COMBATING CO_2 EMISSION AND GLOBAL WARMING THROUGH ENERGY EFFEICENT RETROFITTED HOME MODELS

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Abstract— **Global warming is the observed increase in the average temperature of the Earth's atmosphere and oceans in recent decades. Scientists have concluded that human activities are contributing to global warming by adding large amounts of hear-trapping gases to the atmosphere. Using a case study like Nigeria with a population of about 140 million, the main contribution in this research is focused on a financial and ecological energy efficient home design model by considering how the energy saved from using EEH as a tool for DSM can reduce CO_2 emission. A cost benefit analysis was performed and the system was found to be an efficient method of promoting the use of energy saving devices, managing load demand, efficiently utilizing available energy, environmental protection and creation of reserve (savings). Averagely implementing EERHM will result in a national global warming reduction to the tune of 393.3 X 10^9 Kg of $C0_2$. The technology is recommended to governments and other agencies as part of reducing Co_2 and of global warming.**

Keywords— Co_2, Efficiency, Electricity, Emissions, Energy, Global warming.

1. INTRODUCTION

Global warming poses an extraordinary ecological challenge to today's world. The world's leading atmospheric scientists tell us that a gradual warming of our climate is underway and will continue. This long-term warming trend poses serious risks to our economy and our environment. An increase in global temperatures can in turn cause changes, including a rising sea level and changes in the amount and pattern of precipitation. There changes may increase the frequency and intensity of extreme weather events, such as floods, droughts, heat waves, hurricanes, and tornados. Other consequences include higher or lower agricultural yields, glacial retreat, reduced summer stream flows, species extinctions and increases in the ranges of disease vectors.

2. CARBON DIOXIDE AND THE ATTRIBUTION TO GLOBAL WARMING

The scientific community has reached a strong consensus regarding the science of global climate change. The world is undoubtedly warming. This warming is largely the result of emissions of carbon dioxide and other greenhouse gases from human activities including industrial processes, fossil fuel combustion, and changes in land use, such as deforestation.

When greenhouse gas emissions are under discussion, CO_2 is generally the gas which receives the most attention for its greenhouse effect. Although the radioactive forcing of CO_2 is much less than other greenhouse gases (CH_4, N_2O, CFCs, etc.), CO_2 is emitted in large amounts into the atmosphere and has a rather long atmospheric lifetime. CO_2 is estimated to contribute approximately 60% of the enhanced greenhouse gas effect.

Figure 1 shows the record of CO_2 concentration in the atmosphere from 1959 to 2003, CO_2 concentrations in the atmosphere have been measured at an altitude of about 4,000 meters on the Peak of Maunna Loa Mountain in Hawaii since 1958. The measurements at this location, remote from local sources of pollution, have clearly shown that atmospheric concentrations of CO_2 are increasing. The mean concentration of approximately 315.17 parts per million by volume (ppmv) in 1958 rose to approximately 375.61 ppmv in 2003. And atmospheric CO_2 levels were about 260-280 ppmv immediately before industrial emissions began and did not vary much, from this level during the preceding 10,000 years. It is evident that the rapid increase in CO_2 concentrations has been occurring since the onset of industrialization. The increase has closely followed the increase in CO_2 emissions from fossil fuels.

During the last 20 years, about three-quarters of the anthropogenic emissions of CO_2 to the atmosphere have been due to fossil fuel burning [1].

About 80% of the world's total use of energy is based on fossil fuels and they play an important role in the transport and stationary energy sectors, including electric power generation. The increased amounts of carbon dioxide and other greenhouse gases (GHGs) are the primary causes of the human-induced component of warming. They lead to an increase in the greenhouse effect.

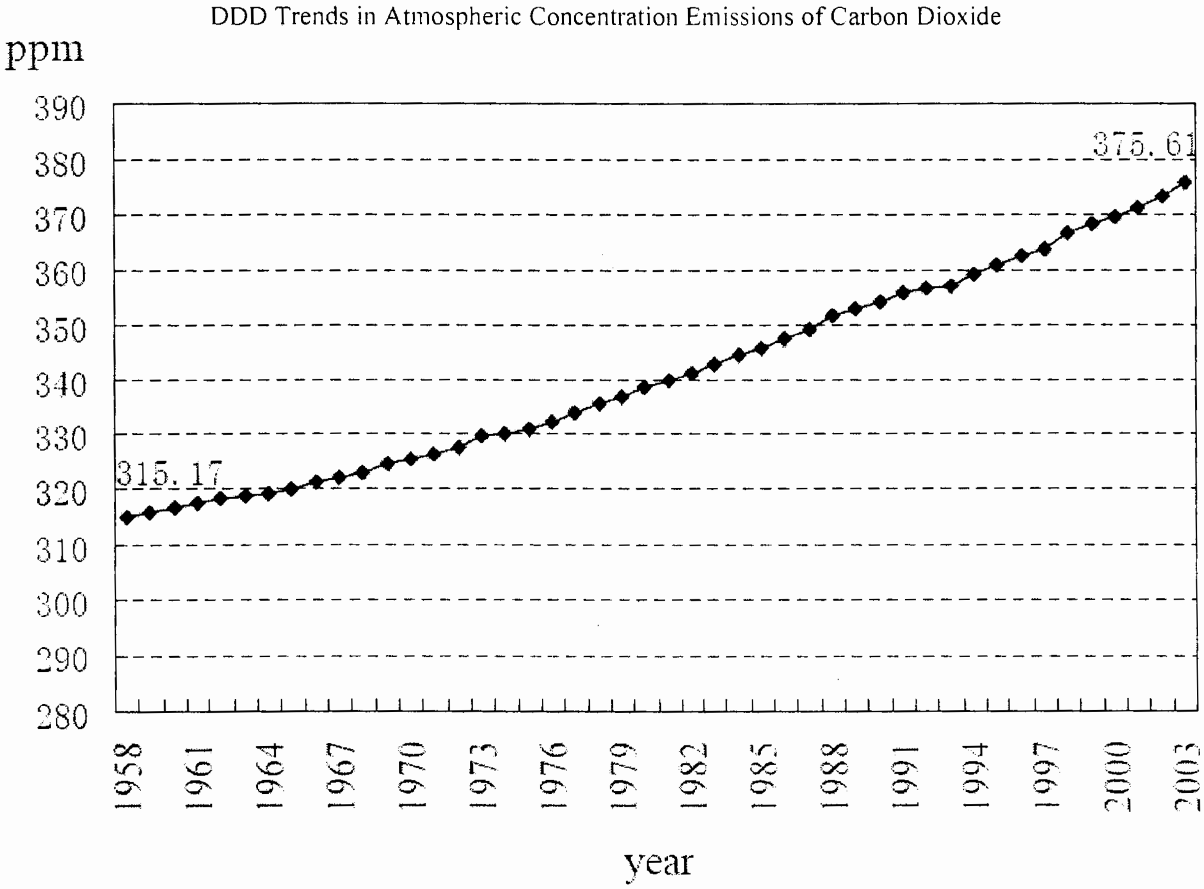
3. POWER GENERATION SECTOR

The most common greenhouse gas is carbon dioxide and the power generation sector is the largest source of the carbon dioxide emissions that contribute to global climate change.

Figure 2 shows the worldwide growth in the use of electricity from 1980 to 2003, while Figure 3 shows the fuels used to produce this electricity. Electricity is critical to any nation's economy, to generate electricity power plants use a variety of fuels, including fossil fuels --- coal, natural gas, and oil, which account for about two-thirds of the electricity---and nuclear fuels as well as other sources.

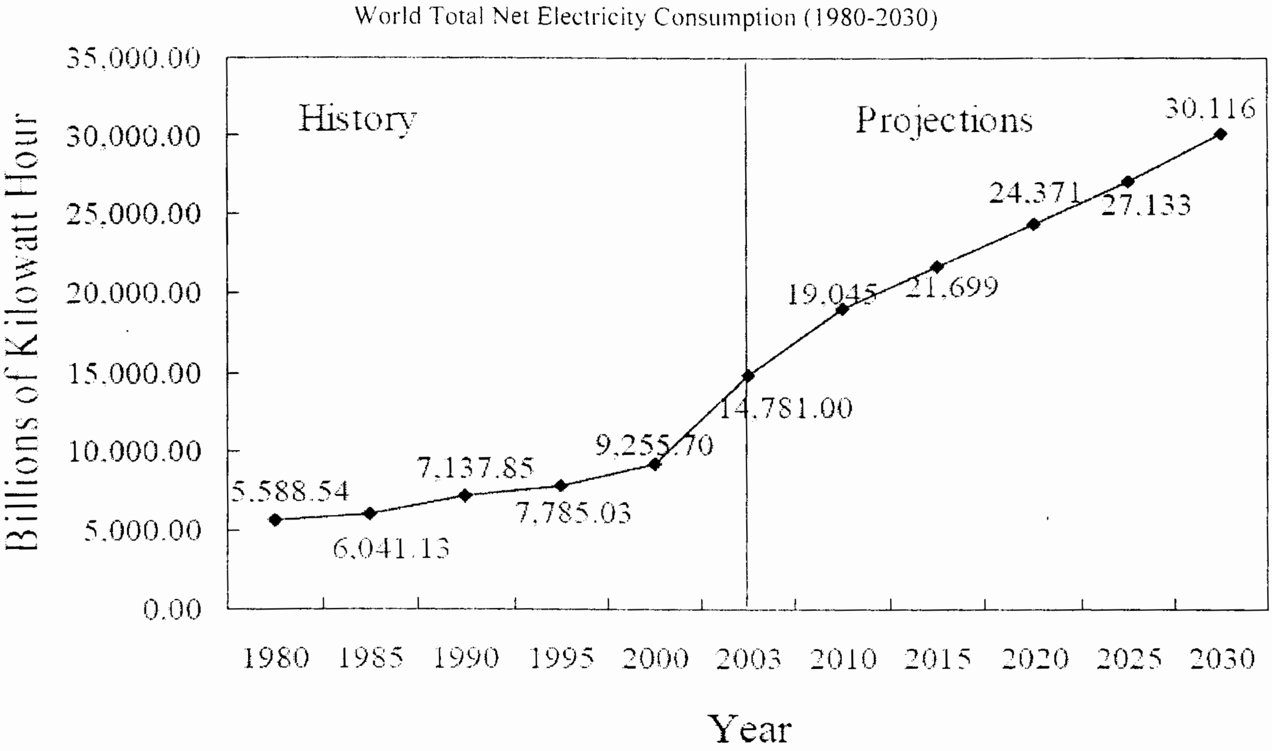
Type of fuel used is an important factor in emissions because fuels have significantly different ratios of CO_2 emissions per unit of energy consumed. Coal produces 21% more CO_2 than oil and 76% more CO_2 than natural gas per unit of energy consumption. Nuclear, solar, wind hydroelectric, and biomass energy sources do not result in significant CO_2 emissions. As a result of the combustion process, electric power plants emit huge CO_2 emissions which can pose environmental and human health risks.

In the reference case, worldwide installed electricity generating capacity grows from 3,710 gigawatts in 2003 to an estimated 6,349 gigawatts in 2030, at an average rate of 2.0 percent per year. To achieve reductions in CO_2 emissions, power plants must limit their emissions under the Kyoto Protocol. Should CO_2 reductions be deemed necessary, it is likely that the electricity and other power sector would be required to make significant contributions to reduce CO_2 emissions.



Source: CDIAC

Fig. 1: Atmospheric CO_2 Concentrations in Parts Per Million by Volume.



Source: IEA

Fig. 2: Total World Primary Electricity Consumption

4. DESIGN OF THE ENERGY EFFICIENT RETROFITTED HOME MODEL

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. It is well known that there is an all round energy crisis all over the world and efforts are being made to conserve energy during the stages of conversion, transmission and distribution and at end use equipment [2].

To manage energy demand would include the optimal utilization of existing capacity and or remodeling existing infrastructure [3, 4]. One way of remodeling in the domestic sector is to replace existing appliances with Energy Efficient (EE) ones by 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).

4.1. METHODS AND RESULTS OF INVESTIGATION

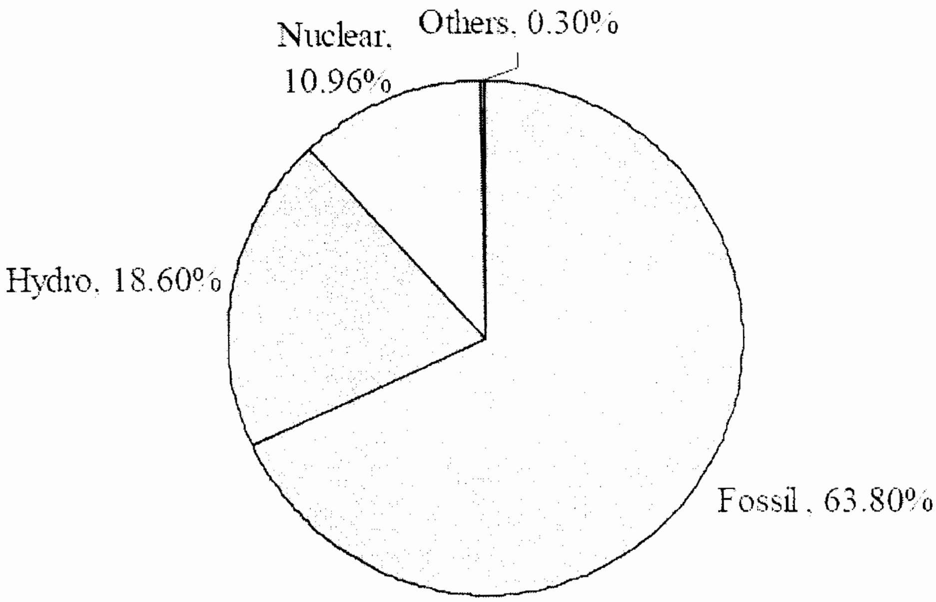
A critical survey was carried out in the staff residences of Igbinedion University Okada Crown Estate (1-Bedrooms, 2-Bedrooms and Duplexes) to ascertain the provisions made for lighting, air-conditioners, cooking and other load types (Television, VCD, Microwave). An attempt was made to estimate the total load requirement as- built, i.e. the Conventional Home Model (CHM) based on the power requirement of the conventional model and the load types used. It was compared with the energy efficient model 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 1. A new computation was performed to determine the new load requirement for the various categories of houses. The cost implication of the as – built electrical service (CHM) was prepared as shown and also compared with the energy efficient model in Table 2. Finally a comparison was performed between the as-built model and the energy efficient model to determine its usability as a DSM and Co_2 emission reducing tool and by carefully highlighting the energy savings and the amount of Co_2 that will reduced directly by reducing our electricity use. Table 3 and Figure 6 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.

4.2. DATA COLLECTION

The main data for this research was collected from our previous research in [5]. 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.

The full details of the power ratings and specifications of each load type as it was collected in the conventional (as-built) technology and the energy efficient model can be seen in [5].

World Electricity Generation by Fuel Type



Source: IEA, 2000b

Fig. 3: World Electricity Generation by Fuel Type.

Table 1: Load Type and Power (kw) Requirement of CHM (As – built) and EERHM

LOAD TYPE	CONVENTIONAL MODEL (AS BUILT) (kW)	ENERGY EFFICIENT MODEL (kW)
Air Conditioner	1.865	1.000
Water Heater	3.200	1.200
Lighting	0.060	0.012
Ceiling Fan	0.050	0.020
Television, Toaster	0.300	0.300
Cooker Unit	3.600	3.600

4.3 ASSUMPTIONS, RELEVANT INFORMATION AND FORMULAE

Energy efficiency is a complex computation, and should not be oversimplified into terms like kilo-watt per hour (kWh) only. To gain a close understanding the following assumptions were made:

- 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.
- 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 As at 2nd February, 2009.

Table 2: Home Type, Load and Power (kW) Requirement of the CHM (As-Built) and EERHM

HOME TYPE	AIR CONDITIONERER	WATER HEATER	LIGHTING	CEILNG FAN	TELEVISION / TOASTER	ELECTRIC COOKER	CONVENTIONAL POWER DEMAND PER HOME (kW)	ENERGY EFFICIENT POWER DEMAND PER HOME (kW)
1 - BEDROOM	3	1	17	3	12	1	19.240	12.964
2 - BEDROOM	4	2	20	4	14	1	25.205	15.920
3 - BEDROOM	5	2	23	5	15	1	27.670	17.376
DUPLEX	8	4	27	7	16	1	34.85	20.364

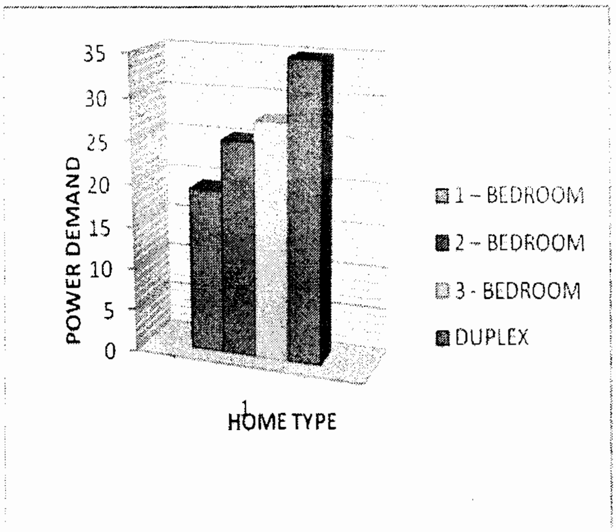


Fig. 4: Chart Showing Power Demand of Home types (As-built).

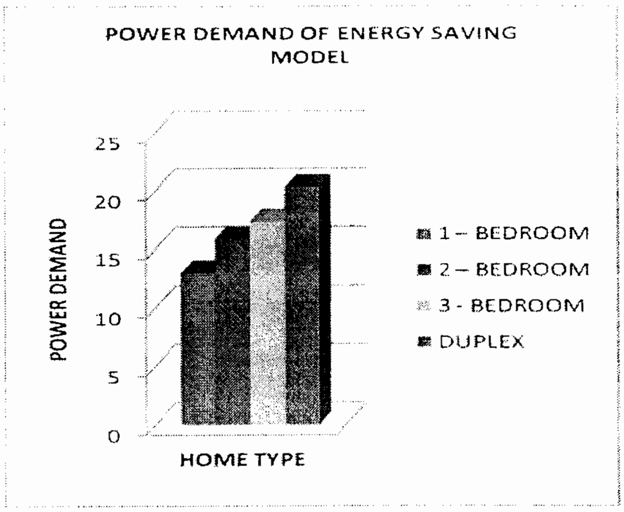


Fig. 5: Chart showing Power Demand of Home types (Energy Efficient Model).

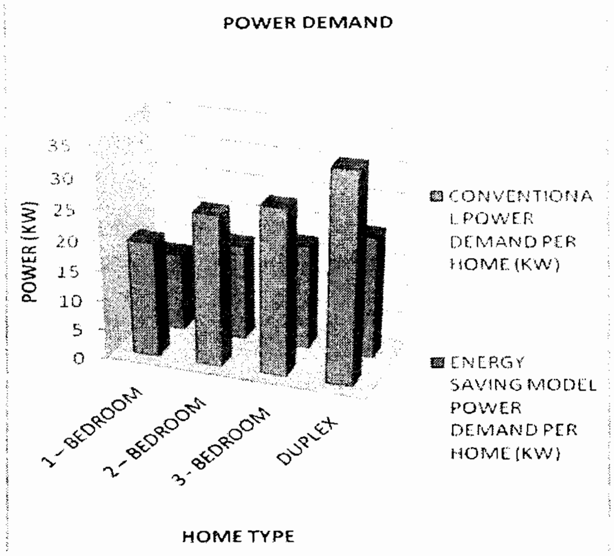


Fig. 6: Comparison of Power Demands for the Conventional and Energy Efficiency Model.

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

The difference in values of power demand of the two technologies is obvious (figure 4 and 5), resulting in a substantial difference in energy cost.

4.5. 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 3 below.

Table 3: 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 X10^6 (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

4.6 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).

4.7 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)

4.8 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 is

= N 12,496.6 x 10^9 - N 7922.0 x 10^9

= N 4574.6 x 10^9 ($ 30.9 x 10^9)

Table 4: Cost comparison of the CHM &EERHM.

TECHNOLOGY	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

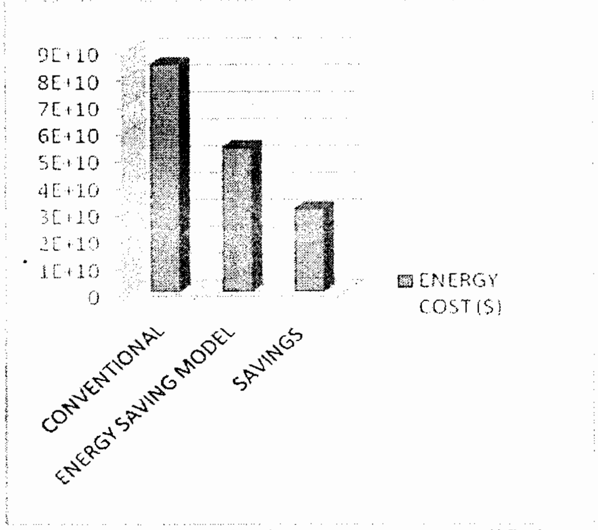


Fig 7: Cost Saving per Annum Amplified.

5. EFFECT ON GLOBAL WARMING

For every kWh of energy you consume, a certain amount of CO_2 will have been emitted by a power station somewhere, often several different power stations. Greenhouse gas emissions from the production of electricity vary due to regional differences in source fuel. Several other gases are emitted during the combustion of fossil fuels that could contribute to climate change. The amount of CO_2 emitted depends on electricity supplier. National averages for most countries are available in AMEE Data Wiki [6]. CO_2 is by far the largest component of the gaseous emissions of electricity production, and any contributions the other gases (methane, nitrous oxide, etc.) have on this number are insignificant. The carbon intensity of a nation and of each local electrical utility varies greatly depending on the fuel mix. For example, in the UK, using 1 kWh of electricity results in the emission of 0.527 kg of CO_2, often just written as $kgCO_2$ [6] while in United State of America, national average CO_2 emission is 0.608kg per kWh of electrical power. Approximately 78% of CO_2 emissions in the U.S. are tied to electrical power generation. Figure 7 shows the global warming potentials (kg Co_2) of different energy sources.

Table 5: National Averages of $C0_2$ Emission of Selected Countries.

S/N	COUNTRY	C02 EMISSION (kg/kWh)	YEAR OF STUDY
1	EU25	0.537	2005
2	EU15	0.494	2005
3	JAPAN	0.38	1997
4	UK	0.527	------
5	TAIWAN	0.7	1999
6	MALAYSIA	0.56	1999
7	KOREA	0.487	1996
8	US	0.608	1999

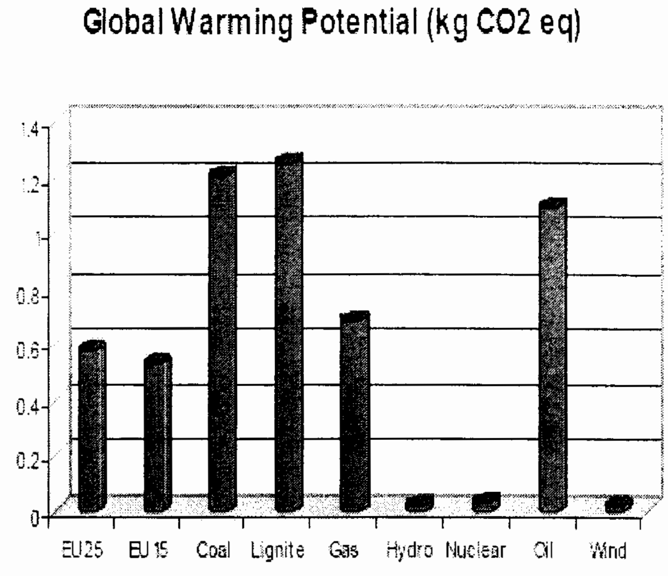


Figure 8: Global Warming Potential of Different Sources of Energy. [7]

From our research 36.6% of energy will be saved from using EERHM which is 762.4 KWh (see table 6). The effect of this on $C0_2$ emission and global warming is that the percentage decrease in the power consumption will lead to a decrease in power generation and directly reduce $C0_2$ emission.

We will use the EU25 and EU15 technology mixes in our calculation with the average value of 0.537 and 0.494 kg/kWh respectively [7]. Using these values above the following inference as shown on table 6 were made.

Table 6: $C0_2$ Emission Comparison of CHM and EERHM using EU25 and EU15 Technology Mixes.

TECHNOLOGY	ENERGY DEMAND (KWh) X 10^9	$C0_2$ EMISSION (KG) X 10^9	
		EU25	EU15
CONVENTIONAL (CHM)	2082.8	1118.5	1028.9
ENERGY SAVING MODEL (EERHM)	1320.3	709.0	652.2
SAVINGS	762.4	409.4	376.6

Therefore by implementing the EERHM we will save the atmosphere about 409.4 X 10^9 Kg or 376.6 X 10^9 Kg of $C0_2$ based on the EU25 and EU15 mixes.

Averagely implementing EERHM will result in a national global warming reduction to the tune of 393.3 X 10^9 Kg of $C0_2$.

6. CONCLUSION

While reducing emissions is extremely important, so is the efficient use of energy resources. This benefits the user in the form of reduced operating costs, and society as a whole by reducing our total energy demand and contributions to global warming. When implemented, the EEH can drastically reduce greenhouse gas emissions and substantially increase energy efficiency. Promotion of EEH models will go a long way to manage the present global energy crisis and provide creation of reserve energy savings for individuals, SME's, commerce, ICT, industry and governments.

These EEH energy efficiency measures can be implemented by individuals, corporate and government agencies alike, giving both energy and financial savings. The amount of Co_2 that will be reduced if implemented is significant from the research. Making the proposed EEH model a win-win solution to the global energy crisis. Thus the war against Co_2 emission and global warming can be clearly won.

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