Cleaner Cordwood Heating: Preliminary Design

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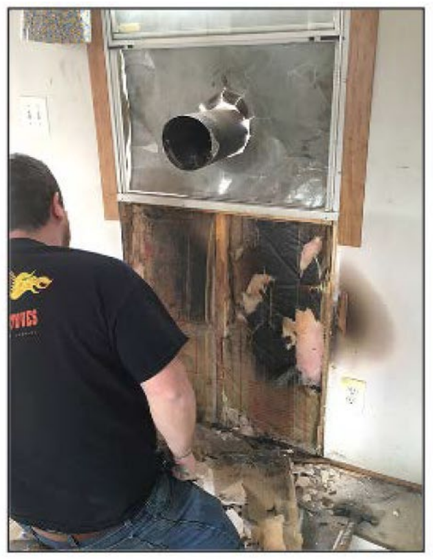
Problem Statement

- Residential wood heating represents the 3rd largest source of primary PM2.5 in the country, and 25% of all area source toxic cancer risks.
- Exposure to these toxics is inversely correlated with income, disproportionately affecting low-income households and especially tribal communities in the north and southwest US.
- Today 12 million wood heaters are in use, and of these 65% (7.8 million) are still older, inefficient devices.
- EPA recommends that old stoves be gradually changed out. However, progress on this front has been limited, with few appropriate and affordable replacement options available.
- Many communities are moving to curtail or eliminate wood burning to meet increasingly stringent air quality guidelines, significantly impacting the households who rely on wood as their primary source of heat.
- This project aims to develop low-cost solutions to help improve efficiency in wood heaters and reduce emissions.
- Biomass is the oldest form of solar energy storage, and projects like this can help to keep clean and renewable wood fuels in the low-carbon energy mix.



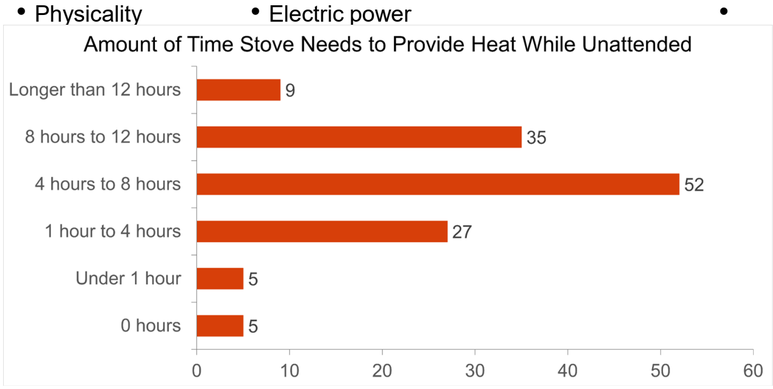
An example potbelly stove installed in a household with improper venting and clearances (left), and the scorching on the wall that resulted (right). The authors noted that the flue was completely clogged with creosote upon removal (Stove Stories, n.d.)

Needs Assessment

Goal: Conduct customer discovery and needs assessment in rural and tribal communities via online surveys, household visits, and stakeholder interviews to understand needs and generate themes to inform design.

Results: Themes identified so far and example survey data collected

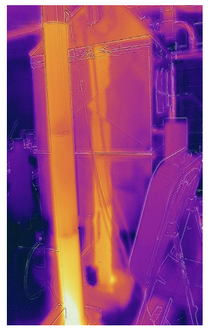
- Comfort heat preference
- Experiential knowledge
- Fuel
- Physicality
- Electric power



Improving Heat Transfer

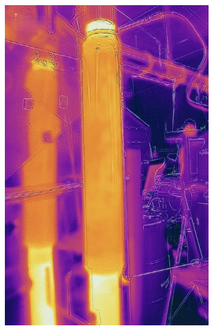
Goal: Compare several retrofit attachment prototypes to utilize heat currently lost from the chimney to increase efficiency

Results: Thermal images of prototypes and comparison of heat transfer performance

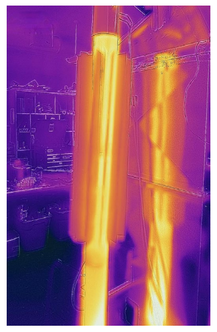


Baseline Chimney

Heat Spreader



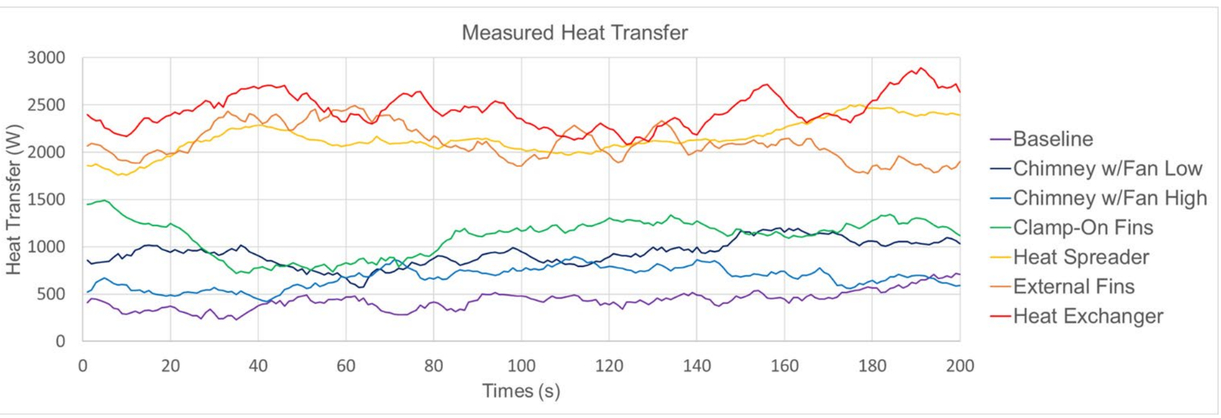
Heat Exchanger



Outside Fins

Clamp-On Fins

	Baseline Chimney	Chimney w/ Fan (Low)	Chimney w/ Fan (High)	Heat Spreader	Heat Exchanger	Exterior Fins	Clamp-On Fins
Heat Output	433 W	932 W	600 W	2147 W	2441 W	2103 W	1105 W



Of the three retrofits the team worked with, the Exterior Fins balanced safety, practicality and efficiency. While the Heat Exchanger was the most efficient, it requires an auxiliary fan or plumbing into the stove body, increasing installation complexity. The Heat Spreader was also efficient, but the complex shape slowed down the exiting flue gas and would be difficult to clean.

Improving Combustion

Goal: Develop a new stove concept specifically for the demanding use case of tribal and rural households that heat exclusively with wood

Requirements:

- Long-duration burn of 8+ hours (see needs assessment above)
- Adjustable heat output
- Still function with power out
- Still function with wet wood
- Efficient heat transfer to room
- Low emissions of PM, CO, and products of incomplete combustion

Approach:

- Insulated firebox to enable long-duration burn with wetter wood
- Fan-driven jets of primary and secondary air to increase mixing and reduce soot and other products of incomplete combustion
- Sensor feedback and automation to modulate fans and maintain optimal combustion conditions as fuel load evolves
- Natural draft air delivery for power-out situations
- Radiant heat exchanger for high-temperature exhaust

Results:

- Prototype complete
- Initial testing in process

Next Steps - Phase 2:

- Test prototype with target users and iterate design based on real-world feedback

Expected Performance:

- Past work with turbulent jets of fan-driven air has resulted in 90% reductions in PM from baseline
- Performance target is emitting less than 1 g/hr PM using cordwood in a representative use pattern.
- Preliminary testing has achieved 2.3 g/hr PM and 1.1 g/min CO average emission rates over a multi-load burn including startup.

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