# Clean Combustion Technology with Efficient and Autonomous Wood Heater Operation over the Full Cycle

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**Project Objectives**:

The objective of this project is to develop a modern non-catalytic wood heater for residential applications utilizing wood chips, cord wood, and wood pellets. Experimental and computational techniques will be utilized to advance the wood heater technology in four areas: (1) novel and innovative designs of combustion chamber geometry, air flow distribution, mixing of combustion air with gasification products, etc., to reduce emissions, (2) thermoelectric generators (TEGs) to produce electricity and manage battery power distribution to operate the wood heater independent of the grid, (3) effective heat extraction methods to increase the average efficiency, and (4) automation to optimize the operation for all phases of the wood burning cycle including start-up, steady-state, over-feeding, overnight burn, and burn out. All electrical and mechanical systems will be integrated to produce the wood heater prototype for testing. The project will use a baseline wood heater that meets the 2020 EPA regulations, and is sold by our industrial collaborator.

**Project Work Description**:

Clean combustion will be achieved by segmenting the combustor into distinct primary and secondary zones and combustion air will be supplied by forced convection as opposed to natural convection in current systems. The combustor design will demonstrate reduction in particulate matter (PM) emissions by 25-50% compared to the EPA 2020 emissions limits. Standalone power will be generated by solid-state TEGs integrated into the wood heater to ensure that a surplus of energy will be available to replenish the energy stored in a battery during the burn cycle. The electrical and thermal subsystems will be developed independently and then the combined system will be integrated with the wood heater. Heat removal by radiation and natural convection will be supplemented on-demand by convection heat transfer using strategically located variable speed fan(s). The final system will demonstrate an increase in efficiency of 5-15% compared to the baseline design. The wood heater will be automated through evaluation of robust sensors, controller hardware/software development, and a smart control algorithm to convert sensor outputs into control signals to vary speeds of combustion and convection airflow fans in real-time. A prototype will be built and undergo extensive dilution tunnel (following EPA Method 5G) testing to optimize and quantify performance over the complete wood burning cycle. The total cost of the wood heater installation is expected to remain within 10% of the total cost of the baseline system. The final prototype will be integrated with Smart Apps and will be ready for field testing.

**Potential Impact**:

The wood heater developed in this project will operate at high efficiency and produce low emissions during all stages of the wood burning cycle. The heat release rate in the wood heater will adjust to the heating load demand of the residence to always attain high efficiency. It will be a direct vent system, the first of a kind in the industry; replacing the flue pipe with a vent pipe will increase efficiency and save costs both for installation and maintenance. Results of the study will be widely disseminated to help the wood heater industry and the technical community at large.

Major participants of the project are The University of Alabama, Unforgettable Fire, LLC (a small US business with existing wood heater products in the market), and Virginia Tech.