Developing Stoves to Achieve the '50%/90%' Future: Stoves in Use That Address Health and Climate Issues

Dean Still and Nordica MacCarty

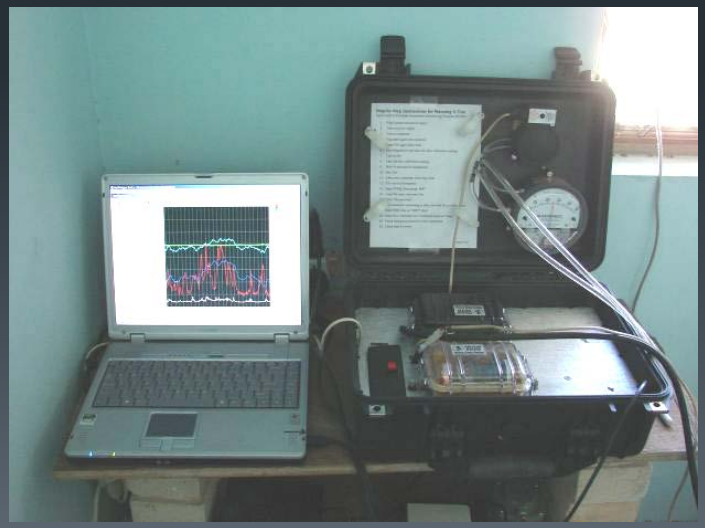
Aprovecho Research Center
Advanced Studies in Appropriate Technology Laboratory
79093 Highway 99, PO Box 1175
Cottage Grove, Oregon 97424 USA
541-767-0287
www.aprovecho.org

Millions of Stoves / Modernizing Traditional Energy

- Since 1976, Aprovecho has assisted over 100 projects around the world leading to Millions of Rocket stoves. Thanks, Peter Scott and GTZ!
- As performance requirements have become more demanding there has been a general move from artisanal production to centralized manufacturing.
- Low emission stoves that protect health with reduced global warming potential are a reality in labs.

Defining Stove Performance

- Hundreds of stove designs have been tested at Aprovecho using the PEMS, resulting in a WBT library. Thanks to Nordica, Karl, Damon!
- Lessons Learned: Mixing results in clean combustion (Fan) or force gas and smoke to enter flame (TLUD).
- Increasing heat transfer efficiency is the ‘magic’ that decreases fuel use.
- Sam Baldwin and Larry Winiarski describe how to make 50% fuel reduction stoves.
- 90% reduction of CO and PM has been achieved in the lab.



Aprovecho Stove Test Library

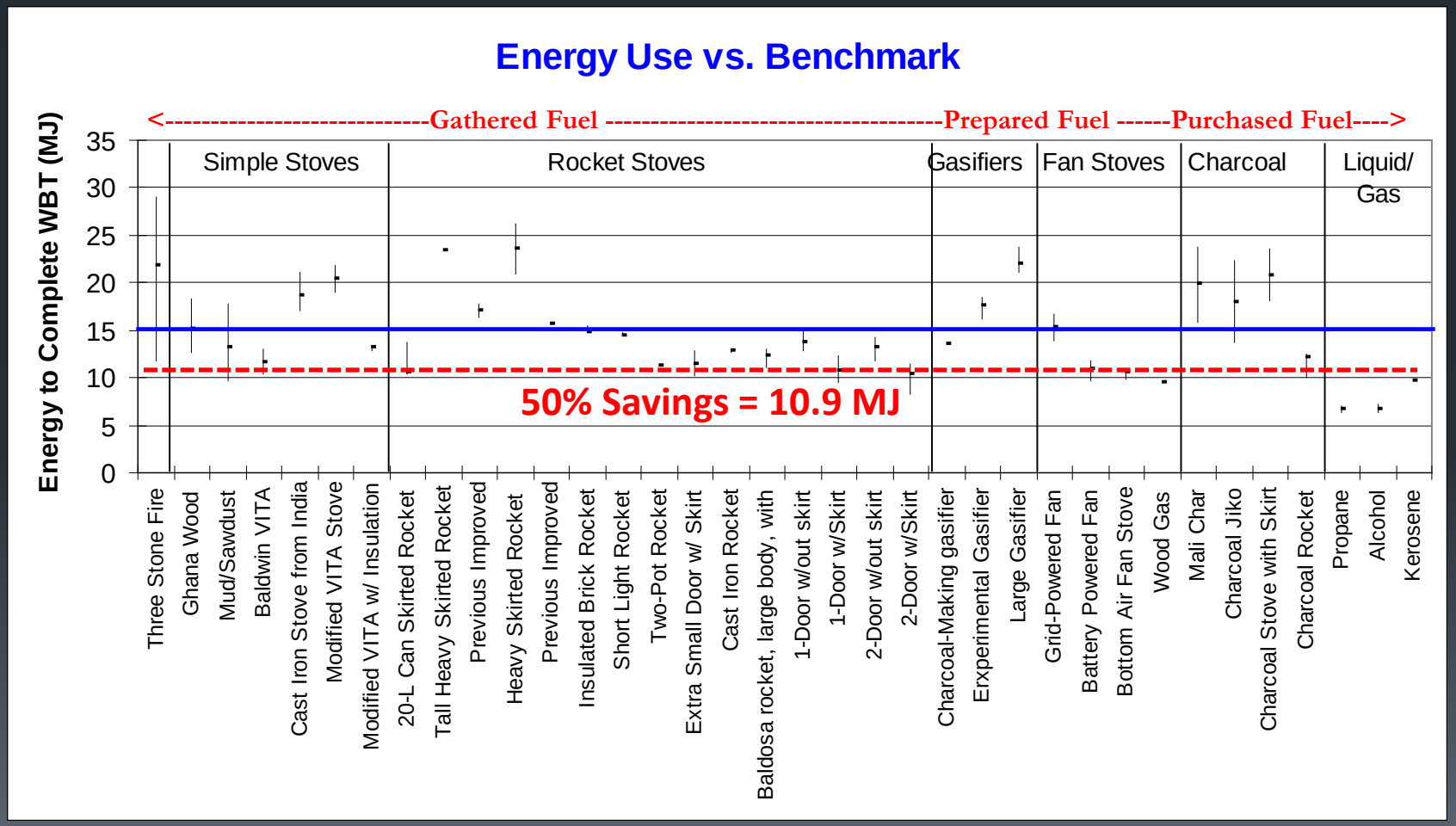
- Testing with the WBT helps to:
  - Discover what works well.
  - Predict the effects of design changes.
  - Determine if a design is optimized.
- Stove test library published in *Energy for Sustainable Development*, September 2010
- Shell Foundation/Aprovecho Benchmarks have been developed and used since 2005 based on the WBT and the PEMS emission hood.
- The WBT is a standardized test resulting in comparable results between labs. (Jetter, 2008)

50%/90% WBT Benchmarks?

- WBT 50%/90% Benchmarks could be created.
- Using the WBT library, a **50%/90% reduction compared to open fire** would be:
  - 50% Fuel Use: 625 g wood or **10.9 MJ** energy
  - 90% reduction Carbon Monoxide: **6.5 g**
  - 90% reduction Particulate Matter: **170mg**
- **Can we go this low in CCT field testing?**

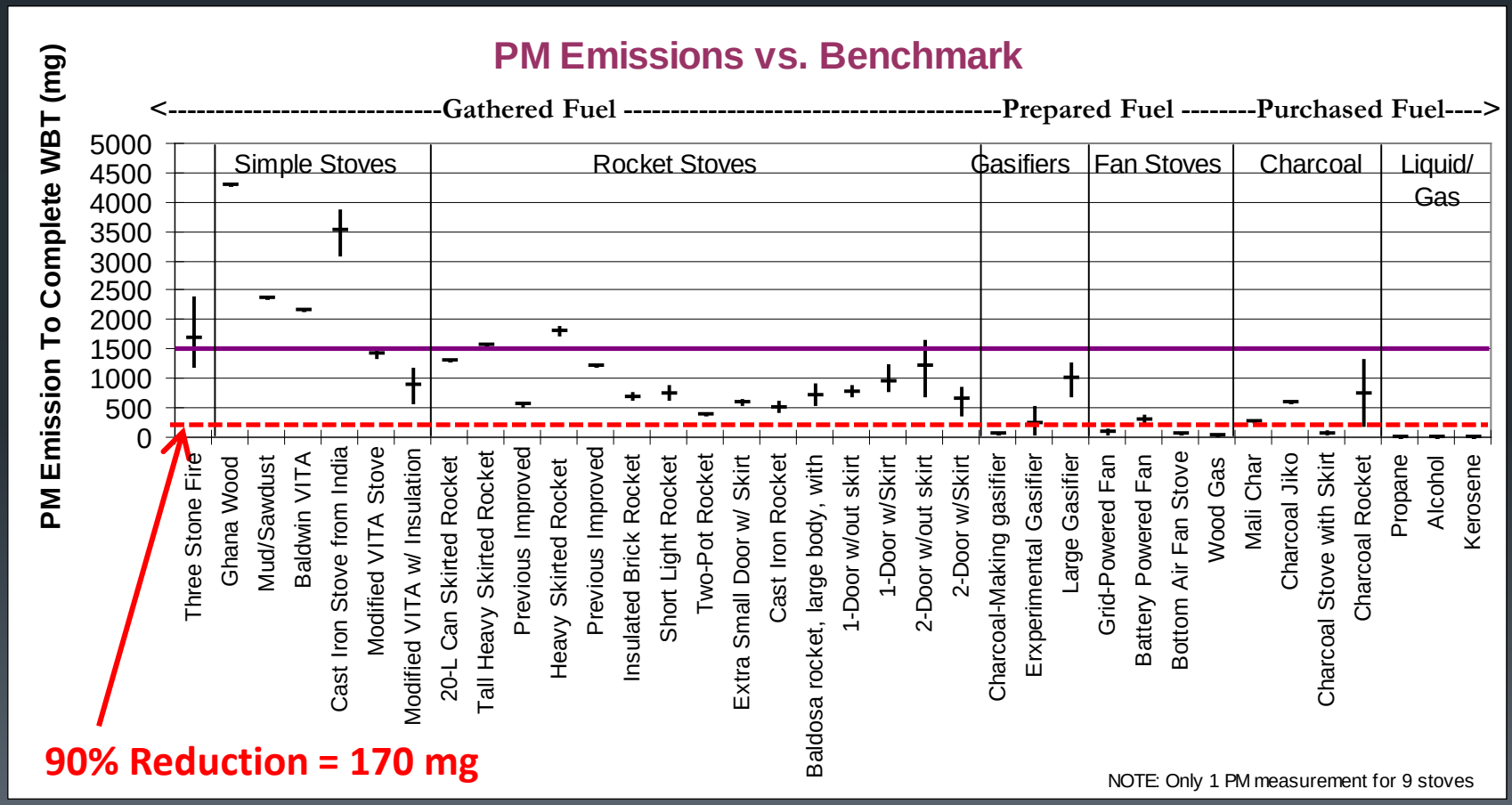
WBT Proposed Benchmark: Energy Use

A cooking stove should use less than 15 MJ (or 10.9 for a 50% reduction) of energy or 850 grams of testing wood to complete the WBT.



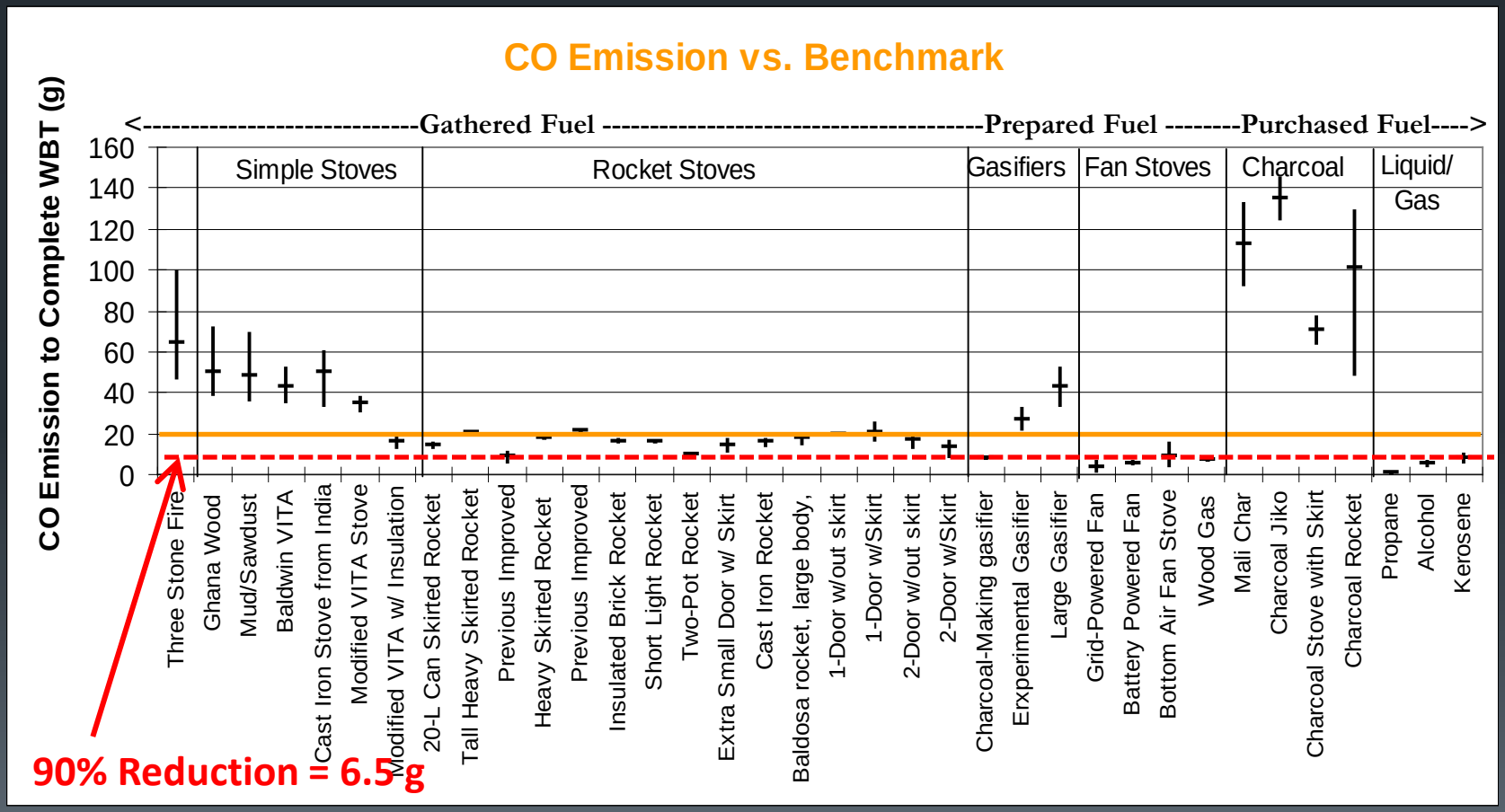
WBT Proposed Benchmark: Particulate Matter Emissions

A cooking stove should emit less than 1500 milligrams (or 170 for a 90% reduction) of Particulate Matter to complete the WBT.



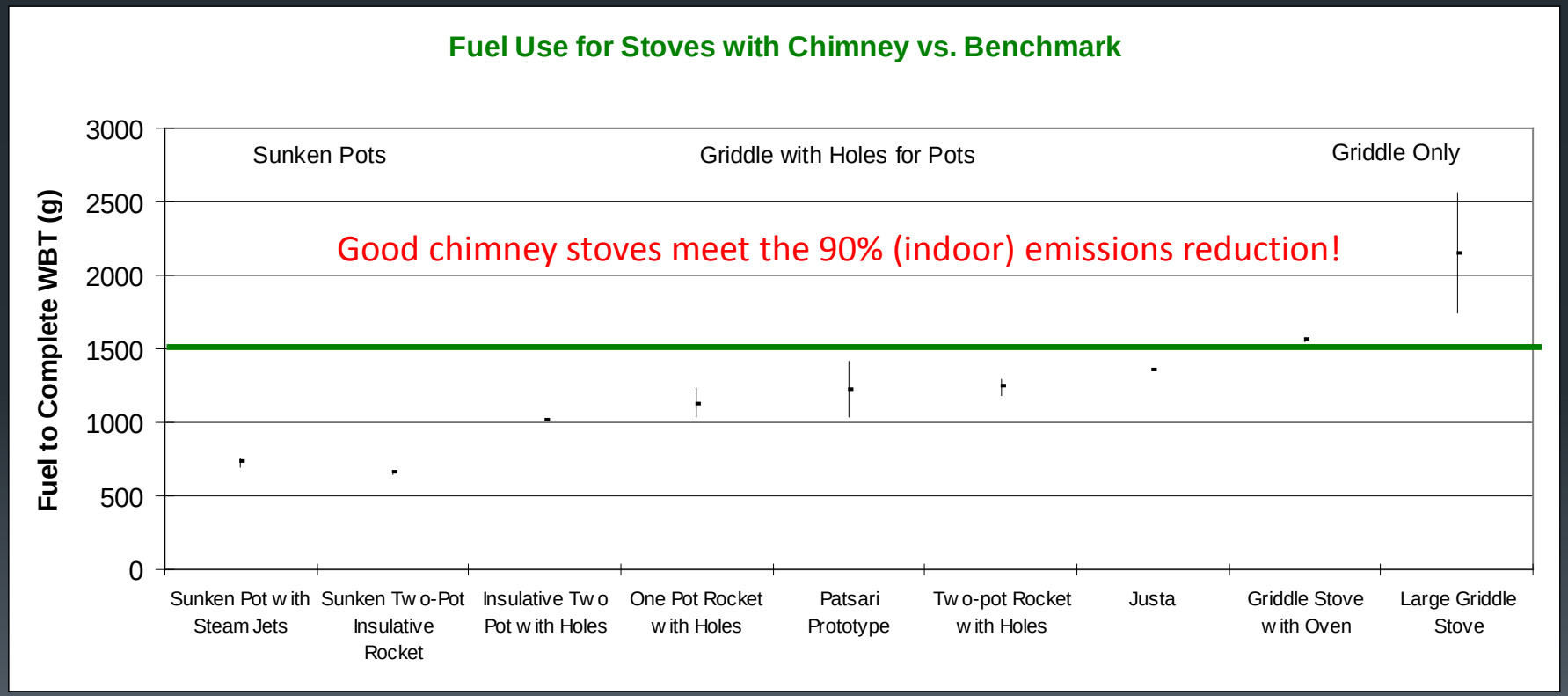
WBT Proposed Benchmark: Carbon Monoxide Emissions

A cooking stove should emit less than 20 grams (or 6.5 for a 90% reduction) of Carbon Monoxide to complete the WBT.



WBT Proposed Benchmark: Chimney Stoves

A cooking stove with chimney is exempt from the previous standards provided it does not leak. A stove with functioning chimney should use less than 30 MJ of energy or 1500 grams of testing wood to complete the WBT.



A stove with chimney is checked for leaks by placing a HOBO-type CO meter 30 cm above the stove.

If less than an average of 50 ppm CO is emitted, the stove is exempt from non-chimney standards

Types of Improved Stoves:
1.) Natural Draft Rocket Stoves

Fuels: Sticks, woody biomass, Gathered fuels, some crop residue

Higher temperatures, mixing, metering and then forcing the gases against the bottom, sides of the pot reduces fuel use and emissions

Envirofit, $25

StoveTec $8-$12

WBT data	Time to Boil	Fuel Use	CO Emission	PM Emission
3-Stone	38	1253	65	2363
Rocket	38	650	20	783

51% Reduction with Skirt

70% Reduction

67% Reduction

Types of Improved Stoves:
2.) Fan Stoves

TOP LOADING
Fuel: Pellets, small pieces
Philips, $60
WoodGas, $55
Oorja, $25

SIDE FEED
Fuel: Sticks, gathered biomass

StoveTec/Biolite TEG, $30

Burning the fuel with forced air jets at the bottom and/or top of the combustion chamber creates high velocity mixing which dramatically decreases fuel use & emissions.

WBT data	Time to Boil	Fuel Use	CO Emission	PM Emission
3-Stone	38	1253	65	2363
Fan	14	614	6	293

51% Reduction | 91% Reduction | 88% Reduction

Types of Improved Stoves: 3.) Semi-Gasifiers

Fuel: pellets, briquettes, some crop residues

Yunnan Gasifier, $45

Daxu Stove, $50

Burning the fuel with carefully controlled primary and secondary air within a closed stove results in efficient fuel use, and emissions are removed through the chimney.

WBT data	Time to Boil	Fuel Use	CO Emission	PM Emission
3-Stone	38	1253	65	2363
Yunnan	22	734	8	317

41% Reduction | 88% Reduction | 87% Reduction

Types of Improved Stoves:
4.) Natural Draft Gasifiers (TLUD)

Fuels: Pellets, some gathered fuels

Champion Stove, $30

Vesto Stove, $60

World Stove, $35

Top lighting, limiting the Primary Air in a TLUD, secondary burn, results in very low particulate matter emissions.

WBT data	Time to Boil	Fuel Use	CO Emission	PM Emission
3-Stone	38	1253	65	2363
TLUD	27	737	18	255

41% Reduction

72% Reduction

89% Reduction

Types of Improved Stoves: 5.) Institutional Stoves

Fuels: Sticks, woody biomass, Gathered fuels, some crop residue

Transferring heat to the bottom and sides of a very large pot efficiently uses the heat from the fire and emits fewer emissions.

WBT data	Time to Boil	Fuel Use	CO Emission	PM Emission
3-Stone	38	1253	65	2363
60L Stove	32	305	7	181

(Data Normalized for 5L)

76% Reduction

89% Reduction

92% Reduction

Stove Performance Comparison

	Time to Boil	Fuel Use	CO Emission	PM Emission
3-Stone	38	1253	65	2363
Rocket	38	650 w/skirt	20	783
Fan – Top loaded	14	614	6	293
Fan – Side Feed	34	722	6	151
Semi-Gasifier	22	734	8	317
TLUD Gasifier	27	737	18	255
Institutional 60L	32	305	7	181

(Data is from Water Boiling Test)

Knowing which Stove Works: Testing is *Essential*

- LABORATORY
  - Stoves are carefully designed and optimized in the laboratory
  - WBT/Emissions measurements quickly, inexpensively highlight promising technologies

- FIELD
  - Stoves **must** be re-designed/modified with input from cooks
    - Consumer testing is *at least* ½ of stove development
    - Focus groups must be involved when selecting, comparing, choosing stove models. It does not matter if a stove performs well in the lab if the cooks don't use it or will not buy it!

Limitations of Testing Targets

- There are many more aspects to a stove than performance and emission reduction! The stove must be in use, loved by cooks. The ‘competition’ (a three stone fire) is free!
- A stove that is not used will not be effective – therefore it is crucial to have consumer approval be an integral part of product development.
- TESTING IN THE FIELD becomes more important than extensive lab testing.
- Without consumer approval our new stoves will sit on shelves or become flower pots.
- In-field testing is absolutely crucial to also ensure that 50%/90% stoves achieve performance and emission goals.
- Let’s not fail a third time!

Can the WBT Predict In Use Performance?

- A lot of time over the last five years has been spent debating the WBT and attempting to bring it closer to field results.
- Some have adapted WBT to use local pots, local fuel, timing, etc.
- Conditions in the field are highly variable so it's difficult to adequately adjust the WBT. The cook is probably the biggest variable. Can we bring enough cooks into the lab?
- The CCT/KPT in field tests help predict actual performance.
- Use the CCT/w emissions? Cooks use their own techniques, fuels, foods, compares traditional to new stove. Use hood or nose/mouth emission measurements?

Follow Chapter Five in Sam Baldwin's Book…

- Laboratory, Production, Field, and Market efforts are detailed in: "*Biomass Stoves: Engineering Design, Development, and Dissemination*".

1. WBTs and CCTs are used to select promising prototypes
2. Templates are developed using local pots, fuels, etc.
3. Limited production of small number of stoves made to analyze costs, methods.
4. Stoves are used by local cooks to determine acceptability and actual measured performance.
5. At the same time, stoves are in stores on a commission basis to measure commercial viability.
6. On the basis of these tests, modifications are made as needed and the process is repeated (and repeated) until success is achieved.

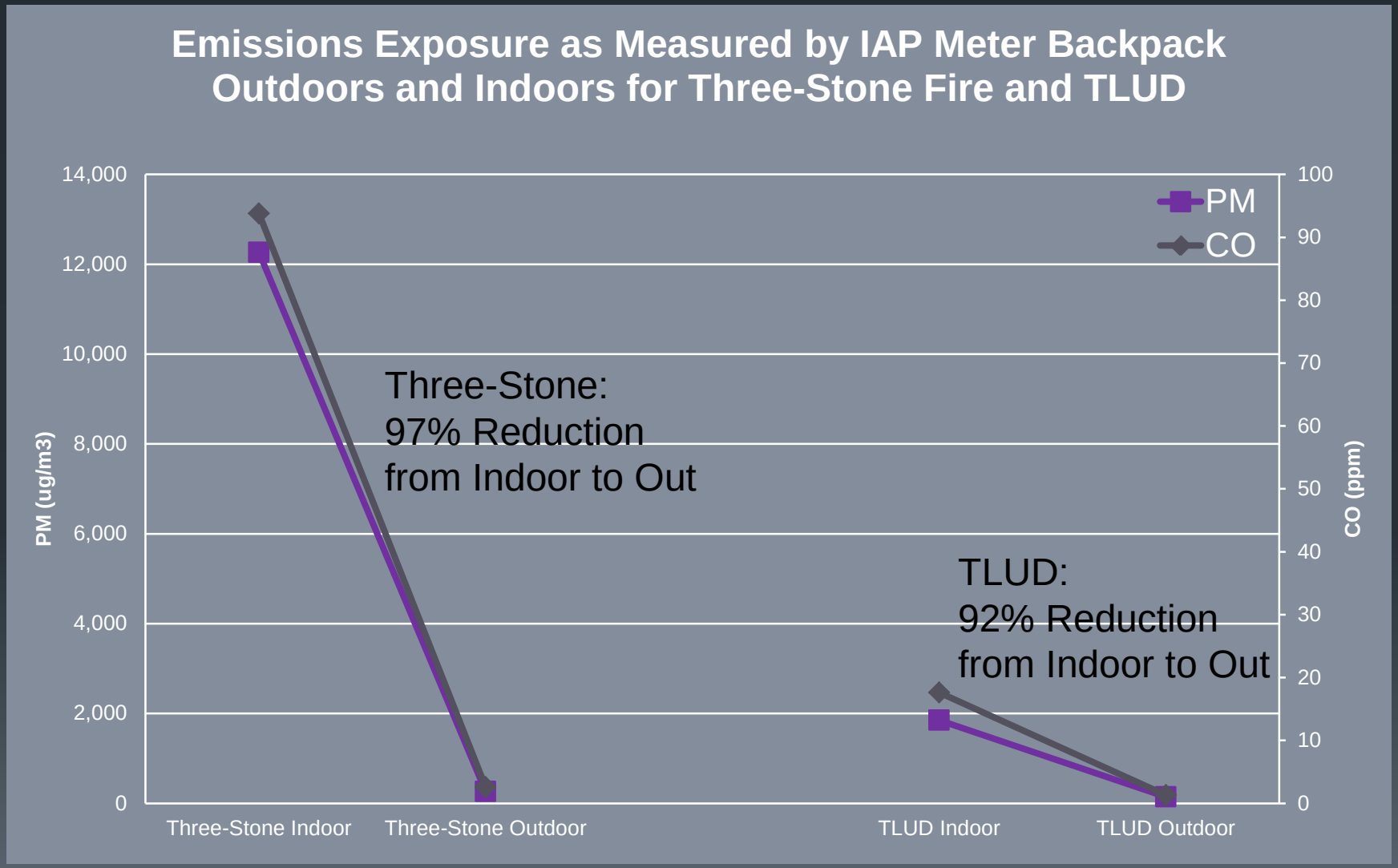
Measuring Emissions: IAP Exposure

In the Aprovecho IAP Meter, a small fan draws a sample through a “snorkel” into the meter, allowing a better measurement of actual exposure

Perhaps benchmarks based on exposure could be developed? Measurements of exposure could be directly related to EPA and WHO guidelines, unlike other methods.

Aprovecho is following up the extensive WBT testing with CCT in Test Kitchen and under a veranda testing using the IAP Meter.

Measuring Exposure to the Cook Indoors and Out



Clean Cook Stoves at Market Price

Carbon credits can reduce the consumer price of new clean stoves

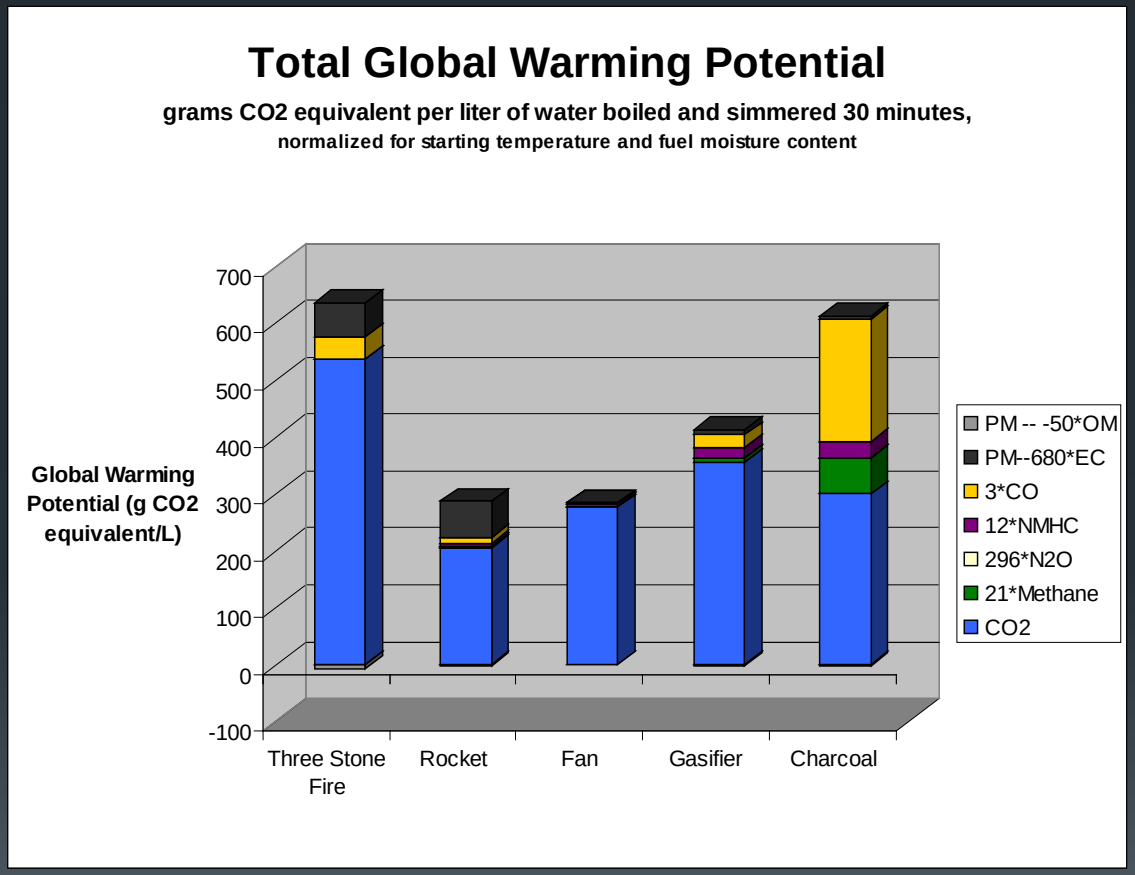
My Uncertain Estimates:
(will vary with market, etc)

Carbon credit income per ton per year: ~$5-$10/year

5 years?

Stove generates 1-4 tons CO2e savings per year

calculated CO2 savings switching from coal to renewable biomass– about 3.8 ton CO2e/yr.



From "A Laboratory Comparison of the Global Warming Potential of Five Major Types of Biomass Cooking Stove" *Energy for Sustainable Development*, June 2008

Summary

- There are promising new generation stoves in existence
- The stove community could proceed to multiple-site in-field testing of performance w/emissions, user satisfaction, and durability.
- The stove community could support mass manufacturing/distribution for best quality, lowest price for successful purchased stoves.
- There can be millions of stoves ready to address climate change *and* health in the near future.
- Very clean stoves can be sold at the local market price due to a $5-$10/year carbon credit.

NOLS saying as 5 people push a 2,000 pound boat up a steep beach:

If we all push easy, it's hard

If we all push hard, it's easy.