Solar Technologies and Forced draft cookstoves: Key to Household Contribution towards Low Carbon Development in Kenya

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Abstract

Lack of access to modern and clean forms of energy in most African countries remains a major challenge in cutting down greenhouse gas (GHG) concentrations in the atmosphere. The critical role energy plays in facilitating social-economic development quests for appropriate frameworks in order to realize adaptation goals. How effective a given framework is designed and implemented marches a proportional effect on sustainable development and for this case in energy. It should start from household level, agri-food industries to multi-production plants. Much attention has been directed to reducing industrial emissions while anthropogenic forcing at household level is neglected. Approximately 70% of Kenyans use biomass as fuel, with 90% in rural areas exclusively using the resource as main cooking fuel. Occasionally, this is combusted using traditional jikos, which use more wood. In efficient cookstoves, not only emit large amounts of particulate matter and carbon monoxide but also contribute to deforestation increasing chances of climate variability and eventually change. The government of Kenya through the ministry of environment, water and natural resources, acknowledges that infrastructure (energy and transport in particular) are very crucial for climate resilience and transition to a low carbon economy. Besides geothermal power, renewables such as wind, solar and small hydro systems will continue to play critical roles in enhancing accessibility to power by majority of Kenyans lacking access to grid connectivity. Much of household income is spend on treatment costs, leaving less disposable income to meet other needs. The increasing shortage of wood fuel and high cost of charcoal may lead the poor to using dried dung, a condition likely to worsen indoor air pollution. The poor face another problem of high cost of fuel wood and charcoal. In urban areas , about 60% of residents use charcoal and 40% firewood. The long hours women need to search for wood reduces time available for other productive activities. Research findings indicate that on average, largest portion of household budget, approximately 85% for the rural poor and 65% for urban poor is directed to food consumption. This means that the poor have little to spend on other essential services such as energy. Thus, in spite of its inefficiency, biomass remains the most accessible fuel by majority of households due to its availability and affordability. The inefficient combustion of wood leads to particulate emissions including harmful gases that retard efforts towards low carbon development.

Key words; energy access, climate resilience, inefficient cookstoves, and low carbon development.

1. Introduction

Small-scale renewable energy solutions continue to play a critical role in enhancing accessibility to clean energy. As economies grapple with high fossil fuel prices, majority of countries are now adopting renewable energy technologies as alternative to oil whose cost has been heightening with dwindling supply base. Approximately 80% of Kenya's industrial sector is powered by fossil fuels, which makes up 28.57% of national energy consumption, an aspect that threatens stability of its economy in the near future. Petroleum fuel accounts for about 28.57% of the total final energy consumption while electricity and combustible renewables account for about 3.11% and 67.65% of the total final energy consumption (KIPPRA 2010). International Energy Agency, estimates that Kenya's electrification rate stands at 19% with about 34 million people lacking access (IEA 2013).

According to UNECA (2013), approximately 33 million people (83% of population) lack access to modern energy. Considering household lighting, majority of families use kerosene and candles. This has considerable impact on the health of over 90% of rural population compounded with in-efficient biomass combusting cookstoves. The government committed itself to enhancing rural electrification to increase the number of households using clean energy mainly for lighting. This has not been adopted by majority of rural households due to the high upfront costs. Other renewable energy technologies such as wind and ocean thermal energy conversion are under exploitation and capacity is expected to increase though emphasis by the government has been on geothermal power sector. Solar energy is rapidly picking up in comparison to other renewables. Solar technologies were boosted by the previous administration when economic incentives were put in place to lower end user price for solar devices. This saw a marked increase in number of solar appliances purchased.

The question of who should be responsible in ensuring sustainability in energy resources starts with an individual. That is, our activities at the household level can easily indicate our role in sustainability of energy resource base ranging from type of stoves we use, fuel, as well as efficiency of energy operated appliances in our homes. One way of ensuring low carbon development to offset green house emissions is adopting improved cookstoves and clean lighting solutions. In rural areas, clean lighting mechanisms are mainly evident by scattered solar powered lanterns. Studies have shown that there are links between biomass combustion and respiratory illnesses in women and children. Approximately 4–5 million children in developing countries die annually due to acute respiratory infections. Cooking devices used by majority of households have very poor thermal efficiency which trigger serious health concerns due to unclean combustion.

The combination above with unsuitable cooking spaces is the main cause of indoor air pollution (IAP) in Kenya estimated to be causing the death of 14,300 people annually. According to Schirnding (2001), women who undertake most of the cooking at the household level are exposed to twice as much particulate emission as their male counterparts, and are on the average twice as likely to suffer from respiratory infections. Since all these arise due to use of lighting and cooking devices and feed stalks that emit greenhouse gases and particulate matter in alarming concentrations, it is necessary for households to adopt low carbon technologies such as solar appliances that support clean lighting and cooking. Thus, this paper will highlight magnitudes to which boycotted use of such devices can help reduce global warming.

A low carbon pathway includes distributed clean energy solutions for households and institutions (such as solar lanterns, improved cookstoves and LPG cookstoves, and energy efficient lighting and appliances), which can have huge social and economic benefits. Improved cookstoves can better the lives of individuals, particularly women and children, in rural and urban areas – by reducing time to collect fuelwood, reducing indoor air pollution, and potentially introducing cost savings to households. Access to modern energy solutions enables income-generating activities, health services, access to communication and improved education outcomes – all of which are of particular benefit to women and children. The mitigation potential of stepping up distributed clean energy technologies is over 10 MtCO2e per year in 2030. Some of the options, such as solar lamps, have very attractive payback times and can introduce cost savings to consumers.(NCCAP,2013)

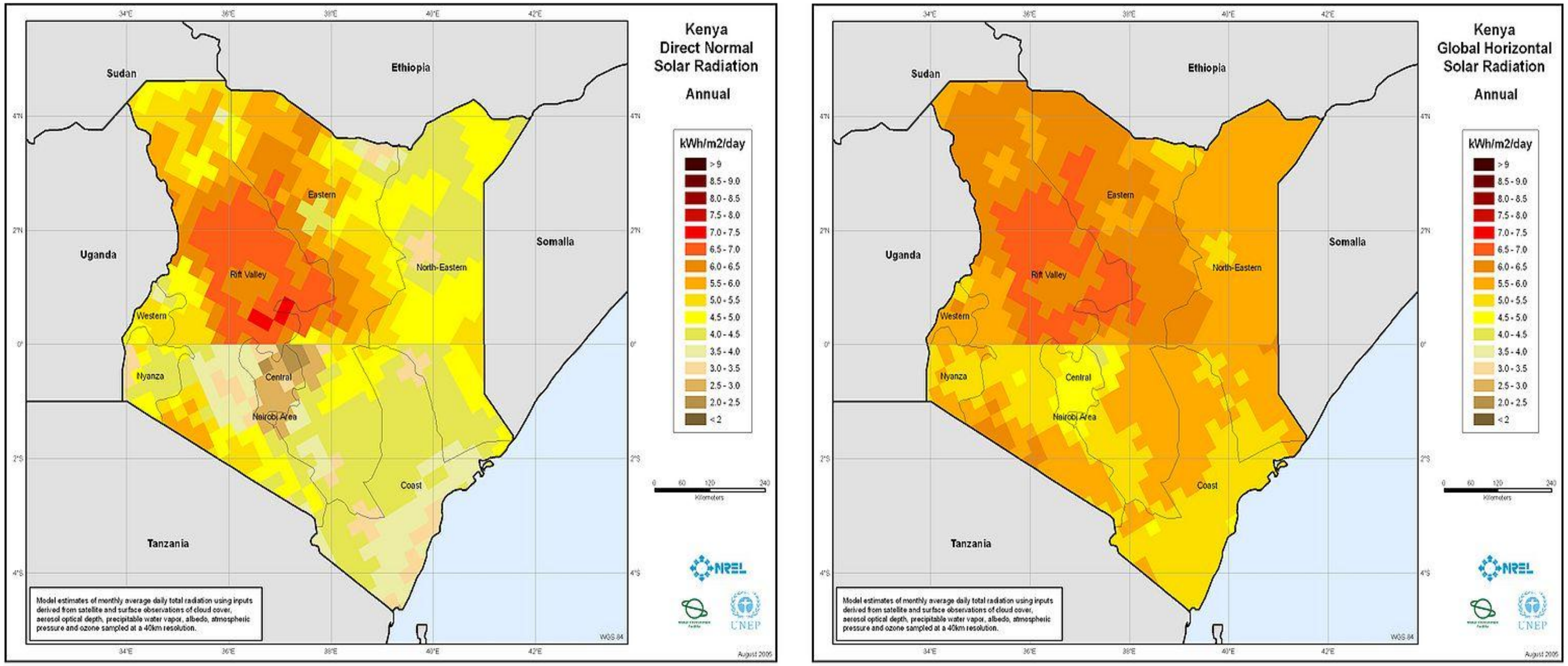
1.1 Forced draft cookstoves

When establishing efficiency of a cookstove, one parameter that must be taken into account is the emissions characteristic of the stove. That is, the amount of carbon monoxide and particulate matter emitted by the cookstove. Efficiency wise, the cookstove should demonstrate ability to lower the time taken to reach boiling point (thermal efficiency) and reduce the amount of fuel within a considerable range against traditional stove. Combustion efficiency is one other component that stove fabricators need to consider, though this in most cases is neglected as losses relating thereto are estimated to be in the range of 1-10%. Nonetheless, consumer preferences tend to affect the characteristics of the stove that is finally released to the market. Some of the key aspects considered under consumer preference include price, ease of ignition, rate of cooking, type of port size supported etc .In this case, a fabricator may end up using cheap materials to lower market price whereas the move may compromise lifespan- another critical consumer preference when buying a stove.

Many households prefer traditional stoves due to their ease in use and time taken to prepare meals. Thus, despite how improved a stove may be, fabricators should ensure that it does not take longer time to cook a meal compared to the traditional one. This has occasionally been witnessed with rocket stoves. This brings us to stoves that have an 'aided' force to increase force of air supply to the combustion chamber in a controlled manner. If fire in the combustion chamber is not well regulated, the stove may end up consuming unnecessary fuel (especially forced draft cookstoves), increasing power output, and decreasing the thermal efficiency. In Kenya, majority of biomass cookstoves have a natural draft even the so called forced draft simply have secondary air holes to force in air at upper levels of combustion chamber but this is not aided by external power supply. As such, this paper investigates utility of two forced draft cookstoves (fun operated with battery as power source) against output from ordinary stove(KCJ).

1.2 Solar energy base in Kenya

Solar energy technologies prove to be the most convenient low carbon technologies that communities could strive for meeting their cooking and lighting requirements alongside a myriad of energy demands at household and industrial levels. Kenya receives 4 – 6 kWh per square meter of insolation per day (Byakola et al, 2009). Thus, according to the direct normal irradiance distribution below(on the map), the area matching delivery of 6.0 kW/m^2 per day in the country is approximately 106,000km^2. This has the potential to deliver 638,790 TWh. Despite this potential, only a small portion is harnessed and converted into utilizable forms. About 220,000 solar (photo voltaic)PV units are in use in Kenya generating 9GWh of electricity. This covers about 1.2% of households in the country. Over the last three years, the number of home systems installed has grown at an average of 20,000 units per annum and the demand is projected to reach 22GWh annually by 2020(Republic of Kenya,2009).



*Source:*NREL

Kenya annual direct normal and annual global horizontal solar irradiance

2. Presentation of field study findings conducted among households in Nakuru, Kenya.

The next section highlights findings from kitchen performance test carried out during the first quarter of 2014 with objectives as specified below;

2.1 Objectives

The main objective of carrying out this field study was to gather qualitative and quantitative energy data regarding performance of integrated domestic energy unit (IDEU) and Philips forced draft cookstoves from households in Nakuru and compare results to performance of ordinary Kenya ceramic jiko owned by majority of residents in the region.

Specific Objectives

2.1.1 To establish the average daily energy requirement for typical households and per capita energy consumption in Nakuru using three models of cookstoves

2.1.2 To estimate the average daily fuel consumption of a typical household in Nakuru region using three distinct stove models

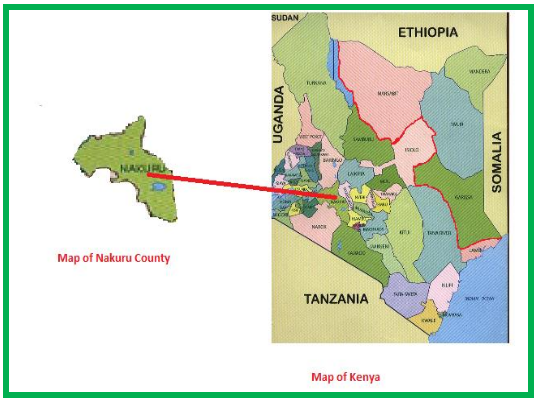
2.1.3 To establish specific fuel consumption of three different stove models in five households in Nakuru using a common cooking characteristic

2.1.4 To gather qualitative information from households on the general performance of Philips and integrated domestic energy unit(IDEU)

3. Materials and Methods

3.1 Area of Study

The tests were carried out in five households in Nakuru, Heshima division. Nakuru County can be located on latitude 0.2833° S and longitude 36.0667° E, in the Rift Valley region of Kenya and has a population of 1,603,325 people, according to 2009 national census. Settlement in the county is mainly made up of rural set ups hence majority of population rely on biomass for energy.



Map showing position of Nakuru County in Kenya

3.2 Data and methodology

Both secondary and primary data were accessed during the study. Secondary data was mainly used during the desk review stage prior to actual field visits in order to understand both social and physical dynamics of the area of study. Procedures used in capturing the data followed the stove testing protocol developed by Approvecho. The five households selected for the tests were identified upon administration of semi-structured questionnaires. Twenty-two participants representing different households were interviewed out of which five were selected.

3.3 Stove models studied

As reflected by the specific objectives above, this study aimed at comparing the kitchen performance of two types of forced draft cookstoves, against the performance of local cookstove used by residents in Nakuru region. The common model of cookstove not only in Nakuru but across the country is Kenya Ceramic Jiko(KCJ).

3.3.1 Kenya ceramic jiko_natural draft cookstove

The Kenya Ceramic Stove, is a charcoal-burning stove with fuel efficiency ranging between 20 - 50% if compared with a traditional three-stone fire (Walubengo, 1995).

Illustration of model 1cookstove (natural draft) used in the study

Display of KCJ jiko

Display of Kuni mbili jiko

The jiko was developed after study of a Thai 'bucket' stove that was examined partially through a 'South-South' dialog over stove characteristics and design (Kamenn D, 1995). According to UNDP(2012), over 50 percent of all urban homes and 16 percent of rural homes in Kenya use KCJ for cooking .

3.3.2 Philips forced draft cookstove

Unlike the KCJ stove, Philips and IDEU mentioned in the next section are forced draft stoves. Philips stove comes with an internally fixed battery and fun that supports oxidation of fuel. The battery is charged using electrical power source using an adopter.

An illustration of model 2 coosktove used in the tests9forced draft)

Display of Philips micro-gasifier

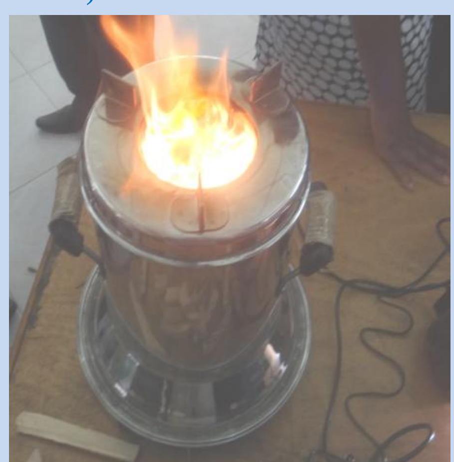
Demonstration session

3.3.3 Integrated Domestic Energy Unit -forced draft cookstove

The integrated domestic energy unit (IDEU micro-gasifier stove) comes with a charge controller along with one light and multi-plug mobile phone charging system. The system includes a solar panel that powers the battery fixed within the charge controller.

An illustration of model 3 cookstove used in the tests (forced draft)

Display of IDEU micro-gasifier stove



Demonstration session

A connector from the charge controller is fixed onto the stove at a jerk-point to the fun. All the three outputs are controlled by individual switches (i.e. the fun, mobile, and bulb connection points).

4. Findings

4.1 Quantitative data findings from kitchen performance (KPT) and Controlled Cooking(CCT) tests

The tables below give a summary of the findings of Kitchen performance and controlled cooking tests carried out during the study. These have been segregated into three categories with respect to the first three specific objectives respectively.

Table 1: Results of the controlled cooking test

Stove Model	Cooking Characteristic	Household	Specific Fuel Consumption(g/kg)	% difference in specific fuel consumption in relation to TERI as ref. model	% cooking time in relation to TERI as ref. model
TERI	White tea	HH002	67	-	-
PHILIPS	White tea		59	11	(-)36
KCJ	White tea		133	(-)99	-21
TERI	Rice +Irish potatoes	HH004	43	-	-
PHILIPS	Rice +Irish potatoes		30	31	(-)10
KCJ	Rice +Irish potatoes		91	(-)110	(-)10
TERI	Porridge	HH003	39	-	-
PHILIPS	Porridge		41	(-)5	(-)19
KCJ	Porridge		42	(-)8	4

Table 2: Daily fuel consumption using respective stove models

<table>
<tr><td colspan="4"></td><td>Daily Fuel Use(kg)</td><td>Fuel use per capita(Kg/person)</td></tr>
<tr><td>House Hold ID</td><td colspan="3">KPT</td><td>Average</td><td>Average</td></tr>
<tr><td rowspan="4">HH001</td><td>Type of fuel</td><td colspan="2">Wood</td><td rowspan="2">3.4</td><td rowspan="2">3.9</td></tr>
<tr><td>Stove Model</td><td colspan="2">KCJ</td></tr>
<tr><td>Type of fuel</td><td colspan="2">Wood</td><td rowspan="2">1.7</td><td rowspan="2">3.8</td></tr>
<tr><td>Stove Model</td><td colspan="2">Philips</td></tr>
<tr><td rowspan="6">HH002</td><td>Type of fuel</td><td rowspan="2">Kuni Mbili</td><td>Maize Cobs</td><td>1.7</td><td>0.5</td></tr>
<tr><td>Stove Model</td><td>Wood</td><td>1.1</td><td>2.7</td></tr>
<tr><td>Type of fuel</td><td colspan="2">Maize cobs</td><td rowspan="2">2.1</td><td rowspan="2">0.6</td></tr>
<tr><td>Stove Model</td><td colspan="2">Philips</td></tr>
<tr><td>Type of fuel</td><td colspan="2">Wood</td><td rowspan="2">1.7</td><td rowspan="2">3.0</td></tr>
<tr><td>Stove Model</td><td colspan="2">IDEU</td></tr>
<tr><td rowspan="6">HH003</td><td>Type of fuel</td><td colspan="2">Charcoal</td><td rowspan="2">1.4</td><td rowspan="2">0.3</td></tr>
<tr><td>Stove Model</td><td colspan="2">KCJ</td></tr>
<tr><td>Type of fuel</td><td colspan="2">Pellets</td><td rowspan="2">1.4</td><td rowspan="2">0.3</td></tr>
<tr><td>Stove Model</td><td colspan="2">Philips</td></tr>
<tr><td>Type of fuel</td><td colspan="2">Charcoal</td><td rowspan="2">0.9</td><td rowspan="2">0.2</td></tr>
<tr><td>Stove Model</td><td colspan="2">IDEU</td></tr>
<tr><td rowspan="5">HH004</td><td>Type of fuel</td><td colspan="2">Charcoal</td><td rowspan="2">1.5</td><td rowspan="2">0.4</td></tr>
<tr><td>Stove Model</td><td colspan="2">KCJ</td></tr>
<tr><td>Type of fuel</td><td colspan="2">Charcoal</td><td rowspan="2">2.0</td><td rowspan="2">0.5</td></tr>
<tr><td>Stove Model</td><td colspan="2">Philips</td></tr>
<tr><td>Type of fuel</td><td colspan="2">Charcoal</td><td>1.0</td><td>0.3</td></tr>
</table>

Table 3: Daily Energy use as a result of using respective stove model

<table>
<tr><td colspan="4"></td><td>Daily energy use (MJ)</td><td>Energy use per capita (MJ/person)</td></tr>
<tr><td>House Hold ID</td><td colspan="3">KPT</td><td>Average</td><td>Average</td></tr>
<tr><td rowspan="4">HH001</td><td>Type of fuel</td><td colspan="2">Wood</td><td rowspan="2">63.6</td><td rowspan="2">11.4</td></tr>
<tr><td>Stove Model</td><td colspan="2">KCJ</td></tr>
<tr><td>Type of fuel</td><td colspan="2">Wood</td><td rowspan="2">31.2</td><td rowspan="2">5.6</td></tr>
<tr><td>Stove Model</td><td colspan="2">Philips</td></tr>
<tr><td rowspan="6">HH002</td><td>Type of fuel</td><td rowspan="2">Kuni Mbili</td><td>Maize Cobs</td><td>26</td><td>6.8</td></tr>
<tr><td>Stove Model</td><td>Wood</td><td>22.2</td><td>5.8</td></tr>
<tr><td>Type of fuel</td><td colspan="2">Maize cobs</td><td rowspan="2">32.0</td><td rowspan="2">8.4</td></tr>
<tr><td>Stove Model</td><td colspan="2">Philips</td></tr>
<tr><td>Type of fuel</td><td colspan="2">Wood</td><td rowspan="2">31.8</td><td rowspan="2">7.6</td></tr>
<tr><td>Stove Model</td><td colspan="2">IDEU</td></tr>
<tr><td rowspan="6">HH003</td><td>Type of fuel</td><td colspan="2">Charcoal</td><td rowspan="2">40.1</td><td rowspan="2">8.7</td></tr>
<tr><td>Stove Model</td><td colspan="2">KCJ</td></tr>
<tr><td>Type of fuel</td><td colspan="2">Pellets</td><td rowspan="2">21.5</td><td rowspan="2">4.7</td></tr>
<tr><td>Stove Model</td><td colspan="2">Philips</td></tr>
<tr><td>Type of fuel</td><td colspan="2">Wood</td><td rowspan="2">26.1</td><td rowspan="2">5.7</td></tr>
<tr><td>Stove Model</td><td colspan="2">IDEU</td></tr>
<tr><td rowspan="6">HH004</td><td>Type of fuel</td><td colspan="2">Charcoal</td><td rowspan="2">42.0</td><td rowspan="2">10.2</td></tr>
<tr><td>Stove Model</td><td colspan="2">KCJ</td></tr>
<tr><td>Type of fuel</td><td colspan="2">Charcoal</td><td rowspan="2">36.3</td><td rowspan="2">8.8</td></tr>
<tr><td>Stove Model</td><td colspan="2">Philips</td></tr>
<tr><td>Type of fuel</td><td colspan="2">Wood</td><td rowspan="2">28.9</td><td rowspan="2">7.1</td></tr>
<tr><td>Stove Model</td><td colspan="2">IDEU</td></tr>
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5. Analysis of the results

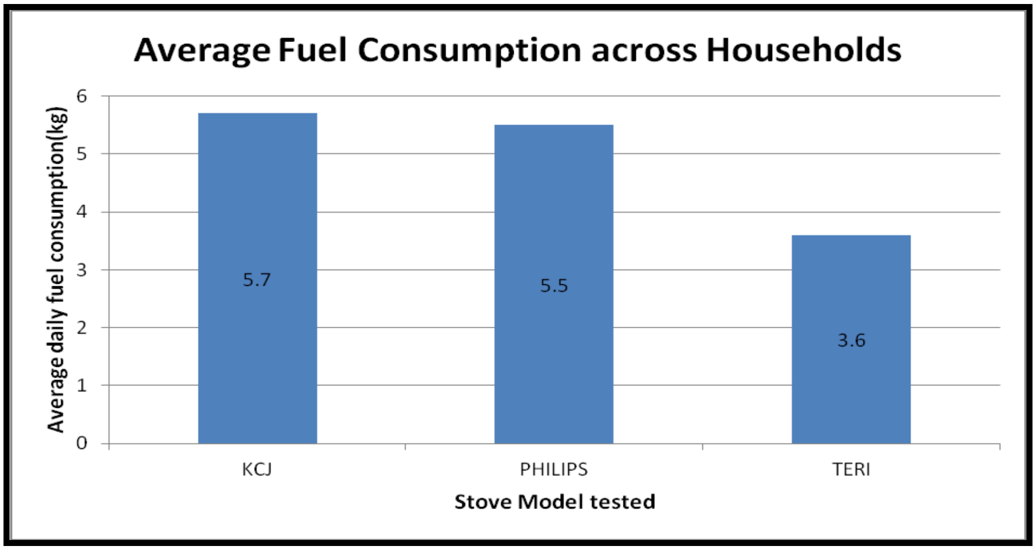
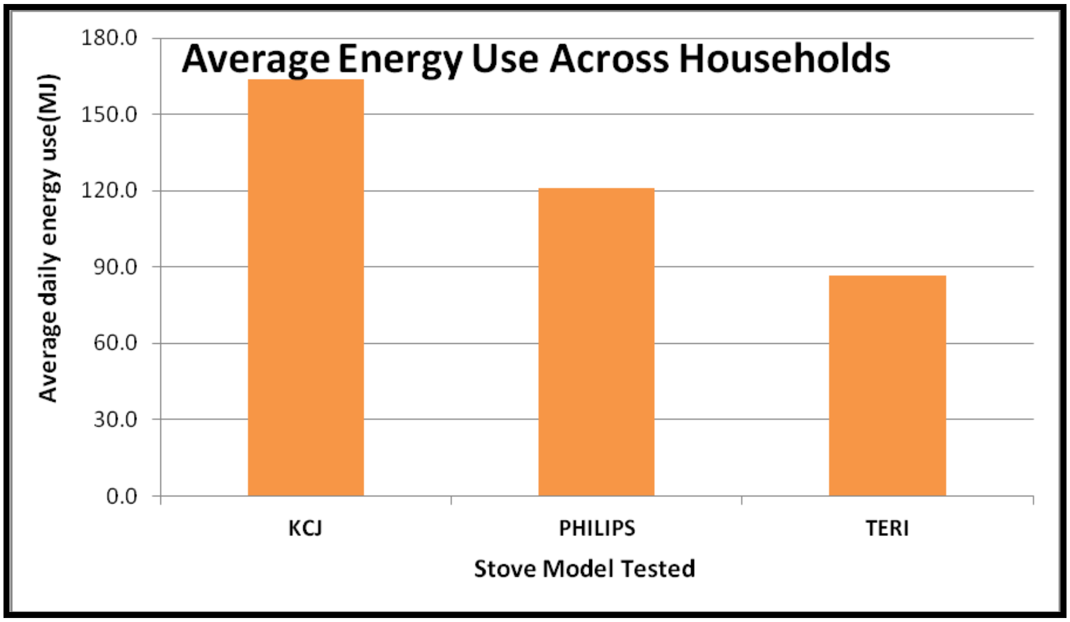
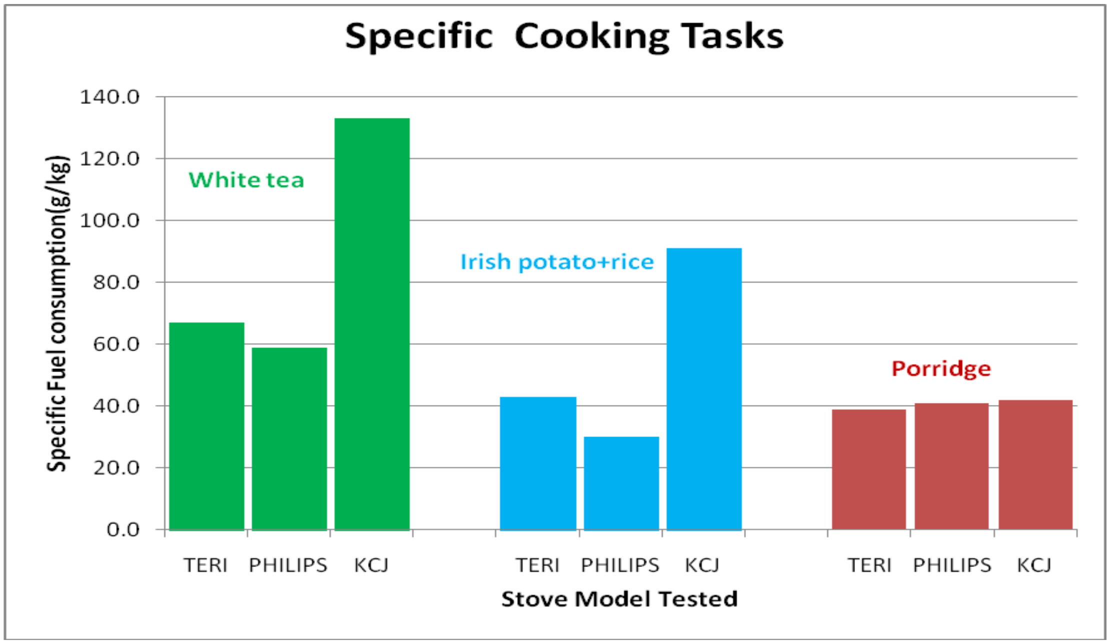


Figure Graph of average daily fuel consumption against stove model tested during KPT



Graph of average daily energy used against stove model tested during KPT



Graph of Specific fuel consumption against stove model tested during CCT

6. Summary of the results

Results from one household were disregarded during the third schedule of the tests after it was noted that there was no consistency in the data from her household (HH005) due to use of multiple stoves at the time of test contrary to test protocol. The quantitative results of the kitchen performance test indicated that IDEU stove is the most fuel efficient, followed by Philips and then the ordinary stove(Kenya ceramic jiko).According to the findings, the average energy needs for a typical household in the region is 48Mj if one is using KCJ,29.9Mj Philips and 28.9Mj for IDEU micro-gasifier stove. Thus, households likely to adopt micro-gasifier cookstoves who are currently using KCJ will save up to 50% of energy wasted when using KCJ.

It should be noted that KCJ is an improved stove hence if the two micro-gasifier models were tested against traditional three stone jiko, the amount of energy saved on average will be over 80%. This can be confidently linked to the ability to enhance complete fuel combustion. It should further be noted that during the study, a mixture of fuel types were used so as not to affect the normal household criteria, that is; based on fuel demand of a given meal, a household would choose to use firewood, charcoal, or maize cobs. On the other hand, controlled cooking test results indicated that KCJ has the highest specific fuel consumption rate, followed by IDEU and

Philips respectively for the different cooking tasks. In this study, three cooking tasks were tested i.e. white tea, porridge, and mixture of Irish potatoes and rice. As such, time and total fuel consumed and mass of meal prepared were determined. On average, KCJ depicted specific fuel consumption (g/kg) of a particular meal as 88.7g/kg, IDEU micro-gasifier as 49.6g/kg and Philips micro-gasifier as 43.3g/kg. Even though various fuel types were used in the study, use of pellets with Philips and IDEU stove depicted the best performance followed by charcoal, wood and maize cobs respectively.

Each stove model was left in the households for a period of one month, one at a time to allow the users to assess any constrains or notable behaviors of the stoves. It was reported that IDEU micro-gasifier stove requires much orientation to use as opposed to Philips and KCJ models. As well, it requires constant solar or AC charging after every meal has been prepared to maintain battery quality. This is contrary to Philips model that once charged, the battery conserves this power for a period of 5-6days. Nevertheless, users preferred the stove to other models since it is fast in cooking, conserves more fuel in comparison to the rest and is integrated with lighting and phone charging systems which make them not to pay for kerosene for lighting nor mobile phone charging fees.

With regard to Philips model, users complained of faster wearing out of the inner lining that eventually makes the stove useless within a short period. Users also reported difficulties in maintaining the air holes whenever clogged. Further, since the stove (Philips) is top loading, the base lining should be constructed in a manner that it does not, burn out when hot charcoal or a wood piece falls on it. Some of the users also considered the stove slow in lighting/picking up and taking more time for cooking than other models. One user reported her sufuria melting out in the process of cooking due to more concentration of flames in the central part instead of spreading out. However, they reported that this model is good when cooking time-consuming meals that do not require presence of on looker as opposed to IDEU model which burns wood quickly. Further, the model (Philips) stores power for a considerable length of time without necessarily requiring charging after every meal.

7. Emission reduction at household level

The Global Energy Assessment (GEA) created a large set of energy transition scenarios which are consistent with the target of 2°C by United Nations Framework for Climate Change(UNFCC). Expansion of carbon capture and storage and renewable energy production such as solar are among the most critical measures for staying within the 2°C target. According to the assessment, if energy demand is not drastically reduced through energy saving and efficiency measures, significantly fewer options remain available for staying within the target range (UNEP 2012).

According to Kenya's National Climate Change Action Plan, 2013 GHG emissions will continue to rise in proportion to the expanding population. GHG emissions are expected to increase from 59 $MtCO_2e$ in 2010 to 102 $MtCO_2e$ in 2030 where 2012 is the base reference. The largest absolute growth in emissions is expected in energy and transport, with energy emissions increasing from 10 $MtCO_2e$ in 2010 to 33 $MtCO_2e$ in 2030 and transport emissions increasing by about three times in the same period. The low carbon analysis indicates a maximum reduction potential of about 15per cent below the 2010 reference base by 2015; and that this reduction potential could grow to almost 70 per cent in 2030. A very positive development in recent years is the significant reduction in the cost of photovoltaic (PV) power generation. At the start of 2012, prices of photovoltaic modules dropped by 50% compared to earlier years (McCrone et al., 2012).

With reference to household test results reported above, all the houses wanted to own the integrated domestic energy unit (IDEU) because of the additional lighting component and mobile phone charging system. It is an encouraging factor among clean energy technology promoters to see rural women accept and appreciate technologies such as this. According to willingness to purchase survey contacted during one of the forums where the stove was introduced within the region, over 95% of the participants were willing to purchase the stove.

Using the case of IDEU and KCJ concerning average fuel consumption from the graphs above, we note that a household using KCJ stove uses 5.7kg of wood. Assuming the same family uses traditional three stone jiko (which is owned by over 98% of rural households, then it would require approximately 9kg of wood. On the other hand, the integrated domestic energy unit (IDEU) uses 3.6kg of wood per day, by the same household. Assuming that two-thirds of households in the region using traditional stove shifted to IDEU (272,924 households), then, 1,474tonnes of wood fuel will be saved in a single day. Extrapolating these values over a one-year period implies 322,806 tones of wood are saved.

Using equation one below 1,

NCV= 19.2-(0.2164*MC)= (y) GJ/t…………………………………………………………(1)

Where NCV is the net calorific value

MC is the Moisture content expressed as a percentage

Energy saved in this case is

$[19.2 - (0.2164*11)*5.31*10^8]/1*10^3$ =5,429,597Gj. ……………………….…………….(2)

This yields energy per capita saving of 5.09Gj.

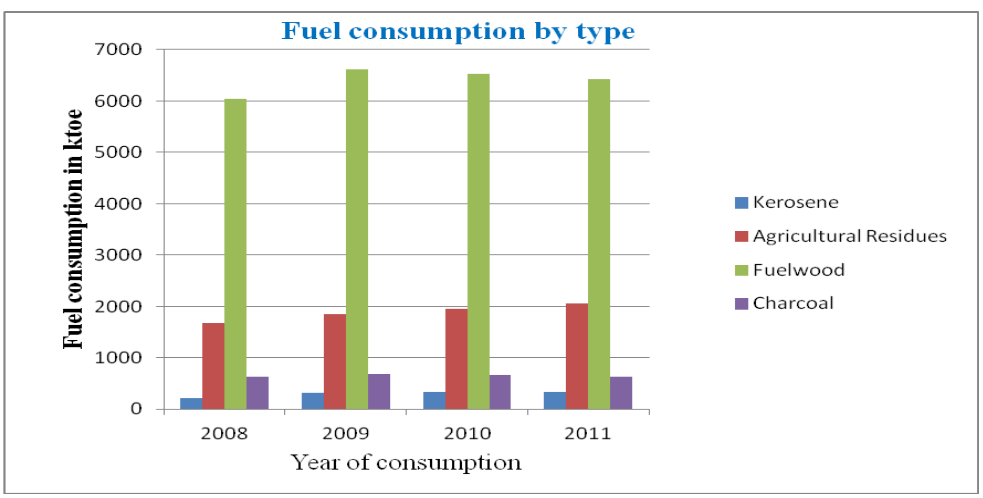
Kenya's energy per capita in 2011 was recorded as 482.1kgoe/a ie 20.28Gj per year. Extrapolating the values in (2) above to national outlook, assuming a half of the population[1] will use efficient systems with equivalent energy saving magnitude realizing the same per capita savings of 5.09Gj a year, reveals that the country will receive a matched boost of 13% oil equivalent relief from its annual expenditure on fossil fuels.

[1] Halving the number of total population able to use systems of equivalent to per capita energy savings here takes care of the vast social and economic impediments to access of IDEU within the population sample of 39 million people

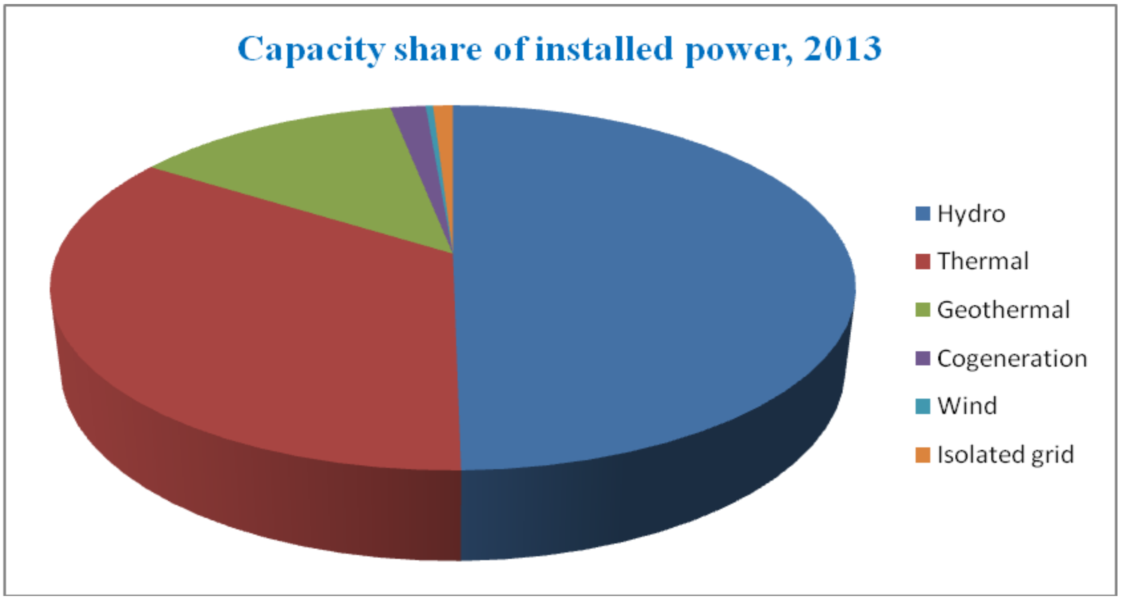
The table below illustrates fuel types commonly used across sectors in Kenya

Type of fuel	setting	Fuel share by Consumer	cooking	Lighting
Kerosene	Urban	58%	-	58%
	Rural	25%	-	25%
	Commercial	11%	-	11%
	Other Industrial	6%	-	0
Fuel wood	Urban	5%	4%	2%
	Rural	80%	68%	8%
	Commercial	10%	8%	0
	Other Industrial	5%	0	0
Agricultural residues	Urban	20%	17%	2%
	Rural	60%	51%	6%
	Commercial	10%	8%	0
	Other Industrial	10%	0	0
Charcoal	Urban	75%	75%	0
	Rural	20%	20%	0
	Commercial	5%	5%	0
	Other Industrial	0	0	0

Adopted from NCCAP, (2013)



National fuel consumbtion between 2008 and 2011.



Installed power capacity in megawatts, data adopted from UNECA 2013.

8. Limitations of the study

The study was limited in terms of arriving at the results especially taking into account that not one type of fuel was used during the study. Various fuels have distinct caloric values hence affects the overall performance of the stove. Further, varying moisture content for the different biomass fuels used could have significant effect on overall efficiency. For the case of forced draft, the heat in the combustion chamber has to first dry the fuel before combustion starts a factor that impairs the performance and sometimes ends up emitting smoke.

9. Conclusion

Introduction of forced draft cookstoves among the rural and peri-urban residents has a positive impact of saving over 80% of fuel against the traditional three stone jiko. Stove fabricators should target stoves that can burn out majority of solid biomass fuels without restriction on type. The aspect of after sales services should be prioritized where new technologies are introduced. For the IDEU model tested in this study, a technician had to visit households that reported difficulties or failure of a component of the system frequently. Somehow, this could be attributed to the technical operations for which the user is acquainted almost the second or third day of using the device. As such, it is very important to consider gender dimensions when designing and disseminating improved cookstoves. Prior to the aforementioned roll out, technicians from nine couties were trained on maintenance of charge controllers and entire stove system that makes up the IDEU forced draft stove. Finally, before introducing stoves to the market, it is significant that user feedback is obtained especially from the target zones where the stoves are to be introduced and socio-cultural as well as physical constrains associated with the technology assessed. There is need for grassroots sensitization on sustainable use of energy resources especially those that promote low carbon development. As Kenya strives towards reducing its emission levels, emphasis on adaptation is critical. Promotion of decentralized energy systems such will not only promote a cleaner environment but also improve service access through micro-enterprise development.

10. Recommendations.

10.1 Technical recommendations

10.1.1 Philips Cookstove

- Fun output should be stepped up
- Air holes to be strategically placed(both primary and secondary)
- Stove should be accompanied by anti-clogging wire to remove ash from the holes
- The base should be raised to suit typical rural households
- Base material should be made of fire resistant material
- Inner lining of the combustion chamber should be made of long lasting material unlike the current one
- Pot holders should be slightly raised and curved to support local needs

10.1.2 Integrated domestic energy Unite (IDEU Cookstove)

- Fuse –operated charge controllers should be replaced by switches
- Stove connecters should be jerk pinned for easier connectivity
- Ample user assistance should be accorded without assumption upon obtaining the stove
- Pot holders should be slightly raised and curved to support local needs
- User precautions should be emphasized especially for the charge controllers and its accessories

10.2 Policy recommendations

- Government need to prioritize solar energy access as part of development targets
- Policy guidelines are required for sustainable development of solar industry
- Appropriate subsidies and incentive programmes need to be devised to support adoption of solar technologies and forced draft cookstoves especially in rural areas.
- An enabling environment through which solar technology actors can enhance their capacity need to be fostered
- Promotion of marketing and awareness creation on ultimate importance of solar technologies and forced draft cookstoves should be emphasized for technicians, entrepreneurs and end – users
- There is need for government to put in place low-interest loans targeting to assist entrepreneurs wishing to start up solar and improved cookstoves enterprises which enhance decentralization of modern energy systems in the long run.
- Potential for solar energy and improved cookstoves to offset GHG emissions need to be emphasized to in initiatives such as Clean Development Mechanism(CDM)
- Government buildings should be constructed with solar sensitive cells instead of plain window pens to cut down on electricity use
- Appropriate policies should be developed requiring all upcoming buildings in cities to install solar far water heating and lighting (at least a reasonable percentage of power supply to originate from solar)

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