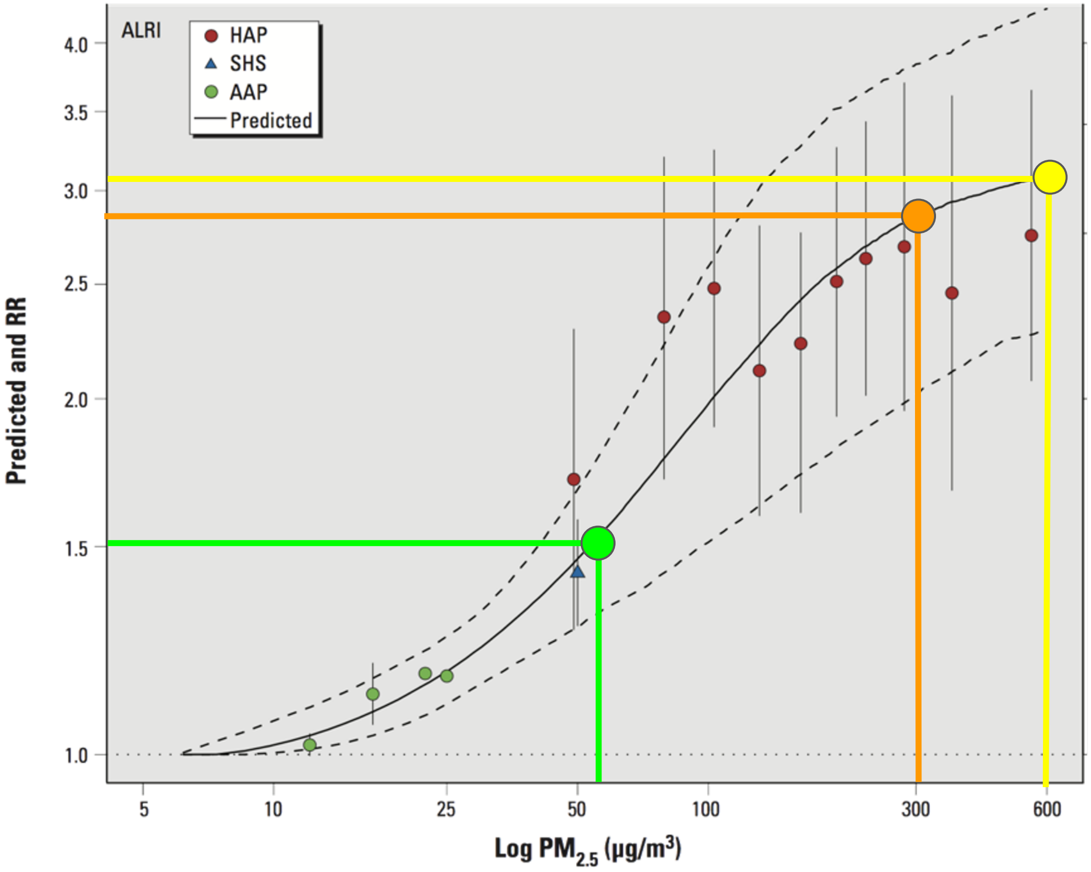
Forced Draft Panel

ETHOS 2020

Intro

Relative Risk of Acute Lower Respiratory Infection in Infants, Burnett et al., (2014)

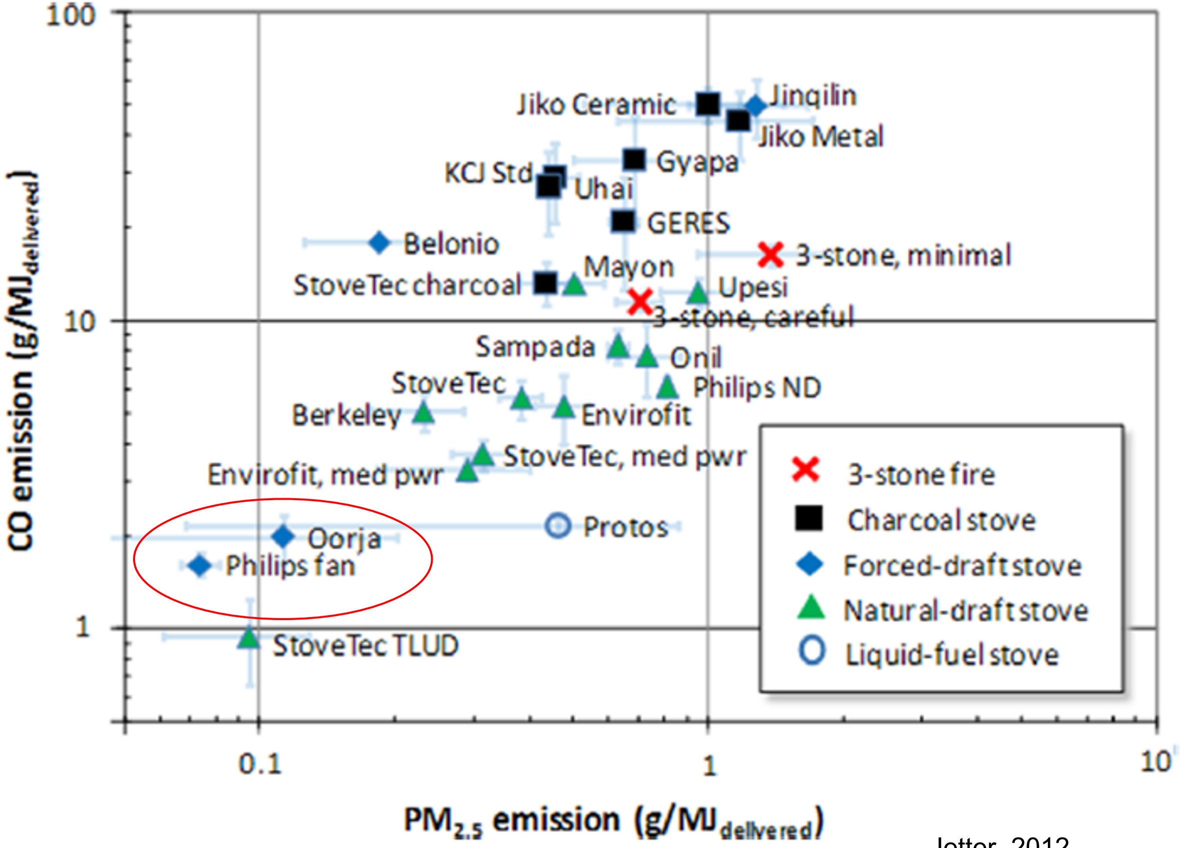


- We start with a stove that results in a 600 ug/m3 HAP.
  - An infant has 3.1x higher likelihood of getting ALRI.
- We introduce a successful intervention that cuts HAP in half to 300 ug/m3.
  - An infant still has 2.9x higher likelihood of getting ALRI.
- What are really need are *very* clean stoves with >90% PM2.5 reductions.

Why is Forced Draft Important?

Forced draft can

- Improve both heat transfer and combustion efficiency significantly
  - Mixing
  - Velocity
- Approach WHO standards, LPG/gas performance
- Improve usability
  - Improves turn-down
  - Burns wet wood better
  - FIre starts more easily
  - Reduces char accumulation



Jetter, 2012

Current Status of Forced Draft Implementation

- Fairly limited development to date
- Few models
- Fewer scaled projects
- Can be designed for pelletized fuels or side feed
- Requires electricity

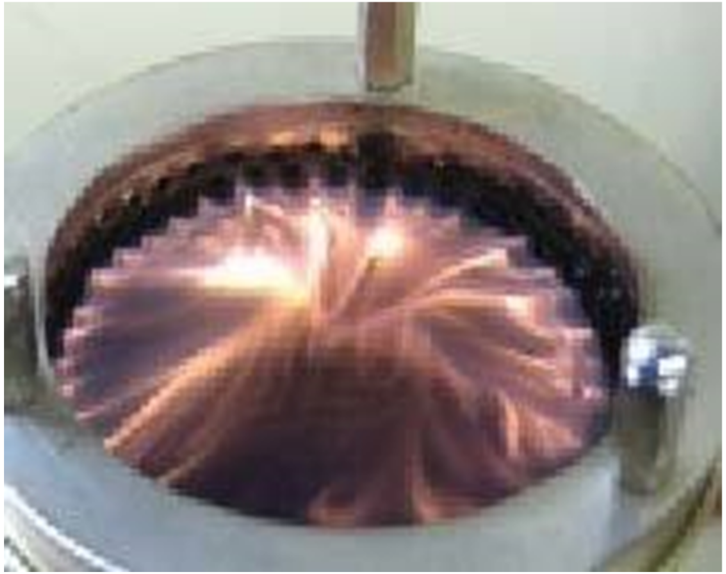
Presenters

Dean Still

Aprovecho
Research Center

1.) TLUDS and Rockets share characteristics

"Molecular" Mixing Results in Cleaner Combustion



1.) TLUDS and Rockets share characteristics

Jet-Flame Rocket w/skirt Mimi-Moto

2 Big Sticks: High-Power Hot Start			
	.5 inch	.75 inch	1 inch
Firepower - kW	3.1	3.4	4.0
Efficiency - %	59%	58%	58%
Time to boil - min	15.7	15.8	14.2
Total PM - mg	86	60	100
PM - mg/MJ	22	15	21
PM - mg/min	2.5	1.7	2.9
CO - g/MJ	0.8	0.7	0.7

High Power Thermal Efficiency 45%

High Power PM mg/MJ 16
Indoor PM Emissions mg/min 2.43
High Power CO g/MJ 0.22

2.) Use a Pot Skirt

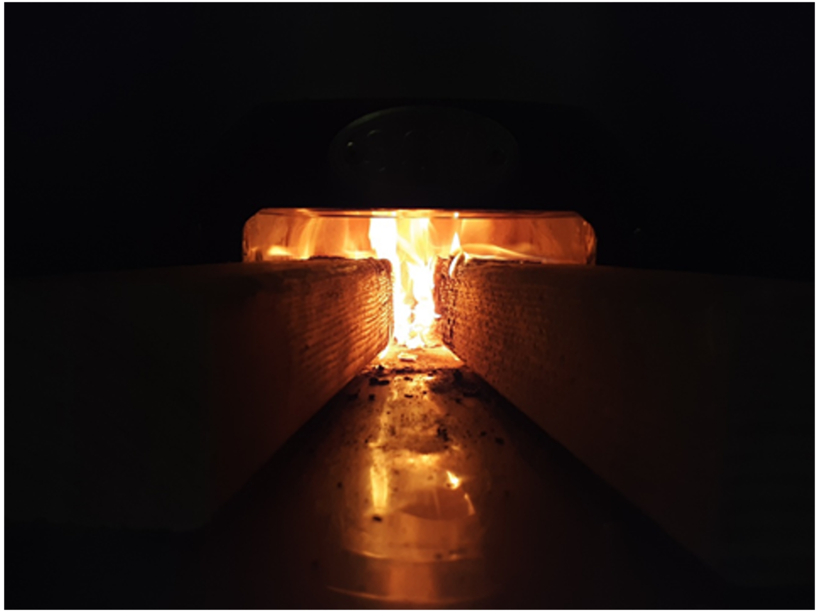
A.) High Velocity
B.) High Temperatures
C.) 6mm Channel Gap

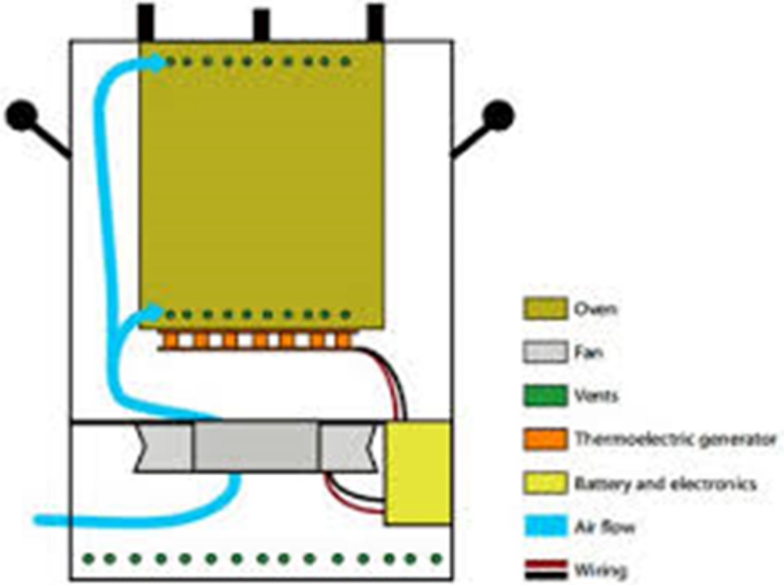
Over 50% Thermal Efficiency!

3.) High T + “Molecular” Mixing

= Clean Combustion Without Much Residence Time

4.) Rocket = Mixing Jets Into Fire
TLUD = Mixing Jets Over Fire

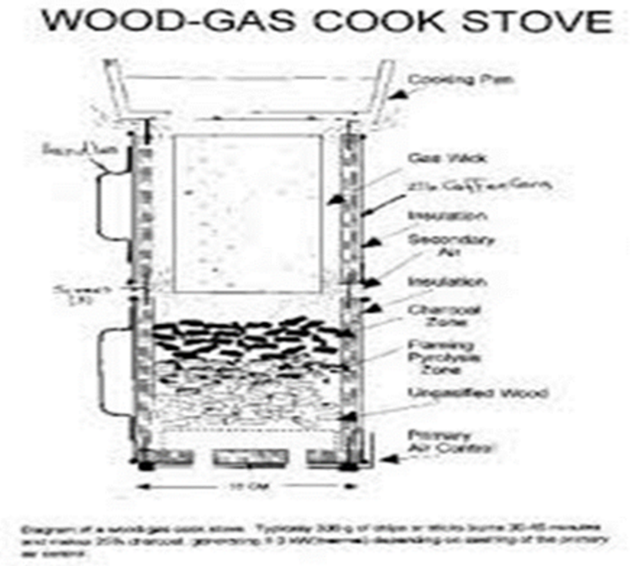




5.) Rocket and TLUD: Meter Fuel or Make Smoke!

Rocket: Burns tips of sticks (8cm)

TLUD: Limit Primary Air



Paul Means

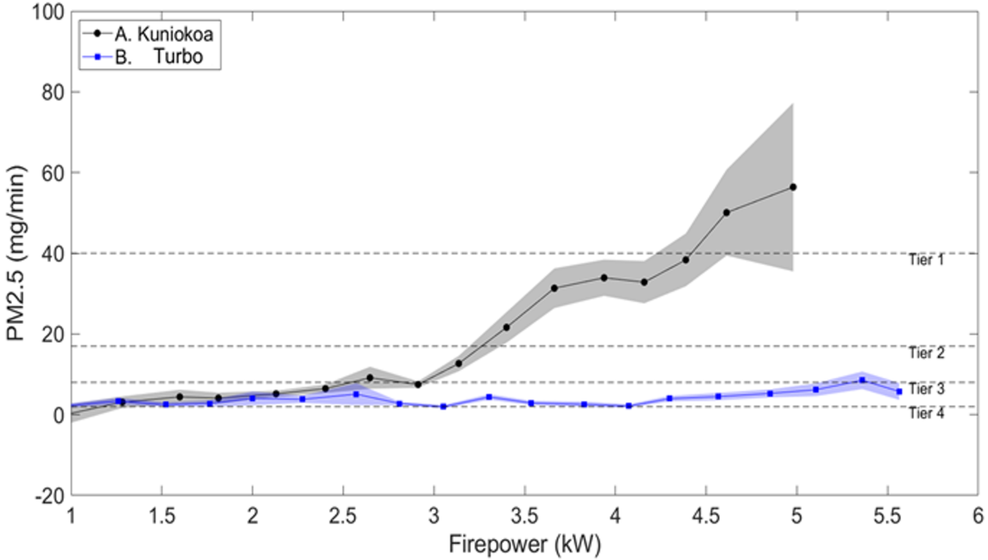
burn
DESIGN LAB

In search of the Holy Grail….“Tier 4” with a stick fed rocket stove

- Design / Modeling / Testing / Design
- User research & home placement
- Refinement (or more DM&T)
- More UR&HP
- Further refinement (DM&T)
- Pilot – 140 stoves.

In Search of the Holy Grail...

Design / Modeling / Testing / Design / Modeling / Testing...



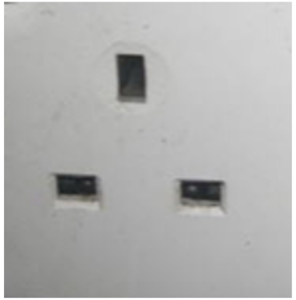
KunioKoa-Turbo

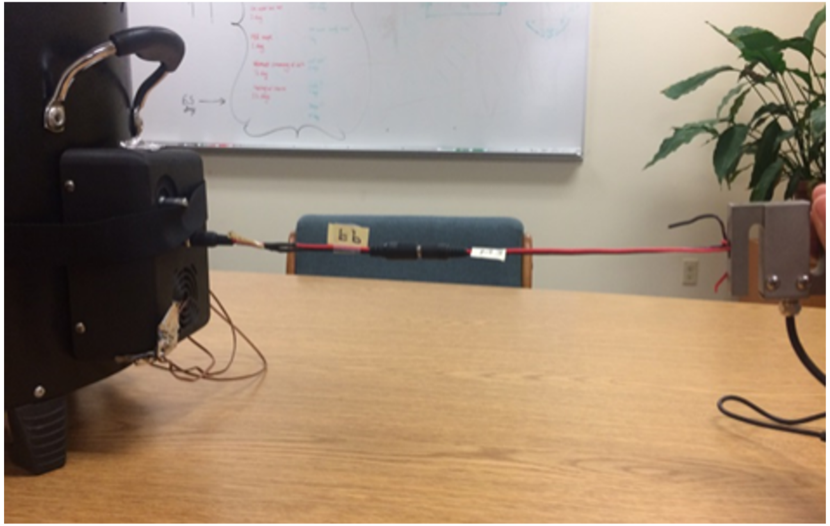
In search of the Holy Grail….

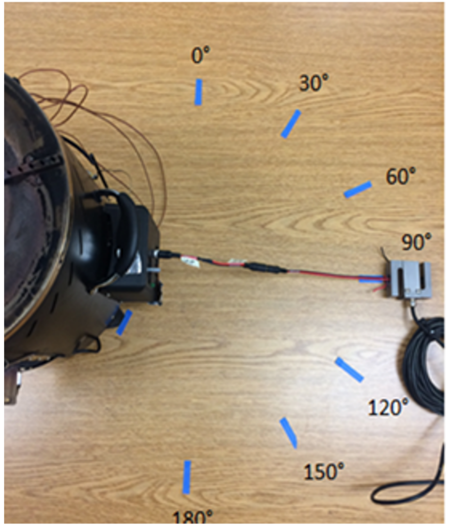
- User Research & Home Placement
  - Focus Groups
    - Side by side comparisons
    - Typical meal preparation
    - Wet & dry wood
  - Home Placements
    - Solar & grid power
    - 3 + weeks
    - SUMS
    - Interviews

In search of the Holy Grail….

- Power
- Chords

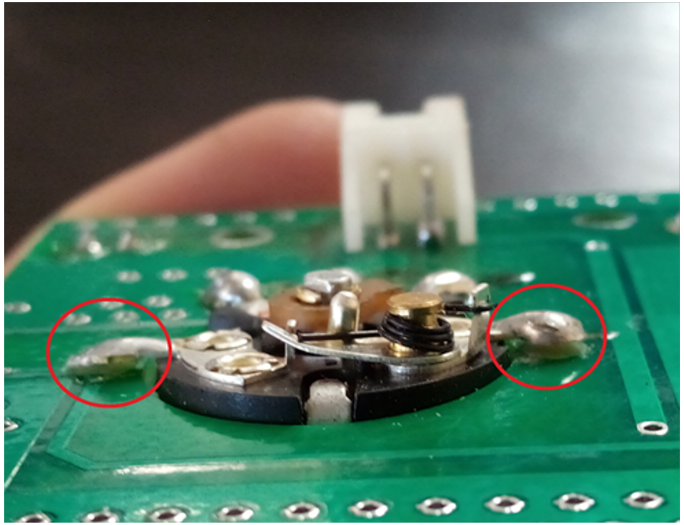


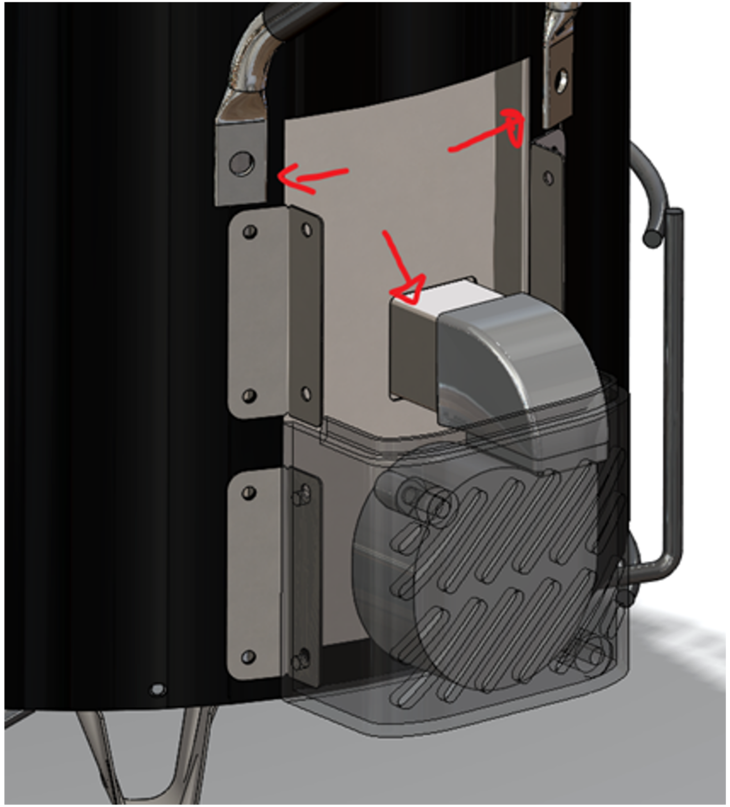




In search of the Holy Grail….

- PCB’s
- Fans

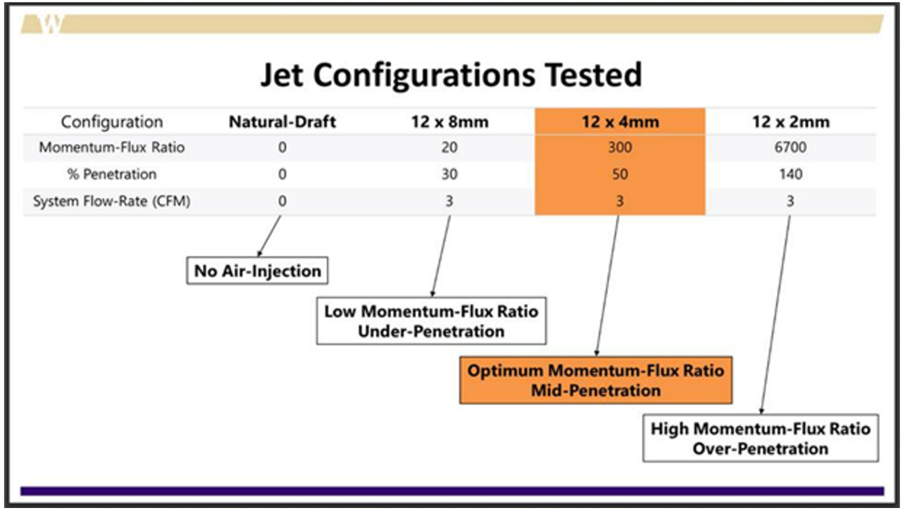




David Evitt

Aprovecho Research Center

Practical Forced Air - What do we know?



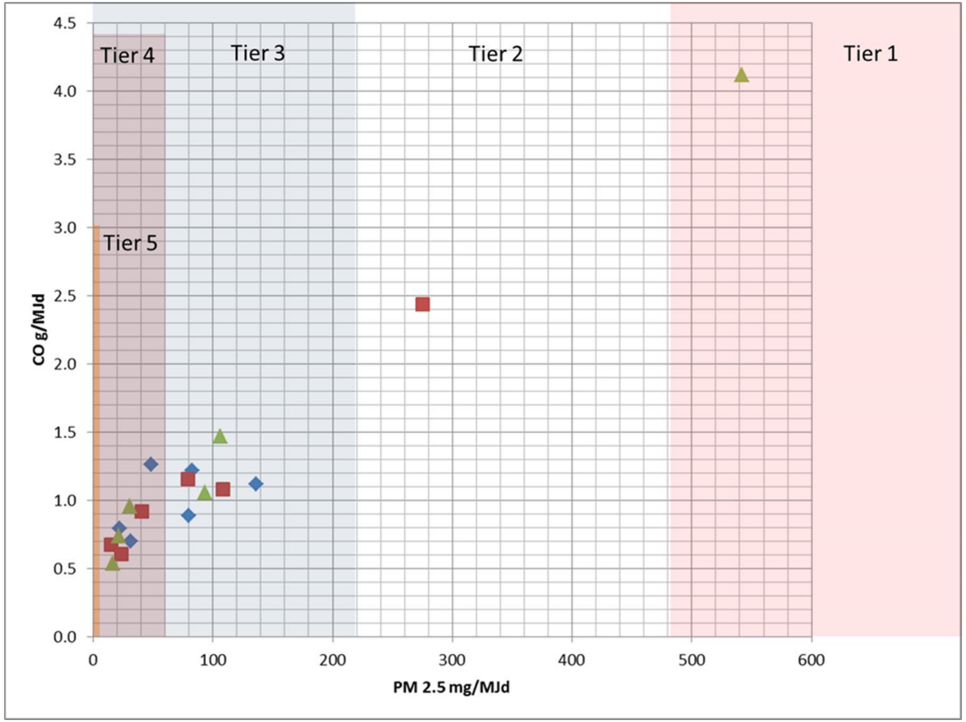
Jet Configurations Tested

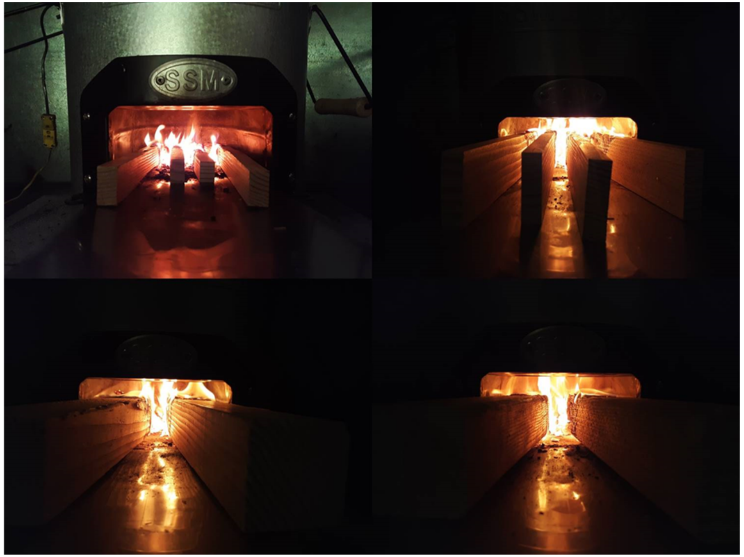
Configuration	Natural-Draft	12 x 8mm	12 x 4mm	12 x 2mm
Momentum-Flux Ratio	0	20	300	6700
% Penetration	0	30	50	140
System Flow-Rate (CFM)	0	3	3	3

Jet-Flame Configuration

30 holes 2mm diameter
.75 inches water pressure
2-2.5 CFM / 60-70 LPM (estimated!)

Lab experiments with the Jet-Flame

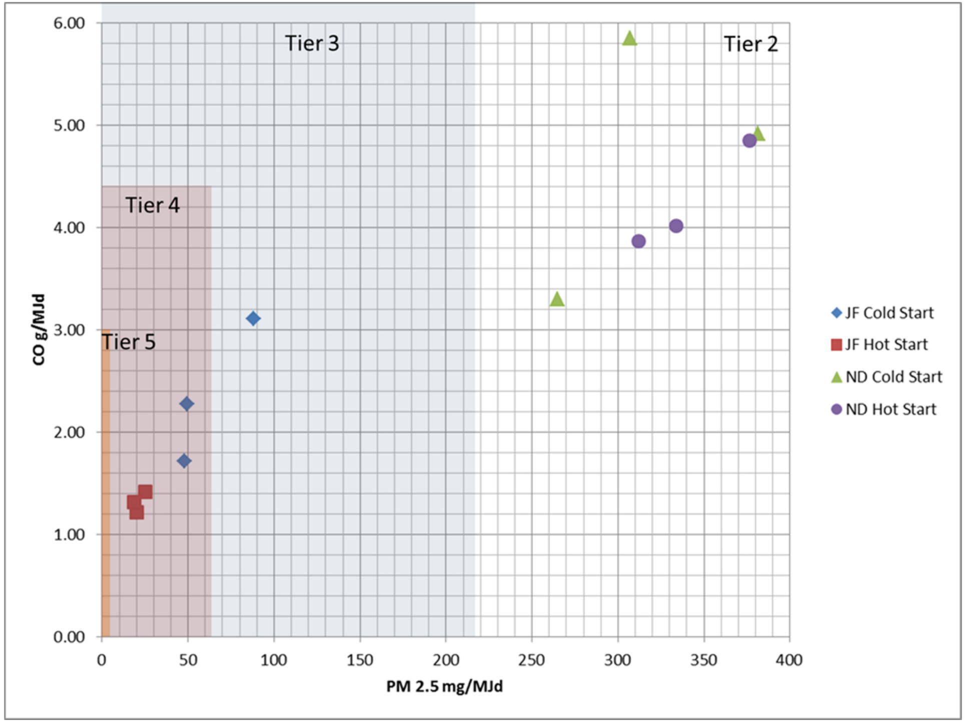


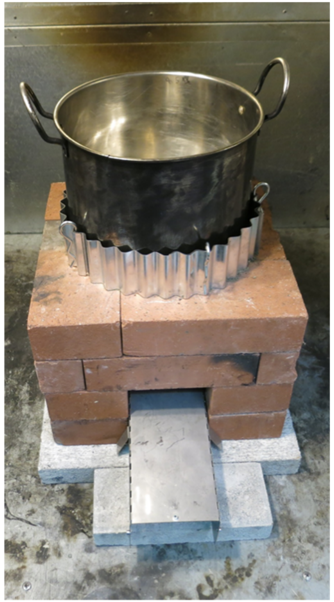


ISO Voluntary Performance Targets

Manufacturer self-test data - for estimation only, no certification implied

Lab experiments with the Jet-Flame





ISO Voluntary Performance Targets

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Lab experiments with the Jet-Flame

High Power Hot Start Natural Draft		
Thermal Efficiency With Char	%	30%
Thermal Efficiency w/o Char	%	26%
Temp Corrected Time to Boil	min	28.8
Firepower	kW	4.2
CO	g/MJd	4.24
PM2.5	mg/MJd	341
aprox BC	mg/MJd	N/A
CO	g/min	0.3
PM2.5	mg/min	22.2
aprox BC	mg/min	N/A

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Lab experiments with the Jet-Flame

High Power Hot Start Jet-Flame			Change from ND
Thermal Efficiency With Char	%	40%	33%
Thermal Efficiency w/o Char	%	40%	53%
Temp Corrected Time to Boil	min	16.6	-42%
Firepower	kW	4.5	
CO	g/MJd	1.31	-69%
PM2.5	mg/MJd	21	-94%
aprox BC	mg/MJd	7	
CO	g/min	0.1	-49%
PM2.5	mg/min	2.2	-90%
aprox BC	mg/min	0.7	

Manufacturer self-test data - for estimation only,
no certification implied

Jet-Flame in Guatemala

18 pieces of wood to cook a pot of tamales cooking

Unutilized (wasted) char after

Jet-Flame in Guatemala

7 Pieces of wood = 60% savings, same cooking time

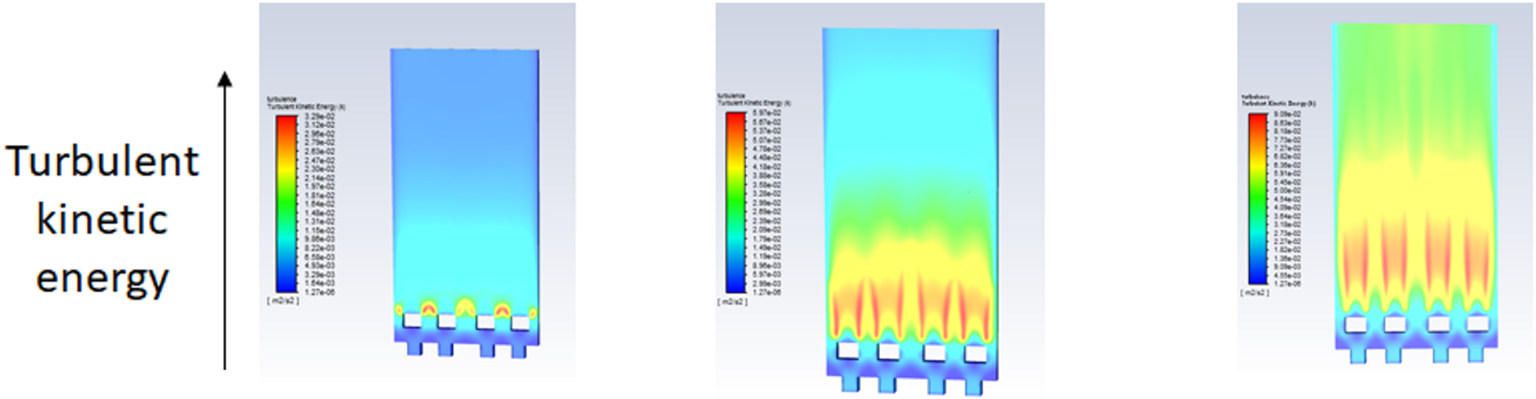
No wasted char after cooking

Nordica MacCarty

Oregon State University

Preliminary Computational Study of Primary Air

- 2D CFD model of SSM rocket stove combustion chamber with primary inlets
- Assumes constant rate of methane production from wood sticks (white blocks)

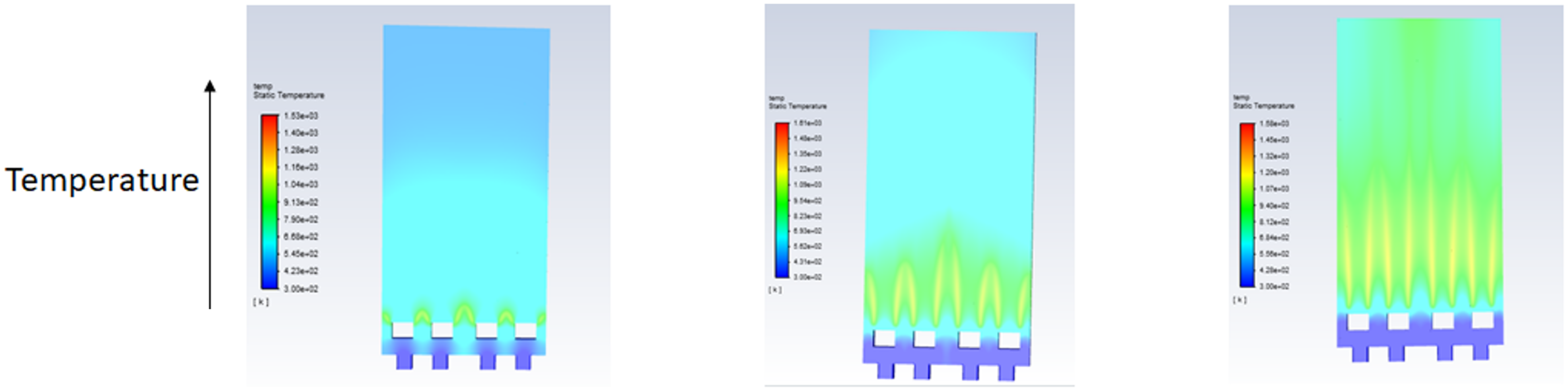


0.05 kg/m^2-s mass flux air   0.16 kg/m^2-s mass flux air   0.25 kg/m^2-s mass flux air

Suggests higher inlet flow leads to more uniform turbulence and air-fuel mixing

Preliminary Computational Study Cont'd

- *Suggests additional mass flow through primary inlets adds supplemental vertical momentum resulting in improved downstream heat transfer*
- *Creates improved distribution of peak combustion temperatures*



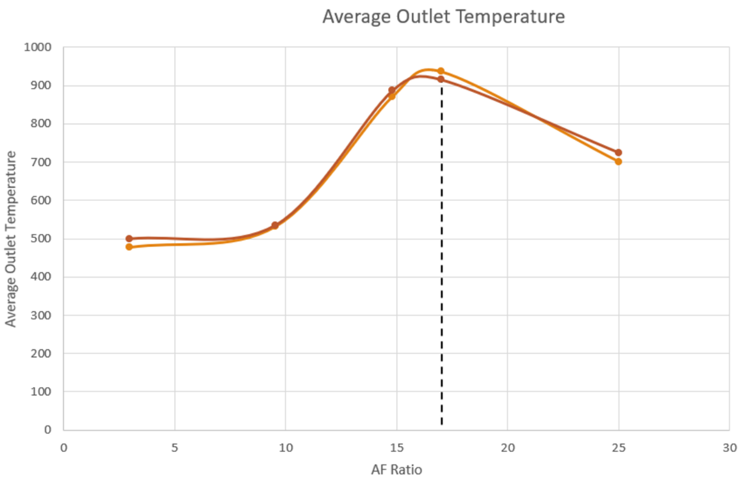
0.05 kg/m^2-s mass flux air

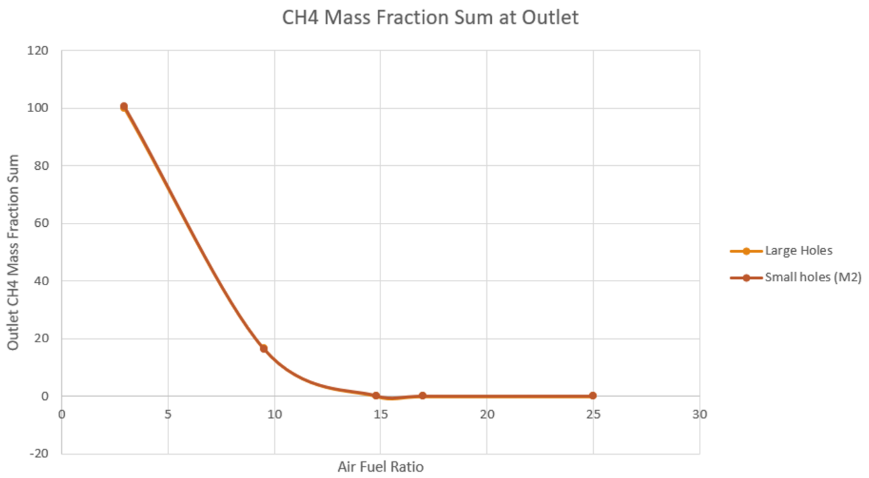
0.16 kg/m^2-s mass flux air

0.25 kg/m^2-s mass flux air

Preliminary Computational Study Cont'd

- Results assuming pure methane fuel release

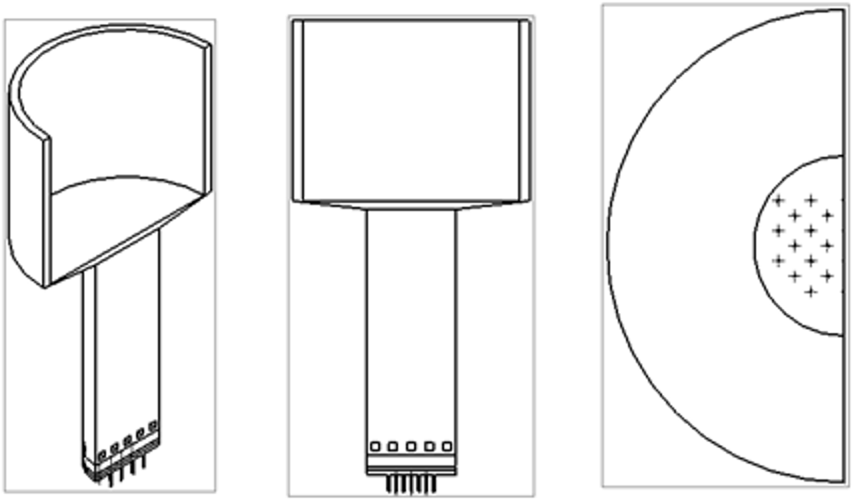




Verifies approach by showing peak average temperatures at methane stoichiometry (AF ratio by mass) and increased fuel consumption as primary air flow is added

Current Work

- 3D CFD model of cookstove with actual Jet Flame attachment
- Integrate an accurate wood-volatile chemistry model
- Characterizing charcoal bed as a porous media
- Varying primary air flow rate, hole size, hole number. Observing thermal efficiency and emissions content.
- Working toward eventual scale-up to higher firepower



3D Geometry

For questions concerning current work, feel free to contact Liam Cassidy via ***cassidyl@oregonstate.edu***

Vahid Jahangiri

INTERNATIONAL LIFELINE FUND
LIFELINE

Feedback from the Field, International Lifeline Fund (Uganda)

Potential Topics for Discussion

- What are critical next steps?
- What do funding organizations need to know/provide?
- How do we build a set of best practices of how to integrate forced draft hardware with stoves?
- How do we validate that lab performance approximates field performance?
- What are the complimentary behavioral changes that can improve the impacts of forced draft stoves?
- How does the requirements for electricity affect the ability for forced draft to scale?
- What is the minimal stove that can protect health?
- What is limiting the widespread use of this technology?