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An investigation into domestic energy consumption in Uganda

Firstname Lastname[1], Firstname Lastname[2] and Firstname Lastname[3]
[1,2] First institution, First city, First country
author-email1, author-email2@first-inst.edu
[3] Second institution, Second city, Second country
author-email3@second-inst.edu

Abstract: Despite an understanding of the need to promote energy efficiency in buildings, little is known about the current state of energy use in domestic buildings across East Africa, as a benchmark from which improvements (if any) could be made. This paper reports on a study of energy consumption in Uganda. The study, part of a wider investigation of energy use in buildings across East Africa, was to establish a benchmark for energy use, with this paper reporting on the findings of energy use in domestic buildings across Uganda. The study contributes to discourse on energy use and energy efficiency in buildings, and enables comparison with studies undertaken in other part of the world. The study made use of a walk through energy audit, and where available, household electricity bills to determine energy use. While the findings suggest strong demand for energy, much of this is still primary energy, with most households making use of traditional energy sources (firewood and charcoal) for cooking and water heating. While average, electrical energy use per capita was relatively low compared to global averages, the nature of energy consumption indicates that this is likely to increase in the future.

Keywords: Energy use: Uganda: Benchmarking: Domestic.

1. Introduction

Growth in domestic energy consumption is a concern across the globe, particularly in relation to its impact on energy supplies (Pérez-Lombard, Ortiz and Pout, 2008). In the context of East Africa, constant electricity blackouts and brownouts highlight the deficit in generation capacity, vis-à-vis the fast growing demand for electrical energy. This has been a result of rapid economic growth, and electrification drives that have seen a large increase in the number of households connected to the electricity grid over the last two decades. Despite efforts to increase generation capacity, whatever is fed into the grid, is absorbed by pent-up demand. In Uganda, electricity generation capacity grew from 0.766 Billion kWh in 1990, to 2.406 billion kWh in 2010, while demand increased from 0.602 Billion kWh to 2.192 Billion kWh over the same period. Overall generation capacity for Uganda, at 70.8kWh per capita in 2007 is low, compared with the per capita average for sub-Saharan Africa of 451kWh, and 9,837kWh for the G7 countries for the same year. Growth in demand is largely attributed to new grid connections as well as from lifestyle changes, by a growing affluent middle class (Pérez-Lombard, Ortiz and Pout, 2008).

Acknowledging the inevitability of increased demand, moves to reduce energy use are largely mute, given the lack of fine grain data on household energy use as a baseline. Consumer behaviour with relation to energy use is largely anecdotal, although suggestions indicate that it is akin to growth seen in other parts of the world. Similarly, architectural projects are seen to take a 'business-as-usual' approach, seemingly based on a view that there is unlimited supply of energy, and there is no link between building design and energy use. This is despite evidence to the contrary, with the numerous blackouts and brownouts, suggesting that the shortage is growing. Construction of residential buildings has also more than doubled since 2007, with more than 60% of planning applications for residential developments (UBOS, 2014). The push to meet a large housing backlog has led to a concentration on short-term requirements for shelter, which does not consider the long-term consequences of this strategy, which has an impact on future energy use. An appreciation of contextual factors that affect energy demand and use is thus an essential prerequisite to proposing any mitigation measures.

2. Background and research strategy

According to Uganda's energy distributor, UMEME (2014), the total number of formal grid connections in 2014 stood at 650,573, of which 590,677 (91%) were domestic connections, accounting for the largest proportion energy demand in the country (Adeyemi and Asere, 2014). Households also account for the fastest growing sector of electricity demand - currently at 13% per annum, which is significant, as by 2001, only 20% of urban households and 1% of rural households were officially connected to the electrical grid (Sebbit, Higenyi and Bennett, 2001; 237). Household energy demand thus presents as an important area for investigation, given the total number of households in 2014 stood at 7,353,427 (UBOS, 2014), suggesting a tremendous potential for growth in the demand for energy, which cannot be fulfilled without major changes to demand side management. Curbing potential demand presents an opportunity to enable more households to connect to the electrical grid, but requires information about current energy use patterns, which the current study seeks to achieve. Understanding existing and potential demand becomes an essential precursor to any energy saving strategies.

The study took in a variety of building types across the three major climate zones of Uganda: Hot and Wet – Savannah [2]; the Cool Wet Highland Climate Zone [4]; and, the Hot-Humid Climate Zone – Lakeside [6]. The larger study was undertaken in more than 200 different buildings, however this paper only reports on residential buildings in urban centres, with 79 households studied. Data was collected through a walkthrough energy audit; the questionnaire used for the audit based on the 'Energy Audit Manual' developed by UNHABITAT in 1988, but modified and updated for the current project. Data collected included: energy used for household activities, major appliances, occupancy patterns, and the nature of construction and materials used. Previous household energy studies undertaken in Uganda: by Sebbit, Higenyi and Bennett (2001), and Lee (2013), were directed at ascertaining the energy mix across households. These studies confirmed that households were heavily reliant on fuel-wood as the primary source of energy, prompting activities directed at replacing wood-fuel with other sources of energy, however without many alternatives, this is a significant conundrum. Each walk through audit took approximately 60 minutes to complete, and included more than 50 separate variables covering the following: general information; site description; building envelope; ventilation; lighting; appliances and energy sources. Data was analysed using IBM SPSS, Apple Numbers and Microsoft Excel. Of the 79 dwellings included, 46 were detached dwellings, and 33 multifamily dwellings (including flats and tenement housing).

3. Findings

The buildings included in the survey showcased a diverse array of housing types, built over the past 70-years. Buildings ranged in size from a tiny 9Sq.m., for the tenement houses, to large detached dwellings of over 600Sq.m, with an average area of 137Sq.m. These buildings sat on lot sizes that ranged from 120Sq.m. to 16,000Sq.m., giving an average plot ratio of about 0.28. Single storey detached housing were predominant in the study, highlighting the dominance of this typology across the country, related to homesteads and farming, but also as being a symbol of upward economic and social mobility. A substantial proportion of buildings surveyed, were constructed after 1990, highlighting the rapid growth in construction after the civil war of the 1980s.

Figure 1: Selection of housing types included in study

Three aspects of the study are presented here: the source of electricity demand; the type of energy used; and, the potential link to energy use to achieve comfort. It was found that materials used for construction varied little across housing types, largely comprising fired clay bricks, with steel or clay tile roofing, and with steel frame windows. There was evidence that some buildings did make use of climate design principles, although newer buildings were less inclined to make use of these basic principles, such as providing appropriate overhangs for north and south facing windows, minimising windows to the east and west, responding to slope, and enabling cross ventilation, where possible. In many cases, the proportions of openings facing due west and due east were equal to that for north and south facing windows. A key aspect of the contextual zeitgeist is a preoccupation with security, with most buildings going to great lengths to install burglar proofing, in the already limited area of openings, affecting interior lighting levels. Most buildings in the study had kitchens within the main building, apart from the tenement dwellings, which were designed specifically for sleeping, with most having shared facilities for cooking and ablutions.

3.1. Sources of energy

Energy used was found to come from three key sources: firewood, charcoal and electricity. Firewood was predominantly used by households in smaller urban centres, with only six households making use of this fuel, with an average of 270kg of firewood per month. Most households made use of charcoal for cooking and water heating (89%), burning through an average of 71kg of charcoal each month. Less prominent, was the use of kerosene (19 households), and LPG (17 households), with an average use of 6.7litres, and 14kg on average per month for each fuel type. Two households had diesel generators to cope with the regular black outs, while one household made use of solar energy as part of their energy regime. The predominance of charcoal as the main fuel source, could in part be attributed to a rapid increase in the urban population, in part, a result of large rural-urban migration over the previous two decades. These new urban dwellers, retain their rural practices, including cooking methods, heightened by a lack of formal energy sources and the perceived costs associated with these. This is significant, as virtually all households surveyed, 68 households were connected to mains electricity, a connection rate of 86%. Energy from different sources is presented in table 1 below:

Table 1: Household energy use per month.

Source	High	Low	Median
Firewood	450.0kg	25.0kg	285.0kg
Charcoal	240.0kg	10.0kg	60.0kg
LPG	50.0kg	3.0kg	7.5kg
Kerosene	50.0litres	0.5litres	2.5litres
Electricity	472.0kWh	7.0kWh	78.3kWh

The high use of firewood and charcoal, suggests that the challenge of changing energy use is far greater than often imagined. The energy mix indicates that households steer clear of formal energy sources (gas and electricity) for cooking and water heating. This is related to the erratic electricity supply, the irregular availability of LPG, along with the commonly held view that these formal energy sources are expensive. The true cost of using charcoal and firewood on the other hand is not immediately evident, as the cost of supplying these relates largely to labour and transportation; the long-term impacts of this are not immediately evident. The intermittent electricity supply also suggests households would search for alternative sources of electricity, however, it was found that use of solar PV and diesel generators was very low, with only two households having generators, and one with PV panels, with no households having solar hot water systems. The low penetration of these devices, despite more than two decades of irregular supplies of electrical energy indicates that there is no definite link in reduced availability of electricity, and use of new non-traditional energy sources. Indeed most households resort to use of traditional sources to meet their energy needs.

3.2. Energy use

More specific analysis of energy use in households was undertaken to understand the patterns of energy use. The average rate of electricity consumption per month was 96.3kWh (1,155kWh per annum). When energy from all sources is included, based on conversion rates from Myles, Olese, and Nathan (2007), this increases, to an average of 698kWh per month, a clear indication of the impact of cooking and water heating on energy consumption. Looking specifically at electrical energy, the rate of 96.3kWh is far below the global average of 3,471kWh, and compared with electrical use in different parts of the world: Australia – 7,227kWh; China – 1,349kWh; Italy – 1,157kWh; South Africa 4,389kWh) (Shrink That Footprint, 2015. This low energy consumption does highlight a key fact, that space heating and cooling are not the norm in Uganda. A review of the consumption patterns across the year revealed limited variation across the year, although households with school-going children did indicate variations related to the number of people in the household during vacations, and the school terms, with electricity demand highest when children were at home from boarding school.

Household energy use in itself is misleading, and it does not account for the different dwelling sizes, which varied considerably. Taking this into account, an attempt to correlate energy use with building area was made, which could give an idea of energy use across the different dwellings. Relating this information to the area of the buildings, it was found that on average households used 9.4kWh per square metre per annum. This relationship, between building area, and energy use per square metre, was plotted in Figure 2, showcasing a negative relationship between the two, as exemplified by the logarithmic trend line.

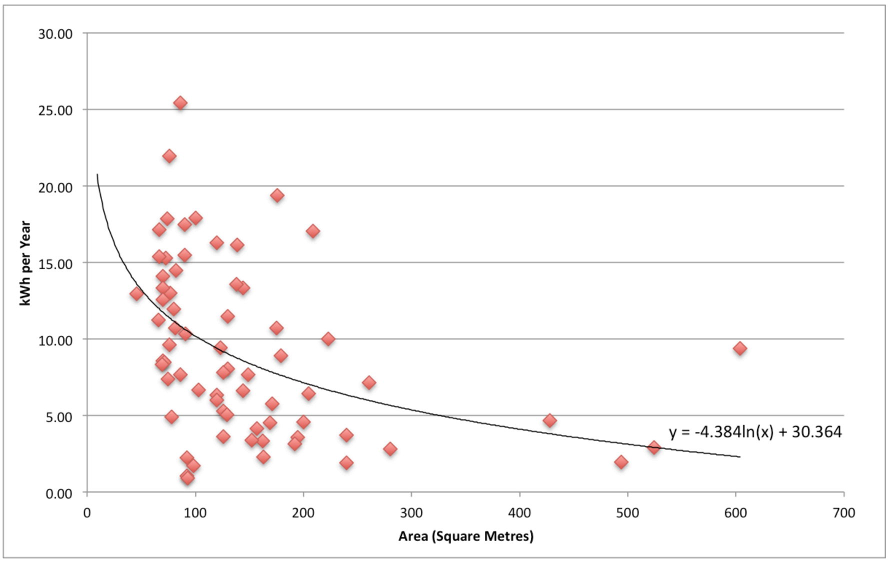

Figure 2: Household electrical energy use per square metre

Seeking to contextualise this figure of 9.4kWh per square metre per annum, a comparison was made with studies undertaken in other parts of the world. Chaiwiwatworakul, Chuangchote and Rakkwamsuk

(2015) found an electricity consumption rate of 23.6kWh per square metre per annum in northern Thailand, while in the UK, Yohanis, Mondol, Wright and Norton (2007), determined electricity consumption to be between 30 and 60kWh per square metre per year (depending on the dwelling type). In this case, it was acknowledged that most households made use of gas or oil for cooking and space heating respectively. Taking all forms of energy into consideration, the energy consumption rate per increases significantly, to 86kWh per square metre per annum, again showcasing the effect of cooking and water heating on energy use. Even without space heating or cooling, this is significantly high.

A review of housing appliances used within the households, as presented in Table 2 below, gives an indication of what households use electrical energy for. For most, lighting is key, and for many compact fluorescent bulbs and fluorescent tubes are used, although a few still make use of incandescent light bulbs. Of the households reporting the appliances being used, all indicated having cell phones within the dwellings, with more than 82% of households reporting more than three devices, with some reporting more than eight devices. The most predominant appliances within households were related to entertainment: televisions, DVD players and Radios/Hifi systems found in about 80% of households.

Table 2: Household appliances.

Item	Per cent of Households
Blender	9.8%
Cell Phone/PDA	100.0%
Computer (Desktop)	17.6%
Computer (Laptop)	60.8%
DVD Player/Games Console	56.9%
Iron	**82.4%**
Kettle (Electric)	**56.9%**
Microwave Oven	**23.5%**
Radio / Hifi	78.4%
Refrigerator/Freezer	54.9%
Television	82.4%
Toaster	**9.8%**
Washing Machine	11.8%

There were only a limited number of kitchen appliances, a consequence of the poor electricity supply that affected their performance, but more so as traditional ways of preparing meals still predominates. Few households had HVAC systems, with portable fans, the only device type noted by households. This low penetration of fans and other climate modification equipment may be linked to the moderate upland tropical climate of the region, which has not impacted on building design, with thermal performance and thermal comfort not primary factors for building occupants. This does raise questions related to future demand in view of climate change, and a growth in affluence and associated links to the expectations householders.

3.3. Energy use and thermal comfort

As suggested by Kwong, Adam and Sahari (2014), the provision of comfort for building occupants is increasingly a key consumer of energy across the tropics, estimated at between 30-60% of total energy consumption across all building types. While the upland tropical conditions of Uganda serves to reduce the demand for climate modification equipment to achieve comfort, nonetheless, this does not account for potential demand arising from the choices made in planning and design. With no clear building performance requirements, buildings tend to utilise traditional approaches to design and layout, having the main façade facing the street. Regardless of the availability of information on thermal performance requirements, it was clear that other factors were more influential in the siting of buildings, with the terrain, and planning of the site as key factors in this regards (See Table 3).

Table 3: Direction of main facade

Item	Per cent of Households
North	4.5%
North-East	15.9%
East	20.5%
South-East	13.6%
South	13.6%
South-West	9.1%
West	13.6%
North-West	9.1%

The high percentage of buildings facing east and west, suggests many buildings have large expanses of unshaded glazing in these directions. While facing east toward the rising sun evokes spiritual ideals, facing the main road traditionally served an important social and cultural function, representing a connection to the world, as sketched out by Kingsolver:

> Kilanga village runs along the Kwilu River as a long row of little mud houses set after-one-the-other beside a lone red snake of dirt road. ... Every red mud house squats in the middle of its red dirt yard, for the ground in the village is cleared hairless as a brick. ... In a long row the dirt huts all kneel facing east, as if praying for the staved-off collapse - not toward Mecca exactly but east towards the village's one road and the river and behind all that, the pink sunrise surprise. .... But no one here stays under a roof. It is in the front-yards - all the world's a stage of hard red dirt under bare foot ... (1998, 35)

This social function is largely forgotten in urban settings, as the news source of choice is from television or radio. Further, security concerns, and a lack of sufficient protection from mosquitoes, with many households lacking mosquito screens, results in extensive burglar proofing, and windows being tightly shut at night. Adding to these are large perimeter walls that restricted wind movements, contributing to discomfort conditions, and a large potential for an increase in energy use to achieve comfort.

4. Discussion

Two areas emerge as providing the greatest potential to affect energy use: building design, and lifestyle changes. Looking first at lifestyle, this has the potential for a large contribution to future energy use, a challenge for any move to reduce energy consumption. This potential growth is a consequence of a current low baseline, and growing demand for labour saving appliances, larger and more powerful entertainment equipment, and changing ideas and perceptions of comfort, suggesting that electrical energy use is likely to climb into the future. Behavioural changes, and education of householders, related to the consequences of the growth in demand, therefore present as a potential area for exploration in attempts are influencing energy consumption through changes in users' attitudes. With virtually no households cooling or heating spaces, technological solutions may have limited impact on energy demand with behavioural change presenting a clear potential for energy saving. While there have been some success in introducing energy efficient light fittings, this is only a small contributor to overall energy use. This however is a long-term objective, given householder's attitudes are influenced by what they see, as presented by Alamuddin (2002), in the article, *'I want a colonial house': The architect versus the other*.

Building design, on the other hand, presents as a real paradox, with the status quo approach contributing to a large potential growth in energy use. Patterns of site layout as well as building orientation and form contributing to long-term challenges related to household energy use. While changing fixtures, and altering user behaviour and practices may provide a potential savings, the current approach to design has changed little over the years, failing to acknowledge changes to the availability of energy let alone acknowledging the constant power blackouts. While the study revealed low use of electrical energy, relative to global energy consumption average, does reveal a large potential for an upswing in energy related energy demand, a consequence of what can be termed a *laissez-faire* approach to planning and design, in which basic principles of building performance are neglected, with the consequences effectively passed on to future building occupants. A study by Ndibwami (2012) suggested that most practitioners were aware of the need for sustainability and energy efficiency in buildings, however not applying these in practice may relate to a lack of any incentive to do so, along with a belief that the application of these principles would dramatically increase the cost of a building. This presents an opportunity for a renewed approach to fulfilling the housing backlog, acknowledging potential energy demand as a factor in determining the direction of future developments.

Awareness of the consequences of current efforts becomes a key factor for engagement with designed environments, as this does affect future use patterns and energy use. Design, it is suggested, has the biggest capacity to reduce potential demand for energy, by designing for resilience, at an urban and individual building level. The potential for implementing energy efficiency measures are clearly evident, but rarely explored, side lined by immediate priorities, such as security. The design and layout of buildings, when viewed in isolation, did acknowledge basic environmental design parameters, were found to be ineffective on site, as the designs were not specific to place. Thus, energy use in the context of Uganda cannot be discussed in isolation of the environment in which the buildings are located. While energy use is currently viewed in the context of individual buildings, it is evident that future demand for energy is intrinsically tied to the broader urban environment. In this case, while the open space around buildings has shielded households from seeking technical solutions, the smaller lot sizes, and increased densities, makes this more likely into the future. Urban design and planning regulations therefore become key factors in discourse on energy use in buildings.

5. Conclusions

This study looked to understand energy use in households in Uganda, and in so doing provide a baseline for future electricity demand. The study itself is on going, and seeks to gather data from at least 100 buildings across the three major climate zones of Uganda. What the datasets indicate thus far is far higher overall energy use than anticipated. Use of electricity, while low by global standards, does have a potential for substantial growth into the future. The low penetration of alternative energy use, and the high percentage of households still making use of firewood and charcoal, presents a worrying picture that highlights the complex nature of energy use in this part of the world.

With the use of electricity growing exponentially, current growth patterns suggest challenges in the future. There is, therefore, need to look at demand side management, and alternative sources of electricity to ensure energy demand can be met, but without adversely affecting the broader environment, as is currently the case with firewood and charcoal. While still preliminary, areas of potential review are clearly evident, situated between socio-cultural factors and lifestyle, and changes to related to the design and construction of buildings.

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