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Research Article

Analysis of Household Energy Efficiency in developing countries using the Long Energy Alternative Planning System (Case Study: Ghana)

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Abstract
Ghana continues to face periodic energy crisis particularly in the power sector. The dominant household energy fuels in Ghana are mainly biomass, oil products and hydropower. Efficient and wise use of available resources would consequently reduce the effects and scarcity of these energy resources and make energy more accessible to many households in future. The objective of this paper is to use the LEAP model to develop three scenaria to depict a business as usual, assumed lower (10%) and higher (30%) energy savings on household energy intensities by 2030. Key factors relevant in the analysis included current and future household size, economic growth and saturation of household energy appliances. The results of this research shows a 30% reduction in total household energy consumption thus, higher energy saving scenario which would save about 1,552 ktoe and reduce GHG emission by 1,077.2 ktCO2 equivalent as compared to the baseline scenario by 2030. This scenario would reduce health risk associated with biomass use and save households income on fuel. Effective implementation of policies and laws banning inefficient household electrical devices such as refrigerators, air-conditioners and lighting bulbs is necessary. In addition, awareness on energy savings on improved cooking stoves and automatic lighting control systems in buildings is beneficial in achieving this target. Meanwhile programs and policies in Ghana should aim at barriers in renewable energy technologies to ensure its significance in the household energy mix.

Keywords
Energy efficiency–LEAP–Households–Energy intensity–Ghana

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Contents

1. Introduction

Although the effects of climate change would be global, developing countries are the most vulnerable and hence the needs for mitigation and adaptation strategies to be implemented to reduce the effects of climate change in these regions. Many literature and studies on energy consumption focus on OECD countries. Bigano et al. conducted a study on the impact of temperature on the energy consumption of the residential sectors industrial and service sectors and did not analyze situations in developing countries [1]. Bessec and Fouquau investigated total electricity use in the EU-15 in all sectors of the economy [2]. Meanwhile, the cases of China and India clearly show examples of rapid economic development from relatively modest energy use to high energy consuming countries. It is imperative that studies and research on energy use in developing countries are advanced in order to achieve sustainable pattern for development and avoid a worst case scenario. Ghana has a current population of about 24.3 million and an average GDP per capita of US $1600(PPP) per year. Ghana is located in the tropics about five degrees north of the equator. In Ghana, the annual population growth rate is 2.2%(2000-2008). Under this current scenario, it is projected that the population of Ghana will reach 35 million by 2030 [3]. Since the 1980's, Ghana has experienced periodic energy crises. The main source of electricity generation in Ghana is the hydroelectric dam. However, dry weather seasonal conditions and long absence of rainfall decrease the water level of dams which lead to the shortage in power production. Biomass fuel accounts for about 85% of household cooking fuel in Ghana. The use of unprocessed biomass fuel has harmful consequences on the health of the households. Indoor house pollution is a major cause of respiratory diseases. Biomass, particularly wood, is not always harvested renewably, from sources that regrow. The products of incomplete combustion of biomass particularly methane and black carbon particles are even more powerful greenhouse pollutants than carbon dioxide, and therefore have higher global warming potential. The impact of these effects is a serious threat to developing countries. Sustainable development is hence a must for all countries, not for developed countries alone. Energy use will continue to rise significantly in developing countries as a characteristic of economic development. Future electricity demand in Ghana is expected to rise with increase in household income as a result of increase in saturation of household electrical appliances. Wood fuel consumption and unconventional fuel remain a greater proportion of the energy mix in Ghana. These energy sources pose significant environmental problems such as climate change, local air pollution and environmental resource depletion. Meanwhile, the Akosombo hydroelectric dam, which is the country's major renewable energy source cannot meet the demands of the growing economy and population in Ghana. The fastest and cheapest way to meeting this demand is energy efficiency. According to Parker et al., residential sector accounts for 22 per cent of global energy consumption and it is a major contributor to resource consumption and greenhouse gas production, as well as air pollution [4]. This has caused an increase widespread interest in finding ways to improve residential energy efficiency. The International Energy Agency emphasizes that energy efficiency is the single most important way to reducing energy related carbon dioxide in the atmosphere and mitigating climate change [5]. A growing body of evidence shows that increased energy efficiency can benefit both society and the environment [6, 7, 8].Effective plans and policies are therefore essential to ensure a sustainable energy mix and energy savings in Ghana. This will ensure a sustainable development of the West African country. In order to develop effective energy efficiency and sustainable energy mix policies in Ghana, insight into current and future energy consumption would be necessary for analysis. This research however does not project total energy consumption in all the sectors of the economy of Ghana. The residential sector which accounts for more than 60% of total energy consumption has been selected for study in this research due to the adequate information and data available on this sector. The main objectives of this research include: a. Analysing current and future household energy demand scenarios in Ghana. b. Estimating energy savings and mitigation potentials of efficient scenaria. The core of this paper would focus on energy efficiency improvements and potential renewable energy resources in rural and urban households in Ghana. In this research, scenarios of baseline and projected household energy use are developed based on current and future demographic and economic situations in Ghana. An optimistic assumed accumulated energy saving potential of 10% and 30% of current energy intensity is used to model a lower and higher energy efficient scenaria respectively by 2030.The main analysis and discussion would be drawn on the energy demand and the environmental effects of each of the scenaria. This research can be useful to policy makers and energy experts especially in developing countries which have similar demographic and economic situations as Ghana. The scenaria developed in this research work may not be the most definite cases to solving and ensuring energy sustainability in Ghana as predicting the future with accuracy is not really possible [9]. Instead, this research work should be regarded as an exercise to developing a set of scenaria analysis tools and initiating a discussion on alternative future energy pathways and efficient technologies for developing countries

2. Materials and Method

The Long range Energy Alternative Planning (LEAP) system will be used in the analysis of the current residential energy consumption as well as create future energy use scenarios for the rural and urban households in Ghana. The LEAP is a software tool that requires data on demographic, economic and energy factors for analysis. It was developed by the Stockholm Environment Institute and has been adopted for use by many organisations in more than 150 countries worldwide [10].LEAP is a bottom up simulation model which is very flexible and easy to use as compared to other energy models. It is purposely intended for medium to long term energy analysis. In this research, we have chosen a time frame of 20 years (2010-2030). This time frame chosen is as a result of the fact that majority of Ghana's developmental plans and policies have a time limit within this period. The study will basically require:

Results of data would be analysed using Microsoft excel tools. Data on this research would be collected from previous research on household and demographic surveys conducted by the Ghana Statistical Service, The Ministry of energy, Ghana, the UN database and accredited individ-

Table 1. Data requirements of LEAP Methodology

Demographic data	Economic data	Energy data
National population	GDP/GNP	National energy plan
Rates of urbanisation	Value added by sectors	Statistical reports on energy
Average household size	Interest rates	Any published energy papers
Age of population	Inflation rates	Data on energy consumption and production
Male/Female ratio	Employment rates	Electrical appliance use and efficient technologies

ual research and surveys. The key data and assumptions used in this research are summarized as follows:

- **Demographic Data**
- National population: 24,223,431 people. [11]
- Annual population growth rate : 2.2%(2000-2008). [11]
- Rates of urbanization: 3.5% annually.ie. 2005-2010. [11]
- Average household size: 5.1 persons per household. [11]
- Male/female population: Women constitute 12,421,770 (51%) with men at 11,801,661(49%). [11]
- Age structure of population from 0 to 15 years (41.3%) from 16 to 64years (53.4%), from 50 years (5.3%). [11]
- **Economic Data**
- GDP/GNP: US $31.20 billion (2010 estimate). [11]
- GDP growth rate: US $6.6%. [11]
- Average income levels: The mean annual household income in Ghana is US $1,327 and the average per capita income is US $43. [11]
- Interest rates: 11.64%.[11]
- Inflation rates: Inflation is expected to reduce from 10.6% in 2010 to 8.3% in 2011. [11]
- Unemployment: The current unemployment rate in Ghana is about 11% [11]

2.1 Final household energy consumption

The final household energy consumption is the main results from the demand data input. Final energy consumption is a product of activity levels and energy intensities.

Final energy consumption = Activity levels × Energy intensities

Activity level is the measure of the economic activities in the sector under investigation. For instance in this research; the activity level is the number of households whereas in a manufacturing firm, the activity level could be the number of finished products manufactures within a period. The energy intensities are the amounts of energy consumed by the end use devices in a period. All household electrical appliances use a specific amount of energy within a specified period. This is only applicable to electrical appliances that have been correctly labeled. However in the case of aggregate energy analysis including fuel types such as wood fuel, kerosene etc., historical consumption statistics and energy balance combined with the activity level is relevant to calculate the energy intensities.

Energy intensity = Total consumption/Activity level.

In calculating total activity level of each end use device, each activity level is multiplied by the percentage share or saturation. Example, country A has a total household population of 16 million households. The rural population forms 30% of the household. If the urban saturation of refrigerators in Country A is 65%, then its urban refrigeration activity would be 7.28 million households.

Table 2. illustrates calculation of end use device saturation

Branch	Activity level	Total activity
Household	16,000,000	16,000,000 households
Urban	70%	11,200,000 households
Refrigeration	65%	7,280,000 households

The final energy demand is calculated by the product of the total activity level and energy intensity at each given technology branch. Dbst = TAbst × EIbst, Where D is the energy demand, A is the activity level is the branch, s is the scenario and t is the technology level.

2.2 Useful Household Energy Consumption

An aggregate energy analysis may consist of different technologies with no specific energy intensities for respective technologies. However, the final energy per activity of the aggregate branch may be known. In this situation, the useful energy demand analysis is a useful tool in calculating the energy intensities of each technology. The energy efficiencies of the various technologies is an important factor in this analysis. The less efficient technology end use devices may consume a greater deal of energy. Example, Consider an energy branch with a final intensity of 100 GJ per activity. Two technology end use devices are used with each having a 50% share. The electricity technology has an efficiency of 100% and the natural gas technology has an efficiency of 70%. Hence the useful energy intensities are 100*50%*100%=50 GJ/ activity and 100*50%*70%=35GJ/activity respectively.

2.3 Energy Intensity of Household Electrical appliances

All electrical appliances are labeled with capacities of electrical consumption unit. A unit of electricity is kWh. Efficient appliances consume less energy than non-efficient ones during the same time. In this research the energy intensity of the household electrical appliances were calculated from data from the Electricity Company of Ghana. The duration of use of electrical appliance however was based on assumption of use and life cycle of end use device. Below is a list of labeled energy consumption rates of electrical appliance in Ghana

Figure 1. Energy consumption rates of electrical appliance in Ghana

Table 3. Total assumed annual energy intensity of electrical appliance

End use device	Hrs. per unit(KWh)	Total assumed annual hourly use	Total Energy Intensity (KWh)
Refrigerator(200 W)	5	15hrs per day *300 days=4500 hr	900
Electric stoves	7mins=0.11	0.5hr a day*200	900
Existing(60watts incandescent)	17	10 hrs. per day*200days	117*2=234
Efficient(60watts fluorescent)	93	10 hrs. per day	21*2=42
Television(80 watts)	12	14 hrs. per day	425
Fan(70 Watts)	14	16 hrs. per day	417
Electric heaters(1000 watts)	1	0.5 hrs. per day*200 days	100
Electric Iron(1000 watts)	1	1hr per day*200	200
Air conditioner(1500 watts)	40 mins= 0.67 hrs.	4 hrs. per day*200	1100

2.4 Developing household energy scenarios for Ghana

Scenarios are self-consistent story lines of how future energy system might change in a specific country or region with respective to socioeconomic changes and policies [10]. Energy efficiency and optimistic growth scenarios would be developed to analyse Ghana's medium term energy future. The household energy scenarios modeled include a baseline scenario, a lower energy saving scenario and a higher energy saving scenario. In this research, only the household sector of Ghana is modeled. The modeling of the household only considers the end use appliances and energy consuming tools used by the households except for transport, production or agricultural purposes. The households have been divided into rural and urban. Each is further divided into whether it is electrified or non-electrified. The basic end use applications of fuel and electricity such as cooling and heating, refrigeration, cooking, lighting etc. are then analysed according to survey of percentage saturation of use of appliance by households. The LEAP tool uses this input to calculate the final energy consumption and useful energy consumption in the business as usual scenario and the mitigation scenarios respectively. The useful energy consumption takes into consideration the efficiency and energy improvements of the end use energy devices.

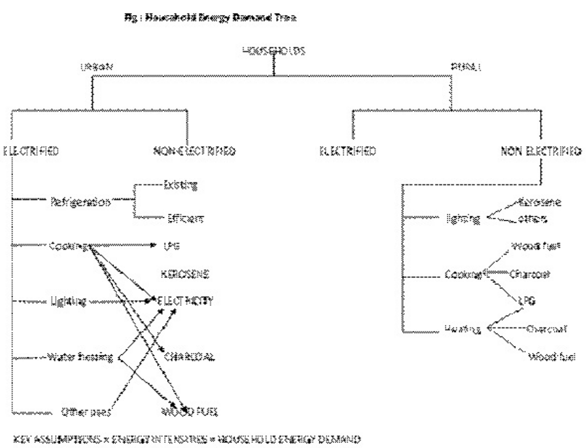

Figure 2. Household Energy Demand Tree

2.5 Baseline scenario (BAS)

This scenario is inherited from the current account scenario. This scenario takes into consideration only the demographic and economic changes that are presumed to occur in the future. It assumes each household would continue to use the same intensity of energy for household purposes without considering energy efficiency technologies and applications

2.6 Lower energy saving scenario (LOW)

This is an optimistic energy saving scenario which is also inherited from the current account scenario. The lower energy efficiency scenario as implied by the name is based on three main factors, economic and population growth rates, technological improvements in end use devices and the national energy policy. This is a highly achievable reduction target considering the recent legislation on energy conservation and education of the public on the wise use of energy in Ghana. The 10% target of energy savings as assumed in this research is justifiably a recommended energy savings as documented in the Strategic Energy Plan of Ghana.

2.7 Higher energy saving scenario (HIG)

This is an aggressive and high energy savings but also optimistic scenario that is also inherited from the current scenario. This scenario assumes a 30% reduction in intensities of household end use device by 2030. Current legislations in Ghana prohibit the importation of inefficient household electrical devices such refrigerators and air conditioners. These devices currently in use in some households in Ghana are more than 30% inefficient than the efficient devices. For example, according to ENERGY STAR, the fluorescent light bulbs use about 65% - 75% less energy than the incandescent light bulbs. Improved charcoal and fuel wood cooking stoves are also about 30%-40% more efficient than the traditional cooking stoves. It is assumed that the ban on inefficient end use devices would phase out these appliances by 2030 and rural and urban household would also resort to improved cooking stoves. The high energy scenario assumption is hence achievable by 2030.

Table 4. Household energy consumption scenarios in Ghana.

Scenario	**BAS**	**LOW**	**HIG**		
Household	2030(% saturation)	Energy intensity (kWh)	2030(% saturation)	Assumed 10% energy savings	Assumed 30% energy savings (kWh)
Urban Rate of elect.	64.8 92		64.8 92		
Refrigeration	95		97		
Existing	60	900	0	810	630
Efficient	40	600	100	540	420
Cooking	100		100		
Electricity	0.5	900	0.5	810	630
Charcoal	68.6	900**	68.6	810**	630**
Fuel wood	19.4	3000**	19.4	2700**	2100**
LPG	11.5	160**	30	144**	112**
Lighting	100		100		
Electricity	76.6(60.0,40.0)	(234,42)	76.6(10,90)	(210,37.8)	(163.8,29.4)
Kerosene	20.8	70*	20.8	63*	49*
Water heating	70		70		
Electricity	3.8	100	3.8	90	70
Wood fuel	22.8	300**	22.8	270**	210**
Charcoal	65.2	100**	65.2	90**	70**
LPG	8.2	10**	8.2	9**	7**
Other uses	60 600		90	540	420
Rural Rate of elect.	35.2 40		35.2 40		
Refrigeration	2.8		5.6		
Existing	95	900	95	810	630
Efficient	5	600	5	540	420
Cooking	100		100		
Charcoal	18.9	900**	18.9	810**	630**
Fuel wood	76.4	3000**	76.4	2700**	2100**
LPG	4.7	120**	9.4	108**	84**
Lighting	100		100		
Electricity	64.5	234	64.5	210.6	163.8
Kerosene	33.6	70*	33.6	63*	49*
Water heating	100		100		
Electricity	1.1	100	1.1	90	70
Wood fuel	72.6	20**	72.6	18**	210**
Charcoal	23.2	20**	23.2	18**	70**
LPG	3.2	5**	3.2	4.5**	3.5**

*Baseline scenario (BAS) *Lower Energy saving scenario (LOW) *Higher Energy saving scenario (HIG)

3. Results and Discussion

3.1 Household energy demand in final units for the scenarios

In 2010, the total household energy demand in Ghana was 4,259.5 ktoe for all the three scenaria. Biomass constituted 89.9% with electricity and oil products forming 5.3% and 4.8% of the total demand respectively. By 2030, the total household energy demand for scenaria HIG, LOW, BAS is expected to be 3863.5ktoe, 4967.4ktoe and 5415.5ktoe respectively. Biomass will continue to be the main household fuel. Meanwhile household demand for oil products increased considerably constituting almost the same percentage share as electricity. Final household energy demand for scenario HIG peaks at 2011 and decrease by 0.1% annually. The higher energy saving scenario would save 1552.0ktoe as compared to 481.1ktoe by the low energy saving scenario in 2030 over the Business as Usual scenario. Final energy use is estimated to decrease from 37.5 GJ per household in 2010 to 25.0GJ, 32.1GJ and 35.0 GJ per household in the year 2030 in the HIG, LOW and BAS scenaria respectively. Due to the assumed changes in the structure of the economy and energy efficiency improvements, household energy intensity by GDP is expected to fall from 5.7 MJ/US$ in year 2010 to 1.4 MJ/US$, 1.8 MJ/US$, 2.0 MJ/US$ in the HIG, LOW and BAS respectively by the year 2030.

Similar studies on scenario and future of renewable energy in Ghana's energy mix was conducted by the UN (CSD-14) in 2006. The IAEA's energy planning tools MAED and MESSAGE was used in analysing the future energy demand in Ghana in this research. The annual GDP growth of Ghana was projected at 4.5% as compared to this research's projected annual GDP growth rate of 6.6%. The UN (CSD-14) demonstration study projected a total final household energy demand by 2030 at 234.81 PJ in comparison with this research value of 226.7 PJ by 2030. The total energy demands of most fuels in the baseline scenario are higher than the other scenaria. However, LPG in the lower energy scenario shows the highest demand projection than the baseline scenaria despite an assumed 10% energy saving target. This is explained by the high saturation of LPG as domestic fuel especially in the urban areas by 2030. LPG is a cleaner source of fuel than biomass and other oil product.

Table 5. UN (CSD-14) energy demand research

	2010	2015	2020	2025	2030
A UN-ENERGY	**Demonstration Study (2006)**				
Urban Household	48.77	57.68	72.92	92.98	115.45
Rural Household	82.77	86.7	95.13	107.33	119.36
Total(PJ)	**131.54**	**144.38**	**168.05**	**200.31**	**234.81**
This Research (BAU)					
Urban Household	69.7	80.9	93	105.9	119.6
Rural Household	108.6	110.3	110.6	109.2	107.1
Total (PJ)	**178.3**	**191.2**	**203.6**	**215.1**	**226.7**

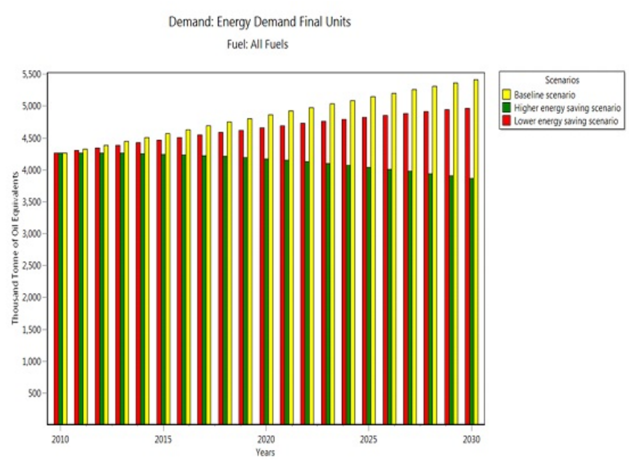

Figure 3

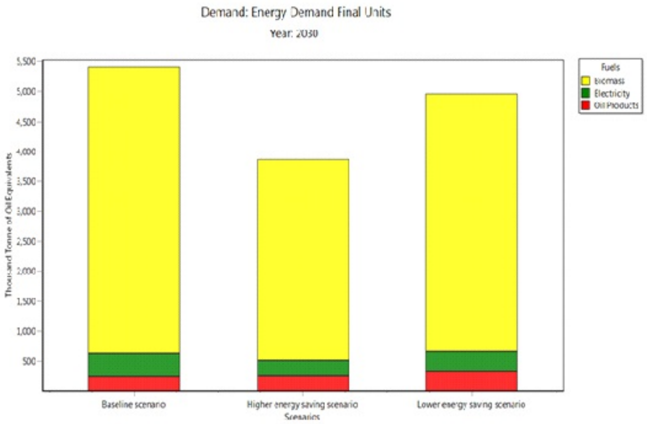

Figure 4. Final Fuel Share by Scenaria

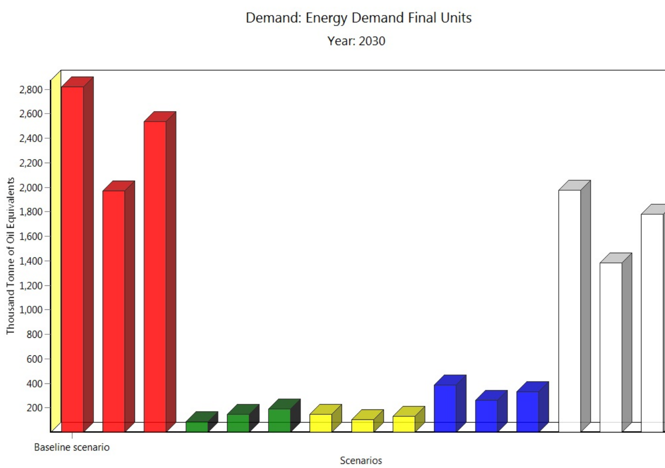

Figure 5. Final Fuel Share by Scenaria

3.2 Household biomass demand

Fuel wood and Charcoal will continue to form more than 85% of household energy demand by 2030.The current household demand in 2010 of 3831.2 ktoe is expected to reach 3356.4 ktoe, 4315.3 ktoe and 4794.8 ktoe for the HIG, LOW and BAS scenaria respectively. The HIG would however lead to a greater reduction in household biomass demand by 474.9ktoe by 2030 over the base year. Rural household's biomass demand constitutes about 94% of the total energy demand in 2030, whereas urban biomass household demand would decrease considerably constituting about 80.5% of the total household energy demand in both efficient scenaria.

3.3 Household electricity demand

Electricity is expected to constitute about 6.7% of the household energy mix. Meanwhile the household electricity demand scenario for HIG is expected to be the lowest. The total household electricity demand is expected to be 3000 Gwh, 3900 Gwh and 4500 Gwh by 2030 for HIG, LOW and BAS scenaria respectively. The annual percentage growth rate in electricity in HIG, LOW and BAS would be -0.2%, 1.6% and 2.4% by 2030.Rural households electricity demand would continue to constitute a small share of the total rural household energy mix. Rural household electricity demand is expected to be 200 Gwh for the higher energy saving scenario and 300 Gwh for both the lower energy saving scenario and the baseline scenario by 2030. According to the Energy Commission's report dubbed "The energy statistics of Ghana" (2000-2008), residential sector accounted for about 2,269 Gwh of electricity consumption in 2008. In this research total household electricity demand would be about 2,600 Gwh in the year 2010 for all the three scenaria.

3.4 Household Oil products demand

By 2030, there is expected to be significant increase in the demand of oil products. Factors such as availability of oil resources and affordable price of LPG are expected to be the key driving force. The greatest demand in oil product is expected in the LOW scenario. The household demand for oil products would increase by 114.7ktoe in the LOW scenario as compared to 43.8ktoe and 29.2ktoe in the HIG and BAS scenaria respectively. Cooking in the urban households account for the greatest end use demand in oil products. The main contributing factor would be a high saturation of LPG users in urban areas by 2030. Kerosene would however remain an insignificant part in the urban household energy demand. Meanwhile kerosene would continue to play a significant role in lighting in both rural and urban households without any increase in current generation and supply of electricity by 2030.However, an increase in supply of electricity by 2030 may cause many households to abandon and switch reliably on electricity.

3.5 Environmental effects: Local air pollution and Global warming potential

In all the three scenaria, total GHG emission is expected to increase by 2030 over the base year figure of 2950.3ktCO2e.By 2030, total GHG emission is expected to be 3,380.1ktCO2e, 4345ktCO2e and 4457.3ktCO2e for scenaria HIG, LOW and BAS respectively. The high energy saving scenario would however decrease total emissions by 0.3% annually whereas total emissions for LOW and BAS scenaria would increase considerably by 1.3% and 1.4% annually. Rural household energy demand accounts for greater contribution to GHG emissions. In the baseline scenario, biomass constitutes almost 90% of the total GHG emissions as compared to about 62% in the urban households. Oil products would also account for about 38% of urban GHG emissions in the LOW scenario. In the HIG scenario, biomass contributes 45% of the total urban household energy GHG contribution .However, in the rural households biomass accounts for a far greater percentage of GHG emission of about 90%.Other greenhouse gases such as methane, carbon dioxide, nitrogen dioxide, nitrous oxide also follow similar emission pathways to the total GHG emission. With regard to GHG emission per households in the three scenaria, only the HIG scenaria shows a reduction in the 2010 level of 0.6 tonnes per household C02 equivalent to 0.5 tonnes per C02 equivalent by 2030.Meanwhile all the other two scenaria depict an increase in per household GHG emission from 0.6 tonnes per household C02 to 0.7 tonnes per household C02 equivalent by 2030. The figure 2.0 and table below illustrates the various GHG emissions

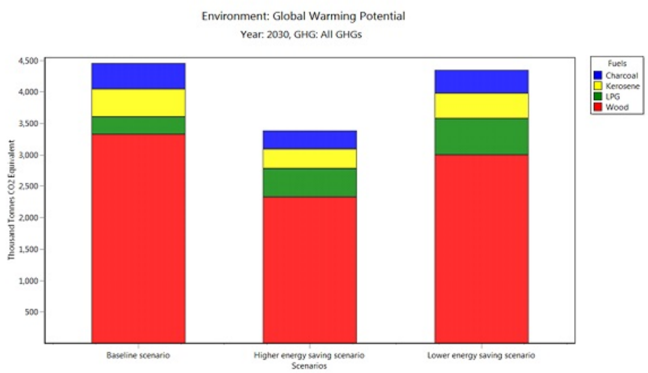

Figure 6

Environment: Global Warming Potential
Year: 2030, GHG: All GHGs
Branch: Demand
Units: Thousand Tonnes CO2 Equivalent

	Baseline scenario	Higher energy saving scenario	Lower energy saving scenario
Charcoal	414	289.8	372.6
Kerosene	442.7	309.9	398.4
LPG	272.5	450.8	579.5
Wood	3328.1	2329.7	2995.3
Total	4457.3	3380.1	4345.8

Figure 7. Showing emissions by type for all scenaria

3.6 Technological innovations in household energy use

The residential sector consumes different forms of energy for different purposes. High biomass consumption is as a result of use as cooking fuel and electricity is popularly consumed on household electrical devices. These consumption trends show greater variety according to income levels, accessibility to energy, culture and lifestyle [12]. Final household energy consumption is a factor of energy intensity. This in turn is dependent on income growth and distribution, household size, and the cost of housing and home appliances. Therefore any reduction in total energy requirements in the household sector is dependent on the wise use of energy in end use appliances by households. Savings in household energy use also have positive effects on the socioeconomic lifestyle of populace. This would put less pressure on the available energy resources and make it cheaper. But economics also argue that when energy becomes cheaper, users do not pay attention to energy saving issues. This is dynamic question that needs critical analysis.

3.7 Lighting

Many households in Ghana are turning to more efficient lighting sources. Compact fluorescent bulbs are more common these days in many homes than the inefficient incandescent bulbs. The compact fluorescent bulbs have an 8000hrs lifetime whereas the regular incandescence have a 1000hrs lifetime Modern fluorescent lamp systems are used with electronic ballasts and solid-state controls, to producing very high light quality with acceptable energy efficiency over a long period of time. A Nano technological approach called Light Emitting Diodes (LED) is also a modern technology in saving energy. LED is solid-state lamp that uses light-emitting diodes (LEDs) as the source of light. It is known to have a lifetime of 30000hrs depending on heat and usage. It costs between US$ 30 and US$50 for an LED home use bulb. Although the initial cost is high compared to other lighting solutions, its energy saving cost and long life makes LED bulbs a better choice. Research in new technologies on design and modification continues in order to further improve its efficiency. Recently, a new lighting technology called ESL (electron-stimulated luminescence) which is expected to have an output 40 lumens per watt and similar lifetime has been introduced onto the market. This new technology does not have the trace amounts of mercury that CFLs contain, and they do not require the manufacturing energy of LEDs hence contributing to the reduction in greenhouse gases. Lighting control systems are also a relevant efficiency practice. Everyone knows that energy is saved by turning off lights when not in use, but most people forget to turn of lights when leaving their rooms. Automatic control lighting systems fitted into housing units in Ghana would prevent excessive use of electricity. The controls can switch lights on and off, or dim lights based on input from sensors which include simple timers, occupancy sensors to detect motion from a person, or photo sensors which operate lights or adjust light levels based on the amount of available daylight. A more renewable lighting technology is the solar lamps and street lights. A solar lamp is a portable light fixture composed of a LED lamp, a photovoltaic solar panel, and a rechargeable battery. These technologies would be best useful in non-electrified areas in Ghana because of its independence on electricity. Additionally, the use of electricity and kerosene for lighting in rural areas is highly inefficient due to large transmission and distribution losses and use of low efficiency devices such as incandescent bulbs and traditional kerosene lamps and lanterns.

3.8 Cooking

Biomass forms the major household cooking fuel in both rural and urban Ghana. Kerosene stoves in Ghana are only used for emergency and quick cooking and heating meals. However, kerosene fuel is used extensively in lighting wood and charcoal stoves in rural and urban households in Ghana. Although the end use saturation of LPG, a cleaner alternative to biomass as cooking fuels may increase by 2030, biomass would still be the main cooking fuel in the household energy mix [13]. The traditional cooking stoves have been improved to provide a more efficient heating for cooking. These technologies reduce fuel consumption and air pollution from traditional biofuels that currently provide cooking energy. Improved stoves have been designed taking into consideration users' habits and have been shown to save substantial amounts of fuel under real life conditions. Meanwhile the cost of these improved technologies is a major barrier to its wide use. Whereas a traditional wood stove would cost less than US$2 to build, improved wood and charcoal stoves cost as much as US$60.However, the efficiency, cost, and performance of stoves alone generally increase as consumers shift progressively from wood stoves to charcoal, kerosene, LPG or gas, and electric stoves. Improved wood and charcoal stoves reduce biomass fuel by about 30% to 50% [14]. For wide use of improved stoves in Ghana, women should be actively involved in educational programs concerning these technologies since they are the main end users. There are enormous advantages of improved cooking stoves from economical and health to environmental ones. [15]

4. Conclusion

A sustainable household energy mix in reference to this research is an ideal scenario that would ensure use of energy resources with least negative impact on the environment and socioeconomic lifestyle of both the rural and urban populates. Biomass fuel will continue to be a major household energy in Ghana. Increasing awareness and education on LPG as a more cleaning source of household cooking fuel would place future LPG consumptions in households at par with electricity. In addition current production of crude oil in Ghana is expected to reduce the price on oil products. In all the three scenarios described in this research, biomass, oil products and electricity would be a significant part of the country's household energy mix. Renewable energy such as solar and wind technologies and biofuels were not modeled into the scenarios due to their insignificance in the country's energy mix. A major factor that influences energy demand and mix is the supply of energy resources. Households use energy sources that are cheaper and readily available. The unreliable supply of LPG is a key problem to its low popularity as a household cooking fuel. Renewable energy resources are a key to sustainable development. Although energy efficiency practice would reduce the pressure on forest and fossil fuel sources, its harmful effects such as indoor air pollution, depletion of forest resource and to a greater extent global warming cannot be overlooked upon. Biofuels, solar and wind energy technologies should be made more attractive to form a significant part of the household energy mix. In all the three scenarios set up in this research work, the HIG is the best scenario considered for a low energy use economy. This scenario will ensure significant decrease in the final household energy demand from 4259.3ktoe in 2010 to 3863.5ktoe by 2030. Its environmental impact is the minimum of the three scenaria. Whiles the total GHG emission for BAS, LOW would be 4457.3kt/CO2 and 4345.8kt/CO2 respectively, the HIG scenario would emit 3380.1kt/CO2 which shows a significant reduction in the level of emissions. In the LOW, HIG scenaria, household's biomass use would reduce and shift slightly into LPG fuel. Though HIG shows greater shift than LOW scenario, it indicates that even a least energy efficiency practice could be beneficial. These energy efficient scenaria would reduce indoor air pollution and pressure on forest resources. According to the Ministry of energy of Ghana, current projects and future energy plans seek to increase the supply of Ghana's domestic energy resources. Despite these supply side factors, adequate efforts should be made on the demand side to minimize the effects of increasing energy cost caused as a result of power shortages and improve the health and quality of life of Ghanaians. In order to minimize energy loss and make energy accessible and cheaper to both rural and urban households in Ghana, this research suggests that;

- Energy institutions in the country should increase awareness of energy savings to the public. It must be emphasized that many household may not understand the technicalities in saving a unit kWh. However, increasing public awareness on money saved on energy bills would be helpful. Efficient lighting, cooking and refrigerating devices should be patronized by households in Ghana.

- Incentives and tax free on importation of renewable energy sources. Further incentives on LPG would make it more attractive than unclean fuels. The purchase cost of renewable products like solar panels, wind turbines and LED lighting systems are comparatively expensive to other energy sources.

- An efficient and regulated market for biofuels and other renewable resources would increase the share of renewables in the household energy mix. Creating an available market for trade in renewables would make attractive the establishment of biofuel farms and also create jobs in the renewable energy sector.
- Effective implementation of policy and legislation on energy efficient appliance is required for whole elimination of inefficient household electrical devices

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