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ENERGY EFFICIENT RETROFITTED HOME MODELS AS TOOLS OF DEMAND SIDE MANAGEMENT

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ABSTRACT

A prototype energy efficient retrofitted home model (EERHM) has been designed using energy efficient technologies and a critical comparative analysis performed with respect to load (kW), type of fittings, and size of cables (lighting and power), size of fuses and net savings. A cost benefit analysis was performed and extrapolations to cover communities/national spread performed as a way of promoting the use of energy saving devices, managing load demand, efficiently utilizing available energy, environmental protection and security, system stability and expansion within available resources and creation of reserve (savings) for individuals, supply authorities and governments. The technology is recommended to governments and other agencies as part of the low cost housing projects.

Keywords: Energy saving devices, Managing load demand, System stability

1. INTRODUCTION

Man's desire for comfort and change in lifestyle has resulted in an increasing need of energy in the domestic sector. As the demand for energy increases there is the burden to increase energy generation and supply capabilities. The cost implication of building new power stations is astronomical but also complicated by their environmental impact. To manage energy demand would include the optimal utilization of existing capacity and or remodeling existing infrastructure [1, 2]. One way of remodeling in the domestic sector is to replace existing appliances with Energy Efficient (EE) ones. This paper focuses on retrofitting(replacing luminaires, resizing air conditioners and water heaters and replacing them with energy efficient replicas) to produce Energy Efficient Home Models (EEHMs) to serve as tools for Demand Side Management(DSM).

2. METHODS AND RESULTS OF THE INVESTIGATION

A critical survey was carried out in the staff residences in Crown Estate (1, bedroom, 2 bedrooms, 3 bedrooms and duplexes – Home Models) to ascertain the provisions made for lighting, heating, air-conditioning, cooking and other load types (television, VCD, toasters, microwave). The survey results are shown in Tables 2 & 3 and Figures 1 & 2. An attempt was made to estimate the total load requirement as- built, i.e the Conventional Home Model (CHM). This is shown in Table 3 and Figures 1 & 2. Determination of fuse rating, distribution board (DB) sizes, and cable diameter by appropriate computation was done. This is shown in Table 1. The cost implication of the as – built electrical service (CHM) was prepared as shown in Table 1. An attempt was made to replace the incandescent lamps with compact fluorescent lamps (CFLs) of equivalent lumen output, the water heaters, and air-conditioners with energy efficient models as detailed in Table 5. A new computation was performed to determine the new load requirement for the various categories of houses. This is shown in Figure 2 and Table 6. Subsequently, the fuse, distribution board sizes, and cable diameter were determined. Finally a comparison was performed between the as – built model and the energy efficient model to determine its usability as a DSM tool by carefully highlighting the cost saving levels. Table 7 and Figure 3 show the compared data. In this paper the as-built technology is also referred to as the conventional technology, and the EEH proposed, as the Energy Efficient Retrofitting Model.

2.1 DATA COLLECTION

To quantify the conventional and energy efficient retrofitted home models, and hence make comparative analysis, load surveys were conducted and data collected/collated separately. The data consist of some selected load types including Air conditioners, Water heaters, Light fittings/luminaires, Ceiling fans, Television/Toaster socket outlets and Electric cooker outlet/ unit. The ratings of all load types are expressed in kW.

2.1.1 Conventional Home Model (CHM)

In the conventional (as-built) technology the power rating and specifications of each load type was collected as follows:

- Air Conditioner (1.865kW, 220V, 50Hz)
- Water Heater (3.20kW, 220V, 8.0Bar, 50Hz, 10L)
- Lighting (0.06kW, 220V)
- Ceiling Fan (0.05kW, 220V,50Hz)
- Television / Toaster 13A Socket Outlet
- Cooker Unit (3.6kW,220v,50Hz)

These are summarized in Table 2 (which shows principally the load type and the power rating of each appliance).
Results for the power demand of these load types are shown in Table 3. For detailed survey and analysis, four home types (1-, 2-, 3-bedroom and Duplex) were considered. A data of standard electrical requirements for each home is tabulated (Table 3), and hence the resultant power demands calculated. The 1-bedroom required 19.240kW; 2-bedroom 25.205kW, 3-bedroom 27.670kW and duplex 34.850kW.
These results are graphically illustrated in column chart (fig. 1).

2.1.1.1 SIZE OF DISTRIBUTION BOARD FOR THE AS-BUILT (CHM)

From load computation for the conventional (as – built) home model (CHM), the total load current is 48.13A for the 2-bedroom.
It is therefore appropriate to choose a 60A (DB).
There are fourteen (14) sub circuits as shown below:

- Two (2) lighting circuits protected by 5 amps fuse each.
- One (1) ceiling fan circuit protected by a 5 amp fuse
- Two (2) ring circuit for TV, toasters, etc protected by 15 amp fuse each
- Six (6) Air conditioner circuits protected by a 15 amp fuse each
- Two (2) Water heater circuit protected by a 20 amp fuse each
- One (1) cooker unit circuit protected by a 20 amp fuse

With the 14 Sub circuits, they can be grouped into six (6) ways using Triple Pole and Neutral (TPN) DB.
The Distribution Board is a 6-way 60A 220V.
The same computation was used for other home types.
The fuse rating and quantity used for the CHM are shown in Table 1.

Table 1: Fuse rating and quantity used for the CHM. [3, 4, 5, 6]

HOME TYPE	RATINGS (AMP)	QUANTITY	COST/FUSE (N)	COST/FUSE ($)	TOTAL COST (N)	TOTAL COST ($)
1- BEDROOM	5	1	150	1.01	150	1.01
	10	1	150	1.01	150	1.01
	15	1	150	1.01	150	1.01
	30	1	150	1.01	150	1.01
2- BEDROOM	5	2	150	1.01	300	2.02
	15	1	150	1.01	150	1.01
	30	1	150	1.01	150	1.01
3- BEDROOM	5	3	150	1.01	450	3.03
	15	8	150	1.01	1200	8.11
	20	3	150	1.01	450	3.03
DUPLEX	10	4	150	1.01	600	4.05
	20	5	150	1.01	750	5.07
	30	11	150	1.01	1650	11.2

Table 2: Load type and power (kW) requirement (As-built) (CHM).

LOAD TYPE	CONVENTIONAL MODEL. (AS-BUILT) (kW)
Air Conditioner	1.865
Water Heater	3.200
Lighting	0.060
Ceiling Fan	0.050
Television, Toaster	0.300
Cooker Unit	3.600

Table 3: Home type, load and power demand (As – built/Conventional)

HOME TYPE	AIR CONDITIONERER	WATER HEATER	LIGHTING	CEILNG FAN	TELEVISION / TOASTER	ELECTRIC COOKER	CONVENTIONAL POWER DEMAND PER HOME (kW)
1 – BEDROOM	3	1	17	3	12	1	19.240
2 – BEDROOM	4	2	20	4	14	1	25.205
3 - BEDROOM	5	2	23	5	15	1	27.670
DUPLEX	8	4	27	7	16	1	34.85

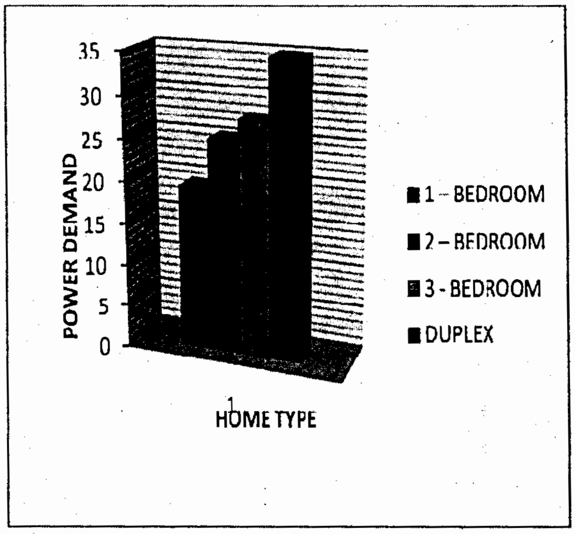

Figure 1: Chart showing Power Demand of Home types (As-built).

2.1.2 ENERGY EEFICIENT RETROFITTED HOME MODEL (EERHM)

In this model, the power rating and specifications of each load type generated by the application of energy efficient technologies was collected/collated as follows (with keen interest on the luminaires, water heaters and air conditioners):

- Air Conditioner (1.00kW, 220V, 50Hz)
- Water Heater (1.20kW, 220V, 8.0Bar, 50Hz, 10L)
- Lighting (0.012kW, 220V)
- Ceiling Fan (0.02kW, 220V,50Hz)
- Television / Toaster 13A Socket Outlet
- Cooker Unit (3.6kW,220v,50Hz)

These are summarized in Table 5, showing principally the load type and the power rating.

Also, results for the power demand of these loads are shown in Table 6.

The same method of analysis used in the Conventional (As – built/CHM) Home Model (sub section 2.1.1), was carried out for the EERHM. The computed power demand for the 1-, 2-, 3-bedroom and duplex are 12.964kW, 15.920kW, 17.376kW and 20.364kW respectively.

The results are graphically represented in Fig. 2.

2.1.2.1 SIZE OF DISTRIBUTION BOARDS (EERHM):

From load computation for the **EERHM**, the total load current is 19.957A for the 2-bedroom.

It is appropriate to use a 30A DB

Also, there are fourteen (14) Sub circuits in this model as shown below:

- Two (2) lighting circuits protected by 5 amp fuse each.
- One (1) ceiling fan circuit protected by 5 amp fuse each
- Two (2) ring circuits for TV, toaster, etc protected by 15 amps fuse each
- Six (6) Air conditioner circuits protected by a 10 amp fuse each
- Two (2) Water heater circuit protected by a 10 amp fuse
- One (1) cooker unit circuit protected by a 20 amp fuse.

With the 14 Sub circuits, they can be grouped into six (6) ways using Triple Pole and Neutral (TPN) DB.

The Distribution Board is a 6-way 30A, 220V.

The same computation was used for other home types.

The fuse rating and quantity used for the CHM are shown in Table 1.

Table 4: Fuse rating and the quantity for the energy efficient tech. [3, 4, 5, 6]

HOME TYPE	RATINGS (AMP)	QUANTITY	COST/FUSE (N)	COST/FUSE ($)	TOTAL COST (N)	TOTAL COST ($)
1- BEDROOM	5	1	150	1.01	150	1.01
	10	1	150	1.01	150	1.01
	15	1	150	1.01	150	1.01
	20	1	150	1.01	150	1.01
2- BEDROOM	5	2	150	1.01	300	2.02
	10	1	150	1.01	150	1.01
	20	1	150	1.01	150	1.01
3- BEDROOM	5	1	150	1.01	150	1.01
	10	6	150	1.01	900	6.09
	15	2	150	1.01	300	2.03
	20	1	150	1.01	150	1.01
DUPLEX	5	3	150	1.01	450	3.03
	10	4	150	1.01	600	4.05
	20	11	150	1.01	1650	11.2

Table 5: Load type and power (kW) requirement (EERHM).

LOAD TYPE	ENERGY EFFICIENT MODEL. (kW)
Air Conditioner	1.000
Water Heater	1.200
Lighting	0.012
Ceiling Fan	0.020
Television, Toaster	0.300
Cooker Unit	3.600

Table 6: Home Type, load and power demand (Energy Efficient Tech.)

HOME TYPE	AIR CONDITIONERER	WATER HEATER	LIGHTING	CEILNG FAN	TELEVISION / TOASTER	ELECTRIC COOKER	ENERGY SAVING MODEL POWER DEMAND PER HOME (kW)
1 – BEDROOM	3	1	17	3	12	1	12.964
2 – BEDROOM	4	2	20	4	14	1	15.920
3 - BEDROOM	5	2	23	5	15	1	17.376
DUPLEX	8	4	27	7	16	1	20.364

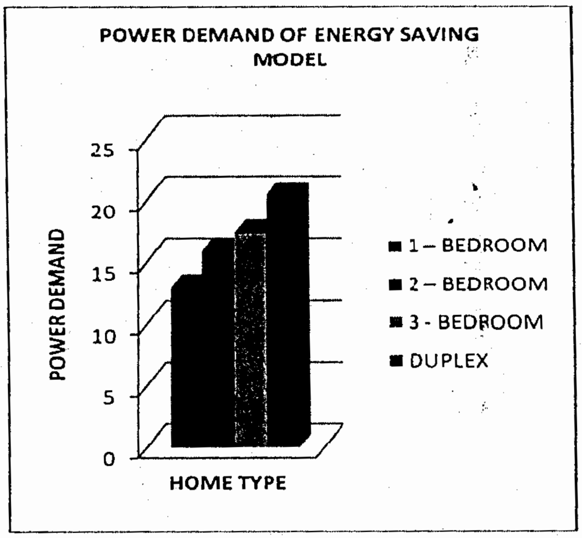

Figure 2: Pie chart showing power demand of home types (Energy Efficient Model.)

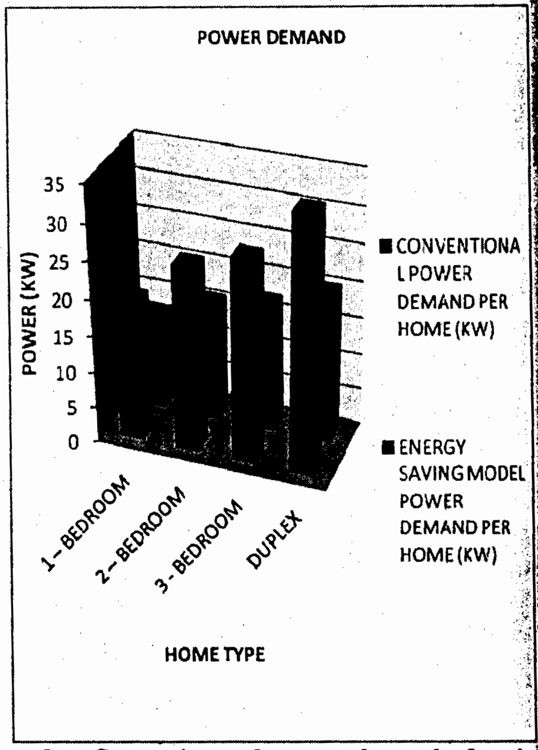

Figure 3: Comparison of power demands for the conventional and energy efficiency model

2.3 ASSUMPTIONS, RELEVANT INFORMATION AND FORMULAE

- Power consumption is for ten (10) hours per day for all appliances on the average
- Average allowable family size is 6 (people)
- Total number houses required nationwide is about 24 million.
- Nigerian population is about 138,283, 240 [11]
- Energy = Power Consumption x Time taken
- Cost of Energy = Power consumption x Time taken x Charge per Kilowatt hour
- Exchange rate of Naira : Dollar = N148:00 : $1:00 (2/2/ 2009)

2.4 COMPARATIVE ANALYSIS OF THE CONVENTIONAL (AS-BUILT) AND ENERGY EFFICIENCY MODEL.

The difference in values of power demand of the two technologies is evident (Figure 3), resulting in a substantial difference in energy cost.

2.4.1 POWER SAVINGS

The total power demand for the conventional(as – built) home model (CHM) is 570.6 x10^6kW (per annum).
The total power demand for the energy efficient retrofitted model is 361.7 x 10^6kW (per annum).
The total power savings:
$(570.6 \times 10^6 - 361.7 \times 10^6)$ kW
208 x 10^6 kW
Summary is in Table 7 below.

Table 7: National power saving (Nigeria) per annum with application of energy efficient model

HOME TYPE	PERCENT CONSTITUENT (%)	TOTAL POWER DEMAND PER ANNUM X 10^6(KW)		POWER SAVINGS X 10^6 (KW)
		CHM	EERHM	
1 – BEDROOM	40	177.4	119.5	57.9
2 – BEDROOM	25	145.2	91.7	53.5
3 - BEDROOM	20	127.5	80.1	47.4
DUPLEX	15	120.5	70.4	50.1
TOTAL	100	570.6	361.7	208.9

2.4.2 COST OF OPERATING THE CHM.

Total power consumed with operation of conventional technology is 570.6 x10^6kW
Assuming light, airconditioner,etc are used for 10 hours daily and Power Holding Company of Nigeria (**PHCN**) charges N6:00 per kW-h
Then total kW-h per annum is:
570.6 x10^6kW x 10 hrs x 365 days
2082.8x10^9kW-h
Total cost = 2082.8x10^9kW-h x N 6:00
= N 12,496.6 x 10^9 ($ 84.4 x 10^9)
This is grahically shown in fig. 4a.

2.4.3 COST OF OPERATING THE EERHM

Total power consumed in the energy saving model is 361.7 x 10^6kW
Therefore total KWh per annum is for 10 hours daily
361.7 x 10^6kW x 10 hrs x 365 days
1320.3 x 10^9 KW-h
Therefore total cost will be
1320.3 x 10^9 KW-h x N 6:00
N 7922.0 x 10^9 ($53.5 x 10^9)
This is also grahically shown in Figure 4a.

Table 8: Cost comparison of the CHM &EERHM.

TECH.	ENERGY DEMAND X 10^9 (KWh)	ENERGY COST X 10^9 (N)	ENERGY COST X 10^9 ($)
CONVENTIONAL	2082.8	12496.6	84.4
ENERGY SAVING MODEL)	1320.3	7922.0	53.5
SAVINGS	762.4	4574.6	30.9

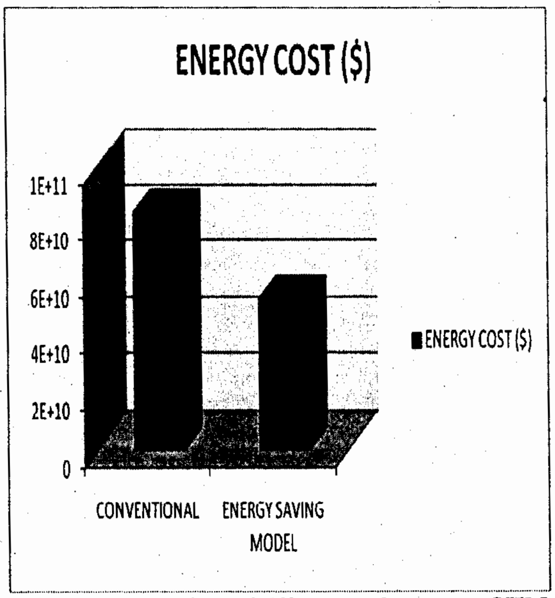

Figure 4a: Cost Difference between CHM and EERHM per annum (Nigeria)

2.4.4 COST BENEFIT ANALYSIS (COST SAVING)

Comparing the utility bills for the CHM and the EERHM, we have,
For the CHM = N 12,496.6 x 10^9
EERHM = N 7922.0 x 10^9
Therefore total cost saved per annum = N 12,496.6 x 10^9 – N 7922.0 x 10^9
= N 4574.6 x 10^9 ($ 30.9 x 10^9) which is as shown in Table 8.

Figure 4b amplifies the savings in cost of operating the EERHM over the CHM.

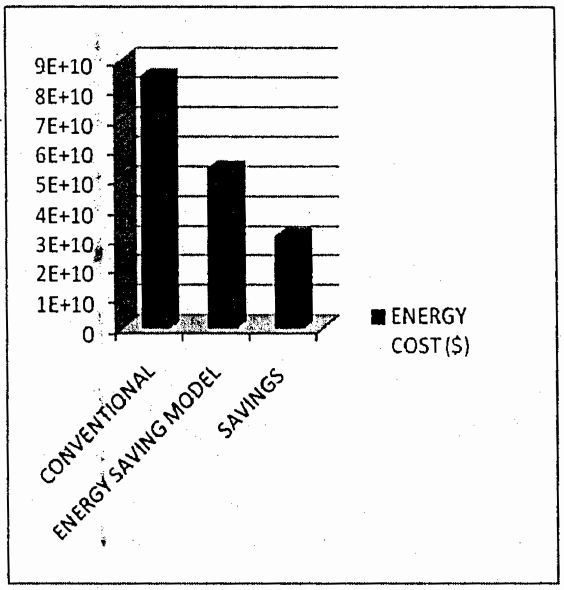

Figure 4b: Cost saving per annum amplified

3. CONCLUSION

An attempt has been made to design an EEH to be used as a DSM tool. The net saving provided by this in terms of extra energy can be used in other sector (industrial/commercial) or to provide extra needs in the domestic sector. Promotion of EEH models will go a long way to manage the present global energy crisis and provide energy for SMEs, commerce, ICT, industry and alleviate poverty by creating employment.

4. RECOMMENDATIONS

The technical detail summarized in Table 3 can serve as a 'Foolish Guide' for the development Energy Efficient homes by town planners and developers, real estate agents, NGOs and governments. Other such models can be provided for schools, recreation centres, parks and the hospitality industry.

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