

Developing a Mobile Thermal Disposal System for On-Site Construction Wood Waste

Grant Proposal

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Author Note

If needed, write notes here with an indented first line. Be mindful, the text in your lit. review should be between 10-12 font size with a chosen font of Caibri, Times New Roman, or Arial. A Table of Contents is *optional*; however, you should format the section headers appropriately to have them show up in the TOC. Lines should be double-spaced.

Executive Summary

The abstract would contain an overall summary of what you (as the author) would like to convey. It would include some of the knowledge gaps that would eventually lead to researchable questions you have identified in the field.

This proposal outlines the engineering design and development of a solution: a portable, on-site device to pyrolyze construction wood waste. This product is envisioned as a mobile unit capable of burning used wood at high temperatures while also providing a mechanism to sort and capture metal contaminants like nails and screws, allowing for their separate recycling.

Finally, the device must be practical for a construction environment. Its portability will be key to the success of the product. It requires an ergonomic design with durable wheels and handles that account for the high resistive forces of uneven terrain to prevent operator injury (Gille, 2025; Baensch-Baltruschat et al., 2020). All testing will be conducted under strict safety protocols, including the use of appropriate fire extinguishing agents (Kim et al., 2024). This project will address these specific engineering goals to develop a product that directly fills the environmental and economic needs identified.

Keywords: emotion understanding, interest, social development, prosocial behavior, infants

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The Problem: Emissions and Decomposition

When construction sites perform demolition, the standard industry practice is to haul all the waste by truck to landfills. This disposal method presents significant environmental and economic problems, and the transportation of this waste generates a massive carbon footprint. Construction waste hauling trucks can produce more than 25 million tons of CO₂ each year (Wei et al., 2022). Furthermore, once this wood waste arrives at the landfill, it fails to decompose significantly. Buried wood products only lose 0-10% of their mass even after sitting exposed or underground for over 2 years. The fact that wood can take centuries to decompose completely leads to issues with it remaining in the planet's limited landfill space forever (Wang et al., 2013).

The Problem: Financial Bottlenecks for Construction Companies

Meanwhile, the current disposal method is a major financial drain as well. Paying for the trucks to move the wood, each dump in a landfill, and all the labor to transport the wood is very expensive. Companies spend roughly 1% of their gross sales on moving materials to landfills (C. Bergeron, personal communication, December 7, 2025). These inflated costs for material disposal fall back on the consumers paying for the construction to occur. Currently, not much is being done to address this issue because of the many structural limitations of the materials candidates addressed below (Wilson et al., 2008). While there are some units for disposing of forest waste, they are much bigger (about 20 cubic yards) and would not fit into a construction site environment. A new solution is needed to change the inefficient cycle of transporting and storing wood waste in landfills.

Potential

One way to solve the issue present would be to develop a thermal disposal system. A thermal disposal system would use heat to burn the wood waste, meaning it would never have to be transported off the construction site.

Greenhouse Gas Considerations

This approach, however, is not without technical considerations. The combustion of wood releases greenhouse gases, gases that overheat the earth by trapping heat from the sun in the atmosphere. Also, the efficiency of the combustion is impacted by factors like moisture content, meaning that the location where the

wood was stored would have to be taken into account (Lai et al., 2024; Flammini et al., 2023). However, preliminary analysis suggests the carbon emissions from a localized, on-site burning would be significantly less than the 83,000 tons per year per city generated by the current construction site to landfill model (Wei et al., 2022).

Metals at High Temperature

If an on-site disposal system were designed, challenges would be faced in regards to material. The burn chamber would have to safely operate at 1800°F - 2000°F because that is the temperature at which wood burns (Lai et al., 2024). This requires a precise selection of heat-resistant alloys, focusing on creep-rupture strength (see Appendix A for the glossary of terms) and deformation to ensure the material does not fail after repeated thermal cycles (Wilson et al., 2008). Heat transfer simulations would be necessary to model thermal stress and ensure heat does not migrate to critical and external components that could come in contact with a user (Xiao et al., 2024).

Preventing Dislocations and Creep

As metals heat up, their atoms begin to gain energy. As they gain more energy, the material's elastic properties holding it in place begin to get overpowered. In a high-energy state, it takes significantly less force to produce a dislocation between the molecules, which causes creep. Within each crystal of metal, two different types of molecular formations reside. The gamma prime phase is the stronger of the two formations, an organized pattern of nickel and aluminum atoms. Meanwhile, the gamma phase keeps the metal ductile so it can bend without breaking by stopping a dislocation from the gamma prime phase from affecting the random structure of the gamma phase.

Magnetization for Ferrous Metals

If the described device were made, it would still have issues with ferrous metals. These metals within the wood would not be burned by the fire. While magnetization is a great first solution, it is ineffective because it loses its polarization at high temperatures (Choi et al., 2018; R. Bradshaw, personal communication, October 17, 2025).

Ash Management

Also, burning wood results in leftover ashes, which cannot be burned any further as they lose all their combustible material in the initial fire. While this could be a problem initially, the reality is that wood waste ashes can be used as fertilizer because they contain essential nutrients (Zhai et al., 2021).

Section II: Specific Aims

This proposal's objective is to develop a solution to wood waste on construction sites by designing a device that can dispose of the material on site.

Our long-term goal is to reduce the amount of CO₂ emissions that are inadvertently generated from wood waste on construction sites. The central hypothesis of this proposal is that a localized, high-temperature thermal disposal system can reduce the net carbon footprint of construction wood waste management by eliminating fossil fuel-intensive transportation and reducing landfill methane generation while simultaneously offering a way to reduce time and money spent disposing of the waste material. The rationale is that the carbon released during efficient combustion is part of the short-term carbon cycle. Meanwhile, diesel emissions and tire and road wear particles (TRWPs) such as microplastics, which are generated by haulage trucks, are cumulative, long-term pollutants (Baensch-Baltrusch et al., 2020). To test this hypothesis and deliver a viable product, we propose four specific aims.

Specific Aim 1: To identify and validate the best metal capable of withstanding 5,000 hours, an industry standard, of operation at an internal temperature of 2000°F while considering other factors such as price and distortion. This involves modeling pieces of metal and applying heat stress to prevent failure modes such as creep-rupture and oxidation scaling (Wilson et al., 2008).

Specific Aim 2: To develop and simulate three distinct combustion chamber designs revolving around heat displacement and thermal management. We will model and test each design to ensure the external surface temperature remains safe for operators (<300°F) while maintaining high internal efficiency for pyrolysis (Xiao et al., 2024).

Specific Aim 3: To quantify the current emissions baseline of the local construction sector. This involves conducting field research ("Bottom Up" method) to calculate the freight characteristics of waste hauling, including

the carbon footprint of Construction Waste Hauling Trucks (CWTHs) and the methane generation of potential landfilled wood (Wei et al., 2022).

Specific Aim 4: To operationally validate the final prototype by measuring its emission production and economic efficiency against the baseline. This includes testing the design to quantify the reduction in fossil-fuel usage, time, and money, for construction companies, highlighting a final return on investment (ROI) for construction companies.

The expected outcome of this work is a fully functional, mobile thermal disposal unit that has been empirically proven to reduce the net carbon footprint of wood waste disposal compared to the landfill model, while safely separating ferrous metals for recycling.

Section III: Project Goals and Methodology

Relevance/Significance

The construction industry faces a critical need for sustainable waste management. Currently, the logistics of moving waste generate massive quantities of CO₂. A single city produces over 83,000 tons of CO₂ annually just by hauling wood waste from construction sites to landfills (Wei et al., 2022). Furthermore, the reliance on heavy-duty trucks contributes significantly to non-exhaust emissions, specifically Tire and Road Wear Particles (TRWP). TRWP emissions are a leading source of microplastics in the environment (Baensch-Baltruschat et al., 2020). By eliminating the transport leg of disposal, this project addresses both atmospheric carbon and terrestrial microplastic pollution. Additionally, it mitigates the issue of biogenic carbon sinks in landfills, where wood fails to decompose efficiently and consumes valuable land volume (Wang et al., 2013).

Innovation

This project innovates by miniaturizing industrial incineration technology for mobile, small-scale applications. Unlike static incinerators, this mobile thermal disposal system utilizes a magnetic filtration system that operates post-combustion to bypass the curie temperature limits of magnets, allowing for the recycling of nails and screws (Choi et al., 2018). It also applies Larson-Miller Parameter (LMP) modeling to accessible materials,

enabling high-temperature durability and product longevity (R. Bradshaw, personal communication, October 17, 2025).

Methodology

Specific aim #1 will use Fusion 360 to conduct thermal stress simulations. Physical testing for 5,000 hours is not feasible within the project timeline. Therefore, we will create a simulation of a 12" by 12" by 1/8" metal plate and apply heat to a single spot in the center of one of the faces. Each metal plate will be tested for its distortion in the corner and on a side, have its Von Mises' Stress recorded, and have its safety factor calculated, and have its price per pound and density recorded.

Specific aim #2 will use the objective best metal found from specific aim #1, along with Fusion 360, to design and simulate three different potential shapes for the burn chamber and see which one best distributes the heat across the entire burn chamber to avoid stress in any particular area. From there, the objective best design will have insulation and an outer casing added to maximize internal temperature for efficiency and minimize external temperature for safety.

For specific aim #3, we will use the Bottom-Up method to calculate emissions based on specific trip data rather than general averages by collecting real field data from local construction sites. We will determine the actual total emissions produced by construction sites to compare with the mobile thermal disposal tested in specific aim #4.

Specific aim #4 will use a physical prototype constructed based on the results of specific aims 1 and 2. Testing will occur in a controlled outdoor environment with a minimum 5-foot safety radius. Testing will also use all safety equipment identified in the "safety" section below, which includes appropriate PPE and Class A fire extinguishers. Wood will be weighed prior to ignition to calculate the efficiency of the device and calculate the emissions produced.

Specific Aim #1:

Determine the lifespan of candidate alloys under thermal stress. The objective is to select a material that can withstand 5,000 hours at 2000°F without creep rupture (time-dependent deformation). Our approach is to simulate a variety of metals using Fusion 360. Each metal will have a heat source applied, and it will be simulated to show the metal strength results after 5,000 hours and at 2000°F. Our rationale for this approach is that a physical 5,000-hour test is impossible within the project timeline. Therefore, a simulation will be run to determine the best metal to use for the combustion chamber in the final design based on the predicted rupture life (Wilson et al., 2008).

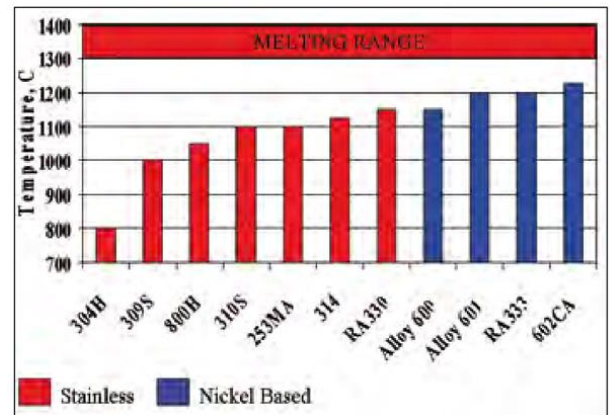


Figure 1. Melting range of metals. Compares stainless metals (red bars) to nickel based metals (blue bars) (Wilson et al., 2008).

Justification and Feasibility. High-temperature alloys degrade rapidly via oxidation and creep. As shown in the graphic above (Figure 1), standard stainless steels lose significant strength above 1600°F/870°C while nickel-based alloys preserve their strength under much more intense heat. This data justifies our need to test different heat-resistant alloys to see which one will last for the required time and be at the best price.

Summary of Preliminary Data. Each of the 5 metals (Inconel 625, Stainless Steel AISI 310, Inconel 718, Stainless Steel 316L, and Steel AISI 1018 118 QT) underwent 4 tests and had 4 additional data points recorded on a 12" x 12" x 1/8" plate of metal. The distortion was measured because an ideal metal would have a low distortion to preserve tolerancing. The safety factor was found to see which metals would have a high safety, and in turn, be less likely to oxidize rapidly at their oxidation temperature. Von Mises Stress was looked at to find what would have the lowest value. A low stress means that the product will not have to undergo much stress at a high heat (2000°F) and high amount of runtime hours (5000 hours). Lastly, the thermal gradient was measured to see how much heat was being dispersed from the metal at any given time. A low thermal gradient is good because heat is not all being released at the same spot.

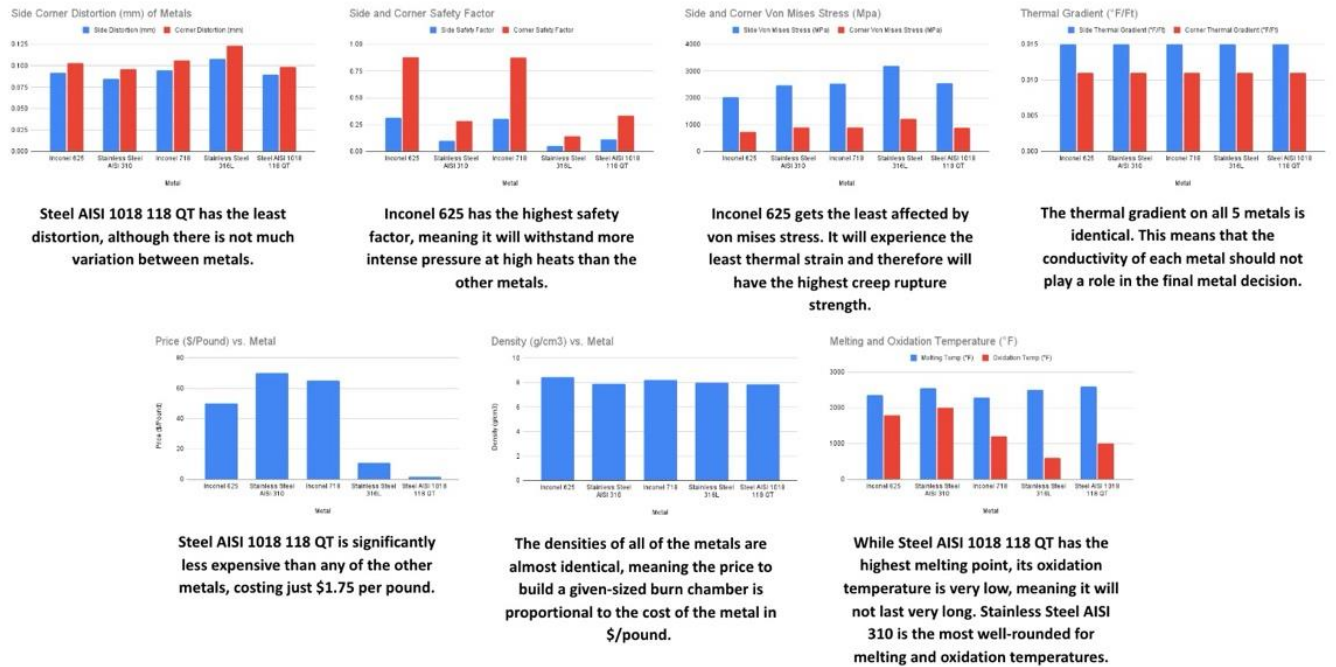


Figure 2. Simulation results for five candidate metals. Shows the Fusion 360 simulation results across seven different categories.

Expected Outcomes. This knowledge will be used to determine the metal that will be used to construct the burn chamber. Steel AISI 1018 118 QT was overall the best metal because it is well-rounded and inexpensive. If Steel AISI 1018 118 QT performs well in test 2 (specific aim 2), then it will remain the metal for the final design.

Potential Pitfalls and Alternative Strategies. If there are simulated issues with rapid oxidation, then Stainless Steel AISI 310 may be used directly beneath the flame as it has a higher oxidation temperature and is less likely to have creep occur.

Specific Aim #2:

Determine the optimal geometry for cooling. The objective is to design a system where the internal fire reaches 2000°F but the outer shell remains safe (<300°F). Our approach is to generate three distinct CAD models that vary in air-gap spacing and insulation, and to simulate their thermal performance using Fusion 360's thermal analysis. Our rationale for

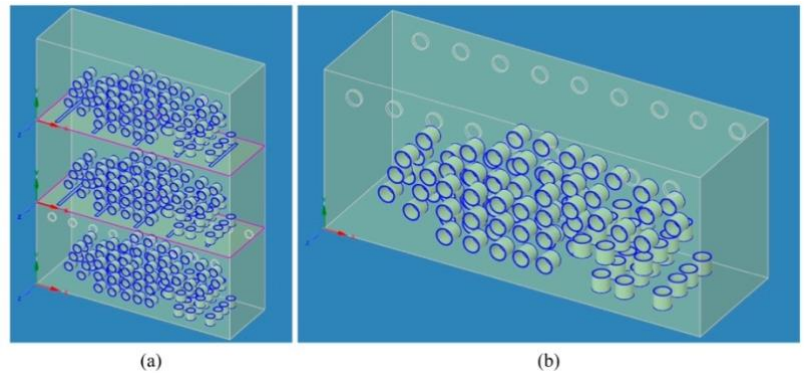
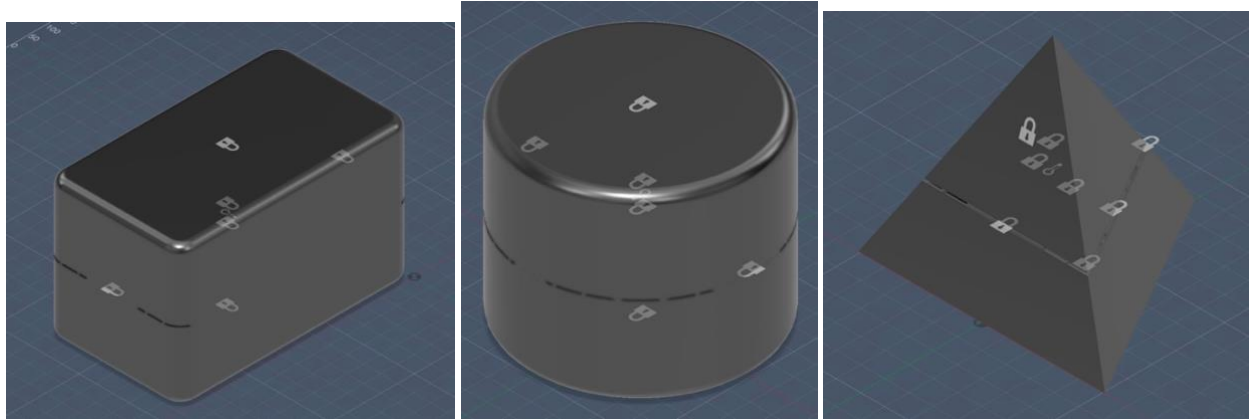


Figure 3. Depicts two shapes for a high-temperature furnace. Design A depicts the a new proposed design which is much more vertical then design B, which depicts the current design (Xiao et al., 2024).

this approach is that Finite Element Analysis (FEA) allows us to visualize heat flux vectors and optimize the design before using material unnecessarily on physical prototypes (Xiao et al., 2024).

Justification and Feasibility. Understanding heat transfer in vertical shafts is critical. Figure 3 (above) demonstrates how vertical furnace designs improve heat absorption efficiency. We will apply these principles to create at least one of the three designs with a natural draft “chimney effect” between the inner and outer walls to remove excess heat.

Summary of Preliminary Data. Three different designs were made using Computer-Aided Design (CAD), which can be seen in Figure 4 below. Each went through four different tests where data points were collected. Each test collected the minimum value, maximum value, value from a measured side (closest to the source of heat), and a value from a measured bottom corner, farthest from the heat. While conclusions for the best design are still in the works, data suggests that the cylinder might be the best shape.



Rectangular Prism

Cylinder

Triangular Pyramid

Figure 4. Three different burn chamber designs. Shows each design made with Fusion 360. The locks represent where a body was fixed for thermal stress analysis.

All three designs were put through four tests; distortion, safety factor, von mises stress, and thermal gradient. All designs incorporated a 2" by 2" mesh grate where a model 2" x 4" x 8" piece of wood sat. Data points were collected and recorded as seen in Figure 5.



Figure 5. Graphs That show the initial results of the tests with the three different design shapes.

When analysis is complete, we expect to have results that use a Pugh chart to show which of the three designs best fits the determined ideal conditions. The result of these tests will show which design will be built.

Expected Outcomes. The overall outcome of this aim is to determine which design and shape the burn chamber should be to optimize the longevity of the product. We expect to determine exactly which design is the objective best to use for the burn chamber.

Potential Pitfalls and Alternative Strategies. It is vital that we test three truly unique designs. If designs are too similar, other designs may get overlooked even if they would have performed better. In order to avoid this, each design will begin with brainstorming and will be built up as an idea before using Fusion 360 to design each burn chamber.

Specific Aim #3:

Determine the current environmental cost of wood disposal. The objective is to quantify the CO2 and TRWP emissions generated by the current truck to landfill model. Our approach is to conduct field research by interviewing local construction firms to obtain data on trip length, load weight, cost per trip, and frequency. We will use the Bottom Up method to calculate total emissions (Wei et al., 2022). Our rationale for this approach is that to prove the product’s value, we must have a rigorous baseline backed by data on exactly what the product will save construction companies in terms of time, money, and emissions.

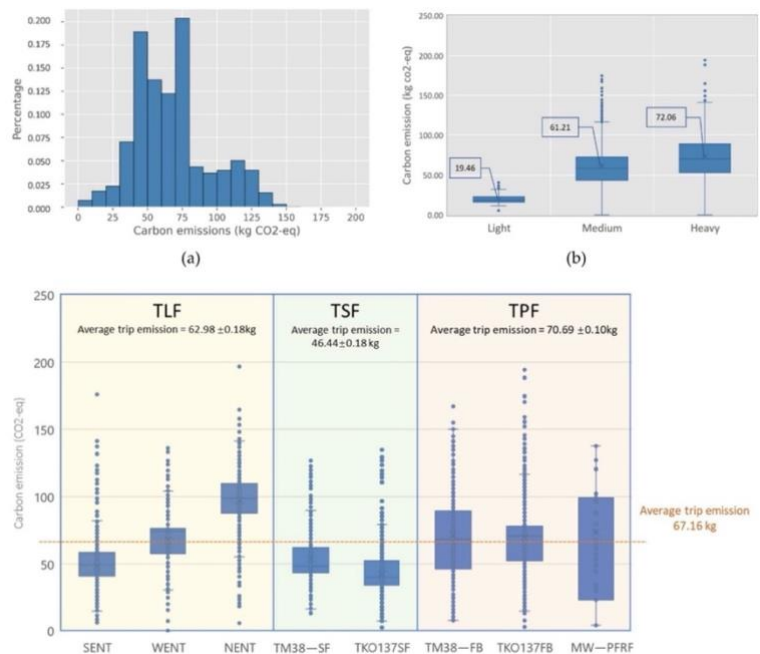


Figure 6. The distribution of carbon emissions per trip and by vehicle/trip type. Heavier trucks and TPF trips (trips to public fills) generate more emissions per trip (Wei et al., 2022).

Justification and Feasibility. Construction trucks are heavy emitters. Figure 6 (above) illustrates the significant carbon footprint that is associated with these vehicles. This data is relevant because it quantifies the “problem” that our device solves.

Summary of Preliminary Data and Expected Outcomes. We expect to have results that reflect research. We believe we will find that companies spend roughly 1% of their gross income purely on wood waste management. We also expect to find that roughly half a billion tons of CO₂ are produced every year from trucks driving wood waste to landfills.

Potential Pitfalls and Alternative Strategies. It is vital that we run many trials for these tests. The data has to be accurate in order to sell the product. Customers expect real data to see what emissions their construction business will prevent and how much money they will save.

Specific Aim #4:

Determine the real-world performance of the device. The objective is to measure the burn rate, ash reduction, and operator time savings of the final prototype. Our approach is to deploy the unit at a test site, measuring the mass of wood before and after burning, and logging the time required versus the time required to load a truck and transport the wood to a landfill. Our rationale for this approach is that we must demonstrate that biogenic carbon released from the wood is less than the fossil carbon released by the trucks, proving that the product’s carbon emissions are net positive (Flammini et al., 2023). We also need to prove that buying and using our product will be more cost-effective than transporting wood via truck.

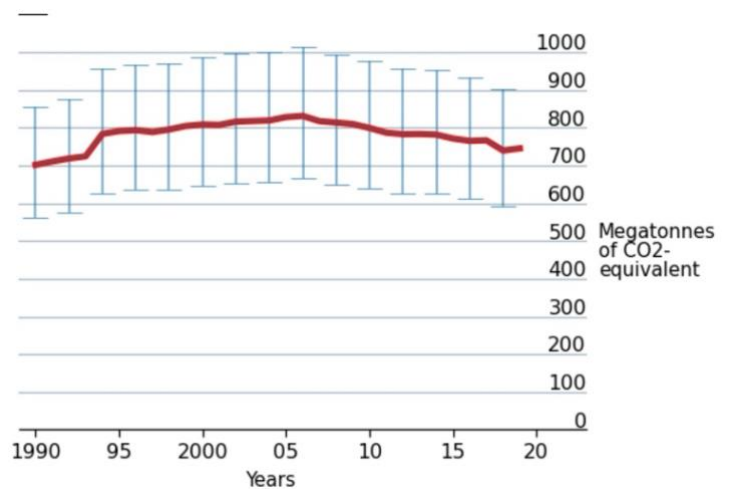


Figure 7. Global GHG emissions from non-renewable wood fuel use from 1990 to 2019. The uncertainty range is shown to give emission estimates because there were limitations with the data (Flammini et al., 2023).

Justification and Feasibility. Figure 7 (above) shows the global GHG emissions from non-renewable wood fuel use from 1990 to 2019. This data is relevant because it can be used to get a general baseline on how much of a dent using the device can make on the atmosphere.

Summary of Preliminary Data and Expected Outcomes. We expect to find that our product produces fewer emissions as calculated in specific aim #3. We expect to see construction sites save time and money while using the product. We expect to see interest in the product to continue testing or even begin manufacturing.

Potential Pitfalls and Alternative Strategies. We must test this product thoroughly. In addition to the reasons highlighted in specific aim #3, it is vital that our product undergoes rigorous testing to ensure that users will not get injured as long as the product is being used properly. If the design is not yet safe for the field, we will develop a safer design to decrease injuries.

Section III: Resources/Equipment

Materials

Materials for Burn Chamber: Stainless Steel Encasing, Screws, Magnets, Metal Angles, Steel Sheets

Materials for Portability: 55 Gallon Drum Mover, Metal Handles, Rubber Wheels, Rubber Swivel Caster Wheels

Equipment

Drill, Cobalt Drill Bits, Impact Driver, Saw Zall, Safety Glasses, Gloves, Angle Grinder, Infrared thermometer, Fire Extinguisher, Fusion 360

Consolation

- Mentorship from Dr. Richard Bradshaw (material analysis and magnetism)
- Mentorship from Mr. Chad Bergeron (sales and fabrication)
- Access to WPI CNC Machine (15 Sagamore rd Worcester MA)

Section V: Ethical Considerations

Safety

The operation of a 2000°F incinerator poses significant thermal risks. We will strictly adhere to safety protocols, including conducting all burns in a cleared 5-foot radius on non-combustible ground. We will utilize infrared thermometers to verify surface temperatures before handling and have Class A fire extinguishers present at all times (Kim et al., 2024).

Environmental Ethics

We acknowledge that burning wood releases CO₂ and particulate matter. However, this project is predicated on a Net Benefit analysis. We are replacing heavy particulate load of diesel engines and the persistent microplastic pollution (TRWP) of tires with the comparatively clearer, short-cycle biogenic combustion of wood. We will report all emission findings transparently, even if they indicate local air quality impacts.

Section VI: Timeline

	September	October	November	December	January
Project Completion Order ↓	Planning each task (Gantt Chart) 5 articles (A Term) Begin product sketches Research Materials 2 Professional Communication	5 articles (A Term) Extensive product research Decide on criteria for success. Reach out to and talk to material analysis expert Reach out to Lab or somewhere else with CNC machine. Build first prototype. Super basic. No spray paint or magnet. Just the barrel with a few grates. Proof of concept. 5 articles (B Term) Design and build prototype 1 in CAD.	Test prototype 1 Make changes to prototype 1 where needed Preliminary data: how heat affects different metals over time Add spray paint, magnet, and any other needed changes for prototype 2 5 articles (B term) CAD prototype 2 3 rd Professional Communication 2 Patents	Preliminary data: model 3 different designs for shape of burn chamber Diagram and chart for poster (communicating preliminary data results) December fair prep. Making poster. Practicing daily and familiarizing with poster. Reach out to construction companies to see how it will fit into their work Begin calculations for net saved pollution	Revise design and CAD based on December fair feedback. Prototype 3 Prototype 3 CAD Testing (real construction sites) Possible Begin Patent for Device
	Due Date Order ↓	Informal Meeting A term	Formal Meeting A term MSEF Proposal Informal Meeting B Term	Grant Proposal Checkpoint 1 Grant Proposal Checkpoint 2 Thanksgiving Assignment MSEF Forms	Grant Proposal Draft #1 Poster Formal Meeting B Term

Section VII: Appendix

Appendix A: Key Definitions

Biogenic Carbon Sinks: Material, such as wood, that has CO₂ trapped inside of it that will be released when it decomposes.

Bottom Up Method: A calculation method for emissions based on specific trip data rather than general averages.

Creep: metal deforming continuously under constant load.

Creep-Rupture Strength: The stress required to cause a material to fracture after a specific long-term period (like 10,000 hours) at a given high temperature.

Crystals of Metal: solid structure where many metal atoms are arranged in a repeating, ordered pattern called a crystal lattice.

Distortion: A mechanical failure occurs due to uneven heating, poor thermal conductivity, and high thermal expansion.

Ferrous Contaminants: small pieces of metal found in wood waste, such as nails, staples, and other metal pieces.

Larson-Miller Parameter (LMP): A metric used to predict the creep-rupture life of metals at high temperatures.

Siloxane Bond (Si-O): The chemical bond in high-temp coatings that resists heat better than Carbon-Carbon bonds.

Thermal Cycle: Repeated heating and cooling to expose a device or material to a range of temperatures while testing for distortion.

TRWP: Tire and Road Wear Particles, a major source of microplastics.

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