Electricity Use Characteristics of Tertiary Institutions in Nigeria: A Case Study of Ramat Polytechnic Maiduguri, Borno State

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***Abstract*--Electricity consumption characteristics of all the buildings in Ramat Polytechnic were investigated. The consumption patterns showed distinct seasonal variation, indicating peek electrical demands during the hot, humid summer months from March – June due to significant air conditioning requirements. Monthly electricity consumption data were gathered and analyzed. Results show an average annual electricity consumption of 1,445,448 kWh/Annum, and an average energy used index of 217.00 kWh/Student/Annum. The energy end users in Ramat Polytechnic are air conditioning, electrical appliances and lighting in which the energy use is 39.5%, 40.5% and 20%, annually respectively.**

Keywords: ***Institution, Energy Use Characteristics, Regression Model***

1.0 INTRODUCTION

Like any other institution, energy utilization in Ramat Polytechnic, Maiduguri Borno State (Nigeria) consumes a lot of energy daily, obviously due to the large number of buildings and facilities in the institutions. Measures are generally not taken in order to conserve the energy in this environment. This is evident in the poor maintenance culture which is one of the maladies in Nigeria. Usually a lot of energy is wasted everyday unnecessarily due to negligence or ignorance. The polytechnic will be saving a lot of money monthly if measures are taken to conserve the energy and use it effectively. This energy efficiency program if developed will help the school redirect utility cost savings back into educational resources, and to improve the learning environment [2].

While so many interpret the swift growth in third world energy consumption as a sign of progress, at times the opposite may be true-development maybe derailed if the energy sector continues on its current trajectory, Imports of energy supplies and equipment are expensive, and their costs contribute to the underlying debt and foreign exchange problems that plague developing countries[14]. Growth in energy use also increases environmental and health problems [13]. Put simply, the third world needs more energy to provide goods and services to growing population, but, for economic and countries environmental reasons, these nations cannot rely simply on expanding supplies as they have in the past. [8].

It is clear that growth in developing countries use of oil, coal and other sources of energy, fuelled largely by speedy industrialization and urbanization, has been rapid. Since 1980 alone, these nations-home to 77% of the world's population-have nearly tripled energy use at a time when it increased in industrial countries by only 21%. Energy use grew much faster than population and even quicker than economic growth.

Despite the increase, people in developing countries use just one ninth as much commercial energy on average as those in industrial countries (see table 1). Per capita consumption, though, can be a misleading indicator of economic or social well being: the service that energy provides is important; the actual amount used is not. A better, though still not exact measure is to gauge energy use by the amount of goods and services provided.

Table 1: World Commercial Energy Consumption 1980 and 2002 [11]

Region	1980		2000	
	Energy consumption (exajoules)	Per Capita (giga joules) per person	Energy consumption (exajoules)	Per Capita (giga joules) per person
Developing countries	30	12	81	21
Latin America	8	26	16	37
Asia	19	10	59	20
Africa	4	10	9	14
Industrial countries	129	180	154	185
Centrally planned economies	44	120	71	167
World	203	55	310	59

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Energy policies in developing countries have largely been dictated by the choices- and needs-of industrial countries. Foremost is the thirst for oil, which has led multinational companies to search the globe for new supplies and to encourage developing countries to export it for foreign exchange [19]. Due to oil's convenience in transportation and storage, most developing countries have also followed the path of developed countries and used oil to fuel industry and transport, as well as for cooking, lighting, heating and production of electricity[17][15]. But while a few nations have greatly helped their balance sheets through these exports, most face a continual drain on scarce foreign exchange as they import oil, a drain that siphons resources away from development. Foreign debt loads-totaling some $1.35 trillion at the start of 1992-also have an oil connection.

In much of the Third World, government-owned companies are deeply in debt from electric power construction programmes. An average of 25 percent of the dollars developing-country governments paid to creditors in the eighties went to pay for past energy projects [12]. At the same time, in an effort to boost economic growth, stem inflation, or simply popular support, governments slashed electricity prices, with tariffs dropping from an average of 5.8c a kilowatt-hour in 1983 to 3.8c by 1988. Overall, consumers in developing countries pay just 60 percent of the cost of producing electricity.

Put simply, many utilities are not earning enough money, even to cover their monthly bills, much less pay back foreign banks. Yet many developing countries still face shortage of electricity.

To close the generating gap, electric utilities throughout the developing world are building power plants as fast as they can. Plans call for spending some $100 billion annually, including $40 billion in foreign exchange, on new power plants and transmission lines through the nineties, according to the World Bank. For many utilities, acting on these plans, will be impossible. The inability of utilities to pay their existing debt has reduced the willingness of private banks to lend them money. Third Word utilities will be lucky to borrow half the $10 billion a year the Bank says are needed. Internal capital markets are also unlikely to make up the rest, given current financial problems [8].

Lahti Declaration on the promotion of energy efficiency and renewable energy through energy auditing which was made by representatives from 39 countries and 8 international organizations, having met at the International Energy Audit Conference in Lahti, Finland. 11th -13th September, 2006, is committed to intensify their work to promote energy efficiency and the use of renewable energy in their countries and organizations. Among many statements declared:

1. They underline that energy auditing procedures, where specialists systematically analyze the energy use of buildings and production processes and make proposals for cost-effective energy efficiency improvements, are key methods in finding the most effective measures to improve energy efficiency. The promotion of the use of renewable energy sources can and should also be a natural part of energy auditing.
2. They encourage governments, in cooperation with the private sector, to create and further develop their own energy audit programmes or activities as part of their energy efficiency programmes, and in so doing to make effective use of international experiences and best practices. They should be complemented by awareness raising campaigns, targeting energy users. In addition self-auditing tools should be developed and made available for energy consumers.
3. They agree to share experiences on existing energy audit methodologies and best practices with the aim to improve and elaborate the effectiveness and quality of commercially available energy auditing services.
4. They recognize that improving energy efficiency and promoting the use of renewable energy requires the implementation of audit results through investments and other measures. Therefore they agree on the need to enhance the availability of versatile and innovative financing mechanisms such as carbon financing, partial risk guarantees as well as energy performance contracting offered by Energy Service Companies.
5. They recognize that government policies have a significant impact on energy efficiency and the use of renewable energy sources. This is also the case with regard to the development of energy auditing activities, as demonstrated in several countries. Experience has shown that successful actions for initiating and scaling up these activities include: (i) creating supportive policy, legal and institutional frameworks as well as market-based incentives, (ii) securing public sector commitment, (iii) promoting private sector involvement and (iv) providing access to funding, by stimulating financial sector interest in energy efficiency and renewable energy investments.
6. They emphasized the need for enhanced international co-operation to help developing countries to: (i) strengthen national policy frameworks and integrate energy efficiency and renewable energy use into national sustainable energy strategies and (ii) enhance national capacity for energy auditing and for implementing cost-effective measures proposed by audits. This will require: (a) making technical assistance for energy auditing as well as financial products accessible to developing countries and (b) disseminating more widely information, knowledge and best practices that support accelerated market development of energy efficiency and renewable energy.
7. Energy Audit Programme (IEAP) could be an effective step to develop and expand global energy audit activities building on existing energy efficiency co-operation programmes. Among the objectives would be to develop local know-how in partner countries and markets to facilitate and establish new and expanded energy auditing business activities [12].

It is in the light of the above declaration that the Department of mechanical Engineering is motivated to pursue as a matter of urgency the enhancement of national capacity for energy auditing and for implementing cost-

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effective measures proposed by audits. Various energy audit studies are now been carried out to systematically analyze the energy use of buildings and production processes and make proposals for cost- effective energy efficiency improvements. This work is one of such studies.

2.0 MATERIALS AND METHODS

The first stage in this study was the data collection phase, in which a meeting was established with the management and all key operating personnel, and they were briefed over the audit objectives, scope of work and description of scheduled project activities. An energy audit questionnaire and check list was drawn to acquire data by interviews and physical checks. The monthly energy billing data and the supporting building information obtained were used to construct various types of electricity use profiles, comparison tables and corresponding correlation plots [2].

In examining further the measured energy consumption data for building stock, different energy use characteristics and patterns were established[7]. In the investigation and evaluation of building energy use, different categories of loads were considered. The first category is base load, which is defined as non-weather related energy use.

Typical examples are artificial lighting, office equipment, and other electrical appliances. The second category is energy used in the air conditioning systems. This requires the determination of how much energy is used for cooling by such systems. The third category is occupancy related energy consumption, which is defined as the quantity of the energy consumed in a building during normal operating hours [1] [3].

In administrative office buildings, the normal operating schedule is eight hour working day from 8.00a.m. - 4.00p.m., five days per week while for lecture halls, staff office, workshops and laboratories the working hours are not easily defined [2] [5].

Fourthly, the non-occupancy related consumption is the energy consumed outside the normal building operating times. It is not uncommon that many office building keep some of the building services functional after working hours in order to maintain certain basic operations and cater for security lights and some other facilities [18].

All data were analyzed to identify energy conservation measures (ECMs), which when implemented, will make the energy usage more efficient, less expensive and/or more environmentally friendly. Also the following analysis would be performed:

A total of seven years (2004-2010) electricity consumption data was collected and analyzed. In all the buildings, the total electricity consumption will vary slightly from one year to another, due mainly to the variations in building used and operations, especially occasional overtime works. To simplify the analysis, the consumption data was averaged over the seven year period. Energy used per student (also known as energy utilization index) is used to compare the energy intensity among different years.

Energy used Index (EUI) =

$$\frac{ELECTRICALCONSUMPTION(KWH)}{NUMBEROFSTUDENTS}$$

$$EUI = \frac{462482}{4169} = 110.93$$ (see table 2 below)

Table 2: Energy Utilization Index for Ramat Polytechnic

Year	Number of students	Consumption (kWh/Annum)	Energy use index (kWh/person/annum)
2004	4170	462482	110.93
2005	5260	1404929	267.15
2006	6610	1817980	275.12
2007	7110	1728138	243.06
2008	7630	1957093	256.40
2009	7580	1060315	138.86
2010	7426	1687199	227.26

The amount of energy use in an office building depends on many factors. Key factors include the original building envelope design, operation efficiency of the ventilation and air conditioning systems, fresh air load for maintaining the indoor air quality required, types of lamps and their efficacy, internal plug loads (example, office equipment), special equipment, which require special environmental control, and the building operation and maintenance [10][16]. The first step in breakdown of energy use is to establish a list of the major services or end-users [9]. The totals of major services or electrical end-users were identified using the following measures.

Regression analysis examines the relation of a dependent variable (response variable) to specified independent variables (predictors) [4]. The mathematical model of their relationship is the regression equation. The dependent variable is modeled as a random variable because of uncertainty as to its value, given values of the independent variables. A regression equation contains estimates of one or more unknown regression parameters (“constants”), which quantitatively link the dependent and independent variables. The parameters are estimated from given data. In practical applications, data could come from any combination of public or private sources [6]. In this analysis the dependent variable is the electrical consumption while the cooling degree- day is the independent variable. Annual electrical consumption and fuel consumption were computed [9].

In the institution, the monthly electricity consumption data is expected to show distinct variations. The linear regression technique was used to relate these distinct variations. The regression techniques decomposes the electricity used into three parts, namely a non-weather dependent component or “intercept”, a weather dependent component consisting of cooling slope and the number of monthly degree days determined for a particular balance or based temperature (T_{base}) such that

$$E = a + b \times CDD \text{ -------------------------(1)}$$

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Where: E = Monthly electricity use (KWH), a Intercept (KWh), b Cooling slope (KWhJ°C), CDD seven year (2004 -2010) average monthly cooling degree days (°C).

The constant "a" can be considered as the base load, such as lighting and office equipment, which are weather independent. The second term "b x CDD" can then be regarded as the weather sensitive load, like ventilation and air conditioning, and the coefficient "b" is the slope of the regression line that indicates the likely variations in ventilation and air conditioning load as a result of per °C change in the cooling degree days. The is the temperature above which cooling will be required and is a function of the indoor design temperature, the thermal characteristics of building envelope design and the magnitude of the various external and internal heat gains such as solar radiation, electric lighting, people and office equipment [9].

The output of the regression analysis shows that for most years the fitness of the models is not as expected. This is because the buildings are not fully air-conditioned and also due to acute shortage of light mostly when it is needed. In the analysis the dependent variable was the electrical consumption while the cooling degree-day (CDD) was the independent variable. But the results show that part of the consumptions goes to the air-conditioning while part goes to the lighting and or office equipments. In the analysis the constant "a" is taken as the non weather related consumption while "b X CDD" is taken as the weather related consumption.

For the year 2000 Excel is used to calculate MBE and RMSE as follows

Table 3: Sample Calculation for MBE and RMSE

MBE 2000				
Y	*Odd*	*X*	*x-y*	*(x-y)*$^{-2}$
33.678	8	38.54017	4.86217	23.6407
33.234	7	35.83349	-240051	5.762448
45.554	10	43.95353	-1.60047	2.561504
47.684	11	46.66021	-1.02379	1.048146
49.1	12.5	50.72023	1.62023	2.6225145
48.9	7	35.83349	-13.0665	170.7337
38.3	7.5	37.18683	-1.11317	1.239147
38.8	6	33.12681	-0.67319	0.453185
35	7.5	37.18683	2.18683	4.782225
34.9	8	38.54017	3.64017	13.25084
29.876	6	33.12681	3.25081	10.56777
27.456	5.5	31.77347	4.31747	18.64055
			4E – 05	255.3053

MBE = $\frac{4E-05}{12}$ = 3.33333E – 06 and RMSE = $\sqrt{\frac{2550353}{12}}$ = 4.61

Table 4 shows a summary of the regression analysis results for the seven years. It can be seen that the coefficient of determination (R^2) varies from 0.50 for year 2008 to 0.64 for year 2007 and year 2009. The average R^2 for the seven years is 0.60, indicating a strong correlation between electricity use and the corresponding CDD.

3.0 RESULTS AND DISCUSSION

The energy carriers used in Ramat Polytechnic are Electricity from national grid and Automotive Gas Oil (AGO). Results show an average annual consumption of 1445448 kWh of electricity and an annual average of 11093.14 143 liters of AGO, which is equivalent to 111085.47 kWh. The energy end users in Ramat Polytechnic are air conditioning, electrical appliances and lighting in which the energy use is 39.5%, 40.5% and 20%, annually respectively.

Table 4: Summary of Regression Analysis Results for Year 2004 to year 2010

Year	A	b	R^2	MBE (MWh)	RMSE (MWh)
2004	6.88673	2.70668	0.59	3.3333E-06	4.61
2005	197.3480	-10.4135	0.60	-0.000146	14.49
2006	21.97997	16.27456	0.62	1.06581E-14	22.0
2007	40.79943	11.57519	0.64	4.08333E-05	19.1
2008	- 5.96837	17.95322	0.50	3.5E-05	30.8
2009	200.4909	-11.7007	0.64	0.005416667	17.1
2010	254.6462	-13.0339	0.59	0.037583333	19.5

The mean bias error provides information on the long term performance of the modeled regression equation. A positive MBE indicates that the predicted annual electricity consumption is higher than the actual consumption and vice versa, and the RMSE is a measure of how close the predicted monthly profile is to the actual one based on the monthly electricity bills. It is worth noting that over estimation in an individual observation can be offset by under estimation in a separate observation. The MBE and RMSE determined for the seven years are also shown in table 4. It can be seen that the MBE was very small, whereas the RMSE ranged from 4.6l year 2004 to 30.8 year 2008.

This suggests that the regression models for individual buildings can give very accurate indications of the annual electricity use, but the monthly estimates may differ from the actual consumption by a few percents. The coefficients "a" and "b" correspond to the weather independent and weather dependent components of the electricity consumption and are affected by the building and building services designs. It was found that the internal load (that is, lighting and equipment) and building envelope load (that is, heat gain through the walls, windows and roofs) showed good correlations with the weather independent and weather dependent components, respectively. For the regression of consumption against CDD and number of students from the year 2004 to the year 2010 is E = 3199270 - 625302CDD + 555. 685 STUDENTS, where E is the electrical consumption in kWh, CDD is the cooling degree day and STUDENTS is the number of students.

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Table 5: Electrical Consumption for Ramat Polytechnic Maiduguri, Borno State

	2004(kwh)	2005(kwh)	2006(kwh)	2007(kwh)	2008(kwh)	2009(kwh)	2010(kwh)
Jan	33678	130600	90000	62720	95000	99082	138700
Feb	38234	107300	136400	131570	115256	95741	178139
Mar	45554	109000	140000	135570	120689	55345	101487
Apr	47684	109600	165340	137020	175564	41111	98253
May	49100	65400	188560	140729	206987	47269	99897
Jun	48900	83600	198400	155200	210340	65979	135325
Jul	38300	112400	185400	160000	220304	85000	142600
Aug	33800	133529	122800	165199	200750	115564	169100
Sep	35000	142700	181300	171298	187968	95489	197500
Oct	34900	140300	177100	182391	175635	113965	119700
Nov	29876	135300	141500	174210	149600	130539	149900
Dec	27456	135200	91180	112231	99000	115231	156598
Total	462482	1404929	1817980	1728138	1957093	1060315	1687199

The above table shows distinct seasonal variations. Even though the variation is not in a regular pattern but the consumption patterns showed distinct seasonal variation, indicating peak electrical demands during the hot, humid summer months from March to June, due to significant air conditioning requirements. And the irregular variation in the consumption is due to irregular supply of electricity in Nigeria [11].

Table 6: Cooling Degree Days for Maiduguri, Borno State

CDD FOR RAMAT POLYTECHNIC, MAIDUGURI, BORNO STATE							
	2004	2005	2006	2007	2008	2009	2010
Jan	8	5.5	5	3.5	8.5	6.5	8.5
Feb	7	8	8	6.5	8	8.5	6.5
Mar	7	9.5	9	10	10	10.5	9.5
Apr	7.5	8	7.5	9.5	10	9.5	8.5
May	6	7	5	7.5	10.5	8.5	8
Jun	7.5	7.5	8	9.5	9.5	10.5	8
Jul	10	9.5	8	10	5.5	11	11
Aug	11	10	10.5	10	9.5	13	10.5
Sep	12.5	10	11	10.5	12	12	10.5
Oct	8	7	8.5	11	11	10.5	11.5
Nov	6	5.5	7.5	11.5	11	7.5	7
Dec	5.5	5	5	7.5	7.5	7	5.5

4.0 CONCLUSION

Electricity consumption characteristics of all the buildings at the main campus of Ramat Polytechnic, Maiduguri were investigated. The consumption patterns showed distinct seasonal variation, indicating peak electrical demands during the hot, humid summer months from March to June, due to significant air conditioning requirements. Based on the average monthly electricity use data, the annual electricity use per student per annum was found to be 216.97 kWh. The difference in electricity use per student per annum will be expected mainly due to the variation in lighting and equipment load density and variation in the students' population.

Detailed energy audits and surveys of the buildings and building services were conducted to obtain a breakdown of electricity use by the three major energy end users in Ramat Polytechnic, air conditioning, lighting and electrical equipment. The percentage energy consumed annually by the three major energy end users is obtained to be 39.5%, 40.5% and 20% respectively.

Based on the conclusion of this study, the following recommendations are made for the existing buildings of Ramat Polytechnic as well as for institutions of similar status. That the management should provide a means of keeping up-to-date record of load demand of all existing electrical appliances and total monthly consumption. That meters should be installed in each building so that individual consumption can be determined and solar energy utilization should be introduced due to its availability in the study area (Maiduguri) being the most appropriate alternative/renewable energy source accessible.

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