


PARTNERSHIP FOR CLEAN INDOOR AIR

Test Results of Cook Stove Performance

Webinar: January 12, 2012

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Today's Speakers

- Brenda Doroski, U.S. Environmental Protection Agency
- Nordica MacCarty, Aprovecho Research Center
- Dean Still, Aprovecho Research Center

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Purpose of Webinar

1. Share the test results of household cook stoves and fuels in the Aprovecho laboratory.
2. Equip Partners with insights on the impact of stove design features on performance to apply to their own stove program.
3. Increase understanding and knowledge of test methods among Partner organizations.
4. Motivate and equip additional Partners to evaluate the performance of their stove.

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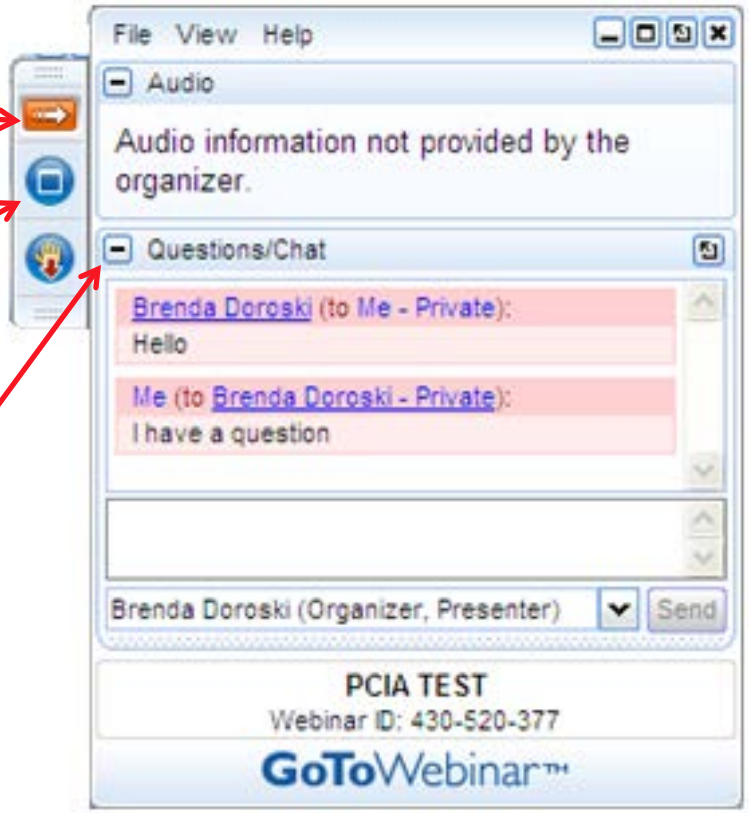
Using the Webinar Technology

Hide Control Toolbar

Maximize Presentation

Question/Chat Feature



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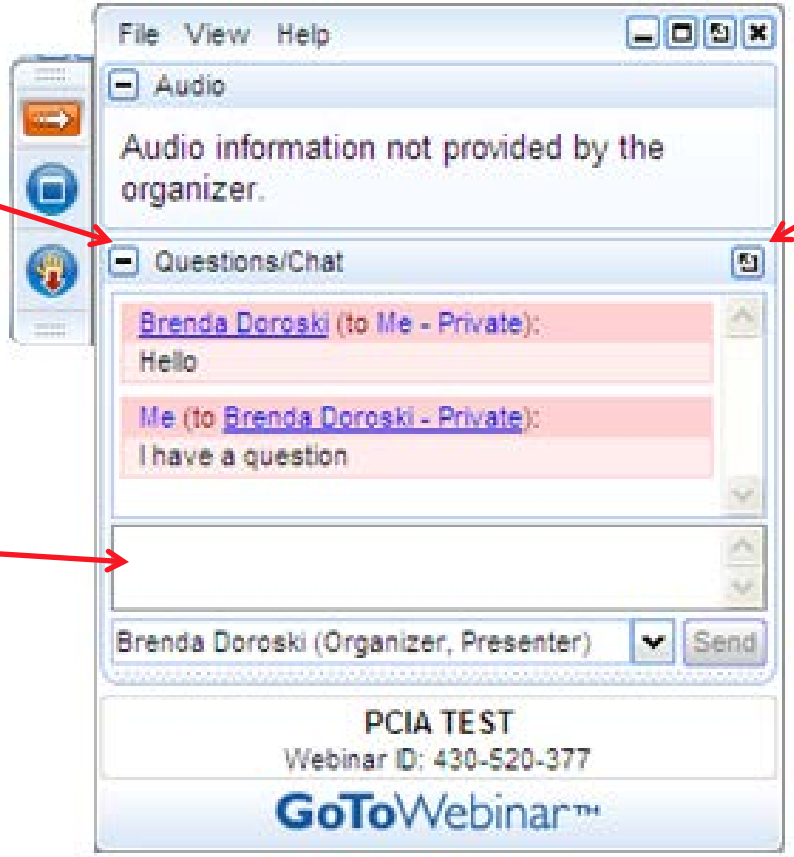
Maximize or Minimize



Pop-Out Feature

Type your question here, then click send

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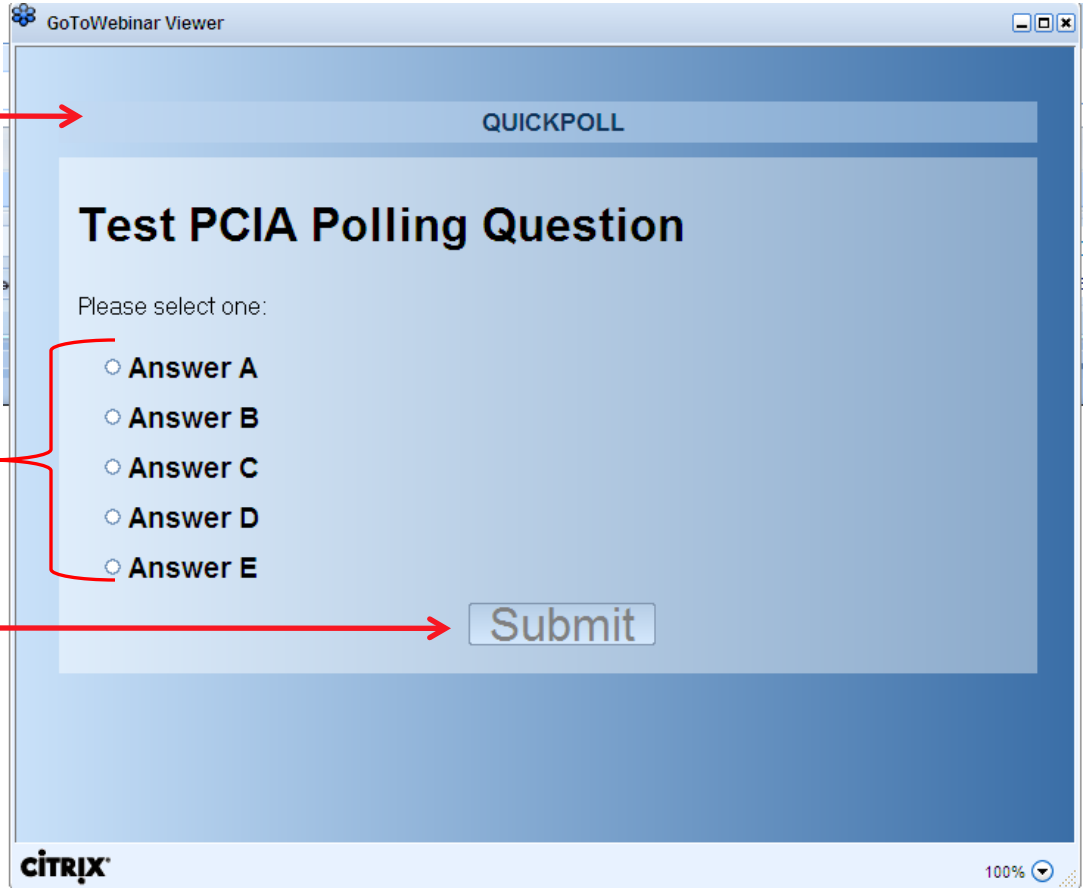
Using the Webinar Polling Technology

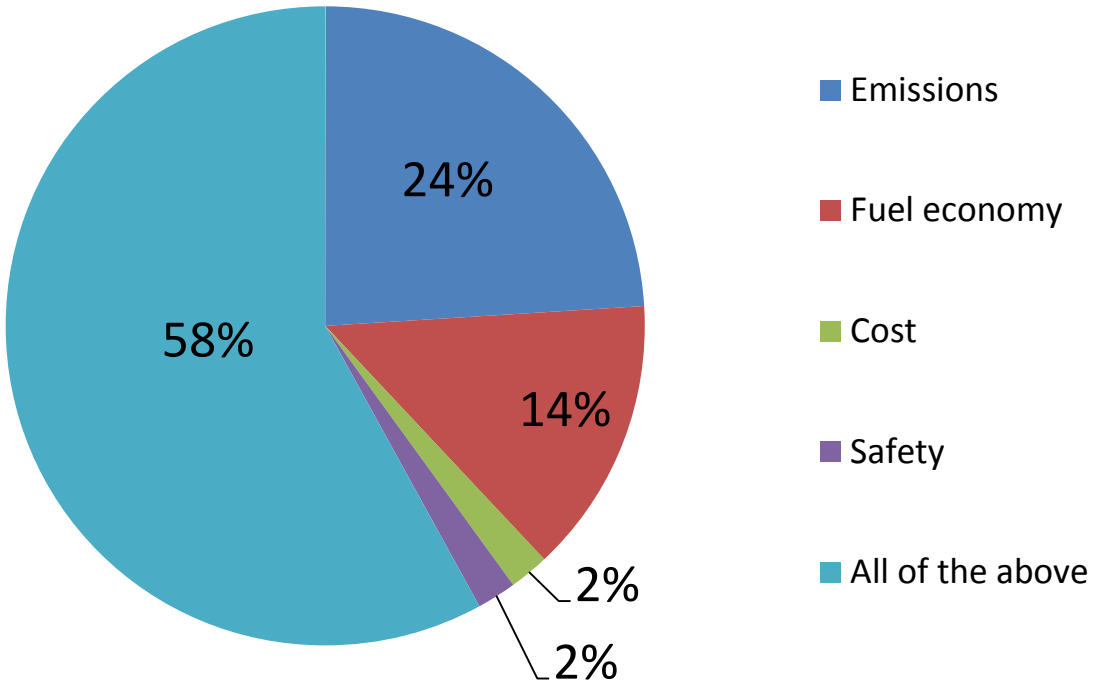
The question will be listed here

Select one answer and then click "submit"



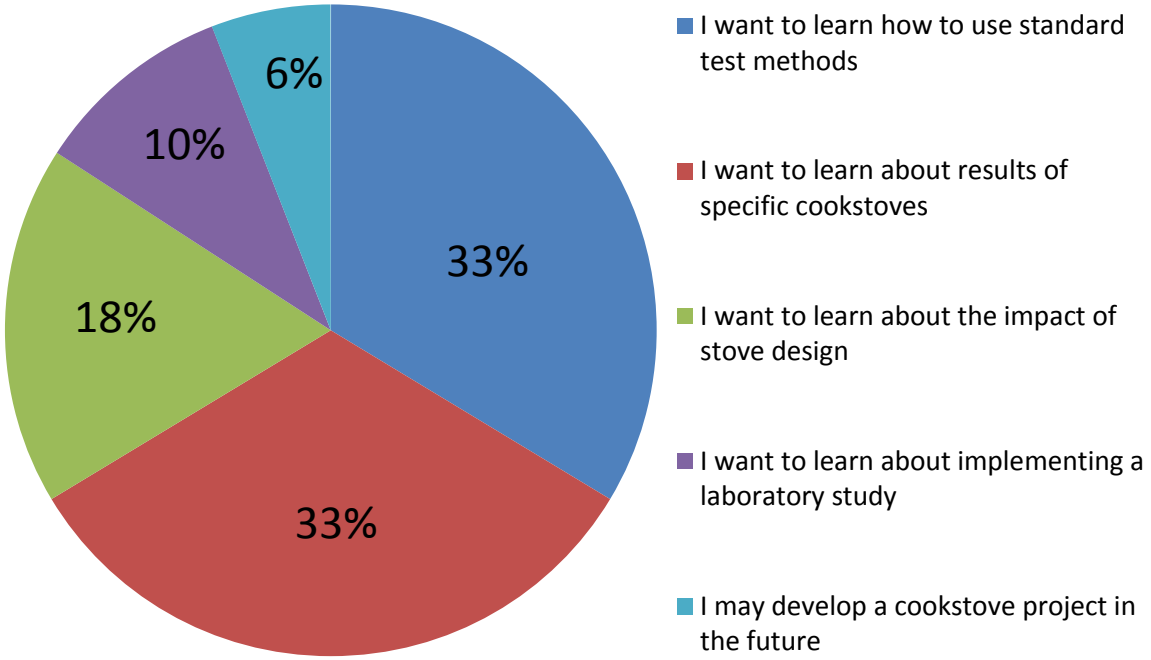
Audience Snapshot

Which of the testing results to be presented in this webinar are you most interested in?



Audience Snapshot

Please explain your reasons for attending this webinar.



Agenda

- PCIA Stove Performance Resources
- Overview of laboratory cook stove study
- Goals for implementing a laboratory study of stove performance
    - Results and uses
    - Surprises and biggest challenges
- Interact/Q&A with the presenters

Stove Performance Testing Protocols

- Water Boiling Test (WBT):

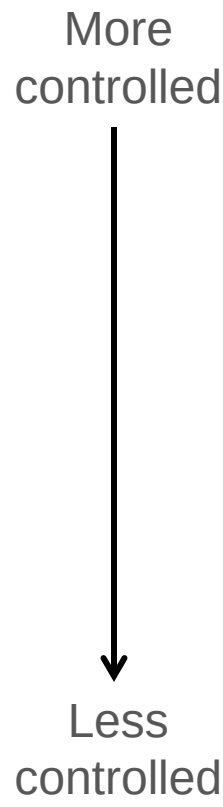
  Tests stove performance to boil and simmer water. Tool for evaluating stove design as well as comparing different stoves using a common protocol.

- Controlled Cooking Test (CCT):

  Tests stove performance preparing common foods cooked by local people in a controlled setting. Designed to assess the performance of the improved stove relative to what it is primarily meant to replace.

- Kitchen Performance Test (KPT):

  Tests stove performance in real-world settings. Directly measures daily household fuel consumption.



Protocols online at http://www.pciaonline.org/testing

Polling Question

If you currently have an improved cookstove program, have you tested the cook stoves you are promoting?

- Yes, using the WBT
- Yes, using another testing protocol (CCT, KPT, other)
- No
- I do not currently have an improved cookstove program

Polling Question

What stove performance test protocols have you used?

- WBT
- CCT
- KPT
- Other
- N/A

PCIA Webinar/Workshop Resources

- Stove Test Results Webinars:
  - Impacts of Household Fuel Consumption for Biomass Stove Programs in India, Nepal and Peru
  - EPA Lab Test Results for Household Cook Stoves
  - Monitoring Fuel Use with the Kitchen Performance Test
- Stove Design and Performance Workshops:
  - Rwanda, Laos, Bangladesh
  - Philippines, Burkina Faso, Indonesia

http://www.pciaonline.org/proceedings

Other PCIA Resources

- Test Results of Cook Stove Performance
- Solid Fuel Household Cook Stoves: Characterization of Performance and Emissions
- Design Principles for Wood Burning Cookstoves (revised June 2006)
- PCIA Bulletin Issue 21 - Stove Testing Protocols, Facilities and Standards Development

http://www.pciaonline.org/resources

Questions to Consider

- How satisfied are you with your organization's ability to measure the performance of the stoves that you promote?
- How satisfied are you with your stove's overall performance?
- What ideas do you have for using stove testing results to improve your stove's performance?

Study Introduction

- Testing of 50+ cookstove designs for efficiency and emissions was conducted from 2003-2010 at the Aprovecho Research Center in Cottage Grove, Oregon.
- The Water Boiling Test was used with:
  - An emissions collection hood and real-time emission measurement, AND
  - A test kitchen with IAP measurements
- Results are presented in two documents:
  - **Test Results of Cook stove Performance**
    - Found at http://pciaonline.org/files/Test-Results-Cookstove-Performance.pdf
  - **Fuel use and emissions performance of fifty cooking stoves in the laboratory and related benchmarks of performance**
    - Published in Energy for Sustainable Development 14 (2010) 161–171
    - Previous email included temporary link for participants

Study Goals

- Investigate Heat Transfer and Combustion Efficiency of different stove designs
- Understand design factors that lead to improved efficiency
- Compare designs from different regions operating under the same conditions
- Observe how/when/where/why emissions are produced
- Use of WBT as an iterative design process tool

Stoves Tested

Wood-burning stoves without chimneys

3 Stone Fire

Ghana Wood

20L Can Rocket

Mud/Sawdust

VITA Stove

Wood-burning stoves with chimneys

Justa Stove

Uganda 2-pot

Patsari Prototype

Onil Stove

Ecostove

Stoves Tested

Wood-burning stoves with electric fans

Wood Flame

Wood Gas

Charcoal stoves

Mali Charcoal

Gyapa Charcoal

Liquid-fuel stoves

Propane

Alcohol - Clean Cook

Kerosene

Solar cooker

Parabolic Solar Cooker

Polling Question

What type of stove/fuel does your organization promote?

- Biomass stove (e.g., wood, charcoal, briquette)
- Coal stove
- Liquid or gas fuel stove (e.g., ethanol, kerosene, LPG)
- Solar
- Other

Laboratory Test Parameters

- Fuel: Kiln-Dried Douglas Fir
  - monitored moisture content between 6-15%
  - 1X1.5X30 cm sticks
- Water: 5 Liters in the International Standard Testing Pot
  - 7-Liter capacity, 20-cm diameter, flat bottom, no lid
- Careful, consistent, constant tending to allow each stove to perform at its best
- Each stove was tested 9 times: 3 times for fuel use only, 3 times under the hood, and 3 times in the test kitchen

Test Method

- Used the WBT (Water Boiling Test), available at: www.pciaonline.org/testing
  - This study used the 2003 version
  - Minor consensus-based revisions over the past few years have led to the current Version 4.0
- Measured emissions during each phase of WBT protocol (cold start, hot start, simmer)
  - Kitchen tests were a shortened WBT, with hot start omitted and simmer shortened to 30 minutes
  - Griddle stoves were tested using 2 pots of water on the griddle, which is not the intended use of the griddle, but does indicate heat transfer

Emissions Testing Method

Direct/Hood Method

- All emissions collected under hood and measured in real-time using:
  - Nephelometer for PM
  - City CO sensor
  - Telaire CO_2 sensor
  - Enerac 2000E

Indirect/Kitchen Method

- Stove operated in a test kitchen with consistent ventilation while monitoring air concentrations using:
  - HOBO CO monitors
  - Buck gravimetric pump and filter system for PM

Emissions Testing Equipment

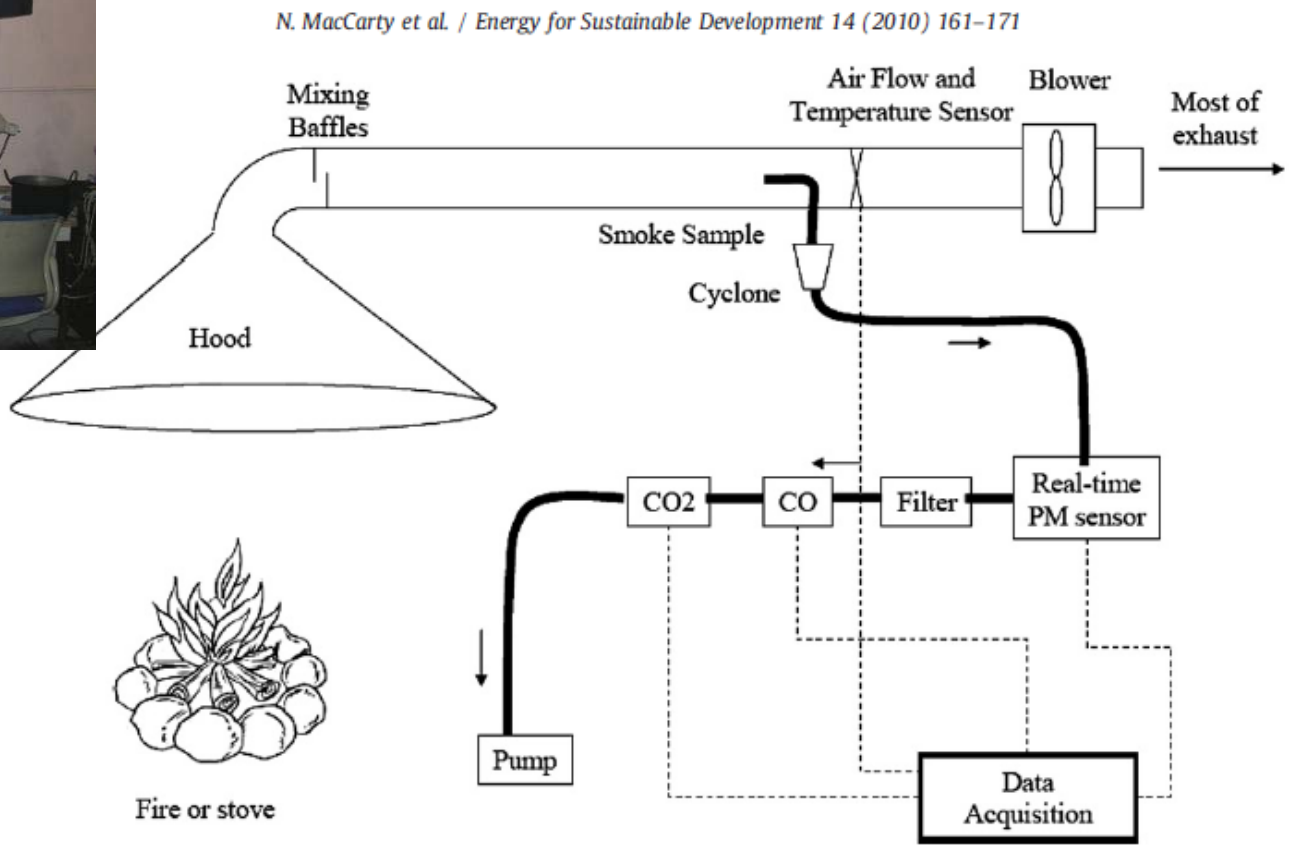


Fig. 1. Emissions measurement schematic (Source: ETHOS Technical Committee, 2009).

Stove Reporting

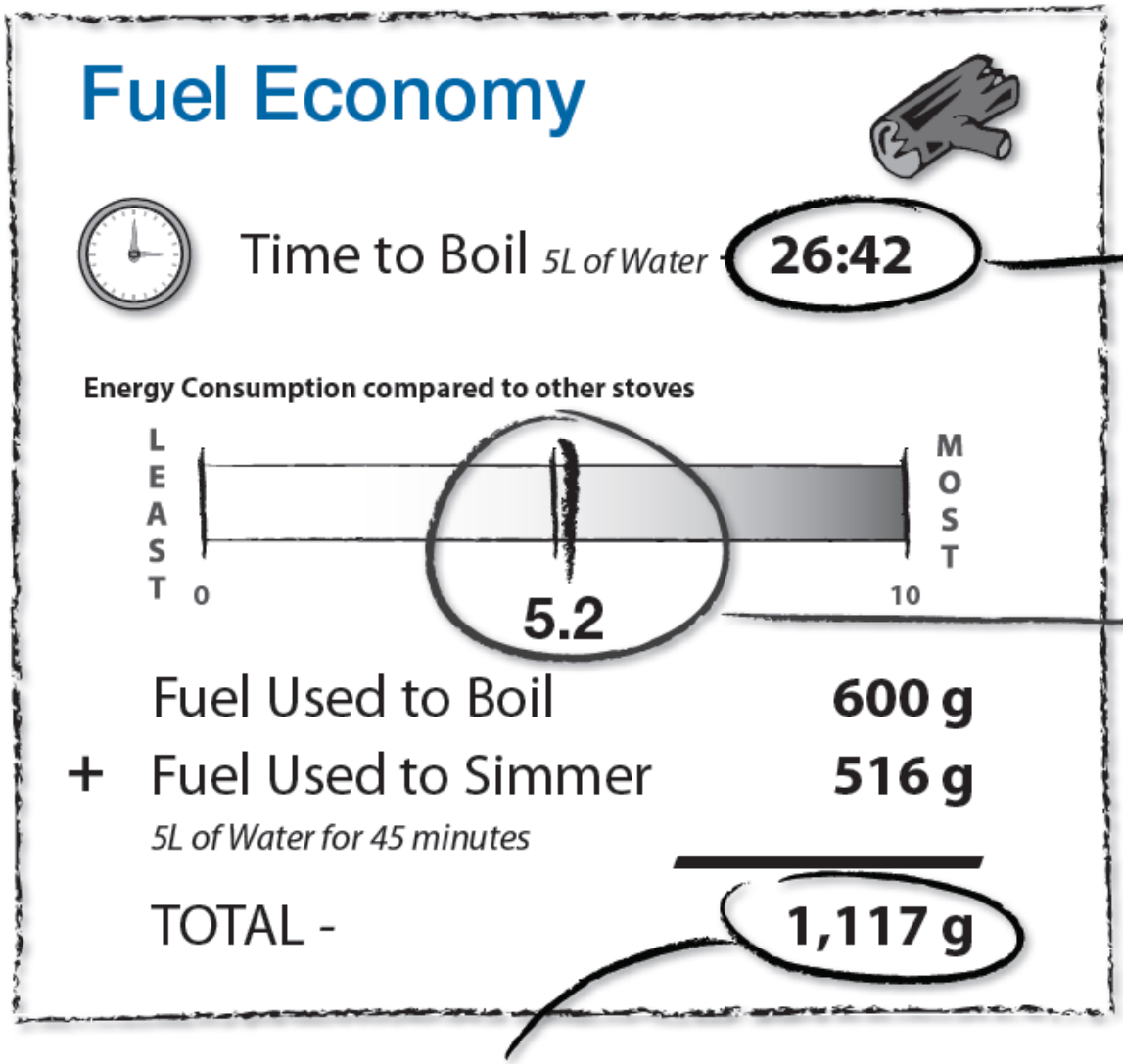
- Time to Boil
- Fuel/Energy used to boil and simmer 5L of water
- For measured carbon monoxide (CO) and particulate matter (PM), we report:
  - Emissions per task (mass per liter boiled and simmered)
  - Average IAP concentrations in kitchen (mass/volume)
- Safety
- Cost to purchase/build

Strengths of Laboratory Results

- WBT results can be used for:
  - Designing cook stoves
  - Comparing performance of stoves under the same operating conditions
  - Screening stoves for field trials
- Fine-Tuning stove designs
- "Benchmarking" stove designs/setting performance targets
- Teaching us how to IMPROVE stove performance then cooks finish design process!
- Design Principles for Wood Burning Cookstoves:
  - http://pciaonline.org/design-principles

Limitations of Laboratory Results

- Results are specific to the standard testing conditions – **does not** predict how stove will perform in-field
  - Stoves must be carefully tended
  - Different cooking needs & techniques will yield different results
  - Still, excellent for side-by-side comparison
  - If a stove does not work in the lab, it will not get any better in the field!
- Griddle stoves can boil water, but it is not their primary purpose.



Time to Boil *5 L of water (expressed in minutes:seconds). The total time is an average of the cold and hot start phases of the Water Boiling Test.*

Energy Consumption *rating is how much energy is used to complete a cooking task. Different fuels can be compared on the basis of energy used. A rating of 1 would mean the stove used less energy compared to a stove that received a higher rating.*

Total *amount of fuel used to bring 5L of water to a rolling boil and then to simmer the water for 45 minutes. The fuel is weighed before and after each test phase to determine the amount of fuel used for each task.*

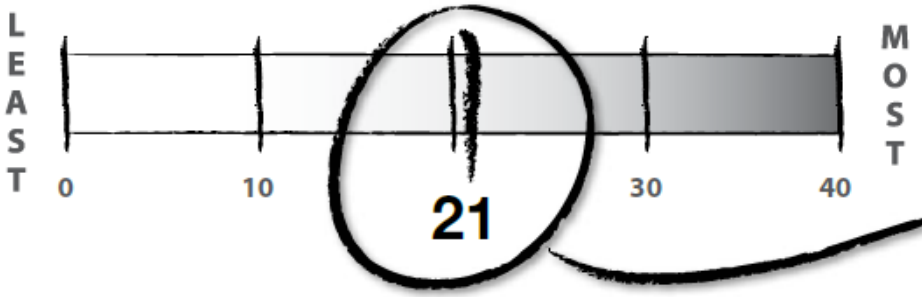
Cost and Safety

Cost = **$ 0.00**

Fuel Use = **100 kg**

estimated per month

Safety Rating

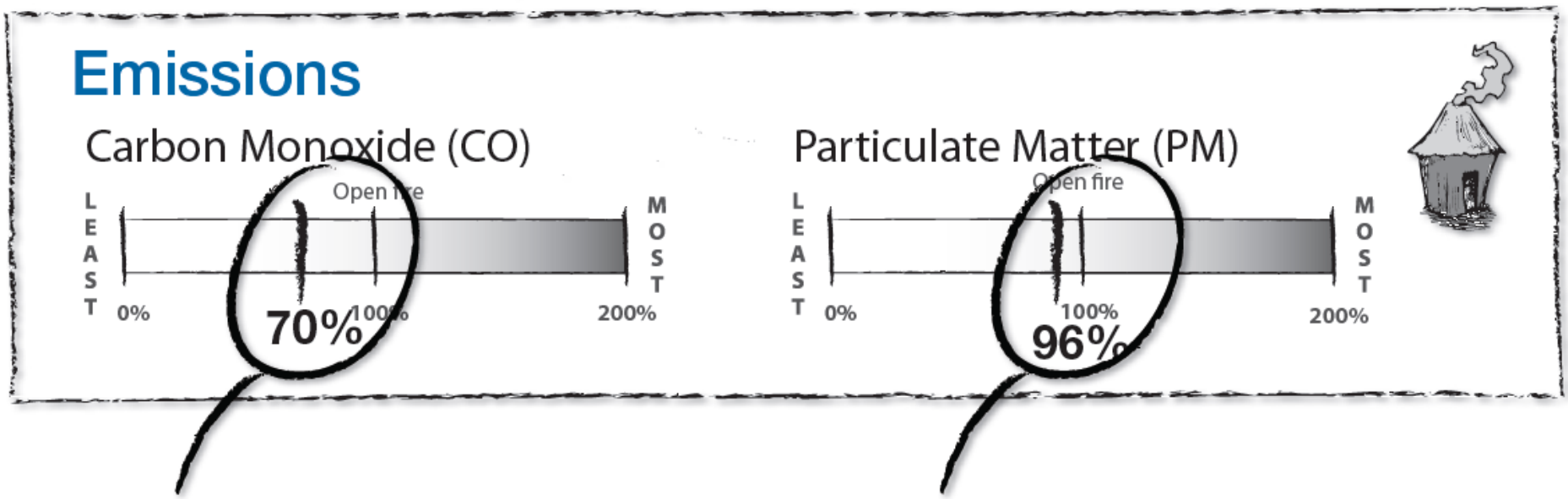


*The **Cost** of buying or building the stove is shown in U.S. dollars.*

***Fuel Use** is the amount of fuel used to bring 5 L of water to a rolling boil and simmer it for 45 minutes twice a day for one month (30 days). This number can be used to compare the monthly costs of operating the stoves based on local fuel costs.*

*The **Safety Rating** is determined by evaluating the stove in multiple categories such as the likelihood of tipping, burns, fire spreading and sharp edges on a scale of zero to 40 points. Appendix B includes the detailed safety evaluation methods.*

Emissions



*The **Carbon Monoxide (CO)** and **Particulate Matter (PM)** ratings show the average relation between stoves based on pollution-level data collected from the test kitchen. The CO and PM averages are based on three tests done in the test kitchen. Percentages were calculated relative to an open fire.*

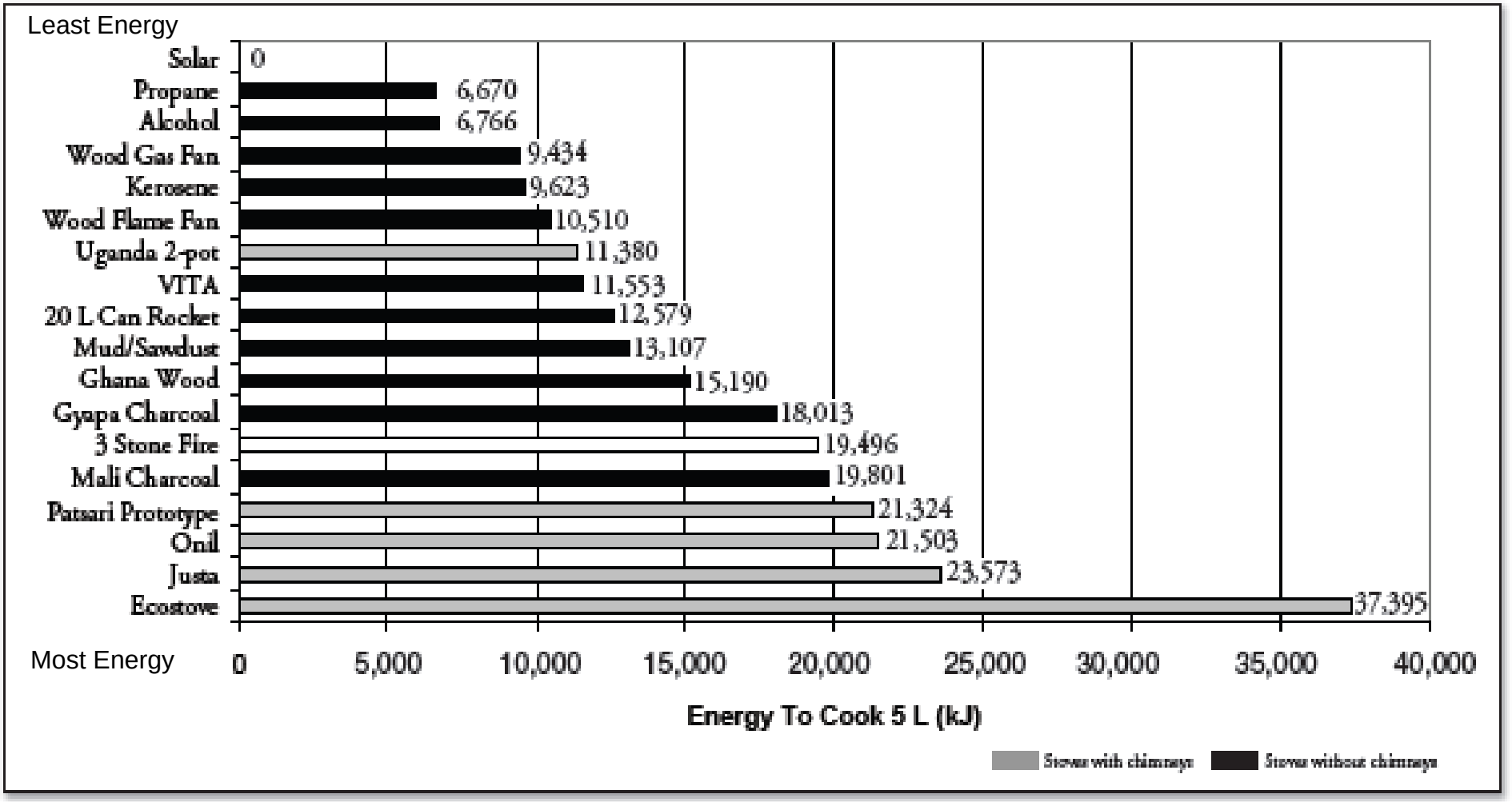
Polling Question

How have you used your stove testing results?

- To improve the overall performance of your stove
- To guide the design of future cook stoves
- To compare the performance of stoves under the same operating conditions
- To benchmark stoves before field trials

3. Energy to Cook

Boil and Simmer 5 L of water for 45 minutes



Energy Use

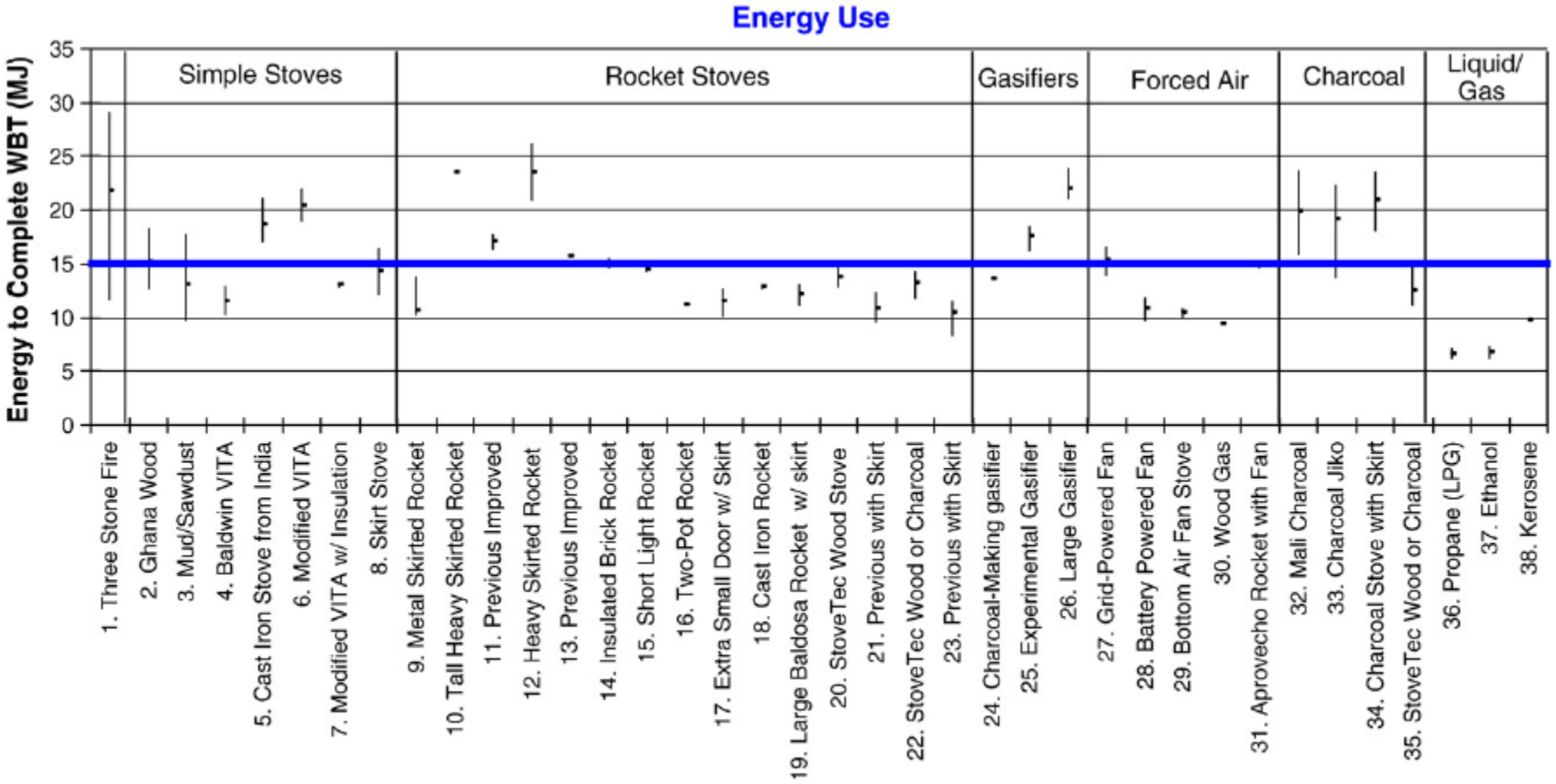


Fig. 3. Energy Use for Stoves without Chimneys to Complete the WBT (Mega Joules). Suggested Fuel (Energy) Use Benchmark: The improved cook stove should use less than 15 MJ of energy to complete the 5-l WBT.

CO Emissions

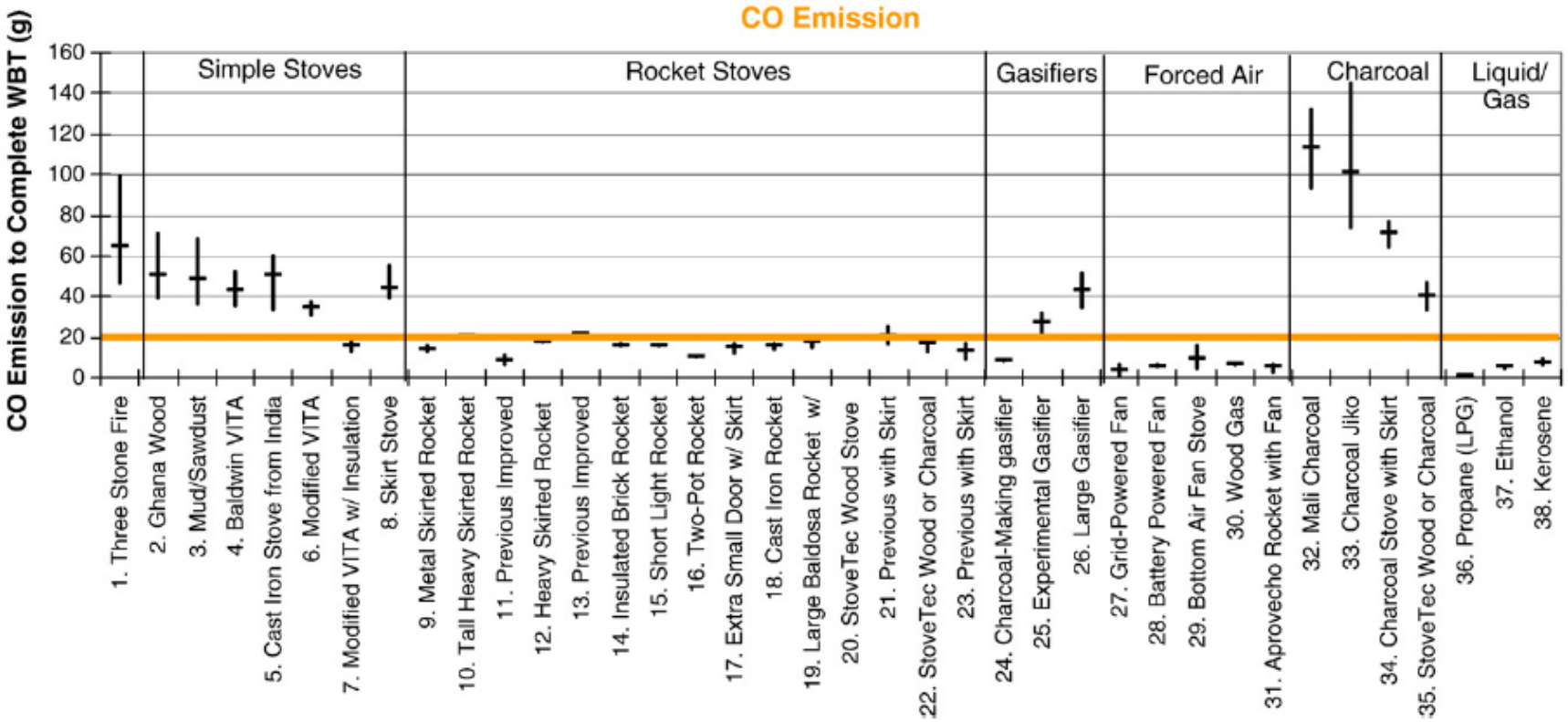


Fig. 4. Carbon Monoxide Emissions to Complete WBT (grams). Suggested Carbon Monoxide Emission Benchmark: The improved cook stove should emit less than 20 grams of carbon monoxide to complete the 5-l WBT.

PM Emissions

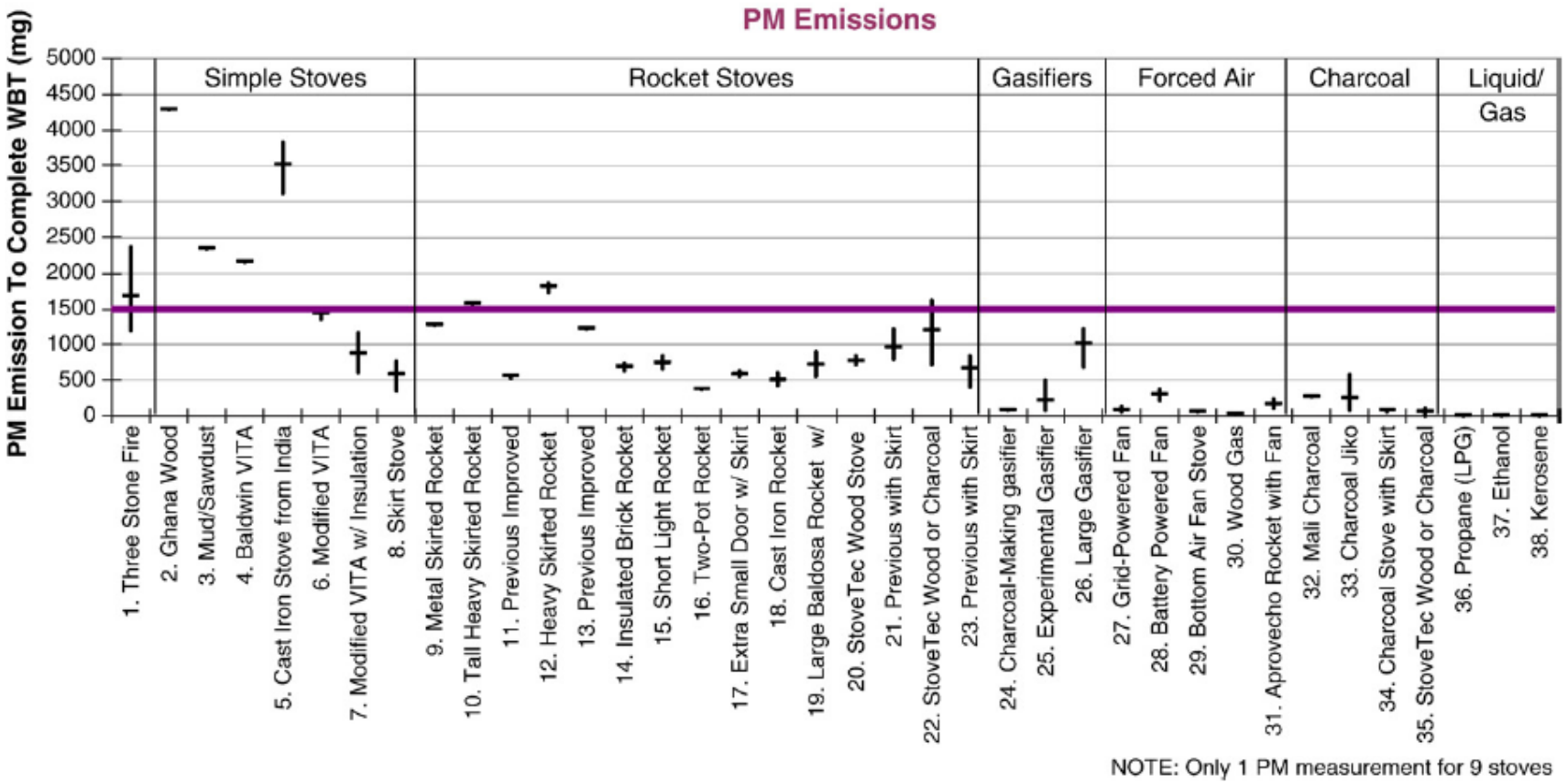
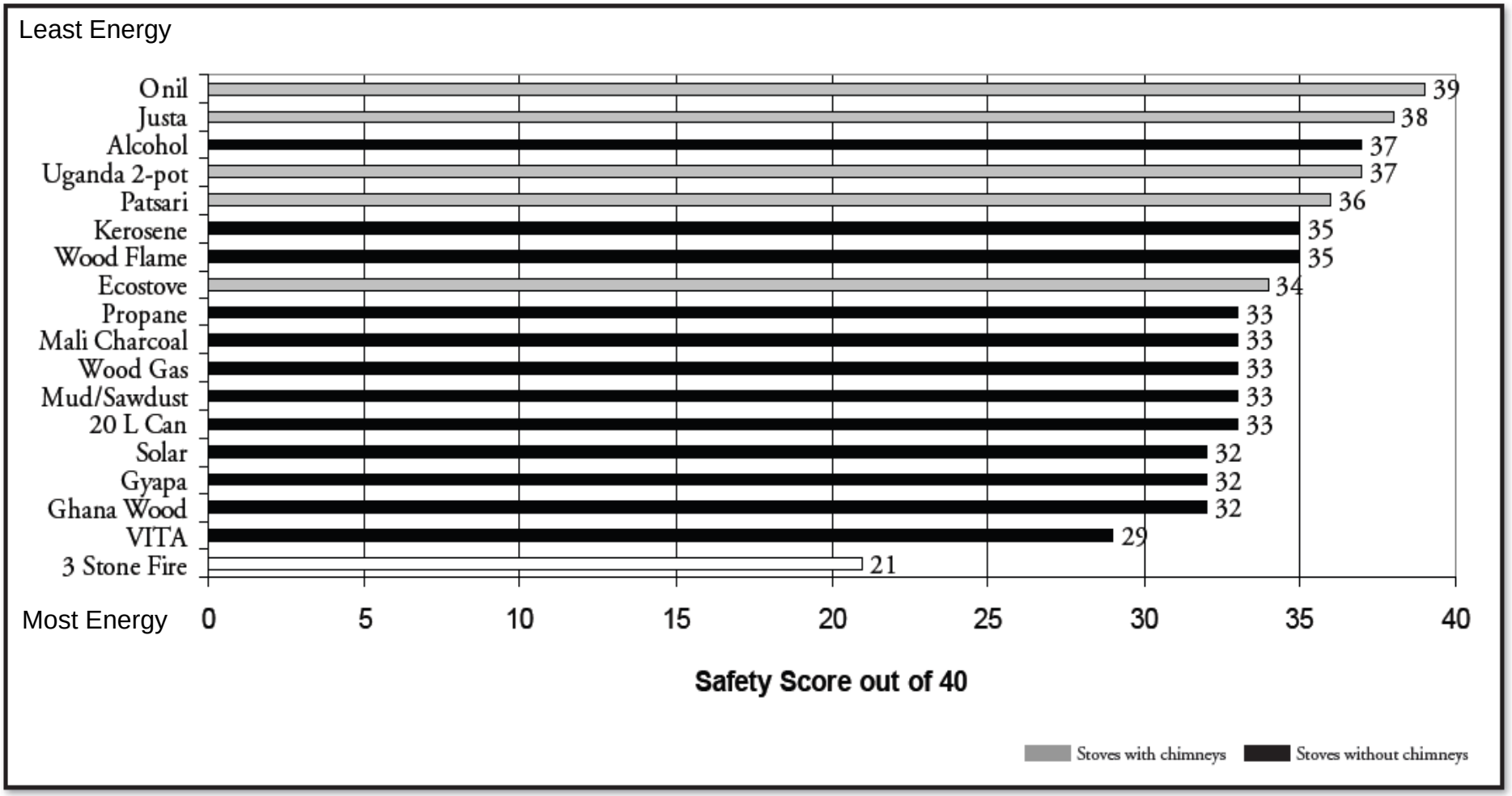


Fig. 5. Particulate Matter Emissions to Complete WBT (milligrams). Suggested Particulate Matter Emission Benchmark: The improved cook stove should use emit less than 1500 mg of particulate matter to complete the 5-l WBT.

6. Safety Ratings

Evaluated on 10 criteria (see Appendix)

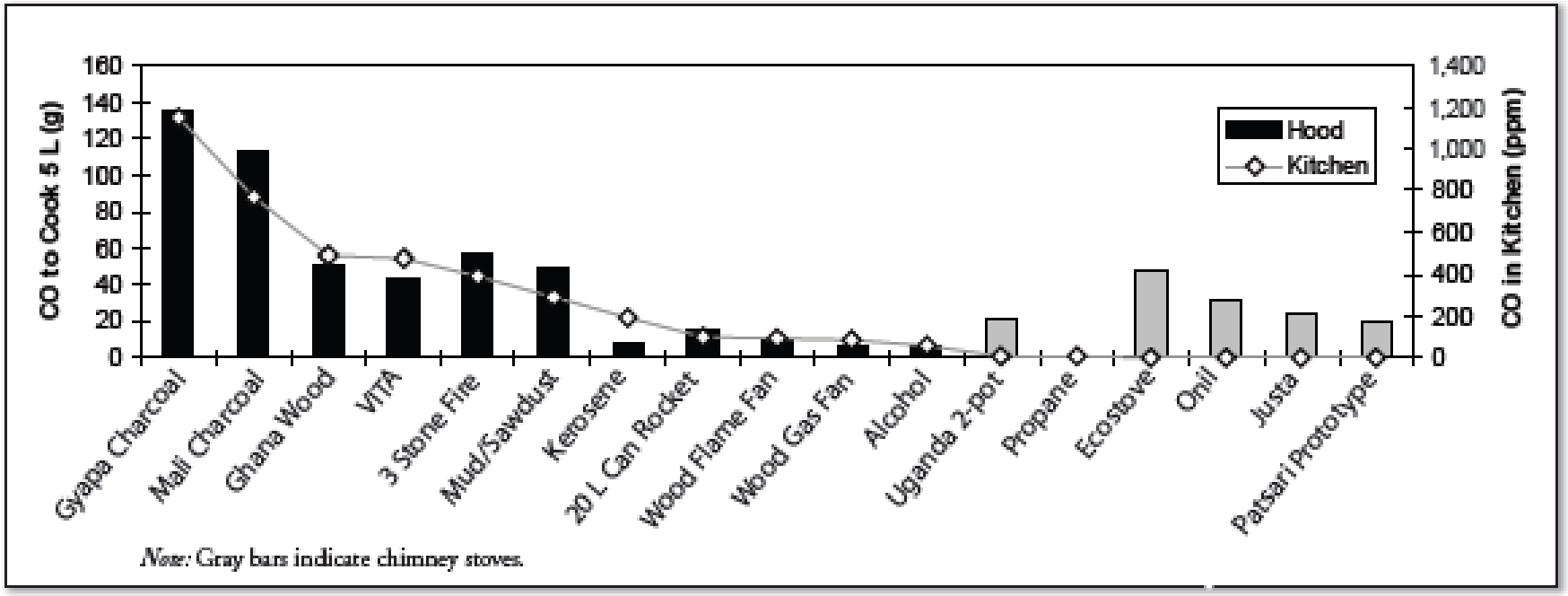


Learning from Improved Stoves

Study Results – Key Findings

Comparison between hood and kitchen results

Figure 47 - CO to cook 5 L under emissions hood and average CO Level in test kitchen



Study Results – Key Findings

Effect of adding a chimney

Figure 14- Comparison of non-chimney and chimney stoves

	Average No Chimney	Average Chimney
Time to Boil	19 min	33 min
Fuel to Cook	870 g	1,400 g
CO in Kitchen	340 ppm	3 ppm
PM in Kitchen	18,000 µ/m³	280 µ/m³

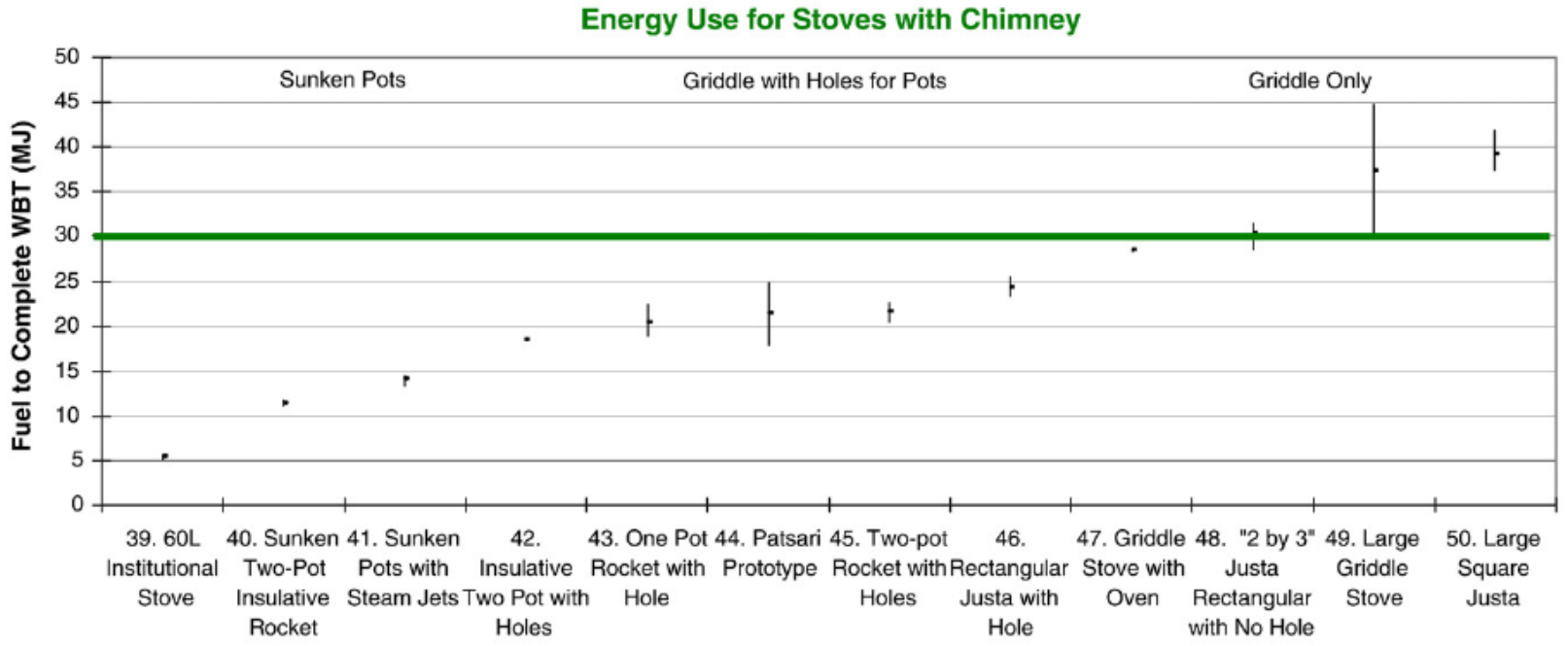
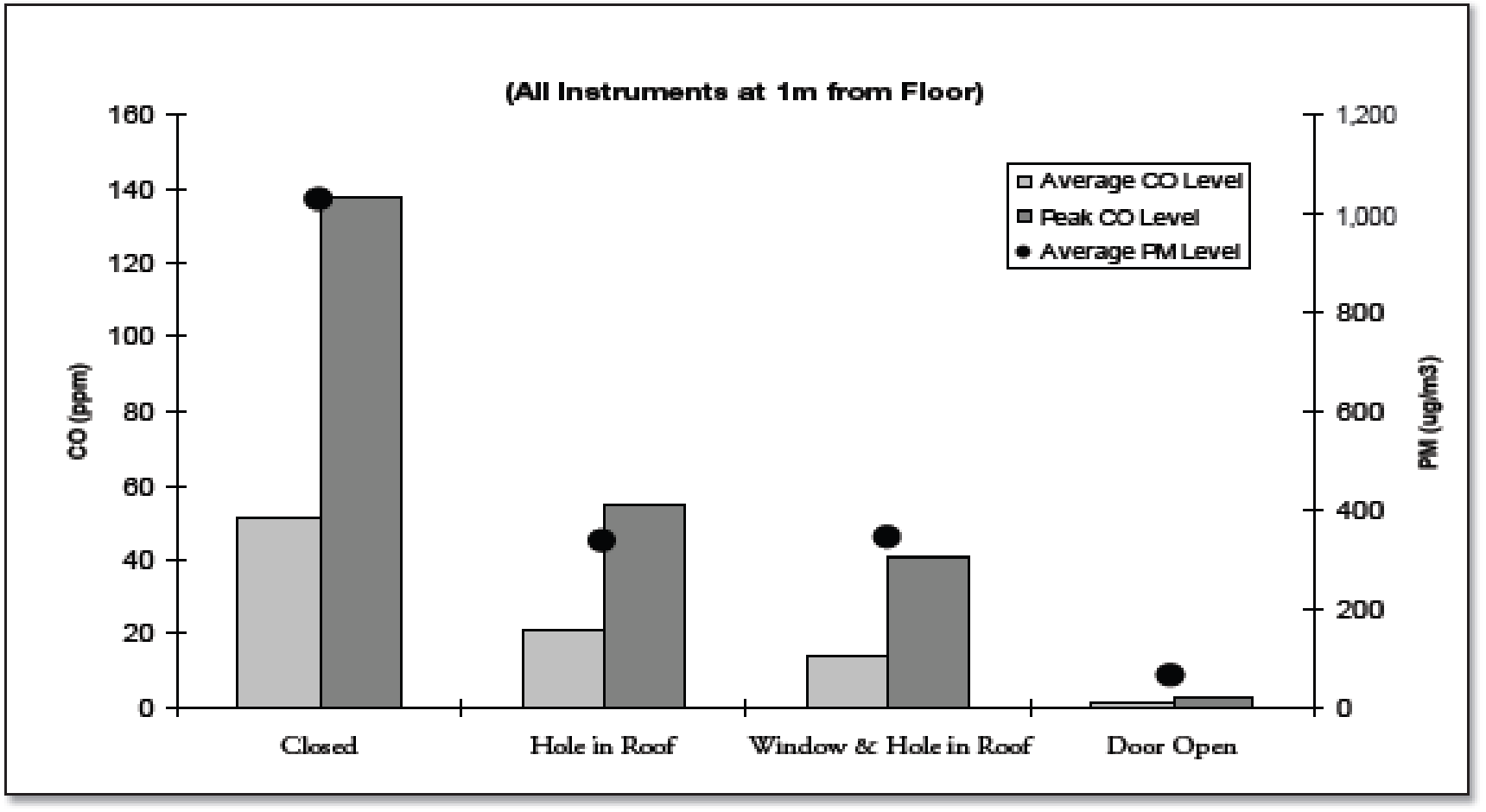


Fig. 6. Energy Use to Complete WBT for Chimney Stoves (Mega Joules). Suggested Fuel (Energy) Use Benchmark for Stoves with Chimney: The improved cook stove with chimney should use less than 30 MJ of to complete the 5-l WBT. Wood burning stoves with chimneys are exempt from the emissions standards for non-chimney stoves if the chimney stove does not allow more than an average of 50 parts per million of carbon monoxide to pollute the air anywhere within 30 cm of the stove.

Study Results – Key Findings

Effects of ventilation on emission levels in a test kitchen

Figure 19 - CO and PM in the test kitchen with differing ventilation



Study Challenges

- First biggest challenge was enabling the emissions instruments to run and compute properly
  - *After a great deal of effort and assistance from Dr. Tami Bond, we used lessons learned to develop the Portable Emissions Measurement System (PEMS) to allow labs around the world to have the same essential testing capability for less cost and effort*
- Second challenge was significant results: Learning how to operate stoves optimally

Conclusions: What works best?

- Functional Chimneys
- Providing an insulated space above the fire for mixing of flame, gases and smoke
- Forcing hot gases against much of the pot
- Adding forced-air/fans

Conclusions: Stove Design and Performance

- Categories of stoves perform differently
- Stoves in categories are better and worse
- Design Principles improve stoves in all categories
- Emission hood allows improvement in all categories

Improving Testing Methods: Recommendations

- Using the WBT and CCT together will help us improve study methods.
- Results compare very well with tests at other labs:
  - Saw good agreement with the same stoves tested by Jim Jetter at the EPA Lab:
    - Jim's PCIA Webinar: http://pciaonline.org/proceedings/webinar-epa-lab-test-results-household-cook-stoves
    - Jim's Article: Solid-Fuel household cook stoves: Characterization of Performance and Emissions, Biomass and Bioenergy 33 (2009)
  - Also good agreement with several other labs on single stove tests

Moving Forward: Recommendations

- Easy to use, accurate emissions testing equipment is essential
- The WBT/CCT combination seems vital to understanding, developing, and benchmarking improved stoves
- The flow of information should penetrate the project from ‘top to bottom’
- Any testing is much better than no testing, and is essential before manufacturing

Considerations…

- “You don’t get what you expect -- You get what you inspect” – Dr. Kirk Smith
- There are currently some good stove designs that come close to or meet the goals of reduced fuel use, reduced emissions, cleaner indoor air, and improved safety… and with more testing and development further improvements can be made
- The iterative design approach under the emissions hood (WBT) directly coupled to consumer requirements (CCT) results in successful stoves

Question and Answer

Please use your Question and Answer pane to type your questions for Dean and Nordica.

Any questions that are not answered during this time will be answered in the Question and Answer document that will be posted to http://www.pciaonline.org/proceedings.

What You Can Do

- Download the stove test reports and resources from the PCIA website.
- Initiate stove testing of your stove.
- Share the 2011 results of your household energy/health program with PCIA.
- Contact your regional testing center.
- Become involved in standards development.
- Look for opportunities to apply for field testing.
- Incorporate new information into your existing stove testing efforts.
- Participate in the March 13th stove testing webinar.
- Look for information on EPA's 3rd round of laboratory stove testing (starting this month).

Regional Stove Testing Centers

- Aprovecho Research Center - United States
- Asia Regional Cookstove Program (ARECOP) - Indonesia
- Centre for Research in Energy and Energy Conservation (CREEC)/Makerere University - Uganda
- China Agricultural University Energy Engineering and Low Carbon Technology Lab (EELC)/Renewable Resources Lab (RRL) - China
- Colorado State University Engines and Energy Conversion Lab - United States
- GERES - Cambodia
- Prakti Design Lab - India
- GIZ - Bolivia - Bolivia
- Prakti Design Lab – India
- SENCICO - Peru
- Sustainable Energy Technology And Research Centre (SeTAR) - South Africa
- Zamorano University - Honduras

Advancing Standards

PCIA / Alliance First ISO International Workshop on Clean and Efficient Cookstoves

- PCIA and the Global Alliance for Clean Cookstoves are jointly organizing the **first ISO International Workshop on the topic February 28-29, 2012 in Amsterdam, Netherlands**.
- Participation is encouraged from all stakeholder categories, including stove manufacturers, implementers, researchers, academics, stove testers, and other cook stove community members. A limited number of travel scholarships will be available.
- http://pciaonline.org/ISO-International-Workshop

Save-The-Date

Upcoming Webinar titled "**Results of Controlled Cooking Tests in Rwanda, Laos and Bangladesh**"

- March 13, 2012
- 11:00am to 12:30pm EST

More information to follow.

Webinar Follow-Up

Please let us know…

- What surprises you the most about what you heard from the laboratory results?
- What new information did you learn about the benefits of laboratory stove testing?
- Why did you choose to participate in this webinar?
- What other topics would you like to see presented?

Following the webinar …

- The presentation and answers to your questions from today will be posted to http://www.pciaonline.org