Low Cost, High-Efficiency Stove for Developing Regions

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BioBlaze

Mission/SOW

In many *developing regions*, cooking methods pose serious health, environmental, and economic challenges. Our team designed a low-cost, high-efficiency biomass stove to address these issues through innovation, sustainability, and practical engineering.

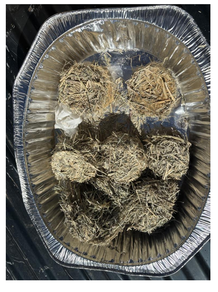
The parameters for this capstone project were:

- Reduce harmful smoke emissions
- Improve thermal fuel efficiency
- Ensure ease of daily use
  - Duration of boiling water 10-30 minutes
  - Remain at boiling temperature for at least 1 hour
- Utilize wheat waste biomass
- Produce biochar as byproduct
- Incorporate sustainable materials
- Include attachments for oven to transfer heat

Our team worked rigorously to design a biomass stove that produces biochar and supports sustainable cooking.

Research

- 2.6 billion people in developing regions rely on biomass (wood, charcoal) for cooking. This trend is expected to grow along with the population growth.
- Pyrolysis has many applications that relate to green technology. One being biochar which are created from crops and waste products.
  - Biochar is a form of charcoal made from biowastes such as manure (cow manure, poultry manure), agriculture wastes (corn stover, leaves, wheat straw, wood chips, etc.) Anaerobic heating takes place which is a process that rapidly decomposes organic material.
- Various agricultural waste are produced daily, leaving behind waste that is usually what is burned.
  - One sustainable solution is to repurpose this waste by forming briquettes, which serve as an efficient and low-cost source of fuel for cooking and heating.



Final Design

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Final Design Breakdown:

- A Top Hatch/Grate
  - Designed surface to place cookware.
- Inner Shell
  - This inner shell traps the heat.
  - Serves as a combustion chamber to maximize fuel efficiency and minimizing emissions from fuel.
- Outer Shell
  - Acts as a covering to trap heat within. Reducing the heat transfer to outside ambient temperature.
  - Holds weight of inner shell and is the base of the design.
- Airflow and Hole Placements
  - Inner shell contains air holes at the top and is elevated from the ground. This creates a second combustion chamber reducing further emissions.
  - To maximize airflow, outer shell includes holes at the bottom.

FEA

Thermal Load

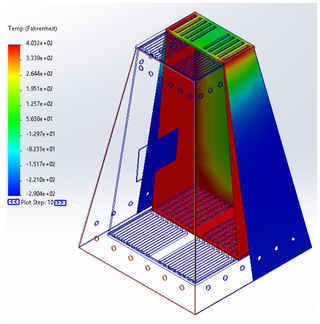


Figure 1. Thermal load on inner shell and outer shell.

- **Figure 1** illustrates a transient thermal power and convection load of 2,500 Btu/s applied at the base and walls of the stove's inner shell.
- The total simulation time is one hour, with time increments of six minutes.
- The initial "cold start" temperature of the stove was 70 °F.

Static Load

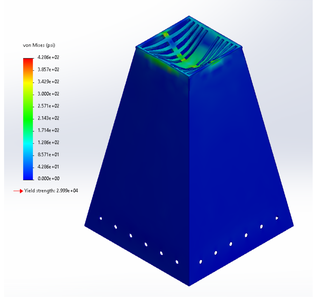


Figure 2. Static load on inner shell and outer shell.

- **Figure 2** depicts a static load of 100 lbs. at the top of stove.
- This is to simulate the potential max weight of food being cooked.
- The stress did not reach critical values, and deformation was not significant to the integrity of the stove's structure.

Test Results

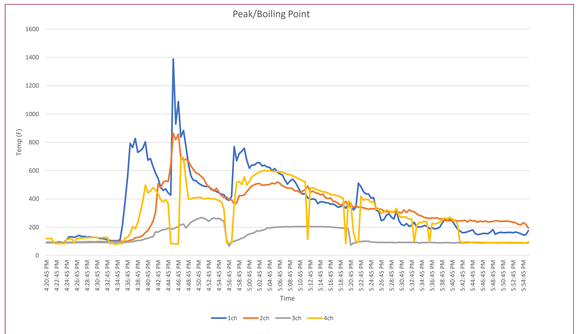


Table 1: First Test

Table 1:
CH 1(Blue): Top ; CH 2(Orange) Bottom ; CH 3(Gray) Side Handle ; CH 4(Yellow): Door Handle

- Half-gallon of water used in testing.
- The initial start 4:23 PM was reset to 4:30 PM as the start time since there was not fire start and it was observed that there would be extra steps needed when using the briquettes as a fuel source. At 4:35 PM< there was smoke visible and by 4:38 PM, it was observed that there was no smoke visible. A boil was achieved at 4:46 PM.

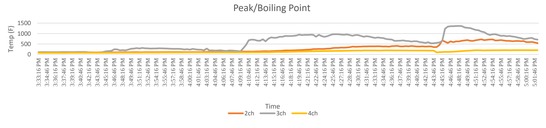


Table 2: Second Test

Table 2:
CH 1: N/A CH 2(Orange): Bottom ; CH 3(Gray): TOP ; CH 4(Yellow):Water

- 1 gallon of water used in testing.
- Initial start 3:34 PM was rest to 3:46 PM due to data error. About 3 lbs. wood and 3 briquettes used. Boil was achieved at 4:28 PM. Hot start at 4:45 PM with 3 lbs. wood was added. 5:00 PM boil achieved. 5:02 PM vents blocked.

Concept Development

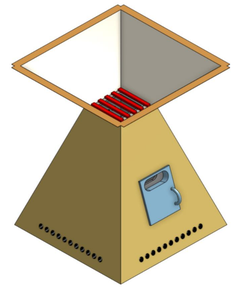
The team explored several design concepts to determine the most effective direction for the optimized biomass stove. **The primary objectives were:**

- Amount of energy needed to boil 1 gallon of water
- Reduce the amount of smoke emissions
- Ensuring cost-effectiveness
- User-friendly design

In addition to stove design, the team incorporated briquettes as a key feature—an eco-friendly fuel alternative made from repurposed agricultural waste. These briquettes not only offer a sustainable source of cooking and heating fuel but also contribute to biochar production, enhancing soil health and carbon sequestration.

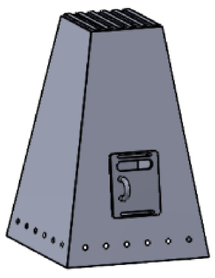
Design Iterations

Design #1



The first iteration included an inverted cone design that reached from the top of the grill plate to direct heat. It also included small holes at the bottom that were closer in proximity.

Design #2



The next iteration consisted of two shells to reduce heat transfer and optimize efficiency. The door of this design slides open left to right for access to the inside chamber.

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