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GANISIR: Web-based Control Panel for Downdraft Gasification of Buyo-Buyo (*Piper Aduncum*) and Falcata (*Paraserianthes Falcataria*) Wood Chips

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ABSTRACT

In remote places, access to stable energy sources is still a major problem (Riva et al., 2018). Fossil fuels and other conventional energy sources are expensive and adversely impact the environment (Jacal et al., 2022). By producing syngas from biomass, small-scale gasifiers provide a sustainable alternative (Chaves et al., 2016). Nevertheless, insufficient control and monitoring capabilities frequently restrict their efficiency. The downdraft gasifier system described in this paper has a web-based control interface that enables users to remotely monitor, modify, and control system functions, such as motors and sensors. The web-based technology makes it easier to precisely regulate important variables like temperature and biomass flow. Moreover, an integrated alert system enables users to immediately shut down operations via the website in the event of overheating. By improving the usability and effectiveness of small-scale gasifiers, this innovative approach hopes to guarantee a more stable gasification process and dependable energy production from locally produced biomass, such as Buyo-buyo (Piper aduncum) and Falcata (Paraserianthes falcataria). To conclude, the results support sustainable practices and better energy availability in remote areas.

Keywords: web-based control panel, multi-fuel downdraft gasifier, wood chips, Buyo- buyo, Falcata

INTRODUCTION

Access to reliable energy sources continues to be a major problem in remote or rural locations (Riva et al., 2018). Conventional energy sources, such as fossil fuels, have negative environmental effects in addition to being costly (Jacal et al., 2022). An alternative is provided by small- scale gasifiers, which produce syngas from biomass and provide a sustainable option (Chaves et al., 2016). However, the effectiveness and utility of small-scale gasifier systems are sometimes limited by their ineffective remote control and monitoring capabilities, especially in environments where regular human oversight is impracticable.

This issue must be resolved in order to increase sustainable energy practices, lessen reliance on fossil fuels, and improve energy access in these communities. Improved management of the gasification process can result in higher-quality gas output, safer operations, and more effective use of biomass resources that are readily available in the area. Furthermore, making gasifiers easier to use through remote monitoring can increase their accessibility, particularly in areas with little experience with technology.

In response to this difficulty, the researchers present a downdraft gasifier system that incorporates a web-based control interface. Users of this system can remotely monitor, modify, and manage gasifier operations such as motors and sensors thanks to the web-based interface. Through the integration of sensors and real- time data display, the system offers customers accurate control over crucial variables such as biomass flow and temperature. This will guarantee a more stable gasification process, which will ultimately result in the dependable generation of energy from biomass that is sourced locally, such as Falcata (*Paraserianthes falcataria*) and Buyo-buyo (*Piper aduncum*). This study provides opportunities to rural areas, local places, and companies that utilize manual downdraft gasifiers, as it can solve the issue regarding the efficiencies of gas production and energy production, difficulties on the operational and technical aspect, potential poses of danger, hazard and risk, and many more.

Gasification is a versatile and transformative process that converts carbon-based materials, such as coal, biomass, and waste, into synthesis gas, also known as syngas. Syngas are a mixture of hydrogen, carbon monoxide, and often carbon dioxide, which can be used to produce energy, including electricity generation, fuel production, and chemical manufacturing. (Ramos et al., 2022).

Consequently, research has paved the way for creating methods for producing energy that benefits the environment. Gasification is a widely recognized technology that uses the energy contained in trash to produce energy, and it is thought to be one of the most effective ways to do so (Vaish et al., 2019).

It is well known for its environmentally friendly aspect, as it substantially offers less harm to the environment. The process can be subdivided into pre-gasification, during gasification, and post gasification, having specific stages illustrated in the figures 1.1 to 1.3.

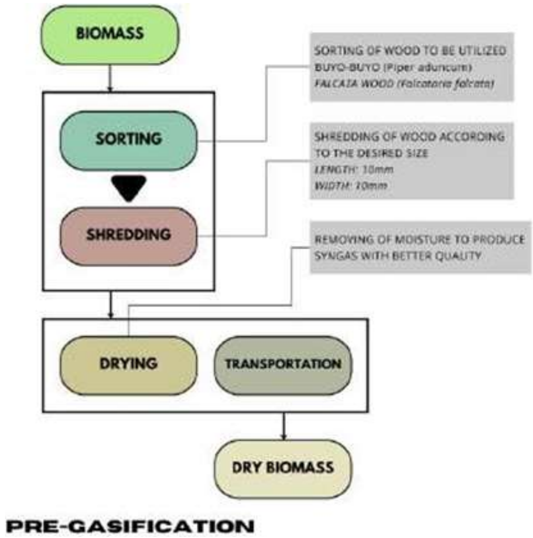


Figure 1.1. *Processes During Pre- Gasification*

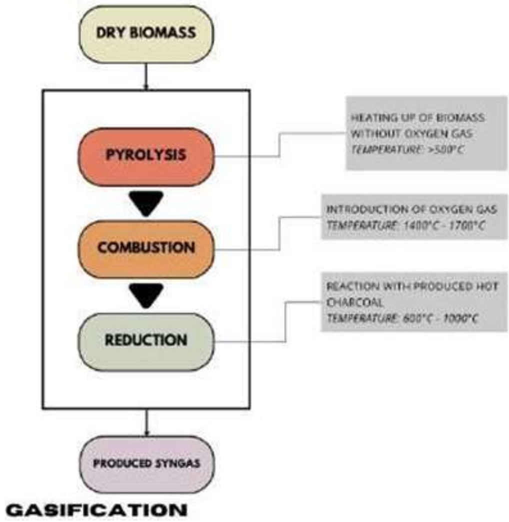


Figure 1.2. *Processes During Gasification*

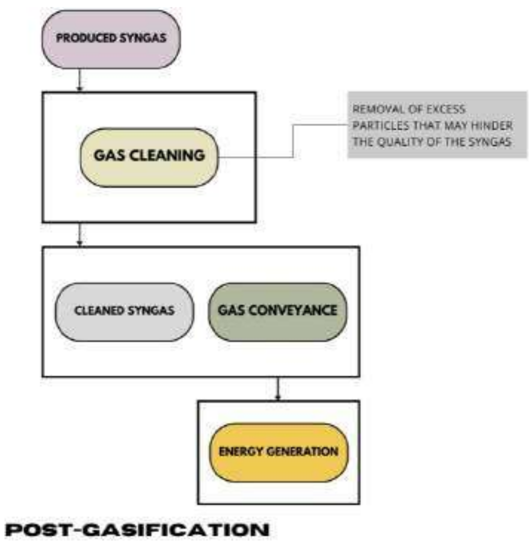


Figure 1.3. *Processes During Post- Gasification*

Precise control of process parameters is essential for gasification technology to function at its optimal level. Syngas are produced from biomass by downdraft gasifiers using regulated interaction between temperature, time, and height level. For optimal performance, control in this context means controlling the feedstock flow and feed rod position of the existing gasifier system.

Studies suggest that the lack of advanced control systems may be limiting the broader adoption and efficiency of this technology (Bianco et al., 2018; Patuzzi et al., 2021). For instance, Patuzzi et al. (2021) highlight the need for consistent, high-quality biomass—characterized by low moisture and low ash content—for small-scale gasifiers to function effectively.

Additionally, discussions state the inefficient handling of char, a by-product of gasification (Bianco et al., 2018; Patuzzi et al., 2021). Although char has potential value for various applications, it is often discarded as waste due to the absence of advanced systems for collection, characterization, and processing. This reflects another critical control gap, which, if addressed, could enhance both the economic and environmental sustainability of gasification. According to Daniyan et al. (2020), effectively managing different fuels requires precise control of variables such as temperature and pressure reduction, which is critical for achieving efficient operation. Extending upon these ideas, this study optimizes the gasification process for Falcata (*Paraserianthes falcataria*) and Buyo-buyo (*Piper aduncum*) wood chips by incorporating an advanced control system for the ideal flowability of the process.

In this study, experiments are conducted to determine the ideal activation and delay duration settings for the auger conveyor (feeder), measured in seconds, to achieve optimal gasification efficiency and biofuel quality for Falcata (*Paraserianthes falcataria*) and Buyo-buyo (*Piper aduncum*) wood chips using particular control systems. The control systems are established after conducting experiments to establish the range of optimal settings for each wood chip species.

Evaluating the website's control settings and biofuel energy output in terms of gas quality and kilowatt production for both Buyo-buyo and Falcata wood chips is an integral part of the process. Similar to another study, this process of evaluating biofuel quality, measured in kilowatts, utilizes a power meter to determine the generator's electrical performance (De Paulo et al., 2016). Through measuring these variables, if produced favorable results, it can imply that the functionality of the developed control panel is advantageous compared to manually operating the gasifier.

Overall, the study focuses on coordinating the activation of the motors utilizing a functional website with the information input of the sensors incorporated in the system. Moreover, collecting accurate computations to be input on the website to optimize both Buyo- buyo and Falcata's output of gas quality.

Studies regarding this aspect have offered promising results, such as the efficiency in the conversion of carbon, as well as its low need for energy to enter production (Bukar et al, 2019). Despite facing challenges such as high capital costs and technical difficulties, the environmental benefits and efficiency gains make gasification a promising technology for a sustainable future. Studies have shown that the emissions of greenhouse gases can be reduced through the use of alternative feedstocks, such as biomass and CO2 (Bachmann, 2023). Gasification stands out as a transformative process with the potential to revolutionize energy production and resource management.

The wood species employed in this study, Falcata (*Paraserianthes falcataria*) and Buyo-buyo (*Piper aduncum*) were selected due to their abundance in the Philippines, specifically in the Davao Region, Davao Oriental, where their unique characteristics make them ideal for gasification procedures (*Falcata Industry*, 2019).

Falcata is a species that is frequently found in Industrial Tree Plantations (ITPs) around the nation. These plantations cultivate Falcata to produce timber while making sure that harvesting methods adhere to legal requirements. These farms are carefully managed for profit to ensure that Falcata harvesting supports expansion while adhering to forestry regulations (Philippine Council for Agriculture, Aquatic, and Natural Resources Research and Development [PCAARRD], 2020). The falcata tree is shown in Figure 2.1.

Figure 2.1. *Falcata Tree*

On the other hand, Buyo-buyo is an invasive plant that causes significant problems for the farmers in the area. Because of its rapid growth and assertive nature in fields, it has become the farmer's common "enemy", where it competes with surrounding plants and crops for vital nutrients. In addition to limiting its spread, using Buyo-buyo in gasification gives farmers an extra benefit by turning this species into a resource for energy. Moreover, Buyo-buyo is a coppicing species. Coppicing means that it can regrow even after being cut down, allowing it to serve as a renewable source of biomass (Petruzzello, 2022). Selecting these two species aligns nicely with the project's goal of optimizing biomass resources and concurrently addressing local farming challenges. The Buyo-buyo shrub is shown in figure 2.2.

Figure 2.2. *Buyo-buyo Shrub*

Biofuels play a vital role in the actions of lessening greenhouse gas emissions, as well as reducing reliance on fossil fuels. This helps address environmental concerns and the need for sustainable energy solutions. These come from organic materials such as algae, plant biomass, and agricultural waste; biofuels offer a cleaner and more renewable alternative to conventional petroleum- based fuels. Studies show that biofuels significantly alleviate environmental issues, especially by reducing greenhouse gas (GHG) emissions and strengthening energy security (O'Connell et al., 2019). Their significance lies in their potential to combat climate change, enhance energy security, drive economic growth, and promote development. Biofuels provide a cleaner, more adaptable, and economically beneficial answer to some of the most pressing environmental and energy challenges. However, biofuels also have their drawbacks. Even though it is known as a clean and efficient alternative, it can still have a dire impact on the environment. These drawbacks include environmental concerns, economic challenges, and certain limitations. Studies have shown that biofuels are being pushed as an alternative to energy production, but their wide implementation could cause serious environmental issues (Jeswani et al., 2020).

METHODOLOGY

Preparation and Collection of Materials

The machine contains a few various components for it to operate before the goal of implementing a web-based control. However, the materials needed for the development of the Web-based Control Panel are; Arduino Nano, CAN Bus MCP2515, Thermocouple Type K (Temperature Sensor), VL53L0X Range Finder Sensor (Fuel Level Sensor), and NodeMCU (IoT), as detailed in Table 1.

Materials	Number of Pieces
Arduino Nano	2 pcs
CAN Bus MCP2515	3 pcs
Thermocouple Type K	4 pcs
VL53L0X Range Finder Sensor	1 pc
NodeMCU	1 pc

Table 1. *Materials*

Arduino Nano (Microcontroller). The Arduino Nano microcontroller board offers a flexible and intuitive platform for programming and electronics applications. The Arduino Nano serves as the machine's way of communicating with its various sensors. A depiction of the Arduino Nano is shown in Figure 3.1.

Figure 3.1 *Arduino Nano*

CAN Bus MCP2515. This module is a critical component of the data transfer system, enabling communication between the sensors and the microcontrollers. It facilitates smooth and efficient communication between the sensors and the main circuit board, allowing data to be transmitted accurately and reliably. This ensures that the information gathered from the sensors is promptly received and processed by the microcontroller, supporting precise adjustments to the gasifier's operation (Figure 3.2).

Figure 3.2 *CAN Bus MCP2515*

Thermocouple Type K. A kind of temperature sensor that is frequently used to measure temperature is the Type K Thermocouple. The Type K thermocouples play a critical role in the machine's dealing with high temperatures. Especially, in the reactor of the gasifier where the temperature level is crucial. The maximum temperature that the temperature sensor can detect is 1,024℃ (Figure 3.3).

Figure 3.3 *Thermocouple Type K VL53L0X (Range Finder Sensor).*

This sensor is used to monitor the feedstock height inside the gasifier. This is crucial as it is important to avoid the possibility of overflowing inside the gasifier as it can lessen its efficiency (Figure 3.4).

Figure 3.4 *VL53L0X (Range Finder Sensor)*

IoT Implementation. For each of the system's motors and sensors, the researchers utilized NodeMCU as their main connector and communication hub for a cohesive system. The NodeMCU enables smooth communication between the various parts, including the temperature sensors, auger conveyor, and relay modules, by utilizing its integrated Wi-Fi capabilities. This guarantees remote monitoring and control of the gasifier system, enabling real-time modifications depending on sensor input (Figure 3.5).

Figure 3.5 *NodeMCU*

Key benefits of digitalizing the control system include remote management and real-time data visualization, which guarantee timely adjustments and constant monitoring. This makes it possible to track gasifier performance effectively from a distance by reducing the need for human checks. In line with current developments in smart technology and data-driven energy management, it improves operational precision and safety.

Hardware Development

The web-based controls for the gasifier system's hardware development process includes the design and integration of essential parts that provide effective sensor and actuator control and communication. This section describes the layout of the two transmitter boxes that house the temperature and range finder sensor, and more importantly, the main control circuit design that uses the NodeMCU as the core controller.

Main Control Circuit. The main control circuit functions as the central hub for the processes' management and control. Its central component is the NodeMCU. The NodeMCU as seen in Figure 3.5, is an open-source IoT platform that makes wireless communication between the user interface (website) and the gasifier system possible. The auger conveyor, feedstock rod, and agitator used in the feeding and burning of biomass are just a few of the components of the system that the NodeMCU is linked to and control. The Main Control Circuit and its block diagram is shown in Figure 4.1 and 4.2.

The 5V relay module and a 12V relay module are among the relays on the circuit board. The 5V relay communicates directly with the NodeMCU, allowing it to manage lower-power components, while the 12V relay is utilized for components that utilize more power like the wiper motors present in the machine.

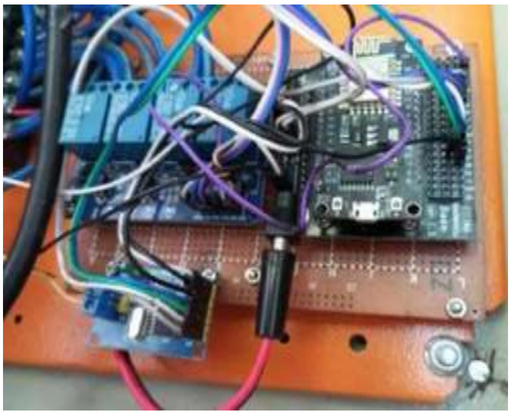


Figure 4.1 *Main Control Circuit*

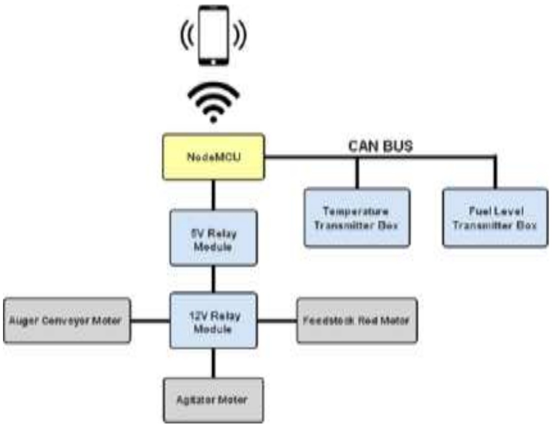


Figure 4.2 *Main Control Circuit Block Diagram*

Transmitter Box for Temperature and Fuel Level. The transmitter box for temperature and fuel level, depicted in Figure 4.3 and Figure 4.5, houses and protects the Arduino Nano and CAN Bus MCP2515. The box protects the electronics from external elements like heat and moisture and makes sure they are positioned firmly for accurate measurements. The range finder sensor that is used in the fuel level transmitter box assists in determining the biomass level within the gasifier, while the temperature sensors keep an eye on the temperature inside the gasifier.

The Arduino Nano and CAN Bus MCP2515 within the transmitter box enable seamless communication of data gathered by these sensors to the NodeMCU. The CAN Bus module ensures efficient data transfer between the transmitter box and the main control circuit through wired connections. The setup of the transmitter box, outlined in Figures 4.4 and 4.6, ensures efficient data transfer to the main control circuit, enabling real-time adjustments to maintain optimal gasification conditions.

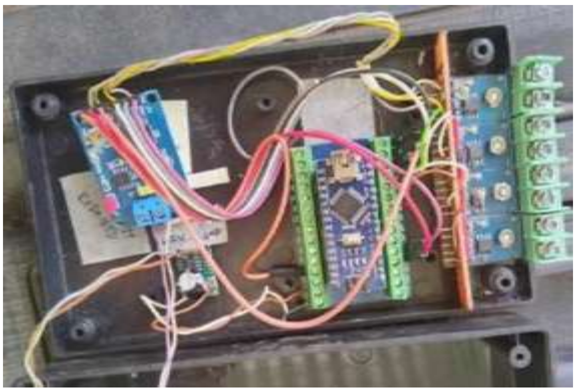


Figure 4.3 *Transmitter Box (Temperature)*

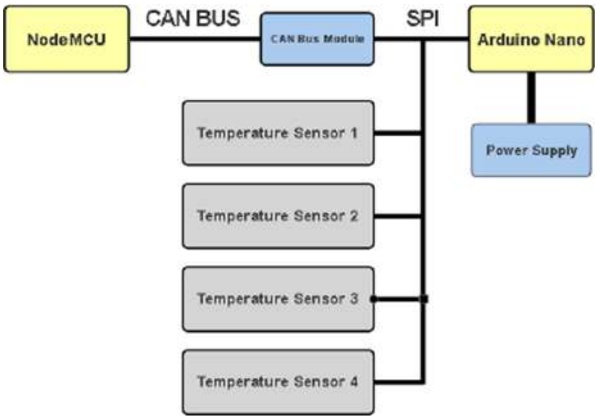


Figure 4.4 *Block Diagram of the Transmitter Box (Temperature)*

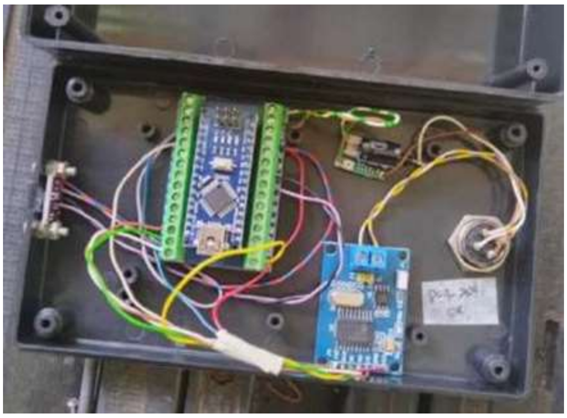


Figure 4.5 *Transmitter Box (Fuel Level)*

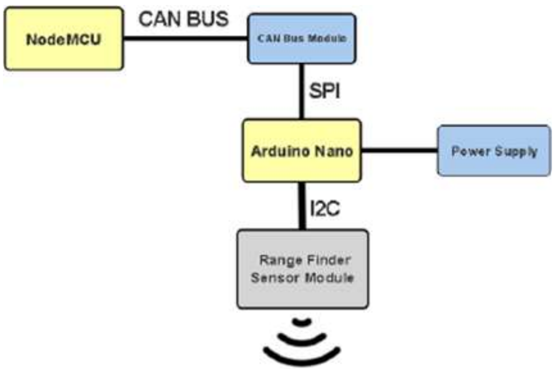


Figure 4.6. *Block Diagram of the Transmitter Box (Fuel Level)*

Together, these hardware components create an integrated system that ensures precise control over the gasifier's operation, streamlining the process of managing biomass input and combustion. This well-designed setup ensures the gasifier operates safely and efficiently, resulting in high-quality gas output.

Software Development

The web-based gasifier system's software development process incorporates control mechanisms and user interfaces to allow for efficient operation and user interactions. This section discusses the usage of Arduino-based programming for controlling components and the development of a web-based interface using HTML that makes it simple for the user to interact with the system.

Due to its greater accessibility across devices including desktop computers, tablets, and smartphones and lack of need for any installations or particular OS compatibility, a website was selected over a mobile app for managing and keeping an eye on the gasifier system. This enables users to use any browser to view the control interface from a distance. A web-based platform also makes upgrades easier because it allows for updates without requiring user downloads.

Development of the Control System using Arduino. The gasifier system's primary functionalities are primarily managed using the Arduino platform. Code is built and uploaded to the NodeMCU, the primary control unit, using the Arduino IDE. This code, as highlighted in Figure 5.1 through Figure 6.1, ensures the seamless synchronization of sensors, motors, and relays to maintain a stable gasification process.

The code regulates the operation of the auger conveyor, feedstock rod, and agitator, as seen in Figure 5.6 and 5.7. Adjusting their timing and speed to maintain a consistent flow of biomass into the gasifier, this consistency is vital for steady gas production. The Arduino code includes safety protocols that continuously monitor the sensors' data, such as temperature (as seen in Figure 5.8) and biomass levels, to ensure the system's stability.

In case of abnormalities or overheating, there is a manual emergency off switch near the main control circuit that terminates all of the gasifier's processes. This approach to functional programming allows for precise control over the gasifier's operation, ensuring reliability and adaptability to various operating conditions.

```
#include <ESP8266WiFi.h>
#include <ESP8266WebServer.h>
#include "SuperMon.h"   // .h file that stores your html page code
#include <EEPROM.h>
#include <SPI.h>
#include <mcp_can.h>
#include <ESP8266HTTPClient.h>
#include <WiFiClientSecureBearSSL.h>
#include <NTPClient.h>
#include <WiFiUdp.h>
```

Figure 5.1. *Code segment that shows the Libraries used*

Figure 5.2. *Code segment that shows the Constants declared*

Figure 5.3. *Code segment that shows the Variables declared*

Figure 5.4. *Code segment that shows the Intranet Definitions and Void Setup*

Figure 5.5. *Code segment that shows the Network Connection Status*

Figure 5.6. *Code segment that shows the Agitator Motor's Control*

Figure 5.7. *Code segment that shows the Feedstock Rod Motor's Control*

Figure 5.8. *Code segment that shows the*

Temperature Sensor's Updates

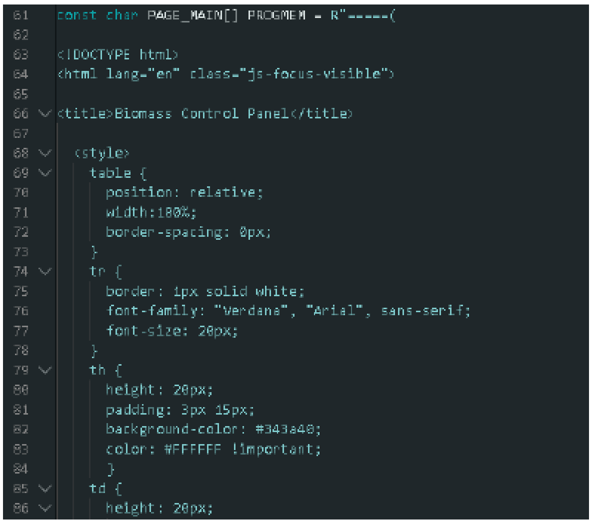
Figure 5.9. *Code segment that shows the HTTPS Updates*

Figure 6.0. *Code segment that shows the CAN Bus Handling*

```
//filter for level sensor
if(rxBuf[6] == ((CAN_ID_LEVELSENSOR & 0x000F0000) >> 16)){
  #ifdef DEBUG

  Serial.println(" ");
  Serial.print("Level sensor data: ");

  for(int i=7; i>=0; i--){
    Serial.print("[");
    Serial.print(rxBuf[i]);
    Serial.print("]");
  }
  Serial.println(" ");
  #endif

  uint16_t vDistance = 0x0000;

  vDistance = vDistance + rxBuf[1]; //D1
  vDistance = vDistance << 8;
  vDistance = vDistance + rxBuf[0]; //D0

  sFeederRod = vDistance;
}
```

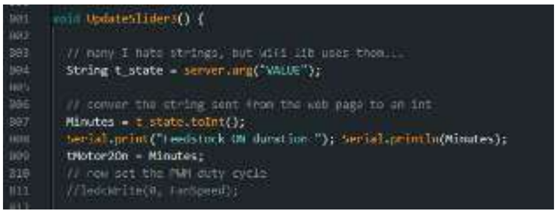
Figure 6.1. *Code Segment for the Fuel Level Updates*

As the main control panel for the gasifier system, the HTML-based platform that is being developed for the user interface is meant to be easily navigable. As depicted in Figure 6.2, this interface's goal is to give users an easy-to-use yet efficient way to control the gasifier, keep an eye on its condition, and change settings as necessary. The interface allows users to adjust critical settings like feedstock input and agitator duration using sliders, as shown in Figures 6.3 and 6.4, and manage the feedstock height (Figure 6.5). In Figure 6.6, the code behind the alert system's functions are presented.



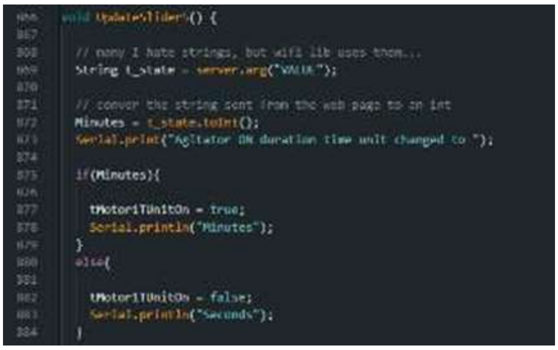
```
const char PAGE_MAIN[] PROGMEM = R"=====(

<!DOCTYPE html>
<html lang="en" class="js-focus-visible">

<title>Biomass Control Panel</title>

  <style>
    table {
      position: relative;
      width:100%;
      border-spacing: 0px;
    }
    tr {
      border: 1px solid white;
      font-family: "Verdana", "Arial", sans-serif;
      font-size: 20px;
    }
    th {
      height: 20px;
      padding: 3px 15px;
      background-color: #343a40;
      color: #FFFFFF !important;
      }
    td {
      height: 20px;
```

Figure 6.2. *Code segment that shows the Web Server using HTML*



```
void UpdateSlider3() {

  // many I hate strings, but wifi lib uses them...
  String t_state = server.arg("VALUE");

  // conver the string sent from the web page to an int
  Minutes = t_state.toInt();
  Serial.print("Feedstock ON duration "); Serial.println(Minutes);
  tMotor2On = Minutes;
  // now set the PWM duty cycle
  //ledcWrite(0, FanSpeed);
```

Figure 6.3. *Code segment that shows the Sliders in the Interface (Feedstock Input)*



```
void UpdateSlider5() {

  // many I hate strings, but wifi lib uses them...
  String t_state = server.arg("VALUE");

  // conver the string sent from the web page to an int
  Minutes = t_state.toInt();
  Serial.print("Agitator ON duration time unit changed to ");

  if(Minutes){

    tMotor1TUnitOn = true;
    Serial.println("Minutes");
  }
  else{

    tMotor1TUnitOn = false;
    Serial.println("Seconds");
  }
```

Figure 6.4. *Code segment that shows the Sliders in the Interface (Agitator Duration)*

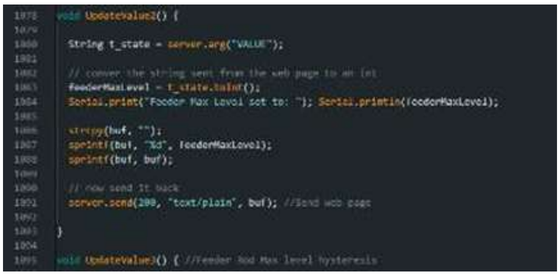


Figure 6.5. *Code segment that shows the Sliders in the Interface (Feedstock Height)*

Figure 6.6. *Code segment that shows the Alert System in the Interface*

Moreover, the interface is designed to present real-time data from the temperature sensors, the biomass feed rates, and the feedstock's height. This structured dashboard is visualized in Figure 7.1 and Figure 7.2, whenever adjustments are needed, they can be performed right from the interface to guarantee seamless operation, including the motors for the auger conveyor, agitator, and feedstock rod. In Figure 7.3, the alert system is shown.

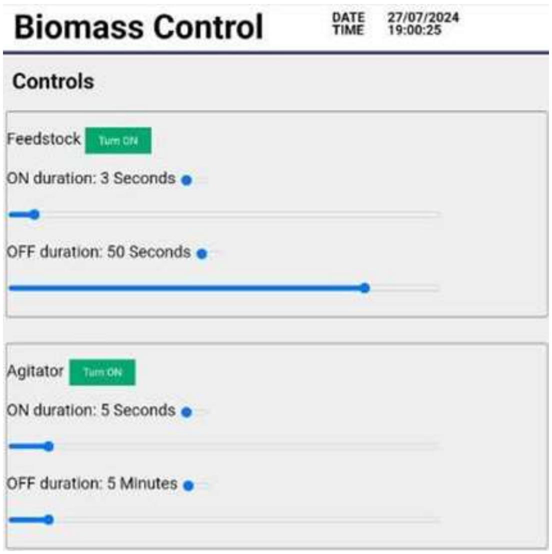


Figure 7.1 *Screenshot of the Web Interface Settings (Feedstock Rate and Agitator)*

Figure 7.2. *Screenshot of the Web Interface Settings (Feed Rod Height and Temperature)*

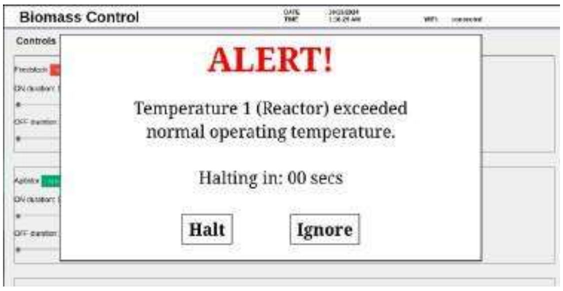


Figure 7.3. *Screenshot of the Web Interface for the Emergency Alert System*

Downdraft Gasifier Setup

The researchers worked with a non- automated downdraft gasifier located in Montevista, Davao de Oro, Philippines. This gasifier is specifically designed for multi-fuel operations but lacks IoT implementation in its current state. The research focuses on establishing a website that functions as a data monitor, motor controls, and with an added alarm system from biomass input to the point of wood burning and maintaining the machine's flowability and efficiency.

Furthermore, the gasifier is equipped with a refractory lining to handle high temperatures and a grate system to support diverse feedstocks. It includes zones for drying, pyrolysis, oxidation, and reduction to facilitate the complete gasification process. The schematics and images below show the designs and process of the gasifier utilized in the experimentation, starting from Figure 8.1 to Figure 8.9.

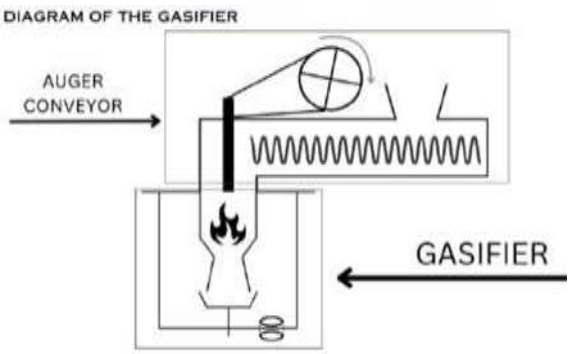


Figure 8.1. *General Design of the Gasifier*

The diagram in Figure 8.1 above shows the general design of the gasifier. The wavy lines represent the auger conveyor within the system, while the lower portion is where the gasification process initiates.

Figure 8.2. *Actual Gasifier*

The image in Figure 8.2 above shows the actual gasifier to compare with the diagrams shown in the figures. In the auger conveyor shown in both figures, the process of drying occurs before entering the gasifier (Refer to Figure 1.2. *Processes During Gasification*). Notably, this is also where the feedstock motor is located, which is a feature to be also controlled in this study.

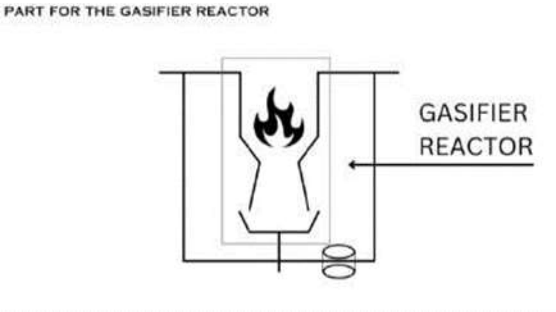


Figure 8.3. *Part of the Gasifier Reactor*

The diagram points out to the gasifier reactor of the system. The fire icon in Figure 8.3 indicates the partial oxidation or burn of the feedstock input in the gasifier.

Figure 8.4. *Inside of the Gasifier Reactor*

In Figure 8.4, appears the partial burning or oxidation of the wood chips or feedstock input of the gasifier. The reactor is where the following significant stages occur in order to produce syngas: pyrolysis, combustion, and reduction (Refer to Figure 1.2. *Processes During Gasification*).

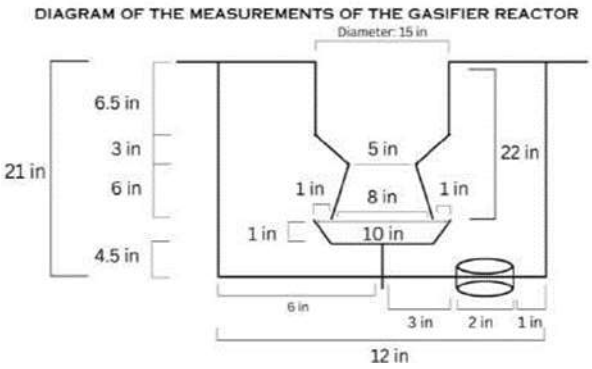


__Figure 8.5.__ Measurements of the Parts of the Gasifier Reactor

Measurements of the gasifier reactor were taken for scaling purposes. Moreover, to allow visualization and sizing of the other components of the machine in Figure 8.5. The structure of the gasifier reactor is shown in Figure 8.6.

The reactor of the gasifier is where the significant stages are (Refer to Figure 8.4. *Inside of the Gasifier Reactor*) occurring and the ideal location for the temperature sensor for data reading in the controls.

__Figure 8.6.__ Structure of the Gasifier Reactor

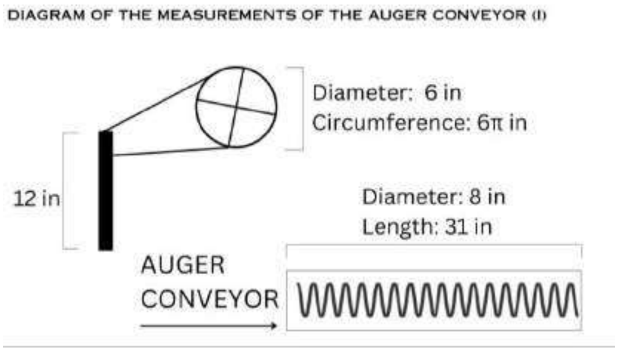


__Figure 8.7.__ Measurements of Auger Conveyor and Feed Rod

In Figure 8.7, the measurements of the auger conveyor were recorded, while the attached feed rod's height was also scaled. Following its structure, the feed rod serves as a potential location for a level sensor having its data input presented in the controls.

Figure 8.8. *Auger Conveyor and Feed Rod*

The image above in Figure 8.8 is the auger conveyor and the feed rod components of the system. For further scaling refer to Figure 8.9. *Measurements of Auger Conveyor.*

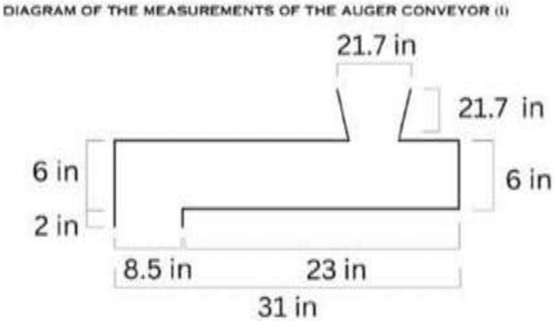


Figure 8.9. *Measurements of Auger Conveyor*

The diagram depicts the precise measurements of the auger conveyor that pushes down the feedstock. For complete visualization of the gasifier, refer to Figures 8.5, 8.7, and 8.9.

Components of the System

Feedstock Settings. The feedstock setting is defined as how frequently the machine is fed with the feedstock. This factor is flexibly controlled and can be changed as this is one of the variables that affects the entire process of the gasifier. This includes the clogging, overflowing, and the production of gasses. In addition, during potential overheating or other difficulties in the system operating it effectively will allow it to serve as another safety measure.

Feedstock Rate. The rate in g/s is a key parameter that helps optimize the gasification process, ensuring efficient conversion of biomass into usable energy. Given that the feedstock rate affects the efficiency and stability of the process. Maintaining an optimal feed rate ensures that the gasifier operates within its designed parameters. For this particular downdraft gasifier, the computed rate was 0.029g/s.

Agitator. The agitator monitors and regulates the gasification process involving the tar ash. It ensures that the tar ashes are leveled down to keep the condition of the interior in a good state. Additionally, it is also where the source of the gasses that are produced from the gasifier is found.

Feed Rod Height. The feed rod height plays an important role in the whole process of the gasifier, specifically in areas where clogging and overflowing are involved. This factor is monitored by utilizing a range finder device, specifically the VL53L0X range finder sensor.

Temperature. Monitoring and maintaining appropriate temperatures in different zones of the gasifier (e.g., drying, pyrolysis, oxidation, and reduction zones) using the temperature sensor is to be observed in the system.

Examination of Gasification Parameters

To begin with, the researchers used wood chips from Falcata and Buyo-buyo to undertake 7 pilot trials to collect baseline data on gas production. To assess the gas output and overall system performance for each type of feedstock, the gasifier runs during these tests under predefined parameters for feedstock rate, agitator, feed rod height, and temperature.

The researchers can identify important variables that affect gas quality and production efficiency thanks to this baseline data, which gives crucial insights into the combustion properties of both wood species. The research group can optimize the circumstances for maximal gas production with each type of wood by assessing the findings and fine-tuning the operational settings, including feedstock rate, agitator, feed rod height, and temperature.

Data Collection

Website Functionality and Optimization in Gas Production. Evaluation of the functionality of the website designed to optimize the gasification process. To achieve this, the researchers focus on testing the website's capabilities while monitoring the impact of various parameters on production efficiency. Although the collection and analysis of gas quality, voltage, and current output serve as supplementary aspects of the investigation, the main emphasis is on systematically adjusting these variables to identify optimal conditions that enhance the gasifier's overall performance. By doing so, the study aims to not only streamline the gas production process but also validate the effectiveness of the control system integrated within the website.

Feedstock settings. This generally refers to the parameters and conditions used for the gasification process. Feedstock is the base material fed into a system or machine to produce a product. This component will be set at varying values to test the website's functionality and controls as well as evaluate the optimal values for each wood chip. Images of the two types of feedstock used, Falcata and Buyo-buyo, are shown in Figures 9.1 and 9.2, respectively.

Figure 9.1. *Image of Feedstock Used (Falcata)*

Figure 9.2. *Image of Feedstock Used (Buyo-buyo)*

Gas Quality. Even if the main focus is the website's functionality, it still remains essential to assess the composition of the gases produced to ensure the gasifier operates effectively. The specific gases measured include hydrogen, methane, carbon monoxide, and carbon dioxide. These gases are detected using specialized sensors tailored for each type: hydrogen (Figure 10.1), methane (Figure 10.2), carbon monoxide (Figure 10.3), and carbon dioxide (Figure 10.4). While the website facilitates the monitoring and optimization of gas production, accurate measurement of these gases is crucial for assessing the overall performance of the gasifier and confirming that it meets operational standards.

Figure 10.1 *RS-H2-N01-OLEDFL-1000P-2 (Gas Sensor for Hydrogen gas)*

Figure 10.2. RS-CH4-N01-OLEDFL- 100LEL-2 *(Gas Sensor for Methane)*

Figure 10.3. RS-CO-N01-OLEDFL- 2000P-2 *(Gas Sensor for Carbon Monoxide)*

Figure 10.4. RS-CO2-N01-OLEDFL *(Gas Sensor for Carbon Dioxide)*

Functionality Test

The researchers ensured the functionality of both the hardware and software components, guaranteeing that they work as intended. A study explores a specific functionality testing method tailored for android mobile applications but discusses principles that can be applied to web applications as well (Yu et al., 2021).

Circuits, Batteries and Software. Through establishing a connection from the website to the gasifier circuits, as well as ensuring that the functions of the website are working. This also implies that the batteries of the gasifier are still powering it up.

Hardware Components. The following hardware components are checked, along with the methods:

Range Level Sensor. By activating the gasifier machine, if the range level sensor is able to detect and send information to the website, it is ensured to be functional.

Thermocouple Type K. Utilizing the gasifier and the website, the gasifier is activated to exert high temperatures to the hardware component, usually around 500°C-800°C. If the hardware component can still detect and send information despite the high temperatures exerted on it, it is ensured to be functional.

The trial process involves several key steps: establishing a connection with the website, activating the gasifier, and verifying if information is successfully transmitted from the hardware components to the website. The functionality tests for the various motors and the alert system are illustrated in Figures 11.1 through 11.4.

Figure 11.1. *Functionality Test for the Motor (Auger Conveyor)*

Figure 11.2. *Functionality Test for the Motor (Feedstock Rod)*

Figure 11.3. *Functionality Test for the Motor (Agitator)*

Figure 11.4. *Functionality Test for the Motor (Alert System)*

Data Analysis

Gas Quality Assessment. When assessing the functionality of the system's control settings, the quality of the biofuel plays a crucial role. The measurement is in kilowatts, utilizing a power meter to determine the generator's electrical performance (De Paulo et al., 2016).

The basis for evaluating the biofuel quality is its gas content namely, carbon monoxide (CO), hydrogen gas (H2), methane (CH4), and carbon dioxide (CO2). Consequently, quantitative standards for biogas-derived syngas are likely due to the technology's recent development. However, they do emphasize key quality considerations, such as controlling impurity levels, which vary depending on the intended use such as methanol synthesis, Fischer-Tropsch synthesis, and general syngas optimization (Yang & Ge, 2016).

In this study, general syngas optimization criteria were utilized, as Rauch, Hrbek, and Hofbauer (2013) underline that a common target H2/CO ratio for many synthesis processes is 2:1. They also emphasize that achieving this ratio directly within the gasifier, rather than adjusting it afterward, is desirable from a cost and efficiency standpoint. This suggests that optimizing the H2/CO ratio during biogas gasification should be a key consideration. Optimizing the H2/CO ratio is also critical for efficient chemical reactions, with future standards possibly targeting specific applications (Solarte-Toro et al., 2018). Additionally, heating value is highlighted as essential for syngas used in combustion, suggesting that standards may eventually set minimum levels based on efficiency requirements (Solarte-Toro et al., 2018, pp. 4, 47).

Cost Analysis

The researchers analyzed the total cost done from the procurement of materials. The materials involved are critical parts of the hardware components. The table for cost analysis is shown in Table 2.

Material	***Amount***	***Cost (Peso)***
MCP2515 CAN Bus Module Board	11	Php 62.00
Arduino Nano Expansion Board	7	Php 55.00
NodeMCU Base Board	4	Php 58.00
VL53L0X	3	Php 60/00
Mini-360	2	Php 76.00
Thermocou ple Type K	11	Php 1894.00
MAX6675 Module	10	Php 950.00
GX12 Module	11	Php 550.00
24V 250W 2750RPM Motor	1	Php 699.00
TOTAL Php 4,404.00		

Table 2. *Table for Cost Analysis*

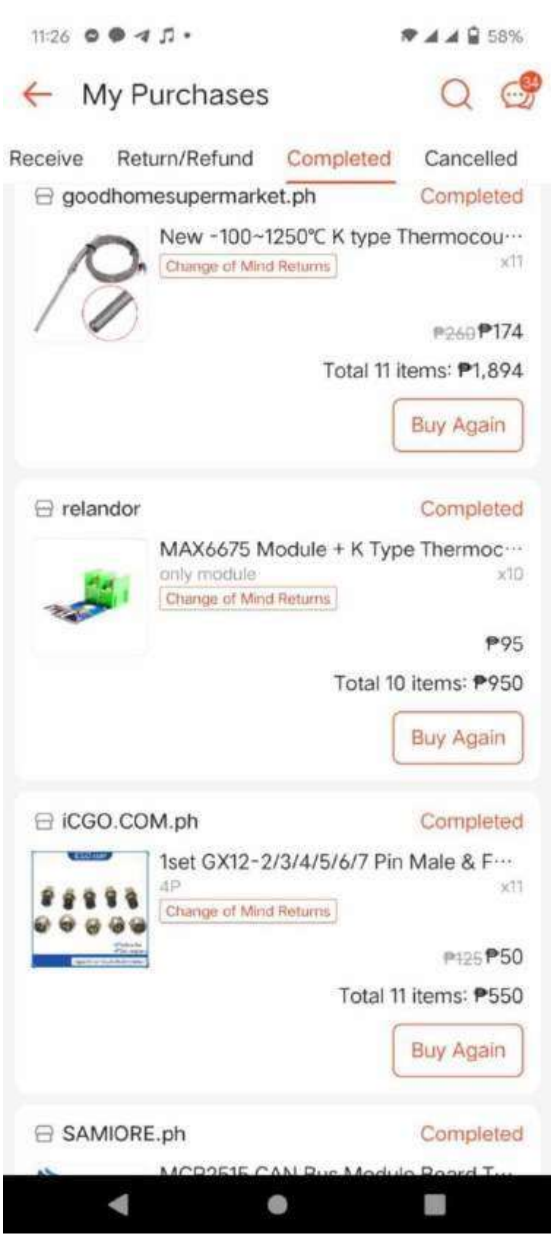


__Figure 12.1.__ Order Receipt (I)

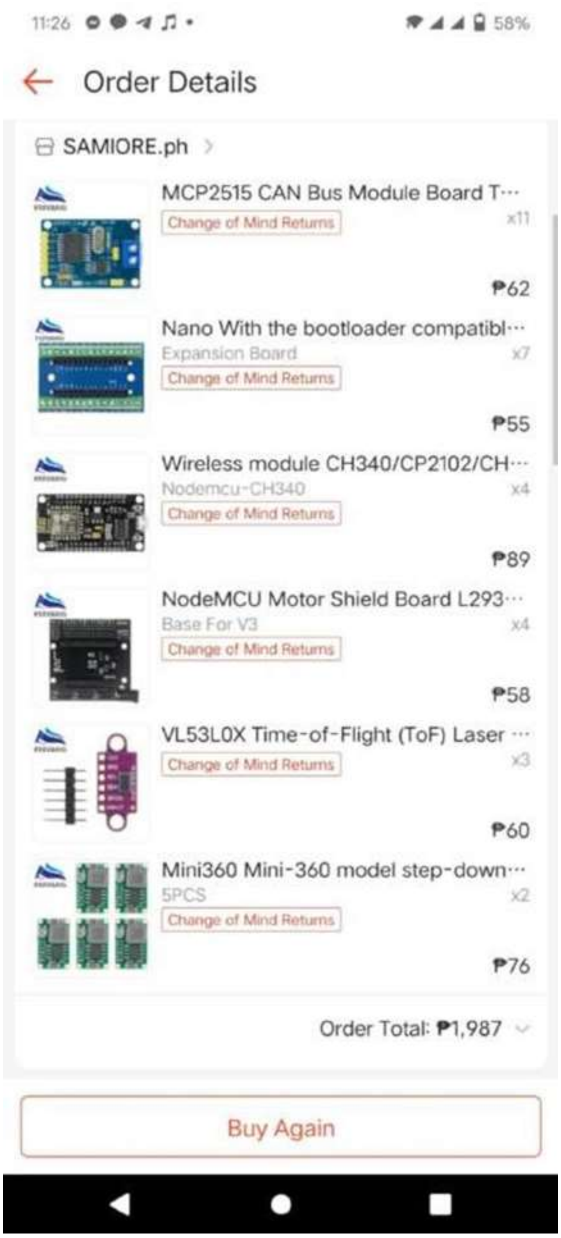


__Figure 12.2.__ Order Receipt (II)

The total cost of creating the website control panel for the study is PHP 4,400. This amount is much lower than the minimum monthly wage of PHP 13,000. In fact, the cost of the website is about 34% of the monthly minimum wage, which shows that it's a cost-effective choice. Research indicates that using web-based systems can significantly reduce costs and save time. For example, one study found that switching to a web-based system led to a 53% reduction in costs related to planning and budgeting. These systems not only make operations more efficient but also improve productivity by reducing the need for manual tasks. In summary, investing in the development of a web-based control panel is a smart financial decision. It optimizes the use of resources while ensuring effective operations.

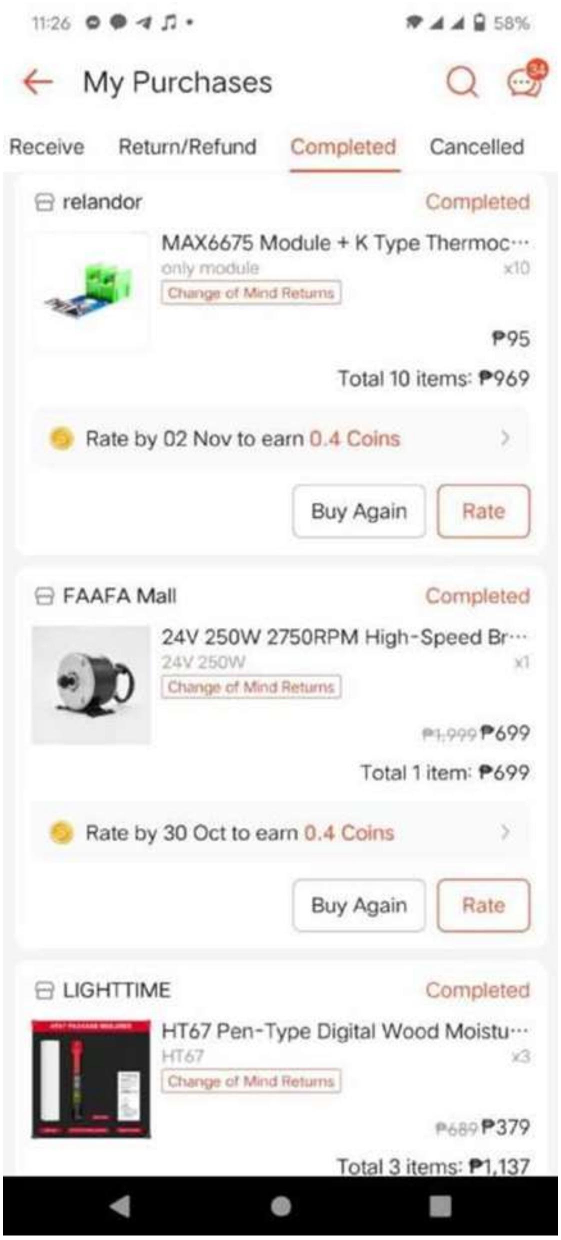


Figure 12.3. *Order Receipt (III)*

The researchers conducted a cost analysis covering the expenses involved in procuring essential hardware components for the project. The analysis detailed the quantities and prices of items like MCP2515 CAN Bus Module Boards, Arduino Nano Expansion Boards, NodeMCU Base Boards, and other critical modules.

The total expenditure for these materials amounted to Php 4,404.00, reflecting the investment in key components required for the project's hardware setup. Figures 12.1, 12.2 and 12.3 show the receipts and purchases done for the procurement of materials needed for the project.

Risk and Safety

During the experimentation of the GANISIR project, the researchers followed the safety protocols as it is an essential step of the procedure. Operators and observers wore face masks throughout the process to prevent inhalation of hazardous emissions, including particulate matter and volatile organic compounds (VOCs), which are byproducts of gasification. These safety precautions are depicted in Figures 13.1 to 13.3.

Figure 13.1. *Safety Protocols (I)*

Figure 13.2. *Safety Protocols (II)*

Moreover, the system was equipped with easily accessible emergency shutdown mechanisms that could immediately halt operations in case of overheating or technical malfunctions. These safety measures not only protect personnel from potential health risks but also ensure the prevention of equipment failure, allowing for timely intervention during troubleshooting or possible emergency scenarios.

Figure 13.3. *Website Emergency Alert System*

RESULTS AND DISCUSSION

Functionality Test

These functionality tests are done in order to test if the hardware and software components of the gasifier and the parts controlled by the website are working. This is based on the study which investigates a functionality testing method specifically developed for Android mobile applications, while also covering principles that can be applied to web applications (Yu et al., 2024).

TRIAL	TIME INTERVAL (SECONDS)	CONNECTION TO WEBSITE	TRANSMISSION OF INFORMATION
1	0.25	Success	Success

2	0.21	Success	Success
3	0.23	Success	Success
4	0.24	Success	Success
5	0.24	Success	Success

Table 3. *Trials to Connection to Website*

The trials assessing the connection between the website and its functionality are summarized in Table 3. The results demonstrate a consistent success rate across all trials. With a success rate of 100% for both variables, it can be concluded that the website, along with its software components and batteries, is fully operational.

Table 4. *Trials for the Functionality of the Level Sensor*

TRIAL	***TIME INTERVAL (SECONDS)***	***DETECTION OF LEVEL SENSOR***
1	*0.23*	*Success*
2	*0.21*	*Success*
3	*0.39*	*Success*
4	*0.19*	*Success*
5	*0.20*	*Success*

The trials for the level sensor's functionality are outlined in Table 4. The results indicate successful detection across all attempts. With a success rate of 100%, the range level sensor is confirmed to be fully functional.

TRIAL	**TIME INTERVAL (SECONDS)**	**DETECTION OF THERMOCOUPLE**
1	0.17	Success
2	0.19	Success
3	0.18	Success
4	0.21	Success
5	0.19	Success

Table 5. *Trials for the Functionality of the Thermocouple Type K*

Table 5 presents the results for the functionality trials of the Thermocouple Type K. All trials achieved successful detection. The results show a 100% success rate, indicating that the Thermocouple Type K is fully operational.

Table 6. *Trials for the Functionality of the Alarm System*

TRIAL	***TIME INTERVAL (SECONDS)***	***ALARM SYSTEM TRIGGER***
1	*0.19*	*Success*
2	*0.23*	*Success*
3	*0.21*	*Success*
4	*0.17*	*Success*
5	*0.22*	*Success*

Table 6 presents the results for the functionality trials of the alarm system in the website. All trials achieved successful detection. The results show a 100% success rate, indicating that the alarm system is fully operational.

Falcata Wood Chips

TRIALS	***FEEDSTOCK SETTINGS***	***FEED RATE***
1A	ON: 2s OFF: 25s	0.029g/s
1B	ON: 2s OFF: 26s	0.029g/s
1C	ON: 2s OFF: 24s	0.029g/s
1D	ON: 2s OFF: 25s	0.029g/s
1E	ON: 4s OFF: 15s	0.029g/s
1F	ON: 4s OFF: 30s	0.029g/s
1G	ON: 4s OFF: 30s	0.029g/s

Table 7. *Settings for Falcata*

The gasifier's settings during the Falcata Wood Chips trials are outlined in Table 7. The feedstock settings varied

slightly across trials, while the feed rate remained consistent at 0.029g/s. The monitored temperature and duration of gasification for each trial are shown in Table 8.

TRIALS	***TEMPERATURE***	***DURATION***
1A	600 °C	2 min
1B	624 °C	3 min
1C	600°C	3 min
1D	603 °C	5 min
1E	555 °C	6 min
1F	612 °C	4 min
1G	617 °C	4 min

Table 8. *Monitored Conditions*

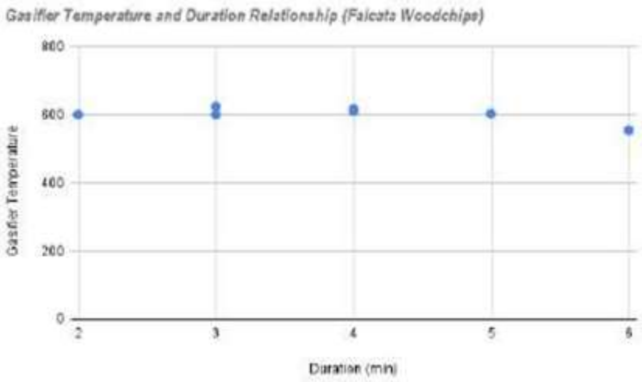


Figure 14.1. *Temperature and Duration Relationship of the Falcata Wood Chips (WEBSITE)*

Figure 14.1 shows the relationship between the duration of when the machine has met the conditions needed and the temperature.

FALCATA	CO (%)	H2 (%)	CH4 (%)	CO2 (%)
M1A	57.00%	42.44%	0.00%	1%
M1B	47.36%	44.38%	0%	8%
M1C	19.29%	79.09%	0.00%	1.60%
M1D	3.20%	95.40%	0.09%	1.20%
M1E	3.44%	95.22%	0%	1.34%
M1F	16.41%	83.40%	0%	0.18%
M1G	20.19%	79.00%	0.00%	0.81%

Table 9. *Produced Syngas Percentage Composition of Falcata Wood Chips (MANUAL)*

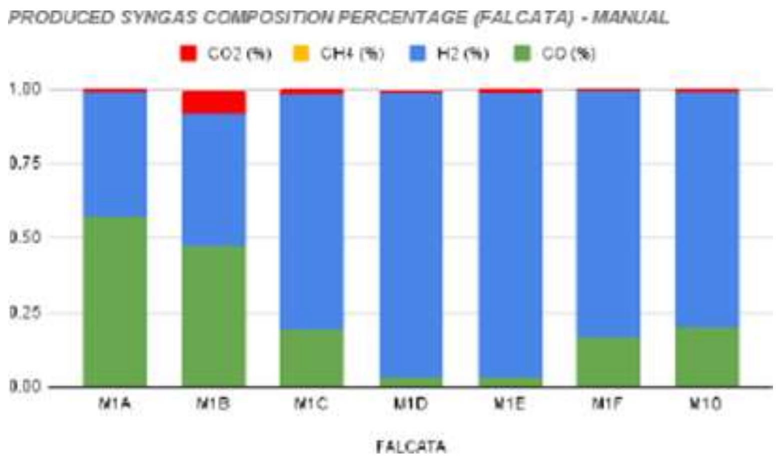


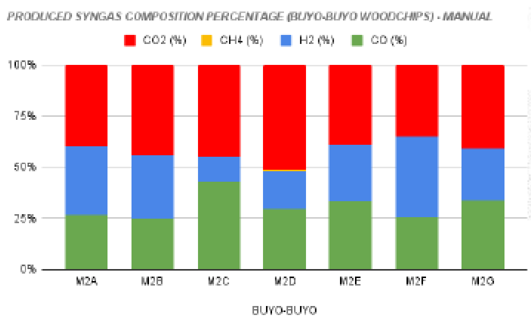
Figure 14.2. *Bar Graph of Produced Syngas Percentage Composition of Falcata Wood Chips (MANUAL)*

Table 9 depicts the table of the gas composition of the produced synthetic gas from the manual tests of Falcata Wood Chips, while Figure 14.2 shows its visual representation. It can be seen that the ratio between the hydrogen gas and the carbon monoxide is inconsistent, with the hydrogen gas being very dominant throughout the tests. Moreover, the presence of carbon dioxide is slightly detected. This implies that, while it can be favorable, it has a slightly unwanted quality.

BUYO-BUYO	CO (%)	H2 (%)	CH4 (%)	CO2 (%)

M2A	26.96%	33.00%	0.04%	40%
M2B	25.00%	31.00%	0%	44%
M2C	43.00%	12.00%	0.00%	45%
M2D	29.33%	18.67%	1%	51%
M2E	33.48%	27.50%	0.02%	39%
M2F	25.40%	39.60%	0%	35%
M2G	34.00%	24.97%	0.03%	41%

Table 10. *Produced Syngas Percentage Composition of Buyo-Buyo Wood Chips (MANUAL)*



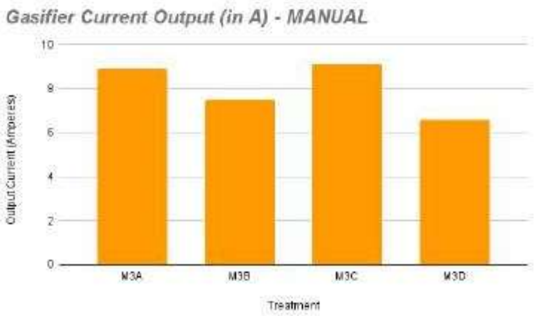


Figure 14.3. *Bar Graph of Produced Syngas Percentage Composition of Buyo-Buyo Wood Chips (MANUAL)*

Table 10 depicts the table of the gas composition of the produced synthetic gas from the manual tests of Buyo-Buyo Wood Chips, while Figure 14.3 shows its visual representation. It can be seen that the ratio between the hydrogen gas and the carbon monoxide is inconsistent, and the presence of carbon dioxide is prominent. This implies that the quality of the synthetic gas is only advantageous on activities where carbon dioxide may be more needed. Other than that, the quality of the synthetic gas may be undesirable.

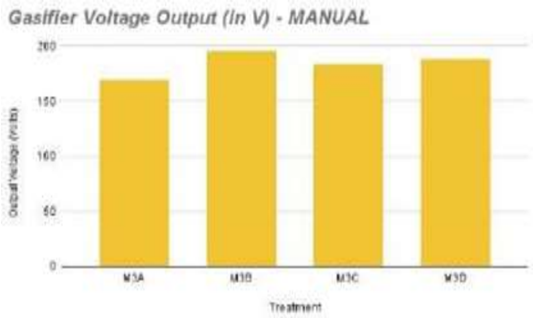


Figure 14.4. *Voltage Output of the Gasifier (in Volts) (MANUAL)*

Figure 14.4 shows the voltage output of the utilized gasifier, measured in volts. With an average of 184.5V, this depicts that, while it shows signs of the gasifier producing electricity consistently, it is only produced at a moderate rate. The standard known volts households need is 210V-240V, meaning that it can be underperforming due to certain existing factors.

Figure 14.5. *Current Output of the Gasifier (in Amperes) (MANUAL)*

Figure 14.5 shows the current output of the gasifier, measured in amperes. With an average of 8.025A, this implies that it generates a small to moderate level of power generation, sufficient for powering household appliances, small machinery, or off-grid systems. Although efficient, the results are lower compared to the one powered by the website.

TRIALS	**CO (%)**	**H2 (%)**	**CH4 (%)**	**CO2 (%)**
1A	71%	28%	0.05%	0.40%
1B	43.40%	55.30%	0%	1.18%
1C	71.63%	28.19%	0.05%	0.11%
1D	43.45%	55.36%	0%	1.18%

1E	29.79%	69.79%	0%	0.42%
1F	58.06%	41.74%	0%	0.20%
1G	52.66%	42.91%	0.08%	0.47%

Table 11. *Produced Syngas Percentage Composition of Falcata Wood Chips (WEBSITE)*

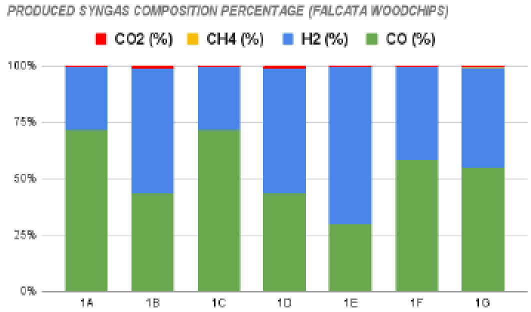


Figure 14.6. *Bar Graph of Produced Syngas Percentage Composition of Falcata Wood Chips (WEBSITE)*

The syngas composition for each trial is detailed in Table 11, and the composition is visually represented in Figure 14.6. It is observed that the presence of Hydrogen Gas (H2) and Carbon Monoxide (CO) is very dominant throughout the tests in comparison with Carbon Dioxide (CO2) and Methane (CH4).

The gas composition data indicates that the biomass gasification machine is performing well in generating syngas rich in carbon monoxide and hydrogen. High CO concentrations are favorable for energy applications, while the low levels of methane and CO2 suggest effective gasification with minimal byproducts. The variability in hydrogen content across tests provides insights into optimization opportunities depending on the intended use of the produced gas. Overall, the results highlight the machine's capability to efficiently convert biomass into valuable gasses for energy production. This implies that the quality of the syngas is very desirable and favorable.

Buyo-buyo Wood Chips

Table 12. *Settings for Buyo-Buyo*

TRIALS	*FEEDSTOCK SETTINGS*	*FEED RATE*
2A	*ON: 3s OFF: 20s*	*0.029g/s*
2B	*ON: 3s OFF: 20s*	*0.029g/s*
2C	*ON: 3s OFF: 20s*	*0.029g/s*
2D	*ON: 3s OFF: 20s*	*0.029g/s*
2E	*ON: 3s OFF: 20s*	*0.029g/s*
2F	*ON: 3s OFF: 20s*	*0.029g/s*
2G	*ON: 3s OFF: 20s*	*0.029g/s*

The settings for the Buyo-buyo Wood Chips trials are provided in Table 12, with the temperature and duration of gasification shown in Table 13. Figure 14.6 illustrates the temperature and duration relationship during the Buyo-buyo trials.

TRIALS	*TEMPERATURE*	*DURATION*
1A	612 °C	10 min
1B	470 °C	10 min
1C	509 °C	10 min
1D	615 °C	10 min
1E	622 °C	10 min
1F	608 °C	12 min

1G	608 °C	8 min

Table 13. *Monitored Conditions*

TRIALS	***FEEDSTOCK SETTINGS***	***FEED RATE***
2A	ON: 3s OFF: 20s	0.029g/s
2B	ON: 3s	0.029g/s

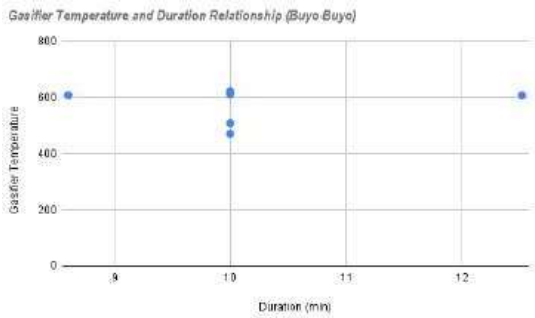


Figure 14.6. *Temperature and Duration Relationship of the Buyo-Buyo Wood Chips (WEBSITE)*

Figure 14.6 shows the relationship between the duration of when the machine has met the conditions needed and the temperature.

TRIALS	**CO (%)**	**H2 (%)**	**CH4 (%)**	**CO2 (%)**
1A	48.02%	23.56%	0.04%	28.37%
1B	22.27%	64.00%	0%	13.73%
1C	15.04%	39.47%	0%	45.48%
1D	27.03%	45.05%	0%	27.92%
1E	36.43%	23.76%	0.02%	39.78%
1F	30.36%	66.87%	0%	2.77%
1G	60.18%	28.56%	0.03%	11.23%

Table 14. *Produced Syngas Percentage Composition of Buyo-buyo Wood Chips (WEBSITE)*

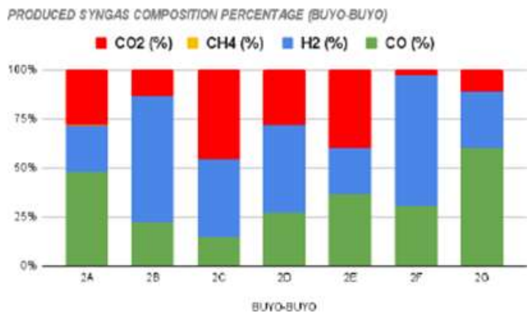


Figure 14.7. *Bar Graph of Produced Syngas Percentage Composition of Buyo-buyo Wood Chips (WEBSITE)*

The syngas composition for Buyo- buyo trials is listed in Table 14, and Figure 14.7 presents the corresponding bar graph of the produced syngas. The presence of the three gasses, specifically Hydrogen Gas, Carbon Monoxide, and Carbon Dioxide, can be observed and is all varied. High levels of carbon monoxide in some tests indicate effective gasification, while hydrogen concentrations in others suggest potential for hydrogen applications. Low methane and variable CO2 levels imply a mix of efficiency in conversion processes.

Overall, the results point to opportunities for optimization based on the intended use of the produced syngas, whether for combustion or hydrogen gas production. Regular monitoring and adjustments in operational parameters will be essential to maximize efficiency and gas quality. This data implies that the quality of the syngas produced from these wood chips is desirable, but is a bit corrupted by a certain small margin.

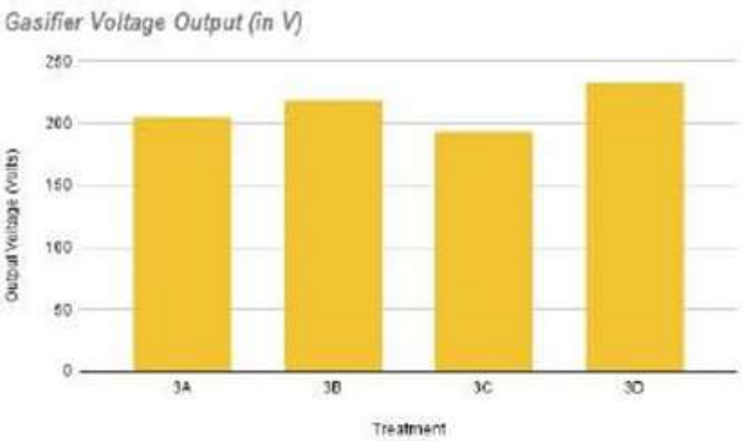


Figure 14.8 *Voltage Output of the Gasifier (in Volts) (WEBSITE)*

The output of the gasifier in terms of voltage is displayed in Figure 14.8, showing an average of 212.25V, it indicates that the gasifier is producing electricity consistently. This level of stability could point to well-regulated gasification.

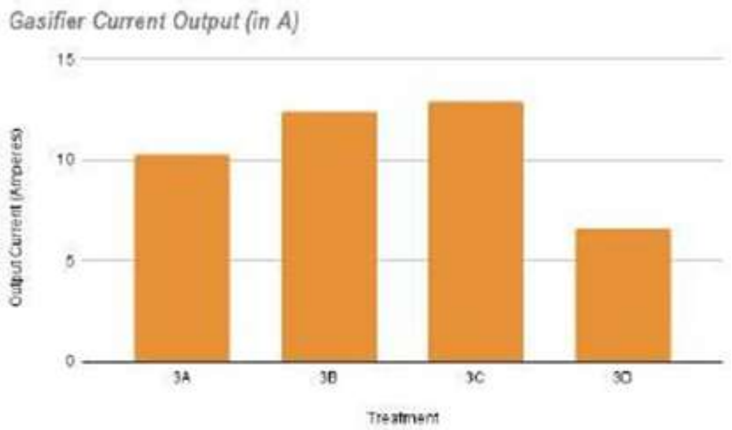


Figure 14.9 *Current Output of the Gasifier (in Amperes) (WEBSITE)*

Similarly, Figure 14.9 shows the current output, with an average of 10.55A, the current output indicates that the machine is successfully generating electrical power from the feedstock material. It also suggests that the machine is operating under relatively steady conditions. If the machine can consistently produce 10.55A, it may reflect optimal gas production from the feedstock, implying that the quality and quantity of gas are suitable for generating that current level.

The data collected relating to the gas content, gas composition, voltage output, and current output implies that the gasifier controlled by the developed control panel is viable for use. The gas content and composition depicted that it has a favorable quality. The electricity outputs show that it generates energy with stability and consistency. Compared to the data from the manual controls of the gasifier, the website data appears to have a better and more favorable quality overall.

Trial	**H2/CO Ratio (%)**	**CO2 + CH4 Content (%)**	**Feedstock Settings**	**Range**
1B	55.30 to 43.40	1.18	ON: 2s OFF: 26s	**ON: Highest: 4s Lowest: 2s**
1D	55.36 to 43.45	1.18	ON: 2s OFF: 25s	
1E	69.79 to 29.79	0.42	ON: 4s OFF: 15s	

Table 15. *Optimal Range of Feedstock Settings*

Trial	**H2/CO Ratio (%)**	**CO2 + CH4 Content (%)**	**Feedstock Settings**	**Range**
1B	55.30 to 43.40	1.18	0.029g/s	**Constant: 0.029g/s**
1D	55.36 to 43.45	1.18	0.029g/s	
1E	69.79 to 29.79	0.42	0.029g/s	
2D	45.05 to 27.03	27.92	0.029g/s	
2F	66.87 to 30.36	2.77	0.029g/s	

Table 16. *Optimal Value of Feed Rate*

Trial	**H2/CO Ratio (%)**	**CO2 + CH4 Content (%)**	**Rod Height**	**Range**
1B	55.30 to 43.40	1.18	46 cm	Highest: 47cm Lowest: 43cm
1D	55.36 to 43.45	1.18	45 cm	
1E	69.79 to29.79	0.42	43 cm	
2D	45.05 to27.03	27.92	47 cm	
2F	66.87 to30.36	2.77	44 cm	

Table 17. *Optimal Range of Feed Rod Height*

Tables 15, 16, and 17 show the optimal settings for the gasifier to produce this quality of syngas. The numbers set on the website must be within the mentioned highest and lowest numbers in order to produce the desired syngas. These are selected according to the ratio of the Hydrogen Gas and Carbon Monoxide, as well as the Carbon Dioxide and Methane content, since the quality of the synthetic gas is determined by these factors.

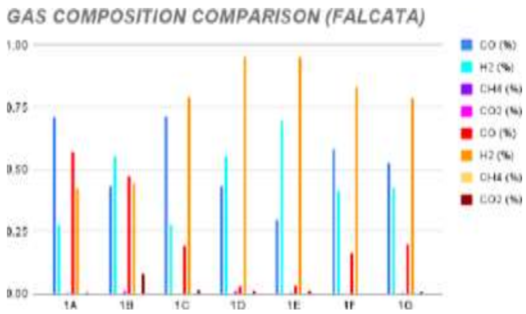


Figure 15.0. *Gas Composition Comparison of Website and Manual for Falcata Wood Chips*

Figure 15.0 shows the comparison of the gas composition between the gas compositions of the gas production with the website functions and the manual functions. The first four on the legends resemble the results controlled by the website, while the last four legends are the ones controlled manually. The gas composition of the website controlled gasifier has a more consistent ratio of H2 and CO, as well as having a better quality than the manually controlled gasifier.

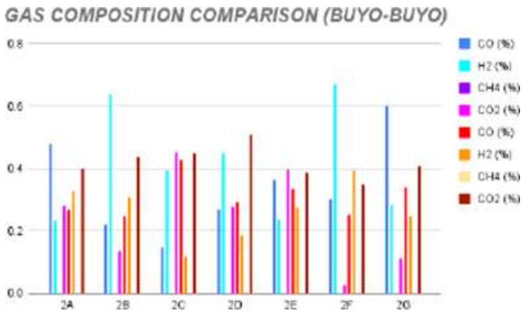


Figure 15.1. *Gas Composition Comparison of Website and Manual for Buyo-Buyo Wood Chips*

Figure 15.1 shows the comparison of the gas composition between the gas compositions of the gas production with the website functions and the manual functions that utilize the Buyo-Buyo Wood Chips.. The first four on the legends resemble the results controlled by the website, while the last four legends are the ones controlled manually. The gas composition of the website-controlled gasifier exhibits a more stable H2 to CO ratio and higher quality compared to the manually controlled gasifier.

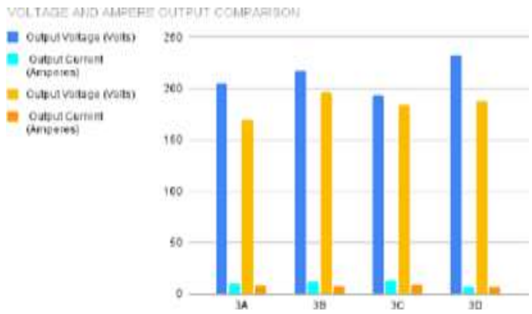


Figure 15.2. *Voltage and Current Output Comparison of the Website Control and the Manual Control*

Figure 15.2 shows the comparison of the voltage and current output of the website control and the manual control of the gasifier. The first two legends depict the website control, while the last two legends depict the manual control. This comparison shows that both the voltage and the current output of the website controlled gasifier is higher than the manually controlled gasifier.

CONCLUSION

The study successfully achieved its objectives by developing a functional web- based control panel for a downdraft gasifier system. The website facilitated wireless control of the gasifier, including the management of motors and sensors, ensuring efficient operation. Real-time data visualization on the website enabled users to monitor the gasifier's performance effectively, providing insights into crucial parameters like temperature and feedstock levels. The evaluation of the web-based control panel confirmed its functionality through rigorous testing, demonstrating the effectiveness of features like temperature sensors, motor controls, and alarm triggers.

The system effectively addressed issues encountered with manual gasifiers, including operational challenges, safety hazards, and technical limitations. The website's control over feedstock settings, feed rate, agitator, feed rod height, and temperature significantly improved the gasifier's performance. The system demonstrated its ability to produce higher quality syngas with a more desirable gas composition compared to manual operation. This was particularly evident in the consistent H2/CO ratio and lower CO2 and CH4 content achieved with the web- based control, as demonstrated in the analysis of Falcata and Buyo-buyo wood chips.

Additionally, the web-controlled gasifier produced higher voltage and current outputs, indicating enhanced energy generation capabilities. Finally, the cost analysis highlighted the economic viability of the web-based control panel. The total cost of PHP 4,400, significantly lower than the minimum monthly wage, positioned the system as a cost-effective solution for enhancing gasifier technology. The study's findings strongly suggest that integrating web-based control systems into downdraft gasifiers offers substantial benefits in terms of efficiency, safety, and economic viability, making it a promising approach for optimizing biomass gasification processes.

REFERENCES

All About MQ Series Gas Sensor. (n.d.). Robocraze. Retrieved August 13, 2024, from https://robocraze.com/blogs/post/m q-series-gas-sensor Bachmann, M., Völker, S., Kleinekorte, J., & Bardow, A. (2023). Syngas from What? Comparative Life-Cycle Assessment for Syngas Production from Biomass, CO2, and Steel Mill Off-Gases. *ACS Sustainable Chemistry & Engineering*, *11*(14), 5356–5366. https://doi.org/10.1021/acssuschem eng.2c05390

Bianco, N., Paul, M. C., Brownbridge, G. P. E., Nurkowski, D., Salem, A. M., Kumar, U., Bhave, A. N., & Kraft, M. (2018). Automated advanced calibration and optimization of thermochemical models applied to biomass gasification and pyrolysis. Energy & Fuels, 32(10), 10144–10153. https://doi.org/10.1021/acs.energyf uels.8b01007

Bukar, A. A., Oumarou, M. B., Tela, B. M., & Eljummah, A. M. (2019). Assessment of Biomass Gasification: A review of basic design considerations. *American Journal of Energy Research*, *7*(1),. https://doi.org/10.12691/ajer-7-1-1

Chaves, L. I., da Silva, M. J., de Souza, S. N. M., Secco, D., Rosa, H. A., Nogueira, C. E. C., & Frigo, E. P. (2016). Small-scale power generation analysis: Downdraft gasifier coupled to engine generator set. Renewable and Sustainable Energy Reviews, 58, 491-498.

Daniyan, I., Mpofu, K., Adeodu, A., & Momoh, O. (2020, January 1). *Development and automation of a 12 kW-capacity gasifier for energy generation*. IEEE Conference Publication | IEEE Xplore. https://ieeexplore.ieee.org/abstract/ document/9040963

De Paulo, A. A., Da Costa, R. S., Rahde, S. B., Vecchia, F. D., Seferin, M., & Santos, C. a. D. (2016). Performance and emission evaluations in a power generator fuelled with Brazilian diesel and additions of waste frying oil biodiesel. *Applied Thermal Engineering*, *98*, 288–297. https://doi.org/10.1016/j.appltherm aleng.2015.12.036

Espina, R. U., Barroca, R. B., Simpao, F. T., & Zamora, R. M. (2024). Temperature profile of a biomass gasification power system. IOP Conference Series: Earth and Environmental Science, 1354(1),012002. https://doi.org/10.1088/1755- 1315/1354/1/012002

Falcata Industry. (2019, May 27). Davao Oriental Official Website. https://davaooriental.gov.ph/invest/ industry-profile-and-investment- leads/falcata-industry/

Frontiers. (2022). Cost-Efficiency Analysis of the Improved Web- Based Planning. Retrieved from https://www.frontiersin.org/journal s/health-services/articles/10.3389/frhs.2021. 787894/full

Golder, S., Islam, M. R., Narayanan, R., Gafur, M. A., Pippia, R., & Tyagi, S. K. (2022). Comparative study of thermal degradation kinetics of two woody biomass samples for bio-oil production. Sustainable Energy Technologies and Assessments, 52, 102158.

Investopedia. (2023). Cost-Benefit Analysis: How It's Used, Pros and Cons. Retrieved from https://www.investopedia.com/terms/c/cost-benefitanalysis.asp

Jacal, S., Straubinger, F. B., Benjamin, E. O., & Buchenrieder, G. (2022). Economic costs and environmental impacts of fossil fuel dependency in sub-Saharan Africa: A Nigerian dilemma. Energy for Sustainable Development, 70, 45-53.

Jeswani, H. K., Chilvers, A., & Azapagic, A. (2020). Environmental sustainability of biofuels: a review. *Proceedings of the Royal Society A*, *476*(2243), 20200351.

Lleno, J. V., Ligalig, R. J., Sarmiento, R. T., & Along, A. A. (2023). Tree diversity, composition, and stand structure of lowland tropical forest in Prosperidad, Agusan del Sur, Philippines. Journal of Survey in Fisheries Sciences, 10(1S), 4810-4830.

LM, M., SRD, F., & N, M. (2023). The socio-economic impact assessment of biofuels production in South Africa: A rapid structured review of the literature. *Cogent Engineering*, *10*(1), 2192328.

Madadian, Edris. (2018) "Experimental observation on downdraft gasification for different biomass feedstocks." Gasification for Low-grade Feedstock 79.

Magdugo, E., Cabanes, J. M., & Gemperoa, A. (2023). IgnisCore: Automated Wood Pelletizer for Biomass Gasification Energy. *Holycross College of Engineering and Technology*.

Myllymaa, T., Holmberg, H., & Ahtila, P. (2018). Techno-economic evaluation of biomass drying in moving beds: The effect of drying kinetics on drying costs. Drying Technology, 37(10), 1201–1214. https://doi.org/10.1080/07373937.2 018.1492615

O'Connell, A., Kousoulidou, M., Lonza, L., & Weindorf, W. (2019).

Considerations on GHG emissions and energy balances of promising aviation biofuel pathways. *Renewable and Sustainable Energy Reviews*, *101*, 504-515.

Patuzzi, F., Basso, D., Vakalis, S., Antolini, D., Piazzi, S., Benedetti, V., Cordioli, E., & Baratieri, M. (2021). State-of-the-art of small- scale biomass gasification systems: An extensive and unique monitoring review. Energy, 223, 120039. https://doi.org/10.1016/j.energy.20 21.120039

Petruzzello, M. (2022, January 6). coppice. Encyclopedia Britannica. https://www.britannica.com/scienc e/coppice

Philippine Council for Agriculture, Aquatic, and Natural Resources Research and Development [PCAARRD]. (2020). Industrial Tree Plantation (ITP) – Industry Strategic Science and Technology Plans (ISPS) platform. PCAARRD's Industry Strategic Science and Technology Programs. https://ispweb.pcaarrd.dost.gov.ph/ industrial-tree-plantation-itp/

Qadra Studio. (n.d.). Web Design Pricing Philippines. Retrieved from https://qadra.studio/pricing/web- design-pricing-philippines/

Ramos, Ana, and Abel Rouboa. "Life cycle thinking of plasma gasification as a waste-to-energy tool: Review on environmental, economic and social aspects." *Renewable and Sustainable Energy Reviews* 153 (2022): 111762.

Rauch, R., Hrbek, J., & Hofbauer, H. (2013). Biomass gasification for synthesis gas production and applications of the syngas. *Wiley Interdisciplinary Reviews Energy and Environment*, *3*(4), 343–362. https://doi.org/10.1002/wene.97 *Relays - Relays - Bosch Auto Parts - Liferay DXP. (n.d.). Bosch Auto Parts. https://www.boschautoparts.com/g/ relays#:~:text=Bosch%20power% 20relays%20are%20used,battery% 20cut%2Doff%20relays*

Riva, F., Ahlborg, H., Hartvigsson, E., Pachauri, S., & Colombo, E. (2018). Electricity access and rural development: Review of complex socio-economic dynamics and causal diagrams for more appropriate energy modelling. Energy for sustainable development, 43, 203-223

Solarte-Toro, J. C., Chacón-Pérez, Y., & Cardona-Alzate, C.A. (2018). Evaluation of biogas and syngas as energy vectors for heat and power generation using lignocellulosic biomass as raw material. Electronic Journal of Biotechnology,33,2–62. https://doi.org/10.1016/j.ejbt.2018. 03.005

Striūgas, N., Zakarauskas, K., Džiugys, A., Navakas, R.,& Paulauskas, R. (2014). An evaluation of the performance of an automatically operated multi-fuel downdraft gasifier for energy production. *Applied Thermal Engineering*, *73*(1), 1151–1159. https://doi.org/10.1016/j.appltherm aleng.2014.09.007

Vaish, B., Sharma, B., Srivastava, V., Singh, P., Ibrahim, M. H., & Singh, R. P. (2017). Energy recovery potential and environmental impact of gasification for municipal solid waste. *Biofuels*, *10*(1), 87–100. https://doi.org/10.1080/17597269.2 017.1368061

Yang, L., & Ge, X. (2016). Biogas and Syngas upgrading. In Advances in bioenergy (pp.125–188). https://doi.org/10.1016/bs.aibe.2016.09.003

Yu, J., Zhang, J., Wu, N., Mei, Y., Zhang, D., Zhu, L., ... & Zhu, S. (2021, April). A Functionality Testing Method Based on Exploratory Testing for Android Mobile Apps. In *Journal of Physics: Conference Series* (Vol. 1856, No. 1, p. 012031). IOP Publishing

APPENDICES

ISEF Forms

Appendix 1.1 Form 1 - Checklist for Adult Sponsor

Checklist for Adult Sponsor (1)

This completed form is required for ALL projects.

To be completed by the Adult Sponsor in collaboration with the student researcher(s):

Student's Name(s): Axl Nash N. Alcoba, Seth Gabriel P. Castañeros, Jessarey S. Zamora

Project Title: GANISIR: Web-based Control Panel for Downdraft Gasification Using Buyo-buyo (Piper aduncum) and Falcata (Paraserianthes falcataria) Wood Chips

1. ☑ I have reviewed the ISEF Rules and Guidelines, including the science fair ethics statement.
2. ☑ I have reviewed the student's completed Student Checklist (1A) and Research Plan/Project Summary.
3. ☑ I have worked with the student and we have discussed the possible risks involved in the project.
4. ☐ The project involves one or more of the following and requires prior approval by an SRC, IRB, IACUC or IBC:
   - ☐ Humans
   - ☐ Vertebrate Animals
   - ☐ Potentially Hazardous Biological Agents
     - ☐ Microorganisms ☐ rDNA ☐ Tissues
5. ☑ Items to be completed for **ALL PROJECTS**
   - ☑ Adult Sponsor Checklist (1)
   - ☑ Student Checklist (1A)
   - ☑ Research Plan/Project Summary
   - ☑ Approval Form (1B)
     - ☑ Regulated Research Institutional/Industrial Setting Form (1C) (when applicable; after completed experiment)
     - ☐ Continuation/Research Progression Form (7) (when applicable)

Additional forms required if the project includes the use of one or more of the following (check all that apply):

☐ **Humans,** including student designed inventions/prototypes. (Requires prior approval by an Institutional Review Board (IRB); see full text of the rules.)
- ☐ Human Participants Form (4) or appropriate Institutional IRB documentation
- ☐ Sample of Informed Consent Form (when applicable and/or required by the IRB)
- ☐ Qualified Scientist Form (2) (when applicable and/or required by the IRB)

☐ **Vertebrate Animals** (Requires prior approval, see full text of the rules.)
- ☐ Vertebrate Animal Form (5A) - for projects conducted in a school/home/field research site (SRC prior approval required
- ☐ Vertebrate Animal Form (5B) - for projects conducted at a Regulated Research Institution. (Institutional Animal Care and Use Committee (IACUC) approval required prior experimentation.)
- ☐ Qualified Scientist Form (2) (Required for all vertebrate animal projects at a regulated research site or when applicable)

☐ **Potentially Hazardous Biological Agents** (Requires prior approval by SRC, IACUC or IBC, see full text of the rules.)
- ☐ Potentially Hazardous Biological Agents Risk Assessment Form (6A)
- ☐ Human and Vertebrate Animal Tissue Form (6B) - to be completed in addition to Form 6A when project involves the use of fresh or frozen tissue, primary cell cultures, blood, blood products and body fluids.
- ☐ Qualified Scientist Form (2) (when applicable)
- ☐ The following are exempt from prior review but require a Risk Assessment Form 3: projects involving protists, archae and similar microorganisms, for projects using manure for composting, fuel production or other non-culturing experiments, projects using color change coliform water test kits, microbial fuel cells, and projects involving decomposing vertebrate organisms.

☑ **Hazardous Chemicals, Activities and Devices** (No SRC prior approval required, see full text of the rules.)
- ☑ Risk Assessment Form (3)
- ☑ Qualified Scientist Form (2) (required for projects involving DEA-controlled substances or when applicable)

☑ **Other**
- ☑ Risk Assessment Form (3)

☑ **I attest to the information checked above and that I have read and agree to abide by the science fair ethics statement.**

Lemuel M. Espinar	Lemuel Espinar	10/11/24
Adult Sponsor's Printed Name	Signature	Date of Review (mm/dd/yy)
09554001461	lemuel.espinar@deped.gov.ph	
Phone	Email	

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Appendix 1.2 Form 1A - Student Checklist

Student Checklist (1A)

This form is required for ALL projects.

1. a. Student/Team Leader: Jessarey S. Zamora Grade: 12
   Email: jessareyzamora919@gmail.com Phone: 09270241248
   b. Team Member: Seth Gabriel P. Castañeros c. Team Member: Axl Nash N. Alcoba
2. Title of Project: GANISIR: Web-based Control Panel for Downdraft Gasification Using Buyo-buyo (Piper aduncum) and Falcata (Paraserianthes falcataria) Wood Chips
3. School: Davao City National High School School Phone: (082) 227 9102
   (if multiple schools, list of the team leader or list all schools).

School Address: F. Torres St., Davao City

4. Adult Sponsor: Lemuel M. Espinar Phone/Email: lemuel.espinar@deped.gov.ph
5. Does this project need SRC/IRB/IACUC or other pre-approval? ☐ Yes ☒ No Tentative start date: ________
6. Is this a continuation/progression from a previous year? ☐ Yes ☒ No
   If Yes:
   a. Attach the previous year's ☐ Abstract **and** ☐ Research Plan/Project Summary
   b. Explain how this project is new and different from previous years on
   ☐ Continuation/Research Progression Form (7)
7. This year's experimentation/data collection:

   08/24/24 — Actual Start Date: (mm/dd/yy)
   10/09/24 — End Date: (mm/dd/yy)
8. Where will you conduct your experimentation? (check all that apply)
   ☑ Research Institution ☐ School ☑ Field ☐ Home ☐ Other: ________
9. Source of Data:
   ☑ Collected self/mentor ☐ Other Describe/url: ________
10. List the name and address of all non-home and non-school work site(s), whether you worked there virtually or on-site:

Name ________

Address: Montevista, Davao de Oro, Philippines

Phone/email ________

11. **Complete a Research Plan/Project Summary following the Research Plan/Project Summary instructions and attach to this form.**
12. **An abstract is required for all projects after experimentation.**

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Appendix 1.3 Form 1B - Approval Form

Approval Form (1B)

A completed form is required for each student, including all team members.

1. To Be Completed by Student and Parent

a. **Student Acknowledgment:**

- I understand the risks and possible dangers to me of the proposed research plan.
- I have read the ISEF Rules and Guidelines and will adhere to all International Rules when conducting this research.
- I have read and will abide by the science fair ethics statement.

Student researchers are expected to maintain the highest standards of honesty and integrity. Scientific fraud and misconduct are not condoned at any level of research or competition. Such practices include but are not limited to plagiarism, forgery, use or presentation of other researcher's work as one's own, and fabrication of data. Fraudulent projects will fail to qualify for competition in affiliated fairs and ISEF.

Axl Nash N. Alcoba		07/23/24
Student's Printed Name	Signature	Date Acknowledged (mm/dd/yy) (Must be prior to experimentation.)

b. **Parent/Guardian Approval:** I have read and understand the risks and possible dangers involved in the **Research Plan/Project Summary**. I consent to my child participating in this research.

Cherryl N. Alcoba		07/23/24
Parent/Guardian's Printed Name	Signature	Date Acknowledged (mm/dd/yy) (Must be prior to experimentation.)

2. To be completed by the local or affiliated Fair SRC

(Required for projects requiring prior SRC/IRB APPROVAL. Sign 2a or 2b as appropriate.)

a. **Required for projects that need prior SRC/IRB approval BEFORE experimentation** (humans, vertebrates or potentially hazardous biological agents).

The SRC/IRB has carefully studied this project's **Research Plan/Project Summary** and all the required forms are included. My signature indicates approval of the **Research Plan/Project Summary** before the student begins experimentation.

Lemuel M. Espinar

SRC/IRB Chair's Printed Name

Lemuel Espinar — 07/23/24

Signature — Date of Approval (mm/dd/yy) (Must be prior to experimentation.)

OR

b. **Required for research conducted at all Regulated Research Institutions with no prior fair SRC/IRB approval.**

This project was conducted at a regulated research institution (**not home or high school, etc.**), was reviewed and approved by the proper institutional board before experimentation and complies with the ISEF Rules. **Attach (1C) and any required institutional approvals (e.g. IACUC, IRB).**

Lemuel M. Espinar

SRC Chair's Printed Name

Lemuel Espinar — 07/23/24

Signature — Date of Signature (mm/dd/yy) (May be after experimentation)

3. Final ISEF Affiliated Fair SRC Approval (Required for ALL Projects)

SRC Approval After Experimentation and Before Competition at Regional/State/National Fair

I certify that this project adheres to the approved **Research Plan/Project Summary** and complies with all ISEF Rules.

Regional SRC Chair's Printed Name	Signature	Date of Approval (mm/dd/yy)
State/National SRC Chair's Printed Name *(where applicable)*	Signature	Date of Approval (mm/dd/yy)

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Appendix 1.4 Form 1B - Approval Form

Approval Form (1B)

A completed form is required for each student, including all team members.

1. To Be Completed by Student and Parent

a. Student Acknowledgment:

- I understand the risks and possible dangers to me of the proposed research plan.
- I have read the ISEF Rules and Guidelines and will adhere to all International Rules when conducting this research.
- I have read and will abide by the science fair ethics statement.

Student researchers are expected to maintain the highest standards of honesty and integrity. Scientific fraud and misconduct are not condoned at any level of research or competition. Such practices include but are not limited to plagiarism, forgery, use or presentation of other researcher's work as one's own, and fabrication of data. Fraudulent projects will fail to qualify for competition in affiliated fairs and ISEF.

Seth Gabriel P. Castaneros — 07/23/24

Student's Printed Name | Signature | Date Acknowledged (mm/dd/yy) (Must be prior to experimentation.)

b. Parent/Guardian Approval: I have read and understand the risks and possible dangers involved in the **Research Plan/Project Summary**. I consent to my child participating in this research.

Merlyn P. Castaneros — 07/23/24

Parent/Guardian's Printed Name | Signature | Date Acknowledged (mm/dd/yy) (Must be prior to experimentation.)

2. To be completed by the local or affiliated Fair SRC

(Required for projects requiring prior SRC/IRB APPROVAL. Sign 2a or 2b as appropriate.)

a. Required for projects that need prior SRC/IRB approval BEFORE experimentation (humans, vertebrates or potentially hazardous biological agents).

The SRC/IRB has carefully studied this project's **Research Plan/Project Summary** and all the required forms are included. My signature indicates approval of the **Research Plan/Project Summary** before the student begins experimentation.

Lemuel M. Espinar

SRC/IRB Chair's Printed Name

07/23/24

Signature | Date of Approval (mm/dd/yy) (Must be prior to experimentation.)

OR

b. Required for research conducted at all Regulated Research Institutions with no prior fair SRC/IRB approval.

This project was conducted at a regulated research institution (**not home or high school, etc.**), was reviewed and approved by the proper institutional board before experimentation and complies with the ISEF Rules. **Attach (1C) and any required institutional approvals (e.g. IACUC, IRB).**

Lemuel M. Espinar

SRC Chair's Printed Name

07/23/24

Signature | Date of Signature (mm/dd/yy) (May be after experimentation)

3. Final ISEF Affiliated Fair SRC Approval (Required for ALL Projects)

SRC Approval After Experimentation and Before Competition at Regional/State/National Fair

I certify that this project adheres to the approved **Research Plan/Project Summary** and complies with all ISEF Rules.

Regional SRC Chair's Printed Name | Signature | Date of Approval (mm/dd/yy)

State/National SRC Chair's Printed Name *(where applicable)* | Signature | Date of Approval (mm/dd/yy)

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Appendix 1.5 Form 1B - Approval Form

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