Heart of the Hearth: Making the Popular Clean, not the Clean Popular

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

DOE BETO Cookstoves Program Review

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Goal Statement

- Apply BioLite's fan-assisted combustion technology to a clean burning and reliable "combustion core" that can be generally incorporated into the most popular stove types

- Supports the DOE Bioenergy goals towards reducing pollutant emissions from biomass cooking by 90% and fuel usage by 50%

Timeline

- Project Start: June 2013
- Project End: December 2015
- 60% Complete

Budget

	FY 13 Costs	FY 14 Costs	Total Planned Funding (FY 15-Project End Date
DOE Funded	$ 37k	$ 405k	$ 441k
Project Cost Share (Comp.)	$ 3k	$ 46k	$ 51k

Barrier

Highest performing cleanest biomass cookstove configurations are often not consistent with traditional cooking and fuel preparation practices

- *Can we apply a simple and robust approach to air-assisted combustion that maintains traditional cooking for widespread adoption?*

Partners

- University of California Berkeley
- Groupo Interdisciplenario de Tecnolagica Rural Apropiado (GIRA)
- National Autonomous University of Mexico (UNAM)

Project Overview

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- Historically, the cleanest biomass stove configurations have been top-lit gasifier stoves that require a high level of fuel preparation and are not compatible with traditional tending and cooking practices
- The project objectives are to:
  - Identify critical fluid-dynamic and heat transfer mechanisms that lead to high combustion and thermal efficiencies
  - Design non-invasive hardware to replicate these conditions inside any general stove architecture
  - Minimize impact to traditional user behaviors and fuel preparation
  - Demonstrate user acceptance and improved stove performance under real-world usage conditions

Technical Approach

1 Investigation of fundamental performance and efficiency factors

Modular stove testing platform

2 Application to specific stove phenotypes

3 User demonstrations and feedback for refinement

Metric	Current	Benchmark
Fuel Usage (Thermal efficiency)	30 to 42%	> 30%
Particulate Emissions (PM_2.5 per mega joule)	50% reduction from Patsari	70% reduction
Unit Cost	Approx $20	$15 USD

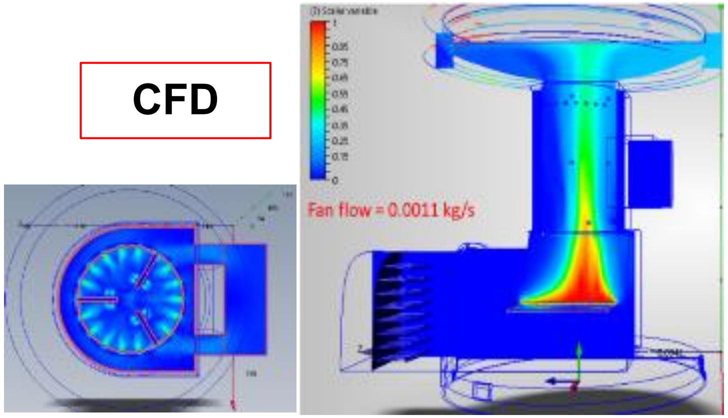
Main Technical Challenge: Producing concentrated high temperature for clean combustion while providing uniformly distributed heat for cooking

(Temp Uniformity Metric)

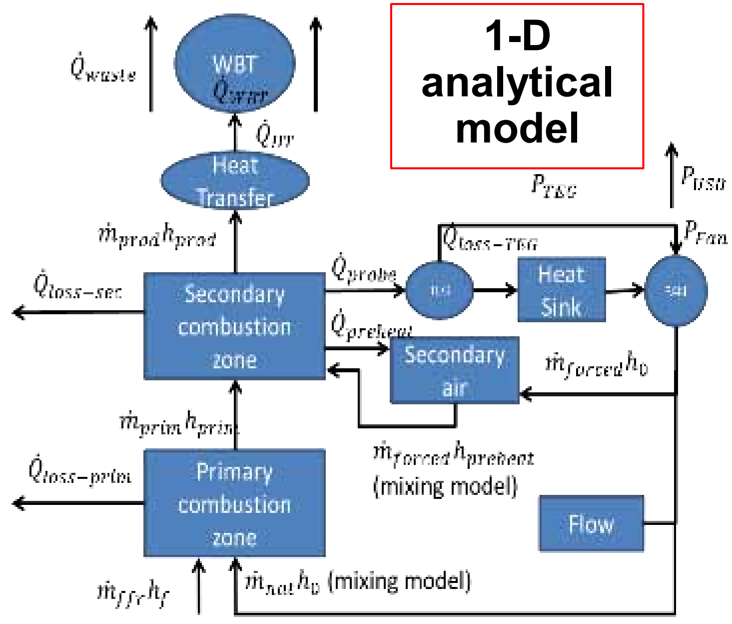
Technical Approach - Tools

Combination of analysis and empirical lab testing to establish feasibility and performance limits – then validate hypotheses

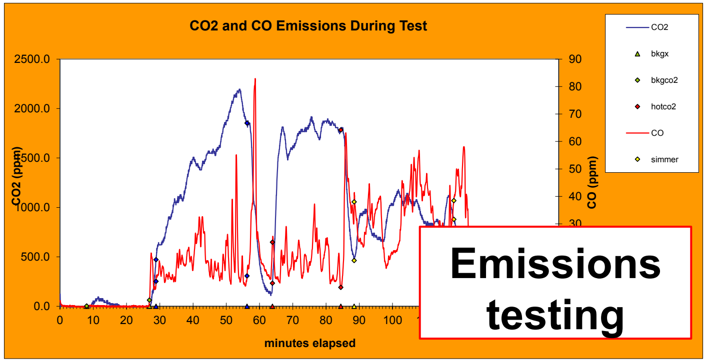
CFD



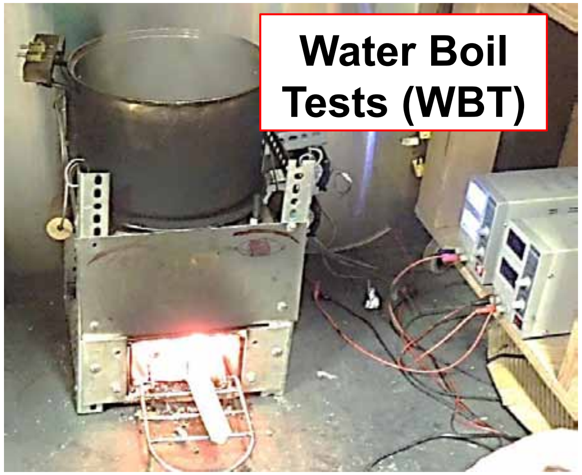
1-D analytical model



Emissions testing



Water Boil Tests (WBT)



Management Approach

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Approach Structure

- Performance-based approach with increasingly more strict phase gates between project phases (Consistent use of DOE PMP tool)
- Performance-based approach with increasingly more strict phase gates between project phases
- Clearly defined sub-contractor roles and scope
- Building commercial viability on top of existing successful stove projects

Success Factors

- Fuel usage and particulate emissions benchmarks
- Temperature uniformity (User acceptability) benchmark
- Cost target benchmark

Potential Challenges

- Emissions reductions targets may not be possible without more intrusive changes to stove design and user behavior
- Benefits of clean cooking and lower emissions may not provide enough customer value to motivate purchase

Progress Summary

Fundamental Parameter Investigation

- CFD analysis to bound limits and inform empirical design space
- Parametric testing with modular stove platform

1st Gen Prototype

- Interim efficiency and emissions targets achieved
- **Milestone #1: Proof of concept** — Nov 2013

2nd Gen Prototype

- Lower cost design and improved temperature uniformity

3rd Gen Prototype — March 2014

- Further simplification and cost reduction
- **Milestone #2: User acceptability achieved**
- **Milestone #3: Cost of goods target achieved** — Feb 2013

In-Home Trials

- Maximize emissions performance within cost / acceptability bounds
- **Milestone #4: Independent 3rd party evaluation of pollutant & IAP reduction**
- **Milestone #5: Evaluate Project for Results and Commercial Suitability**

Detailed Technical Progress

Fundamental Parameter Investigations

- Thermal efficiency parameter sensitivity
- Air injection interaction with natural draft
- Char oxidation parameter sensitivity

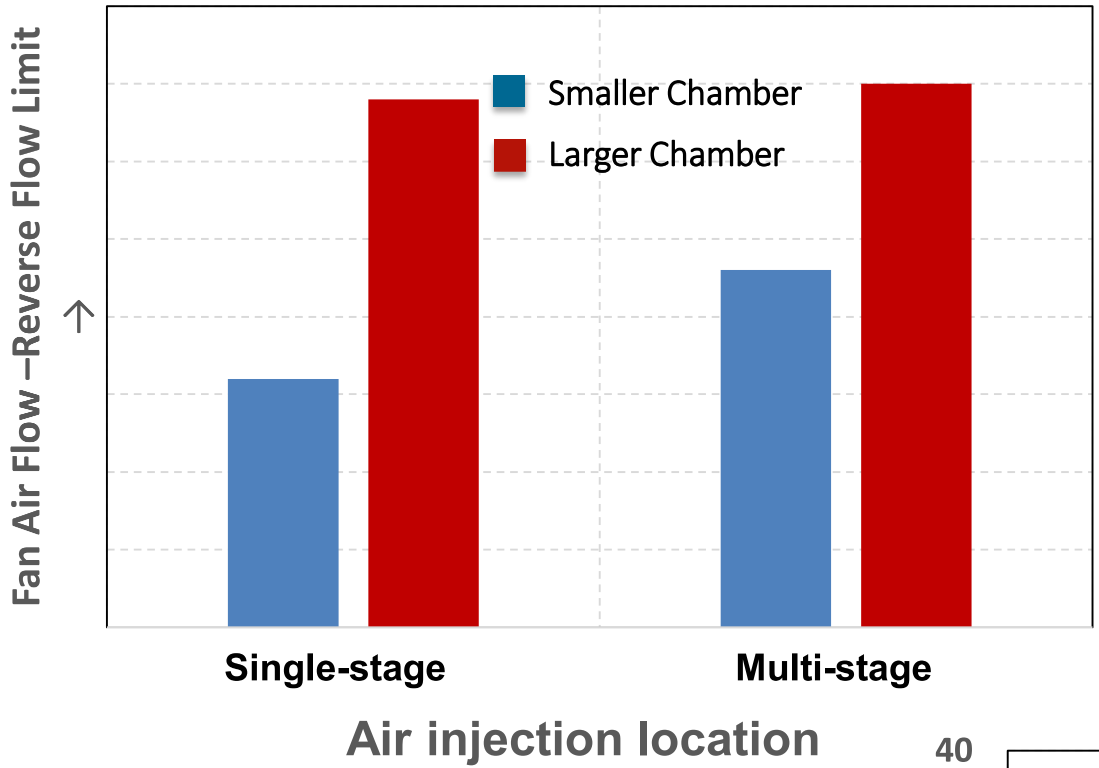
Application to Patsari plancha stove and user feedback

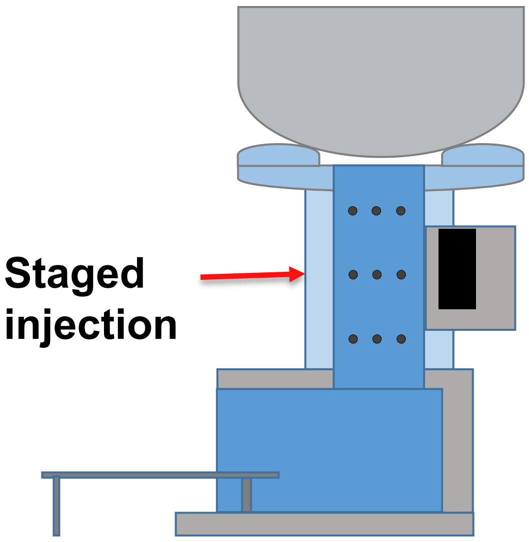
- Temperature uniformity optimization
- Automated activation and fan control
- Reduced noise level

2nd and 3rd Gen Prototypes

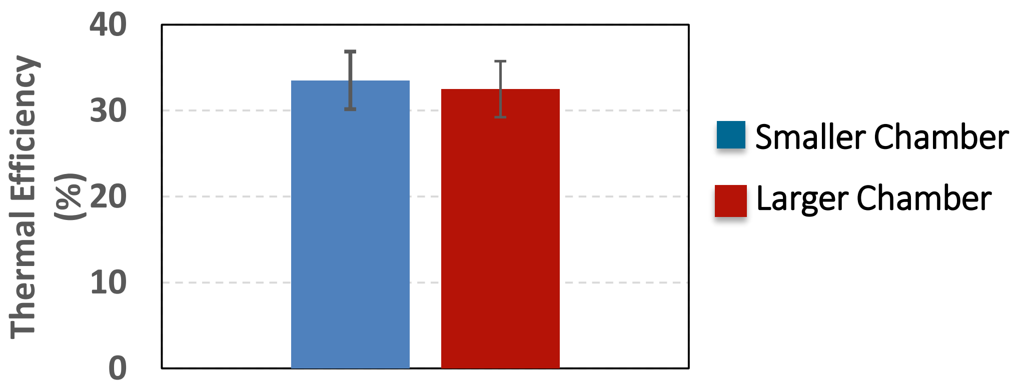
- Achievement of temperature uniformity and cost benchmarks
- Application of fundamental performance parameters to maximize emissions reductions
- Opportunity for further improvement with double-height chimneys

Chamber size, air injection, and reverse flow

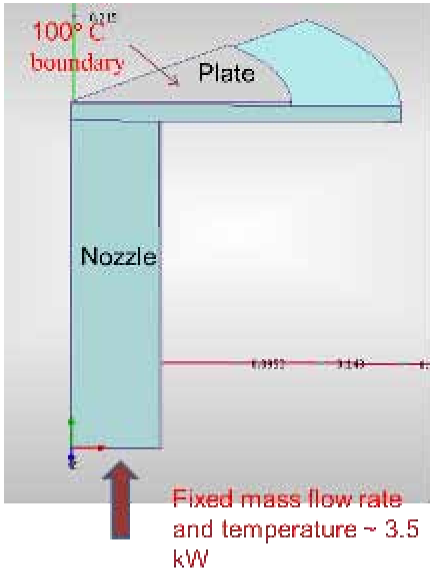


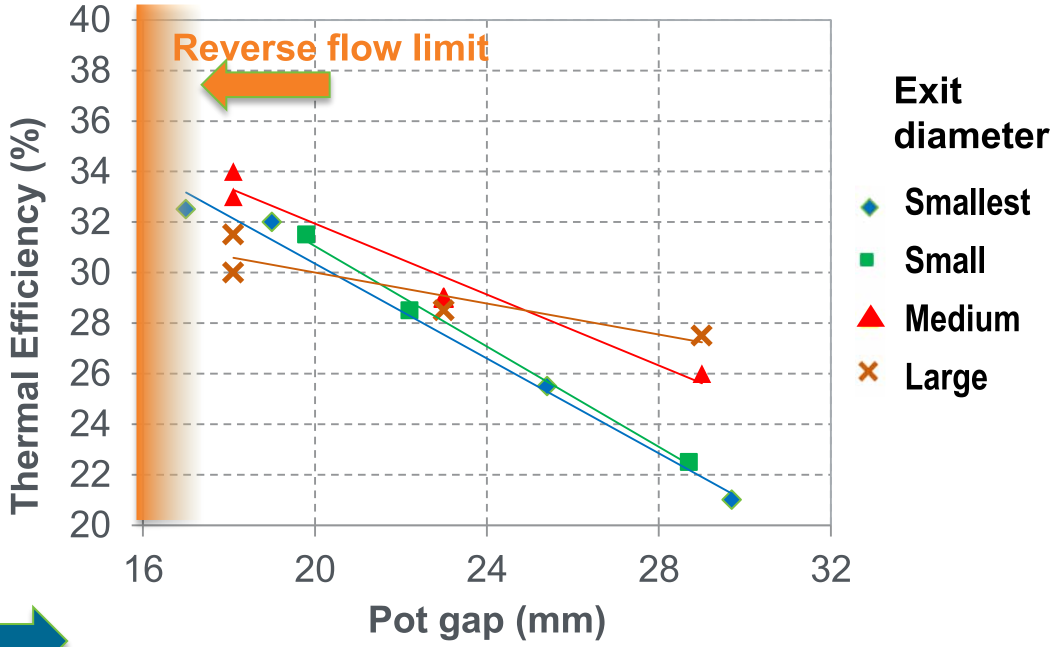


Staged air injection and larger chamber size allow higher fan flow rates before the onset of reverse flow

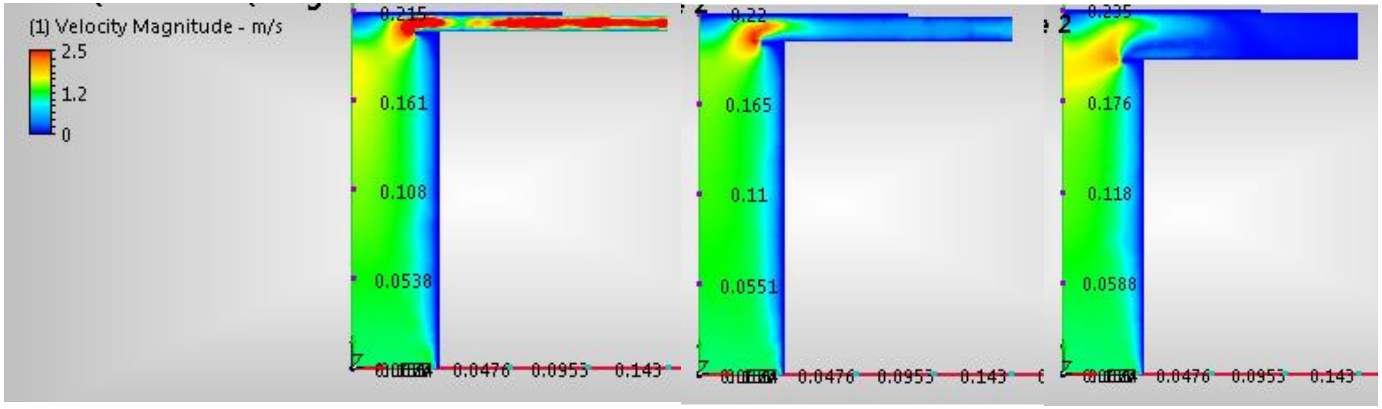


Thermal efficiency and pot gap

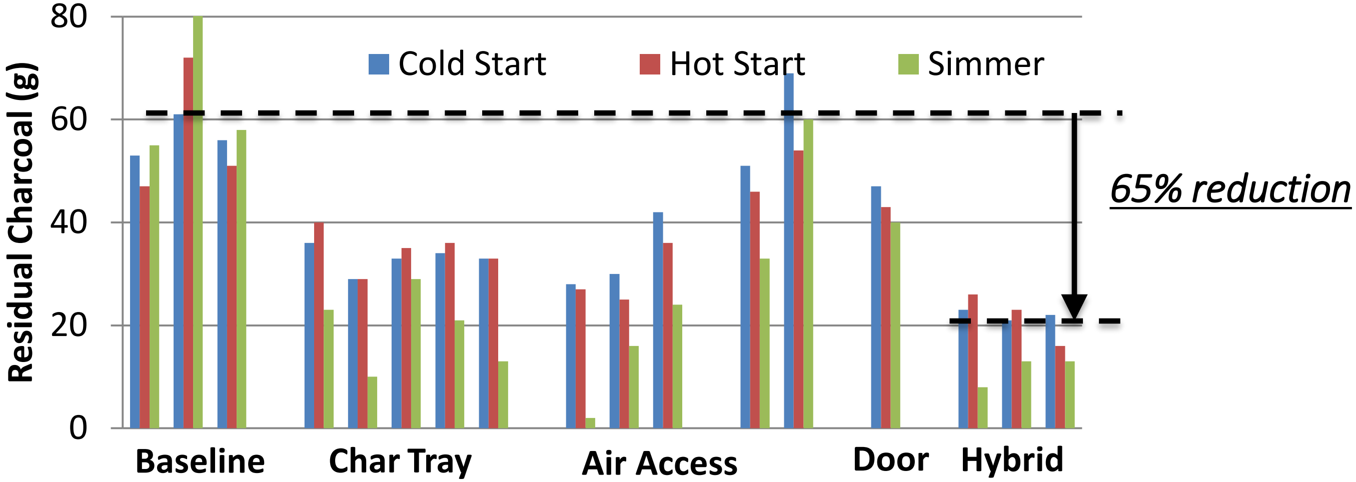




Increasing pot gap → lower scrubbing velocities → lower heat transfer rates

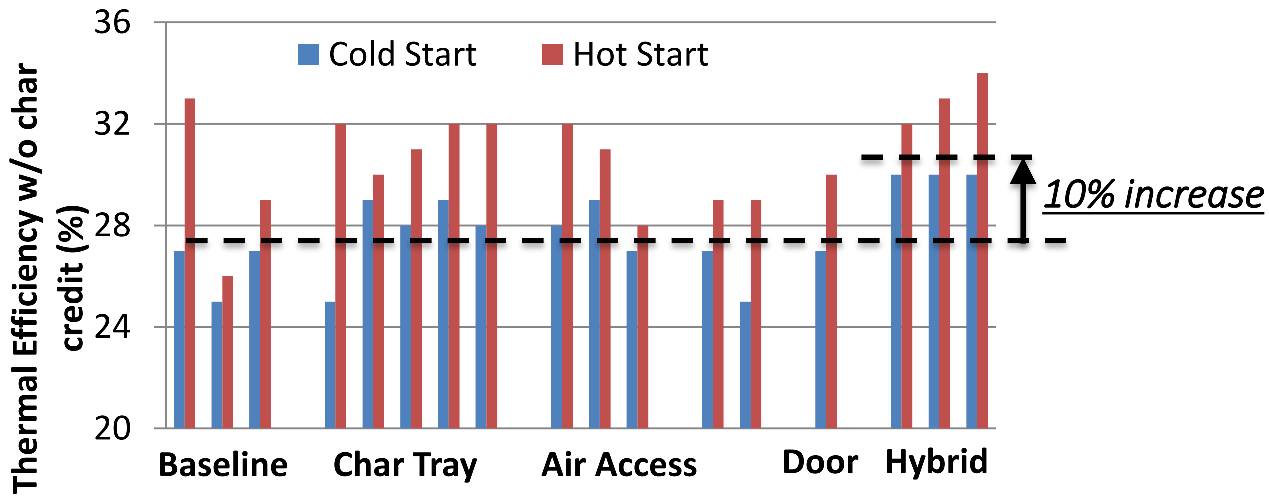


Char Reduction Approach



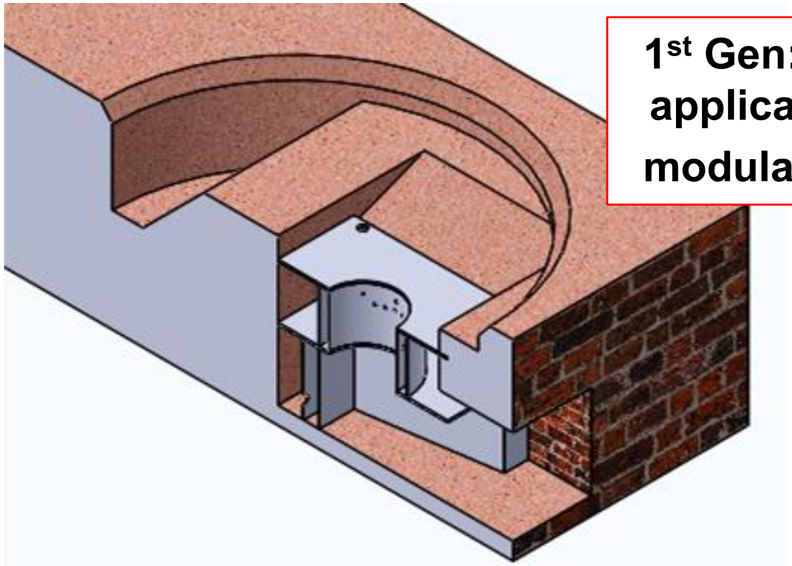
Candidate charcoal tray

Charcoal tray installed in combustion chamber

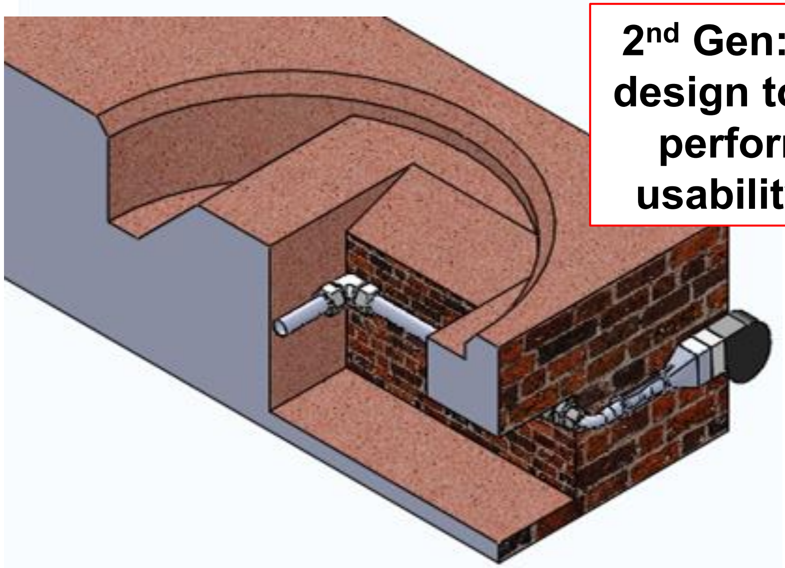


Application to Patsari Stove

- **Application considerations:**
  - Plancha stove architecture is very different from rocket elbows like HomeStove
  - Different cooking style
  - Tasked with improving already improved stove
  - High electrification rates in Mexico make thermoelectric unattractive
  - In-built fixed stove



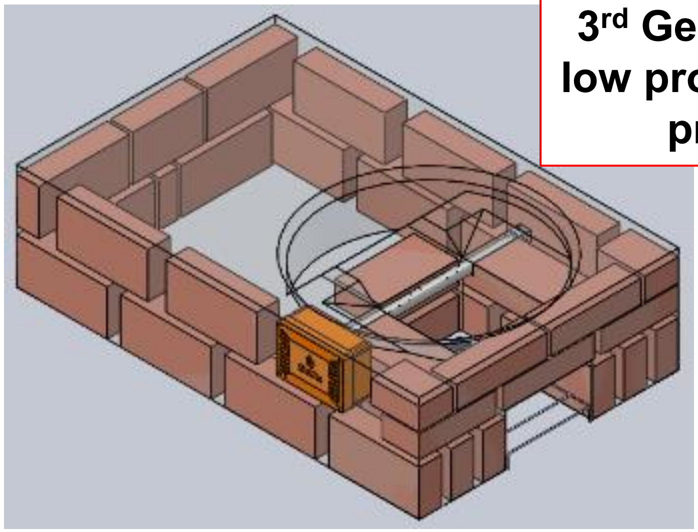
1st Gen: Direct application of modular stove



2nd Gen: Tailored design to balance performance, usability & cost

Low cost simplified design

- **Challenges:**
  - Trade-off between comal temperature uniformity and clean combustion
  - Patsari already reduces indoor emissions. This injection technology cuts outdoor emissions by a significant amount in addition to further reducing indoor concentrations
  - Cost and affordability
  - Audible impact of fan on cooks



3rd Gen: Improved, low profile, low cost prototype

Lab and Kitchen Performance Testing

Controlled Cooking Tests (CCTs)

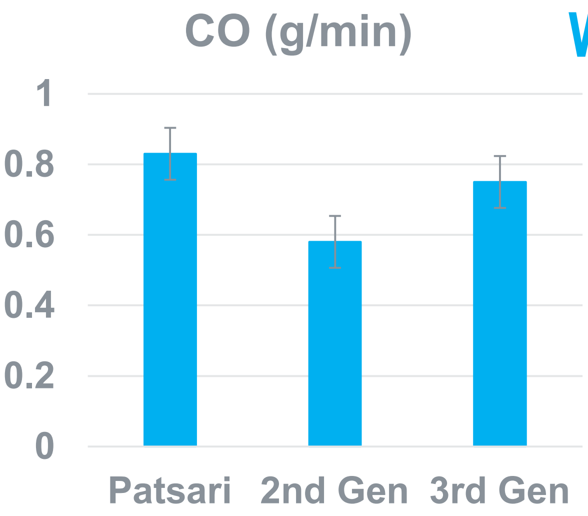
Comal Olla

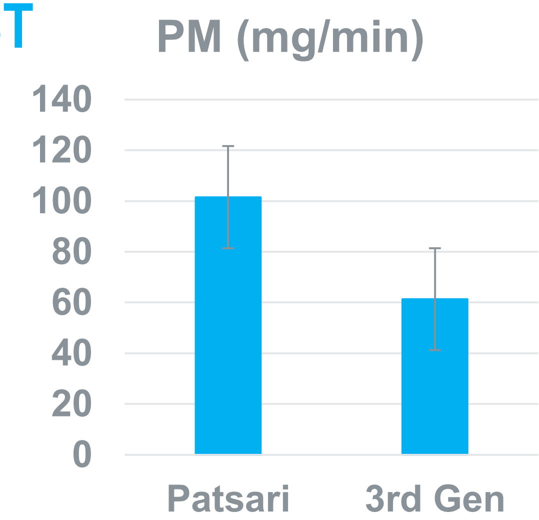
Comal Plancha

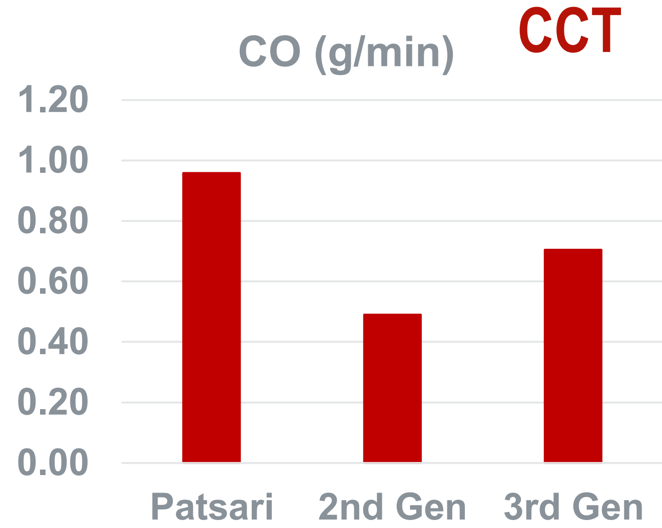
Water Boil Tests (WBTs)

Temperature Profile Tests (TPTs)

Lab and Kitchen Performance Testing - Results

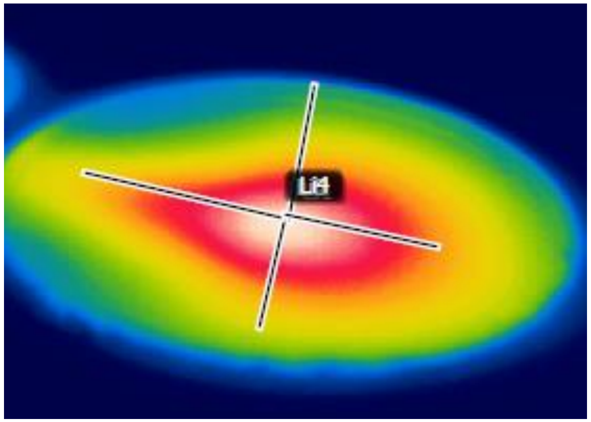




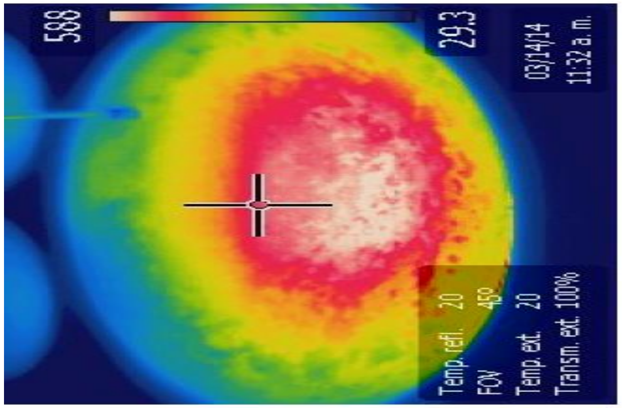


At current PM_2.5 emission rates, tier 3 can be achieved w/ 20% flow leakage

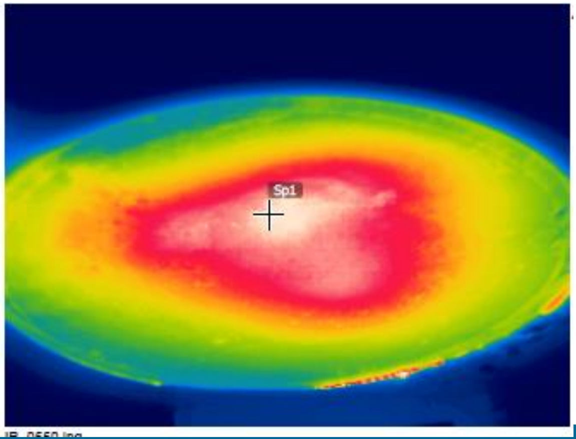
Patsari



TPT 2nd Gen



TPT 3rd Gen



Relevance

- Project approach is user focused
- Provides community insight into how high performance conditions established in the lab can be applied to traditional stove archetypes without having to change fuels or cooking behaviors
- Design for manufacture (DFM) has been employed to minimize cost of production and reduce cost barrier to adoption
- Project will employ an independent emissions monitoring assessment to determine the level of "real-world" improvement achieved in the user-focused framework

Future Work

- March – May
  - Optimize and redesign prototypes for in-home testing – BioLite, GIRA and UNAM
  - Achieve minimum 50-70% PM_2.5 reduction vs. Patsari – Go/No-Go
- May - June
  - Release BioLite turbo attachment design for fabrication (8-10 units) – BioLite
  - User training for Emissions equipment and CCTs – UC-Berkeley
  - Select 8-10 homes for testing; build/modify Patsaris and install BioLite turbo attachment – GIRA
- June - July
  - Conduct in-home trials – UC-B & GIRA
- Aug – Dec
  - Analyze data and prepare final report – UC-B, GIRA, UNAM, BioLite
  - Evaluate commercialization opportunity – Go/No-Go

Summary

- Overview:
  - Project is beyond 50% completion with key milestones met and remaining milestone objectives within reach
- Approach:
  - Milestone management plan is guided by PMP
  - Unique technical approach is to establish key performance parameters, meet user acceptability and affordability targets, then apply performance parameters to maximize emissions performance within those bounds
- Technical Accomplishments:
  - Excellent temperature uniformity (user acceptability) and low cost achieved while reducing PM_2.5 emissions to tier 2-3 levels
- Relevance:
  - Providing a uniquely user-focused project to demonstrate how large emissions reductions are possible within adoptability and cost limitations
- Future Work:
  - 10 Home trial with production-like prototype with independently evaluate emissions reduction of accepted stove configuration