expansion in Rural Sub-Saharan Africa. World Bank Policy Research Working Paper 5193

Energy Commission (2012): Ghana LPG Policy Paper: Towards 50% Access. Accra: Energy Commission

Energy Commission (2012): Situational Report - Sustainable Energy for All Acceleration Framework. Accra: Energy Commission

Energy Commission of Ghana (2006): Strategic Energy Plan 2006-2020 – Woodfuel and Renewables. Accra: Energy Commission

Ghana Statistical Service (2008): Ghana Living Standards Survey 5. Accra: Government of Ghana

Ghana Statistical Service (2012): 2010 Population and Housing Census – Summary Report of Final Results. Accra: Government of Ghana

Ghana Statistical Service (2014): Ghana Living Standards Survey 6. Accra: Government of Ghana

Inkoom, D.K.B. (2009): The Ghana MFP Program – Case Studies on the Ghana Multifunctional Program: Platform private ownership and impacts on the community development - the case of Abease Multifunctional Platform, Pru District, Brong Ahafo Region. UNDP

IEA (2012): World Energy Outlook - Energy Access Methodology. Paris: IEA

IEA (2010): World Energy Outlook 2010. Paris: IEA

IEA (2013): World Energy Outlook 2013. Paris: IEA

Kemausuor et al. (2012): GIS-Based Support for Implementing Policies and Plans to Increase Access to Energy Services in Ghana. Eschborn: EU Energy Initiative Partnership Dialogue Facility

Ministry of Energy (2010): Energy Sector Strategy and Development Plan. Accra: Government of Ghana

Ministry of Energy (2010): National Energy Policy, 2010. Accra: Government of Ghana

Ministry of Lands and Natural Resources of Ghana (2012): Forest Investment Program – Ghana Investment Plan. Climate Investment Funds

National Petroleum Authority (undated): Report on Rural LPG Programme Survey. Ghana

Ocloo, K. (2011): Harnessing Local Potentials for Peri-Urban Water Supply in Ghana - Prospects and Challenges. Dortmund: TU Dortmund

Omane, F. (2013): Status and Development of the Local PV Market Structure. A Paper presentation made on behalf of the Association of Ghana Solar Industries

Otim, G., D. Okaka, and J. Kayima (undated): Design of Biogas Plant for Rural Household in Uganda - Case Study of Apac District. A paper presented at the Second International Conference on Advances in Engineering and Technology (http://news.mak.ac.ug/documents/Makfiles/aet2011/Otim%20(2).pdf)

Practical Action (2012): Poor People's Energy Outlook. Rugby: Practical Action

Practical Action (undated): Energy poverty – The Hidden Energy Crisis. Rugby: Practical Action

Prahalad, C.K. (2005): The Fortune at the Bottom of the Pyramid – Eradicating Poverty through Profits. New Jersey: Pearson Education

Salire, S.M and Calixto-Muhi, P.G. (2010): The role of decentralised energy systems in rural electrification – The Philippines experience

Schäfer, M. and Laufer, D. (2011): The Contribution of Microenergy Systems towards Poverty Reduction: Case Study of an Implementation Strategy for Solar Home Systems in Sri Lanka. Conference Paper - Proceeding of International Conference on Micro Perspectives for Decentralised Energy Supply: 133-161, Berlin: TU Berlin

Stern, D. I. (2004): "Energy and Economic Growth". Rensselaer Working Papers in Economics, Department of Economics, New York: Rensselaer Polytechnic Institute

Subhes, B. (Ed.) 2013: Rural Electrification through Decentralised Off-grid systems in developing countries, Chapters 1&2. Green Energy and Technology Series, London: Springer-Verlag, UK

The Energy Centre (2011): Overview of GIS-based Energy Access Project. A Presentation at District Planning Officers Sensitisation Forum

Todaro M.P. and Smith S.C. (2011): Economic Development – 11th Ed. London: Addison-Wesley

Todaro, M. P., and Smith, S.C. (2009): Economic Development – 10th Ed. London: Addison-Wesley/Pearson Education

Toman, M.A. and Jemelkova, B. (2003): Energy and Economic Development: An Assessment of the State of Knowledge. The Energy Journal, Vol.24, No.4, pp.93-112, International Association for Energy Economics

UNDP (2009): The Energy Access Situation in Developing Countries – A Review focusing on Least Developed countries and Sub-Saharan Africa. New York: UNDP

UNDP (2011): Human Development Report. New York: UNDP

(http://www.techmonitor.net/tm/images/1/13/10may_jun_sf4.pdf)

World Bank (2010) 'Addressing the electricity access gap', Background paper for the World Bank Group Energy Sector Strategy, Washington DC: The World Bank

Other internet sources

http://de.wikipedia.org/w/index.php?title=Kultur_in_Ghana&oldid=133293564 [01/11/2014]

http://en.wikipedia.org/w/index.php?title=Brong-Ahafo_Region&oldid=639720376 [01/11/2014]

http://de.wikipedia.org/w/index.php?title=Upper_East_Region&oldid=135814427 [Accessed 01/11/2014]