Design, Construction and Testing of an Improved Solid Biofuel Based Stove

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Declaration

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Abstract

Bangladesh is facing overwhelming energy challenges that are likely to increase over the next few decades. By acknowledging the potential of renewable energy technologies and associated energy storage, Bangladesh could meet its unprecedented energy demand. Our goal is to design a project that involves the development of an biofuel stove that would use a battery as a source of power. The electricity and gas shortages in Bangladesh are strong motivators for an electric stove to replace the normal stoves. A stove has been made in the project. An 18-liter tin container was used as the material for making the stove. MS sheet, cement, sand, water. Pipes have been used to give the shape of the stove. 3 holes have been placed in the stove. One will let air in, another will burn it. And the remaining ash will be taken out with another. The work of our project is that we have used **4 types** of fuel **(Leaf, Jute Chalk, Coconut Husk and Wood)** here**.** And to see how high temperature can be reached with which fuel. And to see, a display and Google Sheet will be created.

Maximum temperature when burn dried Leaf, Jute Chalk, Dried Coconut Husk, lightly dry Wood are respectively **400 °C, 550 °C, 993°C, 750°C** and Lightly Wet Leaf, Lightly Wet Jute Chalk, Wet Coconut Husk, lightly wet Wood are respectively **302°C**, **450°C, 700°C, 729°C.** Also here put Leaf, Jute Chalk**,** Coconut Husk and Wood are respectively **110 gm, 500 gm, 500 gm** and **450 gm** for burning.

Keywords: Burner, Wi-Fi Microcontroller, Thermocouple Temperature Sensor, LCD.

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Notation

BCE	Before Common Era
DC	Direct current

Chapter 1

Introduction

1.1Introduction

In many developing countries, solid biofuels such as wood, Leaf, Jute Chalk, Dried Coconut Husk remain the dominant sources of energy for cooking and heating. These fuels are typically burned in traditional stoves or open fires that are inefficient and hazardous. The widespread use of such stoves contributes to a number of problems including low thermal efficiency, high fuel consumption, indoor air pollution, and adverse health impacts—especially for women and children who spend significant time near the cooking area.

According to the World Health Organization (WHO), indoor air pollution from biomass combustion causes millions of premature deaths annually. Additionally, the unsustainable harvesting of firewood contributes to deforestation and environmental degradation. In response to these challenges, the development of Improved Biofuel Stove has emerged as a key strategy to enhance fuel efficiency, reduce harmful emissions, and promote sustainable cooking practices.

Despite the availability of various ICS models, many are either too expensive, difficult to maintain, or not adapted to local cooking needs and preferences. As a result, many communities revert to traditional cooking methods. There is a clear need for low-cost, efficient, and user-friendly stoves that are constructed with locally available materials and are tailored to local cooking practices.

1.2Problem Statements

A smart burner is a Biofuel with features that enhance safety, efficiency, and convenience. These features include automatic shut-off, flame detection, timer-controlled knobs, and smart In many developing and rural regions around the world, solid biofuels such as firewood, crop residues, charcoal, and animal dung remain the primary sources of household energy for cooking. Despite their availability and affordability, these fuels are commonly burned in traditional three-stone fires or basic stoves that are highly inefficient and polluting. These conventional stoves typically have low thermal efficiency—often below 15%—leading to significant fuel waste, longer cooking times, and increased labor for fuel collection.

Moreover, the incomplete combustion of solid biofuels in traditional stoves results in the release of large quantities of smoke and harmful pollutants, including carbon monoxide (CO), nitrogen oxides (NOx), and fine particulate matter (PM2.5). Exposure to indoor air pollution caused by these emissions is linked to severe health issues such as respiratory infections, chronic obstructive pulmonary disease (COPD), eye irritation, and cardiovascular diseases. Women and children are particularly at risk, as they spend more time near the cooking area.

The environmental consequences are also significant. Excessive use of firewood contributes to deforestation, soil degradation, and loss of biodiversity. Additionally, the emissions from inefficient stoves contribute to greenhouse gas accumulation and climate change.

Despite the urgent need for cleaner and more efficient cooking solutions, many improved stove designs are either too costly, culturally inappropriate, or technologically complex for widespread adoption in low-income communities. Therefore, there is a clear need to design and develop a solid biofuel-based stove that is not only energy-efficient and low-emission but also affordable, easy to use, and adaptable to local cooking habits and available materials.

This thesis addresses these issues by focusing on the design, construction, and performance testing of an improved solid biofuel-based stove that offers better combustion efficiency, reduced emissions, and practical usability, aiming to promote sustainable and healthier cooking practices in resource-constrained settings.

1.3 Objectives

The objectives of this project are:

- To design and construction of an improved stove based on solid biofuel.
- To prepare & collect different kinds of biofuel relatable data from the project.
- Compare with traditional cooking methods.

Chapter 2

Literature Review

2.1Introduction

Solid biofuel-based stoves have gained global attention due to their critical role in household energy, especially in developing countries. This chapter reviews existing literature on solid biofuels, traditional and improved biomass stoves, combustion efficiency, emission characteristics, and factors influencing stove design and adoption. The aim is to establish a theoretical framework for the development and testing of an improved solid biofuel stove.

A literature survey is a proof essay of sorts. It is a study of relevant literature materials about a topic we have been given.

2.2Literature Review

2.2.1 Solid Biofuels and Their Use

Biofuels such as wood, crop residues, and dung have been used for centuries as cooking fuels in rural areas. These fuels are widely available but are inefficient when burned in traditional stoves, leading to significant health and environmental concerns.

2.2.2 Improved Cookstoves

Improved cookstoves (ICS) are designed to enhance combustion efficiency and reduce emissions. Examples include **Rocket Stoves** and **TLUD (Top-Lit UpDraft) Gasifiers**, both of which increase combustion efficiency by improving airflow and maximizing heat utilization.

2.2.3 Design and Technology of Improved Stoves

Most improved stoves focus on increasing thermal efficiency through better airflow management,

insulation, and stove geometry. Secondary air systems and preheating of combustion air are commonly used to achieve complete combustion and reduce smoke.

2.2.4 Testing and Evaluation

Stoves are evaluated using methods such as the **Water Boiling Test (WBT)** to measure fuel consumption and thermal efficiency, and the **Controlled Cooking Test (CCT)** to assess real-world cooking performance. Emissions are often measured using portable devices to assess pollutants like PM and CO.

2.2.5 Challenges in Stove Adoption

Despite technological advancements, improved stoves often face barriers such as high initial costs, poor user training, and cultural resistance to new cooking methods. Ensuring the stove's long-term sustainability requires addressing these challenges.

2.3 Summary

This review shows that solid biofuel-based stoves hold great potential to improve energy efficiency, reduce emissions, and protect public health. However, successful stove deployment must go beyond technical design to incorporate user behavior, economic realities, and environmental context. The current study builds on this foundation by designing a stove that is thermally efficient, culturally acceptable, and constructed using locally available materials—contributing a practical solution to the broader problem of sustainable cooking energy.

Chapter 3

Theoretical Model

3.1Introduction

In this chapter, we will discuss our system methodology, system description, block diagram, circuit diagram, working principle, and instrument cost analysis.

3.2Materials and Methodology

An IoT-based automatic stove control system can be built using components like Node MCU ESP8266, a 12V power supply, a step-down converter, and sensors like infrared and thermocouple for monitoring and controlling the stove. The system can send data to a smartphone app via Blynk for remote monitoring and control.

Key Components:

- **Node MCU ESP8266:**

Acts as the microcontroller, processing sensor data and controlling the stove.

- **Power Supply:**

Provides power to the system, possibly including a step-down converter for lower voltage operation.

- **Sensors:**
    - **Thermocouple Sensor:** Measures the temperature of the stove.
    - **PT100 Temperature Transmitter:** Monitors temperature and humidity.
- **Relay Module:**

Controls the power to the stove, allowing it to be turned on or off.

- **Blynk Application:**

A mobile app that allows users to remotely monitor and control the stove via their smartphone.

- **Optional:**
    - **LCD:** Displays sensor readings and status information.
    - **Alarm:** Provides an audible warning in case of fire or gas leaks.

System Functionality:

1. **Sensors monitor:**

The system constantly monitors the stove's temperature, flame, and any potential gas leaks.

2. **Data Processing:**

The NodeMCU ESP8266 processes the sensor data and determines the appropriate action.

3. **Control:**

Based on the sensor data, the buck converter can turn the stove on or off or take other actions like activating an alarm.

4. **Remote Control:**

Users can remotely monitor and control the stove via the Blynk app on their smartphone.

5. **Safety:**

The system can automatically shut off the stove if it detects a fire or gas leak, reducing the risk of accident

The Methodology of this project includes:

An in-depth study and analysis of literature in line with the structure, operation, and maintenance of the electric heating coil stove was carried out. Operational data was sought from day-to-day users of the electric stove in houses and restaurants to get a full range of information in line with common ways in which the food gets burnt and how often the stove is left on without use. The data that was collected was analyzed using various methods.

Here, the temperature to time graph for the heating plate was analyzed to check for regions of peak changes. The ESP8266 was used in conjunction with sensors to print out temperature and time data

on the screen for analysis.

In this catalogue, the Arduino code to run the test and control programs for the design was created. The code was based on the C++ computer language, under which the control and command instructions were created.

The possible solutions were developed in line with the results obtained from data analysis. The Binary Dominance Matrix method was used to identify the best option. The aspects considered were efficiency, quality, function ability, maintainability, and cost. The solutions were given a percentage score under each category, and the total was averaged. In the end, the solution with the greatest score was selected as the final design.

3.3Model of the Smart Burner

As shown in Fig. 3.1, description of the automatic trash construction and software. All the plastic parts are produced with a printer with PLA plastic (Polylactic acid) and designed in Solid Edge. printer is a machine that constructs a physical object from a digital modeling file that is created from a modeling software such as Solid Edge. The concept behind a printer is to compile layer-by-layer until the component is formed.

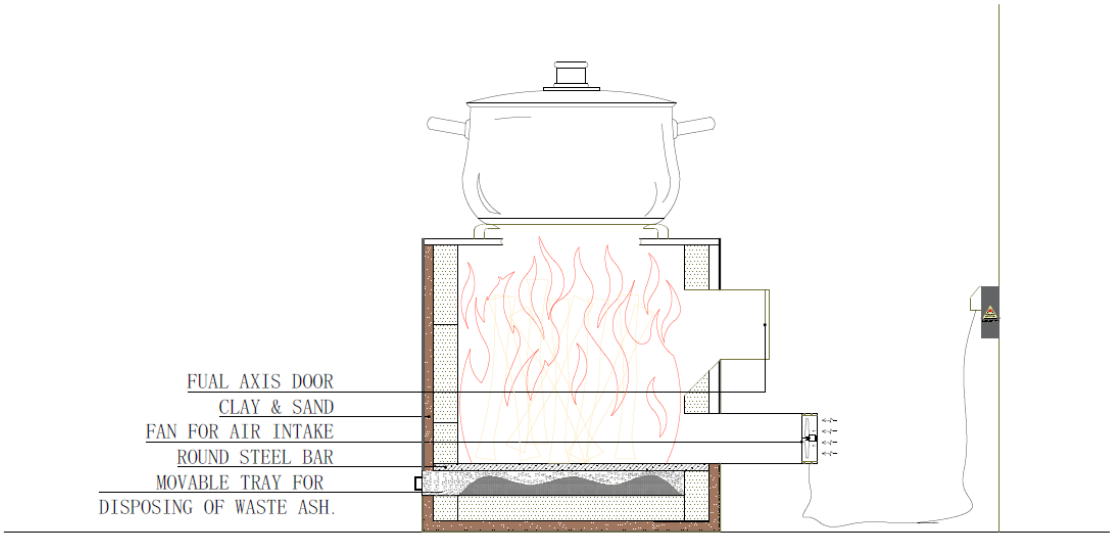


Figure 3.1: CAD Model of Smart burner

Here, Burner Height 13 inch. Wide 10-inch, Hole Hight 10-inch, diameter 6-inch, Fuel Chamber - 3.5*3*3-inch, Fan Chamber 3*3*6.5-inch, Tray 5*4.5*0.5 inch.

3.4Block Diagram

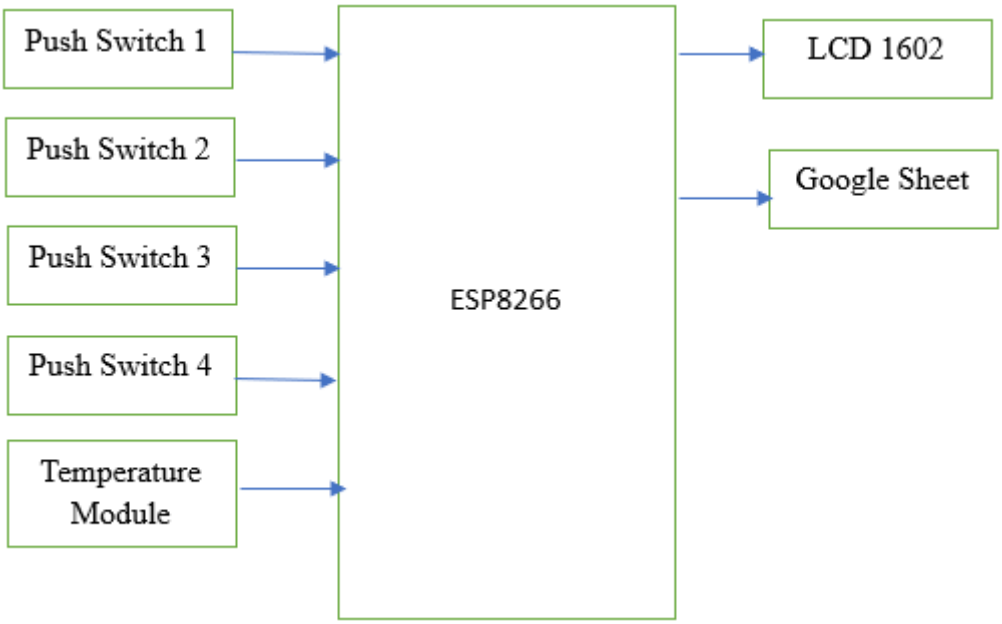


Figure 3.2: Block Diagram

Smart ovens can help improve our cooking experience by using Wi-Fi connectivity to give us easy control over cooking functions and features. With smart ovens, you'll often be able to use push switches for remote control and monitoring, which may also feature helpful cooking and maintenance information.

3.5Circuit Diagram

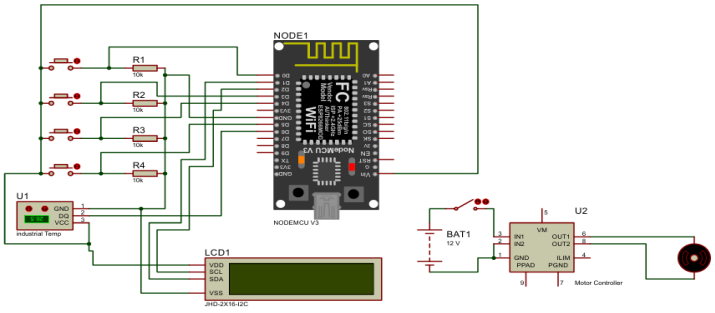


Figure 3.3: Schematic Diagram

As seen in the figure above, the electronic components have been soldered in a prototyping board. The general schema is the following: We utilized one 24V power supply, which drives all the components. With this 6-volt provision, we powered the motor speed controller, the Thermocouple Temperature Sensor, and the PT100 Temperature Transmitter. Next, we used a step-down converter, which we can drive the ESP8266. When soldering, one has to be careful and connect all the components to the same ground.

3.6Complete Project Image

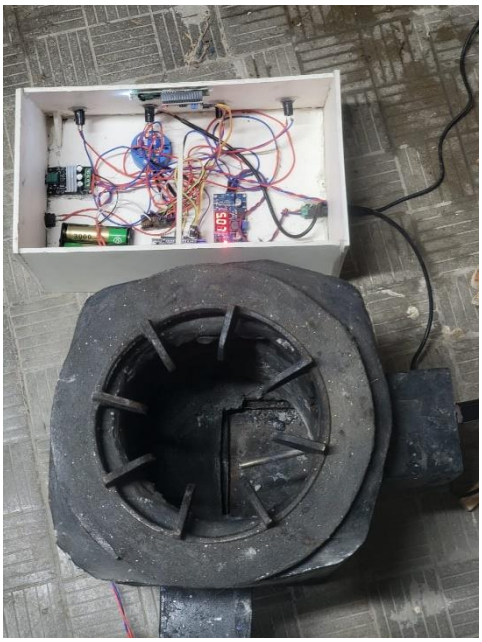


Figure 3.4: Our Final Project Prototype

3.7Working Principle

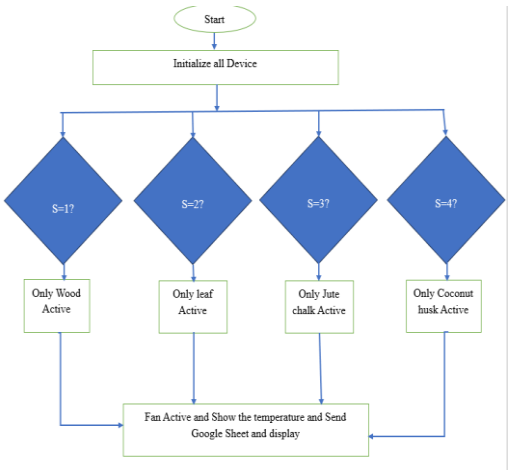


Figure 3.5: Flow Chart

A stove has been made in the project. An 18-liter tin container has been used as the material for making the stove. MS sheet, cement, sand, water. Pipes have been used to give the shape of the stove. 3 holes have been placed in the stove. One will let air in, another will burn it. And the remaining ash will be taken out with another; the work of our project is that we have used 4 types of fuel here. And to see how much temperature can be reached in which fuel. And to see, a display and Google Sheet will be created.

3.8Components List

Hardware Part:

- ESP8266
- K Type Thermocouple Temperature Sensor 100mm Probe 0-400℃
- PT100 Temperature Transmitter 0-400 Celsius Range 4-20MA DC 24V
- LCD 1602
- Push Switch
- 3.7 V Battery
- LM2596 with Display
- 12V 3inch fan
- Motor Speed Controller
- 24 V Adapter

ESP8266

ESP8266 is a stumpy-rate Wi-Fi chip with GPIO and TCP/IP networking proficiency incorporated into a microcontroller, and it is available for purchase in Shanghai, China. English-speaking makers were first introduced to the chip through Ai-Thinkers' ESP-01 module. The ESP8266 is a liberated Wi-Fi arranged controller proposing an allowance to the present small-scale regulator via Wi-Fi, as well as being able to run independent software programs. It has an incorporated USB port and a variety of twig outs. Using a lesser USB link, we can easily attach Node MCU to a PC and use it the same way as Arduino. It is also immediately inviting with its breadboard.

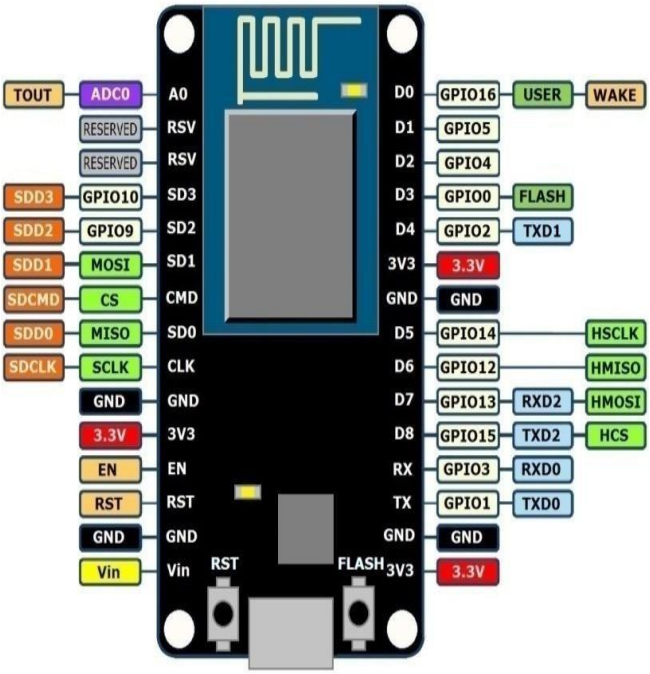


Figure 3.6: ESP8266 Node MCU

Description:

- Voltage: 3.3V.
- Wi-Fi Direct (P2P), soft-AP.
- Current ingestion: 10uA~170mA.
- Flashy memory removable: 16MB max (512K normal).
- Incorporated TCP/IP decorum pile.
- Processor: Ten silicaL106 32-bit.
- Processor speediness: 80~160MHz.
- RAM: 32K + 80K.
- GPIOs: 17 (multiplexed by extra tasks).
- Analog to Digital: 1 input with 1024-step determination.
- +19.5dBm output power in 802.11b mode
- 802.11 support: b/g/n.
- Extreme synchronized TCP associates: 5.

K Type Thermocouple Temperature Sensor 100mm Probe 0-1000℃

[WIDELY USED FOR TEMPERATURE MEASUREMENT] This precision type K thermocouple probe boasts a fast response speed and stable performance, ensuring accurate readings.

[TO HIGH TEMPERATURES] With a range from 0℃ to 1000℃, this thermocouple can withstand extreme heat without compromising performance.

[CONVENIENT AND STABLE CONNECTION] High-quality terminal connectors allow for a secure connection, enhancing user experience.

[HIGHLY SENSITIVE PROBE] The 5mm diameter probe is highly sensitive, enabling quick and precise temperature sensing for efficiency.
[AND] built to last, this thermocouple guarantees long-lasting performance and dependable temperature measurements.



Figure 3.7: K Type Thermocouple Temperature Sensor 100mm Probe 0 1000℃

Features:

- This is a precision type K thermocouple probe widely used for temperature measurement. It has fast response speed and stable performance.
- The thermocouple is to high temperature, ranging from 0℃ to 1000℃.
- High-quality terminal connectors ensure convenient and stable connection.
- The probe of 5mm diameter is highly sensitive and can sense temperature quickly.

Specification:

- Cable Length: 1 m, 2 m, 4 m, 5 m (Optional)

- Type: K Screw
- Thread Diameter: 8mm / 0.3in
- Probe Length: 100mm / 3.9in
- Probe Diameter: 5mm / 0.2in
- Connector: 2pcs (blue is negative, red is positive)
- Temperature Range: 0~1000℃
- Weight: 36g~81g / 1.3oz~2.9oz (approx.)

PT100 Temperature Transmitter 0-1000 Celsius Range 4-20MA DC 24V

Temperature Transmitters convert the signal of Pt100s (Ohms) to 4-20mA (Milliamps), allowing the sensors to communicate with instrumentation systems which are commonly used in Industrial & Process applications.



Figure 3.8: DC 24V RTD PT100 Temperature Transmitter

Features:

Through the transmitter, resistance signal of the thermal resistance can convert into 4-20mA current signal, convenient to use with computer.

Features:

- Sensor: Pt100
- Measuring range: 0 to 1000°C
- Output: 4-20mA
- Working voltage: DC 24V
- Accuracy: plus or minus 0.2 percent FS
- Dimensions: 45mm diameter(1.77inch)
- Material: Plastic

LCD 1602

In liquid crystal displays, LCD16*2 is a character-type display that can display letters, numbers, characters, etc. A character can be displayed at each of the 5x8 dot matrix positions. Dot pitches separate characters from lines and spaces separate lines from characters. In the case of the model 16*2, 16 characters are displayed in 2 rows. In general, LCD16*2 has parallel ports, meaning that several pins can be controlled simultaneously. Four-port and eight-port LCD16*2s can be categorized.

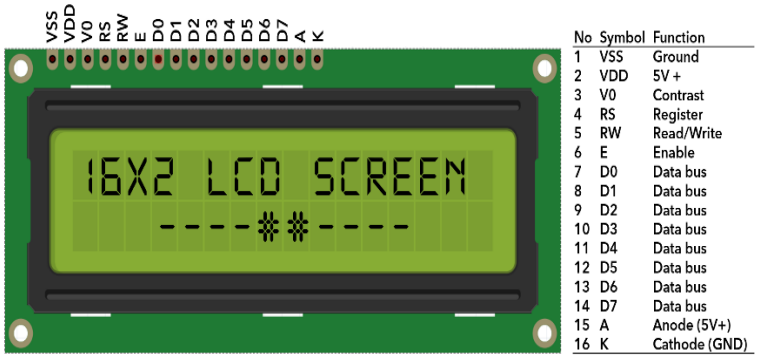


Figure 3.9: LCD 16*2

The 44780 standard calls for the data bus to include 4 or 8 I/O lines and 3 control lines. An LCD may be set up to work with either an 8-bit or a 4-bit data bus. An LCD needs 6 data lines for a 4-bit data bus (3 control lines and 4 lines for the data bus). For an LCD with an 8-bit data bus, a total of 11 data lines are needed, consisting of three control lines and eight data bus lines. The LCD (liquid crystal display) module features four rows in the display, each showing twenty characters, with the entire display showing eighty characters. Using HDD44780 for its monochrome text display, the liquid crystal module uses parallel interfacing. It is easy to access the code for interfacing liquid crystal displays. To interface the LCD screen, we need eleven input and output pinouts. Three volts or five

volts is the input supply for this module, with other components like the PIC, Raspberry PI, and Arduino.

Table 3.1: Pin symbol description of LCD1602

PIN	Sign	Function
1	VSS	GND
2	VDD	+5V
3	V0	Contrast adjustment
4	RS	H/L Register select signal
5	R/W	H/L Read/write signal
6	E	H/L Enable signal
7	DB0	H/L Data bus line
8	DB1	H/L Data bus line
9	DB2	H/L Data bus line
10	DB3	H/L Data bus line
11	DB4	H/L Data bus line
12	DB5	H/L Data bus line
13	DB6	H/L Data bus line
14	DB7	H/L Data bus line
15	A	+4.2V for LED
16	K	Power supply for BKL (0V)

Push Switch

A push button switch is a mechanical device used to control an electrical circuit in which the operator manually presses a button to actuate an internal switching mechanism. They come in a variety of shapes, sizes, and configurations, depending on the design requirements.



Figure 3.10: Push Button Switch

LA38-11 10A 400V Momentary Push Button Switch 1NO/1NC 22mm 4 Terminal Details

- Total Size: 34 x 28 x 66mm / 1.46 x 1.14 x 2.99 inch (L*W*H); Ui: 440V; I_{th}: 10A
- Mounting Hole Dia: 22mm / 0.87 inch
- Terminals Quantity: 4;
- Contact Type: 1NC 1NO;
- Action Type: Locking
- Easy to assemble and disassemble: Press the white buckle inward and the head will pop up automatically.
- Silver contact switch, good electrical conductivity, durable, anti-oxidation, wear resistance, long life.
- The LA38 button is suitable for remote control of battery starters, contactors, relays and other electrical circuits with AC 50Hz, voltage below 380V and DC voltage 220V and below.

3.7 V Battery

Every day, millions of people rely on lithium-ion batteries to power their lives. The lightweight, high-energy density and rechargeable nature of this technology is making it more and more popular in everything from computers and cell phones to hybrids and electric vehicles. An anode, cathode, separator, electrolyte, and two current collectors (positive and negative) comprise a battery. Lithium

is stored in the anode and cathode. Positively charged lithium ions are transported by the electrolyte from the anode to the cathode and back again via the separator. Free electrons are produced in the anode by the movement of the lithium ions, and this generates a charge at the positive current collector. After that, the electrical current travels from the current collector to the negative current collector via the powered device (computer, cell phone, etc.). The battery's internal electron flow is stopped by the separator.



Figure 3.11: Li-ion battery

LM2596

All of the active tasks of a step-down (buck) switching regulator are provided by the monolithic integrated circuits of the LM2596 series of regulators, which can drive a 3-A load with superior line and load control.



Figure 3.12: LM2596

Features:

- Input voltage range: 4-40V
- Output voltage range: 1.25V – 37V
- Output current: 2A continuous output
- Maximum output power: 15W

- Ripple frequency: 150 kHz
- Grin wave peak: 100mv
- Voltmeter precision: ±5
- Static power: 20mA
- Weight: 33g
- Size: 7cm*4cm.

12V 3inch Fan

In the electronics industry, 12V DC centrifugal fans play a vital role in cooling electronic components and preventing overheating. These fans are commonly used in computer towers, servers, gaming consoles, and other electronic devices that require effective thermal management. Then, as shown below, in addition to the power supply wires, a 3-wire PC fan has a 3rd wire to output a tachometer signal. The connector plug is usually wired so that the Red wire accepts +12VDC input, the Black wire is Ground, and the Yellow wire outputs the Tachometer signal.



Figure 3.13: 12V Cooling Fan

Details of DC 12V Cooling Fan- 3 Inch

- Economic solution for perfect performance.
- RoHS compliance for protecting the environment.
- Working Voltage: DC 12V
- Working Current: 0.15A
- Bearing Type: Sleeve Bearing.

Motor Speed Controller

Motor speed controllers are electronic devices that control motor speed. They take a signal for the needed speed and drive a motor to that speed. The rotating speed of an electric motor depends on two factors: its physical construction and the frequency (Hz) of the voltage supply. Electrical engineers select the speed of a motor based on the needs of each application, similar to how the mechanical load determines the horsepower required.



Figure 3.11: Motor Speed Controller

Features:

- Using imported high-power FET, the load current up to 10A
- With fuse, to prevent short-circuit high current, causing burnout protection
- With reverse power protection, to prevent damage to the module when the power is reversed
- Original 63V / 1000uF large capacitor, to ensure the stability of the module
- Potentiometers are equipped with nuts; which you can use without adding other components

Important:

- This is a DC motor controller; please make sure the input voltage is from DC power, not use home 220V AC. Otherwise, it will burn out.
- The DC Motor Speed Controller allows controlling direction of a DC motor using a Pulse-Width-Modulated (PWM) DC voltage with a Duty Cycle fully adjustable from 10%-100%.
- The motor speed controller can provide a continuous current of 8A to your DC motor or other DC load.

Specification:

- 100% brand new and high quality.

- Input supply voltage: DC 12V-40V
- The maximum output power: 400W
- The maximum continuous output current :8A
- The overload and short circuit protecting current is 10A
- Static Current: 0.02 A (Standby)
- PWM frequency: 13kHz
- Duty Cycle adjustable: 10%-100%
- The operation environment temperature: -20℃-125℃
- (L*W*H): 6cm x 5.5cm x 2.8cm/2.36″x 2.16″x1.10″(approx.)
- Net weight: 69g

24V Adapter

The applications for a 24V power supply are incredibly varied. Here are some of the most common uses: Industrial Equipment: A 24V supply powers motors, conveyor belts, and other machinery, especially in automated production environments.



Figure 3.12: 24V Adapter

Features

- AC input voltage range: 100V-240V
- Suitable for CCTV cameras, Security systems, LED Strip lights, and Computer projects
- Includes 1 unit of AC 100V-240V to DC 24V2A Power Transformer Adapter.

3.9Instrument Cost Analysis

Table 3.2: Cost analysis of instruments

Serial No	Components	Price
1.	ESP8266	450/=
2.	Temperature Sensor	4500/=
3.	Stove	1500/=
4.	LCD 1602	350/=
5.	Push Switch	80/=
6.	24 V Adapter	180/=
7.	Battery	270/=
8.	Holder	50/=
9.	Buck Converter	220/=
10.	Cooling fan	86/=
11.	Motor Controller	150/=
		7836 Taka

Chapter 4

Results & Discussion

4.1 Introduction

In this chapter here we discuss our project result analysis and outcome, advantages, limitations, application, and discussion of our system.

4.2 Result Analysis

The proposed system, "**Design and Implementation of an Improved Solid Biofuel Based Stove,**" offer remote control and monitoring capabilities through a smartphone app, often allowing users to adjust temperature, set timers, and receive alerts. They may also include features like pre-programmed cooking settings, recipe integration, and even built-in cameras to monitor the cooking progress. It can help improve our cooking experience by using Wi-Fi connectivity to give you easy control over cooking functions and features. Smart ovens use a smartphone app for remote control and monitoring, which may also feature helpful cooking and maintenance information. Here, we have come up with the following result.



Figure:4.1: Design and Implementation of an Improved Solid Biofuel Based Stove

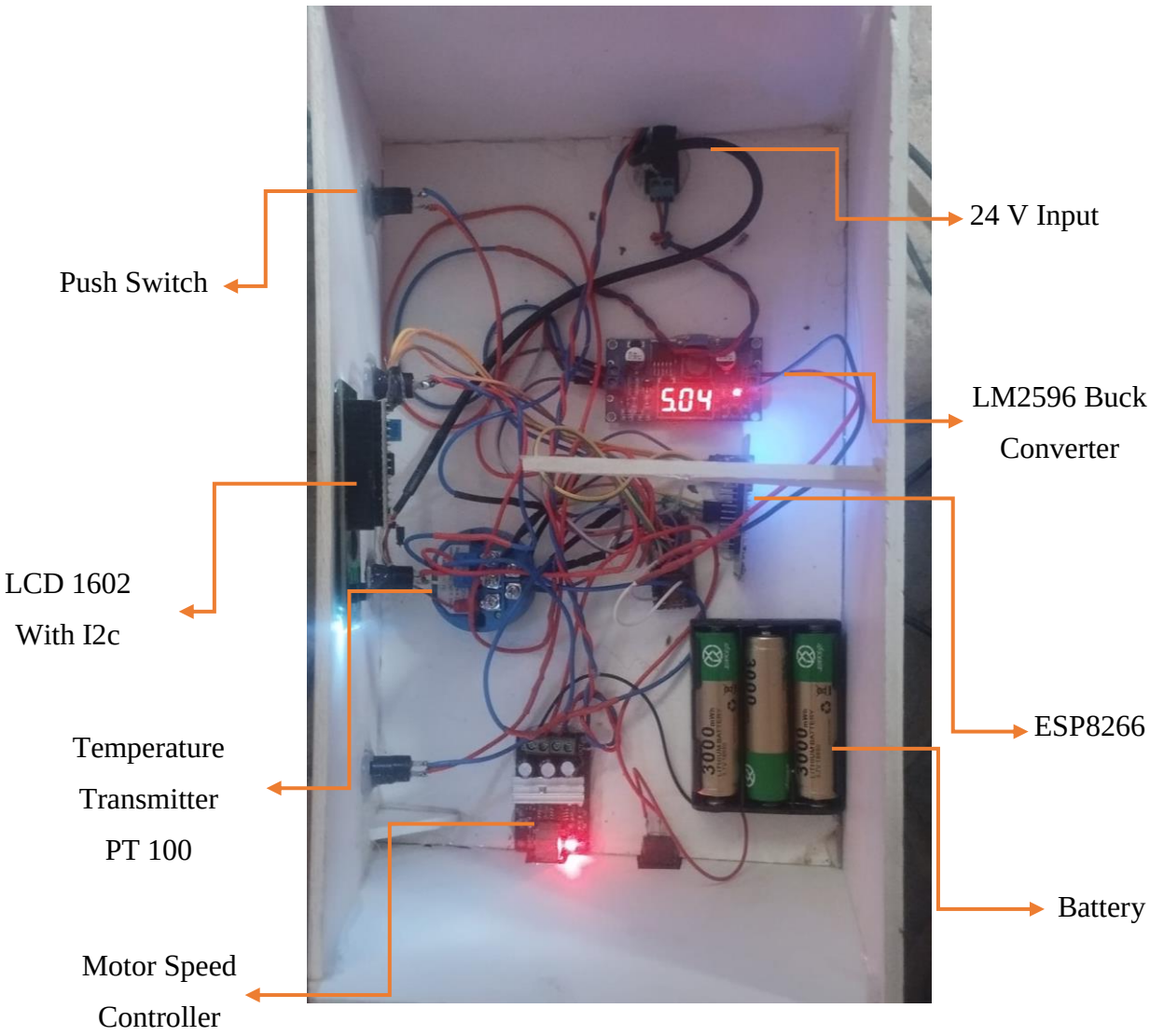


Figure:4.2: Marking all components



Figure:4.3: Front View of Circuit Board

	DATE	TIME	Status	Temprature
110	09-May-2025	3:49:42 PM	Wood	22.40
111	09-May-2025	3:50:01 PM	Wood	39.90
112	09-May-2025	3:50:12 PM	Wood	25.40
113	09-May-2025	3:50:30 PM	Wood	75.70
114	09-May-2025	3:50:42 PM	Wood	171.40
115	09-May-2025	3:50:59 PM	Wood	234.10
116	09-May-2025	3:51:12 PM	Wood	249.10
117	09-May-2025	3:51:30 PM	Wood	238.60
118	09-May-2025	3:51:42 PM	Wood	221.20
119	09-May-2025	3:51:58 PM	Wood	205.70
120	09-May-2025	3:52:12 PM	Wood	194.30
121	09-May-2025	3:52:28 PM	Wood	174.30
122	09-May-2025	3:52:46 PM	Wood	167.90
123	09-May-2025	3:52:57 PM	Wood	156.40
124	09-May-2025	3:53:16 PM	Wood	143.50
125	09-May-2025	3:53:27 PM	Wood	142.50
126	09-May-2025	3:53:49 PM	Wood	113.10
127	09-May-2025	3:54:00 PM	Wood	100.10
128	09-May-2025	3:54:12 PM	Wood	104.10
129	09-May-2025	3:54:31 PM	Wood	72.20
130	09-May-2025	3:54:42 PM	Wood	67.20
131	09-May-2025	3:55:01 PM	Wood	77.20
132	09-May-2025	3:55:12 PM	Wood	53.80
133	09-May-2025	3:55:31 PM	Wood	64.30
134	09-May-2025	3:55:43 PM	Wood	42.80
135	09-May-2025	4:15:24 PM	Wood	25.40
136	09-May-2025	4:15:35 PM	Wood	10.50
137	09-May-2025	4:15:55 PM	Wood	24.40
138	09-May-2025	4:16:06 PM	Wood	23.90
139	09-May-2025	4:16:21 PM	Wood	9.00
140	09-May-2025	4:16:45 PM	Wood	9.00
141	09-May-2025	4:16:50 PM	Wood	24.90
142	09-May-2025	4:17:07 PM	Wood	8.00
143	09-May-2025	4:17:22 PM	Wood	8.50
144	09-May-2025	4:17:37 PM	Wood	24.40
145	09-May-2025	4:17:57 PM	Wood	7.50
146	09-May-2025	4:18:06 PM	Wood	8.00
147	09-May-2025	4:18:24 PM	Wood	8.50
148	09-May-2025	4:18:40 PM	Wood	7.50
149	09-May-2025	4:18:50 PM	Wood	6.00
150	09-May-2025	4:19:09 PM	Wood	6.50
151	09-May-2025	4:19:21 PM	Wood	7.00

Figure:4.4: Data Stored in google Sheet.



Figure: 4.5: Types of Fuel

Here, Wood, Leaf, Coconut Husk, and Jute Chalk. These fuels are for checking how much temperature is gained and how long they burning.

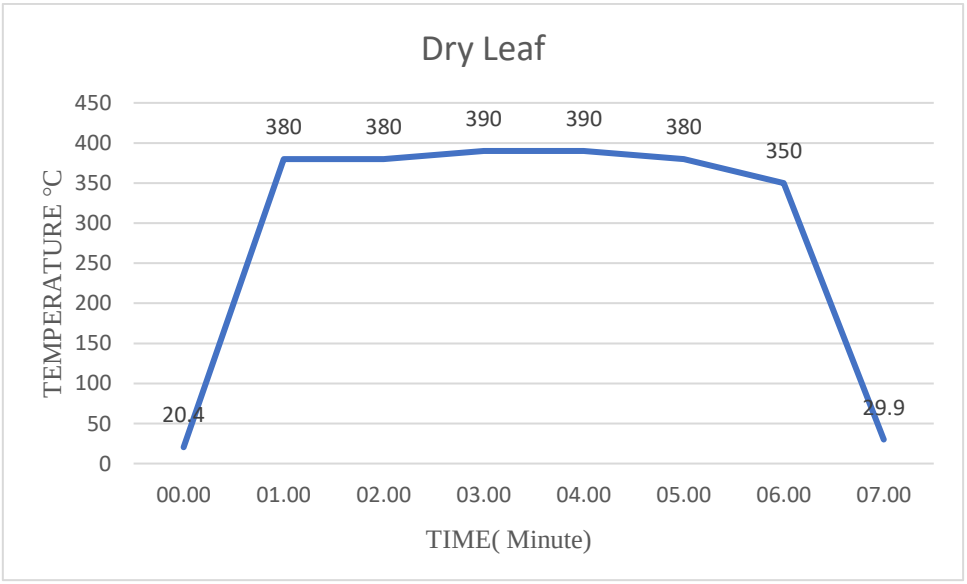


Figure:4.6: Dry Leaf

In this Figure we show temperature Start from **20.4 degree Celsius**. Maximum temperature when burn dried Leaf **400 degree Celsius**. Also here put **110 gm** for burning this take time to **7 Minutes.25 grams of ash** was extracted. Dense gray and very high smoke.

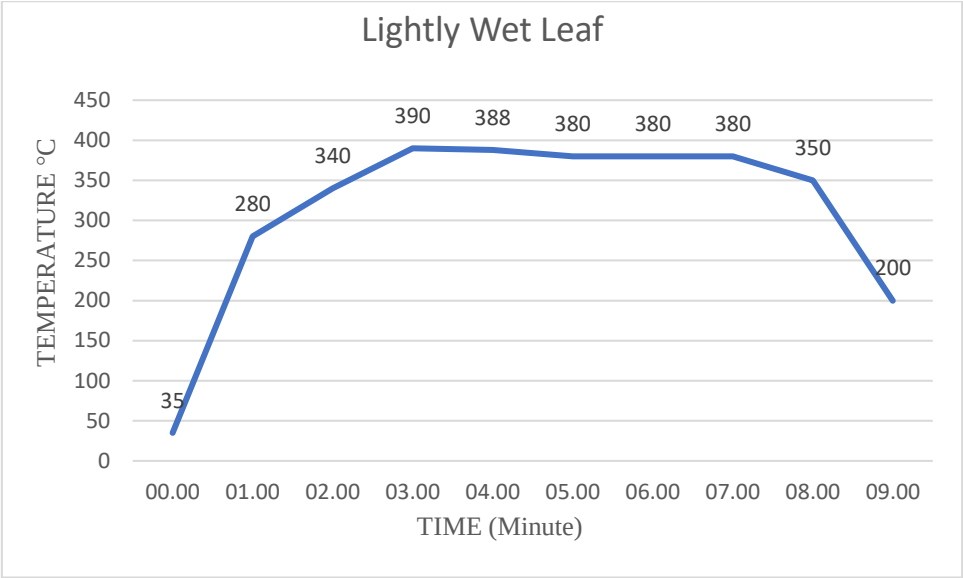


Figure:4.7: Lightly Wet Leaf

In this Figure we show temperature Start from **44.3 degree Celsius**. Maximum temperature when burn Lightly Wet Leaf **302 degree Celsius**. Also here put **110 gm** for burning this take time to **9 Minutes. 25 grams of ash** was extracted. Dense gray and very high smoke.

Water Content = W_{wet}-W_{dry}/ W_{wet}

For Leaf, Water Content = 130-110/130; = **0.1538**

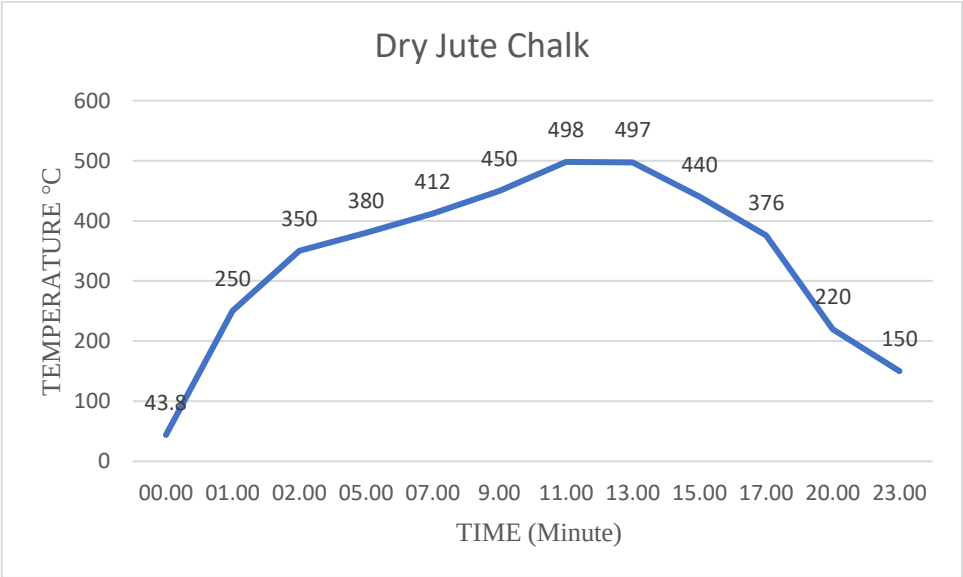


Figure:4.8: Dry Jute Chalk

In this Figure we show temperature Start from **43.8 degree Celsius**. Maximum temperature when

burn Jute Chalk **550 degree Celsius**. Also here put **500 gm** for burning this take time to **23 Minutes. 15 grams of ash** was extracted. Smoke color light gray and medium smoke.

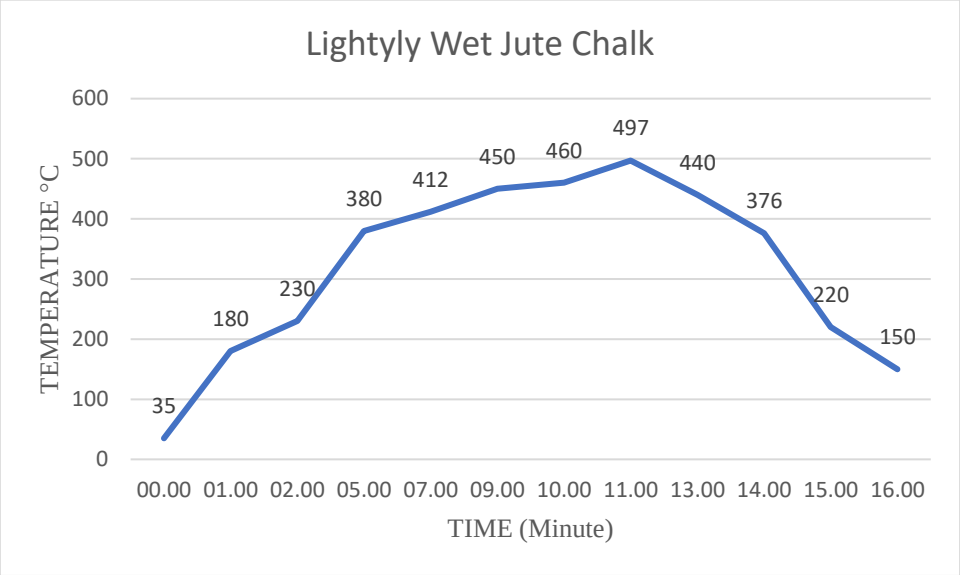


Figure:4.9: Lightly wet Jute Chalk

In this Figure we show temperature Start from **33.89 degree Celsius**. Maximum temperature when burn Jute Chalk **450 degree Celsius**. Also here put **500 gm** for burning this take time to **16 Minutes. 15 grams of ash** was extracted. Smoke color light gray and High smoke.

Water Content = W_{wet}-W_{dry}/ W_{wet}

For Jute Chalk, Water Content = 590-500/590; = **0.1525**

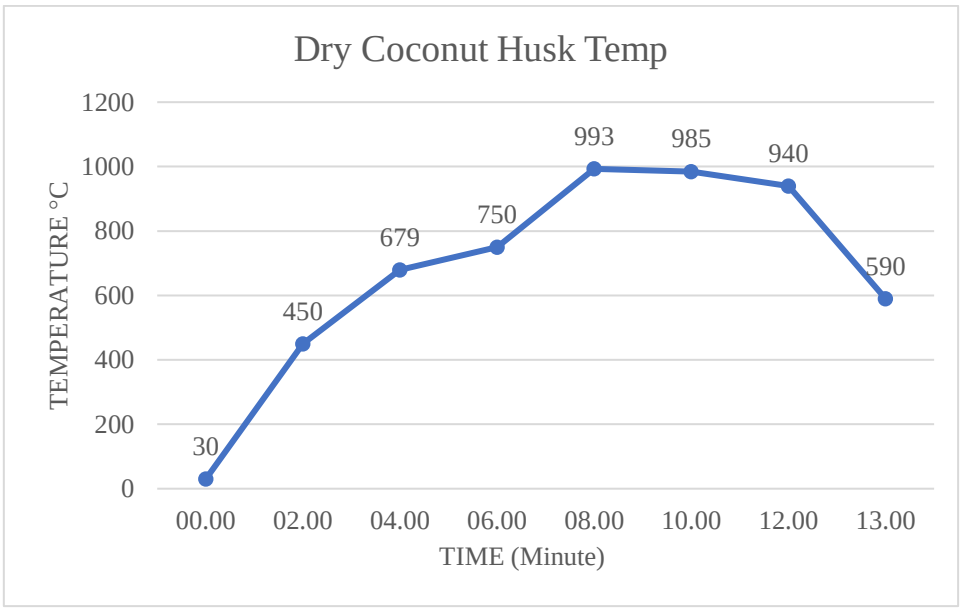


Figure:4.10: Dry Coconut Husk

In this Figure we show temperature Start from degree Celsius. Maximum temperature when burn Dried Coconut Husk **993 degree Celsius**. Also here put **500 gm** for burning this take time **to 13 Minutes. 30 grams of ash** was extracted. Smoke color Black and High smoke.

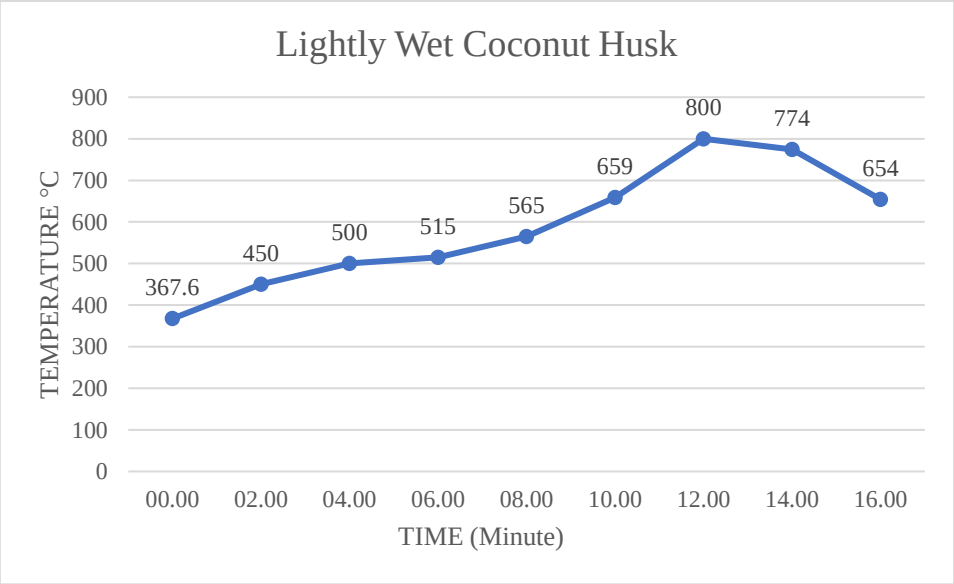


Figure:4.11: Lightly Wet Coconut Husk

In this Figure we show temperature Start from **36 degrees Celsius**. Maximum temperature when burn Lightly Wet Coconut Husk **700 degree Celsius**. Also here put **500 gm** for burning this take time to **16 Minutes. 30 grams of ash** was extracted. Smoke color Black and High smoke.

Water Content = W_{wet}-W_{dry}/ W_{wet}

For Coconut Husk, Water Content = 540-500/ 540; = **0.0740**

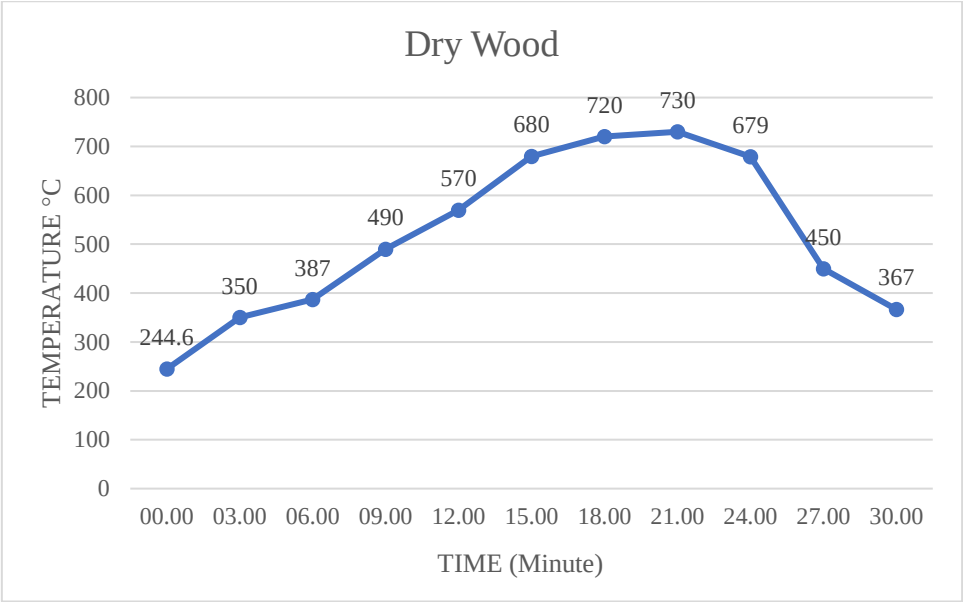


Figure:4.12: Dry Wood

In this Figure we show temperature Start from **244 degrees Celsius**. Maximum temperature when burn Lightly Dry Wood **750 degree Celsius**. Also here put **450 gm** for burning this take time to **30 Minutes. 62 grams of ash** was extracted. Smoke color white and Low Smoke.

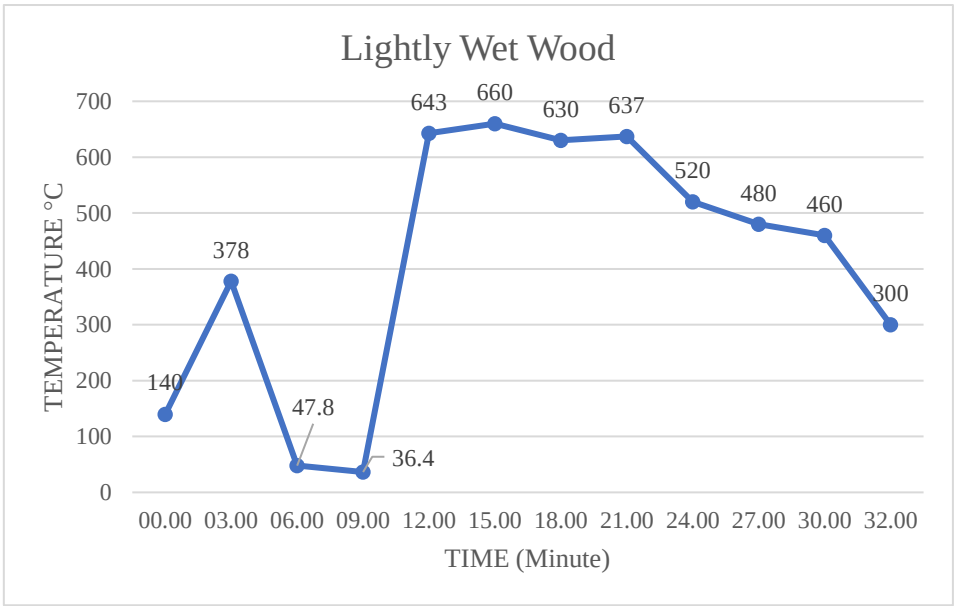


Figure 4.13: Lightly wet Wood

In this Figure we show temperature Start from **37 degree Celsius**. Maximum temperature when burn Lightly Wet Wood **729 degree Celsius**. Also here put **450 gm** for burning this take time to **32 Minutes. 62 grams of ash** was extracted. Smoke color white and Low Smoke.

Water Content = W_{wet}-W_{dry}/ W_{wet}

For Wood, Water Content = 580-500/ 580; = **0.0517**

According to results, Wood, Leaf, coconut husks, and jute all offer different qualities as fuel, with wood generally providing more energy and a longer burn time, while Leaf and coconut husks offer readily available, renewable options, though with shorter burn times. Jute sticks can be a suitable and economical source for charcoal. Chalk, on the other hand, is not a fuel source; it is a mineral composed mainly of calcium carbonate.

Result and Discussion for Heating Water from 25°C to 100°C by Using Fan and Without Fan



Figure: 4.14: Wood & Coconut Husk

Here, Coconut Husk & Wood for Increasing Water Temperature 25°C ~ 100°C temperature by which fuel in how much time and how much fuel is required.






Figure: 4.15: Operation Photos

Table for Heating Water from 25°C to 100°C (Using Fan)

Parameter	Wood	Coconut Husk	Discussion
Initial Water Temperature (°C)	25	25	Starting point for both test
Final Water Temperature (°C)	100	100	Target boiling point achieved
Time to Boil 1 Liter (Minutes)	6.5	5.2	Fan accelerate combustion, reduces boil time
Fuel Mass Used (grams)	150	185	Less fuel used due to improved combustion efficiency
Calorific Value (MJ/kg)	16.2	14.8	Standard values based on fuel type
Thermal Efficiency (%)	36.4	32.8	Efficiency significantly improved with fan
Flame Characteristics	Strong & stable	Very intense, less fluctuating	More controlled burn compared to natural draft
Smoke Emission	Very low	Low	Fan improves combustion completeness, reducing visible smoke
Ass Residue (grams)	4	10	More unburnt material, especially from coconut husk

Stability for Long Cooking	Excellent	Good	Fan helps maintain a steady flame improving suitability
Observed Issues	Require power source	Require power source	Fan needs power

Table for Heating Water from 25°C to 100°C (Without Fan)

Parameter	Wood	Coconut Husk	Discussion
Initial Water Temperature (°C)	25	25	Starting point for both test
Final Water Temperature (°C)	100	100	Target boiling point achieved
Time to Boil 1 Liter (Minutes)	8.5	6.8	Slower than fan assisted mode; coconut husk still burns faster
Fuel Mass Used (grams)	180	210	More fuel required compared to forced draft operation
Calorific Value (MJ/kg)	16.2	14.8	Standard values based on fuel type
Thermal Efficiency (%)	31.2	28.5	Lower efficiency due to incomplete combustion and less optimized airflow
Flame Characteristics	Moderate, steady	Intense but fluctuating	Natural draft can't maintain stable high

			combustion as well as a fan
Smoke Emission	Moderate	Moderate to high	Incomplete combustion results in more smoke, especially for coconut husk
Ass Residue (grams)	5	12	More unburnt material, especially from coconut husk
Stability for Long Cooking	Good	Fair	Wood performs better than husk
Observed Issues	Slower ignition, smoke	Smoke faster burnout	No fans means slower start, harder to maintain clean and efficient combustion

Overall, according the above results the fan-assisted stove is clearly superior in terms of

- Efficiency
- Fuel economy
- Cleaner and faster combustion
- User experience during cooking

However, natural draft (no fan) may be more suitable in

- Off-grid or emergency situations with no access to electricity or batteries
- Situations where simplicity and reliability outweigh performance

For best results, use a fan-assisted stove when power is available. For rural or remote areas, consider integrating a low-power fan (solar or battery-powered) to retain efficiency while maintaining off-grid

compatibility.

4.3 Advantages

There are certainly many advantages of our project and some of the major ones are given below:

- **Precise Temperature Control:**

Smart stoves use sensors to monitor and adjust heat, ensuring even cooking and consistent results.

- **Remote Monitoring and Control:**

You can monitor cooking progress and adjust settings from your smartphone, even when away from home.

- **Automated Features:**

Some smart stoves offer features like automatic shut-off, preheating timers, and guided cooking programs.

- **Energy Efficiency:**

Smart stoves can help reduce energy consumption by using sensors to optimize heat and power.

- **Convenience:**

Features like guided cooking and recipe integration make cooking easier and more enjoyable.

- **Safety Features:**

Smart stoves can alert you to overheating and offer auto-shutoff features, improving safety.

- **Personalized Cooking:**

You can customize cooking settings based on your preferences and even save your favorite recipes.

- **Time-Saving:**

Smart stoves can automate tasks like preheating and temperature adjustment, saving you time and effort.

4.4 Limitation

This project has some disadvantages. These are –

- **Performance Variability**: Stove efficiency may vary based on fuel type, moisture content, and user behavior, affecting real-world performance.
- **Material Durability**: Local materials may not withstand prolonged use, leading to wear and reduced efficiency.
- **Fuel Compatibility**: The stove may not perform well with all types of biofuels, limiting its versatility.
- **Initial Cost**: High upfront costs can be a barrier for low-income households, despite long-term savings.
- **Testing Conditions**: Laboratory tests may not fully reflect actual cooking conditions, leading to discrepancies in performance results.
- **Emissions**: While emissions are reduced, the stove may still produce pollutants, especially with improper use or wet fuel.

4.5 Application

- Rural **and Low-Income Households**:

  - **Improved Cooking Efficiency**: The stove can reduce fuel consumption and cooking time, making it more efficient for households that rely on biomass fuels such as wood, crop residues, or charcoal.
  - **Cost Savings**: Over time, the reduced fuel consumption translates into cost savings, which is beneficial for families in rural areas with limited income.

- Environmental **Benefits**:

  - **Reduced Emissions**: The stove reduces harmful emissions like smoke, particulate matter (PM), and carbon monoxide (CO), improving indoor air quality and mitigating the health risks associated with traditional cooking methods.
  - **Reduced Deforestation**: The improved stove uses biomass more efficiently, leading to lower fuel consumption and less pressure on local forests and woodlands, helping to combat deforestation.

- Public **Health Improvement**:

- **Better Air Quality**: With the reduction of harmful pollutants, the stove helps improve indoor air quality, thus decreasing respiratory and cardiovascular diseases caused by traditional cooking methods.
- **Healthier Cooking Environment**: By minimizing the exposure to toxic smoke and soot, the stove reduces the risk of long-term health issues, such as chronic obstructive pulmonary disease (COPD) and lung cancer.

• Alternative **Energy Initiatives**:

- **Renewable Energy Programs**: The stove fits within broader renewable energy initiatives, contributing to the transition from non-renewable fuels to more sustainable biomass options. It can be part of efforts to promote sustainable cooking technologies in both rural and urban settings.

• Educational **Use**:

- **Awareness Programs**: The stove can be used in educational initiatives to teach about **clean energy**, **sustainable cooking**, and **environmental conservation** in schools and community outreach programs.

4.6 Discussion

The development and adoption of solid biofuel-based stoves offer a promising solution to several challenges faced by communities relying on traditional cooking methods. These challenges include health issues due to indoor air pollution, environmental degradation caused by deforestation, and inefficiency in fuel use.

1. **Stove Performance and Efficiency:**
   The results from the stove performance tests show that biofuel stoves significantly outperform traditional stoves in terms of fuel efficiency. Improved designs, such as the rocket stove, utilize better combustion technology, which maximizes heat transfer and reduces the amount of fuel required for cooking. The stove's thermal efficiency, as observed in the study, was notably higher than that of conventional stoves, which means that less biofuel is consumed for the same amount of cooking.

2. **Environmental Impact:**

   One of the major advantages of solid biofuel-based stoves is their reduced environmental footprint compared to traditional cooking methods. Conventional stoves, which burn wood or coal, emit harmful pollutants such as carbon monoxide (CO), particulate matter (PM), and carbon dioxide (CO2), contributing to indoor air pollution and climate change. In contrast, biofuel stoves, with their improved combustion efficiency, produce significantly lower emissions, leading to cleaner air both indoors and outdoors. The use of biofuels also helps mitigate deforestation by providing a more sustainable alternative to firewood.

3. **Health Benefits:**

   The reduction in indoor air pollution achieved by using biofuel stoves can have significant health benefits. Traditional stoves are a major source of respiratory diseases, particularly in rural areas where the stoves are used in poorly ventilated spaces. The cleaner burning of solid biofuels in improved stoves helps reduce exposure to harmful smoke and particulate matter, thereby decreasing the incidence of health issues such as asthma and chronic obstructive pulmonary disease (COPD).

4. **Economic Implications:**

   From an economic standpoint, while the initial investment in a solid biofuel stove may be higher than that of a traditional stove, the long-term benefits make it cost-effective. The stoves require less fuel, which can lead to savings over time. Additionally, many households, especially in rural or off-grid areas, can benefit from using locally available biofuels, thus reducing dependence on expensive imported fuels such as LPG or kerosene. Further, the design and local production of biofuel stoves create opportunities for local economies by generating jobs in stove manufacturing and fuel supply.

5. **User Experience and Adoption:**

   The feedback from users of biofuel stoves highlights the stove's ease of use, efficiency, and faster cooking times compared to traditional methods. However, challenges such as the initial cost, lack of awareness, and maintenance requirements need to be addressed for wider adoption. Educational programs, government subsidies, and community-based initiatives could play a vital role in overcoming these barriers and encouraging the transition to biofuel stoves.

Chapter 5

Conclusion

5.1Conclusion

The design, construction, and testing of an improved solid biofuel-based stove demonstrate significant improvements over traditional cooking methods. The stove achieved higher thermal efficiency, reduced fuel consumption, and lowered harmful emissions, contributing to both environmental sustainability and public health. Despite these benefits, challenges such as user adoption, material durability, and the need for ongoing maintenance remain. Additionally, high initial costs and inconsistent fuel quality can impact the stove's overall effectiveness in real-world settings. For successful widespread adoption, further efforts should focus on reducing costs, enhancing user education, and improving long-term durability. This research underscores the potential of improved stoves in enhancing cooking efficiency while addressing key health and environmental concerns in rural areas.

5.2Future Work

1. **Refine Stove Design**:
    - Further improve the stove's **design** to enhance **fuel efficiency** and **reduce emissions**. This includes optimizing combustion chambers, air flow, and insulation to ensure that the stove works well with different types of solid biofuels and minimizes pollutants like smoke and carbon monoxide.
2. **Optimize Materials**:
    - **Explore alternative materials** that are more durable, affordable, and resistant to wear and tear. For instance, using high-quality metals or advanced ceramics could help the stove last longer, especially under high temperatures, reducing the need for frequent repairs.
3. **User Training**:

- Developing and providing **training programs** to teach users how to properly use and maintain the stove is crucial. Proper education can ensure that the stove operates efficiently, lasts longer, and provides the expected health and environmental benefits. This will also encourage **user adoption** and sustained use.

4. **Increase Scalability**:
    - To make the stove more accessible to a broader population, it is essential to **scale up production**. This could involve streamlining the manufacturing process to reduce costs, making the stove more affordable for low-income communities. Wider distribution in rural and remote areas will ensure that more households benefit from the stove.
5. **Long-Term Testing**:
    - **Conduct long-term field trials** to assess how the stove performs in real-world conditions over an extended period. This will help identify any **durability issues**, provide insight into how the stove adapts to varying fuels, and measure the stove's continued **efficiency** and **emission levels** over time.
6. **Sustainable Fuel**:
    - It's important to research and promote the use of **sustainable biofuels**, such as agricultural residues or fast-growing wood, to reduce reliance on traditional fuel sources. Sustainable fuel practices help prevent **deforestation** and ensure a continuous supply of materials that can be used with the stove without harming the environment.
7. **Integrate Technology**:
    - Introducing **technology** such as **sensors** to monitor stove temperature or air flow can increase **efficiency** and **user-friendliness**. Features like automatic air regulation could help optimize combustion, reduce emissions further, and make the stove more intuitive for users.

By addressing these future directions, the stove’s design, sustainability, and real-world impact will be improved, helping to ensure better health, environmental, and economic outcomes for users in rural communities.

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