# A Survey on the Feasibility of Replacing the Traditional Tripod Cookstoves with Ecostove and Biomass Consumption Profile in Rural Areas of Delta State, Nigeria

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**EXECUTIVE SUMMARY**

In search of cleaner energy, research revealed that biomass (fuel wood) can be a suitable energy source for the future given its low $CO_2$ emission potential and carbon neutrality. To harness its energy efficiently and economically, a new technology called Ecostove has been innovated and ready to be deployed massively into the rural areas of Delta State, Nigeria to replace the existing inefficient tripod cookstove. This study was instituted to assess its acceptability and devise approaches to its successful introduction. Such mass technological acquisition especially one coming on the backdrop of global environmental regulation as this has to be properly directed to achieve its intended results.

The study was conducted across a select group of rural communities from each of the three senatorial districts of the state. This choice was informed by the high pool of fuelwood users within these rural populations hence the primary target for the Ecostove project. In all, 1,630 households were involved and germanely structured and close-ended polls were given to them to elicit substantial information and data that would be subsequently used in monitoring the progress of the Ecostove project.

The study proved that the dominant fuel type in use in rural communities of the State is fuelwood accounting for about 72% of fuels use. It also showed the mean fuelwood consumption rate is dancing around 11.5kg/day per household. Such elevated value is the consequence of the inefficient combustion using the traditional open tripod stove, ultimately resulting in high $CO_2$ emissions index of about 2.7million tons per annum for the State with respect to fuelwood. With the introduction of Ecostove with its improved efficiency and thermodynamic properties, such value would drop to approximately 1.4millions tons per annum.

Such values when combined with other right actions like energy efficiency practices would reduce total emissions to safety levels.

Also, intended market survey for ecostove returned with favourable results and these would form the basal figures and anchor for subsequent efforts. In one such poll, respondents were asked to indicate their desires to own Ecostove. The result? Over 70% expressed their interest in the novel product. This is an encouraging figure given human conservativeness to change.

Non-quantitative information and observations that hold waters in their own right were also made during the study and these share almost equal weights in positively influencing the implementation of this initiative with our hard data pool as well. A detail observation revealed the availability of clay deposit, the chief constructing material, in exploitable locations across the State. These deposits can be surface or subsurface.

From the findings, the rural communities appear ready for the introduction of solution providing cookstove given the level of displeasure expressed against tripod cookstove. Such displeasure ranges from environmental hazard, through after use cleaning task to too much fuelwood intake. Typical environmental hazards are surrounding heat that brings discomfort while cooking; fly ash and unhealthy indoor emissions.

By dissociating the use of fuelwood in present time from the tradition and culture inherited, the people proved readiness to continue the use of this easily sourced fuel for time beyond prediction even in the face of the predicted economic development and civilisation in the rural communities. However, a potential drift away from fuelwood is still possible and therefore must be considered in long term plans.

However, certain degree of inefficiency attributable to human factor was revealed by the study. This shows that users sometimes contribute to the overall inefficiency of fuelwood consumption. Therefore, emphasis must also be channelled to general energy efficiency sensitisation and campaign programme as a promising solution to climate change and overall economic development of individuals and the nation in general.

## ACKNOWLEDGEMENT

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The contributory efforts of Engr. Henry Anioje and Mr. Emmanuel Ebieh are also recognised. We hold a special thanks to Patrick Ichipi-Ifukor for his contributions and in data computation and analysis. Our profound gratitude goes to Mr. Kemmcho of National Population Commission, Asaba for providing the necessary data on population figures and other demographic information that were used in our extrapolations.

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# LIST OF ABBREVIATIONS

| | |
|---|---|
| Btu | British Thermal Unit |
| CFL | Compact Fluorescent Lamp |
| $CO_2$ | Carbon dioxide |
| GHG | Greenhouse Gas |
| HTE | Heat Transfer Efficiency |
| KWh | Kilowatt-hour |
| LED | Light-Emitting Diode |
| LULUCF | Land Use Land Use Changes and Forestry |
| MCE | Modified Combustion Efficiency |
| MJ | Millijoule |
| NPC | National Population Commission |
| OTE | Overall Thermal Efficiency |
| TACC | Territorial Approach to Climate Change |
| WBT | Water Boil Test |

# CHAPTER ONE

# INTRODUCTION

## 1.1 Background of the study

Prior to the invention of fire, man relied on the four natural sources of energy that we call, today, renewable energy – the solar energy from the sun, hydropower from water, wind power and geothermal power derived from underground. These sources were frugally exploited by plants and animals in nature to maintain a balanced ecosystem.

Following the invention of fire by the early man, fuel wood became the major source of energy and the foundation for technological advancement in human history. The enormous dependence on fuelwood was informed by man's desire to generate energy at point source and when needed. The usage of fuel wood became popular since pre-historic time because it is a readily available source of heat energy at any location and time.

When man realised the dangerous changes in climate, the usage of wood (biomass) suffered criticism on the ground of tremendous loss of earth green cover and excessive emission of greenhouse gases (GHG). However, recent studies have discredited this claim against wood usage on scientific grounds as a stoichiometric analysis of the making of biomass during photosynthesis and degradation during combustion indicates carbon neutrality; that means net atmospheric carbon change is zero. Any net emission is therefore rather dependent on differences in the rates of these two processes. Upsetting this near natural stoichiometric balance in the favour of wood combustion as we have witnessed in recent times may trigger some unforeseen environmental problems that may be difficult to contend with. Hence, there is growing concern on the rate of felling and consumption of woods across the horizon; a fear that truly has its basis.

Major efforts to increase the exploitation of renewable energy are becoming the talk of the day across the globe. Remarkable strides are also being made to conserve energy resources by increasing the efficiency of their production and utilisation processes. Biomass usage is not being left out in such initiatives. It is hoped that enhancing the efficiency of popular biomass utilization machines will greatly reduce the total quantity of biomass consumption and hence retard its rate of degradation. This would consequently reduce the associated volume of greenhouse emissions and the resulting loss of green cover. The carbon payback period also puts into account all the associated activities, energy expended and emissions in the biomass procurement (Hitchen, 2013).

Experts have attributed the sudden rise in greenhouse emission to the geometric rise in world population, the ever increasing thirst for energy, and the significant inefficiencies associated with energy conversion and transfer processes (especially in thermodynamic systems). Energy conversion and utilisation in all human technological processes rarely exceed 60% efficiency. This phenomenon is still a nightmare for power plant engineers as new gas-fired power plants (single cycle) only command about 35% efficiency but can be improved to about 55% in combined cycle (gas and steam turbine) as unveiled by PEI Report, 2013. Jetter et al (2012) reported low efficiencies of 15% and 50% for traditional tripod cookstoves and eco-stoves respectively. Such differences in overall performances of these machines come from improved combustion and heat transfer efficiency.

Biomass is the major source of energy in Delta State with the rural residents constituting substantial percentage of the users. A quick survey conducted in a typical rural village to establish fuel wood consumption pattern showed that average rural household burns about 11.5kg of wood daily using open tripod cookstove. Such rate would quickly strip lands of their forest covers and bring about the adverse and long-ranging environmental outcomes in the long term. To this end, Department of Climate Change, Delta State Ministry of Environment through Territorial Approach to Climate Change (TACC) programme seeks to save the situation via a widespread introduction of efficient fuelwood cookstoves called Eco-stove. It burns more efficiently requiring less woods, has limited GHG emissions, and more enhanced thermodynamic properties. Without underestimating the reluctance of the masses to accept new technology, this study aims to ascertain the possibilities of making eco-stove the main fuel wood cookstove in rural areas of Delta State while building a reliable and evidence-based data bank on the biomass consumption profile which will serve as veritable tools in measuring the degree of success of the eco-stove project. Therefore the following objectives have been set.

However, usage of biomass fuel (wood fuel) for commercial purposes such as agro-products processing is not included in this study.

## 1.2 OBJECTIVES

1 To determine the usage patterns of the various fuels for household needs in Delta State.

2 To determine the perception of costs in the usage of the various fuels for household requirements in Delta State.

3 To estimate the biomass energy consumption profile for household needs which may be relevant for economic and environmental planning in Delta State.

4 To assess the acceptability and willingness of users of the traditional fuel wood open tripod cookstove to adopt the new eco-stove (market evaluation).

5 To assess the end-users' level of awareness of climate change

6 To identify any possible hindrances to the effective deployment of resources encouraging the popular usage of the eco-stove.

## 1.3 Justification of the study

Establishing the biomass consumption profile for households cooking needs in Delta State can be quite important. Upon completion, this study would provide the Team with evidence-based data on the biomass consumption and $CO_2$ emission profile from fuelwood cookstoves. This will serve as a baseline data for projection and measurement of reduction in $CO_2$ emission over time. Furthermore, this study when done will guide properly on the institution of ecostove usage across the state by revealing the possible hindrances to its popular use and acceptability.

## 1.4 BENEFITS OF ECOSTOVE

Usually, residents of rural communities burn enormous amounts of biomass in the tripod cookstove, generating great deal of greenhouse gases that cause climate change and indoor pollution. Sustained extraction of biomass has caused the depletion of earth green cover and the destruction of forest ecosystems. So much energy and time is spent on fuelwood as women and children explore deeper into the forest to gather and haul these fuelwood through long distances. The general experience of rural residents is unprecedented decline of fuelwood resources so that it has become pricier than before.

The replacement of the existing inefficient tripod cookstove with efficient Ecostove will substantially reduce the GHG emission associated with cooking. About 60% reduction in fuelwood usage on daily basis will translate to improved living standard and conservation of forest thereby enhancing carbon dioxide sequestration.

As the world tends towards low carbon economy, any infinitesimal reduction in GHG emission or increase in sequestration is very significant. Through this project, these two phenomena will produce synergistic results as highlighted below:

- A reduction in daily consumption of fuelwood by about 60% will cut a significant amount of GHG being released through biomass cookstove
- Conservation of the forest ecological system and biodiversity

- Boosting the sequestration potentials of the green cover
- As combustion efficiency is improved in the new eco-stove and flue gas channelled out through chimney, indoor air pollution known to cause respiratory and eye problems, will be reduced to near zero.
- The time and energy spent by women and children (particularly the girl-child) will be saved for other life-improving activities (eg studying, social events etc).
- Kitchen that used to be untidy due to smoke, ash and bulky fuelwood will become tidy and ergonomic.
- Incidence of fire burn, irrespective of degree, will greatly be minimised through this project.
- Job opportunities would be created through this project, especially during the implementation as more technicians will be needed to meet with the supply within the project time-frame.
- Money will be saved from the reduction in the fuelwood consumed
- As the technology of eco-stove gains popularity as predicted, users of other cooking fuel will come to embrace eco-stove. This will open up the market for eco-stove makers and fuelwood vendors.

## 1.5 RESEARCH PROBLEM AND QUESTION

This study seeks to answer the critical questions besetting the ecostove project. The relevant study questions include but not restricted to the following:

- Which is the most widely used cookstove and fuel in rural areas of Delta State?
- What informed the wide acceptance of this stove?

- Will the rural residents adopt the more efficient eco-stove?
- What is the users' perception of the relative cost of biomass and its availability?
- What quantity of fuelwood is consumed daily and annually given the estimated population by National Population Commission figures?
- Why fuelwood is the most preferred despite the claims of unsustainable depletion of wood in the nearby bushland?

# CHAPTER TWO

# LITERATURE

## 2.1 FUEL WOOD COMPOSITION

Fuel wood, collectively called biomass, consists chiefly of cellulose (42%), lignin (15-35%) and ash (0.5%). The remainder is moisture content in varying amounts.

Cellulose: $(C_6H_{10}O_5)_n$

Lignin: $C_9H_{10}O_2$, $C_{10}H_{12}O_3$, $C_{11}H_{14}O_4$

These complex organic compounds render wood about 50% of carbon, 6% of hydrogen and 44% of oxygen with latent energy of about 20MJ per Kg of wood.

When fuel wood burns, the carbon content is converted to carbon (IV) oxide and the hydrogen to water with the energy content released. However, insufficient air (oxygen) supply results in incomplete combustions which produce unwanted smoke, methane, tar, charcoal and other flue gas.

By law of conservation of energy which states that energy is neither created nor destroyed but changes from one form to another, the chemical energy content of wood should be converted 100% to heat energy through combustion process under ideal conditions. However, in all energy conversion and utilisation processes, either by machine or direct heating, efficiency rarely exceeds 60%.

## 2.2 ENERGY ANALYSIS OF FUEL WOOD

Fuel wood contains primary energy. This energy was captured from the solar energy during photosynthesis and locked up in the intra-molecular bonds of the complex organic compounds in the tissue of the wood. The energy contents of fuel wood averages around 20MJ/kg or 8600btu/lb (5.5KWh) for hardwood and 21MJ/kg or 9000btu/lb for softwood (Rick Curkeet, 2011). The 21MJ from 1kg of softwood is enough energy to power a unit of refrigerator, 1HP air conditional unit, 32inches LCD television set, a decoder, 7 CFL light bulbs and 3 ceiling fans at once for approximately 3hrs.

By implication, 1kg of commonly available softwood in Delta State will generate equivalent 21MJ of heat energy required to boil 67 litres of water from 25$^{o}$C (ambient temperature) irrespective of duration, assuming no heat loss. In other words, 2 litres of water will require 630KJ of heat, equivalent to 39g of softwood, assuming 100% combustion and thermal efficiency.

However, the best efficiency level one can achieve in the process from combustion to heat transfer is 50% using eco-stove and 15% with the tripod cookstove. This implies that the popular tripod cookstove will require excess of 4.2MJ representing 200g of wood to boil the same 2 litres of water. With eco-stove, 122g of wood or 2.94MJ energy will be saved in the process. This figure seems insignificant but when interpreted with population index of fuel wood users, and considering the quantity and pattern of cooking, a large mass of wood would be saved per annum.

Efficiency in cookstoves is a function of combustion efficiency and thermal efficiency. While combustion efficiency investigates the degree of burning of fuel wood, thermal efficiency explains the actual amount of heat energy utilised from the total energy generated.

Some of the factors that determine combustion efficiency include air supply, surface area of fuel wood, nature of wood and moisture content. Therefore, any stove design must ensure adequate air supply and use of smaller diameter of wood. In the case of thermal efficiency, heat escape route and thermal conductivity of the stove fabricating material are considered. The design must minimize heat loss by conduction and convection via escape route while maintaining a healthy exhaust outlet.

## 2.3 EMISSION ANALYSIS OF FUELS

Ideally, all chemicals are fuel owing to the chemical bond holding atoms together. These chemical bonds possess energy called chemical energy which is released under suitable reaction conditions. Combustion is one of the easy routes of releasing this enormous energy locked in chemical bonds.

While all chemical compounds can be considered fuel, carbon (organic) compounds lead the way as a result of:

- Ease of conversion (combustibility)
- Availability
- High energy content
- Ease of handling

As mentioned earlier, about 50% mass of wood is carbon (Lamlom and Savidge, 2003). This amount of carbon is released into atmosphere in its oxides during combustion process. From the foregoing analysis, 200g of wood in tripod stove will yield 367g of $CO_2$. Use of eco-stove reduces fuel wood and its emissions.

Decaying wood produces the same amount of $CO_2$ it captured during its growth, though in a slower rate. Therefore, it is economic waste and environmental pollution to allow dead wood to decay. Furthermore, very old trees produce enough $CO_2$ than withdraw. Researchers concluded that the carbon sink potential of trees decreases with age. This phenomenon is informed by frequent shedding of leaves and branches with no further observable growth both in trunk girth and height. Consequently, felling aged trees for economic purposes saves the environment.

*Table 2.1: Emission Factors of common Fuels*

<table>
<tr><th>Fuel</th><th>CO2 Emission Factor</th><td rowspan="7">Note that emission is a function of actual fuel quantity used. By far, fuelwood is consumed more therefore emitting more than any other fuel.</td></tr>
<tr><td>Cooking Gas (Propane)</td><td>1.4kg-$CO_2$/litre</td></tr>
<tr><td>Natural Gas (methane)</td><td>5.4kg-$CO_2$/ccf</td></tr>
<tr><td>Kerosene</td><td>2.5kg-$CO_2$/litre</td></tr>
<tr><td>Gasoline</td><td>2.2kg-$CO_2$/litre</td></tr>
<tr><td>Diesel</td><td>2.5kg-$CO_2$/litre</td></tr>
<tr><td>Fuelwood (15% water)</td><td>1.8kg-$CO_2$/kg</td></tr>
</table>

*Adapted from www.engineeringtoolbox.com/co2 emission by fuel*

## 2.4 REVIEW OF EMISSION STATUS

Globally, $CO_2$ emission has increased by 3% in 2011, reaching an all-time high of 34billion tonnes (KAPSARC, 2012). Major contributors to the high figure are the power sector, transportation sector, agricultural sector and host of others. In developed countries, power and transport lead in $CO_2$ emission.

Looking at the Nigerian scene, total emission as at 2010 stood at around 78.9 million tons. Transportation sector seemed to be the major contributor with a figure of about 23.58 million tons; followed by electricity and heating that maintained 18.11mtons as at 2011. Residential and industrial sectors contribute some 2.33 and 4.32mtons respectively (World Bank Indicator, 2010 and 2011).

Owing to the poor state of power sector in Nigeria, $CO_2$ contribution from the sector is low at about 3% as revealed in Nigeria's First National Communication under UNFCCC (2003). However, if all the household power generation capacity is accounted for, this figure will certainly be up. More so, proper account of fuelwood consumption as major energy source to households and its emission index is usually neglected by experts. From table 2.2 and the chart that follows, Gas flaring contributes hugely too to the total emission.

*Table 2.2: Sectoral Emission Index in Nigeria*

| SECTORS | % $CO_2$ Emission |
|---|---|
| Electricity Gen. | 3 |
| Gas Flaring | 30 |
| Transport | 20 |
| Industrial Process | 1 |
| Other Energy | 6 |
| LULUCF | 40 |

*Adapted from First Nigeria National Communication, Under UNFCCC (2003)*

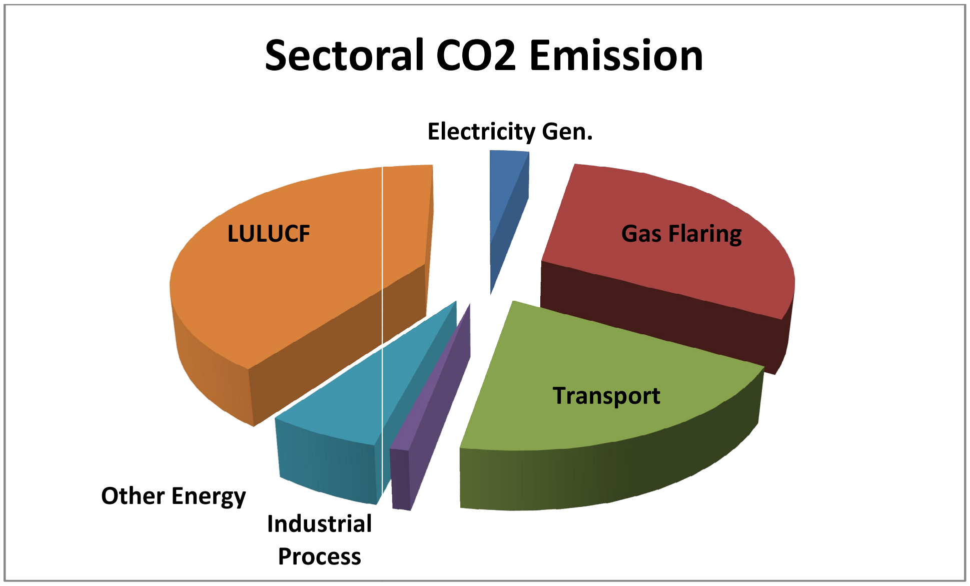


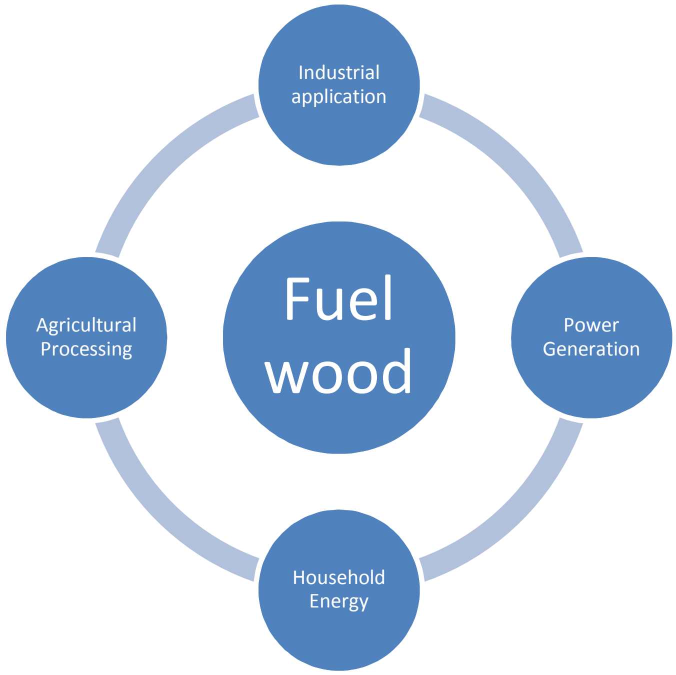

*Fig 2.1: Sectoral Carbon dioxide Emission*

Undoubtedly, fuelwood is the basic source of energy to the rural residents and often in the urban areas. The usage of fuelwood adds substantial amount of carbon dioxide to the atmosphere but often goes unnoticed in total emission calculations. Based on the 50% carbon composition of fuelwood, the emission potential is calculated as 1kg of fuelwood to generate 1.83kg of carbon dioxide.

Using the popular tripod cookstoves which consume averagely 11.5kg of fuelwood per day by typical household of five with cooking pattern of three times per day, an estimated 18kg of carbon dioxide is released.

## 2.5 FUELWOOD USAGE AND DEMAND

The use of fuelwood as major source of energy dates back to the period of the early man. Fuelwood achieved this status of use because of its availability and ease of conversion to heat energy. Fuelwood has sustained and supplied the energy need of households in both developing and developed countries for ages. Households rely heavily on this seemingly renewable energy source for survival.




Before now, fuelwood has only been used for cooking and heating. The development of biomass power plant has placed a huge demand on fuelwood. Therefore, fuelwood is heavily used in major areas – power generation, household cooking/heating, industrial processes and agricultural processes.

At the rural level, fuelwood remains the major energy. It serves almost all of their daily energy need ranging from cooking to processing of agricultural produce. Biomass consumption by the rural areas is predominantly renewable rather than non-renewable biomass.

Simply put; biomass is considered renewable if the producing land area continues to grow plants and non-renewable if the area is cleared permanently for other projects.

Generally, biomass is renewable energy based on its tendency to regenerate within practical human time. It is also a clean energy source; thanks to its carbon neutrality (approximately equal rate of sequestration and production of carbon dioxide). When used efficiently, biomass poses no threat to the climate condition and the ecological system in general.

## 2.6 ENERGY EFFICIENCY

Energy efficiency is the ratio of energy output (net energy used) to energy input (total energy content of fuel burnt) expressed in percentage. There is no machine that can achieve efficiency of 100%; not even human system. Inefficiency means much fuel will have to be burnt to produce the needed energy. Different machines have different rated efficiencies.

The degree of inefficiency in energy utilisation is a problem globally, and it is the main cause of climate change. But the question is; how? Virtually all energy need of man is met by burning of fuels (mostly fossil fuel and biomass). Due to inefficiency, excess fuel is burnt to generate a certain amount of energy, leading to excess emission of GHGs. The overall energy inefficiency is deeply rooted in the general approach of the public to energy consumption.


In addition to the inefficiency of machines, human factors invariably contribute immensely to overall inefficiency. Fuel wastage can be committed knowingly or otherwise.

Cooking requires energy that comes from fuels which possess high potential to add carbon dioxide and other greenhouse gases to the atmosphere. Household contribution to the increase in concentrations of the greenhouse gases is becoming environmental threat. Cooking alone commands higher share of domestic contribution. Unarguably, there is high level of inefficiency in the usage of the various cooking fuels. These range from time and energy wastage to use of inefficient cookstoves. The result is unwanted release of excessive carbon dioxide into the atmosphere.

## 2.7 ECOSTOVE TECHNOLOGY AND DESIGN

Several Ecostove models have so far been developed. All of them share almost the same technological design but different shapes, features and performances. The fundamental operational principle of Ecostove lies on a controlled combustion and improved thermal efficiency. Over 20 models have been certified with several locally made models in operation in developing nations.

The construction of typical Ecostove follows a simple principle as described below. Locally, it is made from clay and sawdust (clay only can serve), and has four major components namely: Fuelwood feeding inlet, Combustion Chamber, Cooking point and Chimney (optional) as shown in Figure 2.2 below. The fuelwood inlet bore leads into the combustion chamber known as the firebox whose wall ideally has a high insulating and reflective surface to conserve and keep the fire hot (above 650C). Internally located above this chamber is the smoke outlet through which a chimney is connected to the outside of the house for flue gas discharge. Also below the firebox are other air outlets to encourage convectional air current for smooth combustion. On top of the stove is firebox opening for placing the cooking pot. Optionally, a soot can is attached along the side of the smoke outlet to clean the soot that gathers there periodically.

Fuelwood is pushed into the firebox through the feed opening a little at a time to ensure its complete combustion and limit the amount of wood oil being driven off at any given time. A netted shelf may be used to support the woods inside the feed to further encourage airflow below it. Cool air rich in oxygen now enters from below the fire and sustains the combustion while hot air containing the smoke (the unburnt gaseous fuel) rises and streams out through the upper smoke outlet. The design of the firebox ensures the refocusing of released heat to reinforce the burning of the wood to completion. Finally, it burns efficiently leaving little charcoal, and releasing heat that is well insulated and more focused on the cooking pot through the upper firebox aperture.

Fig 2.2: A Collection of Produced Ecostoves in the Pilot Scheme

### 2.7.1 PERFORMANCE PARAMETERS OF ECOSTOVE

Investigation into the efficiency of these models is well documented by Jetter et al (2012). Testing of these ecostoves was performed under laboratory and typical field conditions using various fuel types and in both wet and dry conditions. It was typically a comparative study with the old tripod cookstoves. Several parameters are usually considered in this kind of test to ascertain the efficiency.

These include Modified Combustion Efficiency (MCE), Heat Transfer Efficiency (HTE), Overall Thermal Efficiency (OTE), Water Boil Test (WBT). Others include fuel burning rate, time to boil water and power.

**Modified Combustion Efficiency (MCE):** This indicates how well fuel is burned, i.e., how much of the potential energy in the fuel is converted to heat and radiant energy. Incomplete combustion produces and emits fuel like methane and carbon monoxide which are as well dangerous gases. Therefore, a detail study of MCE would include all the carbon in the products of incomplete combustion, and actual combustion efficiency would weigh the products of incomplete combustion by their remaining potential chemical energy. From research, pelletised dry wood produces the best MCE so that using logs of wood in either stove bring about lower MCE.

**Heat Transfer Efficiency (THE):** This is the ratio of energy delivered to the cooking pot versus the total heat energy released from the fuel combustion. Though heat loss is inevitable but can be reduced. Ecostoves are primarily designed to minimize heat loss. Heat loss is the major technical flop of tripod cookstove and it’s the gain of Ecostove. Often, thermally insulating materials are used to construct Ecostove for this purpose.

**Overall Thermal Efficiency (OTE):** This is the combined efficiencies of heat transfer and fuel combustion, and directly relates approximately as:

$$OTE = MCE \text{ x } HTE$$

Emissions of pollutants (in products of incomplete combustion) that harm health are a strong function of MCE. It is important to distinguish the internal efficiencies, MCE and HTE, because these are sensitive to different kinds of design parameters. Many so-called improved stoves in the past, for example, increased OTE (lowered fuel use) by improving HTE (improved heat transfer to the pot), but in the process reduced MCE, thereby actually increasing emissions per meal or per mass of fuel.

Tripod cookstove has the advantage of sufficient supply of oxygen during combustion which translates to lower CO emission and subsequently higher MCE. On the other hand, a perfectly designed Ecostove has proper aeration as open tripod cookstove value with a corresponding increase in HTE value. A well designed Ecostove balances MCE and HTE to achieve a greater OTE. The table below shows the technical data of tripod stove and Ecostove as investigated by Jetter et al (2012)

*Table 2.3: Technical data of Ecostove and Tripod cookstove*

| **Parameter** | **Tripod** | **Ecostove** | **Remark** |
|---|---|---|---|
| MCE | 96% | 96% | |
| OTE | 14.8% | 35 – 52% | |
| Fuel burning rate (g/min) | 27.9 | 9 – 18 | |

*Adapted from Jetter et al (2012)*

# CHAPTER THREE

# STUDY METHODOLOGY

## 3.1 Study Area

Delta State is administratively divided into 25 LGA with an aggregate population of over 4 million people according to the last 2006 population census figure by National Population Commission.

The state is characterised by diverse ethnic cultural background which can influence variations in cooking pattern.

The study was aimed at rural villages where fuelwood is prevailing and may maintain the trend for an extended period. Fuelwood serves the basic energy need of these people in terms of cooking and heating. This level of reliance can be attributed to proximity and availability of fuelwood to the people.

Farming remains the major occupation of the rural dwellers. Averagely, farming operation remains at subsistence level using crude method and with low yield thereby making income generation level poor. By this fact, the rural people can be comfortably categorised into the low income class.

As income saving measure, they prefer using fuelwood that is obtained freely from farm land to other alternative fuels despite their desire to live like their counterparts in the urban areas. Few of them gather the courage to use other fuels and cookstoves despite its relative cost to fuelwood.

Virtually all the rural residents use the traditional tripod cookstove. This stove consumes a lot of wood and produces indoor emission that they are not comfortable with. This led to the separation of kitchen from main building in the rural setting. However, a very few of them use Ecostove without the awareness of its environmental and economic benefit. These so-called Ecostoves were built with deviations from standard specification and design thereby defeating the aims.

*Fig 3.1: Tripod cookstove in use*

The growing demand of fuelwood by the urban dweller for commercial activities and the quest by the rural people to meet with financial obligations has generated another trend in consumption and extraction of fuelwood.

The rural villagers now see this as a new line of business in addition to farming. They are the supplier of this seemingly renewable energy.

A

*Fig 3.2a-c: Typical fuelwood ready for sale by rural people*

B

C

## 3.2 Sample Design and Data Analysis

Representative sample was drawn from the three senatorial districts of Delta State with effective coverage of diverse ethnic cultures across the State. In all, total of effective 1,630 people from 25 rural village clusters participated in the study by consenting to be interviewed.

Participants were principally women between the ages of 35 – 60. Selection of respondents was randomly made without prior knowledge of or considering the cooking fuel in use by the household and the household size. This method was informed by the desire to obtain representative result that can be considered true state of the rural setting.

All data analyses were performed using Microsoft Excel spreadsheet and presented in percentages and graph chart where applicable. Non-response variables were where as well considered in the data analysis.

Responses provided in Section E of the questionnaire were not enough to generate working tool. Most of the respondents displayed some form of discomfort in counting and supplying information on other households in the neighbourhood. As a result, this section was neglected in the analysis and population figure by NPC was used in lieu.

## 3.3 Questionnaire Design

The questionnaire used in this study was designed and presented to the Department of Climate Change, Ministry of Environment for vetting and approval.

The questionnaire which was targeted at rural and suburb dwellers was designed to obtain information in the following sections.

*Section A*: This will obtain general information of the respondent

*Section B*: In this section, the level of awareness in the subject of climate change will be measured.

*Section C*: This section will investigate the prevailing cooking fuel with ultimate concentration on fuel wood. Assessment of the level of awareness of the environmental, health and economic implications of uncontrolled usage of fuel wood will be evaluated.

*Section D*: Under this section, the readiness of the fuel wood users to switch to the proposed Eco-stove will be assessed

*Section E*: Information on the fuel wood usage pattern, population and number of households in respondents' neighbourhood/street will be obtained via this section.

## 3.4 SECONDARY DATA

The population data was obtained from the National Population Commission, Asaba. These data was updated using the NPC projected growth rate of 2.9% annually. Relevant documented literatures and oral conversation were also used.

# CHAPTER FOUR

# RESULTS AND DISCUSSION

## 4.1 GENERAL INFORMATION

The demographic information of the rural communities of Delta State is presented in the table below.

Table 4.1: ***Demographic Characteristics of Rural Areas of Delta State***

| | | (Percent) |
|---|---|---|
| **Occupation** | Farming | 77 |
| | Trading | 13 |
| | Civil Service | 7 |
| | Others | 3 |
| **Household size** | 1 – 2 | 13.6 |
| | 3 – 5 | 35.4 |
| | Above 5 | 51.0 |
| **Age** | 20 – 30 | 14.3 |
| | 31 – 40 | 34.5 |
| | 41 – 50 | 40.0 |
| | Above 50 | 11.2 |
| **Level of Education** | Primary | 40.3 |
| | Secondary | 25.4 |
| | NCE/OND | 17.5 |
| | HND/BSc | 14.6 |
| | PG | 2.2 |

The Table shows the distribution of an adult population in the rural areas of Delta State whose main occupation is farming with household sizes averaging around 5 individuals per home. Literacy level is also hovering encouragingly around 50% for a rural population; a fertile ground and a potential success factor for the Ecostove project

## 4.2 AWARENESS OF GLOBAL CLIMATE CHANGE

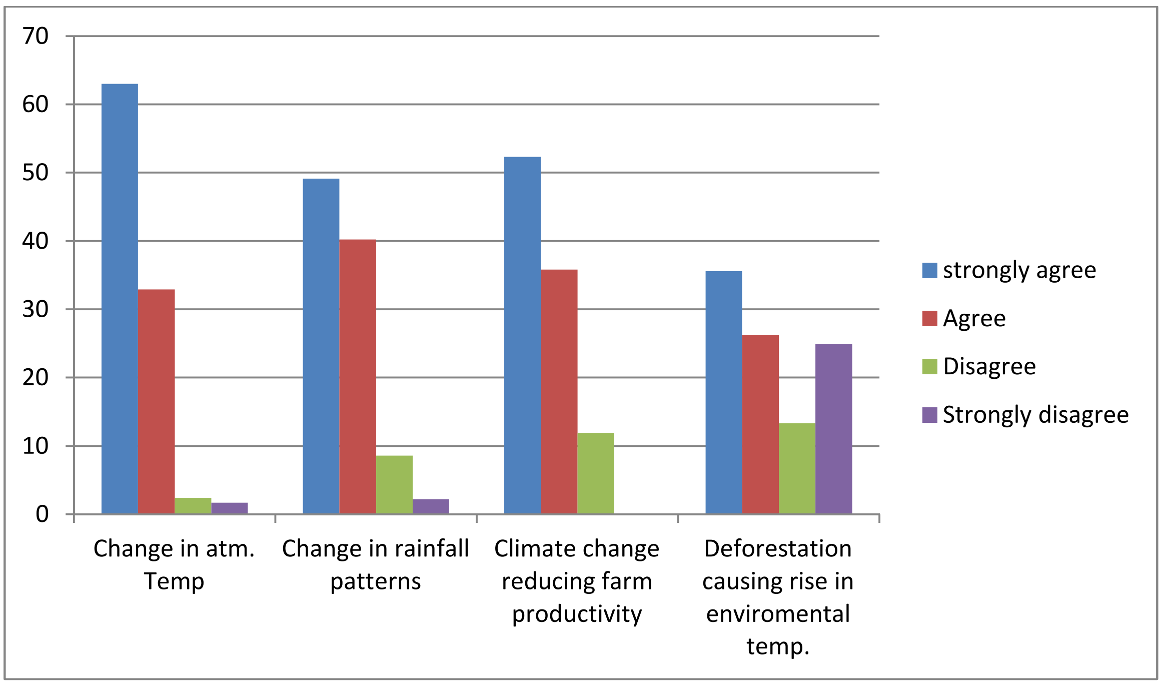



***Figure 4.1:*** *A Presentation of Awareness Levels of Climate Change*

A poll to investigate the degree of awareness among these rural residents was made and the results presented in Fig. 4.1. It generally shows positive responses to the primary indicators of global climate change. About 63% of respondents strongly agreed to rise in atmospheric temperature; over 89% affirmed to changes in rainfall patterns.

Interestingly, they hold the clue that this rise in temperature may be stemming from the massive deforestation in their areas as over 60% confirmed this during the study. In all, it shows an incredibly high level of awareness about climate change within these rural populations. An extension of this is that they are already experiencing the impacts of climate change themselves and are wary of it. This means it would be seemingly easier to secure their support and participation in any campaign orchestrated to abate it. This is a subtle signal of success for the Ecostove project as its essence can quickly be linked to the solution of such ugly trend.

## 4.3 COOKING FUELS USAGE PATTERN

*Table 4.2: Cooking fuel usage*

| Cooking Fuel | Main Fuel (%) | Backup Fuel (%) |
|---|---|---|
| **Fuel wood** | **72** | 24.5 |
| **Kerosene** | **19** | 55 |
| **Gas** | **1.7** | 1.5 |
| **Saw Dust** | **0.8** | 6 |
| **Charcoal** | **7.3** | 12 |
| **Electricity** | **0** | 1 |
| TOTAL | **100** | **100** |

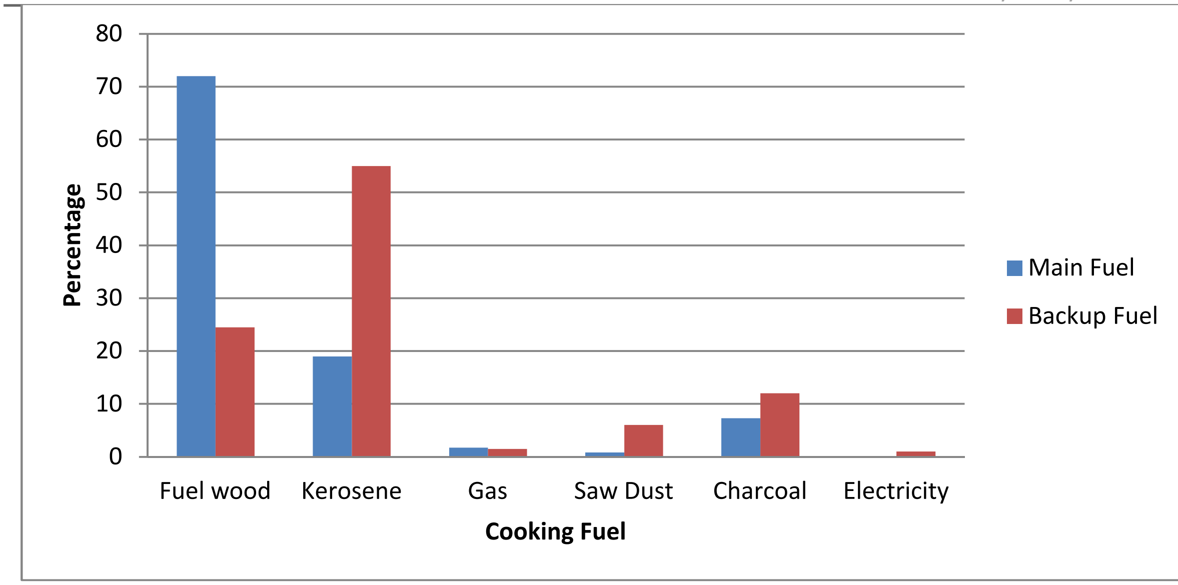



*Fig 4.2: Chart displaying the main and backup cooking fuel in use*

The survey was conducted to ascertain the prevalent cooking fuel in use in these rural neighbourhoods. The result, as illustrated in Table 4.2 and Fig.4.2, shows the following cooking fuel distribution pattern among them. Fuel wood usage tops the chart with 72% of respondents. About 19% represent kerosene users while charcoal maintains 7.3% as indicated by the respondents. Saw dust seems not to be widely used as only 0.8% responded positively to it. The result reflected the pattern and affinity to fuelwood. Availability of fuelwood is the fundamental factor behind this dominance as about 56% of the respondents admitted.

In attempt to discover the backup fuel, 24.5% of the respondents considered fuelwood as a backup cooking fuel. Another 55%, which constitute mainly of fuelwood users, uses kerosene as backup fuel.

The survey further revealed that over 97% of fuelwood consumers subscribe to the tripod stove while a subtle 3% use some forms of the Ecostove type as Fig 4.4 illustrates. Later observation of these ecostoves, excluding the pilot scheme products, showed them to be highly defective and substandard; they were mainly constructed fancifully as local variants of cookstoves without regards to the actual thermodynamic parameters at play in such systems. In other words, essence of use of Ecostove was lost in their designs and making. The inefficiencies associated with these cookstoves resulted in the unnecessarily high levels of $CO_2$ release as the subsequent estimation and analysis would show.

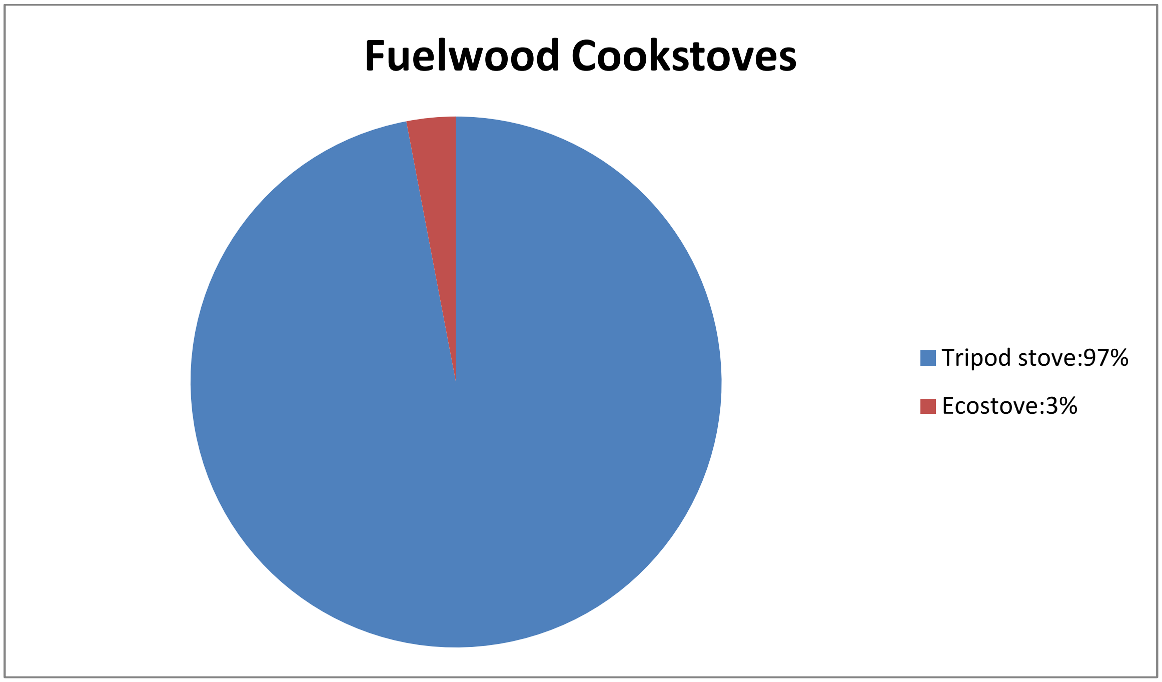



*Fig 4.3: Relative Distribution of Tripod and Ecostove among fuelwood users*

## 4.4 COST PERCEPTION

Information on the comparative cost of the various fuelwood was gathered through the survey. This was performed to ascertain any relationship between cost and widespread usage. The result showed that fuelwood appears to be

cheapest to the users and gas the most expensive as over 82% the rural people considered fuelwood the cheapest of all the cooking fuels. This is further stressed by the level of response in relative cost of fuelwood versus kerosene and gas. (refer to figure 4.)

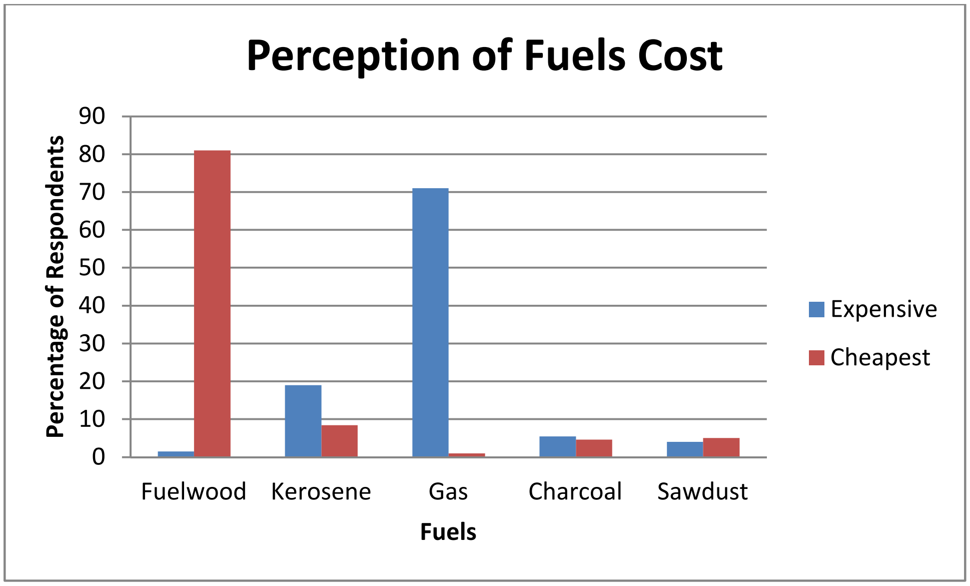



*Fig 4.4: Perceived relative cost of the various fuels*

From the statistics, it could be deduced that the choice of fuelwood seemed to have been largely informed by two disposing factors which hold the potential of influencing the outcome of the Ecostove project. Firstly, availability and proximity of fuelwood especially to the rural farmers made it an irresistible option. Secondly, poverty also determined their fuel choice as majority were subsistent farmers who felt locked in the unhygienic and inconvenient tradition of using fuelwood for lack of money to procure alternative fuels. Its utilisation is well perceived as a reflection of penury and primitiveness. Given the right financial base, these people would defect to other fuels and cooking systems that they perceive to be more refined and sophisticated as indicated by a striking 60%

of the respondents in the study (refer to figure 4.6). This then brings the question of sustainability of the project to bare.

These divergent variables would play out in determining the level of acceptability or resistance that would greet the Ecostove project. This interplay is unpredictable but pilot tests suggest our optimism in the picture.

## 4.5 FUELWOOD CONSUMPTION PROFILE AND IMPLICATIONS

Having established fuelwood as the main cooking fuel in rural areas of Delta State, efforts were also made to measure the extensity of this usage among these people. Three sizable rural communities were chosen and ten households of varied sizes were selected at random from each community to represent the State. The fuelwood was weighed before and after cooking for that day using a weighing balance. The net difference of final weight and initial weight was taken as the amount of wood burnt per day for cooking. The average of all the measurement was calculated. The results of this study are summarised in Table 4.3 below for the three communities.

From the experiment, we see that the mean fuelwood consumption rate is 11.5kg/day/household in the rural communities of Delta State.

*Table 4.3: Household Daily Fuelwood Consumption Measurement*

| COMMUNITY | HOUSEHOLD S/N | HOUSEHOLD Size | FUELWOOD Kg/day |
|---|---|---|---|
| A | 1 | 7 | 12.5 |
| | 2 | 3 | 10.1 |
| | 3 | 4 | 8.3 |
| | 4 | 4 | 10.6 |
| | 5 | 6 | 8.4 |
| | 6 | 5 | 11.6 |
| | 7 | 3 | 10.3 |
| | 8 | 8 | 12.2 |
| | 9 | 6 | 11.2 |
| | 10 | 5 | 10.8 |
| B | 1 | 3 | 9.4 |
| | 2 | 5 | 11.5 |
| | 3 | 7 | 13.4 |
| | 4 | 4 | 10.2 |
| | 5 | 3 | 11.9 |
| | 6 | 6 | 11.1 |
| | 7 | 5 | 12.4 |
| | 8 | 7 | 12.3 |
| | 9 | 3 | 12.5 |
| | 10 | 5 | 10.7 |
| C | 1 | 8 | 14.3 |
| | 2 | 6 | 12.2 |
| | 3 | 7 | 10.5 |
| | 4 | 5 | 11.7 |
| | 5 | 3 | 9.8 |
| | 6 | 5 | 12.1 |
| | 7 | 4 | 10.4 |
| | 8 | 6 | 15.2 |
| | 9 | 8 | 12.8 |
| | 10 | 5 | 13.5 |
| **MEAN** | | | **11.46** |

## 4.6 EMISSION THROUGH FUELWOOD IN DELTA STATE

In an attempt to obtain a holistic picture of the emission index of the State from fuelwood combustion, secondary data were obtained from the relevant agencies, and extrapolations of the $CO_2$ emission indices of these areas were finally calculated using these data. These figures are presented in Table 4.5 for the case of tripod cookstove and Table 4.6 if Ecostove replaces tripod cookstove.

*Table 4.4: Emission index of Delta State with respect to Fuelwood usage in Tripod Cookstove*

| | LGA | 2006 Population Figure | 2014 Population* Projection | Population in Rural Area (57%) | No. of Households (Average size of 5) | Fuelwood Users (72%) | Daily Fuelwood usage (kg) | $CO_2$ Emission (tons) | $CO_2$ Emission/ annum (tons) | Annual $CO_2$ Emission/capita |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Aniocha North | 104062 | 127112 | 72454 | 14491 | 10433 | 119983 | 187 | 68121 | 0.54 |
| 2 | Aniocha South | 142045 | 173508 | 98900 | 19780 | 14242 | 163778 | 255 | 92986 | 0.54 |
| 3 | Bomadi | 86016 | 105069 | 59889 | 11978 | 8624 | 99176 | 154 | 56308 | 0.54 |
| 4 | Burutu | 207977 | 254044 | 144805 | 28961 | 20852 | 239797 | 373 | 136147 | 0.54 |
| 5 | Ethiope East | 200942 | 245451 | 139907 | 27981 | 20147 | 231686 | 360 | 131541 | 0.54 |
| 6 | Ethiope West | 202712 | 247613 | 141139 | 28228 | 20324 | 233727 | 364 | 132700 | 0.54 |
| 7 | Ika North East | 182819 | 223313 | 127289 | 25458 | 18330 | 210790 | 328 | 119678 | 0.54 |
| 8 | Ika South | 167060 | 204064 | 116316 | 23263 | 16750 | 192620 | 300 | 109361 | 0.54 |
| 9 | Isoko North | 143559 | 175357 | 99954 | 19991 | 14393 | 165523 | 257 | 93977 | 0.54 |
| 10 | Isoko South | 235147 | 287232 | 163722 | 32744 | 23576 | 271124 | 422 | 153933 | 0.54 |
| 11 | Ndokwa East | 103224 | 126088 | 71870 | 14374 | 10349 | 119017 | 185 | 67573 | 0.54 |
| 12 | Ndokwa West | 150024 | 183254 | 104455 | 20891 | 15042 | 172977 | 269 | 98209 | 0.54 |
| 13 | Okpe | 128398 | 156838 | 89398 | 17880 | 12873 | 148043 | 230 | 84052 | 0.54 |
| 14 | Oshimili North | 118540 | 144797 | 82534 | 16507 | 11885 | 136676 | 213 | 77599 | 0.54 |
| 15 | Oshimili South | 150032 | 183264 | 104461 | 20892 | 15042 | 172987 | 269 | 98214 | 0.54 |
| 16 | Patani | 67391 | 82318 | 46921 | 9384 | 6757 | 77702 | 121 | 44116 | 0.54 |
| 17 | Sapele | 174273 | 212874 | 121338 | 24268 | 17473 | 200936 | 313 | 114083 | 0.54 |
| 18 | Udu | 142480 | 174039 | 99202 | 19840 | 14285 | 164279 | 256 | 93271 | 0.54 |
| 19 | Ughelli North | 320687 | 391719 | 223280 | 44656 | 32152 | 369752 | 575 | 209929 | 0.54 |
| 20 | Ughelli South | 212638 | 259737 | 148050 | 29610 | 21319 | 245171 | 381 | 139198 | 0.54 |
| 21 | Ukwuani | 119034 | 145400 | 82878 | 16576 | 11934 | 137246 | 213 | 77922 | 0.54 |
| 22 | Uvwie | 188728 | 230531 | 131403 | 26281 | 18922 | 217603 | 338 | 123546 | 0.54 |
| 23 | Warri North | 136149 | 166306 | 94794 | 18959 | 13650 | 156980 | 244 | 89126 | 0.54 |
| 24 | Warri South | 311970 | 381071 | 217211 | 43442 | 31278 | 359701 | 560 | 204223 | 0.54 |
| 25 | Warri South East | 116538 | 142351 | 81140 | 16228 | 11684 | 134368 | 209 | 76289 | 0.54 |
| | **TOTAL** | **4112445** | **5023352** | **2863310** | **572662** | **412317** | **4741642** | **7376** | **2692103** | **0.54** |

[a] Projected population based on 2.9% growth rate forecast by National Population Commission
[b] Average percentage of population living in rural areas; data given by World Bank Indicators-Nigeria-Density and Urbanisation, 2010.
[c] Daily fuelwood usage is estimated at 11.5kg/day/household using Tripod cookstove
[d] Calculated emission index based on the conversion standard of 1kg wood = 1.83kg of $CO_2$ assuming 15% moisture content

*Table 4.5: Emission index of Delta State with respect to Fuelwood usage if Ecostove is in use*

| | LGA | 2006 Population Figure | 2014 Population[a] Projection | Population in Rural Areas (57%)[b] | No. of Households (Average of 5) | Fuelwood Users (72%) | Daily Fuelwood Usage (kg)[c] | Daily fuelwood CO2 Emission (kg)[d] | CO2 Emission/annum (tons) | CO2 Emission/capita |
|---|---|---|---|---|---|---|---|---|---|---|
| **1** | Aniocha North | 104062 | 127112 | 72454 | 14491 | 10433 | 62600 | 97374 | 35542 | 0.28 |
| **2** | Aniocha South | 142045 | 173508 | 98900 | 19780 | 14242 | 85449 | 132916 | 48514 | 0.28 |
| **3** | Bomadi | 86016 | 105069 | 59889 | 11978 | 8624 | 51744 | 80488 | 29378 | 0.28 |
| **4** | Burutu | 207977 | 254044 | 144805 | 28961 | 20852 | 125112 | 194611 | 71033 | 0.28 |
| **5** | Ethiope East | 200942 | 245451 | 139907 | 27981 | 20147 | 120880 | 188028 | 68630 | 0.28 |
| **6** | Ethiope West | 202712 | 247613 | 141139 | 28228 | 20324 | 121944 | 189684 | 69235 | 0.28 |
| **7** | Ika North East | 182819 | 223313 | 127289 | 25458 | 18330 | 109977 | 171070 | 62440 | 0.28 |
| **8** | Ika South | 167060 | 204064 | 116316 | 23263 | 16750 | 100497 | 156324 | 57058 | 0.28 |
| **9** | Isoko North | 143559 | 175357 | 99954 | 19991 | 14393 | 86360 | 134333 | 49032 | 0.28 |
| **10** | Isoko South | 235147 | 287232 | 163722 | 32744 | 23576 | 141456 | 220035 | 80313 | 0.28 |
| **11** | Ndokwa East | 103224 | 126088 | 71870 | 14374 | 10349 | 62096 | 96590 | 35255 | 0.28 |
| **12** | Ndokwa West | 150024 | 183254 | 104455 | 20891 | 15042 | 90249 | 140382 | 51240 | 0.28 |
| **13** | Okpe | 128398 | 156838 | 89398 | 17880 | 12873 | 77240 | 120146 | 43853 | 0.28 |
| **14** | Oshimili North | 118540 | 144797 | 82534 | 16507 | 11885 | 71309 | 110922 | 40486 | 0.28 |
| **15** | Oshimili South | 150032 | 183264 | 104461 | 20892 | 15042 | 90254 | 140390 | 51242 | 0.28 |
| **16** | Patani | 67391 | 82318 | 46921 | 9384 | 6757 | 40540 | 63060 | 23017 | 0.28 |
| **17** | Sapele | 174273 | 212874 | 121338 | 24268 | 17473 | 104836 | 163073 | 59522 | 0.28 |
| **18** | Udu | 142480 | 174039 | 99202 | 19840 | 14285 | 85711 | 133323 | 48663 | 0.28 |
| **19** | Ughelli North | 320687 | 391719 | 223280 | 44656 | 32152 | 192914 | 300078 | 109528 | 0.28 |
| **20** | Ughelli South | 212638 | 259737 | 148050 | 29610 | 21319 | 127915 | 198972 | 72625 | 0.28 |
| **21** | Ukwuani | 119034 | 145400 | 82878 | 16576 | 11934 | 71607 | 111384 | 40655 | 0.28 |
| **22** | Uvwie | 188728 | 230531 | 131403 | 26281 | 18922 | 113532 | 176599 | 64459 | 0.28 |
| **23** | Warri North | 136149 | 166306 | 94794 | 18959 | 13650 | 81902 | 127399 | 46501 | 0.28 |
| **24** | Warri South | 311970 | 381071 | 217211 | 43442 | 31278 | 187670 | 291921 | 106551 | 0.28 |
| **25** | Warri South East | 116538 | 142351 | 81140 | 16228 | 11684 | 70105 | 109048 | 39803 | 0.28 |
| | **TOTAL** | **4112445** | **5023352** | **2863310** | 572662 | 412317 | 2473900 | 3848152 | 1404575 | 0.28 |

[a] Projected population based on 2.9% growth rate forecast by National Population Commission

[b] Average percentage of population living in rural areas; data given World Bank Indicators-Nigeria-Density and Urbanisation, 2010.

[c] Daily fuelwood usage is estimated at 6kg/day in using Ecostove

[d] Calculated emission index based on the conversion standard of 1kg wood = 1.83kg of $CO_2$ assuming 15% moisture content.

The usage of fuelwood adds substantial amount of carbon dioxide to the atmosphere. Based on the 50% carbon composition of fuelwood, the emission potential is calculated as 1kg of fuelwood to generate 1.6kg of carbon dioxide (assuming 15% moisture content of total wood mass). Using the popular tripod cookstoves which consume averagely 11.5kg of fuelwood per day by typical household of five with cooking pattern of three times per day, an estimated 18kg of carbon dioxide is released.

Given the population of rural communities in Delta State which is about 2,863,310 distributed in approximately 572,662 households as shown in Table 4.5, the emission index of the State on fuelwood on cooking alone is estimated at 2.7million tons/annum (with the open tripod cookstove in use). Rural household $CO_2$ emission index is about 18kg per day through fuelwood. Assuming Ecostove is in use, the emission figure would drop to about 1.4million tons/annum and emission index down to about 9kg per day. This difference is based on the 48% drop in fuelwood consumption in Ecostove.

In making such estimations, the following assumptions were made:

- that the rural populations are the main users of fuelwood neglecting their urban counterparts.
- that fuelwood is used solely for cooking ignoring its use in industrial processes.

## 4.7 ECOSTOVE ACCEPTABILITY

As stated earlier in the preceding sections, Ecostove brings about reduction in fuelwood consumption for cooking and makes for more hygienic and healthy kitchens. Its acceptability and sustainability among these rural populations is anchored on these main factors:

- Desire to cut down fuelwood consumption
- Readiness to continue using fuelwood

### 4.7.1 ASSESSMENT OF FUELWOOD REDUCTION NEED

The levels of importance respondents placed on the need to reduce their fuelwood consumption after careful explanation of the significance of such reduction are shown in Fig 4.8. When asked how necessary to reduce fuelwood daily consumption, 60% of the rural residents considered it **very important** to reduce their fuelwood consumption. Another 27% voted reduction at the level of **important**. Some 9% and 4% feel it is **unimportant** and **very unimportant** respectively to do so; meaning they are comfortable with the system. Bottom-line? 87% see the need to reduce daily fuelwood spent on cooking. The reason behind this is fundamentally to reduce the burden of gathering fuelwood, economic and the need to save their forests from the rapid deforestation they have witnessed in recent years. Those were the basic concerns. Efforts made to tie this with global climate change only seemed remote and secondary to them.

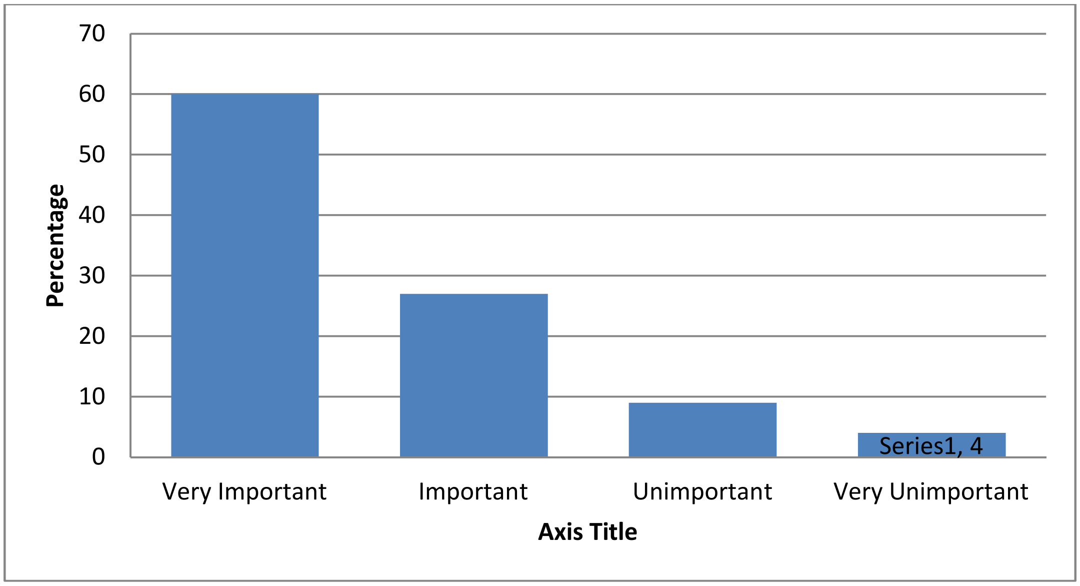



*Fig.4.5: Chart of how important to reduce fuelwood consumption.*

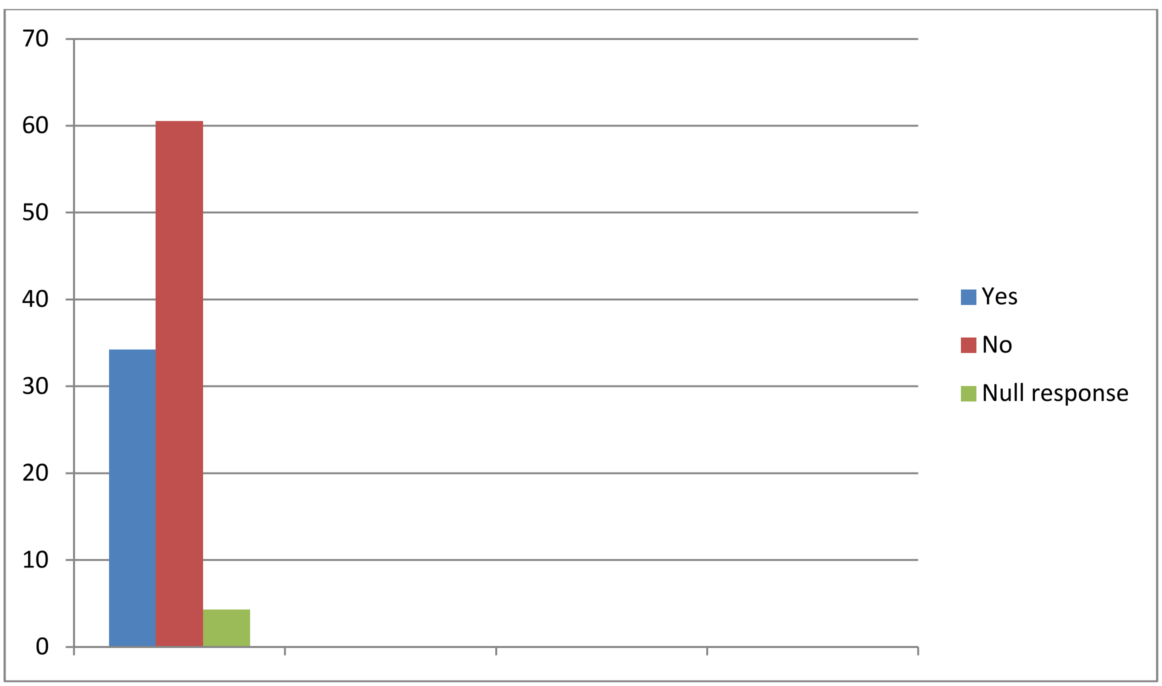



*Fig 4.6: Readiness to continue using Fuelwood*

The desire to continue the use of fuelwood was also assessed and this is shown by Fig.4.6. About 61% expressed their intention of opting out of fuelwood usage if it gets more expensive than it is owing to depletion of its forest reserves. They often consider use of fuelwood as an indicator of poverty and that urban dwellers use other fuels due to relative improved living standard. This sells out poverty as the major factor lurking behind their present use of fuelwood; hence sustained usage of fuelwood is dependent on economic status of respondents.

From the preceding sections, it can be argued that their poor perception of fuelwood was mainly occasioned by these factors:

- Relative cheapness of fuelwood which these rural populations were quick to associate with their poor living.
- The poor hygiene and stains associated with the use of fuelwood.
- The indoor pollution (the release of gaseous pollutants and heat) associated with fuelwood (via the tripod stove) hence the habit of separating the kitchen from the main house in these rural settings.
- The inconvenience associated with the use of fuelwood (especially in the setting and extinguishing processes).
- Poor technological sophistication and lustrelessness of traditional fuelwood systems.

Any effort to encourage the continued use of fuelwood as part of the objectives of this program in the long term must address these factors reasonably to grant these people enough worth in using it. Ecostove promises to eliminate some of these problems but may ultimately be overridden by stronger competitions from more modernised cooking systems that use fossil fuels.  Efforts should therefore be made to incorporate all these factors in future designs.

### 4.7.2 WILLINGNESS TO OWN ECOSTOVE

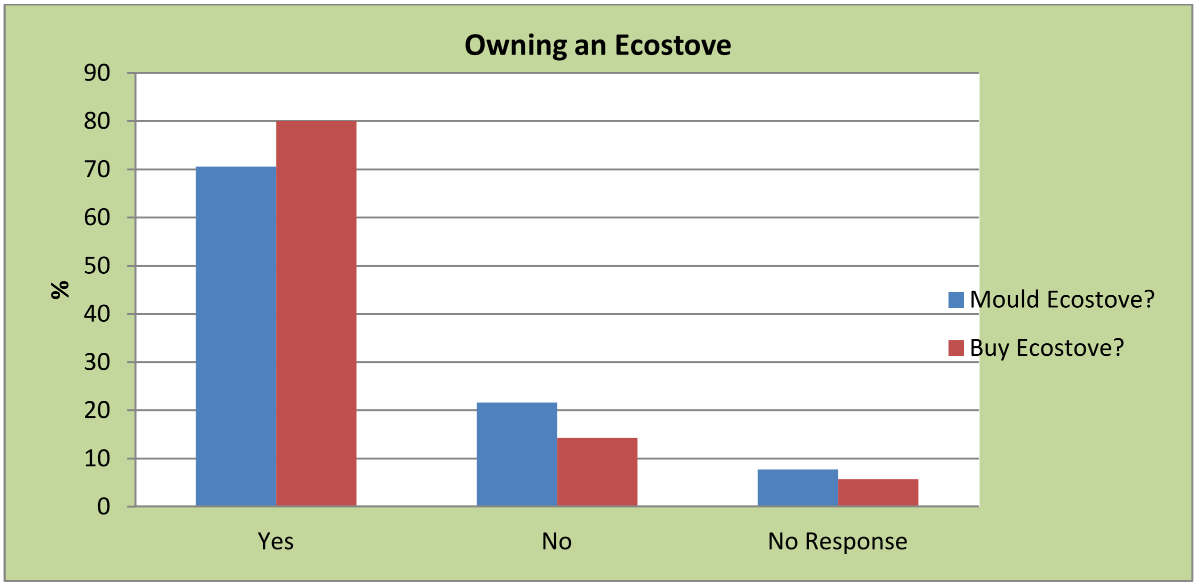



*Fig 4.7: Percentage of rural residents willing to own Ecostove by self-made or purchase*

A market survey to evaluate the appeal of Ecostove was carried out after careful description of its ideal features and benefits to these rural populations. The readiness of rural residents to adopt the new Ecostove is reflected in the level of responses on the choice to buy or make it at home. Most people showed interest in the technology as shown in figure 4.7. From the Fig 4.7, 70% and 80% answered yes to readiness to make or buy Ecostove respectively; 21% and 10% were conservative in their responses to hold onto their traditional tripod cookstove as they probably perceive it to have better aeration and hence faster in cooking. The remaining 9% and 5% were indifferent.

The preceding result heralds a huge chance for success of the Ecostove project. In fact, pilot tests for the marketability and deployment of Ecostove in Omonu, Ebor and Ugono Orogun communities returned with untold success. The little failures recorded in those experiments were not coming on the backdrop of rural conservativeness as originally anticipated but rather from the chaotic co-ordination that characterised them.

Also observed during this study is the large deposit of the primary raw material, clay required for the mass production of Ecostove in these rural settings. This would greatly reduce the cost of the production making the people more receptive to this development.

## 4.8 GENERAL OPINION ON FUELWOOD

The chart presented in Figure 4:8 below displays the popular opinion of fuelwood users on the cost, advantages and disadvantages of using fuelwood. Most prominent is the high percentage (47% strongly agreed and 27% agreed) of the rural residents consenting to the fact that fuelwood in tripod cookstove causes environmental hazard, suffocation and presents extra challenge of cleaning after cooking. This shows the degree of dissatisfaction in using the tripod cookstove and the long desire to devise a more user friendly, clean and efficient cookstove that will still make use of the cheap and readily available fuelwood.

Speaking of energy efficiency, some 44% and 24% affirmed at the level of strongly agreed and agreed respectively that wastage of heat energy do not bother them much. That is to say, much of the fuelwood consume is wasted through human inefficient factors and not solely by the cookstove inefficiency. However, this human associated inefficiency can be attributed to somehow uncontrollable feature of tripod cookstove once started.

Even as opposing as it may appear, many fuelwood users hold firm to the fact that it is easier to operate fuelwood cookstoves than any other fuel stove and that their continuous use of fuelwood has nothing to do with tradition and traits passed down through ancestors, rather based on ease of operation and availability. These further confirm the ground a soft landing for the Ecostove project.

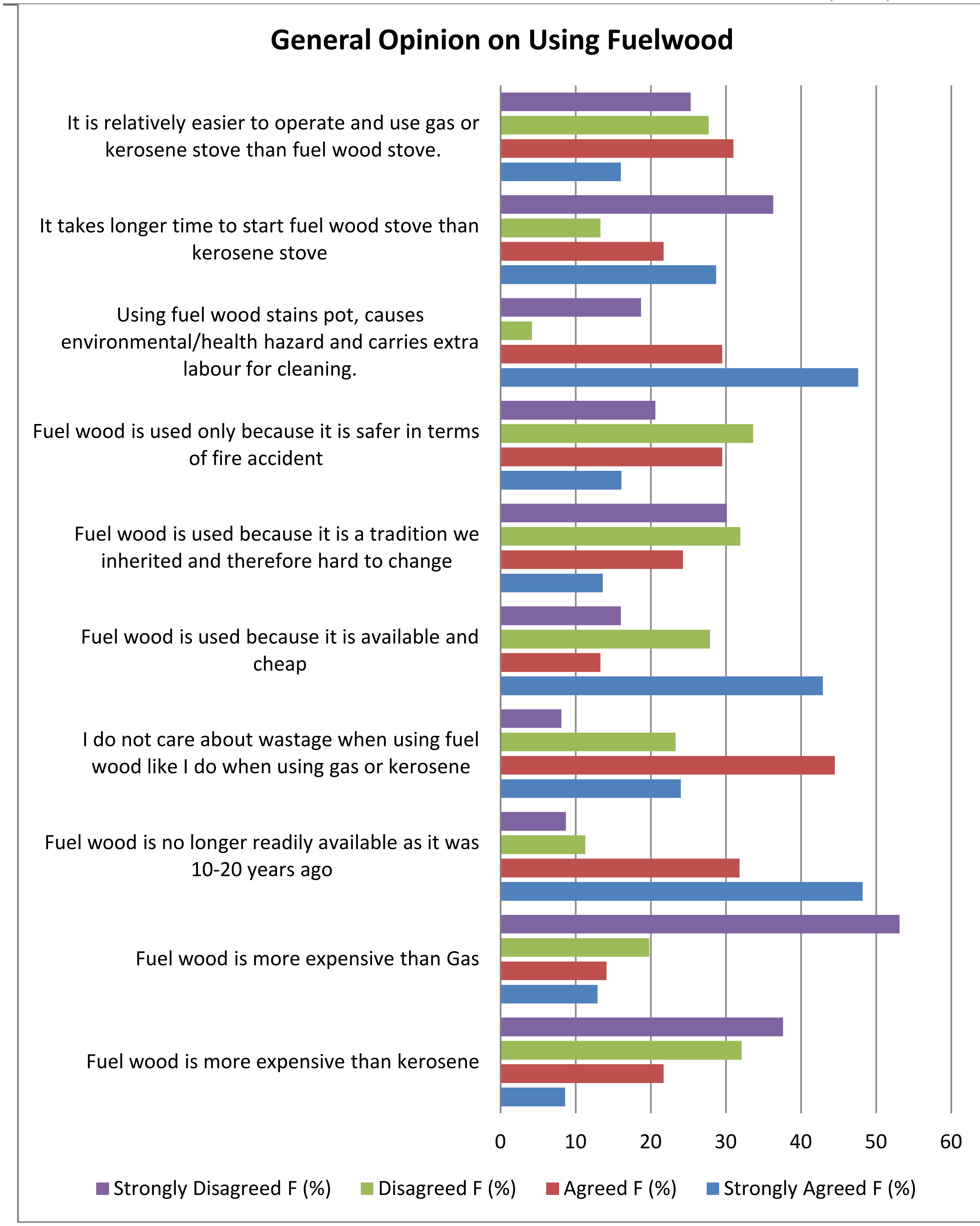



*Fig. 4.8: A Chart on the General Opinion on using Fuelwood*

# CHAPTER FIVE

# CONCLUSION AND RECOMMENDATIONS

## 5.1 CONCLUSION

The survey was undertaken to primarily investigate the current status quo on the cooking fuel usage pattern and the corresponding cookstove commonly in use among rural population in Delta State with the view of replacing them with the new innovated more efficient ecostove.

From the findings, larger parts of the population in the rural areas use fuelwood for their daily energy need in the inefficient tripod cookstove. About 72% of the people use fuelwood of which 97% of them use it in tripod cookstove; leaving a staggering 3% consuming their fuelwood in Ecostove that lost the necessary defining specification.

The ground appears soft and ready for the smooth take off of the Ecostove deployment project as discovered from the study. With 70% and 80% of the rural residents marking their interest in owning this piece of technology by DIY approach or purchasing it if available respectively, the project certainly will make a positive impact in so many ways.

Also very important is the fuelwood consumption index by households which was measured to be averagely 11.5kg per day using tripod cookstove. When Ecostove is fully introduced, this figure will drop to around 6kg per day by the same households. By extension, daily emission by the state with respect to fuelwood usage among the rural communities is estimated to be around 7376tons/day and can dip to 3848tons/day if Ecostove is widely used.

Majority of the people are already aware and experiencing the climate change, especially through the prominent indicators – temperature and rain pattern. This awareness will again create a basis to enlightening the populace on the need to replace tripod cookstove with the efficient Ecostove.

From the findings, the rural communities appear ready for the introduction of cookstove that will provide solutions to the displeasure expressed against tripod cookstove. Such displeasure ranges from environmental hazard, through after use cleaning task to too much fuelwood intake. Typical environmental hazards are surrounding heat that brings discomfort while cooking; fly ash and unhealthy indoor emissions,

By dissociating present fuelwood usage from the tradition and culture inherited, the people proved readiness to continue the use of this easily sourced fuel for time beyond prediction despite the trend of economic development. However, a potential drift away from fuelwood is still possible and therefore must be considered in long term plans.

## 5.2 RECOMMENDATIONS

The impacts of global climate change are becoming more perceptible now than ever as modern researches have shown. These are battle calls to save the planet earth and its associated biodiversity from such abrupt decimation. For such efforts and initiatives to be effective and meaningful, it must be orchestrated and co-ordinated from a global platform. Thanks to the UN and other

Non-Governmental Organisations that have shared in such programs and missions over the years through funding, campaigns and researches etc. Such actions have substantially mitigated this negative spiral in ways untold.

With such efforts having been flagged off by the international community, it is our deepest intention to extend and prop such noble programs in our domestic scene Nigeria. However, pursuing such initiatives among people who are still beset with fundamental life challenges is bound to suffer some hitches, not to mention the inefficiencies associated with their public policy implementations. To ensure the success of such programs in such landscapes, very tactical and pragmatic approaches must be devised that would subtly get the job done leaving little traces of conflicts and discomforts.

These battles are being fought from many fronts; from the reduction in the dependence on fossil fuels to the campaign for efficient use and conservation of energy. Nevertheless, these efforts have to be properly organised and co-ordinated to yield the desired results with the least possible resources available or else it would be mere lip services and ultimate wastes.

The Ecostove project is one of these many battles initiated to curb these declining climatic conditions of our terrestrial planet. As glimpsed from the preceding chapters, the generation of carbon dioxide, the major culprit implicated in climate change has reached an all-time high hence the need to cut down on the level of the associated activities leading to such generation. For years, fuelwood $CO_2$ emissions have silently gone unnoticed and unaccounted for. This study has been able to help in establishing these figures for future use and such figures seem significant enough to justify any effort sparked off to reduce them. As the study indicated, Ecostove seems to be a promising tool in that regard hence the need to mobilise our resources in that direction. This should not be seen as an attempt to undermine the pursuit of other potential solutions but rather as a pioneer and praiseworthy effort in handling such challenge.

In such chase for solution, it pays to remind ourselves about the initial objectives we set out to achieve originally through this project; they are:

- To reduce the production of $CO_2$ by decreasing fuelwood consumption through the introduction of Ecostove.
- To reduce the wastage of economic resources ie time and money spent on fuelwood procurement
- To prevent the unhealthy indoor pollutions and thermal dissipations in homes associated with the use of fuelwood.
- To improve the hygiene and ergonomic attributes of kitchens in rural areas.
- To encourage the regeneration of forest and its ecosystems for all the benefits it holds to man.

Keeping these in mind would guide us from drifting away into futile lanes in search of lasting solutions in such wonderlands.

## LIMITATION FACTORS

Having clearly defined our objectives, it seems only natural to identify and anticipate the few potential hurdles we may run into in realising them.

- The anticipated conservativeness and inertia of man to change as change is naturally stressful and uncertain.

- The poor perception of fuelwood usage being held by these rural populations and consequent feelings of inferiority associated with it.
- The cost of procurement of the ideal raw materials needed in making globally standardised Ecostove.

These are not meant to deter us from the goals already set but to sharpen our insights in appreciating any challenge we encounter during the delivery of such program.

## DESIGNING THE ECOSTOVE PROJECT

Acquisition of Ecostove for or by these end users in a meaningful way requires concerted and holistic actions on the hand of government and individuals alike. If not, such attempts would return with mixed results that are difficult to measure and track thereby incurring more costs. In responding to the question of acceptability and sustainability, such program should be separated into two phases:

- Phase I: acquisition of Ecostove in the short term
- Phase II: sustaining the use of Ecostove (fuelwood) in the face of changing economic landscapes to continually renew and improve the forest ecosystem and its carbon sink capacity.

These phases have their respective costs and gains as we shall see.

## ACQUISITION OF ECOSTOVE

In acquiring Ecostove, a natural argument arises as to who should muscle up the major responsibility of its cost and production. Leaving this in the hands of these rural end users who can barely cater for their basic life needs may ultimately result in utter failure owing to the aforementioned challenges and the relative tendency for them to play aloof to the program as they perceive it to be of secondary significance. Such would require very stringent policy making and implementation that the people may find repulsive and intrusive. Also is our inherent poor tradition of transgressing and disrespecting state laws and policies in sheer nonchalance. With such realities at play, such approach may go futile.

The second option is to allow the government to bear these costs and production. This seems better in prospect but also has its pitfalls. The prettiest option would be to tactfully find a middle course between these two larger alternatives that would get the job done efficiently with little muss and fuss. Below are some suggestions offered on the basis of the observations and findings garnered during this research with regards to the socio-cultural realities obtainable in our environment:

1. **Training and empowerment of manufacturers:** this is to ensure the adherence to the UNDP guidelines and expectations in making such items used for environmental controls and regulations. This requires the collective and phasic training of chosen manufacturers who have been in related industries using these guidelines and specifications. This has the merit of benefiting these specialised individuals through market creation for their novel product. It also holds the benefit of easing the monitoring of the progress and qualities of the Ecostoves at point sources where they are being produced. Thirdly, it will serve to prevent defective manufacturing by the rural people as was observed during this study. And lastly, this would guarantee some measures of sophistication and lustre in the designs of Ecostove that would ultimately preserve and improve the pride of its users.

**2. Organising of workshops to introduce Ecostove in rural communities:** re-orientation of rural populations is a primary tool for this job. They need to know the potential effects of their continued and inefficient flaring of fuelwood at such rates. They should be required to look back in silent retrospect of the original beauty of their forests before their aggressive and merciless destruction. Perhaps this may breathe a new sense of sanity and grace into their thinking. Tying such appeals with the purpose of Ecostove may help them to see grounds for change and adopt it as their new cookstove. Such workshops should be packed with practical demonstrations to verify the actual reduction in fuelwood consumption that is being preached about Ecostove. Organising such workshops needs properly trained personnels with effective communication skills than can appeal to both their reasonings and emotions.

**3. Subsidizing the price of Ecostove:** this is the core of government participation and the part where the major financial burdens lie. Thanks to the availability of clay, the main raw material used in making Ecostove which has therefore been naturally subsidized. The remaining cost now lies in the expertise and labour involved in the manufacturing, and other material inputs. Government can aid in the final delivery of Ecostove to these rural populations by further subsidising these bills to encourage its adoption and end use.

**4. Banning the production and sale of tripod stoves:** a giant but discomforting stride in this program would be banning the production and sale of the traditional tripod stove. Although this would be hurtful for individuals involved in the value chains of this business, but ultimately, it is worth the price. An attempt would be made to reduce this shock by declaring the intention to ban far ahead of the actual ban. With zero distribution of tripod stove and the rusty degeneration of the ones in present use, people would gradually opt out from its use into the novel Ecostove.

## SUSTAINABILITY OF FUELWOOD USAGE

Answering the question of sustainability is very vital before the full implementation of the project and its policies to avoid stepping into unknown waters. Such answers would intensify our determination to bring it to fruition. As noted in the early chapters, the major objective of this study can again be versed in one concrete sentence: **to encourage the use of fuelwood *while* concurrently reducing the inefficiencies associated with such use through the introduction of ecostove.** Reduction of such inefficiencies ultimately results in lesser consumption of fuelwood per household. Again, there is the tendency to drift away into the use of more modern cookstoves run on fossil fuels (which have higher emission potentials) due to their better perception when they can be afforded. These then generate two broad challenging questions for our cherished noble program:

- How long would these rural dwellers continue to use fuelwood given the changing economic scene and the increasing rural-urban migration?
- How long can our forest reserve be able to support our continual supply of fuelwood given the rate of its depletion and our needfully campaigned future dependence on it because of its low emission potential?

Responding to these puzzles demands that we start mapping out our long term sustainability plans from the outset. In addressing the first , it pays to review the reasons for the possible abandonment of fuelwood in preference for more refined fuels; they are:

- the poor hygiene and stains associated with the use of fuelwood
- the indoor pollution (the release of gaseous pollutants and heat) associated with fuelwood (via the tripod stove).
- the inconvenience associated with usage of fuelwood (especially in the setting and extinguishing processes).
- poor technological sophistication and lustrelessness of traditional fuelwood systems.

These can get in the way of sustained use of fuelwood but thanks to our ecostove that proposes to eliminate much of these defects. Making Ecostove (or other fuelwood cookstoves) more competitive in the world marketplace of cookstoves would need more than its present features. It will certainly require more sophistication, refinement and elegance commensurate with that of fossil fuel cookstoves. Without these appeals, such dreams would end in mere fantasies.

## SAVING OUR FORESTS

Our tropical forests are being depleted faster than they can be replenished resulting in the rapid decimation of their rich flora and fauna. So many human activities have been implicated in this ugly trend. With the consideration of fuelwood as a better cooking fuel for the future given its low emission potential and high latent energy, it becomes essential to highlight these activities and discover whether they are worth the wastes of our forests:

1. Farming: humans in search of fertile fallow lands for farm cultivation destroyed these forests. These farming systems completely ignore all

2. Conservative measures hence causing almost irreversible damages to these forest ecosystems.
3. Lumbering: the felling of trees for many purposes eg timber production, fuelwood etc has contributed a significant quota in the overall deforestation process.
4. Industrialisation: the clearing of bushlands for the construction of industrial plants and processes, pipelines and other economic activities has resulted in overnight destruction of forest life forms that required ages to evolve.
5. Expanding human settlements: with exponential increase in human population resulting from our higher survival capacity, we have finally encroached and interfered with the wilds.
6. Bush burning: forest hardly burns owing to its freshness but a stripped one does. After farm cultivation, it becomes bare and susceptible to bush fires. This consequently destroys the ability of such forest to regenerate itself and its native biodiversity.

Perpetuating the use of fuelwood in the near future would demand practical and significant steps taken to mitigate such drastic and environmentally destructive activities. Such measures may include:

I. Conservation of soil: effective and efficient use of soil for agriculture can be achieved by:

a) Use of organic and inorganic manures to salvage barren soils and boost farm productivity within a given land space.
b) Total avoidance of bush burning at all stages of farm operations
c) Adoption of other best agricultural practices to enhance productivity

II. Human population control

III.Modifications in the design and construction of human settlements

These are mega-projects and programs that require high levels of co-ordination and organisation. Today, they seem secondary but tomorrow, when the effects of global climate change intensify, they would matter.

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# APPENDICES 1

## Questionnaire used in the Study

# ECO-STOVE AND FUEL WOOD CONSUMPTION STUDY

**DATA COLLECTION FORM**

DATE: ____

FORM NO: ____

### INTRODUCTION

This questionnaire attempts to gather information about the use of fuel wood as cooking fuel in Delta State. Though fuel wood is a renewable energy and therefore its usage as a source of energy must be encouraged in very sustainable manner. However, general concern is the inefficiency associated with fuel wood usage in the popular open tripod cookstove that waste much fuel wood through enormous heat loss and consequently releasing much carbon dioxide and other greenhouse gases into the atmosphere.

The continuous and unsustainable extraction of fuel wood from the forest now questions the renewable character of biomass and ultimately reduce the carbon sink (storage) capability of green forest.

This and other human activities to satisfy human need for energy have caused noticeable changes in the climatic factors especially in global temperature; hence global warming.

The introduction and acceptance of Eco-stove will play a saving role to the situation by reducing fuel wood usage, improve the carbon storage capability of forest, bring the renewable nature of biomass(wood) to its glory and eventually cut down GHG emission.

By participating in this study, you are helping Delta State government to fight climate change through the "Territorial Approach to Climate Change" to take the right decision on the fuel wood Eco-stove and other alternative cooking fuels exploitable within our vicinity.

### CONFIDENTIALITY

All information supplied in this form will be treated with absolute confidentiality. No part will be disclosed to third party. You are therefore encourage to complete this form to the best of your knowledge and with all seriousness.

### INSTRUCTIONS

Please tick appropriately and write eligibly where applicable.

Thank you.

## Section A: General information

Community: ______ LGA ______

Name of Respondent (optional) ______

Gender: *Male* [ ] *Female* [ ] Age [ ] Household size: [ ]

(Number of people living in your house)

Marital Status: *Single* [ ] *Married* [ ] *Widow* [ ]

Highest education: *Primary School* [ ] *Secondary* [ ] *NCE/OND* [ ] *HND/BSc* [ ] *Post Graduate* [ ]

Occupation ______

Which of these cooking stove do you currently have? (tick as many as you have)

- [ ] Kerosene stove
- [ ] Fuel wood tripod stove
- [ ] Gas cooker
- [ ] Saw-dust stove
- [ ] Charcoal pot
- [ ] Electric stove
- [ ] Eco-stove

How many times do you usually cook in a day? ______

## Section B: Awareness of Climate Change

1) Have you heard about global warming, sometimes called climate change? Yes [ ] No [ ]

2) Through which medium? TV[ ] Radio[ ] Newspaper[ ] Public places[ ] Institutions[ ]

| S/N | Variables | Strongly Agree | Agree | Disagree | Strongly disagree |
|---|---|---|---|---|---|
| 1 | There is increase in atmospheric temperature than before | | | | |
| 2 | Rain fall pattern has changed a lot from usual | | | | |
| 3 | There is increase in amount of rainfall now than before | | | | |
| 4 | More area is being flooded these days | | | | |
| 5 | Climate change is reducing farm productivity | | | | |
| 6 | Felling of trees is making the environment hot | | | | |

## Section C: Fuel Wood consumption

1. Which of these is your main cooking fuel? (the one *you regularly use*)
   Fuel wood ☐ Kerosene ☐ Gas ☐ Saw-dust ☐ Charcoal ☐ Electricity ☐
2. Which is your backup cooking fuel?
   Fuel wood ☐ Kerosene ☐ Gas ☐ Saw-dust ☐ Charcoal ☐ Electricity ☐
3. If fuel wood, how do you source for it?
   Free from bush/farm ☐ Buy from wood vendors ☐
4. Would you still use fuel wood if you were to buy it?
   Yes ☐ No ☐
5. Do you think your preferred cooking fuel is the cheapest?
   Yes ☐ No ☐ Don't know ☐
6. Does availability influence your choice of cooking fuel?
   Yes ☐ No ☐
7. Assuming you buy your fuel wood, have you ever compared its cost with other cooking fuels like gas and kerosene?
   Yes ☐ No ☐
8. If yes, which of these do you think is most expensive?
   Fuel wood ☐ Kerosene ☐ Gas ☐ Charcoal ☐ Saw-dust ☐
9. Which of these is the cheapest?
   Fuel wood ☐ Kerosene ☐ Gas ☐ Charcoal ☐ Saw-dust ☐

| S/N | Variables | Strongly agree | Agree | Disagree | Strongly disagree |
|---|---|---|---|---|---|
| 1 | Fuelwood is more expensive than Kerosene | | | | |
| 2 | Fuel wood is more expensive than Gas | | | | |
| 3 | Fuel wood is no longer readily available as it was 10 - 20 years ago | | | | |
| 4 | I do not care about wastage when using fuelwood like I do when using Gas or Kerosene | | | | |
| 5 | Fuel wood is used because it is available and cheap | | | | |
| 6 | Fuel wood is used because it is a tradition we inherited and therefore hard to change | | | | |
| 7 | Fuel wood is used only because it is safer in terms of fire accident | | | | |
| 8 | Using fuelwood stains pot, causes environmental/health hazard and carries extra labour for cleaning | | | | |
| 9 | It takes longer time to start fuel wood stove than kerosene stove or Gas cooker | | | | |
| 10 | It is relatively easier to operate and use Gas or kerosene stove than fuel wood stove | | | | |

## Section D: Eco-stove acceptability

*(Eco-stove is a kind of stove formed from mud or fabricated with metal that uses less fuel wood than the commonly traditional tripod cookstove and produces much heat energy for cooking with the option of channelling the smoke to outside of the kitchen.This easy-to-make stove can be portable or kitchen in-built along side chimney.)*

1. How important do you think it is to reduce your fuel wood usage?
   Very Important ☐ Important ☐ Unimportant ☐ Very unimportant ☐
2. Have you heard or seen a fuel wood cookstove called eco-stove that uses much less fuel wood and produces less smoke than tripod stove?
   Yes ☐ No ☐
3. Do you still like to use fuel wood despite its seeming high cost and depletion?
   Yes ☐ No ☐
4. If taught how to mould eco-stove using clay, would you mould and start using it?
   Yes ☐ No ☐
5. Is clay readily available in your vicinity?
   Yes ☐ No ☐
6. Are you ready to buy eco-stove that will save you more money, save your health and the environment over time?
   Yes ☐ No ☐
7. Does any person in your neighbourhood use eco-stove?
   Yes ☐ No ☐

## Section E: Fuel wood usage in neighbourhood

*Please you are expected to take a quick count and statistics of households on your street. Take your time to enumerate and give a near accurate figure to the questions below*

Name of Street ☐

Number of Household on your street ☐

How many households on your street use the following cookstove/fuel mainly?

☐ Kerosene
☐ Fuel wood
☐ Gas
☐ Saw-dust
☐ Charcoal
☐ Electricity

What is the population of the street (estimate) ☐