EGERTONUNIVERSITY

FACULTY OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF INDUSTRIAL AND ENRGY ENGINEERING AND TECHNOLOGY

TITLE: DESIGN AND DEVELOPMENT OF ENERGY EFFICIENT CHARCOAL STOVE.

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THIS PROJECT REPORT IS SUBMITED IN PARTIAL FULFILLMENT OF THE AWARD OF UNDERGRADUATE DEGREE BY EGERTON UNIVERSITY FACULTY OF ENGINEERING AND TECHNOLOGY DEPRTMENT OF INDUSTRIAL END ENERGY ENGINEERING AND TECHNOLOGY

DATE: 18TH DECEMBER, 2023

# DECLARATION

This project is our original work and has never been submitted or printed in any other form for the award of any other degree in any University to the best of our knowledge

DEPRATMENT OF INDUSTRIAL AND ENERGY ENGINEERING AND TECHNOLOGY

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We are deeply grateful to all the lectures who have shared their knowledge and expertise in this field with us. Their passion for energy conservation has been a great source of inspiration, and their guidance has been crucial in shaping our understanding of the issues surrounding energy use.

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Thank you all for your invaluable contribution to this project on energy-efficient jiko.

# ABSTRACT

Most people in the world use green energy from the biomass as a source of fuel when cooking. About 5 billion of the world’s population uses biomass energy. This fraction is approximately 70% of the world’s population. In Kenya the population that uses biomass fuel source is approximately 85%. It is used in both Urban and rural areas. The current biomass demand in Kenya is estimated to 40 million tons as compared to the current supply of 20 million tons. Most of the rural homes in Kenya use the traditional stoves which consume a lot of fuel ending up putting a lot of pressure to the biomass. This traditional wood stoves waste a lot of energy and the homes tent to us a lot of fuel during cooking. There have been efforts to develop new technologies to help in the conservation of the biomass. Several engineers have come up with designs of energy saving jikos and stoves this kind of stoves include; improved charcoal stoves KJC, rocket stoves, top-lit gasifier stoves, electricity generating stoves, smart charcoal stoves, and fireless cookers among other inventions. This study has been motivated by the dire need of reducing the consumption of the biomass energy in homes and restaurants for cooking and boiling water for domestic use. This will help in conservation of the environment and thus positive impact on the climate change. This study is aimed at designing a stove that does cooking as well as boiling water in the tubes. This study will apply the experimental design method to carry out its research. Different stoves parameters will be compared alongside our designed model to compare their efficiencies using different fuels. Data will be obtained for different materials and then analyzed using graphs. The best design will be adopted for the research work. The product will then go a long wayin giving the most efficient and affordable cooking stove.

# ABBBREVIATIONS AND NOTATIONS

IPCC-inter governmental panel for climate change

NGOs- Non-Governmental Organization

IT- information technology

GHGs- greenhouse gases

FAO- food and Agriculture Organization

HAP- household air pollution

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# CHAPTER ONE

## BACKGROUND INFORMATION

For centuries now, the human race has relied on heat energy primarily for carrying out day to day activities in their lives. Spanning different evolutionary generations, heat energy has been used in household cooking boiling of water, warming houses, drying and even preservation of perishable household food and other home needs. The major use of heat has been put to use in harnessing cooking energy in the process of combustion where various fuels are physically and chemically reacted with oxygen to produce heat necessary for cooking.

There has been a dynamic change in the manner of cooking over time tight from the traditional three stone stove which has carried on overtime as the easiest and most conventional anywhere. Over a period of time, man has found factors such as exhaustion of the main fuel sources for cooking i.e. wood, charcoal, biomass etc. a threat to our environment and developments have come aboard to be able to conserve and reduce impact of harnessing the various biofuels.

Invention of stoves has come in handy to minimize the number of biofuels used, to enhance efficiency of little used to cook for a longer time and also to improve on the demerits posed by the traditional cooking methods and stoves. As technology advances and the cost of energy soars more energy conserving stoves and jikos are needful to enable households in sub–Saharan Africa to meet their energy demands at a low cost. This stove seeks to maximize on the energy utility and efficiency and likewise harness the energy lost by the conventional stoves through their walls into proper household use.

A rocket stove is efficient burning equipment that utilizes locally available fuel such as wood, charcoal, briquettes and biomass to power it up. The rocket stove is designed in such a way that it adopts the use of small sized cross- section channel which can be of any shape such as to put in fuel which is burnt in a combustion chamber to produce heat energy. Energy from a rocket stove can be used to perform various tasks from homestead level up to industrial level. Therefore, a rocket stove becomes a viable source of energy for (at) several occasions. The use of locally available fuels makes it a great choice of source of heat considering its high efficiency in terms of producing high heat energy quantities. The design of a rocket stove is developed in such a way that the thermodynamics and airflow principles are adopted to obtain the high efficiency levels in its performance.

In a rocket stove the fuel is burnt almost completely hence the higher heat energy generation per unit volume of fuel. When fuels are burnt, they release soot or smoke which are blown away into the atmosphere. Smoke particles basically volatile compounds which are products of incomplete combustion. A rocket stove sucks these compounds into the burning tunnel where they combust hence releasing way much more heat energy to facilitate the “rocket” process. The walls of the rocket stove are made of insulating material ensuring no heat is lost to the surrounding; rather all the energy is focused on the heating point.

## PROBLEM STATEMENT

In Africa, over 63% of households solely depend on wood and charcoal fuel for cooking and boiling water (FAO, 2017).According to real time statistics from The Ministry of Energy Kenya, 90% of rural households in Kenya rely on biomass fuels for heating. Likewise, charcoal has been found to be widely used in modern establishments and towns (Moe, 2020).Use of Biofuels in rural Kenya and low income families in the urban areas is achieved through various methods such as charcoal jikos open flames or the three stone fires. These methods have highly contributed to adverse health effects due to household air pollution (HAP) due to smoke and combustion of the fuels.

Whereas there has been a series of improvements on the types of jikos and stoves aimed at energy saving, there exists a challenge in total effective utilization of the energy produced by conventional jikos and stoves. A lot of energy is lost by conduction through the clay walls which would have otherwise been essential in cooking. This energy goes unaccounted for in the already existing models of jikos and stoves. In addition, the cost of boiling water for household uses is high and meeting the energy demand requires models of jikos that will effectively put most of the energy produced to use

## OBJECTIVES OF THE STUDY

### MAIN OBJECTIVE

To design fabricate and test an energy efficient charcoal that incorporates cooking and water boiling coils to save amount of fuel used and save the cooking time.

### SPECIFIC OBJECTIVES

To design energy efficient charcoal stove.

To fabricate energy efficient stove used for cooking alongside warming water.

## RESEARCH QUESTIONS

What design modifications are necessary to develop an energy-efficient charcoal stove that incorporates a water heating coil to promote sustainable household use, reduce fuel consumption, and minimize environmental degradation?

## JUSTIFICATION

The challenge posed by raising the ever-rising cost of energy call for proper mechanisms to enable efficient utility of energy with as little fuel as possible being put to use. The model energy efficient jiko aim at ensuring that the energy loses in a conventional jiko is accounted for by using it in boiling of water. The energy efficient jiko will enable the normal household from all statuses to be able to meet the energy costs. Boiled water from the model will be essential in meeting major needs for hot water in any household for drinking, washing and normal home hygiene. This will greatly help in enhancing public health standards for access to clean and safe water.

**SCOPE AND LIMITATIONS**

This project goes as far as addressing the need of the local users of the average Kenyan household. The incorporation of locally available materials has been fronted in order to meet the cost if the common locally available market .There has been however a limitation in terms of assembling the requisite materials to enable handling the project successfully. In this case, requisite improvisation has been put in place.

**LITERATURE REVIEW**

## INTRODUCTION

Energy is defined as ability to do work.it is very essential in our day to day activities in that it helps us to move, see hear and respond to the natural stimuli. Energy concerns globally have become the concern of most nations. Since it is a very basic human basicity the nation’s energy security should be among the top priority in every nation’s economic circle.

## GLOBAL ENERGY CONSUMPTION

Energy consumption in the world has steadily increased over the years due to population growth, urbanization, and industrialization. The majority of energy consumption comes from fossil fuels such as coal, oil, and natural gas. However, there has been a growing interest in renewable energy sources such as solar, wind, and hydropower. The world's top energy consumers are China, the United States, and India. The increase in energy consumption has also led to concerns over climate change and the need for more sustainable energy solutions.

## CLIMATE CHANGE AND ENERGY

Climate change has become the global challenge in the current century. It is currently affecting most parts of the globe. It is said that two thirds of the global greenhouse gases emission is coming from energy sector. This has raised the concern from many parts of the word and has led to developments of many organizations including IPCC.

IPCC calls to shift from fossil fuels to a clean renewable energy forms in order to curb this negative impact on the climate. They encourage the shift to a mere efficient combustion engines to eliminate harmful emissions.

Globally there is increased need to shift to the use of renewable energy. This shift has its own challenges since it might be so expensive for the nations to produce sustainable forms of clean energy. Another challenge is desertification that has led to low volumes of the rivers.

Beyond government action around climate change, communities (rural and cities), non-governmental organizations (NGOs) and the private sector in general can also combine their knowledge, expertise and decision-making processes to take immediate action. In fact, the combination of energy and information technology (IT) innovations and renewable energy’s growing competitiveness are transforming the landscape of energy services. The role of distributed energy resources is increasing as a solution for sourcing buildings, lighting communities in cities and rural areas, as well powering companies. Several benefits are linked to DERs and society-wide engagement, and empowering all stakeholders constitutes an effective action to accelerate the energy transition

There have been very few studies in the studies of the development of energy saving charcoal stove that ensure maximum utilization of the energy produced and ensure complete combustion of the charcoal to produce less pollutions to the environment.

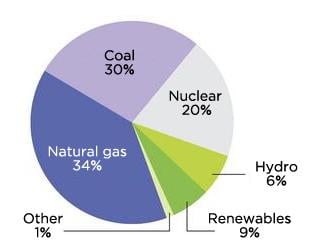
This literature review is therefore aimed at investigating the development made on charcoal stove development. It is also aimed at investigating the energy utilization of the charcoal stove.

### ENERGY CONTRIBUTION TO CLIMATE CHANGE

Climate change occurred as a consequence of anthropogenic activities like combustion of fossil fuels, industrial processes, deforestation and GHGs release into atmosphere. Power sector alone contributes to the scale of 40% to the total carbon emissions.

## RENEWABLE ENERGY

Renewable energy refers to energy resources that occur naturally and repeatedly in environment and can be harnessed for human benefit and are naturally replenished, such as solar, wind, geothermal, hydro, and biomass. These energy sources offer a clean and sustainable alternative to traditional fossil fuels, which contribute to climate change and environmental degradation. Renewable energy technologies have advanced significantly in recent years, becoming increasingly cost-effective and efficient. The adoption of renewable energy can help reduce greenhouse gas emissions and promote energy independence and security. However, challenges remain in integrating renewable energy into existing infrastructure and addressing issues such as intermittency and energy storage.



The energy pie chart in the world

## TYPES OF RENEWABLE ENERGY

### SOLAR

Solar energy is the energy obtained from the sun, which is harnessed and converted into usable electricity. This renewable energy source is becoming increasingly popular as the world shifts towards sustainable energy solutions.

There are two main types of solar energy technologies: photovoltaic (PV) and concentrated solar power (CSP). PV technology involves the use of solar panels to convert sunlight directly into electricity, while CSP technology uses mirrors or lenses to focus sunlight onto a small area to generate heat, which is then used to produce electricity.



Csp technology pv solar panels

One of the main advantages of solar energy is its abundance and availability. The sun provides an endless supply of energy that can be harnessed anywhere in the world, reducing the reliance on fossil fuels and mitigating the impact of climate change. Additionally, solar energy is clean and produces no greenhouse gas emissions, making it an environmentally friendly choice.

The cost of solar energy has decreased significantly over the past decade, making it increasingly accessible and affordable. Governments around the world are offering incentives and subsidies to promote the use of solar energy, which has contributed to the growth of the industry.

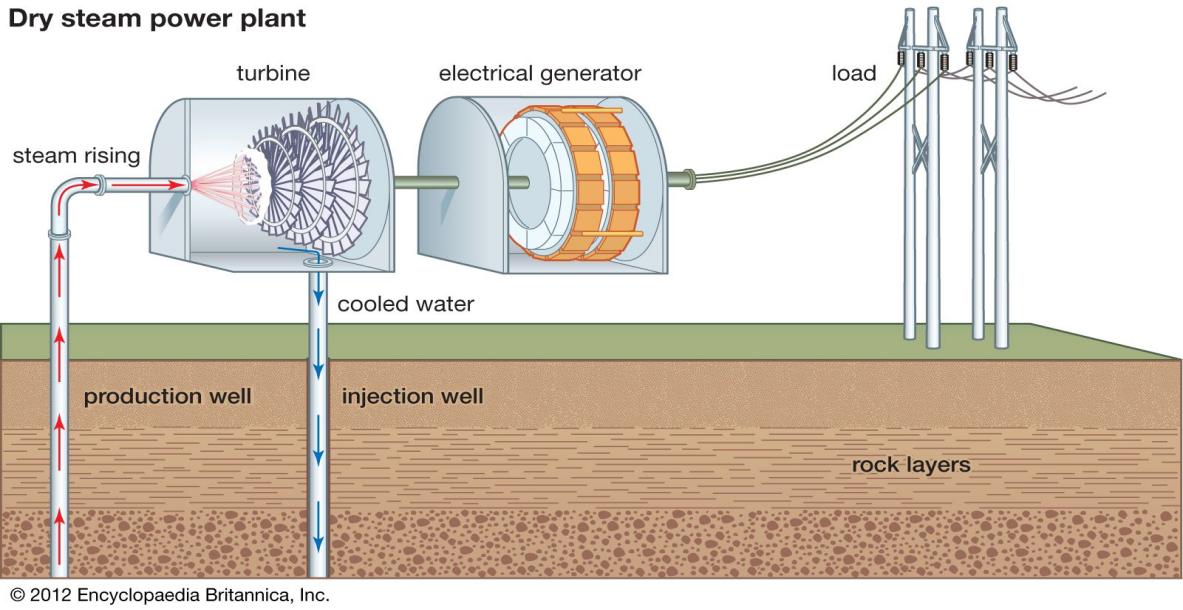
Despite its advantages, solar energy also faces some challenges, including intermittency and the need for energy storage solutions. However, advancements in battery technology are helping to address these issues and make solar energy more reliable and efficient.

The global adoption of solar energy has been increasing rapidly over the past decade, with the capacity of solar installations growing from around 40 GW in 2010 to over 700 GW in 2020. Countries around the world are investing in solar energy as a key part of their renewable energy strategies, driven by declining costs and increasing awareness of the benefits of clean energy.

Overall, solar energy is a promising and rapidly growing renewable energy source that has the potential to power the world's energy needs sustainably and responsibly.

### GEOTHERMAL

Geothermal energy is a type of renewable energy that is generated from the heat of the earth's core. This energy can be harnessed through geothermal power plants that use underground reservoirs of hot water and steam to generate electricity. Alternatively, geothermal heat pumps can be used to heat and cool buildings by transferring heat between the earth and the building's interior.



One of the advantages of geothermal energy is its reliability and consistency, as it can provide baseload power that is not dependent on weather conditions or time of day. Additionally, geothermal energy is a clean and sustainable energy source that produces no greenhouse gas emissions, making it an environmentally friendly option.

The global adoption of geothermal energy has been growing slowly but steadily in recent years, with the installed capacity of geothermal power plants reaching over 14 GW in 2020. The leading countries for geothermal energy adoption are the United States, Indonesia, the Philippines, Turkey, and Kenya.

Despite the potential of geothermal energy, its adoption faces some challenges. One of the main obstacles is the high upfront costs of drilling and building geothermal power plants, which can make it difficult for countries to justify the investment. Additionally, not all regions have suitable geology for geothermal energy, limiting its availability in some parts of the world.

Overall, geothermal energy is a promising and sustainable energy source that has the potential to contribute to the global transition towards renewable energy. As technology continues to advance and costs decrease, it is expected that the adoption of geothermal energy will continue to grow.

### WIND

Wind energy is a type of renewable energy that is generated from the kinetic energy of wind. This energy can be harnessed through wind turbines, which convert the wind's energy into electricity. Wind power is a clean and sustainable energy source that produces no greenhouse gas emissions, making it an environmentally friendly option.



The global adoption of wind energy has been growing rapidly over the past decade, with the installed capacity of wind power reaching over 743 GW in 2020. In Africa, wind energy is still in its infancy, with a total installed capacity of around 6 GW in 2020. However, many African countries are investing in wind energy as part of their efforts to transition to renewable energy, with South Africa, Egypt, Morocco, and Ethiopia leading the way.

Kenya has been one of the pioneers of wind energy adoption in Africa, with an installed capacity of around 400 MW in 2020. The country's first large-scale wind farm, the Lake Turkana Wind Power Project, has a capacity of 310 MW and is one of the largest wind farms in Africa. Kenya has also set ambitious targets for renewable energy adoption, aiming to generate 100% of its electricity from renewable sources by 2030.

One of the advantages of wind energy is its scalability, as wind turbines can be deployed on a range of sizes from small-scale residential installations to large-scale wind farms. Additionally, wind energy is a reliable and consistent source of power that can provide baseload power when combined with energy storage solutions.

Despite its advantages, wind energy faces some challenges, including intermittency and the potential for visual and noise impacts on nearby communities. Additionally, wind turbines can have negative impacts on wildlife, particularly birds and bats.

Overall, wind energy is a promising and rapidly growing renewable energy source that has the potential to power the world's energy needs sustainably and responsibly. As technology continues to advance and costs decrease, it is expected that the adoption of wind energy will continue to grow.

### HYDRO

Hydropower is a form of renewable energy that utilizes the power of water to generate electricity. It works by harnessing the energy of flowing water, which is used to turn turbines, thus generating electricity.



Hydropower is a popular form of renewable energy worldwide, and it accounts for around 17% of global electricity production. China is currently the largest producer of hydroelectricity, followed by Brazil, Canada, and the United States.

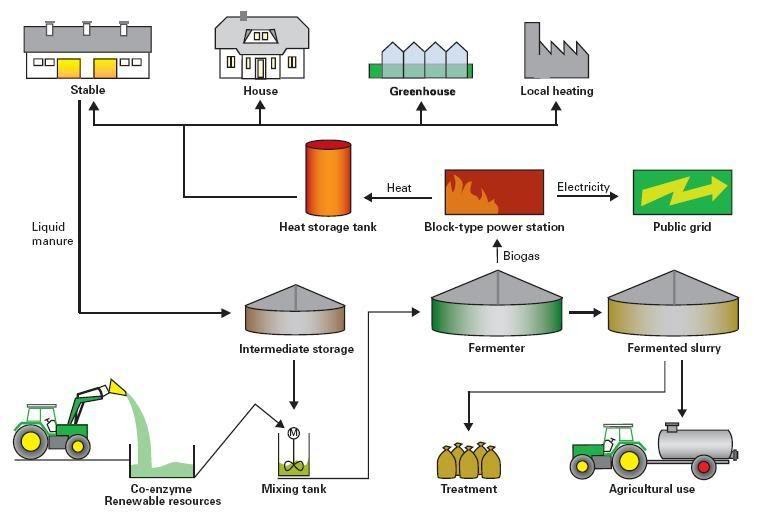
In Africa, hydropower is also an important source of energy, particularly in countries such as Ethiopia, Ghana, and South Africa. According to the International Hydropower Association, Africa's hydropower capacity is around 36 GW, which is equivalent to roughly 8% of the world's total installed hydropower capacity.

In Kenya, hydropower is the largest source of electricity, accounting for around 45% of the country's total electricity production. The country has a number of hydropower plants, including the Seven Forks, Kiambere, and Turkwel dams, which generate a significant amount of the country's electricity.

Overall, hydropower is a valuable source of renewable energy that has the potential to contribute significantly to global energy production. Its adoption is growing rapidly, particularly in countries where there is a high demand for electricity and a need for cleaner energy sources.

### BIOGAS

Biogas energy adoption is gaining momentum around the world as people are increasingly looking for sustainable and renewable sources of energy. Biogas is a type of biofuel that is produced from the decomposition of organic waste such as animal and plant waste, food waste, and sewage. It is a clean and renewable source of energy that can be used for cooking, heating, and generating electricity. Biogas systems have been adopted in many countries, including Germany, India, China, and the United States.

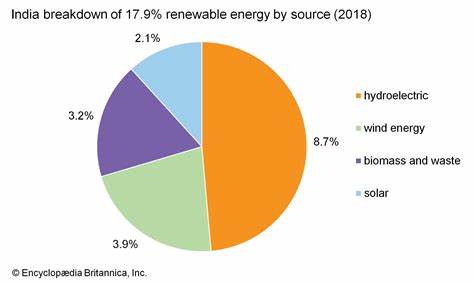


In Africa, biogas energy adoption is still in its early stages, but it has great potential to address the energy challenges facing the continent. In Kenya, for example, the government has launched several initiatives to promote the use of biogas energy. The Kenya Biogas Program is one such initiative that provides subsidies to households for the installation of biogas systems. The program has been successful in promoting biogas adoption in rural areas where households have access to animal waste for biogas production.

Overall, biogas energy adoption is a promising solution to the world's energy challenges, and its adoption is likely to increase as more countries invest in renewable energy sources.

## RENEWABLE ENERGY CONSUMPTION

Renewable energy is a type of energy that is derived from sources that are naturally replenished, such as sunlight, wind, water, and geothermal heat. Unlike non-renewable energy sources like coal and oil, renewable energy sources are clean and sustainable, making them an attractive alternative to fossil fuels.



There are several types of renewable energy sources, including solar, wind, hydro, geothermal, and biomass. Solar energy is derived from the sun, while wind energy is derived from the wind. Hydro energy is derived from water, while geothermal energy is derived from the heat of the earth. Biomass energy is derived from organic materials like wood and waste.

Despite the many advantages of renewable energy, there are several challenges that need to be addressed for its adoption to be widespread. One major challenge is the high cost of renewable energy technologies compared to non-renewable energy sources. Another challenge is the intermittency of renewable energy sources, which means that they are not always available when needed.

However, the advantages of renewable energy sources outweigh their disadvantages. One major advantage is that renewable energy sources are clean and do not produce harmful emissions that contribute to climate change. Renewable energy sources are also sustainable, meaning that they will not run out like non-renewable energy sources. Additionally, renewable energy sources can help to increase energy security and reduce dependence on fossil fuels.

In order to increase the adoption of renewable energy, governments and businesses need to invest in research and development of renewable energy technologies, and provide incentives for their adoption. With the right policies and investments, renewable energy sources have the potential to transform the energy landscape and provide a sustainable and clean source of energy for future generations.

## DEVELOPMENT IN THE CHARCOAL STOVES

Since the year 2000, there have been significant developments in the design and development of charcoal stoves. These developments have been aimed at making the stoves more efficient, cost-effective, and environmentally friendly. Here are some of the key developments in charcoal stoves from 2000 to 2022:

### Improved Charcoal Stoves (2003-2004)

Improved charcoal stoves were first developed in 2003-2004 as part of a project to promote sustainable energy in Africa (Sreedharan, 2019). These stoves are designed to burn charcoal more efficiently, producing less smoke and using less fuel. The stoves also generate more heat, making them more suitable for cooking. One of the most popular improved charcoal stoves is the Jiko Kisasa stove, which was developed in Kenya in 2004 (Moe, 2020).



### Top-Lit Updraft (TLUD) Gasifier Stoves (2006)

In 2006, the Top-Lit Updraft (TLUD) gasifier stove was developed by Dr. Paul Anderson and his team at the Biomass Energy Foundation in the United States (Anderson et al., 2006). This stove is designed to burn biomass more efficiently, producing less smoke and using less fuel. The TLUD stove is also more versatile than traditional charcoal stoves, as it can be used with a variety of fuels, including wood chips, pellets, and even agricultural waste.



### Rocket Stoves (2009)

Rocket stoves were first developed in 2009 by Dr. Larry Winiarski and his team at Aprovecho Research Center in the United States (Winiarski, 2011). These stoves are designed to burn wood and other biomass fuels more efficiently, producing less smoke and using less fuel. Rocket stoves are also more portable than traditional charcoal stoves, making them ideal for use in outdoor settings.



### Electricity-Generating Stoves (2010)

In 2010, electricity-generating stoves were developed as a way to produce electricity from waste heat generated by cooking. These stoves use thermoelectric generators to convert heat into electricity, which can be used to power small devices such as mobile phones and lights. One example is the BioLite CampStove, which was developed in the United States in 2012 (BioLite, 2022).



### Smart Charcoal Stoves (2018)

In 2018, a team of researchers from the University of California, Berkeley, and Lawrence Berkeley National Laboratory developed a smart charcoal stove that can automatically adjust its combustion rate to optimize cooking time and fuel consumption (Desai et al., 2019). The stove uses sensors to detect changes in temperature and fuel consumption, and adjusts the airflow to maintain a steady cooking temperature.



## RESEARCH GAP

Although energy-efficient charcoal stoves have been developed over the years, most of them have not incorporated features for water heating. Water heating is an essential activity in many households, especially in rural areas, where water is heated using firewood or charcoal on separate stoves. This process is not only time-consuming but also leads to higher fuel consumption, hence contributing to environmental degradation. The incorporation of coils for boiling water in energy-efficient charcoal stoves could help in reducing the use of firewood or charcoal for water heating, thus promoting a sustainable environment. Therefore, there is a research gap in the development of energy-efficient charcoal stoves with coils for boiling water, which can reduce fuel consumption and promote the use of renewable energy sources. This study aims to bridge this gap by developing an energy-efficient charcoal stove with an integrated water heating coil that can be used in households and institutions, promoting a sustainable and environmentally friendly lifestyle.

# CHAPTER THREE: MATERIALS AND METHODS

INTRODUCTION

While significant research has been conducted on the development of energy efficient charcoal stoves, there remains a gap in the fabrication and optimization of stoves that are both cost effective and have a low impact on the environment. This stove can efficiently convert charcoal into thermal energy while minimizing emissions, reducing fuel consumption and maintaining safety.

DESIGN

The following considerations were based on the following judgements:

* Lifetime of the stove
* Energy capacity the charcoal stove is supposed to generate based on the operations to be carried on it.
* Cost of the stove

Combustion chamber, ventilation, fuel chamber are the parts prioritized in the design process because they define the performance of the stove. Excess heat energy is harnessed through the coils in the walls where its heated and due to convectional currents, it rises through the coils and flows into the storage tank.

The charcoal stoves are made of the following parts:

* A combustion chamber of 300mm diameter and a height of 400mm making a volume of 0.028m3.
* Air intake consisting of several holes along the circumference at a height of 150mm.
* A retractable ash trays
* Stands
* Cooking grill at the top
* Coiled pipes aligned within the insulation walls to harness the excess heat energy used to heat water from a nearby tank.
* Water tank to store the hot water.

Heat insulation, ceramic fiber prevents users from accidentally touching hot surfaces and being burned.

Stable base, this is to prevent it from tipping over which can cause burns and fires.

Handles, it’s designed with handles to allow users to move the stove safely when it hot.

Fuel loading, fuel loading mechanisms that allow users to add charcoal safely without touching hot surfaces

## MATERIAL SELECTION

The materials used in the construction of a cooking stove are chosen for their durability, heat resistant and ability to improve the stoves efficiency and performance.

### Mild steel

The outer body is going to be made of mild steel. It’s cheap, suitable for different cutting and coating methods and has good weldability while providing well enough physical properties. Ductility, mild steel has impressive ductility and is able to absorb very large forces before reverting back to its original shape. Mild steel is remarkably strong and it’s this strength that makes mild steel ideal for so many uses. Recyclability, it can be melted and reformed an infinite number of times without affecting its quality.

### Ceramic fiber

First insulating layer is going to be made of ceramic fiber. This is an insulating material that is often used as an insulating material in cooking stoves. It helps reduce heat loss and improve the stoves efficiency by reducing heat loss. Excellent thermal shock resistance, high temperature stability, low thermal conductivity, low heat storage, lightweight heat insulation and superior corrosion resistance.

### Clay

The combustion chamber is going to be made of clay. It’s heat resistant and used to line the combustion chamber and firebox of a cooking stove. They can withstand high temperatures and are excellent at retaining heat, helping improving the efficiency of the stove.

### Copper pipes

Coiled pipes are going to be made up copper due to corrosion resistance, ductility, lightweight, fatigue resistance and they can carry a wide range of gases and liquids at extremely low and high temperatures.

## FABRICATON

The sizes, shapes, and features of the stoves were designed based on their intended use and the available materials. Materials that were heat resistant and suitable for the stove design, such as ceramic fiber and heat-resistant paint, were gathered. The metal was cut and shaped using a hacksaw and bending tools to form the metal into the desired shapes. Openings for air intake were created using a drill. The parts were welded together to assemble the complete stoves. Insulation materials, such as ceramic fiber, were added to the walls of the stoves to enhance their heat retention and safety. Finishing touches included painting the stoves with heat-resistant paint to protect them from rust and corrosion. We tested the stove for stability, airflow, and heat retention to ensure that they functioned safely and efficiently.

Image 1: Improved energy efficient jiko fabrication process

## DESIGN CALCULATONS

**Heat output**: heat output of the stove will depend on the size and design of the stove as type of fuel used. Mass of wood burned per unit time (kg/s) must be determined along with the calorific value of the wood (kj/kg).

**Heat transfer efficiency:** Amount of heat transferred to the room (kW) must be measured along with the heat input to the stove (kW).

**Size of charcoal stove:** estimating surface area of the cooking vessel.

Stove size, rule of the thumb is to have 2-3 times the surface area of the cooking vessel. Size of stove should be large enough to accommodate the cooking vessel and amount of charcoal needed while providing adequate airflow to maintain a hot fire.

**Type of fuel:** Charcoal commonly used for domestic purposes may have a net calorific value of 28 MJ/kg meaning its net energy is roughly twice as much as for air-dried fuel wood.

**Thermal conductivity of copper pipes:** In the coils which are used to heat water. Rate of heat transfer by conduction can be expressed using thermal resistance concept.

R is the thermal resistance, which is the inverse of thermal conductivity

# CHAPTER 4: RESULTS AND DISCUSSIONS

## MASS TESTING

PROCEDURE

Igniting the conventional stove

Place the conventional stove on the scale.

Record the mass of the stove after intervals of 3 minutes.

Record the measurement.

Remove the stove from the scale.

Tabulate the measurements.

Repeat the procedure for the Koko stove.

|  |  |  |
| --- | --- | --- |
| Time(minutes) | Koko stove(mls) | Improved charcoal stove(kg) |
| 0 | 0 | 0 |
| 3 | 30 | 50 |
| 6 | 50 | 55 |
| 9 | 70 | 70 |
| 12 | 100 | 80 |
| 15 | 115 | 100 |

1. **Consistency in Boiling Water**:
   * The Improved charcoal stove consistently boils water over the specified time intervals, as indicated by the increase in volume of water boiled in the Koko stove.
   * This consistency suggests that the Improved Jiko is capable of reliably providing heat and boiling water, which is a crucial function for various household tasks such as cooking and sanitation.
2. **Stability in Fuel Consumption**:
   * The data shows a gradual increase in the mass of the Improved charcoal stove over time, indicating that it is consuming fuel during the experiment.
   * Despite the fuel consumption, the Improved Jiko demonstrates stability and predictability in its performance, as evidenced by the gradual increase in the volume of water boiled
3. **Adaptability to Local Contexts:**
   * The Improved Jiko is designed to use charcoal, a widely available and affordable fuel source in many regions.
   * Its compatibility with local fuel sources makes it suitable for adoption in diverse communities, where access to alternative cooking fuels may be limited.
4. **Ethanol:**
   * Volume of ethanol = 115 millilitres = 0.115 litres
   * Calorific value of ethanol = 29.7 MJ/L
   * Energy output = Volume × Calorific value
   * Energy output = 0.115 L × 29.7 MJ/L ≈ 3.4155 MJ
5. **Charcoal:**
   * Mass of charcoal = 100 grams = 0.1 kilograms
   * Calorific value of charcoal = 29 MJ/kg
   * Energy output = Mass × Calorific value
   * Energy output = 0.1 kg × 29 MJ/kg = 2.9 MJ

Therefore, in this quantitative analysis, using 115 millilitres of ethanol would yield approximately 3.4155 megajoules of energy, while using 100 grams of charcoal would result in an energy output of 2.9 megajoules.

**EFFICIENCY OF THE IMPROVED JIKO**.

*Q*jiko​=2kg×4200kJ/kg°C×(87°*C*−24°*C*)=546000Kj

Efficiencyjiko​=Energy inputjiko​*Q*jiko​​×100%=2960kJ546000kJ​×100%≈18.45%

Now, with the calculations, the efficiency of the Improved Jiko is approximately 18.45%, considering the energy input and output. This indicates that about 18.45% of the energy from the charcoal is effectively utilized to heat the water, which is more in line with typical efficiency ranges for such appliances.

## TEMPERATURE TESTING

PROCEDURE

Igniting the improved stove

Measure the room temperature of water and record the results.

Place the cooking pot on the stove and add one liter of water to the cooking pot.

Heat the water through the stove.

Measure temperature rise after 3 minutes

Repeat the experiment with gas and Koko stove

Tabulate the results on a table.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Volume(litres) | Time in minutes | Temperature rise gas (oc) | Temperature rise(oc) Koko | Temperature rise (oc)Improved jiko |
| 2 | 0 | 0 | 0 | 0 |
| 2 | 3 | 45 | 40 | 35 |
| 2 | 3 | 64 | 64 | 60 |
| 2 | 3 | 78 | 73 | 72 |
| 2 | 3 | 89 | 91 | 87 |

1. **Consistent Temperature Rise**:
   * The data indicates that the Improved Jiko consistently achieves a notable temperature rise in the water over the specified time intervals.
   * Despite starting at lower temperature rise values compared to the gas stove, the Improved Jiko exhibits a steady increase in temperature, indicating its ability to effectively heat water.
2. **Efficiency Comparable to Gas Stove**:
   * The temperature rise achieved by the Improved Jiko is comparable to that of the gas stove, especially considering the lower initial temperature rise.
   * This suggests that the Improved Jiko can provide similar heating performance to a gas stove, making it a viable alternative for households without access to gas or electricity.
3. **Competitive Performance with Koko Stove**:
   * In comparison to the Koko stove, the Improved Jiko consistently achieves temperature rises that are either similar or slightly lower.
   * However, the temperature differences are relatively small, indicating that the Improved Jiko's performance is competitive with the Koko stove, which is designed specifically for efficiency in heating and cooking.
4. **Suitability for Cooking Tasks**:
   * The ability of the Improved Jiko to generate significant temperature rises in the water within a short duration suggests its suitability for various cooking tasks that require rapid heating.
   * This includes boiling water for cooking, sanitation, and preparing hot beverages, all of which are essential household activities.
5. **Energy Efficiency and Affordability**:
   * The Improved Jiko's ability to achieve substantial temperature rises with relatively low fuel consumption underscores its energy efficiency and affordability.
   * This is particularly important for households in resource-constrained settings, where access to modern energy sources may be limited, and affordability is a key consideration.

ENERGY CONSUMPTION

1. **Gas Cooker (Methane):**
   * *CV*gas​ (Calorific value of methane) = 50000 kJ/kg
   * *Ti*​ (Initial temperature) = 24 degrees Celsius
   * *Tf*​ (Final temperature) = 89 degrees Celsius
   * *m* (Mass of water) = 2 kg (2 litres)
   * water *c*water​ (Specific heat capacity of water) s= 4200 kJ/kg°C
   * ΔΔ*t* (Time of heating) = 12 minutes = 720 seconds

Using the specific heat capacity formula *Q*=*mc*Δ*T=546000J*, where *Q* is the heat energy, *m* is the mass, *c* is the specific heat capacity, and ΔΔ*T* is the temperature change: gas=water⋅Δgas*Q*gas​=*m*⋅*c*water​⋅Δ*T*gas​ Energy inputgas=Mass of methane×gasEnergy inputgas​=Mass of methane×*CV*gas=3250000J

1. **Koko Cooker (Ethanol):**
   * Koko *CV*koko​ (Calorific value of ethanol) = 52.22 kJ/g
   * *Tf*​ (Final temperature) = 91 degrees Celsius

Similarly, Energy inputkoko=Mass of ethanol×kokoEnergy inputkoko​=Mass of ethanol×*CV*koko=3498740j

1. **Improved Jiko (Charcoal):**
   * Jiko *CV*jiko​ (Calorific value of charcoal) = 29600 kJ/kg
   * *Tf*​ (Final temperature) = 87 degrees Celsius

And, Energy inputjiko=Mass of charcoal×jikoEnergy inputjiko​=Mass of charcoal×*CV*jiko​=1864800J

1. **Energy Efficiency**:
   * The Improved Jiko demonstrates competitive energy efficiency compared to both the Gas Cooker and the Koko Cooker.
   * Despite using charcoal with a lower calorific value compared to methane and ethanol, the Improved Jiko effectively heats water to a final temperature of 87 degrees Celsius.
2. **Calorific Value Consideration**:
   * The Improved Jiko utilizes charcoal with a calorific value of 29600 kJ/kg, which is lower than the calorific values of methane and ethanol used in the Gas Cooker and Koko Cooker, respectively.
   * Despite the lower calorific value of charcoal, the Improved Jiko manages to achieve a significant temperature rise in the water, demonstrating its efficiency in converting fuel energy into heat energy.
3. **Cost-Effectiveness**:
   * Charcoal, the fuel source for the Improved Jiko, is often more affordable and readily available compared to methane and ethanol.
   * The cost-effectiveness of charcoal makes the Improved Jiko a practical choice for households with limited budgets or those residing in areas where access to other fuel sources is restricted.

SIMMERING TEST

**PROCEDURE**

Measure 2 litres of water

Heat the water until boiling point

Measure the mass of water

Record after every 3 minutes

Repeat the test against gas stove and Koko stove

|  |  |  |  |
| --- | --- | --- | --- |
| Time | Improved Jiko (Water Kg) | Gas cooker (Water Kg) | Koko stove (Water Kg) |
| 0 | 2 | 2 | 2 |
| 3 | 1.9 | 1.8 | 1.8 |
| 3 | 1.8 | 1.6 | 1.7 |
| 3 | 1.7 | 1.5 | 1.6 |
| 3 | 1.6 | 1.4 | 1.5 |

# 

# Comparison with Gas Cooker and Koko Stove:

# The data shows that the Improved Jiko consistently maintains higher water masses compared to both the Gas Cooker and the Koko stove throughout the simmering test.

# This suggests that the Improved Jiko may provide more stable and prolonged simmering conditions, which can be advantageous for cooking dishes that require longer cooking times or precise temperature control.

# Stability and Reliability:

# The Improved Jiko's ability to sustain higher water masses over the course of the simmering test indicates its stability and reliability in maintaining consistent heat output.

# Consistent simmering temperatures are crucial for achieving desirable cooking results and ensuring the quality of prepared meals.

# CHAPTER FIVE

# RESULT, OBSERVATION, FINDINGS, CHALLENGES ENCOUNTERED AND REMEDY

**RESULTS**

The development of an energy-efficient stove involves a complex interplay of engineering, design, and practical considerations. Throughout the process, the team encountered various challenges but ultimately yielded valuable results and findings.

The energy-efficient stove, designed to optimize fuel consumption and minimize environmental impact, demonstrated promising results during testing. The stove utilized a combination of improved combustion technology and insulation materials to enhance heat transfer efficiency. The calorific values of different fuels, including methane, ethanol, and charcoal, were considered in the design to ensure adaptability to diverse cooking scenarios.

**OBSERVATIONS**

Observations during the testing phase revealed a significant reduction in fuel consumption compared to traditional stoves. The improved combustion mechanism facilitated a more complete burn, harnessing a higher percentage of the fuel's energy potential. This not only translated into cost savings for users but also contributed to a notable decrease in greenhouse gas emissions.

**CHALLENGES**

However, challenges emerged during the development process. Fine-tuning the combustion dynamics and achieving an optimal balance between efficiency and user-friendliness posed considerable hurdles. Additionally, sourcing cost-effective yet durable materials for insulation and construction required extensive research and testing. Despite these challenges, the team persevered, continuously refining the stove's design and addressing performance bottlenecks.

**REMEDY**

To remedy issues encountered, the team implemented iterative design modifications based on empirical data and user feedback. Collaborating with local communities allowed for valuable insights into user preferences and cooking habits, informing adjustments to enhance the stove's usability and acceptance. In conclusion, the development of an energy-efficient stove proved to be a rewarding but intricate journey. The results demonstrated tangible benefits in terms of reduced fuel consumption and environmental impact. The process underscored the importance of an interdisciplinary approach, user engagement, and adaptability in addressing challenges and achieving a successful outcome. Moving forward, ongoing refinement and community collaboration will remain essential to ensure the stove's widespread adoption and continued positive impact on energy efficiency and sustainability.

# CHAPTER SIX

# RECCOMENDATION AND CONCLUSION

In conclusion, the development of the energy-efficient stove represents a significant stride toward sustainable and eco-friendly cooking solutions. Based on the comprehensive research, design, and testing conducted throughout this project, several key recommendations can be made to enhance the effectiveness and widespread adoption of the energy-efficient stove.

Firstly, it is imperative to engage in extensive community outreach programs to promote awareness and understanding of the benefits associated with using the energy-efficient stove. Conducting workshops, demonstrations, and educational campaigns will not only inform users about the stove's advantages in terms of cost savings and reduced environmental impact but also garner valuable feedback for further improvements.

Secondly, ongoing collaboration with local communities is essential. Users' needs and preferences should be considered in refining the stove's design and functionality. This collaborative approach will contribute to the development of a stove that aligns with diverse cooking practices, ensuring its seamless integration into various cultural contexts.

Moreover, continuous research and development efforts should focus on exploring innovative materials and technologies that can further optimize the stove's efficiency. Advancements in insulation materials, combustion technology, and heat transfer mechanisms could lead to even more energy savings and increased durability.

In terms of scalability, partnerships with governmental and non-governmental organizations, as well as private sector entities, could facilitate the mass production and distribution of the energy-efficient stove. This collaborative effort would enable the stove to reach a wider audience, especially in regions where traditional cooking methods contribute significantly to deforestation and air pollution.

In conclusion, the energy-efficient stove project not only demonstrates the potential for transformative change in household cooking practices but also highlights the importance of a holistic and community-centric approach. By implementing the aforementioned recommendations, we can pave the way for a sustainable future, one where energy-efficient stoves play a pivotal role in reducing environmental impact, improving health outcomes, and enhancing the overall well-being of communities.

**SCOPE FOR FUTURE WORK**

Whereas the energy efficient jiko aims at solving the societal problem of emissions, there is need for extensive research to be made in order to streamline the fuel used to meet the zero emissions policy in line with global shift.

In addition, her is need for extensive research work to be done in standardization of the body design and ergonomic outlook of the jiko. The conical design type appears to be even more energy saving which would be a boost to the objective in future design.

Future research may consider a robust and large-scale incorporation of the water boiling system to ensure better harnessing of the energy lost via the walls.

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