

**DOE Bioenergy Technologies Office (BETO)
2021 Project Peer Review**

**Fire MAPS - Secure Performance Monitoring and
User Alerts System**

Date

Technology Area Session

Paul LaPorte
MF Fire, Inc.

Project Overview

Improper operation of wood stoves leads to massive unreported emissions, producing the majority of wood stove air pollution.

- **Goals:** *Develop a hardware/software platform that can eliminate user-contributed emissions across all 12 million wood stoves installed in the U.S.*
- **Main idea:** *(1) Monitor wood stove performance data in real-time. (2) Deliver timely and relevant guidance so users can optimally operate their wood stoves, which (3) Eliminates 50-80% of the user-contributed emissions*
- **Today:** *Wood stoves are approved based on lab-tested emissions, but improper or sub-optimal operation by users increase real-world emissions by up to 600%*
- **Importance:** *PM2.5, the primary harmful byproduct of burning wood is a leading cause of respiratory illness and lung disease. Eliminating user-contributed emissions can have the single largest positive impact for wood heat on air quality.*
- **Risks:** *(1) Predictive modeling and guidance may fall short of expectations when applying to wood stove designs across the entire installed base, due to broad differences in design. (2) User behavior may not change significantly, leading to results less than the target goals.*

1 – Management

- Team centers around a Ph.D. combustion expert, IoT product development expertise and project manager.
- The project is managed using best practices as defined by Project Management Institute.
- Team utilizes weekly formal status meetings as well as daily scrum session to manages progress and key decisions. A separate weekly finance meeting ensures the product adheres to the overall schedule and budget.
- An integrated set of management tools are used to track the project and preserve a record of communication and decisions, such as Slack, Asana, and Google Drive
- The team has successfully worked together on other patented and commercial wood stove technologies for over 6 years.
- Strong collaboration and communication enable the team to keep sight of progress and spot issues early. We utilize a proven, formalized process for product development, which enables the team to work through challenges and test core hypothesis.

2 – Approach

- MF Fire started with a research-based insight that wood stove emissions were only partially reported and that the majority of real-world emissions were generated by users imperfectly operating their stoves.
- We examined what creates variability in emissions at the user level and discovered large sensitivity in emission results from user behavior. Preliminary testing showed the potential to reduce real-world emissions by 50-80%.
- To eliminate user-contributed emissions, MF Fire is developing a hardware/software platform that enables wood stove users get real-time information and guidance that allows them to operate wood stoves in a cleaner way
- Challenges:
 - Create a full test matrix of potential user behavior and measure emissions impact from changing each behavior
 - Create an adaptive algorithm that be automatically map to any stove in operation so that valid guidance can be delivered to users.
 - Create guidance system that motivates people to use the system to make positive changes in operating behavior.
- The team has had success creating a real-time system to monitor and automate wood stove operation, however no retrofit is allowed to existing wood stoves to automate known issues. The transition to providing real-time guidance to the operator and building an inexpensive system to do this is critical
- We are at the first major go/no-go decision – full system test. Success will clear the way for field tests with wood stove owners in their own homes.
- Progress metrics: confirm data is accurately monitored and communicated throughout the system, culminating is accurate guidance delivered to the user in real-time. 10 field test units have been built in preparation for home deployment.

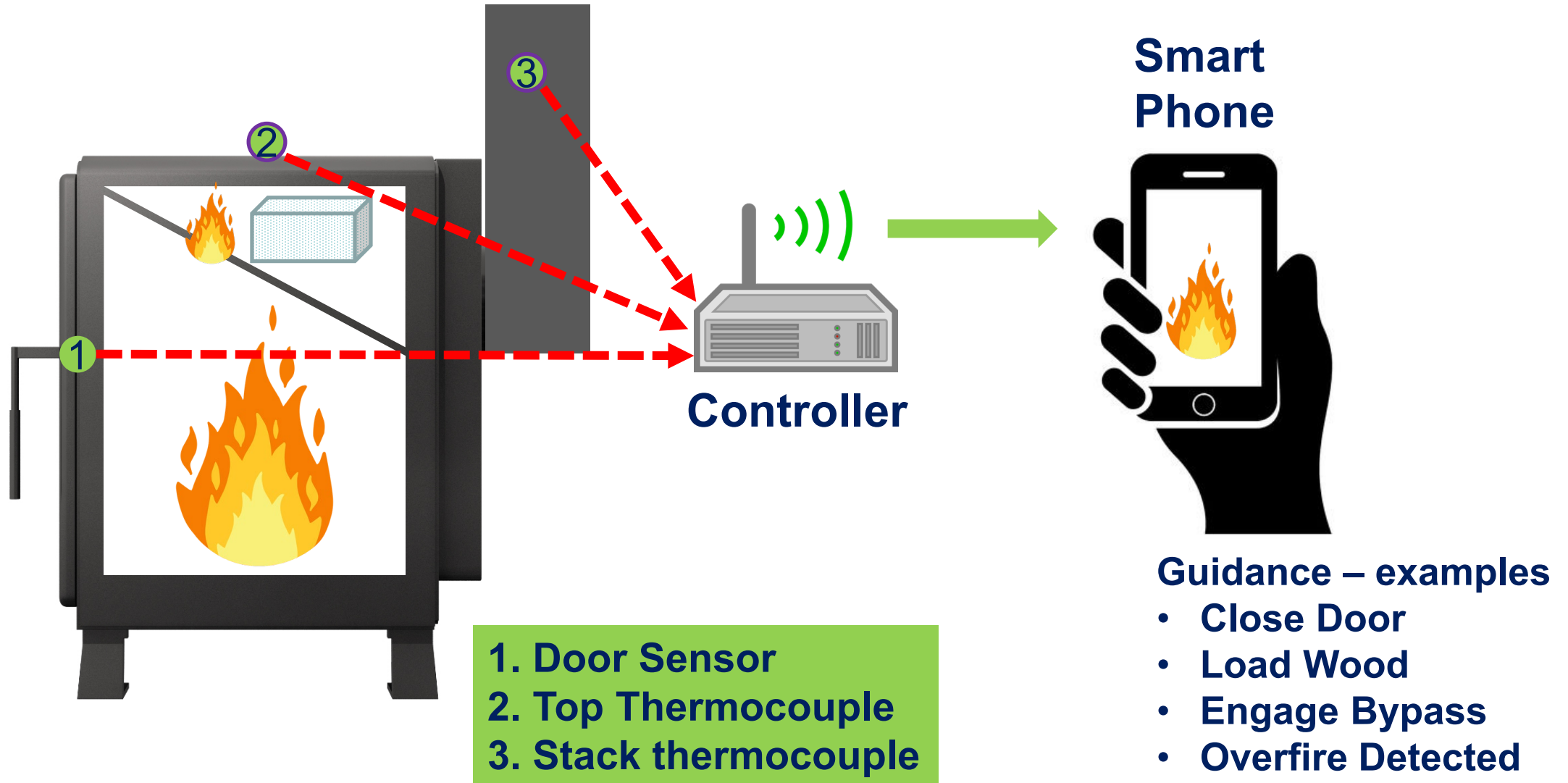
3 – Impact

- Big pressures from all parts of society and government to make wood heat cleaner.
- Fire MAPS has the potential to dramatically reduce real-world emissions across all 12 million stoves in the US and 100 million stoves worldwide while delivering sub year ROI for users
- Once results are known, we will publish peer-reviewed articles in the academic and scientific communities while promoting the innovation through popular news outlets. We will actively seek large support from domestic and international governments to accelerate wide deployment.
- A typical wood stove is owned for 20 years or more. This innovation has the chance to make a generational change without the need to wait 20 years to percolate through users.

4 – Progress and Outcomes

- We have completed the major system development required for alpha field tests, the next critical milestone
 - IoT device that uses sensors attached to the wood stove to monitor and communicate with a cloud service that processes the data, determines the fire's state, and delivers real-time guidance and alerts to a user's phone
 - User app created and ready for alpha test deployment
 - Preliminary tests of user behavior and impact to emissions completed (drives alerts)
 - Cloud user burn database live
 - 10 test units built and ready for deployment in consumers' homes
 - Extensive live burn use and testing over the last 30 days
- Learned:
 - Which user behaviors to focus on improving to generate most impactful results
 - To provide accurate predictive modeling – the key to deliver timely guidance
- What we don't know yet
 - Can we deliver proper guidance across a broad enough range of stoves
 - Can we change user behavior

Fire MAPS Physical System

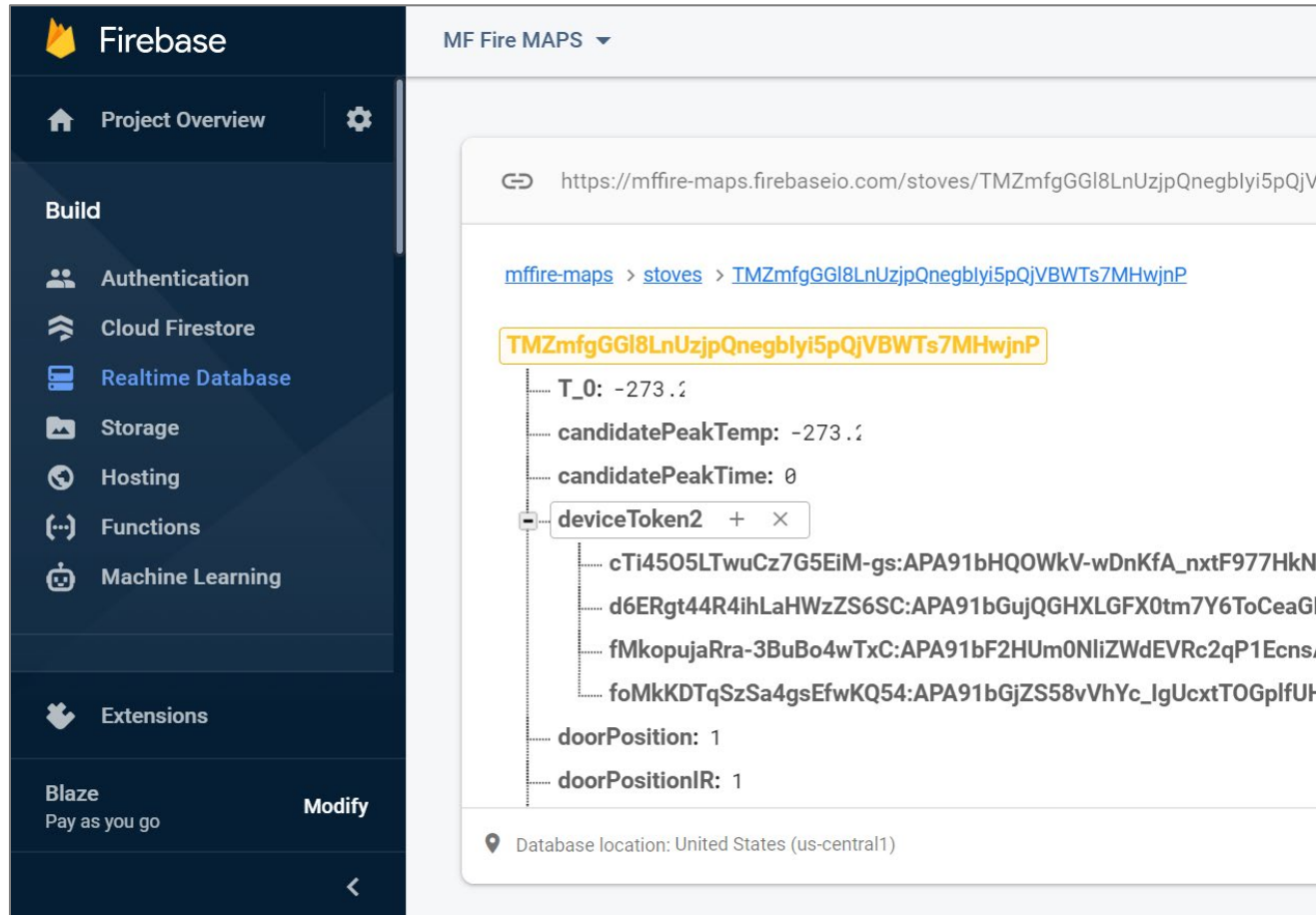


Fire MAPS Hardware

- Sensors
 - Door sensor (mechanical, IR)
 - Thermocouples (2)
- Hardware
 - Printed circuit board
 - Sensor modules
 - Case



Cloud Database

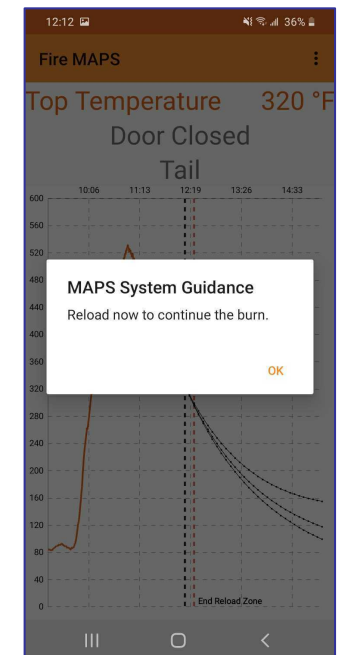
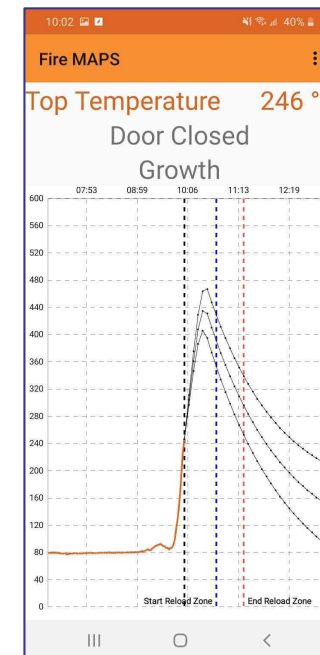
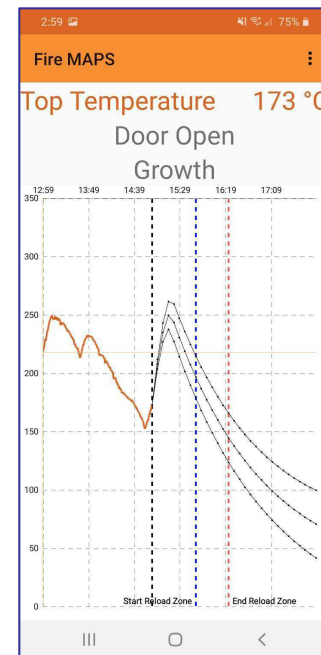
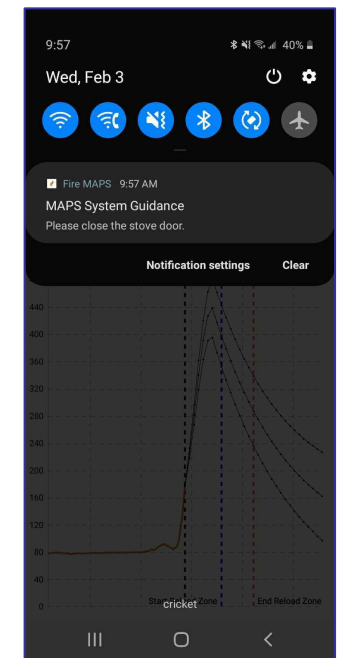
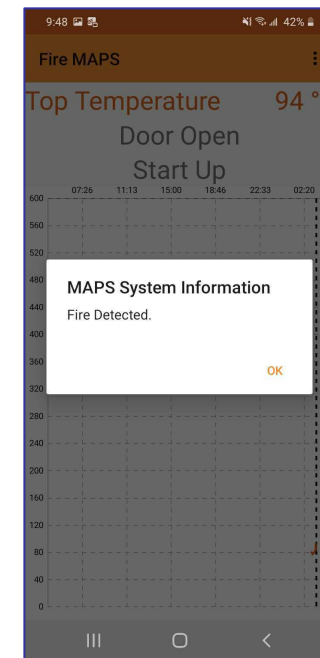
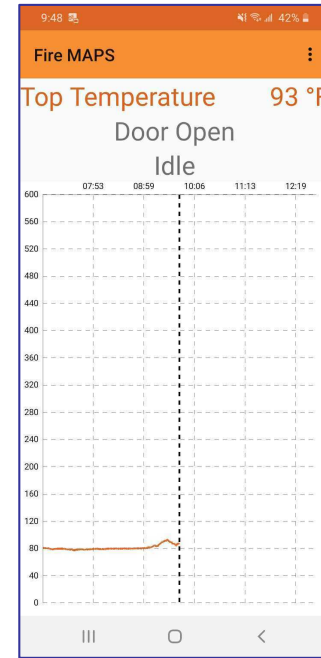


The screenshot displays the Firebase console interface. On the left is a dark sidebar with the 'Build' section expanded, showing options like Authentication, Cloud Firestore, Realtime Database (highlighted), Storage, Hosting, Functions, and Machine Learning. The main content area shows the 'MF Fire MAPS' project with a URL: `https://mffire-maps.firebaseio.com/stoves/TMZmfgGGI8LnUzjpQnegblyi5pQjV`. Below the URL, a breadcrumb path reads `mffire-maps > stoves > TMZmfgGGI8LnUzjpQnegblyi5pQjVBWTS7MHwjnP`. The selected node is `TMZmfgGGI8LnUzjpQnegblyi5pQjVBWTS7MHwjnP`, which contains a JSON object with the following data: `T_0: -273.12`, `candidatePeakTemp: -273.12`, `candidatePeakTime: 0`, `deviceToken2` (expanded to show four long alphanumeric strings), `doorPosition: 1`, and `doorPositionIR: 1`. At the bottom, it indicates the database location is 'United States (us-central1)'.

- Captures and continuously logs data from the sensors
- Performs a backend analysis of the data
- Communicates to users registered to a particular stove.

Phone App

- Built w/ working communication to smart controller and database
- Receives and displays data from the smart controller
- Provides automatic and manual user notifications



Summary

- Wood stove users contribute up to 600% of a wood stove's lab-tested emissions rating
- Most of the user created emissions is attributable to improper or sub-optimal stove operation
 - Lack of real-time data about the fire or fuel, i.e. -
 - Is fire well established enough to close the door
 - Is the stove hot enough to engage the bypass
 - Why is the wood not burning this time (wood is too wet)
 - Lack of understanding of how to properly operate a given wood stove for best performance, i.e. -
 - When is the best time to reload
 - Does it matter when I engage the bypass
 - Putting stove in low burn mode at the wrong time
- Fire MAPS is solution to educate and train wood stove users to lower emissions and get more efficiency from their stoves

Quad Chart Overview

Timeline

- Oct 1, 2019
- Anticipated September 2022

	FY20 Costed	Total Award
DOE Funding	\$406,167	\$989,644
Project Cost Share	\$106,550	\$255,500

Project Partners

- N/A

Project Goals

Create a system that:

1. Reduce/eliminate user-contributed emissions
2. Monitors wood stove use and performance data in real-time.
3. Delivers timely and relevant guidance to users so that they can optimally operate their wood stoves.
4. Changes wood stove user behavior
5. Creates first ever industry and government burn database.

End of Project Milestones

1. Validated system that monitors and provides real-time guidance to users as conditions change throughout the fire.
2. A test matrix that captures and reports on the real-world, user-contributed emissions.
3. A commercially viable product that is ready for affordable mass adoption.
4. A national burn database for research and policy decisions.

Funding Mechanism

DE-FOA-0002029
FY19 BIOENERGY TECHNOLOGIES OFFICE MULTI-TOPIC,
AOI 3: Efficient Wood Heaters