AN INVESTIGATION OF THE ENVIRONMENTAL IMPACT OF RISING HOUSEHOLD ENERGY DEMAND IN KENYA

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REFERENCE NO	ABSTRACT
ENVR-05	This paper discusses the findings of the study on environmental impact of rising households' energy demand in Kenya. The study used data collected during the national census and by the survey smaller scale in rural, peri-urban and urban households from five different regions in the country in two different periods and a comparison of the data findings was made. The findings revealed that kerosene was a major fuel for lighting in the household while fuelwood and charcoal were the major source of fuel for cooking and water heating. It conclusion from the findings revealed that the increase in the number of households created an impact through pollution, deforestation and soil degradation on the environment. The Recommendation made is that the government to take the lead in implementing the environmental mitigation projects mainly on controlling the use of fuelwood and charcoal.
Keywords: Kenya, *environment, households, biomass, kerosene.*	

1. INTRODUCTION

Sustaining a healthy environment is a prerequisite to improving people's health conditions in this universe. Recent study findings show that environmental degradation activities are directly linked to national and global individual health problems [1]. This development has therefore aggravated the deteriorating environment and loss of biodiversity. In light of this, this state has to be improved to amiable level through environmental impact assessment of these activities.

Given that the increase in world population tops the ranks as leading contributor of environment degradation [2], economic and social activities have also emerged as other contributors in this process of human settlement. These are important activities which are aimed at reducing energy poverty but equally contribute to environmental degradation in the form of deforestation, change in land use and greenhouse gas emission [3]. With this trend not brought under control, this process ends up with two scenes of increased use of energy of either fossil fuels, particularly in the developed countries, or biomass fuels in the developing countries where both scenes produce greenhouse gases, which aid in degrade the environmental degradation.

While an increase in number of households accessing modern energy has been viewed as an indicator of economic growth in the country, ignoring environment issues in this would render this process unsustainable. In view of this development, it is essential to carry out an assessment of environmental degradation of activities related to increased demand of household energy [3]. This process shall facilitate the formulation of policy intervention to ameliorate the environmental impact as exemplified through climate change and increased greenhouse gas emissions.

When analysis is done on the pattern of population growth in Kenyan for the last 50 years, it is evident that there is a correlation between population increase and the number of households in Kenya (KNBS). This development, has substantially contributed to the negative impact on the environment mainly by the increased allocation of land devoted to woody biomass production for

supply of fuelwood (Bradley 1988). On the other, this development has heavily influenced a skewed pattern of population distribution towards high agricultural potential areas, which constitute 20 percent of the country and has a settlement of 75 percent of the country population [4]. Against this backdrop, an environmental impact assessment is crucial for increased demand of households' energy for the simple fact that 84 percent of Kenya households energy needs is supplied from biomass [5].

The aim of this paper is to present the findings covering the period 1990-2014 using published literature and data collected from rural, peri-urban and urban households from five sampled villages across the country.

2.0. HOUSEHOLD ENERGY USE

With current literature indicating a correlation of an increase in households' size with population growth in developing countries, it is logical to deduce that this trend leads to an increased demand in households' energy. For instance, the reports on the Kenya National Population Census for the years 1989, 1999 and 2009 had 21.4 million, 28.7 million and 28.6 million people respectively and, these figures corresponded to 4.4 million, 6.4 million and 8.8 million households[6]. Farther analysis shows that these findings translate to an increase of 46.4 percent households in 1989-1999 and 37.6 percent households in 1999-2009 periods. Therefore, this is evidence that an increase in population often leads to an increase in number of households.

In view of this trend where the increase in population corresponds to an increase in the number of households, an inference is made from the two publications, the Beijer Institute and Republic of Kenya [7, 8] that there is a corresponding increase in households' energy consumptions. The 2009 National Population and Households' Energy Use Census report further shows that households cooking and water heating depended heavily on biomass energy and lighting depend on kerosene and electricity [5].

Against this backdrop, this is a demonstration that the leading source of fuel for cooking, water heating and lighting in households in Kenya contribute a significant environmental degradation mainly through deforestation and greenhouse gas emissions (GHG).

2.1. Analysis of Households' Energy

In this study, two sets of data collected at the same location but in different periods were used to analyse the increase in energy demand so as to ascertain the environmental impact. The first set of data, an extract of the 2009 National Population and Housing Census Report[6] which covers a large sample of households from five villages where the second set of data was also collected in a span period of six years. In this paper, fuel for lighting and fuel for cooking and other uses are analysed separately. A contrast the sources of fuels used in these households was done based on the changes in a span of six years.
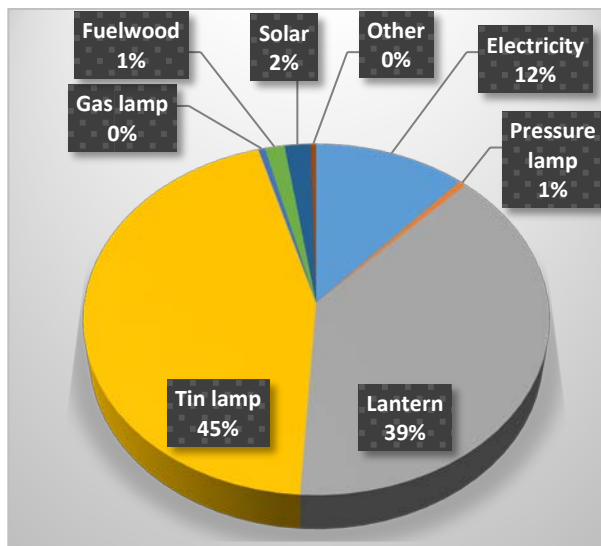
2.1.2 Households' Lighting Fuels

The types of lighting fuel used for analysis is done using data in the 2009 population and housing census report and the field study on households in five different villages in Kenya as shown in figure 1and figure 2 respectively.

It is clearly evident from this result that the combination of tin lamp, lantern and pressure lamps which use paraffin as a source of fuel constitute 85 percent of the households. These findings demonstrate clearly that there is a huge amount of CO_2 emissions from burning this fossil fuel hence, a significant contribution of greenhouse gases. A further 1 percent emission is from fuelwood but the rest is from electricity and solar which is 14 percent and does not emit any CO_2.

The findings of data collected in 2015 on the sources of fuel used for lighting in households of the five villages are shown in figure 2 and indicate that paraffin is a major source of fuel

for lighting, with over 50 percent of the households using it for lighting.


Source: KNBS (2010)

Fig.1. Lighting fuel used in households

The findings for the other set of data collected in 2015 about sources of fuel used for lighting in households in the five villages are shown in figure 2. These results is an affirmation that paraffin as a major source of fuel for lighting in households as it supplies more than 50 percent of the households.

When the two sets of result in figures 1 and 2 are contrasted, there is a significant drop and increase on use of paraffin and electricity in these households respectively, although this may not be accurate because of the smaller sample selected in the second set data used.

The results in figures 1 and 2, shows that there is a clear demonstration of a decline in the use of paraffin as a source of fuel in the households while at the same, there is an increase use of electricity and solar as a source of fuel for lighting. This is a clear evidence that there been initiatives put in place since the first study was conducted which has led to this improvement. Nevertheless, this contrast may not be a true reflection for the entire five regions for the simple reason that a very small sample was used to make this contrast. But one fact

remains unchanged, that the volume of CO_2 emissions from the use of paraffin as a source of fuel for lighting in households is still high.
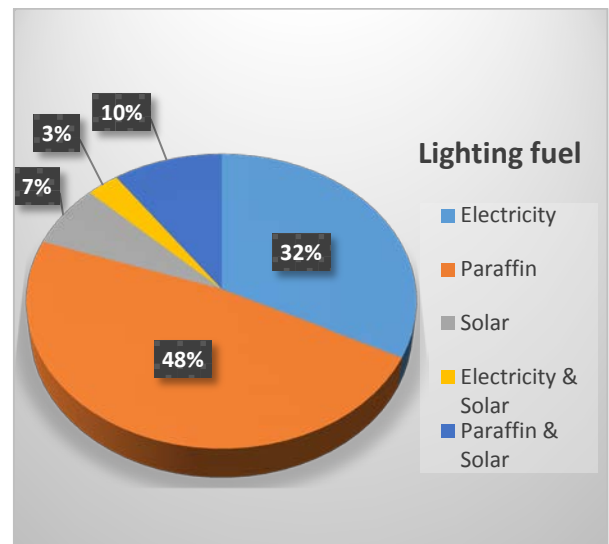
Source: Collected data from field (2015)
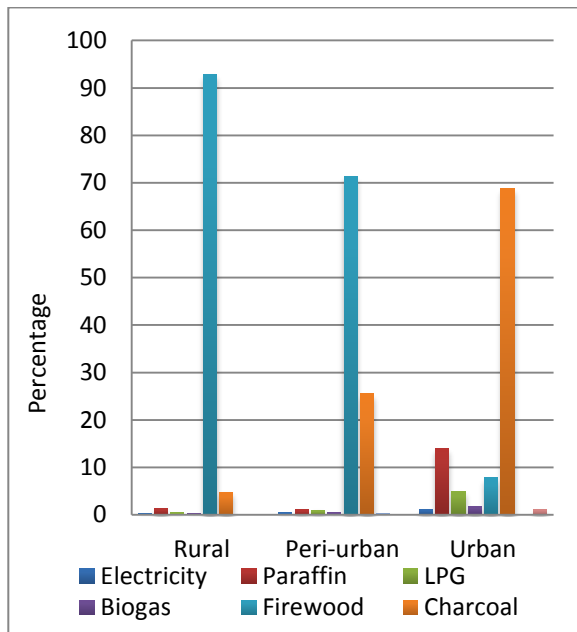
Fig.2. Lighting fuel used in households

Therefore this indicates that a huge amount of paraffin is consumed and a lot of CO_2 is emitted which is a major contributor to greenhouse gases and has a negative impact on the environment through global warming.

2.1.3 Households Cooking Fuels

The analysis of households' fuels for cooking is done using the data obtained from the 2009 population and housing census report and the field survey which are presented in figure 3 and figure 4 respectively.

It is shown in figure 3 that 92.9 percent, 4.8 percent and 1.4 percent of rural households used firewood, charcoal and paraffin fuels respectively for cooking. The remaining portion comprises biogas, electricity and liquid petroleum gas (LPG). For peri-urban, 71.3 percent and 25.5 percent of firewood and charcoal are used respectively. For urban households, 68.8 percent, 14 percent, 7.9 percent, and 5 percent of charcoal, paraffin, firewood and LPG fuels are used respectively. Therefore, these findings confirm that firewood and charcoal are a major source of

fuel for cooking and heating water in these villages before the end of the year 2009.


Source: KNBS (1990)
Fig.3. Cooking fuel used in households

In figure 4, all rural households used fuelwood for cooking and heating while 13.1 percent and 3 percent of households used charcoal and paraffin respectively. It is also shown in figure 4 that all peri-urban households used fuelwood, 30 percent, 10 percent and 5 percent households used charcoal, LPG and kerosene respectively. In the third category, all urban household used charcoal also, 42.9 percent and 38.1 percent of households used LPG and kerosene respectively.

When contrasting the two sets of data which are separated by a six year period, fuelwood and charcoal still are a major source of fuel, it is only in the urban areas where other fuels like LPG, Paraffin, charcoal s are easily are used in comparisons with the other fuels.

The evidence of these findings is therefore a reflection of the frequency and volume of trees cut down as firewood and charcoal fuels for the households in these regions, which is also the same for the major parts of the country. With increased demand of these fuels in households, there is an urgent need for energy policy to provide alternatives sources

so that the trees from individual farms and forests can be conserved and ultimately reducing hence environmental degradation.
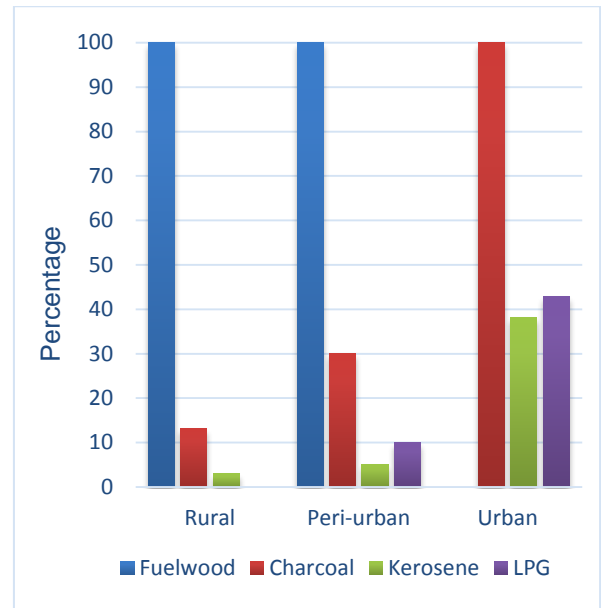
Source: Collected data from field (2015)
Fig. 4. Cooking fuel use in

Given this trend in which biomass is a dominant source of fuel, most urbans and peri-urban households use more than one source of fuel which is determined by the type of food cooked. This practice is influenced by the cost of fuel and convenience of access to these fuels.

3.0 ENVIRONMENTAL IMPACT

A prerequisite of a substantial environmental impact evaluation of rising households energy demand in Kenya is premised on the sound knowledge of the constitution of an environment. Thus, an environment is the natural world which comprises of air, water, and the land in which people, animals, and plants live. With this explanation, it is inferred that an environment has the physical, bilogical and social components. Therefore, a critical evaluation of the three components of environment will provide informed findings.

In determining the enviromental impact due to increased households energy demand, evaluation of the changes on the state of air, climate, water, soil, plants, human settlement and other microorganism forms the basis to

classify based on how they are impacted by this increased household energy demand. On this basis, impact assessment is analysed based on the atmosphere and, the ecosystem.

3.1. The Atmosphere

A delineation of the atmosphere as a layer of gases, knowns as air, that sorrounds the planet Earth and retained by the Earth's gravity is pivotal for this analysis. This atmospheric layer of gases comprises of nitrogen, oxygen, argon and other gases in the ratio 78.09 percent, 20.95 percent, 0.93 percent, 0.03 percent respectively.

This small fraction of 0.03 percent of atmospheric gases which is referred to as greenhouse gases (GHSs), is the focus of this study with the current global composition of carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and fluorinated gases at 82 percent, 10 percent, 5 percent, 3 percent respectively[9, 10].

With available evidence, the combustion of fossil fuels has released greenhouse gases (GHGs) mainly CO_2 and the concentration has recent in recent years leading to the current global warming [11]. This fact is further exemplified by the CO_2 emission in Kenya as shown in figure 5. In 1980, 5.75 million metric tons of CO_2 was emitted as compared to 13.45 million metric tons of CO_2 in 2012, this was a double increase of CO_2 emissions. In comparing the two periods 1980-2002 and 2002-2012, the emissions figure doubled from 2.3 to 5.6 million metric tons of CO_2. This increased rate of CO_2 emissions is evidence of the global warming effects which has brought inconsistence in global climate. In Kenya the CO_2 emissions from combustion of fossil fuels is mainly from the households' energy demand and the transport sector.

With the findings of the 2009 National Census and Households Energy Use shown in figure 1 that 69.5 percent of the country's households used paraffin for lighting[6], and and also the findings of a field survey of households energy shown in figure 2 that over 50 percent

households depended on fossil fuels for lighting, it is suffice to concluded that combustion of paraffin by lamps produced large amount of CO_2 emissions.
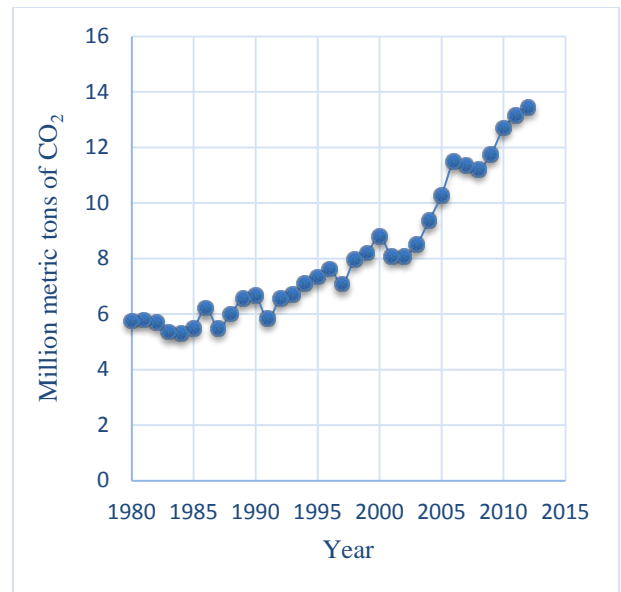
Source: EIA 2013

Fig.5. Carbon dioxide emissions from combustion of fossil fuels

With recent laboratory findings and field measurements indicating that 7-9 percent of paraffin used in wicked paraffin lamps is converted to black carbon [12], and a further laboratory tests results showing that both hurricane and simple kerosene lamps produce 98 kilogrammes and 33 kilogrammes respectively of carbon emissions per year [13], it is evident that there is a huge amount of carbon dioxide (CO_2) and black carbon emitted into the atmosphere based on the findings in figures 1 and 2. Finding of another study conducted in Kenya revealed that households' charcoal stoves emitted more greenhouse gases than the wood stoves [14]. These results is evidence of pollution of the atmosphere of high magnitude in the households in Kenya.

Against this backdrop, a significant amount of heat is generated by emission black carbon and release of CO_2 to the atmosphere and whose effects have contributed significantly to climate changes, a fact supported by Kenya at the recent UN climate summit in paris where a commitment was made to cut the carbon

emission by 30 percent by the year 2030 [15]. It is also acknowledged by the international climate experts that the world should urgently substitute the carbon intensive fuels with renewable energy if curbing the climatic changes has to be reality[16].

Therefore, with earlier evidence showing a close correlation of population increase of people in Kenya with the number of households, it is logical to surmise that the CO_2 black carbon emissions from combustion of paraffin (kerosene) in lamps used for lighting is a major contributor of global warming which have adverse effect on climate and changes in environment.

3.2. The Ecosystem

The focus of the analysis on how the increased households energy demand impact on the environment shall be underpinned on the definition of an ecosystem which states that it is existence of living organisms in one given area which interact and forms a complex relationship between them and nonphysical environment.

With recent studies having shown that approximately 75 percent of the country population lives in 20 percent of the land mass, which is agriculturally productive and the rest being arid and semi-arid [4], it is important to note that increased demand for biomass fuel endangers the Kenyan forest and water catchment ecosystems, a key component of the environment[17].

The findings from the studies in five villages in different regions of the country about households energy use are shown in figures 3 and 4. The data was collected from three rural villages and one each from peri-urban and urban village. The data revealed that fuelwood is the main source of energy in rural peri-urban households while charcoal, kerosene (paraffin) and liquid petroleum gas (LPG) is for urban households. Since the use of kerosene and LPG which is classified as fossil fuel is limited to urban areas and discussed

above, the fuelwood and charcoal (Biomass) shall be analysed.

With revealing of data in figures 3 and 4 that fuelwood and charcoal fuels (Biomass) is a predominant source for the rural households in Kenya and, most of it sourced in the local vicinity of the homesteads through cutting the trees and forests, there is bound to exist a serious environmental degradation particularly in the sorroundings of rural households [2].

Given that the supply of fuelwood supply to the peri-urban households is obtained from cutting trees directly dedicated to fuel plantation, it is the by-product wood, the dead branches and twigs, surpluses from agricultural land clearance which provide the biggest proportion [18]. This is an affirmation that the supply of fuelwood supply, land disturbance due to forest clearance to create space for agricultural activities and human settlement due to population increase are main agents of deforestation which ultimately damage the forest ecosystem.

With the revealation that the highest demand of biomass is highest in the rural villages where there are is no market mechanisms to regulate the demand and supply of this resource, the depletion of this resource is imminent [19, 20], hence a serious environmental degradation would happen soon. While the majority of the rural households are poor and their limited income is spent on food, they get biomass fuel for free and this situation make it difficult for them to adjust to alternative sources of fuel [21], hence their continued reliance on this source would ultimately lead to the depletion of both the forest and water ecosystems, which are interdependent.

With these rural regions being denuded of their forest and wood resources, they are exposed to soil erosion, soil degradation, and loss of biological diversity [2, 22], thus a negative enviromental impact is experienced which destroys the ecosystem.

4. DISCUSSION

After establishing that the population growth has a direct correlation to the number and size of households in Kenya, it is inferred that the increase in population in the country will increase the demand of households' energy.

With the revelation from the data, it is shown in figures 3 and 4 that fuelwood and charcoal are the main source of fuel for cooking and water heating in rural, peri-urban and urban households. On the other hand, kerosene and LPG as the main source of fuel for lighting in all households in the three categories of households as shown in figures 1 and 2. When making analysis about these source of fuels, they have different impact because of their calorific efficiency hence they shall different emissions and subsequently different impacts on the environment.

With the national census results having shown that about 70 percent of Kenya population lives in rural households [6], a large amount of black carbon and CO_2 will be released to the atmosphere due to the combustion of kerosene used for lighting and the use of fuelwood and charcoal to cook and boil water in the households. These processes will cause a big challenge to constrained environment considering that large population occupies a small area of the country. In view of this, the should be new changes to policies governing the environment and the land, among them, making the arid and semi-arid areas be cultivable through planting of trees so that they are habitable. The planted trees shall also serve as source of fuel for households energy needs and also as a black carbon and CO_2 filter. To achieve this goal, a concerted effort of environmental, agricultural and water experts would need to formulate a workable solution as an integrated plan. This would changes the dry lands and enhance the land use activities which are steered by the United Nations Environmental Programme (UNEP). This venture would be easily achieved if the environmental expert can work closely with the Government of Kenya, considering that the UNEP headquarters is based in the country. With the current policy of increasing the forest area in the country to 10 percent of the area is not plausible since the agricultural land which is cultivable and densely populated is highly emotive.

The other long term solution is intensify the environmental education to institution of learning so that as young people grow, they understand the need to participate in making changes to environmental issues. Introducing a clustered development in the rural regions particularly the high density populations regions, more room for food farming and planting of trees with an aim of reducing the environmental degradation and reduction in pollution through the planting of trees[23], which is a key activity towards controlling the climatic changes.

While the urban households have a higher purchase power to access charcoal, kerosene and LPG for cooking and water heating, the majority of the rural households do not have any income to purchase their households cooking and water heating fuel. In most cases they access it for free or from trees planted in their farms, hence it is not seen as an expense. In this set up the rural households do not have any option to switch to hence maintain using the fuelwood and to some places the use of charcoal. The situation regarding the greenhouse gas emissions is likely to maintain or increase if the circumstances do not improve.

The only available alternative is for the government to introduce favourable credit schemes to the households so that they can acquire solar lamps and solar cookers. For those regions who have a substantial income, there is some improvement through the use of rural electrification programme and solar lamps used for lighting, but not much improvement in fuel for cooking and boiling of water as evident in contrasting the results in figures 1-4. It is therefore likely that it would take a little longer to get the substitute for fuelwood fuel for rural households as the forests and trees continue to be denuded unabated.

For instance, it would be a big challenge to sustain the supply of LPG fuel to rural

households as compared to fuelwood because of the high initial cost of the appliances required and supply logistics involved. Currently, it is only the urban area which are near the petroleum pipeline and all weather roads that access the fuel. These problems have made the supply of LPG unreliable and in terms of cost and supply to most households, hence there has to be appropriate integrated planning of settlement and supply of food and households energy in all settlements in the country. Without solutions to these challenges, then fuelwood would continue to be the fuel of choice for the poor in both urban and rural households. This implies that there a level the environment degradation will not improve soon considering that on the other there is a competition between agriculture and tree planting for the available cultivable land.

Whereas the use of charcoal, kerosene and LPG fuels would reduce the amount of trees cut for fuelwood, on the other hand an increase in air pollution will be experience as revealed by a recent study done in Kenya where the charcoal-stoves were found to produce more greenhouse gases than fuelwood wood-stoves [14]. If the GHG emissions from the combustion of kerosene and LPG fuels are combined, there would have to be an increase in the number of trees to be planted to curb the increase of these emissions. Although there has been the increase in the number of the cookstoves use in the country, there has been not quality control of the emissions control for those in the market, hence less impact likely to exist for a little longer. Any improvement in quality control cause a shift from using woodstoves which have low efficiency and thus reducing the volume of trees cut for fuel.

With commercialization of charcoal production suggested in the policy documents, the process of implementation has not commenced since the initiative has to be started by the government.

5. CONCLUSIONS

In view of the revelation of the findings and the development in the other sector which sector which impact directly on the supply of households fuels use in Kenya, it is concluded that the increased demand of households has an impact on the environment. Although this study has identified it as a serious challenge to the environment, there has no clear solution which would be implement besides the small scale which is done by non-governmental organizations' on a commercial basis. On this basis, the government of Kenya has to take the lead in implementing the projects suggested in the energy policy document. This would ask for a special vehicle to implement this new approach.

REFERENCE

[1]   M. Donohoe, "Causes and health consequences of environmental health degradation and social injustice," *Social Science & Medicine*, no. 56, p. 15, 2003.

[2]   K. Baidya, "Firewood shortage: Ecoclimatic disasters in the third world," *International Journal of Environmental Studies*, vol. 22, no. p. 18, 1984.

[3]   B. Sovacool. (Date). Diversity: Energy Studies Need Social Science, *Nature. 511 (7511)*, p.^pp. 529-530. Available:

[4]   Republic of Kenya, "Sessional Paper No. 3 of 2009 on National Land Policy," M. o. Lands, Ed. Nairobi: Government Printer, 2009.

[5]   KNBS. Household Source of Cooking Fuel by County and District [Online]. Available: http://www.knbs.or.ke/index.php?option=com_phocadownload&view=category&id=99&Itemid=639 [Accessed: 25/07/2014].

[6] KNBS. 2009 Population & Housing Census Results [Online]. Available: *www.tisa.or.ke/uploaded/reso urces/KNBS-2009-Census-Highlights.pdf*

[7] P. O'Keefe, Raskin, P., Bernow, S., "Energy and Development in Kenya: Opportunities and Constraints," in *Energy Environment and Development in Africa 1*, vol. 2014. Stockholm and Uppsala: The Beijer Institute and The Scandinavian Institute of African Studies, 1984.

[8] Ministry of Energy, "Study on Kenya's Energy Demand, Supply and Policy Strategy for Households and Small, Small Scale Industries and Service Establishments," Nairobi 2002.

[9] EPA. Greenhouse Gas Emissions [Online]. Available: https://www.epa.gov/ghgemiss ions/overview-greenhouse-gases

[10] US EPA. Greenhouse Gas Emissions [Online]. Available: https://www.epa.gov/ghgemiss ions/overview-greenhouse-gases

[11] 2018 National Academy of Sciences. What You Need to Know About Energy [Online]. Available: http://needtoknow.nas.edu/ene rgy/energy-costs/environmental/

[12] Lam et al., "Household light makes global heat: High black carbon emissions from kerosene wick lamps," *Environmental Science Technology*, vol. 46, no. 24, p. 18, 2012.

[13] E. Mills, "Technical and economic performance analysis of kerosene lamps and alternative approaches to illumination in developing countries," Lawrence Berkeley National Laboratory, Berkeley, California 2003.

[14] R. Bailis, Ezzati, M., Kammen, D.,, "Greenhouse Gas Implications of Household Energy Technology in Kenya," *Environmental Science Technology*, vol. 37, no. p. 9, 2003.

[15] R. Bounagui, "Kenya pledges to cut carbon emissions 30% by 2030," in *The Guardian*, 2015.

[16] IPCC. Climate Change 2007:Synthesis Report [Online]. Available: http://www.ipcc.ch/publication s_and_data/publications_ipcc_fourth_asse ssment_report_synthesis_report.htm

[17] Republic of Kenya, "National Environmental Policy, 2013," Environment, Ed. Nairobi: Ministry of Environment, Water and Natural Resources, 2013.

[18] G. M. Leach, R.,, *Beyond the Wood Fuel Crisis: people, Land and Trees in Africa*. London: Earthscan Publications Ltd, 1988.

[19] Practical Action-(EAO). Biomass Energy Use in Kenya [Online]. Available: http://pubs.iied.org/pdfs/G029 85.pdf. [Accessed: 13/03/2014].

[20] Practical Action, "Biomass Energy Use in Kenya," International Institute for Environment and Development (IIED), Edinburgh 2010.

[21] G. Leach, Gowen, M.,, *Household Energy Handbook: An Interim Guide and Reference Manual*. Washington, D.C.: The International Bank for Reconstruction and Development / The World Bank, 1987.

[22] J. Westoby, "Introduction to World Forestry," *International Development*, vol. 2, no. 4, p. 558, 1989.

[23] E. Mokua, "Clustered Development are a Promising Solution to Food Insecurity and Climate Change," in *Daily Nation*. Nairobi: Nation Media Group, 2014.