Case Study of Monthly Disparities between Consumed and Billed Household Electricity in Ghana

Emmanuel Yeboah Osei, Barbara Caroline Kwofi

Abstract— This paper used electricity meter readings to comparatively assess the monthly disparities between actual household electricity consumption and Electricity Company of Ghana billed consumption for a 3-bedroom house in Ghana for a duration of eight months from April to November 2013. This case study was done to provide empirical insight into the nature of residential electricity bill irregularities based on concerns of some households. The empirical results showed monthly disparities throughout the duration of study. The electricity bills in kWh units were over-billed for September, October, and November by 70.4%, 9.1%, and 4.6% respectively. This resulted in inflation of the real cost of electricity consumption of 88.5%, 8.9%, and 4.5% for the respective months. However, the electricity bills in kWh units were under-billed for April, May, June, July, and August by 19.3%, 27.0%, 46.4%, 4.2%, and 39.1% respectively. This again resulted in deflation of the real cost of electricity consumption of 18.4%, 25.8%, 44.4%, 4.1%, and 37.9% for the respective months. These disparities revealed a fundamental problem of the Electricity Company of Ghana not billing the exact monthly electricity consumption for this case study. However, the overall disparity was an over-billing of just 1.2% which was relatively small compared with the disparities for the individual months. The Electricity Company of Ghana confirmed that such disparities are usually corrected as and when complaints are made to their offices.

Index Terms— Case study, ECG, electricity bill, energy consumption, energy efficiency, Ghana.

1 INTRODUCTION

Globally, the availability and use of modern forms of energy have been closely associated with economic development and this makes energy very important for emerging economies [1] [2] [3] [4] [5]. Energy will continue to play a very important role in driving the economic and infrastructural development of various developing nations [6] [7] [8] [4]. Ghana as a country is of no exception and will need to increase the availability of energy, especially electricity, to help increase access and transform various sectors of the economy including health, education, sanitation, business, etc.

The implementation of energy efficiency (EE) measures helps to make more energy available for use from fixed supplies. EE is an effective way to reduce energy consumption (EC) in order to enhance the security and reliability of energy supply [9] [10] [11] [12]. Residential and commercial buildings offer great potentials for energy savings since they consume about as high as one-third of global energy [13] [14] [15]. EE in buildings has helped various nations save significant amounts in cost. For instance, EE measures implemented in Chinese residential buildings saved the City of Tianjin an avoided investment in a 300 Megawatts (MW) thermal plant between 2005 and 2009 [15].

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Again, EE measures supported and implemented in Germany by the German Public Bank "Kreditanstalt für Wiederaufbau" led to average annual energy savings of 2.1 Terawatt hours (TWh) for about 280,000 flats between 2006 and 2010 [16]. This is enough energy to power a little more than 580,000 households per year in African cities without any additional power generating infrastructure assuming each house consumes only 300 kilowatt hours (kWh) per month. The International Energy Agency (IEA) has estimated that buildings will account for about 41% of global energy savings potential by 2035 [17]. In the case of developing countries, the need to enhance the security of energy supply in order to increase access to electricity will require vigorous implementation of EE measures in addition to the expansion of power generating infrastructure.

Ghana as a developing country continues to advocate for the implementation of EE measures in various households as means to reduce EC and safeguard the reliability of energy supplies. However, these EE advocacy activities are usually done with focus on total national energy savings without the intricate considerations on whether EE actually benefits the energy consumer in direct financial terms. Although EE measures can help save both energy and cost at the national level, EE makes more sense to the residential energy consumer if these savings in cost translate to the reduction of household electricity bills. In other words, residential EE does not make sense if there is a disconnection between actual household electricity consumed and billed electricity in both kWh and costs. There have been some concerns or suspicions among various residences in Ghana that their monthly electricity bills are sometimes higher and do not always reflect their actual electricity consumptions. In that regard, this paper evaluates the nature of the disparities between actual household EC and

billed EC for a Ghanaian case study with data from the household electricity meter. This is done to present an empirical insight into the extent of the deviations of monthly billed electricity from the actual household EC for this case study for the period of data collection. This paper is organized into various sections that mainly explain the research relevance, objectives, analytical framework, results, discussions, and conclusion.

2 Problem Statement and Research Relevance

Advocating for the use of energy efficient appliances for households has been one major tool employed by various government and not-for-profit agencies aimed to reduce electricity demand in Ghana. Ghana as a country has found herself in different cycles of national energy crises which have been widely discussed by [18] [19] and caused primarily as a result of growth in energy demand and inefficiency or waste in the use of energy. Currently (in 2015), Ghana is in another period of energy crisis where the national available power supply is incapable of fully meeting the demand. These waves of energy crises continue to have negative effects on the national economy and these publications [20] [21] from the Ghana Ministry of Finance confirm this. Past attempts to salvage the energy situation led to the development of two main energy policy documents (Strategic National Energy Plan (SNEP) and National Energy Policy (NEP)) to help provide directions to solve the energy problems [22] [23]. These policy documents tried to approach the energy situation from two main perspectives namely – 1) increasing and diversifying energy generation and 2) implementing EE measures. However, despite the various energy projections made in these documents, Ghana still continues to face energy crisis.

EE has been on the agenda of Ghana as a country. The Ghana Energy Commission (GEC) has implemented programmes in the direction of EE where the use of low-power-consuming appliances including air conditioners, refrigerators, lights, etc. have been promoted [24]. This has led to the development of a Mandatory Appliance Standards and Labelling Programme where importers are required to only sell household appliances that meet minimum EE and performance standards approved by the Ghana Standards Board [25]. Although these programmes are ultimately targeted at reducing the aggregate national power demand, there are concerns of disconnection of these programmes from the actual EC implications for the residential energy consumer. There are concerns among various residences that use post-paid electricity meters that monthly electricity bills are usually high and do not correspond with actual household EC no matter how hard they try implementing EE measures. Although these allegations may be true with regards to ECG personnel not being able to physically access and read various residential post-paid electricity meters due to genuine challenges, no scientific proof has been given till date. This research attempts to find an empirical perspective in relation to the above allegations by making comparative assessments between actual household monthly EC and ECG billed EC for a 3-bedroom residential house case study in Ghana for eight months duration from April 2013 to November 2013.

3 Research Objectives

This research is meant to present a case study of the disparities between actual household EC and ECG billed EC in Ghana as an empirical insight into the level of deviations of monthly electricity bills from actual consumption. This is to find out whether the disparities are substantial or not in order to help confirm or dispute the claims of unfair billing from ECG. The specific objectives of this paper are enumerated below.

a) To collect monthly aggregate EC figures (in kWh) for the whole house for eight months duration from April 2013 to November 2013.
b) To compile the available ECG monthly electricity bills and compare with the actual household monthly EC for the same duration.
c) To assess the disparities between the actual household monthly EC and the ECG billed EC in kWh and in financial terms.
d) To present a perspective based on the empirical results.

4 Methodology

4.1 Overview of Method

The total EC for the three-bedroom house in kWh was recorded from the household post-paid electricity meter at the beginning and end of each month from April 2013 to November 2013. The monthly ECG bills (in kWh and costs) for the house were also compiled for the same duration and compared with the actual household EC readings taken. The disparities between the actual household EC and ECG billed EC were calculated for each month in kWh and in percentage terms. These disparities were again valued in fiscal terms according to the standard electricity tariffs in the ECG bills.

4.2 Description of Household

The house had three main bedrooms, one store room, one hall, one kitchen, two toilets, two bathrooms, two corridors, one office space, and one veranda. A sketch of the general layout of the house is shown in Figure 1. The type of electricity meter used in the house was the post-paid type where readings were taken once a month by personnel from ECG and billed accordingly. There was random availability of electricity due to frequent power outages or erratic power supplies. The occupancy of the house was an average of three people who slept every night in BR1, BR2, and BR3 with the house occasionally accommodating extra visitors and sometimes being empty in the daytime.

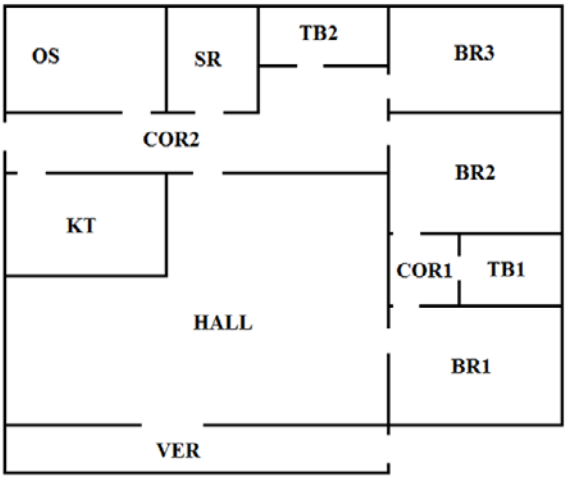

Figure 1: Schematic layout of house in case study [a]

TABLE 1
ITEMS ON A TYPICAL MONTHLY RESIDENTIAL ECG EC BILL IN GHANA

No.	Item	Item Description
1	EC units	This item displays the consumed electricity units for the month in kWh.
2	Charge rate and cost of EC units	This item displays the charge rate or tariff for the EC units in GH¢/kWh and the cost of the total EC units recorded for the month in GH¢.
3	Service Charge (SERV CHG)	This item is an added levy which displays a fixed charge in GH¢.
4	Government Special Levy (GV S Levy)	This item is an added levy which displays a different charge rate in GH¢/kWh and the total charge in GH¢ with respect to the recorded EC units.
5	Street Light (STREET LT)	This item is an added levy for street lights which displays a charge rate in GH¢/kWh and the total charge with respect to the recorded EC units.
6	Other Miscellanea	This item usually contains miscellaneous details of previous paid bills, balances, and other items.

4.3 Analytical Framework

The household electricity meter readings (in kWh) were taken at 5:00 GMT on the first day of each month for the eight months duration of the study. The household EC per month was calculated as the difference between the respective 5:00 GMT meter reading for the first day of the month in question and subsequent 5:00 GMT reading for first day of the next month. This is mathematically expressed in (1).

$$E_m = E_{500nm} - E_{500tm} \quad (1)$$

Where:
E_m is the EC per month in kWh.
E_{500nm} is the meter reading for the first day of the subsequent month in kWh.
E_{500tm} is the meter reading for the first day of the month in question in kWh.

The difference between the actual household EC and ECG billed EC for any particular month was calculated according to (2). Positive difference represents over-billing whiles negative difference represents under-billing.

$$E_{mdiff} = E_{mb} - E_m \quad (2)$$

Where:
E_{mdiff} is the difference between the actual household monthly EC and the ECG billed EC in kWh.
E_{mb} is the ECG monthly billed EC in kWh.

The percentage difference between the actual household EC and ECG billed EC for any particular month was calculated according to (3).

$$\%E_{mdiff} = ((E_{mb} - E_m)/E_m) \times 100\% \quad (3)$$

Where:
$\%E_{mdiff}$ is the percentage monthly EC disparity.

The cost of the actual electricity consumed for any particular month was calculated according to the rates provided on the ECG residential monthly bill sheet for that particular month. The total cost of electricity consumed for each month comprised the cost in relation to the actual EC units and other mandatory added charges as explained in Table 1. Table 1 itemizes the various components that make up the total ECG EC bill for any particular month. The cost of the difference between the actual household EC and ECG billed EC for any particular month (in Ghana Cedis (GH¢)) was calculated according to (4).

$$C_{mdiff} = (E_{mdiff} \times C_E) + C_{mand} \quad (4)$$

Where:
C_{mdiff} is the cost of the difference in EC per month in GH¢.
C_E is the cost of a unit of electricity in GH¢/kWh.
C_{mand} is the total cost of other mandatory charges as specified by items 3, 4, 5, and 6 in Table 1

The total cost of the difference between the actual household EC and ECG billed EC for the eight months duration of study (in Ghana Cedis (GH¢)) was calculated as the cumulative sum of the monthly cost differences. The percentage total difference in costs between actual household EC and ECG billed EC for the duration of study was calculated according to (5).

$$\%C_{Tdiff} = ((\sum C_{mb} - \sum C_m) / \sum C_m) \times 100\% \quad (5)$$

Where:
$\%C_{Tdiff}$ is the percentage total cost of EC disparity for the eight months duration.
$\sum C_{mb}$ is the sum of the costs of monthly ECG bills for the duration of study.
$\sum C_m$ is the sum of the costs of actual monthly EC for the duration of study.

5 Results and Discussions

5.1 Actual Household EC versus ECG Billed EC for the Various Months

A comparison of actual household EC and ECG billed EC as shown in Figure 2 presents the monthly disparities between the two from April to November 2013. Figure 3 also shows the percentage differences between household consumed electricity and ECG billed electricity for the various months. Generally, it is evident from Figure 2 and Figure 3 that September 2013 recorded the maximum disparity where the ECG EC bill was overestimated by 211.9 kWh which represented 70.4% difference. The least disparity between consumed and billed EC occurred in July 2013 where the ECG EC bill was underestimated by 9.3 kWh which represented only 4.2% difference. April, May, June, and August had underestimated ECG EC bills with disparities of 19.3%, 27.0%, 46.4%, and 39.1% respectively between actual household EC and ECG billed EC for each month. The ECG EC bill for October and November 2013 were overestimated by 25 kWh and 12.2 kWh respectively which again represented respective variations of 9.1% and 4.6% between actual household EC and ECG billed EC.

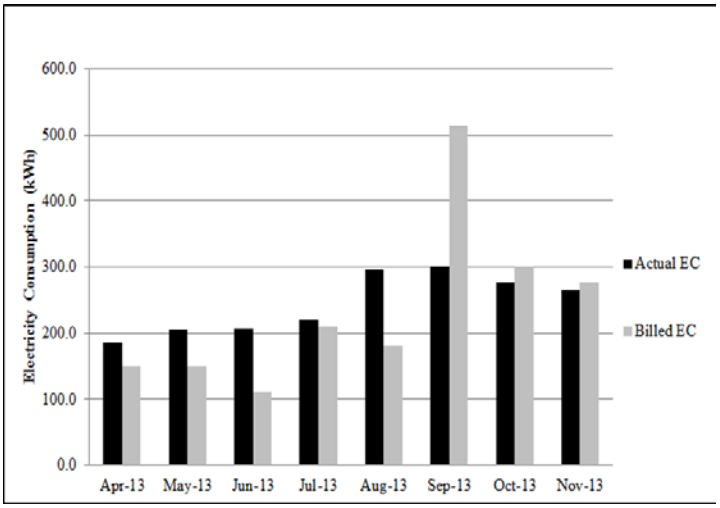

Figure 2: Comparison of actual monthly household EC and ECG billed EC

TABLE 2
TOTAL COST DIFFERENCE FROM APRIL TO NOVEMBER 2012

Month	Total Consumed EC Cost	Total Billed EC Cost	Cost Difference
Apr-13	GHC 34.39	GHC 28.07	-GHC 6.32
May-13	GHC 37.85	GHC 28.07	-GHC 9.78
Jun-13	GHC 38.12	GHC 21.19	-GHC 16.93
Jul-13	GHC 40.44	GHC 38.80	-GHC 1.64
Aug-13	GHC 53.72	GHC 33.35	-GHC 20.37
Sep-13	GHC 54.71	GHC 103.13	GHC 48.42
Oct-13	GHC 89.85	GHC 97.81	GHC 7.96
Nov-13	GHC 86.32	GHC 90.17	GHC 3.85
TOTAL	**GHC 435.40**	**GHC 440.59**	**GHC 5.19**

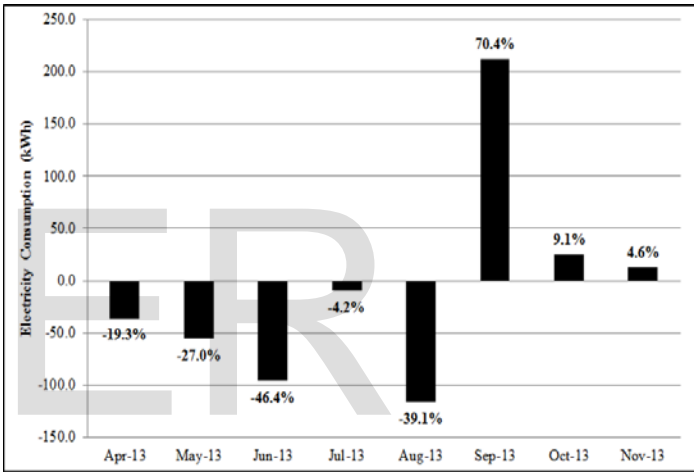

Figure 3: Percentage monthly disparities between actual household EC and ECG billed EC

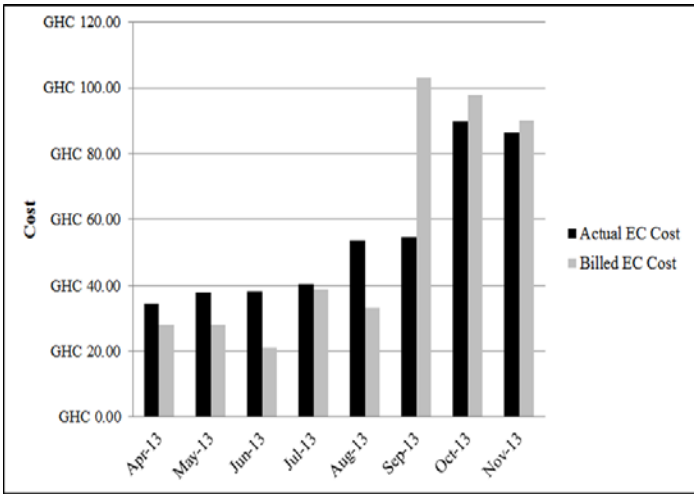

Figure 4: Disparities between total costs of actual household EC and ECG billed EC

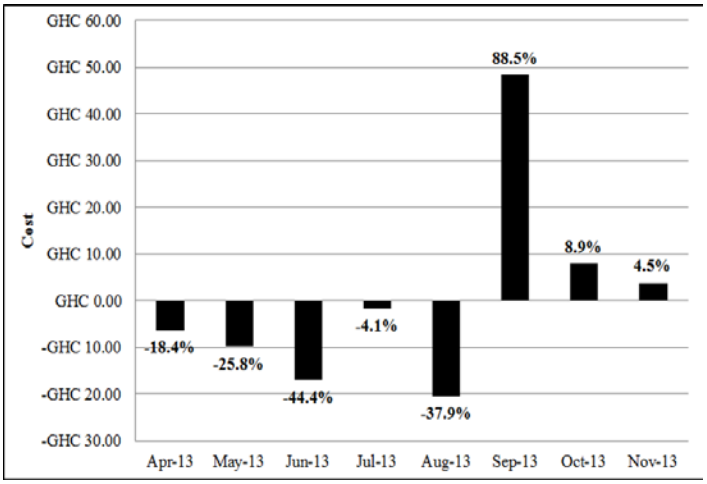

Figure 5: Percentage differences between total costs of consumed EC and billed EC

5.2 Financial Analysis

Figure 4 shows the cost of electricity as billed for the house by ECG for the various months from April to November 2013. This same figure shows the actual household EC cost as calculated according to the actual EC from the electricity meter readings in this case study. Figure 5 shows a graph of the percentage differences between the costs on the ECG EC bills and the calculated costs of the actual household EC for the various months. These calculations were based on the rates of the various items provided on the electricity bill sheet for each particular month as generally outlined in Table 1. From Figure 4 and Figure 5, there were disparities between the costs on the ECG EC bills and the calculated costs of the actual household EC for each month. September 2013 registered the largest cost disparity of an excess charge or over-billing of 88.5% which was GH¢48.42 in monetary terms. July 2013 recorded the least cost disparity of GH¢ 1.64 which represented an under-billing of just 4.1%. The ECG EC bills for April, May, June, and August 2013 were under-charged by 18.4%, 25.8%, 44.4%, and 37.9% respectively. In monetary terms, these differences were GH¢ 6.32, GH¢ 9.78, GH¢ 16.93, and GH¢ 20.37 respectively. In contrast, the ECG EC bills for October and November 2013 were over-billed by 8.9% and 4.5% respectively. In monetary terms, these cost differences were GH¢ 7.96 and GH¢ 3.85 respectively. However, the total cost disparity for the eight months duration of study was just GH¢ 5.19 which represented a cumulative over-billing of the ECG EC bills of only 1.2%.

5.3 Perspective

The distribution and sale of electricity to various residential houses in the southern part of Ghana is the primary responsibility of ECG and since a significant number of these households use post-paid electricity meters, personnel from ECG read these meters on a monthly basis to help prepare the corresponding EC bills. However, the household monthly EC disparities between actual consumption and ECG billed consumption of up to over 70% over-billing in kWh and more than 80% artificial inflation in EC cost as shown in this case study indicate clearly that there was a fundamental problem with the ECG billing process for this case study. The problem as shown in this research was that ECG monthly EC bills were not always true reflections of the actual household EC for this case study. This could mean that the monthly household meter readings were sometimes not taken or not considered in the preparation of the monthly ECG bills. Nevertheless, the cumulative cost disparity for the eight months duration of an over-billing of merely 1.2% shows that the disparities tend to diminish with time or in the long term. This was confirmed from communications with ECG which revealed that this problem indeed existed and that ECG always attempted to correct the disparities for various households whenever there was a customer complaint or when they had the opportunity to physically read the relevant residential post-paid meters. This response from ECG again establishes that the concerns of high monthly EC bills among various residences may be valid so far as the issue is not reported to the ECG for numerical reconciliation and correction.

6 Conclusion

In this paper, monthly EC readings were taken continuously for eight months (April to November 2013) for a 3-bedroom house case study in Ghana with a post-paid electricity meter. These actual household EC readings were analysed and compared with the monthly ECG EC bills for the house for the same eight months duration. It was found from the analysis that there were monthly disparities between actual household consumption and ECG billed consumption for all the eight months. The ECG EC bill for September 2013 was over-billed in the neighbourhood of more than 70% in kWh terms which translated to over 80% excess artificial cost in the bill. The ECG bills for October and November were also over-billed by 9.1% and 4.6% respectively in kWh and these again transformed into 8.9% and 4.5% artificial inflation in the respective EC costs. However, for the months of April, May, June, July, and August, the ECG EC bills were under-billed in kWh terms by 19.3%, 27.0%, 46.4%, 4.2%, and 39.1% respectively. These under-billings transformed into artificial decreases in the costs of ECG EC bills of 18.4%, 25.8%, 44.4%, 4.1%, and 37.9% respectively for the various months. The overall disparity for the eight months period of study was an over-billing of just 1.2% in kWh terms which was relatively small compared with the individual monthly disparities. The main problem found by this study was that the monthly ECG bills for the household were not always indicative of the actual monthly EC. However, this problem of disparities tends to diminish with time as ECG rectifies the problem as and when customer complaints are made to them. Since the dynamics of household EC bills has implications for the implementation of EE measures, it is recommended that ECG puts in measures to ensure that residential electricity consumers pay only for what they consume. One main way is to make the use of pre-paid meters widespread so that electricity consumers can have greater control over their EC bills.

7 ABBREVIATIONS

BR1 Bedroom 1
BR2 Bedroom 2
BR3 Bedroom 3
COR1 Corridor 1
COR2 Corridor 2
EC Electricity Consumption or Energy Consumption
ECG Electricity Company of Ghana
EE Energy Efficiency
ESMAP Energy Sector Management Assistance Program
GEC Ghana Energy Commission
GH¢ Ghana Cedis
GHC Ghana Cedis
GoG Government of Ghana
IEA International Energy Agency
KT Kitchen
kWh Kilowatt hours
MoE Ministry of Energy of Ghana
MW Megawatts
NEP National Energy Policy
OECD Organisation for Economic Co-operation and Development
OS Office space
OT Outside
PURC Public Utilities Regulatory Commission
SNEP Strategic National Energy Plan
SR Storeroom
TB1 Toilet and bathroom 1
TB2 Toilet and bathroom 2
TWh Terawatt hours
UNDP United Nations Development Programme
VER Veranda

8 ENDNOTES

a. Nomenclature for the household schematic is fully described in the abbreviations section.
b. The previous Ministry of Energy has currently been divided into Ministry of Petroleum and Ministry of Power.

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