ENERGY USE IN OFFICE BUILDINGS IN AFRICAN LDC'S: A CASE OF SIERRA LEONE

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ABSTRACT

African LDC's after independence adopted development strategies that led to the construction of high rise buildings in their cities that are very energy intensive and expensive to maintain. Due to the reliance on electricity as thier main source of energy, a source which security of supply is not guaranteed, significant problems has emanated in the supply of energy in this sector, hence the study aims at improving energy efficiency in such buildings.

Five typical buildings each above 7 storeys were surveyed and the energy consumption profiles were constructed for each buildings. The results of the survey presented the scope to examine the potential for energy conservation and estimates are provided for such potential. The results of the study made it possible to suggest certain guidelines for the design and operation of such buildings in the region.

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INTRODUCTION

Development strategies adopted by African LDC's during their post independence period were aimed at constructing high-rise buildings in their cities utilising architecture imported from Europe and America. The designof these buildings ignored aspects such as the use of indigenous materials, traditional architectural skills, cost of energy bills, maintenance problems, culture and climate. Besides the use of these buildings as offices they also serve as symbols of prestige and pride to authorities, however, they have contributed very little to the overal socio-economic development of the region.

Office buildings in the sub-Saharan Africa is the largest single user of commercial energy outside the transport and industrial sectors, and the largest consumer of electricity. In the Economic Community of West Africa states, these buildings use 40% of the electrical energy produced: (ECOWAS, 1981). Current trends show that construction of high rise buildings in cities is on the increase, a situation that will have a profound impact on the region's energy demand. Also it will appear that recent buildings are getting more energy intensive, a situation that will put further stress on energy demand and the region's energy security is not guaranteed: (Davidson, 1987).

Introducing energy efficiency in building design and operation can have substantial financial payback for the region in a relatively short time. It has been shown in several parts of the world that energy efficient buildings can be constrcuted without sacrificing comfort level of its occupants. Unfortunately, indigenous traditions of architectural designs that did consider the benefits of wind, shading and sunlight were not considered in the more recent building design in the region. To overcome deficiency they have constrcuted buildings with massive air-conditioning requirements and high energy consuming structures which so far have proved totally unacceptable to the region. The need for environmentally conscious building design that re-discover the past of the region without sacrificing comfort of its occupants is very important for the future.

This paper intends to develop energy profiles of selected office buildings in the capital of Sierra Leone, a typical country in the region based on a survey carried out. The results from the energy profiles assisted in suggesting guidelines for energy and environment conscious buildings design in the country. The results are expected to be applicable to other countries in the region.

SIERRA LEONE CONTEXT

Sierra Leone is a small country of 72,326 km^2 situated on the south west coast of West Africa lying between latitudes $6^{o}55'$ and $10^{o}N$ and longitudes $10^{o}16'$ and $13^{o}18'W$. Apart from the coastal swamps, most of the country is above 200m with the interior rising up to 1900m. The total annual rainfall is over 3000mm and can be as high as 5350mm in the coastal area. Maximum mean monthly temperatures is in February to April (30-34^{o}C) and minimum in July to August (25-28^{o}C). Relative humidity is very high above 60% for most of the year. The population is estimated to be 3.76 million by the last census in 1985 and annual growth rate is 2.5%, though for the capital, Freetown is 7%. Population density varies from 123/km^2 in the western area to 11/km^2 in the north west of the country. Only about 20% of the population live in urban areas. Table I summaries the general characteristics of the climate of the country for 1985.

Sierra Leone is endowed with vast hydro and forest resources, but the former is yet to be exploited while the latter is used recklessly. At present imported crude oil is used to satisfy over 95% of its commercial energy needs, while firewood and charcoal contributes to about 80% of the total primary energy demand. Over 90% of the electricity is produced by diesel driven generators (Davidson, 1984) Due to the current economic problems and certain technical problems, the electricity supply has been seriously hampered. The problems of this sub-sector include poor management and maintenance of equipments, high tariffs in comparison to consumer's earning power, high losses and inadequate fuel supply. It has resulted in the system being very unreliable, random load shedding and substantial growth in private generation. Table II illustrates the situation of the sub-sector.

Freetown, the capital of Sierra Leone is selected for this study because it has most of the high rise energy intensive building of the country. These buildings use substantial amount of the electricity produced locally to satisfy lifting, cooling and lighting demands. The survey reported below provides the facility to carry out a deeper analysis of energy consumption by office buildings.

THE SURVEY

In order to establish the use of energy in office buildings, five high-rise buildings were surveyed. These buildings were carefully selected to be representative of similar buildings in the city. All the buildings chosen exceeded seven floors. Among the five, two are government buildings that housed most government ministeries, they are labelled G1 and G2 respectively, two banks, one commercial and the other the Central bank labelled B1 and B2 as well. The fifth is an insurance building labelled I1. All these buildings are mainly offices with the exception of the banks that have banking halls on their first floors. The general details of the building surveyed are given in table III.

The various estate managers of the selected buildings were contacted for permission to carry out the survey. The building plans were consulted and the project staff spent at least two days in each building to get the necessary data. Data collected include information on the physical characterisitcs such as details on air-conditioning, window shading, orientation of the building etc. During the survey details on occupancy, hours of use, equipment installed, electricity records etc. were also collected. The national power utility were contacted to cross check electricity bills. In analysing the results, the electricity use was estimated from equipment power rating, hourse of use, and load factors. Local contractors were contacted for further details on air-conditioners and elevators. Other details of the analysis are included below.

Results of Survey

All the buildings surveyed use electricity to satisfy nearly all their energy needs with the exception of B2 and I1 that carry out limited cooking using liquified petroleum gas. The analysis shows that the contribution by this energy source to the total is very small and can be ignored. The results therefore presented indicate only electricity use in the buildings surveyed. Table III also contains details on the occupation density which was calculated from the total floor area and the number of people in the buildings.

In the analysis, no comparison was made on the electricity bills for the various buildings for the years considered in the study. However, the bills for the last year 1986 was used later in the analysis. This was decided upon because of the rapid changes in the tariffs at irregular intervals and the irratic fluctuating exchange rate of the local currency.

The electricity consumption of the different buildings was analysed for three years, 1982, 1984 and 1986. The average annual growth rate which could have assisted the analysis of these figures were not evaluated because using the figures as given in table IV will not reflect the true picture. The sudden drops and increases shown from year to year are a direct result of load shedding and power cuts. These results do not reflect improvement or growth in the buildings. The electricity figures given by the national utility was used as they were accepted by various estate managers as satisfactory. Despite these problems, the results in table IV show that with the exception of building B1 and I1, electricity consumption dropped between 1984 and 1986 by about 14% with G1 over 60%. These changes can only be attributed to the large number of power cuts and not energy conservation measures. These results are a clear indication of demand being suppressed because of the unreliability in power supply. Though electricity data was not available for G2 in 1982 but from the results, it is by far the largest consumer which should be expected from the floor area which was five times the average of the others (table III). However, the electricity consumption is only four times the average of the others. Another factor that is responsible for the high consumption in G2 is that it is located in an area that has the least number of power cuts, hence have access to electricity than the others. When considering the power used up by a square metre, the figures for the banks are very high and the range from the others are wide. In 1986, with the exception of B1, the variation from the mean is not substantial. The high load in B1 is responsible for high values which was repeated in the power consumed per occupant as well, though the differences is not as large except for G1 that has very poor load in comparison.

Table V gives the breakdown of electricity consumption by end-use. As a percentage of the total, in buildings with central air-conditioning, it accounts for between 44-55% of the total. The government buildings do not have central units but wall units in the offices of the heads and this accounts for the relatively lower consumption by air-conditioning. It is striking to note that with the exception of the banks that have installed computers and some minimum machinery that require cooled environment, the air-conditioning is for the occupants. It is usual in buildings that suffer from malfunctioning of the central system to have room units in certain offices as supplements as in the case of B1. Due to the low air-conditioning in government buildings, the contribution to the total by lighting is very high, 64% in G1 and 46% in G2, this was not the case for the others, 13% in I1, a building that is considered to be poorly lit. On the average about 20% of the total energy is consumed by elevators, a direct result of number of floors. The design of the buildings now make it very uncomfortable to climb the stairs during power cuts. G1 do not have an elevator as well but has been out of order for over 3 years so was not considerd in the analysis. On the whole, consumption by equipments is under 10% and 3% for the government buildings. The results shown in table V suggest that a more detailed analysis be made of the air-conditioning and lighting loads. It was done in terms of rated power and the annual usage with respect to the area and occupancy. The results obtained are given in table VI.

The commercial buildings seem to have much higher air-conditioning power in terms of the area than government buildings (29.7 w/m^2 to 9.5 w/m^2). This difference is reduced when the usage is considered, on the average 49.6 to 16.9 kwh/m^2 and 571 to 175 kwh/occupant for commercial to government buildings. This experience was not repeated for lighting levels. The worst buildings is I1 which apart from G2 it is about a third of the average of the rest. Similar patterns was noticed for the lighting use, though B1 clearly emerged as the building that consumes the highest.

It was assumed in the analysis that the buildings surveyed did not have substantial improvement in terms of area or equipment during the period under study except the computer facilities in B1 and B2. In calculating the energy end-use, load factors (ratio of actual load to rated load) were estimated based on discussion that were held with the estate managers and contractors of elevators and air-conditoners. As an example, the load factor for the air-conditioners was taken as 0.7.

It could be argued that data obtained are point readings and may not be typical. However, the discussions with the estate managers did confirm the readings. Examination of climatic data for the period studied shows that variations in humidity and temperature have little effect on the data hence were ignored.

Discussion of Results

From the results obtained in the survey and the discussion that were held with the various estate managers, it shows that there is significant scope for energy conservation in the building sector in Freetown.

Areas of possible intervention, include reduction of operating hours, introduction of new high efficiency lights, regular servicing and maintenace of all equipment and more regular power supply.

Significant saving can be made by switching off of air-conditioning system using time-clocks and moderating the cooling temperature. The discussions and general observation reveal that air-conditioners are left for long hours after work unattended. It will cost only to have someone to switch it off when it is not needed. In some of these buildings, the occupants do have to put on extra clothing to combat the indoor temperature of the building.

In most of these buildings, a set of 2 65w fluorescent tubes are used for lighting, significant savings can be made by reducing the voltage and also introducing new high efficiency lights and would not cost extra (36w tubes with same output as 40w).

The discussions reveal that regular servicing and maintenance are not carried out in the office equipments, especially for air-conditioners and elevators. Hence in mostly, they are not used efficiently. Savings can be made by instituting regular maintenance schemes.

Due to the power supply situation, all commercial buildings have private generating sets capable of supplying the power needed for lighting and the running of the èlevators. Buildings with computers do have separate units to ensure that the equipment are in the specified environment. Private auto generation is very expensive, according to World Bak calculations, it cost twice the price of the national utility (World Bank, 1987).

Potential for energy conservation in these buildings were estimated using the above discussions and the 1986 electricity bill. The results are shown in table VII. The calculations were carried out assuming that the buildings are carrying out their normal duties as identified during the survey. The results show that all the buildings can make savings in the excess of 30% of their present electrcity bills except G2 and I1. G2 is one of the most recent buildings in which ventilation and light ng loads were significantly reduced by the design. I1 needs significant improvements in lighting as can be seen from the table. The low figure for light improvement is due to the advocacy in t is paper for more lighting. The lighting requirement can be reduced substantially at B1 and this accounts for the high savings, 53% on present electricity bill. Generally, the tariffs change so frequently, hence the values for the cost should be treated as such.

Comparing the results with other parts of the world shows that energy consumption in the country is generally low. Though there are climatic and socio-cultural differences, but data available from Fiji and Papual New Guinea can be used for comparison. For air-conditioning 60-70 w/m^2 for Papua New Guinea, 40 w/m^2 for Fiji and about 25 w/m^2 for Sierra Leone. For lighting, Fiji records 15 w/m^2, and this works show 13/w^2. (Siwatibau, 1987).

Despite the generally low figures for Sierra Leone, yet still certain guidelines can be suggested regarding the design and operation of office buildings in the country.

SUGGESTED GUIDELINES

As can be seen from the results, there exist a lot of scope for improvement in the design and operation of office buildings. Some of these measures may require some investments but will prove beneficial in a long run.

Measures in design should include the following:

- the consideration of climatic factors such a reduction of solar radiation, use of cool air for night ventilation, shading and correct use of air movement.
- determination of comfort levels and identification of neutral temperature in order to reduce air-conditioning requirements.
- minimisation of external heat into the building and utilization of passive cooling.

Measures for the operation should include the following:

- underake energy audit at regular intervals and using staff members to monitor energy use and identification of conservation options.
- resetting temperatures and time-clocks to reduce air-conditioning load.
- use room units only in rooms that need cooling.

- switching off lights and equipments when not needed.
- replacing 65w fluorescent tubes with 40w or new high energy tubes.

These measures given above are not exhaustive but can provide some guidelines towards building conservation in Sierra Leone and in the region in particular.

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Table I. Climatic Data for Freetown, Sierra Leone Average Values for 1985

Month	Air Temp (°C)	Humidity (%)	Radiation: Sunshine hours 1980	Radiation: Total ($MJ/M^2 dy$)	Rainfall mm
Jan.	27	78.5	220.7	17.9	- -
Feb.	28	79.5	190.2	18.7	- -
Mar.	27	75.5	168.6	21.3	6 6
Apr.	27.4	77.6	135.4	21.7	- -
May	25.5	75.0	124.5	18.3	116.2
June	22.3	85.0	111.2	17.1	185.8
July	21.4	92.5	47.3	14.8	928.3
Aug.	21.5	93.5	65.3	13.5	545.2
Sept.	22.3	86.0	90.0	15.5	443.8
Oct.	24.6	82.5	118.8	18.5	173.1
Nov.	25.1	88.0	156.9	16.6	190.3
Dec.	25.8	68.0	125.4	17.6	5.9
Annual	24.8	81.8	1554.3	17.5	2544.6

Source: Geography Dept., F.B.C. & Ref. (8)

Table II. Basic Data of the Electricity Sub-Sector

	National Supply			Private		Total
	Western Area	Provinces	Total	Mines	Small holders	
1986 Installed Capcity(mw)	58	13	71	33	30	134
Generation (Gwh)						
1971	76	17	93	70	N.A	163
1981	132	30	162	72	N.A	234
1986	85	8	93	64	40	197
Sales(Gwh)						
1981	60	12.6	12.6	-	-	-
1986	62.3	14.9	77.2	-	-	-
Losses (%)						
1981	27	35	28	10	-	-
1986	27	90	29	10	-	-

Source: N.P.A., World Bank

Table III. Main Features of Buildings Surveyed.

Bldg.	Air-Con.	Elevators	No. of floors	Floor Area (m^2)	No. of Occupts.	Area/Occup. m^2
G1	Room	Yes	9	3774	600	6.3
G2	Room	Yes	10	22146	1800	12.3
B1	Both	Yes	7	3852	400	9.6
B2	Central	Yes	13	4856	300	16.2
I1	Central	Yes	11	3826	330	11.6

Table IV. Electricity Consumption by Buildings Surveyed.

	Mwh/year			Kwh/m^2			Kwh/Occupant		
	1982	1984	1986	1982	1984	1986	1982	1984	1986
G1	222	372	127	58.8	98.6	33.7	370	620	212
G2	-	1898	1620	-	62.2	53.1	-	1054	900
B1	588	287	757	153	74.5	197	1470	718	1893
B2	486	432	374	100	90	77	1620	1440	1247
I1	101	112	197	26.4	29.3	51.5	306	339	597

Table V. Annual Consumption of buildings surveyed by end use, 1986 (mwh).

Bldg.	Air Con.	Lights	Elevators	Equipments	Total
G1	41	82	-	4.0	127
G2	508	750	317	45	1620
B1	332	199	173	53	757
B2	167	123	47	37	374
I1	108	26	45	18	197

Table VI. Usage details of air-conditioning and lighting 1986.

Bldg.	Air-Conditioning			Lighting		
	Power (w/m2	Usage Kwh/m2	kwh/occ.	Power w/m2	Usage kwh/m2	kwh/occ.
G1	14.3	10.9	68.3	20	21.7	137
G2	22.9	282	5.2	5.2	33.9	417
B1	34.5	86.2	830	20.7	51.7	498
B2	25.5	34.4	557	13.2	25.3	410
I1	27.7	28.2	327	4.6	6.8	79

Table VII. Potentials for energy conservation

Bldg.	Net Annual Savings Le,000					% of 1986 Elec. Bill
	Red. of Time	Intro. of New lghts.	Regular Serv.	No. Auto generation	Total	
G1	11.24	43.28	3.86	9.40	67.78	35
G2	58.09	165.93	30.92	19.94	274.88	27
B1	11.62	25.58	3.34	10.81	51.35	53
B2	42.28	50.94	8.60	51.21	153.03	35
I1	20.77	2.13	5.65	14.58	43.13	26