



# Solid-Fuel Stove Testing

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National Risk Management Research Laboratory  
Air Pollution Prevention and Control Division  
Research Triangle Park, NC**

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ASEAN-US Next-Generation Cook Stove Workshop**

# Report Documentation Page

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# Introduction

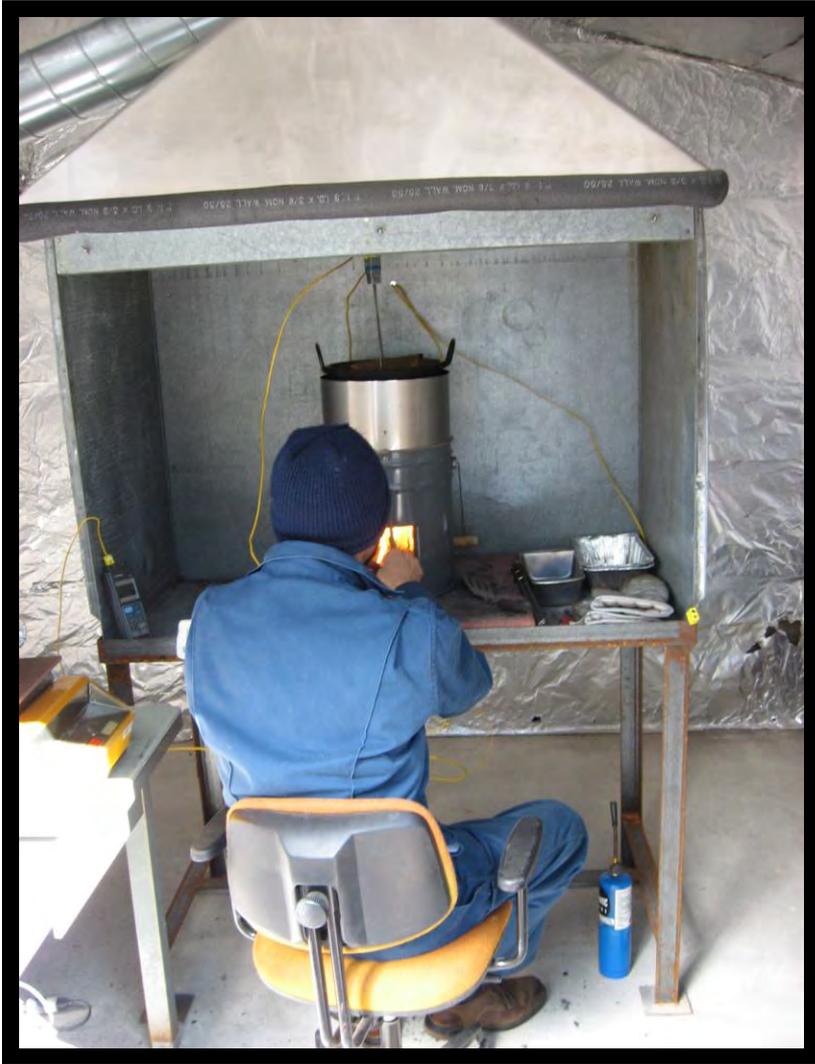
- Stove testing is important and necessary
- Lab tests provide valuable information, but are inadequate for predicting field performance
- Field tests are needed
  - Controlled Cooking Test protocol
  - Kitchen Performance Test protocol

# Objectives of Our Testing

- Determine if stoves have improved fuel efficiency and lower pollutant emissions compared with traditional stoves
- Provide useful information to PCIA (Partnership for Clean Indoor Air) partners and others disseminating stove technology in the field
- Compare test results with a PCIA partner, Aprovecho Research Center, using a standard test protocol

# Methodology

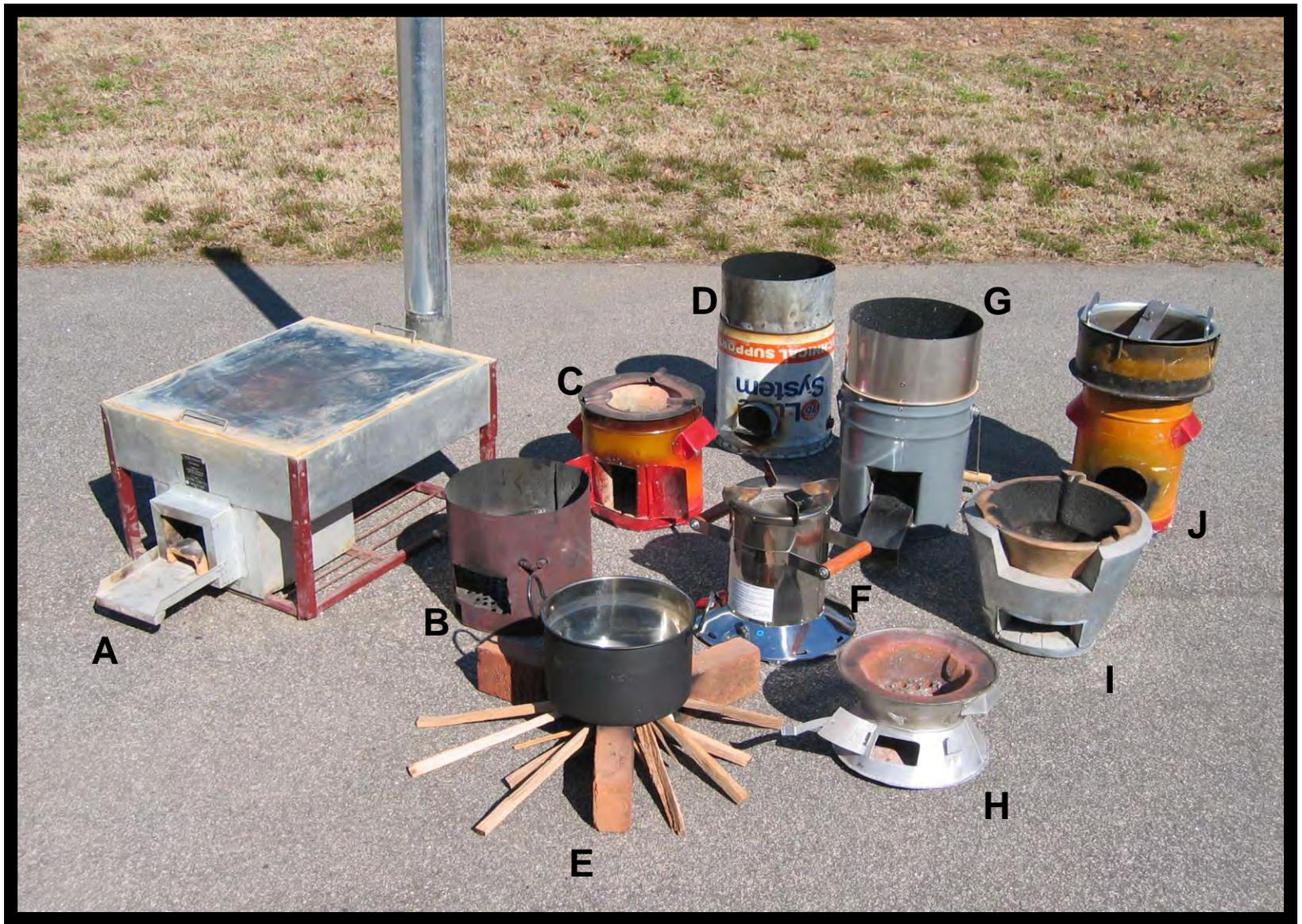
- Tested 14 stove/fuel combinations for performance and emissions
- Used WBT (Water Boiling Test) Protocol
  - Stove cold, 5L water heated to boil, high power
  - Stove hot, 5L water heated to boil, high power
  - Stove hot, 5L water maintained at simmer, low power
- Captured emissions with a hood and duct system
- Measured CO<sub>2</sub>, CO, and THCs (total hydrocarbons) with CEMs (continuous emission monitors)
- Measured PM (particulate matter) with filter method and ELPI (Electrical Low-Pressure Impactor)
- Sampled PM for OC/EC (organic carbon/elemental carbon) analysis



**Stove testing in emissions hood**



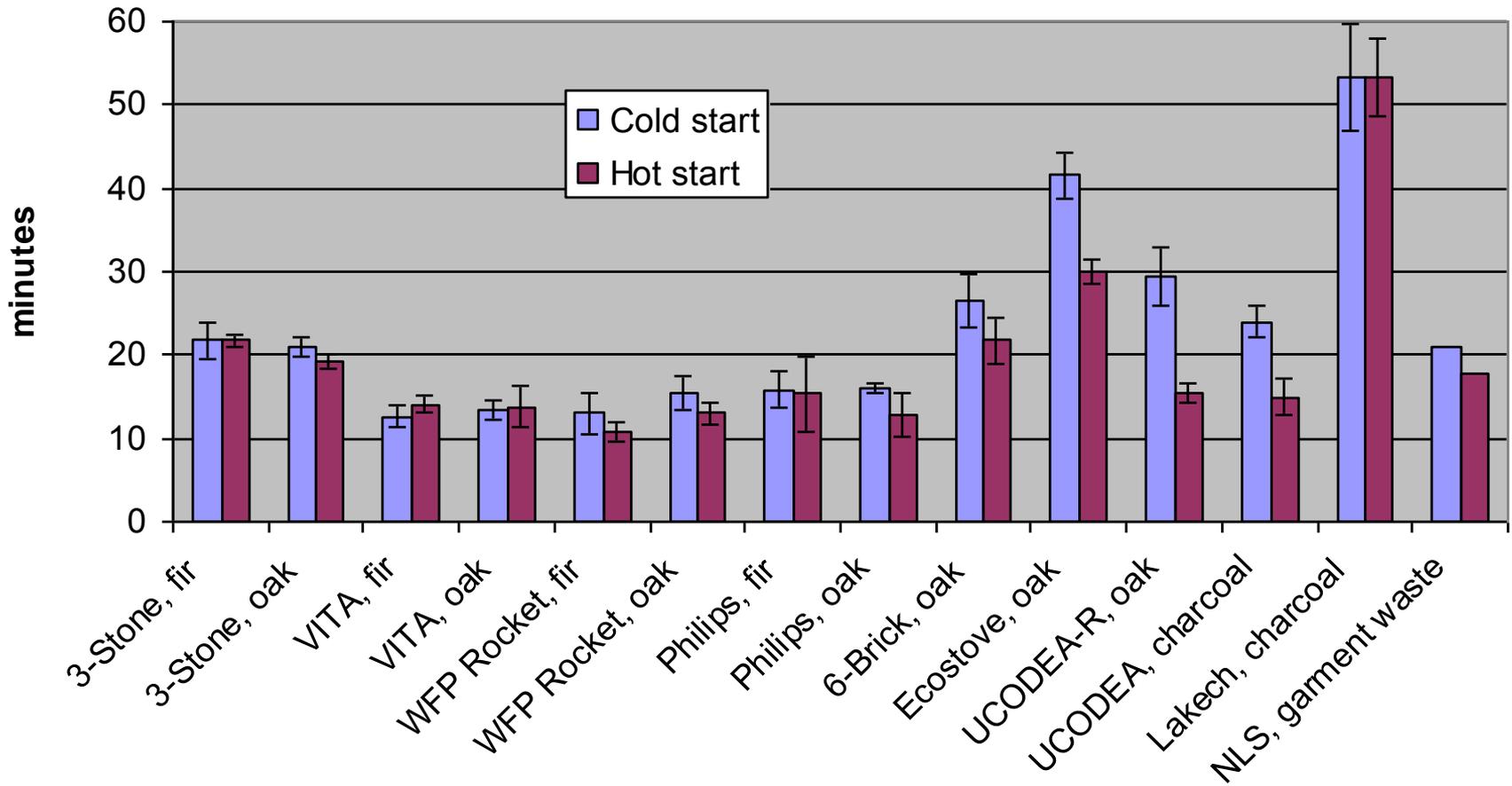
**Continuous emission monitors**



**Stoves tested: A Ecostove, B VITA stove, C UCODEA charcoal stove, D WFP rocket stove, E 3-stone fire, F Philips stove, G 6-brick rocket stove, H Lakech charcoal stove, I NLS stove, J UCODEA rocket stove**

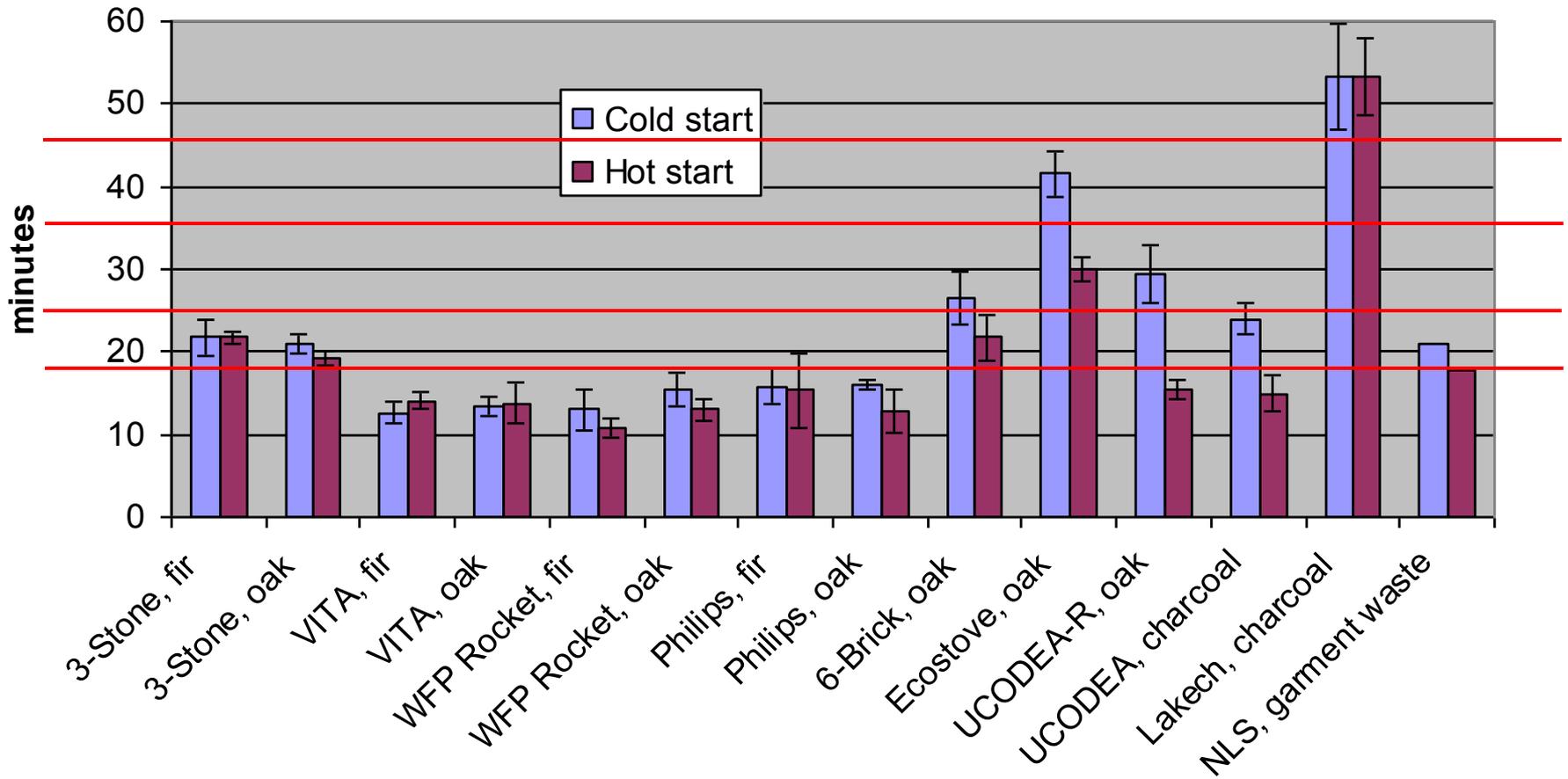
# Results

## Time to Boil

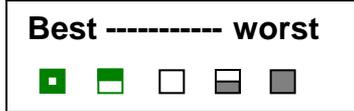


# Results

## Time to Boil

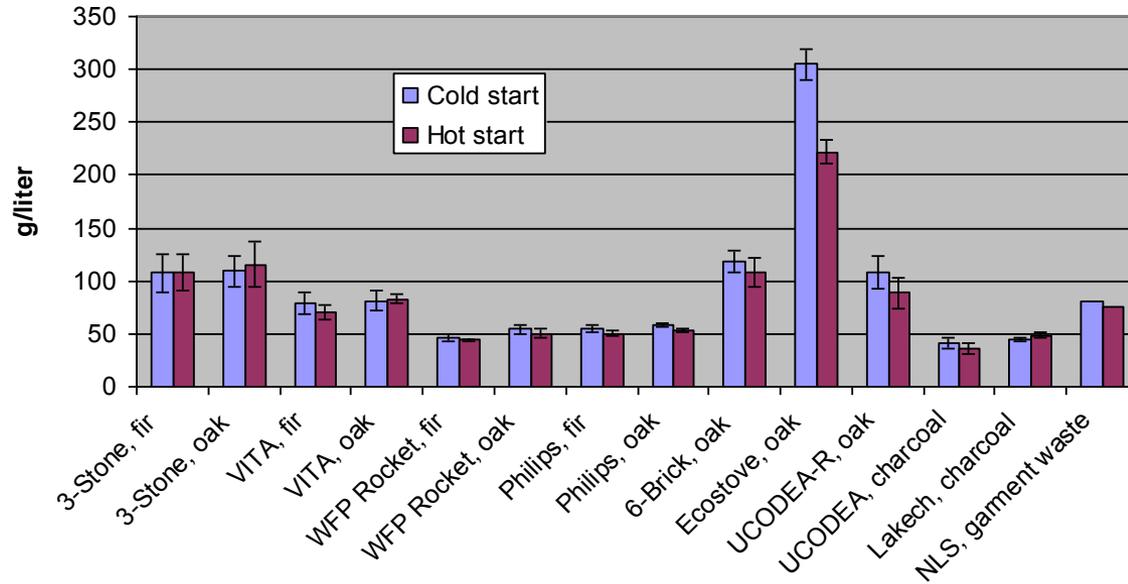


# Performance

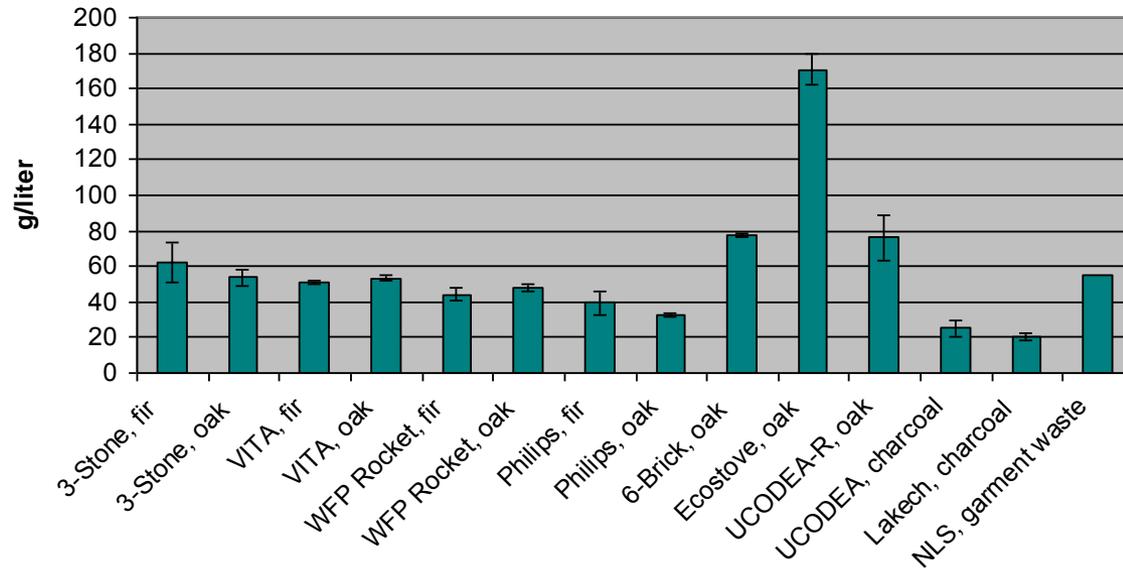


	Time to boil		Thermal efficiency			Specific fuel consumption		
	High power		High power		Low power	High Power		Low power
	Cold start	Hot start	Cold start	Hot start		Cold start	Hot start	
3-Stone, fir	Light green	Light green	Light grey	Light grey	White	White	White	White
3-Stone, oak	Light green	Light green	Light grey	Light grey	White	White	White	White
VITA, fir	Green	Green	White	White	White	Light green	Light green	White
VITA, oak	Green	Green	White	White	White	Light green	Light green	White
WFP Rocket, fir	Green	Green	Green	Green	White	Green	Green	Light green
WFP Rocket, oak	Green	Green	Light green	Light green	White	Green	Green	Light green
Philips, fir	Green	Green	Light green	Light green	Light green	Green	Green	Light green
Philips, oak	Green	Green	Light green	Light green	Green	Green	Green	Green
6-Brick, oak	White	Light green	Light grey	Light grey	Light grey	White	White	Light grey
Ecostove, oak	Light grey	White	Dark grey	Dark grey	Dark grey	Dark grey	Light grey	Dark grey
UCODEA-R, oak	White	Green	Light grey	Light grey	Light grey	White	Light green	Light grey
UCODEA, charcoal	Light green	Green	White	White	Green	Green	Green	Green
Lakech, charcoal	Dark grey	Dark grey	Light green	Light green	Green	Green	Green	Green
NLS, garment waste	Light green	Green	White	White	White	Light green	Light green	White

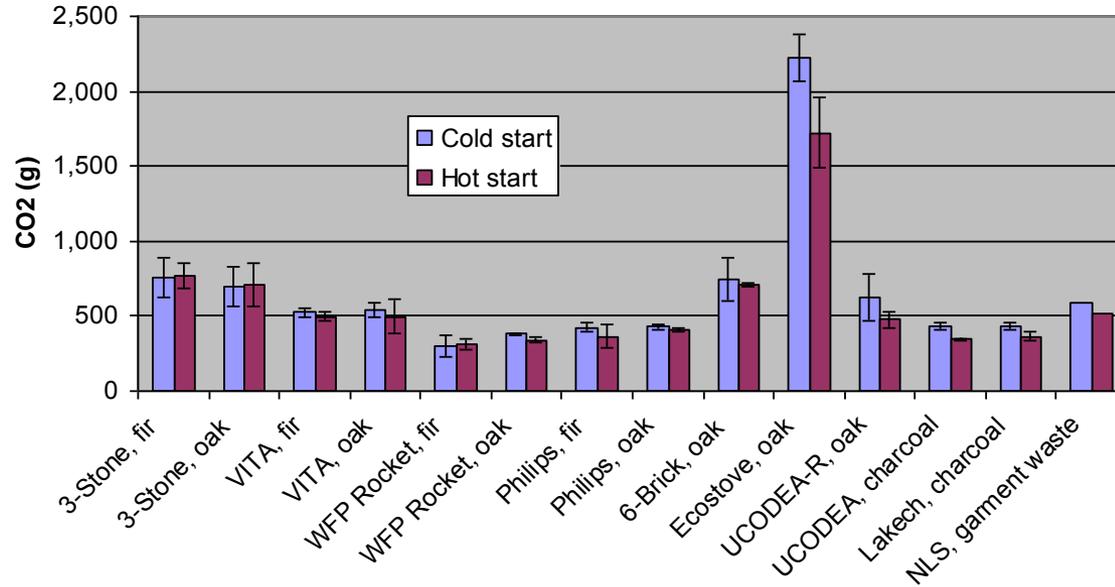
### Specific Fuel Consumption, High Power



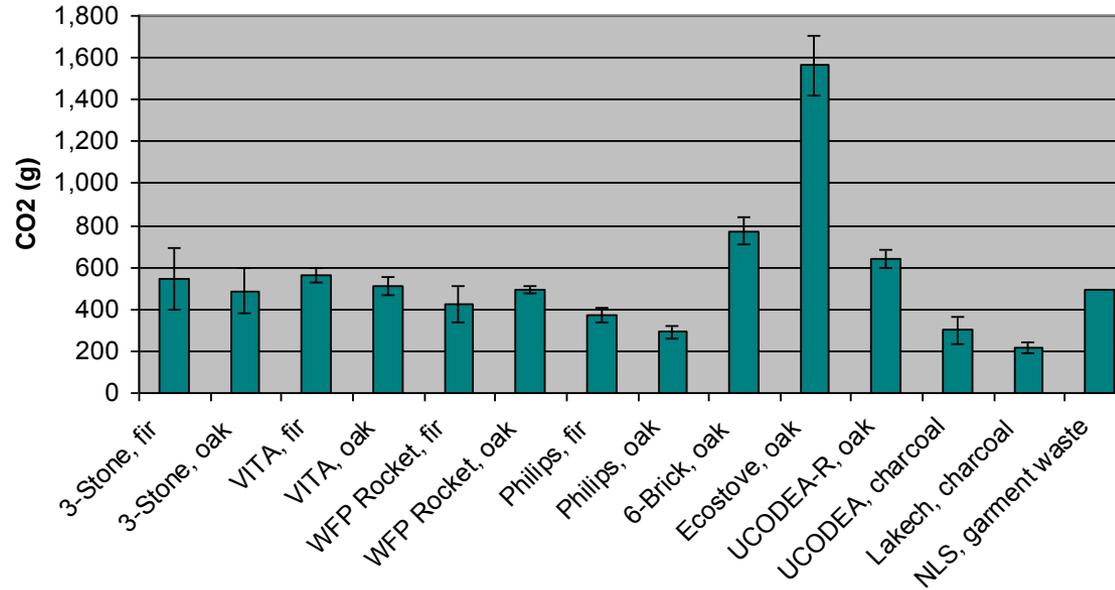
### Specific Fuel Consumption, Low Power



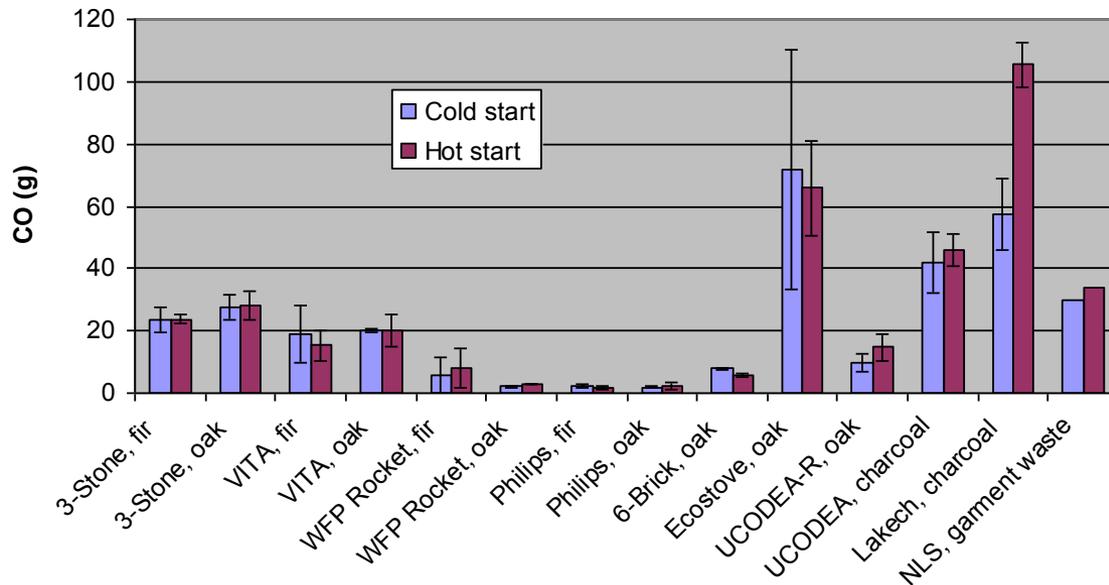
### CO2 Emissions, High Power



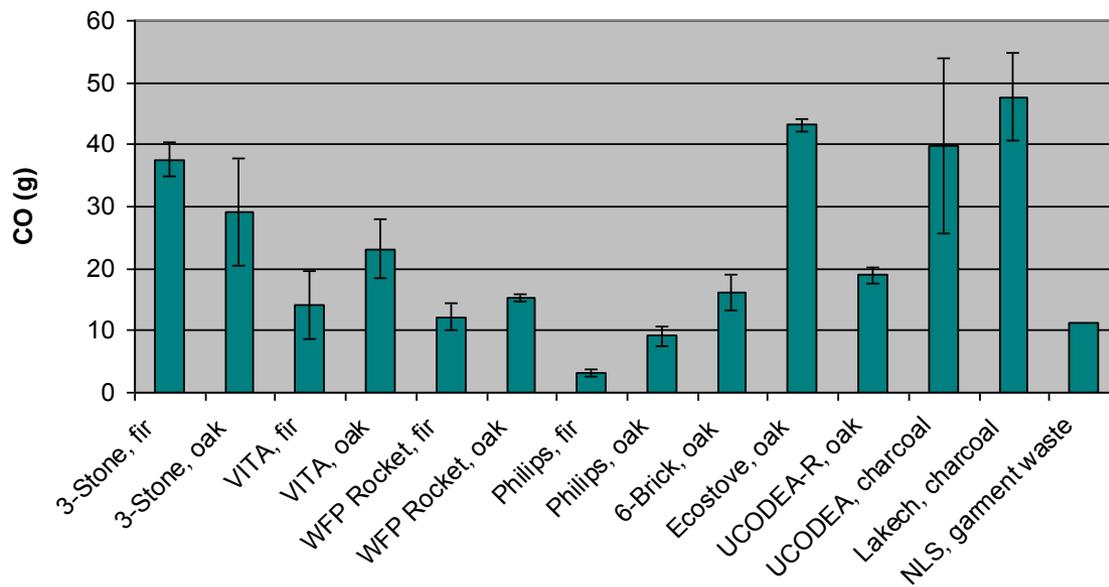
### CO2 Emissions, Low Power



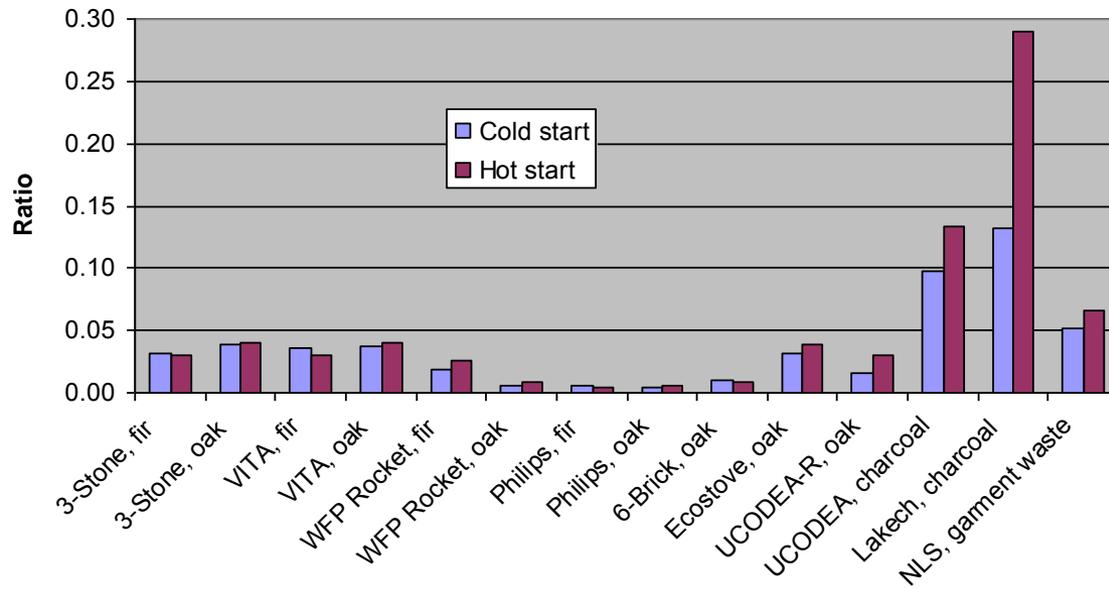
### CO Emissions, High Power



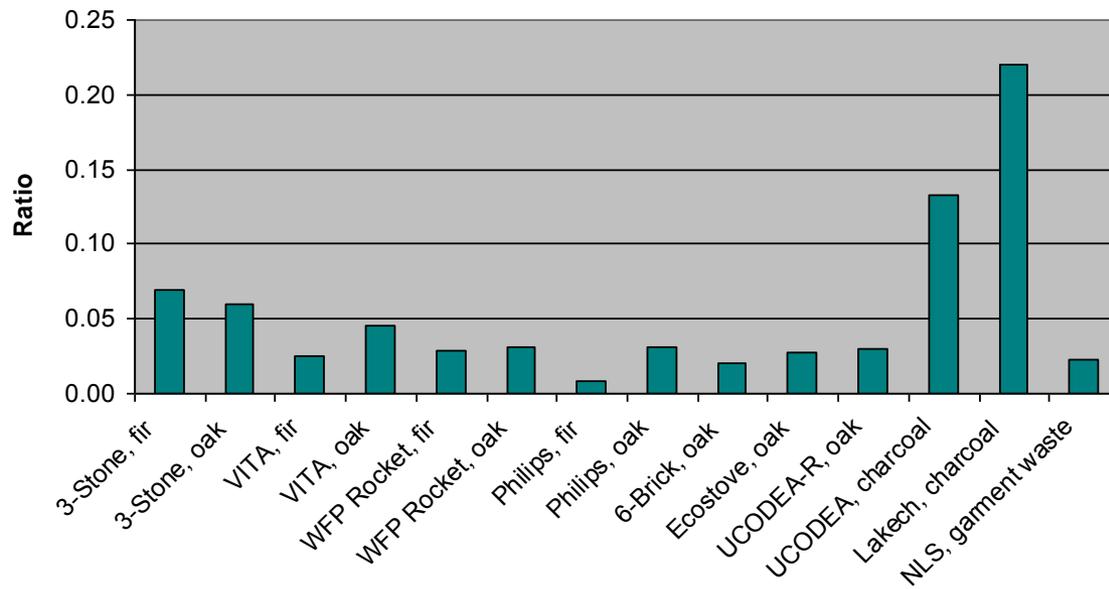
### CO Emissions, Low Power



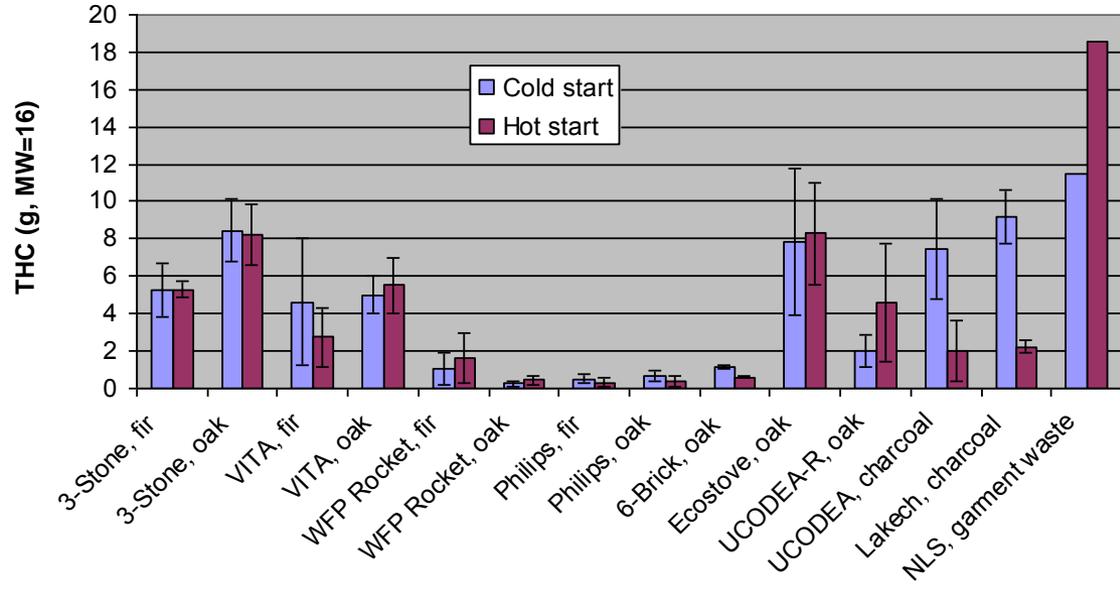
### CO/CO2 Ratio, High Power



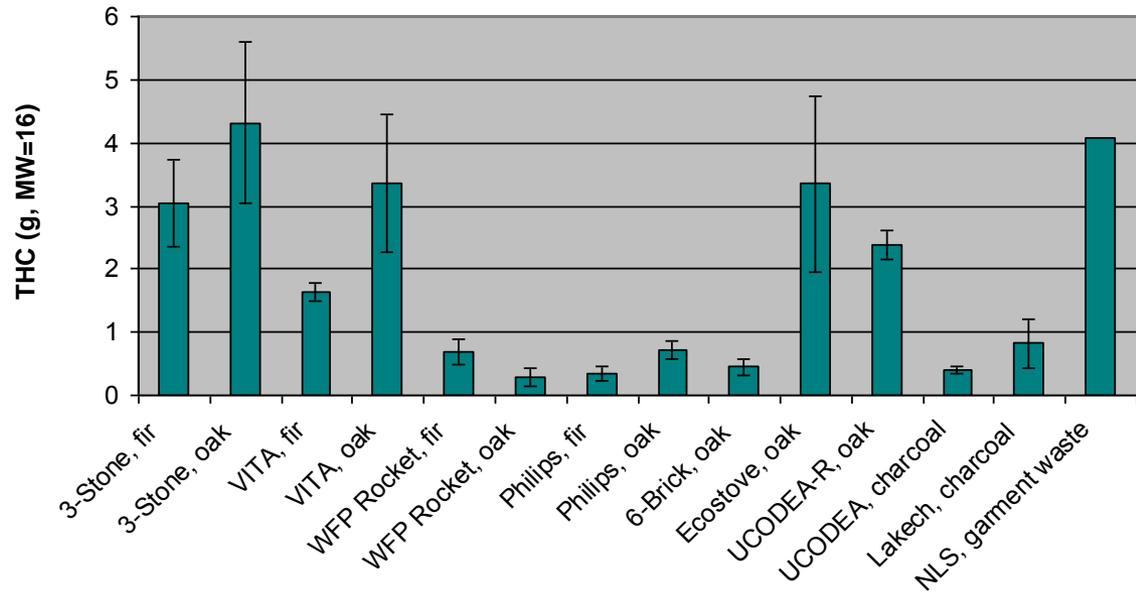
### CO/CO2 Ratio, Low Power



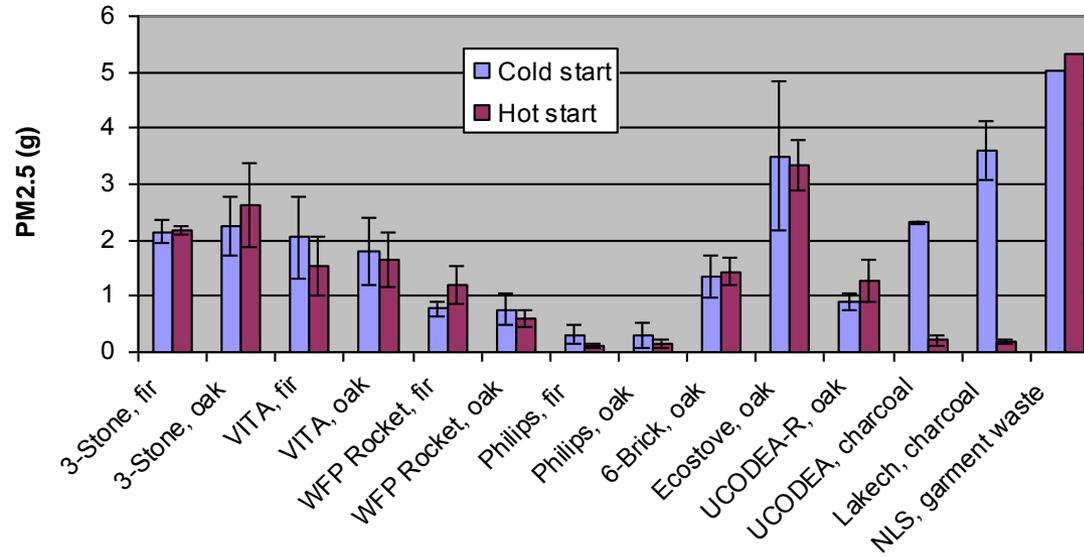
### THC Emissions, High Power



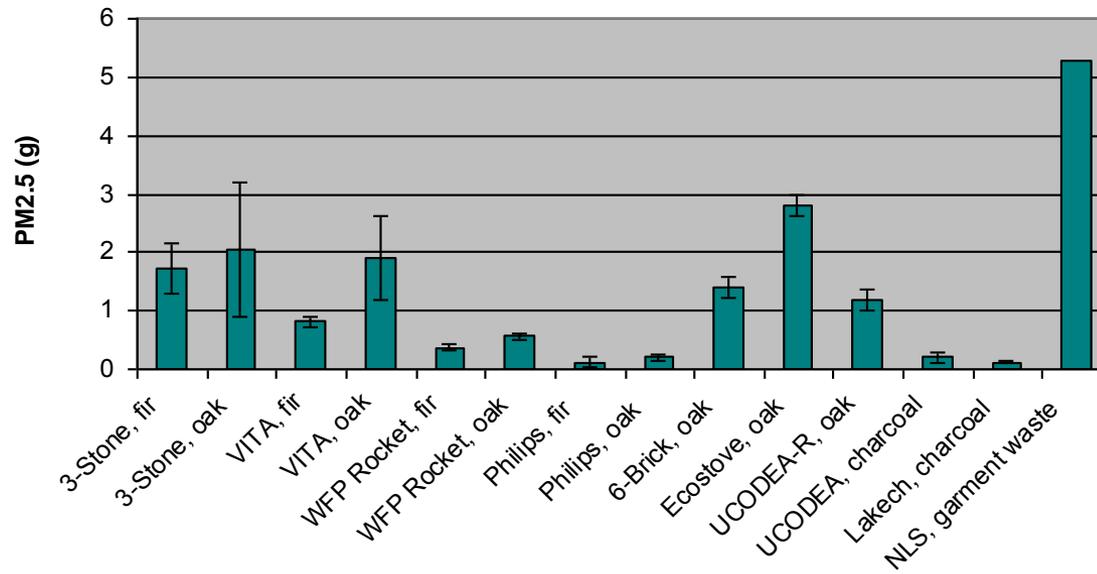
### THC Emissions, Low Power



### PM2.5 Emissions, High Power



### PM2.5 Emissions, Low Power





## **WFP (World Food Program) Rocket Stove**

- + Excellent overall performance**
- + Low emissions**
- + Low cost**
- Short lifetime**



## **Philips Stove**

- + Best overall performance**
- + Lowest emissions**
- More expensive than other stoves**
- Shorter pieces of fuel required**



## **Ecostove**

- + Chimney reduces indoor air pollution**
- + Griddle top designed for making tortillas or frying foods**
- Not well suited for boiling water or cooking in a pot**
- \* Could be improved for cooking with a pot by providing a removable disk on top to directly expose bottom of pot to hot combustion gases**

# Conclusions

- Stoves with smaller heated mass tend to have:
  - Faster time to boil
  - Better fuel efficiency
  - Lower pollutant emissions

# Conclusions

- Comparison of results between labs showed that results can be replicated when the same stove and fuel are tested using the WBT protocol.
- Ability to replicate results could be improved by:
  - Detailed documentation of stove operation technique
  - Consistent training of stove operators
  - Specifications for the fuel
  - Improved specifications and quality control for stove dimensions and materials

# Further details and information:

- Jetter, James J. and Peter Kariher. Solid-fuel household cook stoves: Characterization of performance and emissions. *Biomass and Bioenergy* 33 (2009) 294-305.
- [www.pciaonline.org/research](http://www.pciaonline.org/research)



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- Michael Hays and Pamela Barfield of EPA/ORD

# Our next stove tests

- Will include latest mass-produced stoves
- Will compare performance and emissions with varying moisture content of fuel
- Will include measurements of CO, CO<sub>2</sub>, CH<sub>4</sub>, NMHC, PM, BC/EC/OC
- Will begin January 2010
- Comments and advice welcome!