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Stove Performance Testing

Dhaka, Bangladesh
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Mike Hatfield – Aprovecho Research Center, USA

Aprovecho Research Center

Started in 1976

mission to “serve as a research and dissemination center for appropriate technologies”

This move was brought on by first large failure

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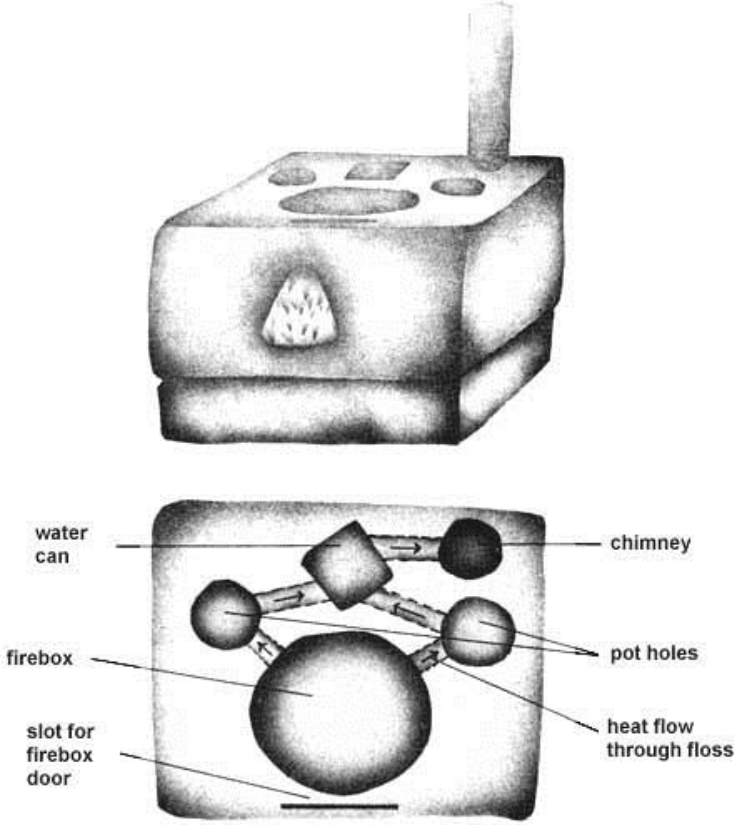
The Lorena Stove – Late 1970's



How the Lorena stove works

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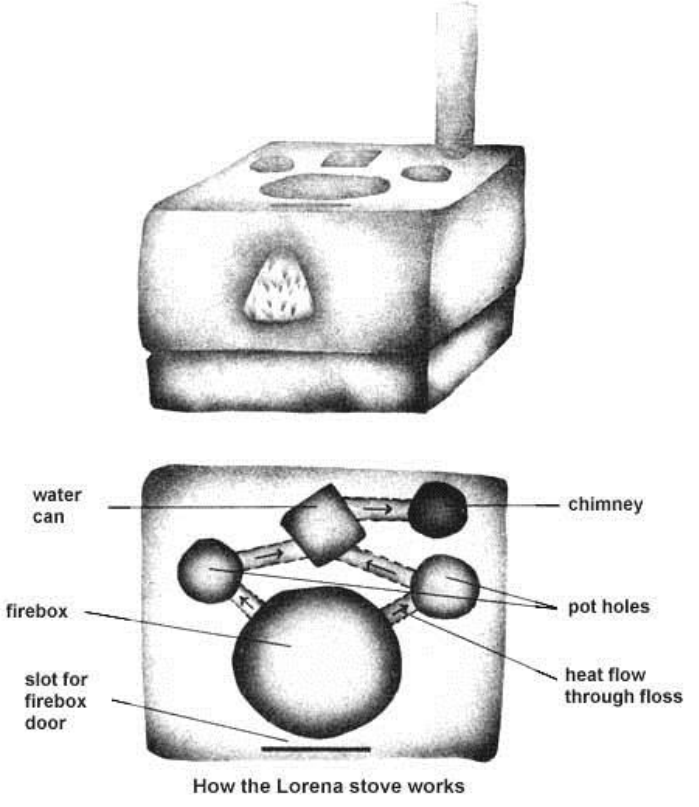


How the Lorena stove works

3 stone fire – as high as 20% efficiency

Lorena – as low as 4% efficiency

Our Task

To know health and fuel use impact of every stove we have distributed…

Millions of stoves…

Just that easy!!!!!

Why Test stoves?

Determine the impact of ICS projects using methods that are…

- Standardized and repeatable
- Comparable within and across projects
- Statistically sound

…but still appropriate and flexible enough to adapt to local circumstances and constraints!

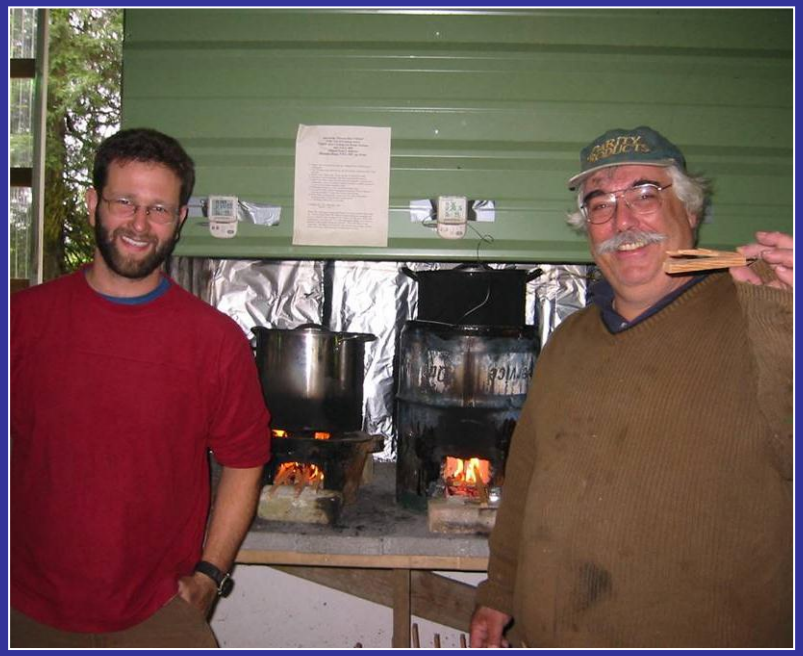
- Caveat: Monitoring is important but question of allocation of resources

And because everything…

Stove Performance Testing (SPT)

Past and present

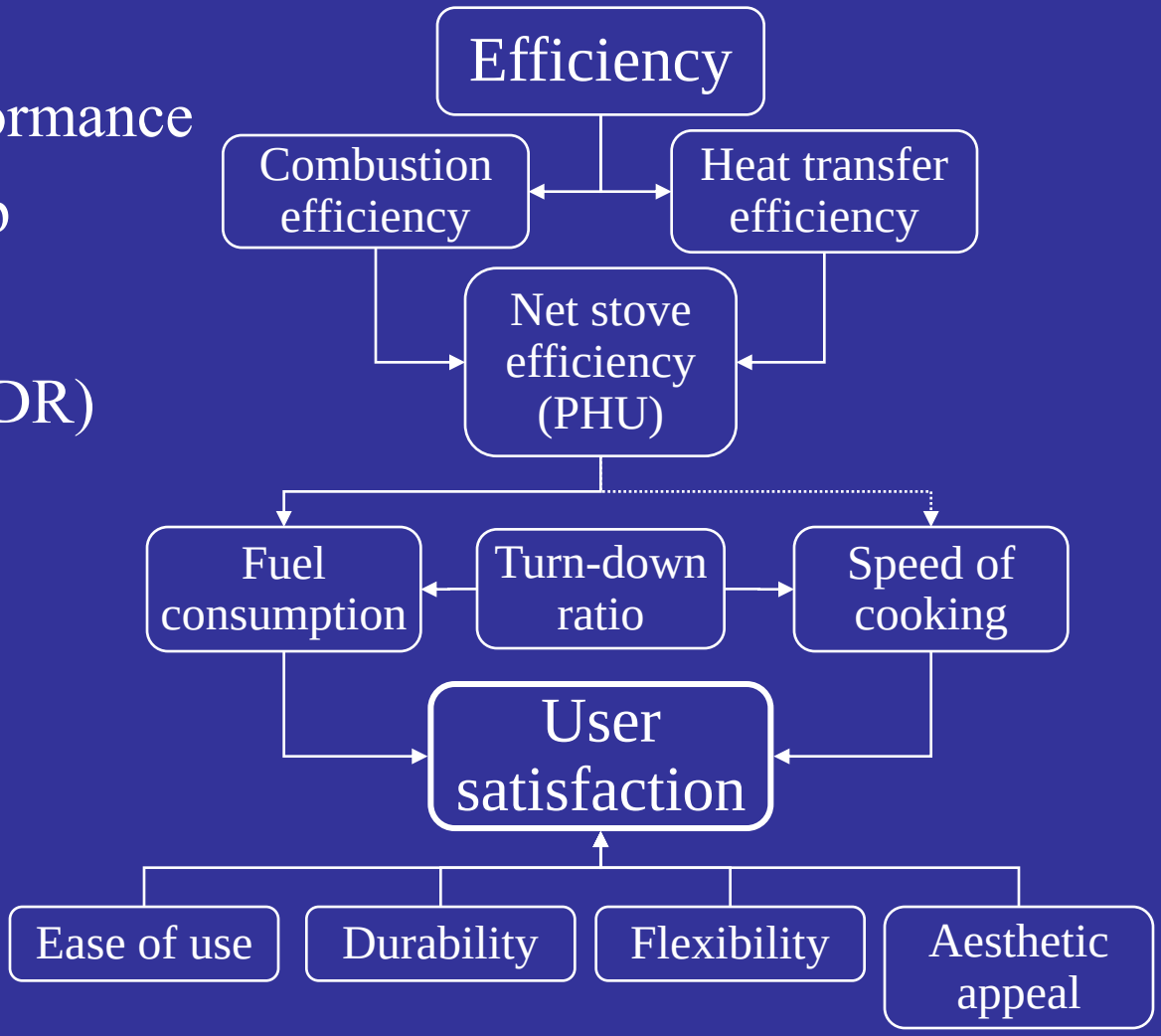
- In 1985 VITA developed a set of protocols for testing stove performance
- Functional, yet somewhat cumbersome and not generally used
- In 2003 Shell/EPA request UC Berkeley and Aprovecho to develop a new set of universally adopted SPT protocols



What is *Stove Performance*?

Measures of Stove Performance

1. Efficiency/exit temp
2. Fuel consumption
3. Turn-down ratio (TDR)
4. Speed of cooking
5. Emissions
6. *User satisfaction*

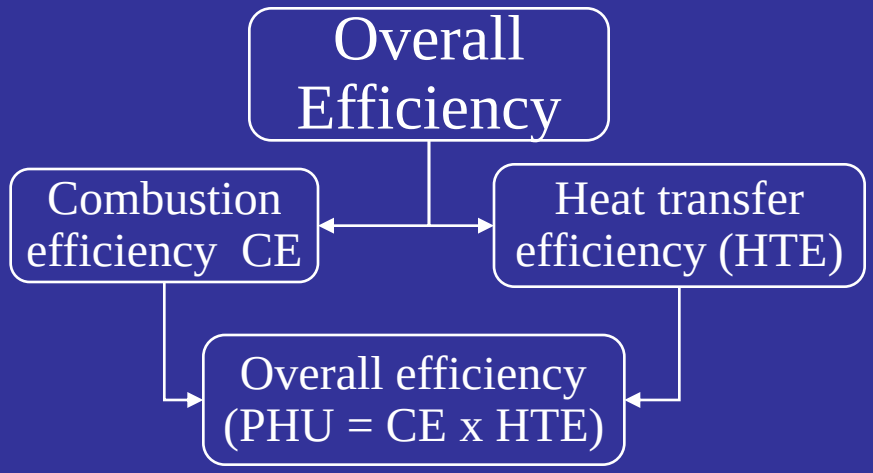


Measures of performance

1. Efficiency

Entirely lab-based

- Combustion efficiency
- Heat transfer efficiency
- PHU (Percentage Heat Utilized)



Measures of performance

1. PHU (Efficiency)
   - Fairly easy to measure directly (assuming fuel HV is known)

$$\frac{\text{Energy into the food (or water)}}{\text{Fuel energy consumed}}$$

Energy into food = energy it took to the rise in water temp (called sensible heat) + energy required to evaporate water (called latent heat)

Fuel energy consumed is found by taking the energy in the amount of wood consumed and subtracting the energy left in the charcoal*

Measures of performance

1. PHU
   - Fairly easy to measure directly (assuming fuel HV is known)

$$\frac{\text{Energy into the food (or water)}}{\text{Fuel energy consumed}}$$

So if we compare 2 stoves, the one with the higher PHU is the “better” stove right ?

Not necessarily! Because PHU rewards the stove that makes a lot of steam

Measures of performance

2. Specific Consumption- The amount of fuel needed to complete a particular task (example: boil a kilo of water, cook a kilo of food, or bake a kilo of bread, or bring to a boil and simmer for 45 minutes-simulated cooking task)

For us this is the most useful number to make a guess as to which stove will most likely save fuel in real use

$$\text{Specific consumption} = \frac{Mw - 1.5Mc}{Mf}$$

Specific Consumption vs. Efficiency

Stove 1

- Time to boil 10 minutes
- Wood burned 1000 grams
- Water vaporized 100 grams
- Water remaining 4.9 liters

Stove 2

- Time to boil 100 minutes
- Wood burned 1000 grams
- Water vaporized 1000 grams
- Water remaining 4.0 liters

Specific Consumption vs. PHU

Stove 1	
Time to boil	10 minutes
Wood burned	1000 grams
Water vaporized	100 grams
Water remaining	4.9 liters

Stove 2	
Time to boil	100 minutes
Wood burned	1000 grams
Water vaporized	1000 grams
Water remaining	4.0 liters

Eff= 9.9 %	Eff= 21.3%
SC = 204 grams/liter	SC = 250 grams/liter

Measures of performance

3. Turn-down ratio (TDR) or Control efficiency

- For the most part cooking has two parts
  - a- high power (bringing to a boil)
  - b- low power (simmering)

- TDR is ratio of high to low power

Measures of performance

3. Turn-down ratio (TDR) or Control efficiency

- High TDR (a large difference in fuel consumption between boiling and simmering phase) is a good indicator that the stove will use less wood

- Stoves with large TDRs may be more preferable to users

Measures of performance

4. Speed of cooking

This is more a measure of user friendliness than fuel consumption

Time to boil (WBT)

Time to cook (CCT)

Measures of performance

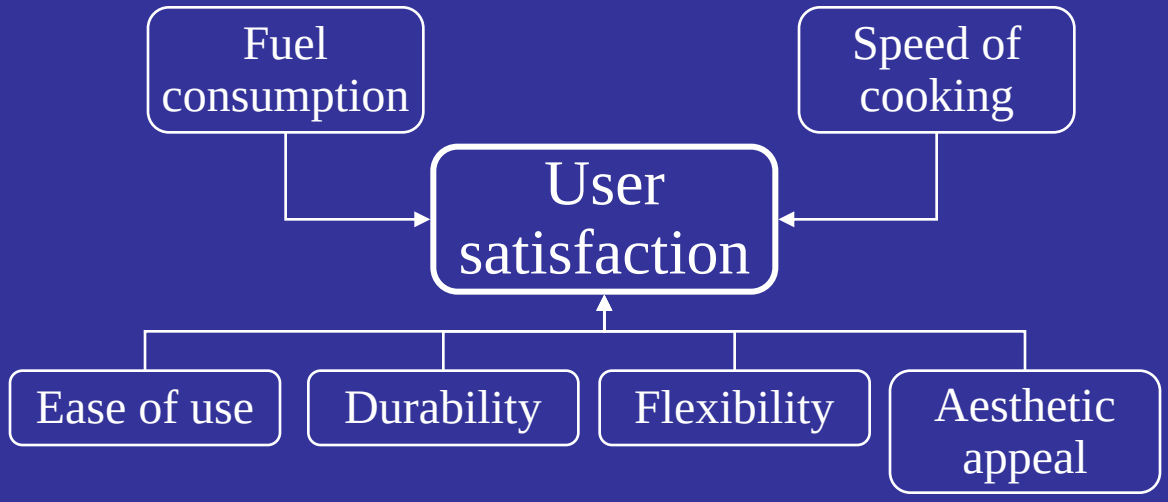
5. Emissions

Testing of emissions/exposure/dose is a much less exact science without proper equipment

With PEMS/IAP meter we hope to make this more accessible

Measures of performance

6. Overall User satisfaction
   - Hard to measure, subjective, and dependent on many factors



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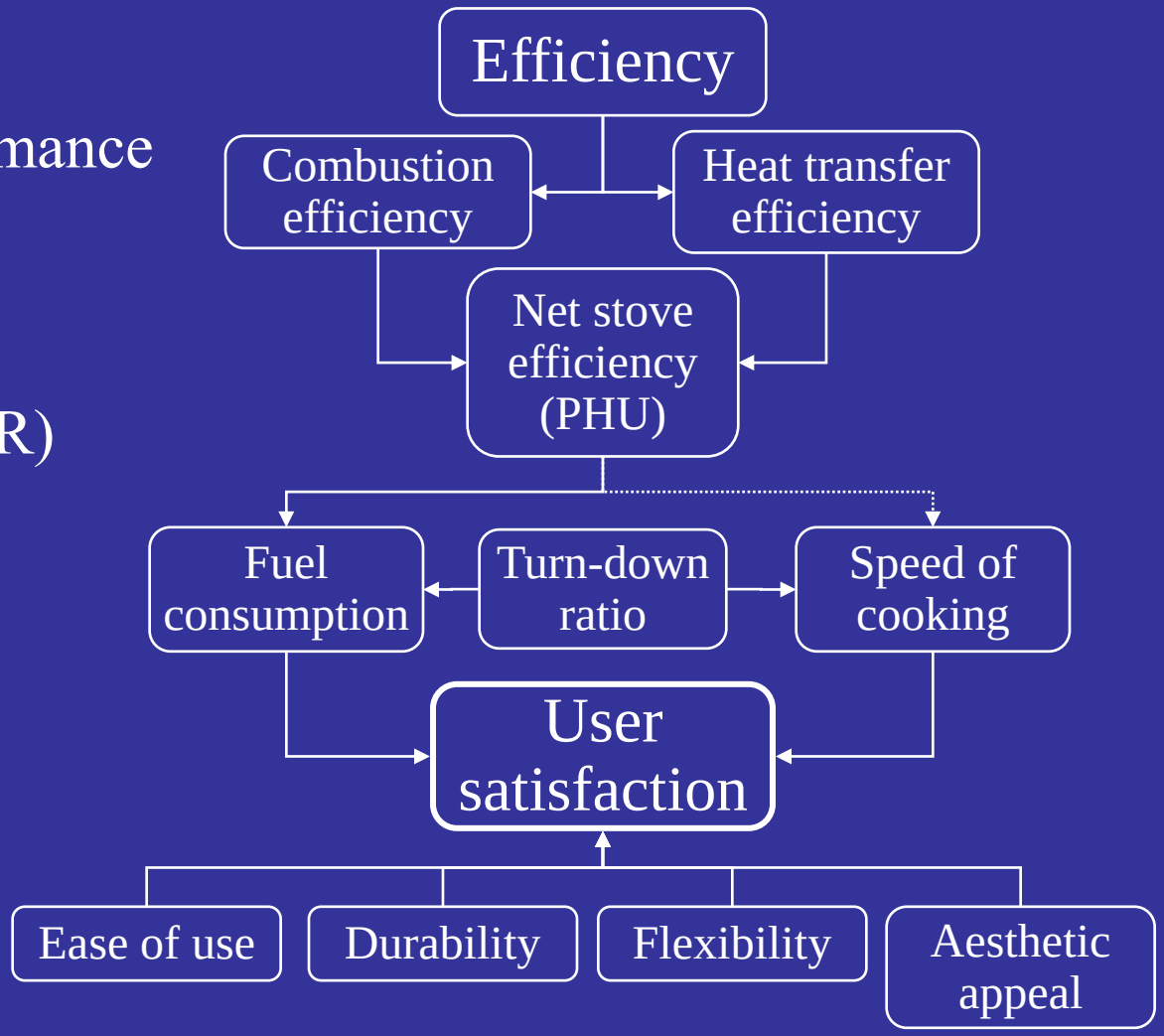


Testing Options

1. Water Boiling Test
2. Controlled Cooking Test
3. Kitchen Performance Test

Water Boiling Test

1 - Based largely on VITA (1985) and Baldwin (1986) with small modifications

- **Limits variables**
- **Transferable between various projects**

Lab-based test provides 4 of the 6 indicators of SP:

1. PHU
2. Specific Consumption
3. TDR
4. Time to boil
5. Emissions (possible)

Overview of the WBT

Each WBT consists of 3 parts:

- High-power cold start
- High-power hot start
- Low-power (simmer)

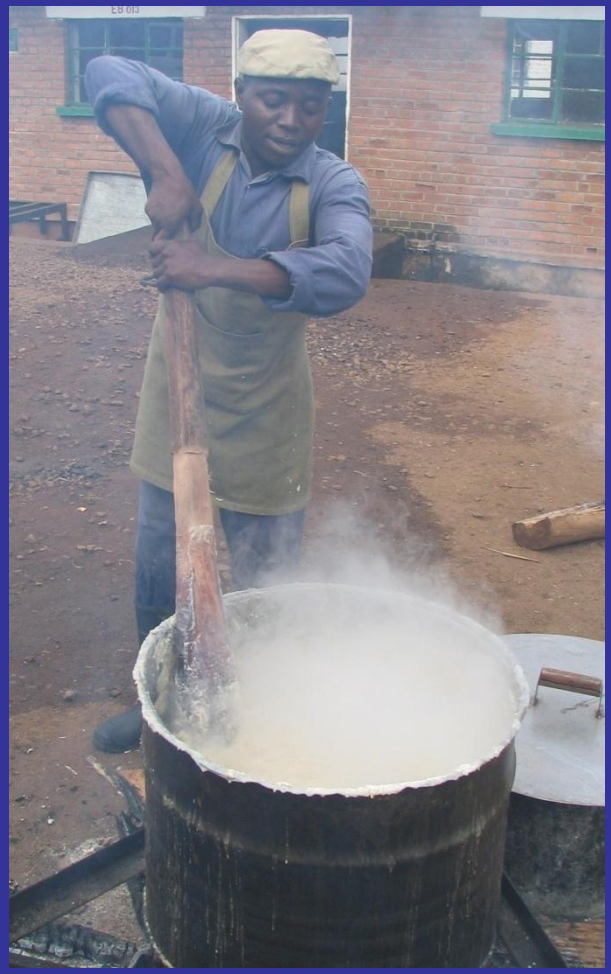
And takes roughly 2 hours to complete

We recommend 3 tests of each type of stove

Sufficient to detect a 30% improvement with 95% confidence if the pooled CV of measurements is 15% and a 20% improvement in PHU if the pooled CV is 10% (more on this later).

Controlled Cooking Test **(CCT)**

- Lab controlled test with added variables of an actual cook cooking real food
- Only can be used to compare two stoves from a particular project
- Compares fuel consumption (specific consumption), and speed of cooking
- Much better at predicting actual stove performance and fuel consumption in the field



Kitchen Performance Test **KPT**

More complex than WBT:

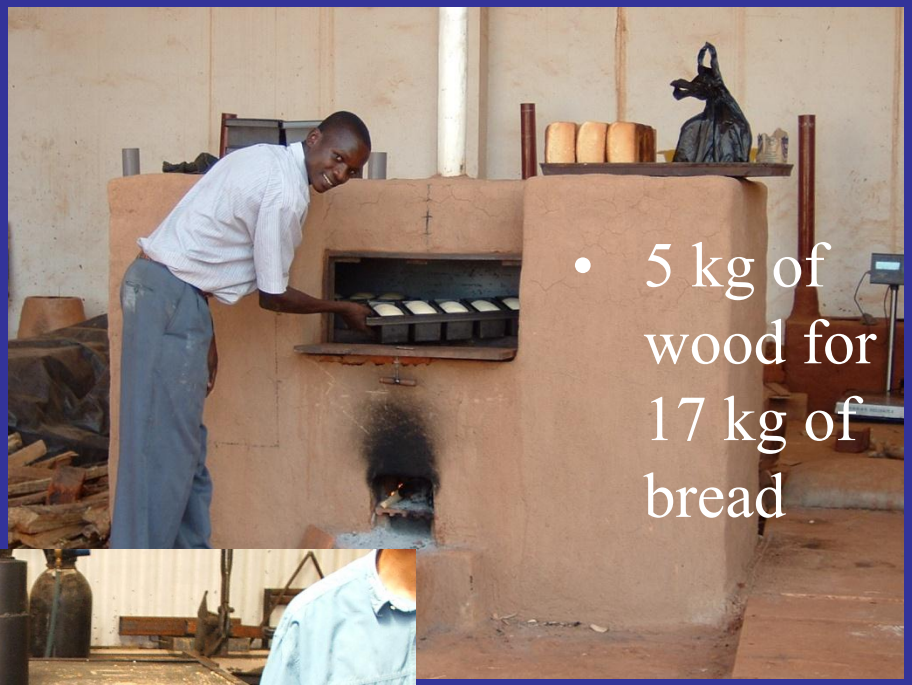
- –Both qualitative survey and quantitative measurements
- –Takes stove testers into peoples households
- –Sampling procedure and study design are critical
- –Variability in “real-world” setting increases the number of samples needed to make results statistically valid (more later).
- –Gives daily wood consumption and gauges user satisfaction

Where to find the detailed tests

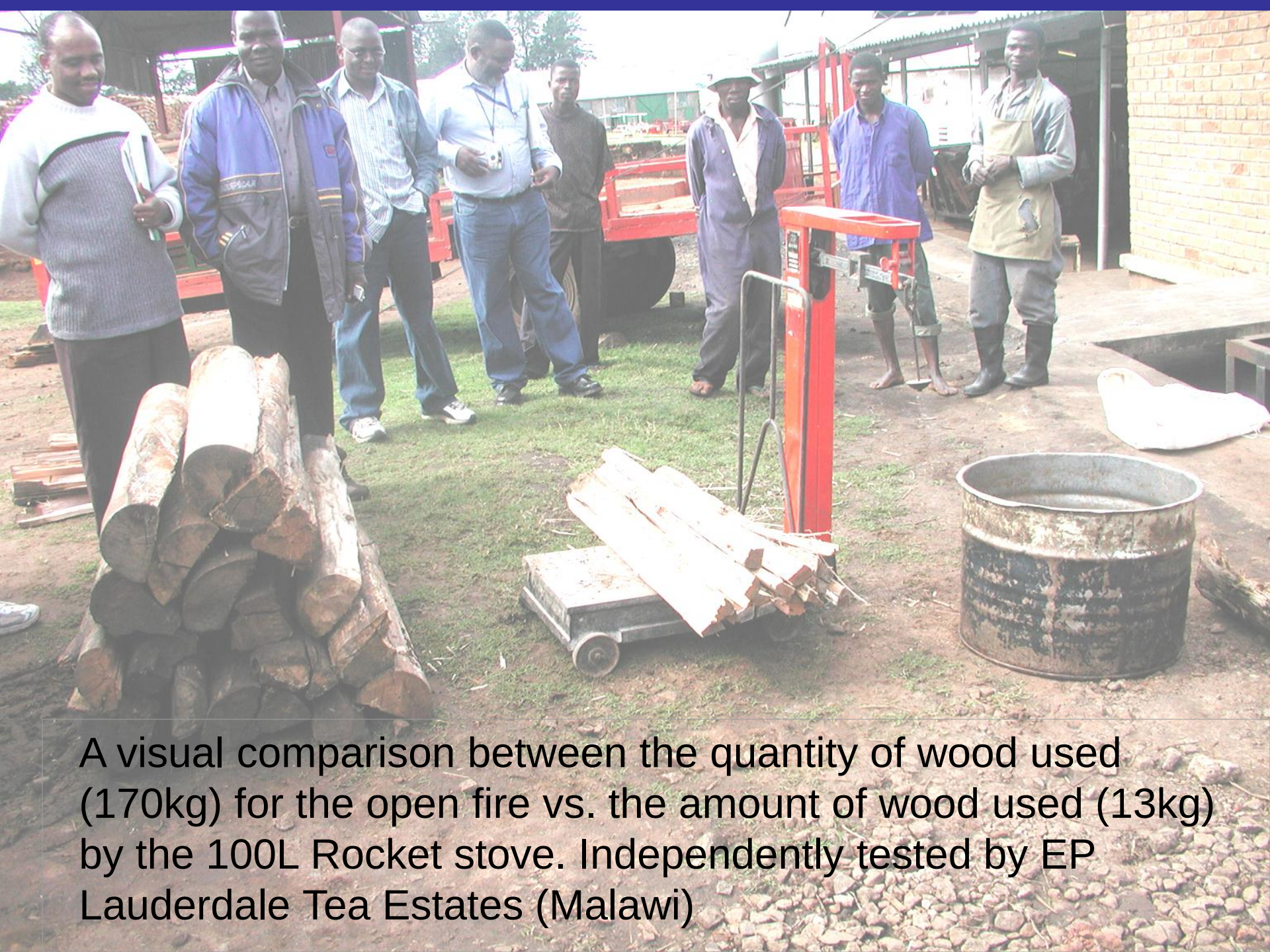
http://www.aprovecho.org/lab/pubs/testing

Rocket Bread Oven

200 kg of wood for
17 kg of bread



- 5 kg of wood for 17 kg of bread



A visual comparison between the quantity of wood used (170kg) for the open fire vs. the amount of wood used (13kg) by the 100L Rocket stove. Independently tested by EP Lauderdale Tea Estates (Malawi)

Stove Design and Performance

Thank

You