Investigation into a Distribution Network Energy Utilization: Ilaro Community as Case Study

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Abstract

Energy audit, with emphasis on utilization, is an inspection, survey and analysis of energy flow for energy conservation in a building, system or process to reduce the amount of energy input into the system without negatively affecting the output. Most of the efforts to address the challenges of poor energy availability are focused on generation and transmission with less attention paid to utilization. This work investigated the utilization of electricity in residential areas of a power distribution network with the aim of providing measures to minimize waste and cost of electricity. The methodology involved the use of data from electricity consumers about electricity consumption vis-à-vis the type of the building, electrical appliances in the building and their billing methods. Heating appliances take 58 %, motorized equipment 21 %, ICT equipment 11 % and lighting devices 10 %. Replacing incandescent lamps with ESLs can save 4.13 % energy. If government can proscribe incandescent lamps, a saving of 4.13-9.29 % can be achieved. If consumers switch to more energy-efficient motorized appliances, another 21% of energy shall be saved. A government policy mandating the use of prepaid meter billing will greatly conserve energy as it engenders energy-saving culture in consumers.

Keywords: Energy audit, electrical loads, ESL, Energy utilization, energy management.

1. Introduction

Over the last several years, the emphasis and importance placed on energy conservation and saving has grown exponentially. This is primarily due to increasing cost of energy as well as the considerable media attention it has fostered. Energy exists in several forms as heat, kinematic or mechanical, light, potential, electrical, or any other forms as the capacity of a physical system to perform work (Syed, 1985). Less attention is paid to energy management which comprises energy audit. An "audit" is a systematic approach which follows a structural, documented plan (Audit Plan). The audit must be planned and structured in such a way that those carrying out the audit can fully examine and analyze all important evidence (Hayes, Dassen, Schilder & Wallage, 2009). Energy Audit is also said to be an inspection, survey and analysis of energy conservation in a process, building or system to reduce the amount of energy input into the system without negatively affecting the output (Ladda, 2014; Leslie, Pearce, Harrap, & Daniel, 2012). Such efforts in reducing avoidable losses, improving the effectiveness of energy use efficiency by conducting energy audit, implementing the energy conservation measures and carrying out post installation monitoring and set targets is termed energy management (Datta, 2010).

Energy being generated in Nigeria is not sufficient to meet the peak demand of the consumers and this is causing instability in supply. Loads are generally divided into constant loads and varying loads. Constant load appliances draw about the same amount of power all the time examples of such are light, fans, stereo etc. Some of the constant load can also be classified under varying load because they vary slightly. While varying Load appliances consume different

energy over their operating condition. Examples are fridges, irons, electric ovens, heaters, air conditioners. Some motorized appliances, for example, washing machine, dish washer, fans and indicator light may continue running even when the appliances are in the "off" state (Kemp, 2007). A considerable amount of electricity used at home goes into lighting (Ebenezer, 1987). Good energy management can contribute to energy efficiency and it includes:

- Ensuring that spare heat are not vented away but put into use
- Lighting is activated when required
- Carrying out energy audits i.e. measuring and analyzing the amount of energy used by a building or company to ensure that all aspects of energy management are optimized.

Typical energy consumption pattern is presented in Figure 1 where industrial use takes the highest of 49% and commercial 8%. Others consumers are in between.

2. Materials and methods

The objective of this work is an aspect of energy management involving the investigation of the utilization of energy with respect to residential area of Oke-Ola and Lower mission areas of Ilaro. Data were gathered from electricity consumers by moving from house to house in the two designated areas. Questionnaires were administered to respondents who can tell the types and numbers of electrical appliances available in the building and also provide electricity bills and receipts.

One hundred questionnaires were administered on one-on-one basis out of which only seventy-five of them were considered to have sufficient information for analysis. Data were analyzed based on an assumption of a five (5) hours daily average power supply. Of these five hours, various electrical appliances were assumed to operate for some certain number of hours as indicated in Table 1. The tariff used during the study was based on N16:11k per kilowatts hour (kWh) and one month is calculated as thirty (30) days.

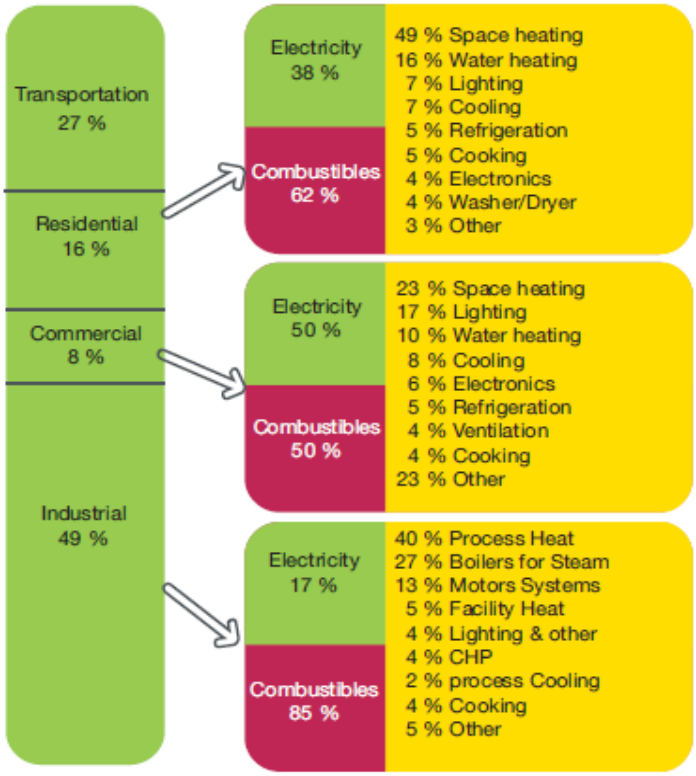

Figure 1: Typical energy consumption and key area of energy usage by type (Schnieder Electric, 2008)

Table 1: Estimated hours of operation of appliances used for the study

Electrical appliances	Daily assumed hours of operation (hrs)
Lightings	3
Boiling ring	0.25
Electric cooker	1.5
Pressing iron	0.5
Toaster	0.17
Microwave	0.33
Blender	0.08
Water pump	0.58
Washing machine	1
Air conditioner	1
Standing fan	2
Ceiling fan	2
UPS	2
Desktop PC	2
TV	2.5
Radio	2.5
VCD	2.5
Sound system	2.5
Laptop	2
Electric kettle	0.25
Refrigerator	2.5

Electricity consumers on estimated billing were analyzed by checking the degree of correspondence with which their electrical appliances conform to how much they pay using the N16:11k per KWh energy charges. Detailed analysis of tables, graphical depictions and important calculations were also carried out. The data were classified based on electricity meter (billing system). Based on the foregoing classifications, the seventy-five (75) questionnaires selected are as presented in Table 2.

Table 2: Classification based on billing system

Billing system	**Number of Respondent**	**Percentage (%)**
Prepaid meter	15	20
Postpaid meter	45	60
Estimated billing	15	20
Total	75	100

3. Results and Discussion

Buildings under pre-paid billing system consist of both 3-bedroom flat and 4-bedroom flat. They are labeled as Residence R1-R15 in Table 3. All the building under the postpaid meter category are labeled “R16” to “R60” for analysis. These buildings consist of flats and the multi-habited house popularly called “face-to-face”. They are presented in Table 4. All buildings under the estimated billing category are the so-called “face-to-face”. They were labeled as “R61” to “R75” for analysis and presented in Table 5.

Table 3: Summary for buildings using prepaid meter

Building	Total load (kW)	Lightings (kW)	Heating appliances (kW)	Motorized equipment (kW)	Electronics ICT equipment (kW)	Unit purchased
R1	3.271	0.668	1.2	1.3	0.103	99.8
R2	5.434	0.396	2.4	1.85	0.788	138.6
R3	8.222	0.384	5.4	1.55	0.888	99.8
R4	3.382	0.312	1.2	1.63	0.24	99.8
R5	3.421	0.288	1.2	1.81	0.123	50
R6	4.475	1.08	1.2	1.630	0.565	50
R7	7.168	0.468	4.5	1.890	0.310	99.8
R8	4.655	0.460	2.4	1.625	0.17	99.8
R9	6.117	0.444	4.2	1.350	0.123	50
R10	6.329	0.276	3.6	1.975	0.478	138.6
R11	2.599	0.384	1.2	0.892	0.123	99.8
R12	15.194	0.456	8.1	6.02	0.618	79.25
R13	7.511	0.648	4.9	1.62	0.343	50
R14	9.963	0.9	4.2	1.71	3.153	50
R15	11.241	0.468	5.4	4.42	0.953	99.8

Table 4: Summary for buildings using postpaid meter

Buildings	Total load (kW)	Lightings (kW)	Heating appliances (kW)	Motorized equipment (kW)	Electronics / ICT equipment (kW)	Energy consumption for 3 consecutive month (kWh)			Satisfied with charges?
						1st	2nd	3rd	
R16	0.525	0.36	-	0.07	0.095	31	0	51	YES
R17	4.685	0.66	3.6	0.14	0.285	0	7	228	YES
R18	3.903	0.444	2.4	0.45	0.611	28	0	0	YES
R19	2.405	0.36	1.2	0.42	0.425	0	0	214	YES
R20	6.596	0.348	3.6	1.78	0.868	119	0	103	YES
R21	2.390	0.36	1.2	0.38	0.45	88	96	100	YES
R22	5.463	0.66	3.2	0.83	0.773	11	16	57	YES
R23	5.045	0.615	3.2	0.69	0.54	189	203	226	YES
R24	3.887	0.492	1.2	1.32	0.875	58	111	53	YES
R25	4.144	0.504	2.4	0.88	0.36	71	166	143	YES
R26	4.190	0.6	2.4	0.5	0.69	17	2	5	YES
R27	2.460	0.435	1.2	0.34	0.485	91	60	71	NO
R28	2.490	0.48	1.2	0.38	0.43	99	0	180	NO
R29	0.908	0.66	-	0.14	0.108	23	18	0	NO
R30	2.350	0.36	1.2	0.62	0.35	40	30	0	NO
R31	0.725	0.48	-	0.17	0.075	2	4	40	NO
R32	6.417	0.492	3.6	1.17	1.155	202	84	152	NO
R33	8.765	0.9	5.3	1.2	1.365	88	201	214	NO
R34	3.681	0.276	2.4	0.28	0.725	241	195	158	NO
R35	2.538	0.29	1.2	0.35	0.698	42	63	68	NO
R36	4.618	0.36	2.4	1.4	0.458	140	83	118	NO
R37	12.728	0.588	7.8	0.7	3.64	32	109	121	NO
R38	3.430	0.372	1.2	1.37	0.488	0	58	108	NO
R39	3.488	0.3	2.4	0.45	0.338	86	98	87	NO
R40	6.084	0.574	3.6	1.085	0.825	186	-	210	NO
R41	9.098	0.92	5.7	1.83	0.648	150	116	100	NO
R42	5.911	0.836	3.4	1.21	0.465	177	218	89	NO
R43	4.681	0.608	2.2	1.7	0.173	192	68	113	YES
R44	3.593	0.588	1.2	1.7	0.105	98	37	85	NO
R45	5.316	0.306	3.6	1.255	0.155	46	80	74	NO
R46	3.973	1.2	1.2	1.3	0.273	79	56	18	YES
R47	4.355	0.54	2.4	1.16	0.255	54	32	38	YES
R48	2.395	0.3	1.2	0.41	0.485	101	126	89	NO
R49	7.01	0.9	4.6	0.71	0.8	213	197	236	NO
R50	7.112	0.712	4.4	1.2	0.8	182	-	147	NO
R51	8.994	0.704	6.8	0.86	0.63	37	89	301	NO
R52	11.947	0.672	8.6	1.94	0.735	157	106	138	NO
R53	4.998	0.57	2.4	1.06	0.968	89	95	101	YES
R54	11.253	0.688	8.4	1.385	0.78	143	180	64	NO
R55	3.684	0.684	1.2	0.96	0.84	86	79	111	NO

R56	6.14	0.88	3.6	1.3	0.36	196	211	179	NO
R57	8.731	0.536	6.1	1.23	0.865	0	110	117	YES
R58	12.008	0.668	9	1.345	0.995	237	196	217	NO
R59	11.616	0.576	9	1.24	0.8	189	143	186	NO
R60	10.06	0.98	7.4	1.19	0.49	237	254	199	NO

Table 5: Summary for buildings on estimated billing

Building	**Total load (kW)**	**Lightings (kW)**	**Heating appliances (kW)**	**Motorized equipment (kW)**	**Electronic / ICT equipment (kW)**	**Charges (#)**	**Satisfied with charges?**
R61	4.186	0.632	2.4	0.57	0.58	2000	NO
R62	0.986	0.456	-	0.17	0.36	2000	NO
R63	0.728	0.42	-	0.1	0.208	2000	YES
R64	11.418	0.54	9.0	0.94	0.938	2000	YES
R65	2.182	0.252	1.2	0.31	0.42	2000	YES
R66	4.1	0.36	3.1	0.38	0.26	2000	YES
R67	1.95	0.132	1.2	0.17	0.448	2000	YES
R68	2.46	0.36	1.2	0.5	0.14	2000	YES
R69	1.873	0.193	1.2	0.14	0.34	2000	YES
R70	2.725	0.72	1.2	0.52	0.285	2000	YES
R71	0.695	0.36	-	0.24	0.095	2000	YES
R72	0.916	0.468	-	0.34	0.108	2000	NO
R73	3.695	0.36	2.4	0.34	0.595	4000	NO
R74	1.615	0.96	-	0.56	0.095	3000	NO
R75	0.547	0.132	-	0.17	0.245	1000	NO

Consumers using prepaid meter utilize energy-saving lamps (ESLs) more than incandescent lamps. This is a pure indication that consumers using prepaid meter are more conscious of the energy they consume compared to consumers using postpaid meter and those on estimated billing. Also, there is a wide variation between energy unit purchased monthly and the analyzed energy consumed monthly for consumers using prepaid meter. This signifies that consumers using prepaid meter tend to live within their means and it is made known that they are automatically cut off the supply once the unit purchased is exhausted. Energy consumption for consumers using postpaid meter and those on estimated billing can be reduced by replacing incandescent with ESLs. Replacing a 60 W incandescent lamp with 36 W ESL means 40% of the energy-saving and it is important to note that energy being saved add up to energy being generated. The monthly energy consumptions for the 60 W incandescent and 36 W ESLs are 5.4 kWh and 3.24 kWh respectively. Thus there is a saving of 2.16 kWh by the ESL.

Figures 2 and 3 show the bar charts of each section of electrical appliances of buildings using prepaid meter and estimated billing respectively. Figure 2 consists of 3-bedroom flat and 4-bedroom flat apartments where appliances such as refrigerator, microwave, electric kettle, toaster, electric cooker, sound system were used. Most of the appliances were heating appliances with higher watt ratings. This makes the total heating appliances value to be higher than lightings, motorized equipment and electronics equipment in each building. Figure 3 consist of 3-bedroom flats and the "face-to-face" buildings using postpaid meter. In these buildings, the total wattage of heating appliances also takes the higher values. It was observed that most of the buildings were the "face-to-face" buildings with some of

them having boys quarters built beside the main buildings or at the back of the main building. This makes the total wattage of heating appliances in those building higher. It can also be seen that motorized equipment which are mostly found in flats are always next in total wattages in the individual buildings using prepaid meter on the chart as compared to the "face-to-face" building on postpaid meter.

About 60% of estimated consumers were satisfied with their billing system while the remaining 40% expressed dissatisfaction. This exposes the disparity in this billing method. It is a well-known fact that consumers under this category are billed arbitrarily after the post-paid consumers' bills have been computed.

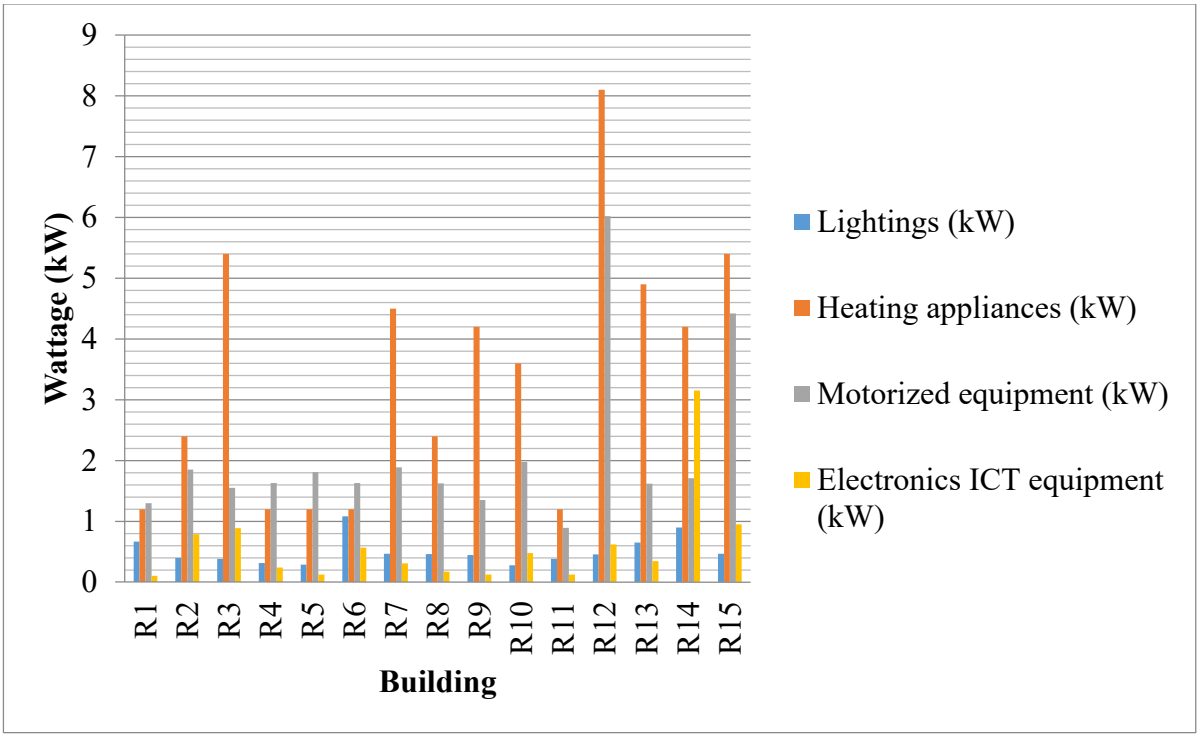

Figure 2: Appliances present in buildings using prepaid meter.

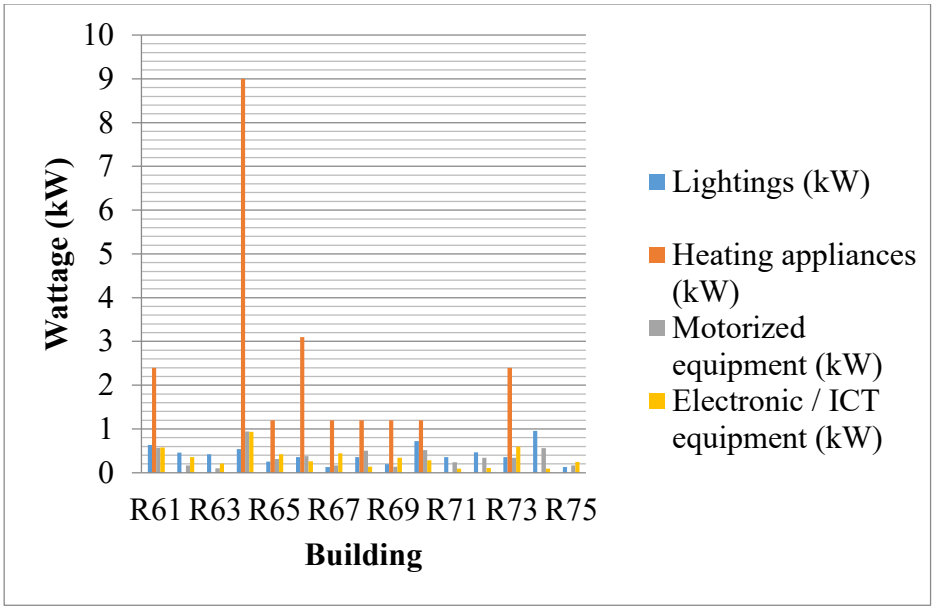

Figure 3: Appliances in buildings on estimated billing.

Figure 4 consists of building which are on post-paid meter. Heating appliances accounted for the highest consumption in this case, but in most cases, lightings consume more electricity than any other appliances in the buildings due to more time of its consumption. Electricity consumers who claim they do not make use of most of their electrical appliances except from lightings, would be shocked that it is the lightings that takes a higher percentage of the electrical energy they consume monthly. The case where lightings seem to consume less than other appliances would turn out as where the wattage of heating appliances is extremely high and where ESL is utilized. The total consumption of energy in all 75 residences is presented in Figure 5 which shows that heating appliances take 58 %, motorized equipment 21 %, ICT equipment 11 % and lighting devices 10 %. This is so because many households encountered used largely ESLs. The results of the surveyed houses are comparable to those presented in Figure 1.

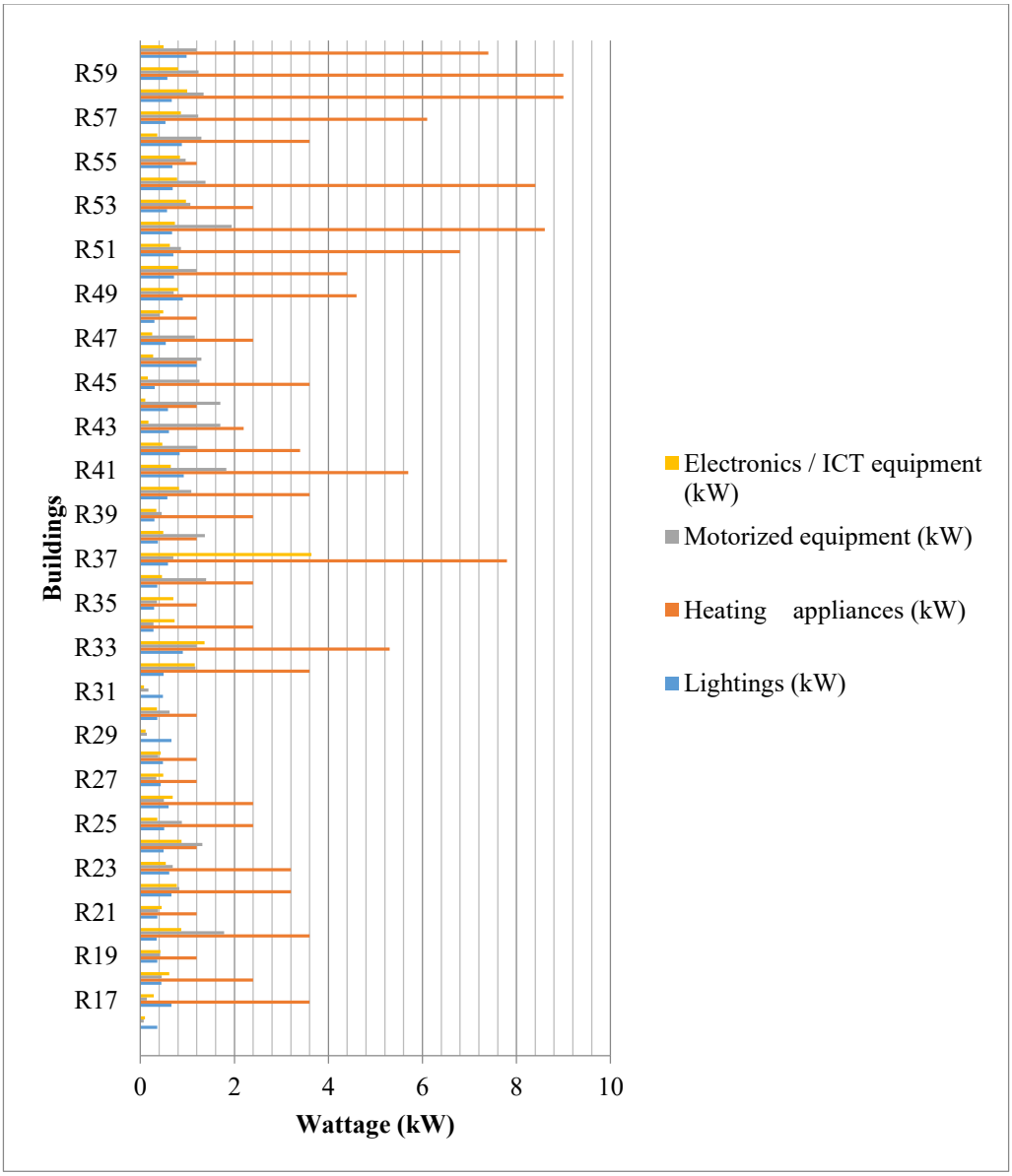

Figure 4: Appliances in buildings using postpaid meter

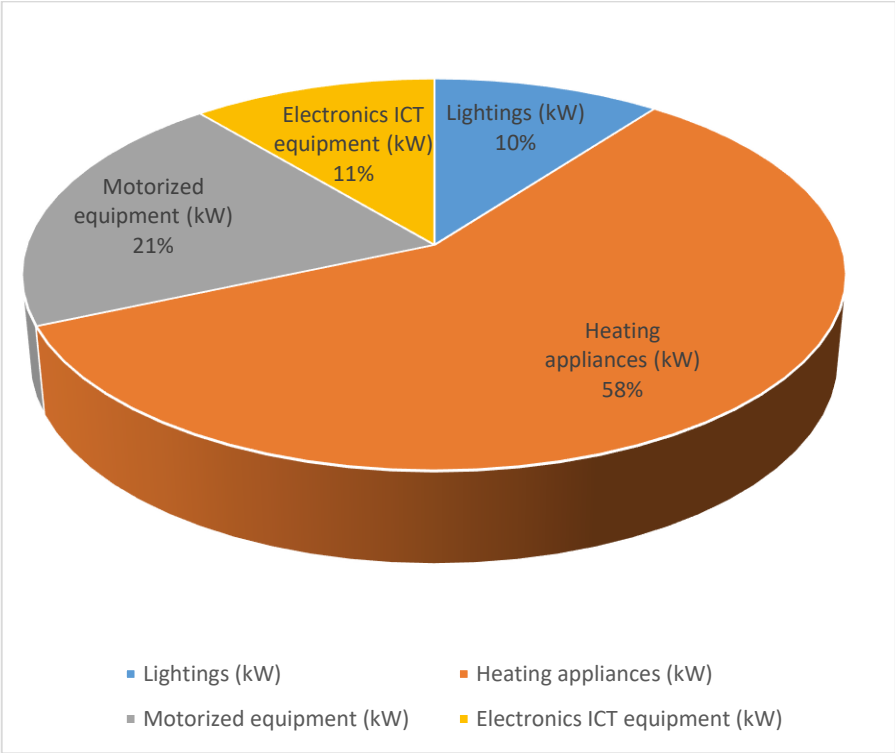

Figure 5: Summary of all types of load in all buildings

4. Recommendations and Conclusion

This study has investigated the utilization of energy with respect to residential area. Inspection, survey and analysis of average energy consumed in Oke-Ola and Lower mission area have been carried out. Measures of reducing energy consumption and cost of electricity are deducible from the data analysis and presentation.

Prepaid meter provides a better means of monitoring energy consumption since it is digitally constructed; its domination would provide solution to most of the complaints made by electricity consumers. Postpaid meter also provides the means of monitoring energy consumption but not quite easy to monitor compared to prepaid meter. Electricity consumer on estimated billing cannot monitor energy consumption, and this might result to over payment bringing loss to the consumer or under payment which brings loss to electricity distributors and the government.

Further, a quick glance at the electricity bills of consumers using postpaid meter shows that most of the consumers owe the electricity distributors heavily. This means that consumers are consuming more than they can afford to pay.

If all postpaid and estimated billing buildings replace incandescent lamps with ESLs, a 40% saving in power in energy consumption by lighting devices will be achieved. In other words, 15.93 kWh of energy shall be saved. That is about 4.13 % in overall energy consumed. Also, this is a saving of N256.57. Also, if all consumers can switch to LED lamps, the energy saving goes up to 90 % energy consumed by lighting devices only. This will result in an overall saving of 9.29 % of total energy consumed.

Motorized equipment constitute 11% energy consumption−higher that lighting devices. A considerable portion of the energy consumed can be saved if older motorized equipment are replaced with newer energy-efficient ones. This can also constitute a saving of up to 30 % of the energy such devices consume or 21 % of overall energy consumed.

Electricity is the highest contributor to global warming; starting from its generation down to its consumption. Thus, a reduction in energy consumption would ensure that the environment is kept safe. This reduction can take place effortlessly by the adoption of prepaid meter by the majority of energy consumers. Thus, the adoption of the prepaid meter would invariably result into more energy made available to consumers from the present meager production in the country, less fossil fuel burning and a cleaner environment.

Recommendations

The following recommendations will ensure better energy management:

- Lightings and other electrical appliances should be turned ON only when they are needed.
- There should be a strong government policy and enforcement to ban the manufacture and importation of incandescent lamps so as to save the insufficient power from wastage. In the long run, incandescent lamps shall be phased out just as in developed countries.
- Estimated billing should be eradicated. Also, all postpaid billing should be replaced with prepaid meters. Thus, government should put in place a regulation that will make all consumers use prepaid meter as it engenders energy-saving culture.
- Energy consumers should be encouraged to switch to more energy-efficient motorized appliances.
- Residents should replace incandescent lamps with ESLs, and the government should help in subsidizing ESLs to make it affordable.
- Electronics appliances that have standby mode should be disconnected from power supply when not in use. Such devices are known to be phantom loads (devices that consume energy in standby mode).
- The use of renewable energy source should be implemented.
- Use of energy star qualified appliances. The more stars, the more energy efficient the appliance.

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