



Solid-Fuel Stove Testing

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Air Pollution Prevention and Control Division
Research Triangle Park, NC**

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ASEAN-US Next-Generation Cook Stove Workshop**

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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

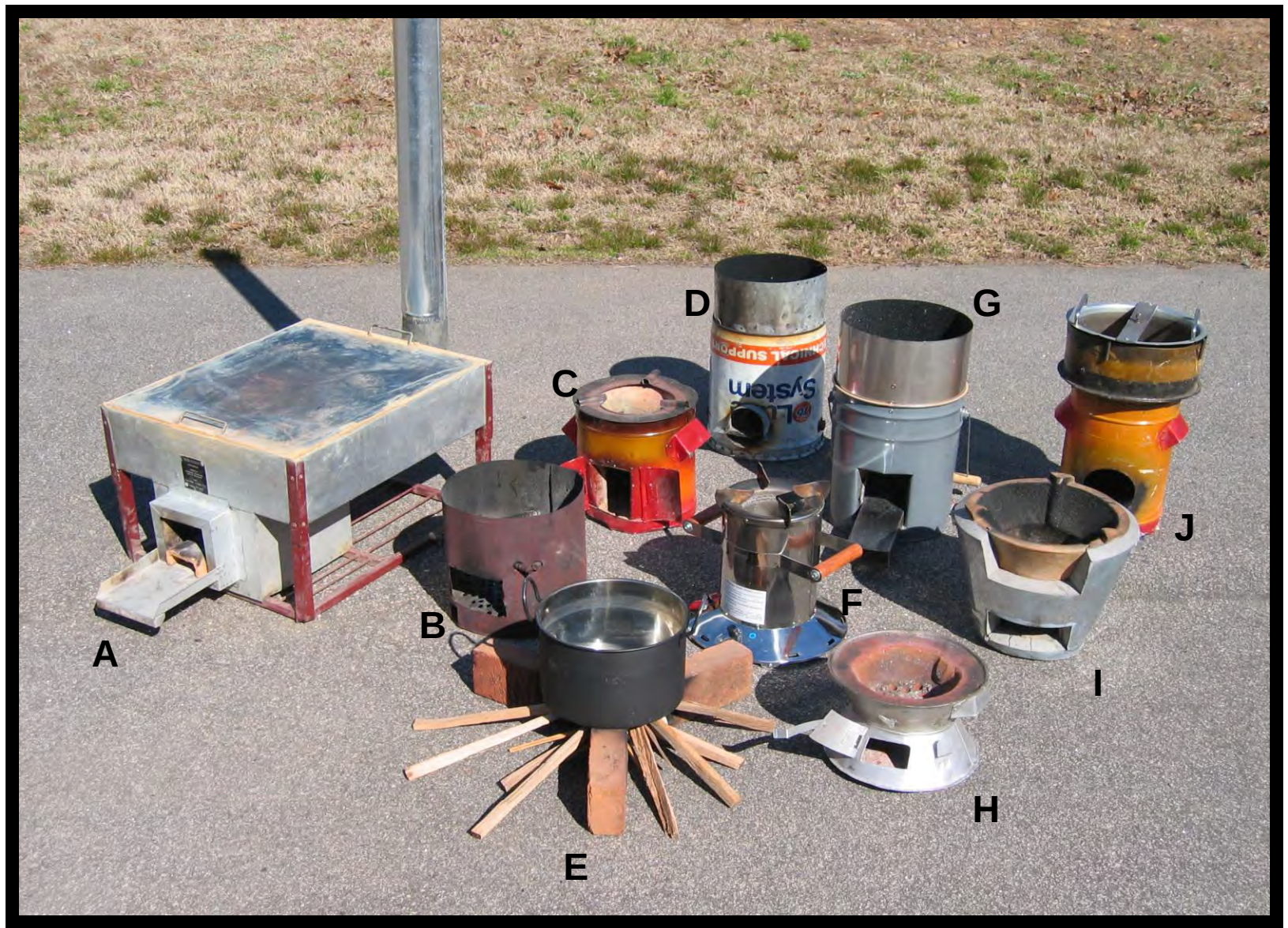
- Tested 14 stove/fuel combinations for performance and emissions
- Used WBT (Water Boiling Test) Protocol
 - Stove cold, 5L water heated to boil, high power
 - Stove hot, 5L water heated to boil, high power
 - Stove hot, 5L water maintained at simmer, low power
- Captured emissions with a hood and duct system
- Measured CO₂, 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



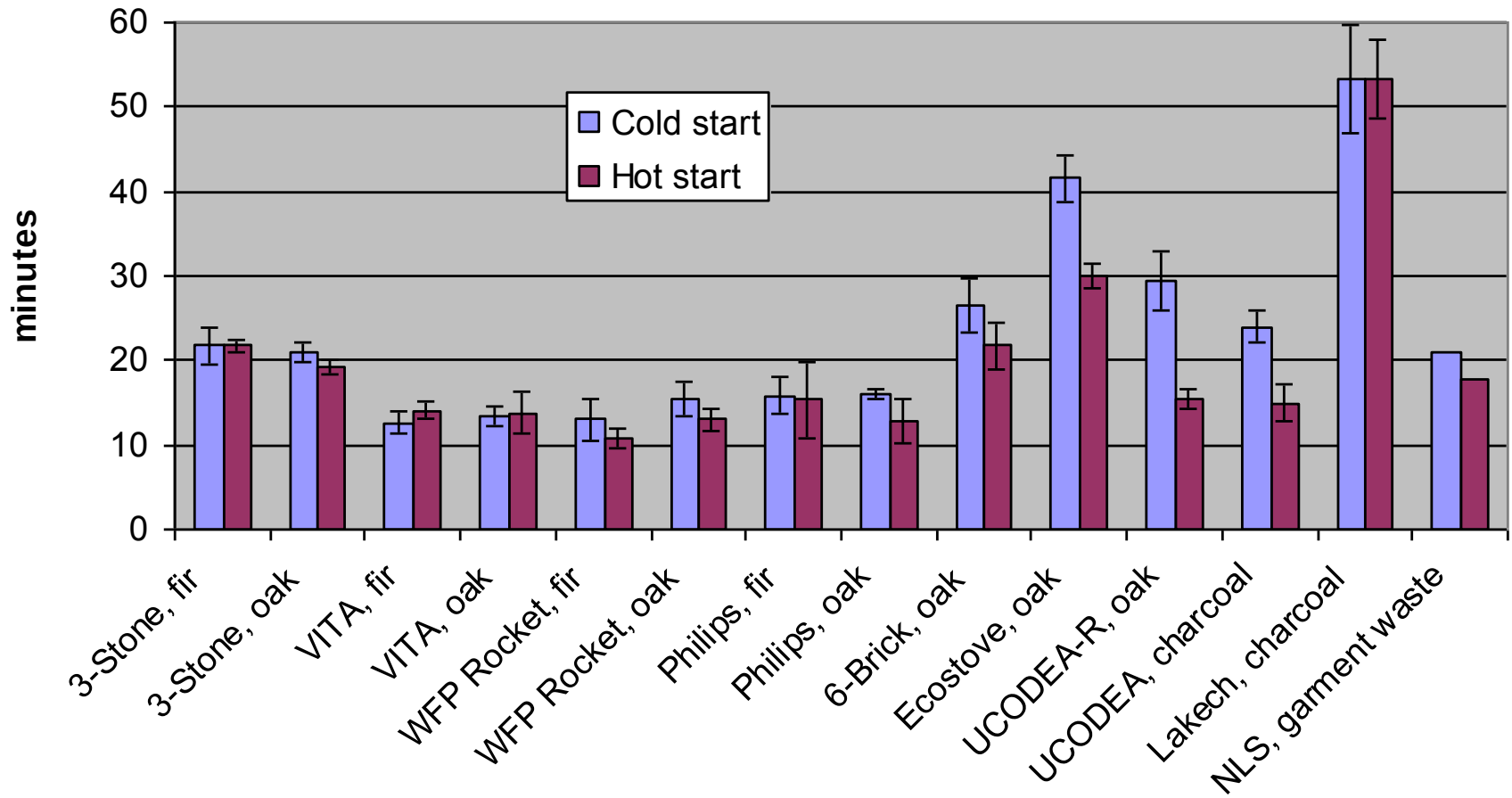
Continuous emission monitors



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

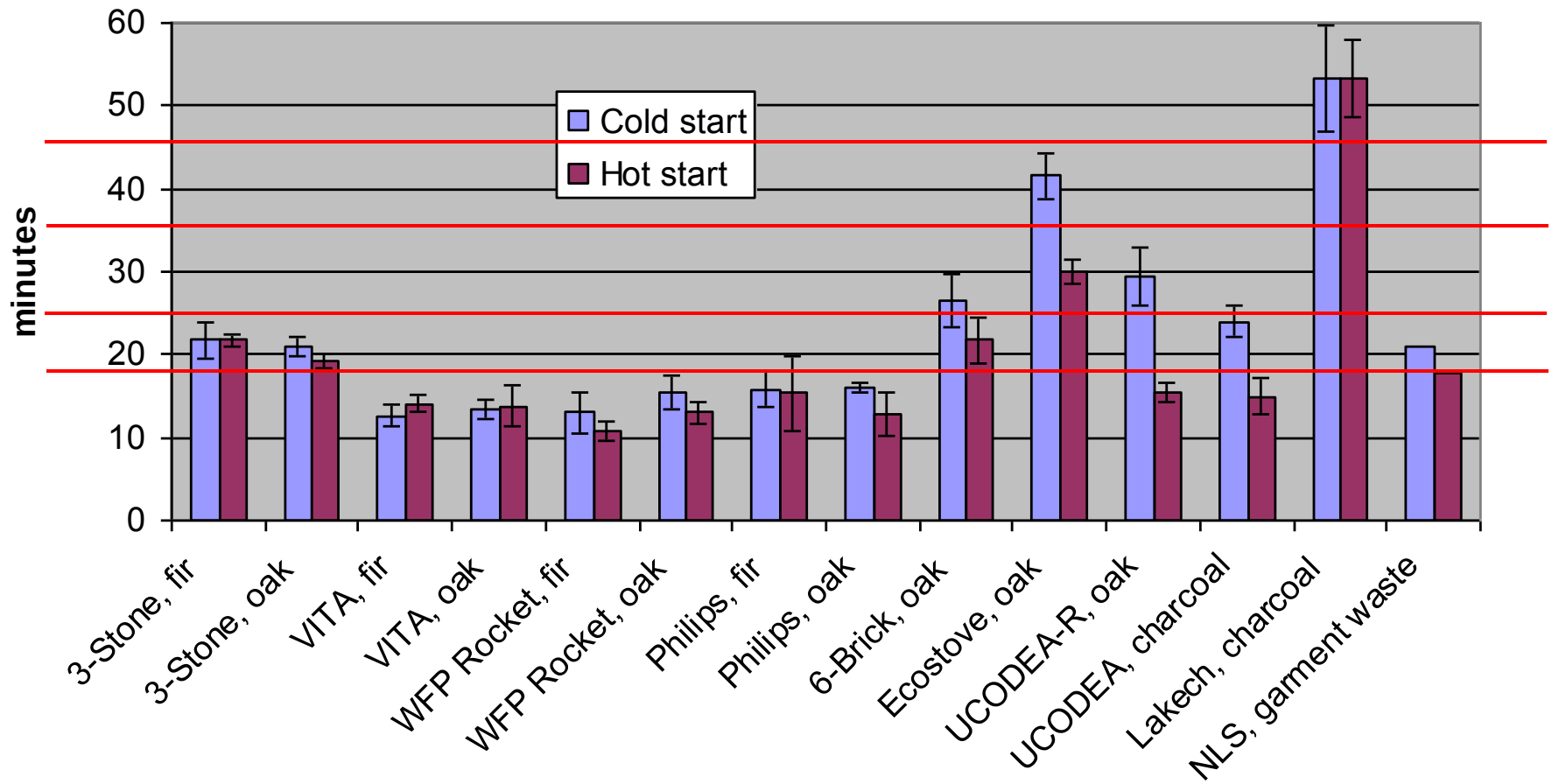
Results

Time to Boil



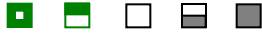
Results

Time to Boil



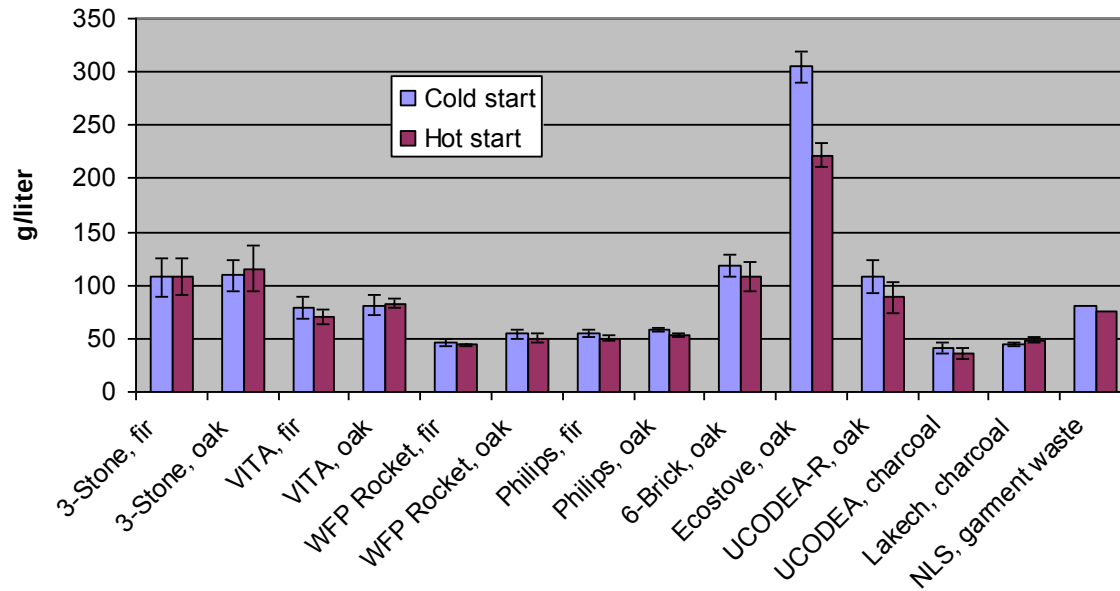
Performance

Best ----- worst

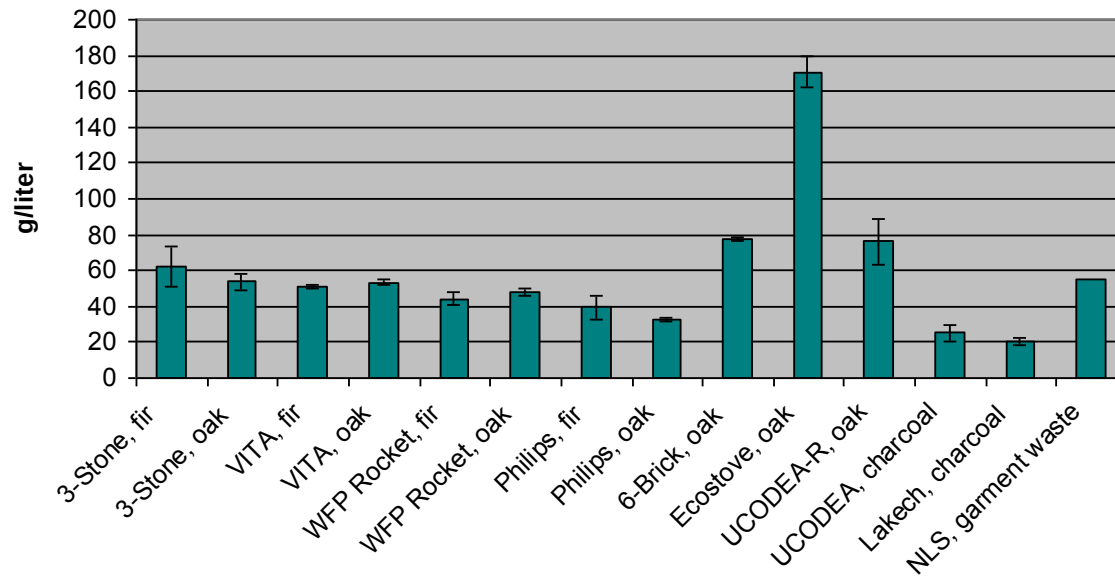


	Time to boil		Thermal efficiency			Specific fuel consumption		
	High power		High power		Low power	High Power		Low power
	Cold start	Hot start	Cold start	Hot start		Cold start	Hot start	
3-Stone, fir								
3-Stone, oak								
VITA, fir								
VITA, oak								
WFP Rocket, fir								
WFP Rocket, oak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

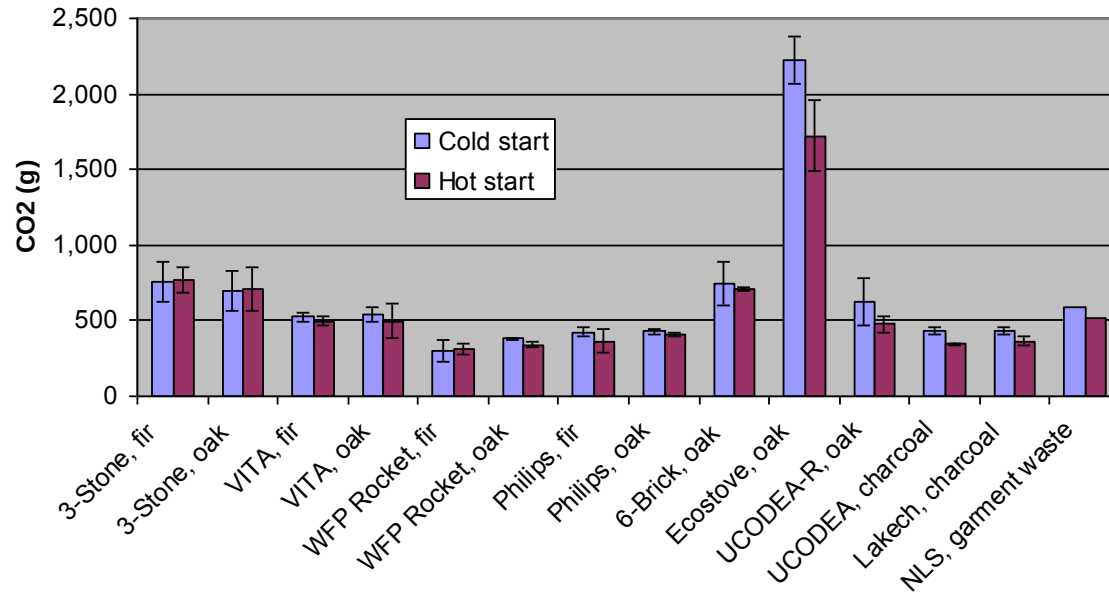
Specific Fuel Consumption, High Power



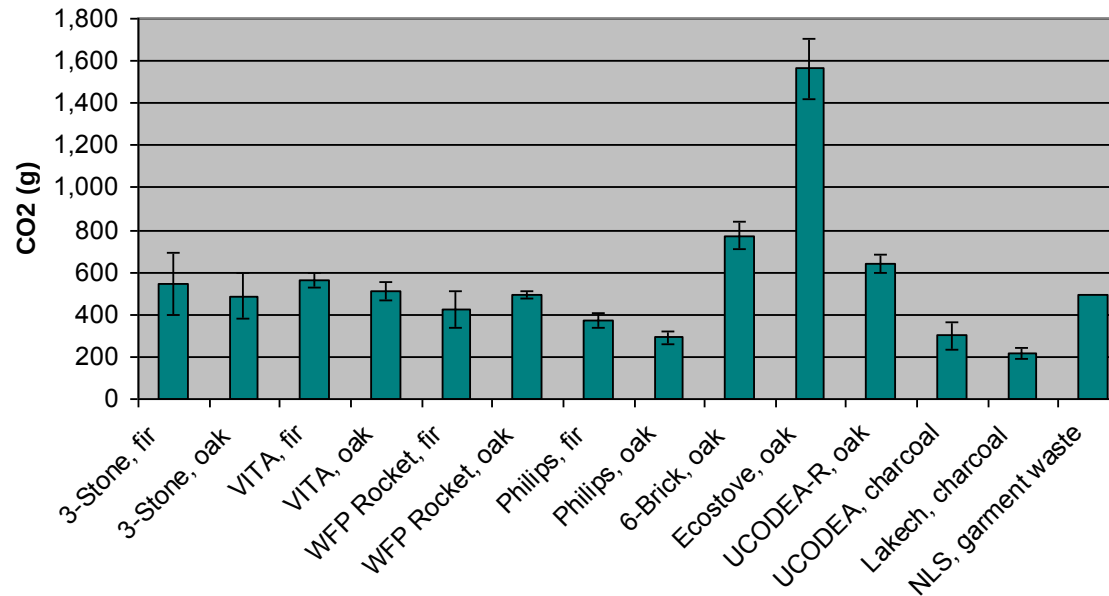
Specific Fuel Consumption, Low Power



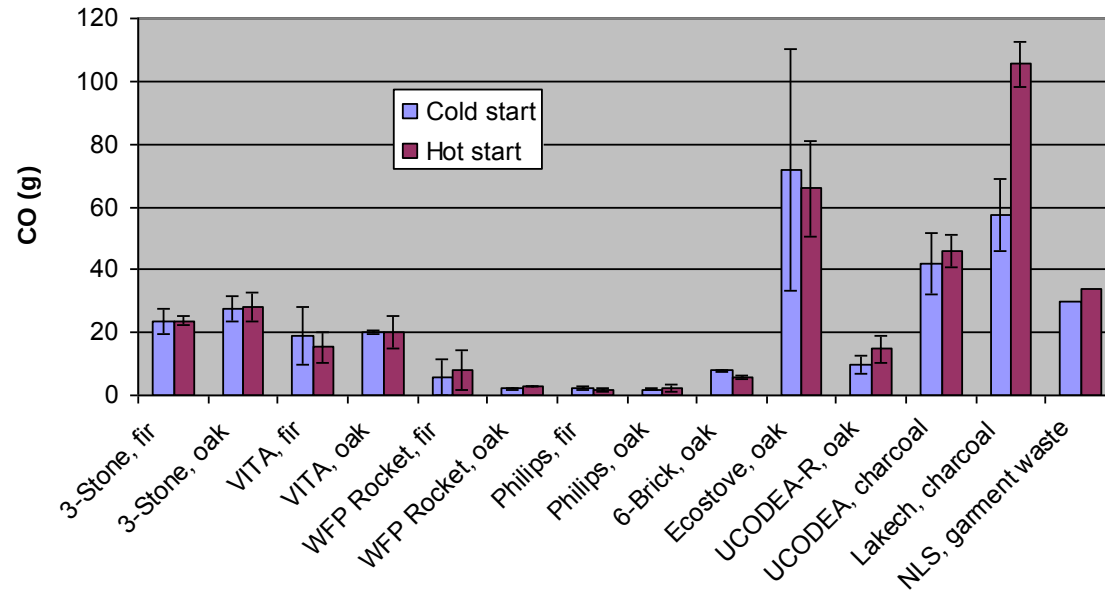
CO2 Emissions, High Power



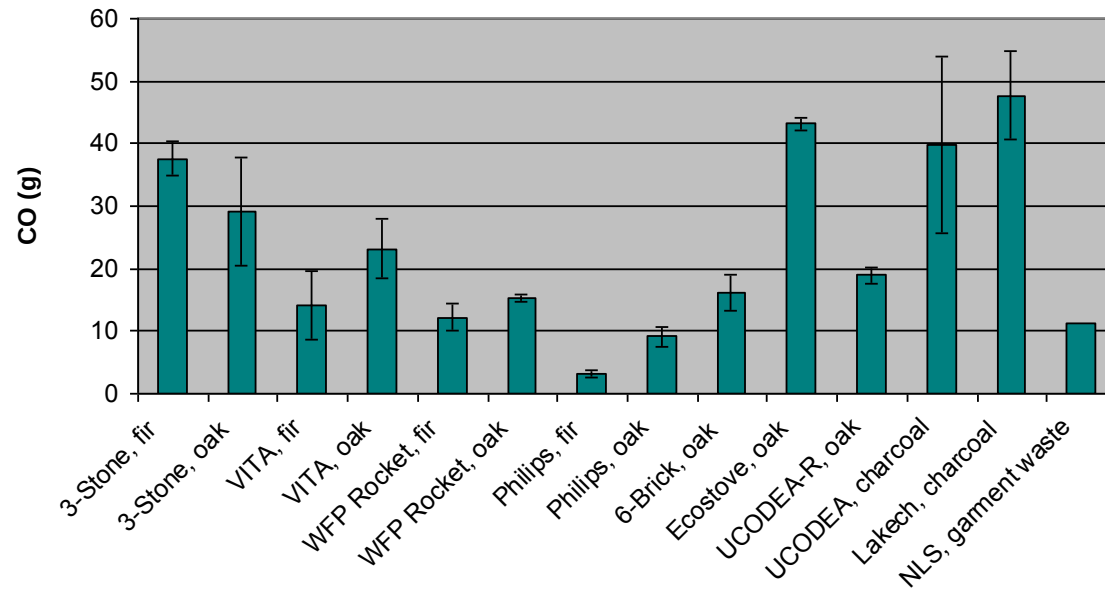
CO2 Emissions, Low Power



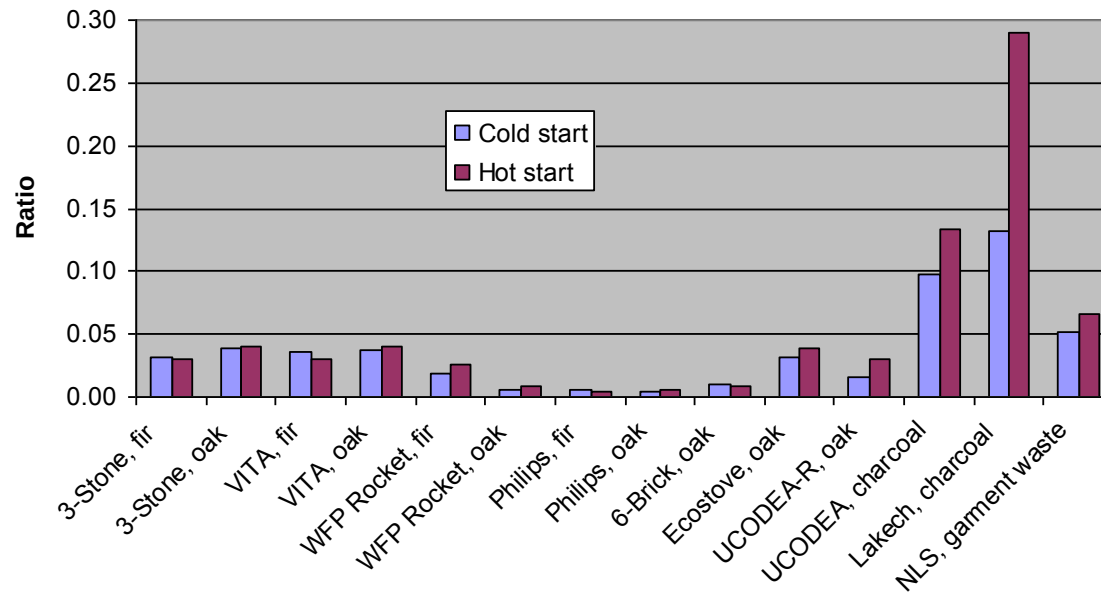
CO Emissions, High Power



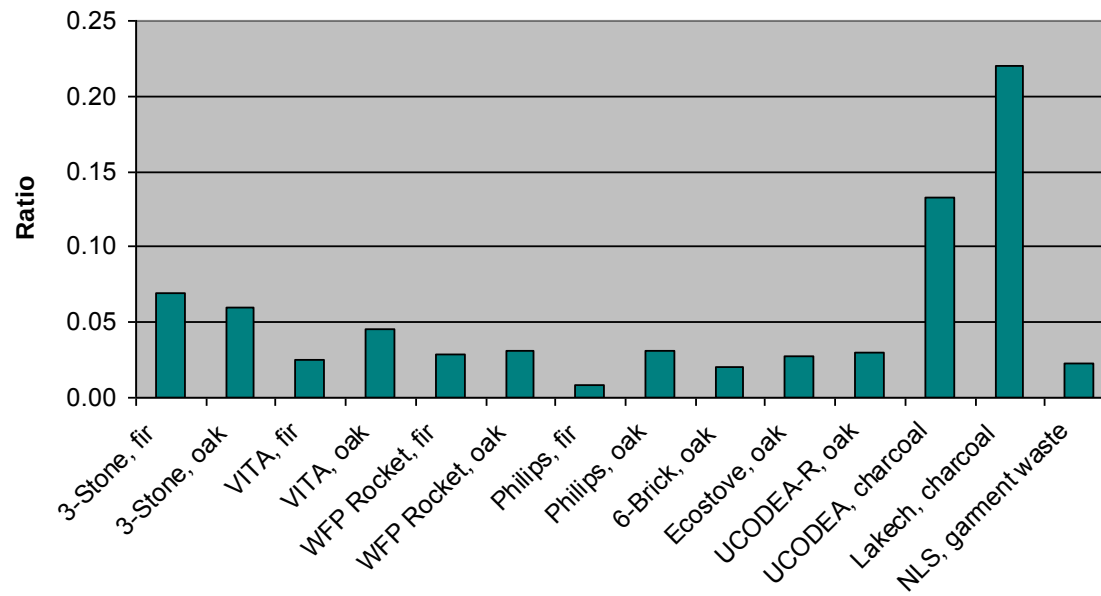
CO Emissions, Low Power



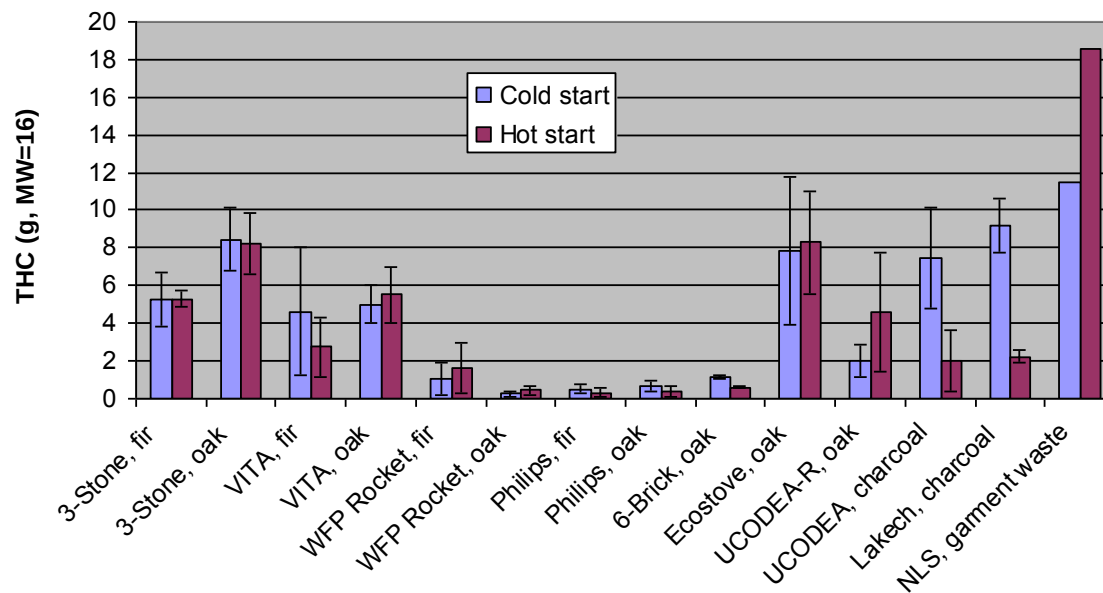
CO/CO₂ Ratio, High Power



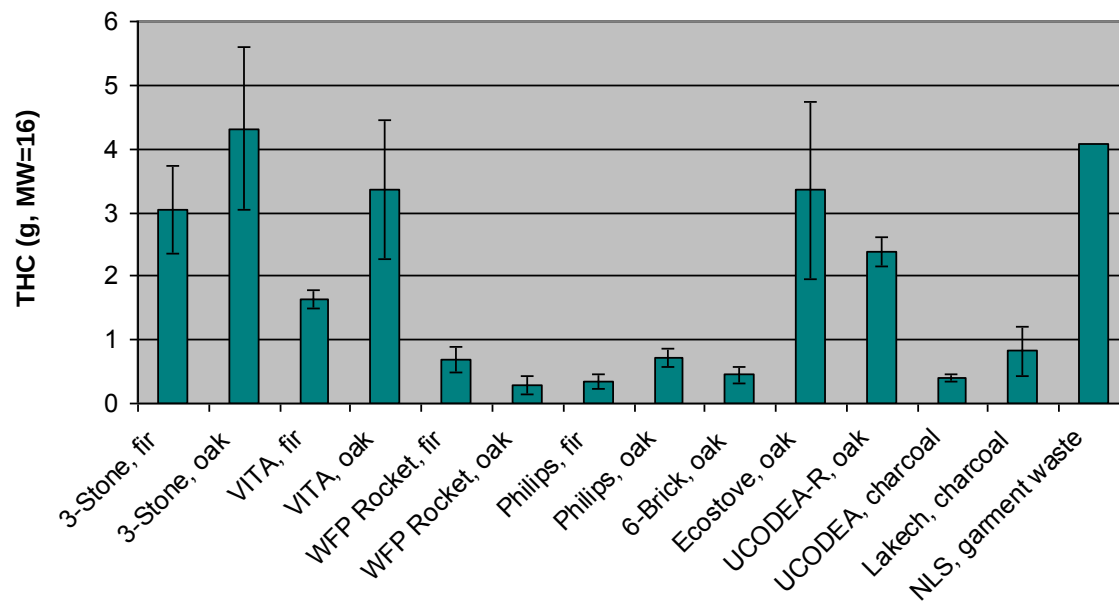
CO/CO₂ Ratio, Low Power



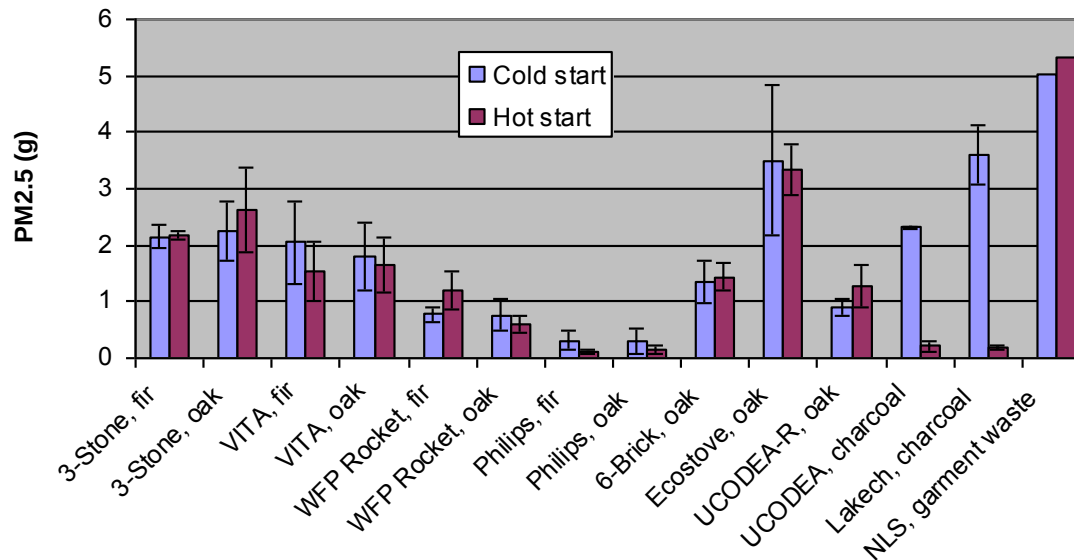
THC Emissions, High Power



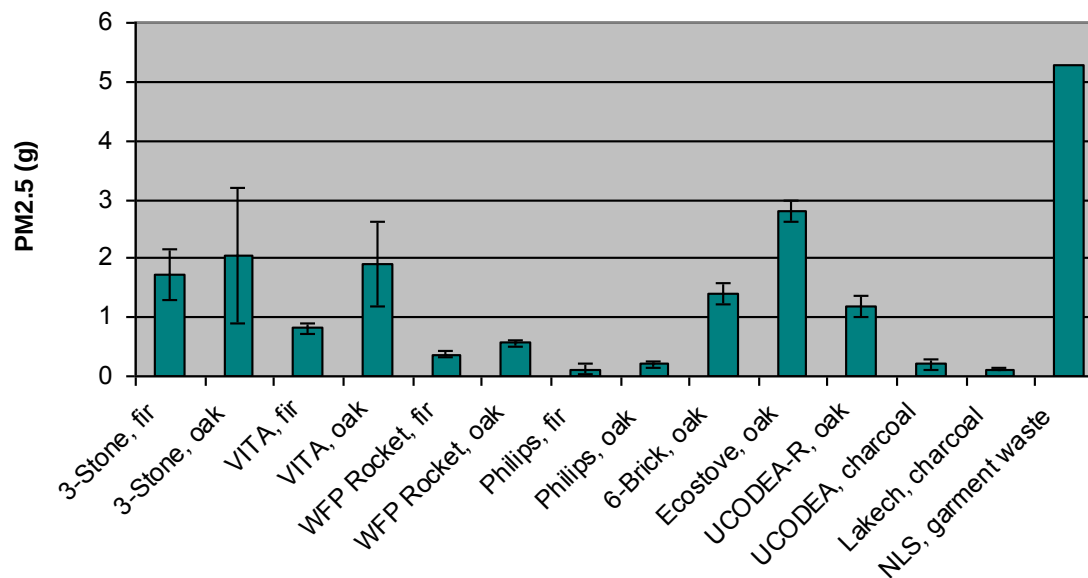
THC Emissions, Low Power



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



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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, CO₂, CH₄, NMHC, PM, BC/EC/OC
- Will begin January 2010
- Comments and advice welcome!