



**Technical Introduction to
the CleanCook Stove**

Performance of the CleanCook Stove with Alcohol Fuels Compared with Traditional and Improved Solid Fuel Stoves, Kerosene and LPG Stoves

Aprovecho Research Center

June 2010

Reference:

Fuel Use and Emissions Performance of Fifty Cooking Stoves in the Laboratory and Related Benchmarks of Performance

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MacCarty, N, Still, D, and Ogle, D, 2010. "Fuel Use and Emissions Performance of Fifty Cooking Stoves in the Laboratory and Related Benchmarks of Performance," Energy for Sustainable Development 14(3): 161-171.

Energy Use

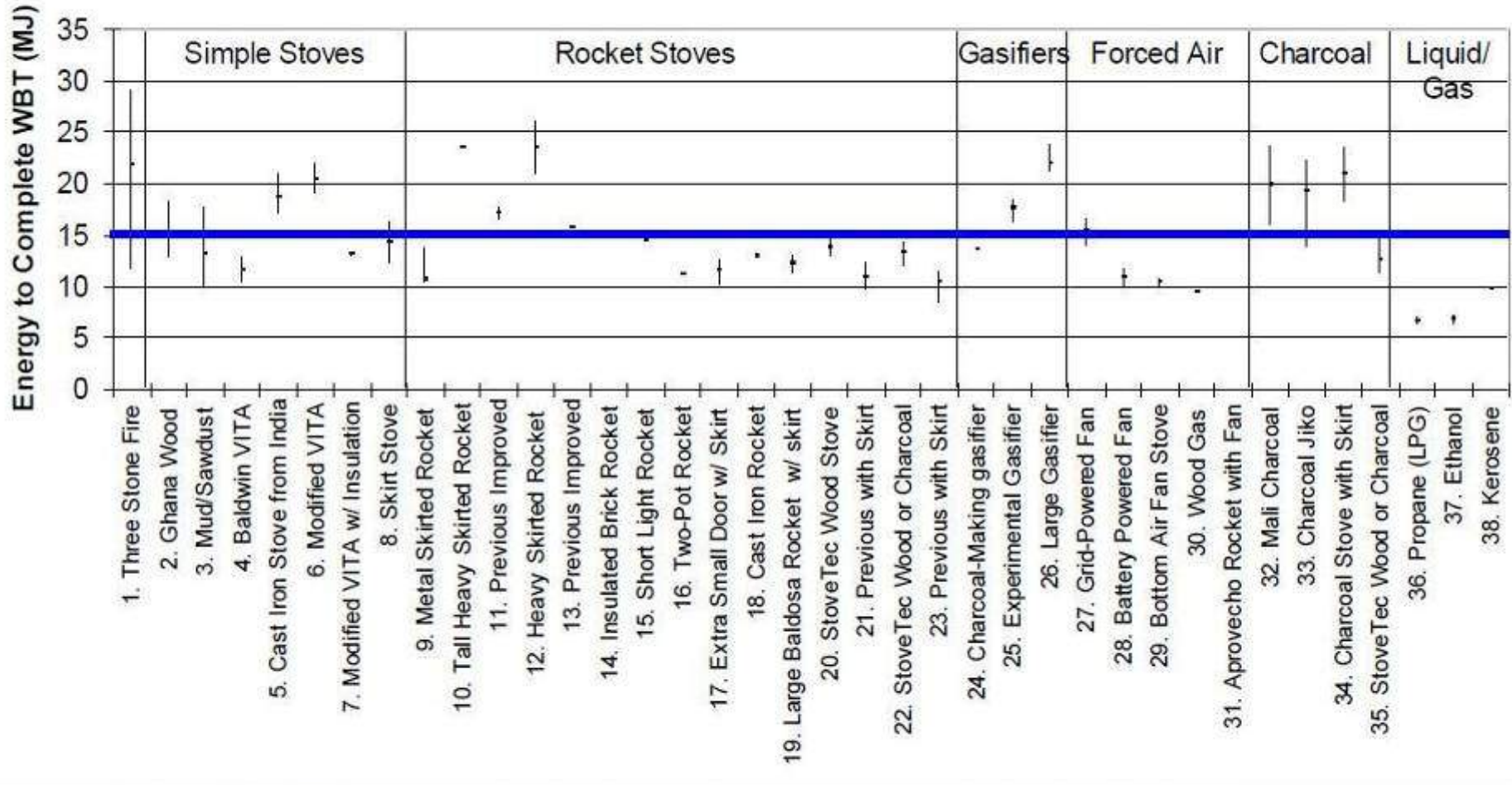


Figure 3.1 – Energy Use for Stoves without Chimneys to Complete the WBT (Mega Joules)

Suggested Fuel (Energy) Use Benchmark: *The improved cook stove should use less than 15 MJ of energy to complete the 5 liter WBT.*

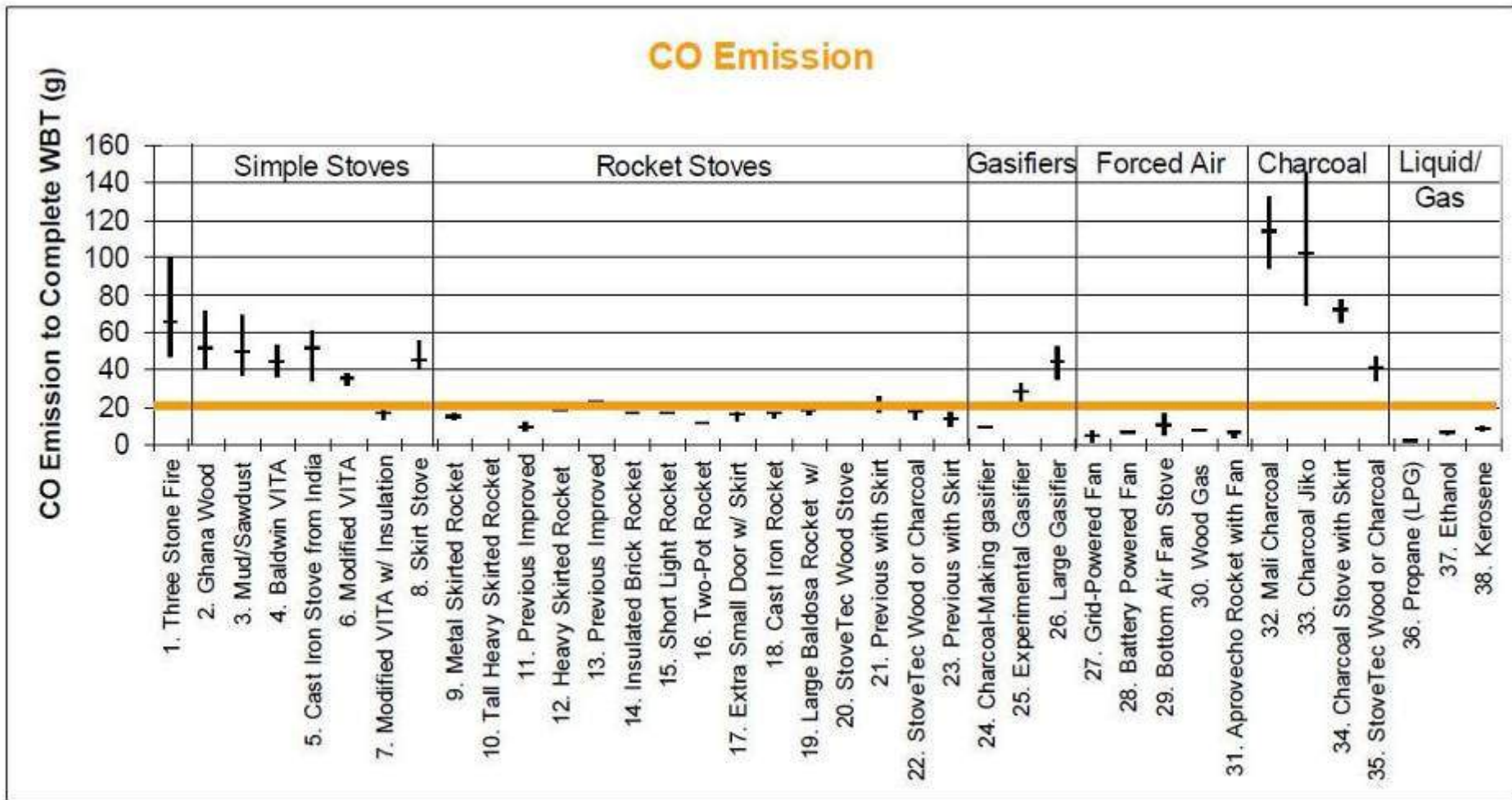


Figure 3.2 – Carbon Monoxide Emissions to Complete WBT (grams)

Suggested Carbon Monoxide Emission Benchmark: *The improved cook stove should emit less than 20 grams of carbon monoxide to complete the 5 liter WBT.*

PM Emissions

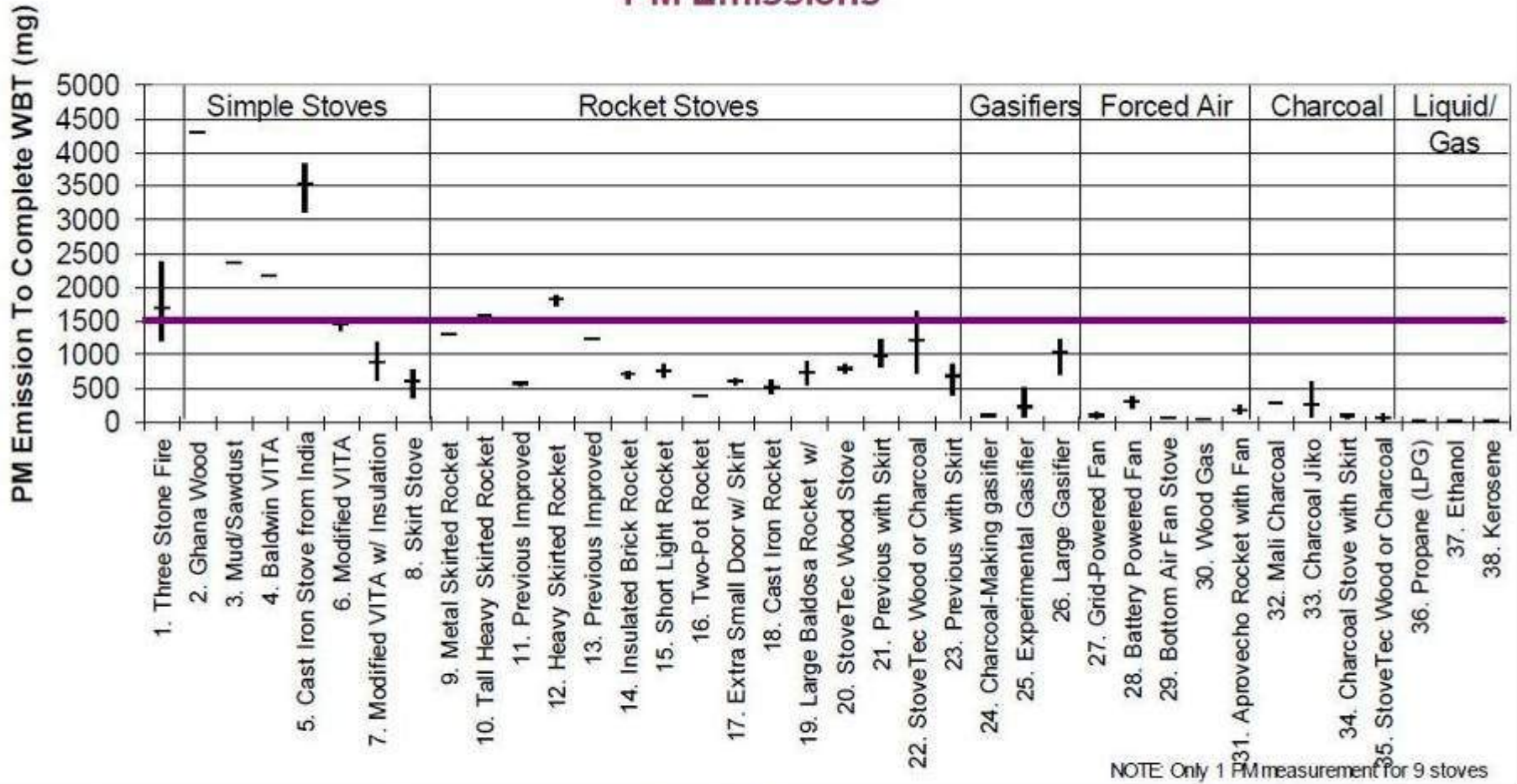


Figure 3.3 – Particulate Matter Emissions to Complete WBT (milligrams)

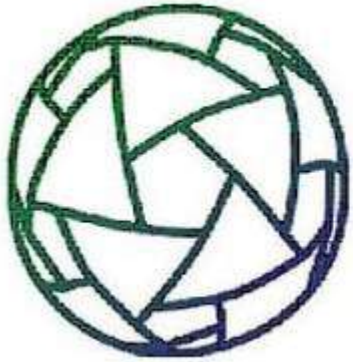
Suggested Particulate Matter Emission Benchmark: *The improved cook stove should use emit less than 1500 mg of particulate matter to complete the 5 liter WBT.*

	Gasifiers			Forced Air Stoves					Charcoal Stoves				Liquid/Gas Fuels		
	24. Charcoal-Making gasifier	25. Experimental Gasifier	26. Large Gasifier	27. Grid-Powered Fan	28. Battery Powered Fan	29. Bottom Air Fan Stove	30. Wood Gas	31. Aprovecho Rocket with Fan	32. Mali Charcoal	33. Charcoal Jiko	34. Charcoal Stove with Skirt	35. Stove Tec Wood/Charcoal Rocket	36. Propane (LPG)	37. Ethanol	38. Kerosene
Benchmarks Met?	YES	NO	NO	NO	YES	YES	YES	YES	NO	NO	NO	NO	YES	YES	YES
29 Energy Use (MJ)	13.6	17.6	22.0	15.3	10.8	10.5	9.4	15.0	19.8	19.1	20.8	12.6	6.7	6.8	9.7
30 PM Emission (mg)	70	225	1001	89	293	48	27	151	260	251	71	44	5	4	10
32 CO Emission (g)	8	27	43	4	6	9	7	6	113	102	71	41	1	5	8
33 Fuel Use (g)	741	961	1234	792	614	609	460	722	655	613	657	439	140	317	223
34 Time to Boil (min)	27.3	17.9	26.4	13.2	13.9	19.5	23.7	33.7	38.6	18.9	28.3	30.0	23.0	31.6	42.5

Looking at all of the stoves, and comparing the improved solid fuel stoves to the clean fuel stoves, only the clean fuel stoves (principally LPG and the alcohols) meet and exceed the highest standards for efficiency, low PM emission, low CO production, and low trace emissions (methane, volatile organic compounds).

While pressurized kerosene stoves burn more cleanly, kerosene wick stoves, as well as kerosene lamps, produce high PM, high CO and high VOCs, including aromatic compounds that are suspected carcinogens.

While improved solid fuel stoves may burn cleanly in the laboratory, in the field under normal use their performance is subject to wide variation. The CleanCook stove performs consistently under all conditions.



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Results of Testing of the CleanCook Stove for Fuel Use and Carbon Emissions

Prepared for Project Gaia, Practical Action, and World Bank

By Nordica MacCarty
June 26th, 2009

In this round of testing, Global Warming Commitment (GWC) values were developed for the CleanCook stove. Values were generated using the 5-liter water boiling test (WBT) with an uncovered pot.

It should be noted that since the CleanCook is powered at 1.5kW (as opposed to 2 or 3X for a wood-burning stove), it takes longer to boil an uncovered pot of water. This results in heat loss from both water and pot. This yields an inaccurately low efficiency values for the CleanCook and slightly higher emissions values. Even with this disadvantage intrinsic to the test for lower powered stoves, the CleanCook scored best of the stoves.

The stove is powered at 1.5kW to save fuel. Computing efficiency using covered pots yields a higher value (64 %). Time to boil is less, thus emissions, as low as they are, are less.

Table 3.4 – Emission Factor Summary

Measured Thermal Efficiency Per MJ	Ethanol Measured		Kerosene Default		Wood Default	
	Combusted	Delivered	Combusted	Delivered	Combusted	Delivered
	52.5%		52%		20%	
CO ₂	64	122	71.9	138	112	560
Methane	0.02	0.038	0.0022- 0.023	0.004- 0.044	0.3	1.500

From this data, ethanol is the clear choice in terms of lower global warming impact. In addition to the lower emission factors per MJ delivered than both wood and kerosene, a key advantage to ethanol for climate change is that the CO₂ emissions may be greenhouse neutral if the ethanol is “grown” sustainably, moving this figure essentially toward zero (not accounting for fuel processing).

Previous calculations of expected CO₂ emission factors based on a carbon balance for Ethanol, LPG, and Kerosene showed agreement with this study and the IPCC defaults.

Table 3.5 – Expected CO₂ emission factors based on Carbon balance

Fuel	Molecular Formula	Carbon Fraction	Energy Content (MJ)	Combustion Efficiency (estimated)	Stove Efficiency (reported)	gCO ₂ /MJdelivered
Ethanol	C ₂ H ₆ O	52%	21	95%	64%	133
LPG	C ₃ H ₈ ,C ₄ H ₁₀	82%	50	98%	57%	103
Kerosene	C _n H _(2n+2)	85%	43	95%	50%	137

Aprovecho Safety Evaluation

Stoves are evaluated for safety. Each stove is given a safety score out of a possible 40 points, based on the protocol developed by Nathan Johnson of Iowa State University. The protocol includes an evaluation on a scale of 1-4 (with 4 being highly safe) in ten different areas. The CleanCook stove scores as follows:

CleanCook Safety Evaluation	Score/4
Sharp Edges/Points	4
Cookstove Tipping	4
Containment of Combustion	4
Expulsion of Fuel	4
Obstructions Near Cooking Surface	4
Surface Temperature	4
Heat Transfer to Surroundings	4
Cookstove Handle Temperature	4
Flames/Heat Surrounding Cookpot	4
Flames/Heat Exiting Fuel Chamber	3
Total Score (out of 40)	39/40







ISO International Workshop Agreement Guidance for Clean Cookstoves




A collaborative effort of
The Partnership for Clean Indoor Air
The Global Alliance for Clean Cookstoves
and
The Cookstove Community

Performance Indicators...

Current Efforts

Fuel Use 	Is the stove efficient?
Emissions 	How much pollution is emitted by the stove?
Indoor Air Quality 	Does the stove reduce indoor pollutant concentrations with a chimney or have emissions so low that IAQ goals are achieved without a chimney?
Safety 	Does the stove reduce the risk of burns, poisoning, and other injuries?

Future Efforts

Climate Impact 	What affect will the stove have on the local and global environment?
Durability/Life 	How long is the stove going to last with normal use?
Field Testing 	How does the stove perform in the field? [This is especially important for built-in-place stoves .]

Tier Levels

Tier 0	No Improvement Over Open Fire / Baseline
Tier 1	Measureable Improvement Over Baseline
Tier 2	Substantial Improvement Over Baseline
Tier 3	Currently achievable technology for Biomass Stoves
Tier 4 	Stretch Goals for Targeting Ambitious Health and Environmental Outcomes

Tier “Bookend” Numbers



Performance Indicator	3-Stone Fire	Aspirational Goal
Fuel Use	Low Power Specific Energy Consumption: 0.050 MJ/(min x L) High Power Thermal Efficiency: 15%	Low Power Specific Energy Consumption: 0.017 MJ/(min x L) High Power Thermal Efficiency: 45%
Emissions	Low Power CO: 0.20 g/(min x L) High Power CO: 16 g/MJ delivered Low Power PM _{2.5} : 8 mg/(min x L) High Power PM _{2.5} : 979 mg/MJ delivered	Low Power CO: 0.09 g/(min x L) High Power CO: 8 g/MJ delivered Low Power PM _{2.5} : 1 g/(min x L) High Power PM _{2.5} : 41 mg/MJ delivered
Indoor Emissions	CO: 0.97g/min PM _{2.5} : 40mg/min	CO: 0.42g/min PM _{2.5} : 2mg/min
Safety	Iowa State University Rating System: 45	Iowa State University Rating System: 95

The CleanCook and ISO Standards

The USEPA has now tested the CleanCook Stove (Q4 2012) and confirmed that it is a **Tier 4** stove—able to achieve ambitious health and environmental outcomes. This latest round of testing confirms the field testing conducted in 10 countries to date as well as the extensive laboratory testing at Aprovecho Research Center and other labs.

Impacts of ethanol intervention on personal exposure in household studies conducted in Madagascar (from a study by Practical Action Consulting, Project Gaia, Inc. and others in Madagascar for the World Bank, 2008-2011).

Pollutant	Ambositra		Vatomandry	
	Mother	Child	Mother	Child
CO	-74%	-64%	-53%	-35%
PM2.5	-62%	-63%	-44%	-47%

How does the CleanCook Stove perform relative to other improved or advanced stoves?*

Performance Gains of CleanCook (CC) Ethanol Stove over Other Stoves (5-liter WBT; pot without lid)			
Baseline is 3-stone fire	Reductions by CC Stove	Improvement in Performance	Conclusion
Energy use	69.00%	321.00%	CC is 3 times more efficient
PM emissions	99.80%	41850.00%	CC is over 400 times cleaner
Carbon Monoxide (CO) emissions	93.40%	1300.00%	CC is 13 times cleaner
Baseline is StoveTec Rocket	Reductions by CC Stove	Improvement in Performance	
Energy Use	50.80%	202.00%	CC is 2 times more efficient
PM emissions	99.50%	19575.00%	CC is 196 times cleaner
CO emissions	75.00%	400.00%	CC is 4 times cleaner
Baseline is Charcoal Jiko	Reductions by CC Stove	Improvement in Performance	
Energy Use	64.40%	280.80%	CC is 2.8 times more efficient
PM emissions	98.40%	6275.00%	CC stove is 63 times cleaner
CO emissions	95.10%	2040.00%	CC stove is 20 times cleaner
Baseline is Wood/Charcoal Rocket Combo	Reductions by CC Stove	Improvement in Performance	
Energy Use	46.00%	185.30%	CC is 1.8 times more efficient
PM emissions	91.00%	1100.00%	CC is 11 times cleaner
CO emissions	87.90%	820.00%	CC is 8.2 times cleaner

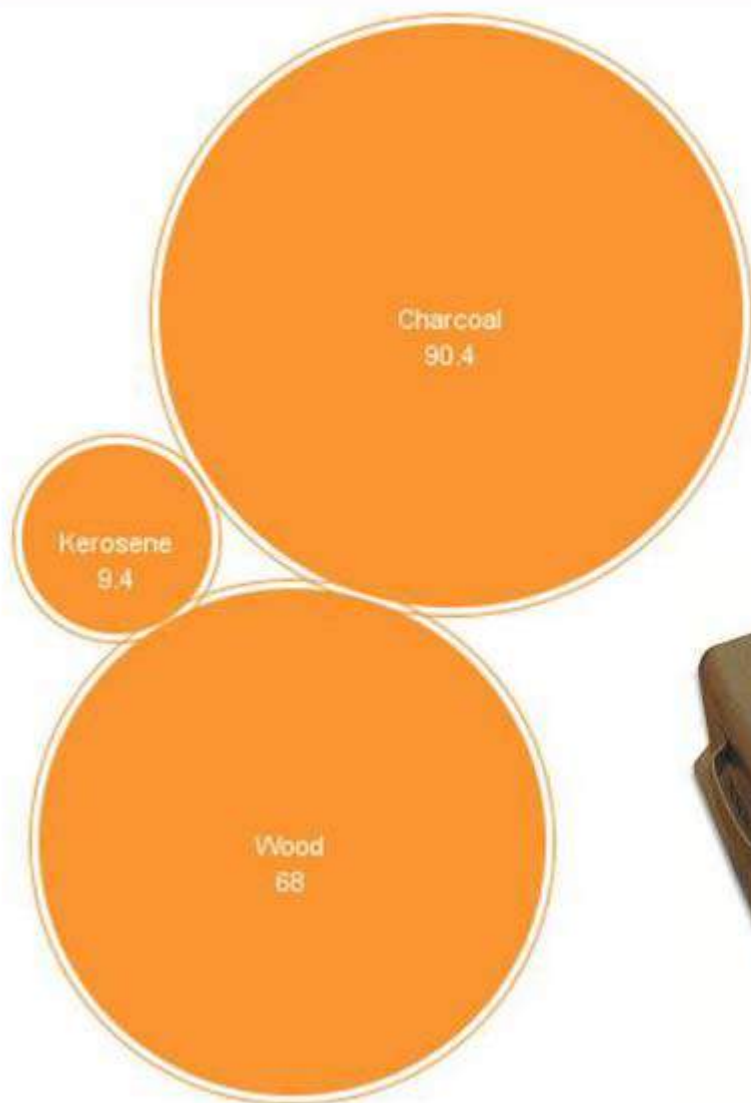
* Based on the data provided by MacCarty, Still, and Ogle, Fuel Use and Emissions Performance of Fifty Cooking Stoves in the Laboratory and Related Benchmarks of Performance, Energy for Sustainable Development (ESD), Volume 14, Issue 3, September 2010, Pages 161-171.

The test used was the 2003 University of California-Berkeley (UCB) revised Water Boiling Test (WBT) Version 3.0, using an uncovered pot (without lid). The CleanCook stove showed superior numbers in all three benchmarks. Using a covered pot test (lid on), the gains by the CleanCook stove are even greater.

Performance Gains of CleanCook (CC) Ethanol Stove over Other Stoves (5-liter WBT; pot without lid)			
Baseline is Forced Air (Fan) Stove	Reductions by CC Stove	Improvement in Performance	
Energy Use	44.30%	179.40%	CC is 1.8 times more efficient
PM emissions	96.70%	3040.00%	CC is 30 times cleaner
CO emissions	22.00%	128.00%	CC is 1.3 times cleaner
Baseline is Gasifier Stove	Reductions by CC Stove	Improvement in Performance	
Energy Use	56.40%	229.40%	CC is 2.3 times more efficient
PM emissions	97.30%	3687.50%	CC is 37 times cleaner
CO emissions	71.50%	350.00%	CC is 3.5 times cleaner
Baseline is Kerosene Stove	Reductions by CC Stove	Improvement in Performance	
Energy Use	29.90%	142.60%	CC is 1.42 times more efficient
PM emissions	60.00%	250.00%	CC is 2.5 times cleaner
CO emissions	37.50%	160.00%	CC is 1.6 times cleaner

These tests shows that the CleanCook uses fuel most efficiently (most economically), that substantially less carbon monoxide is produced, and that soot and smoke are eliminated. In contrast, some improved and advanced solid fuel stoves can emit high levels of CO and PM and perform unevenly in the field.

Tons of CO₂-equivalent Displaced by the Stainless Steel CleanCook Stove Over a 10 Year Lifespan



CARBON SAVINGS ESTIMATES SHOWN IN TONS OF CO₂ EMISSIONS DISPLACED PER STOVE PER YEAR:

Charcoal: 9.043

Wood: 6.8

Kerosene 0.944

Calculations made by Impact Carbon and Project Gaia, Inc. from data gathered from Ethiopian project sites, 2004-2011



Dometic single burner
Stainless Steel stove: runs
on ethanol or methanol

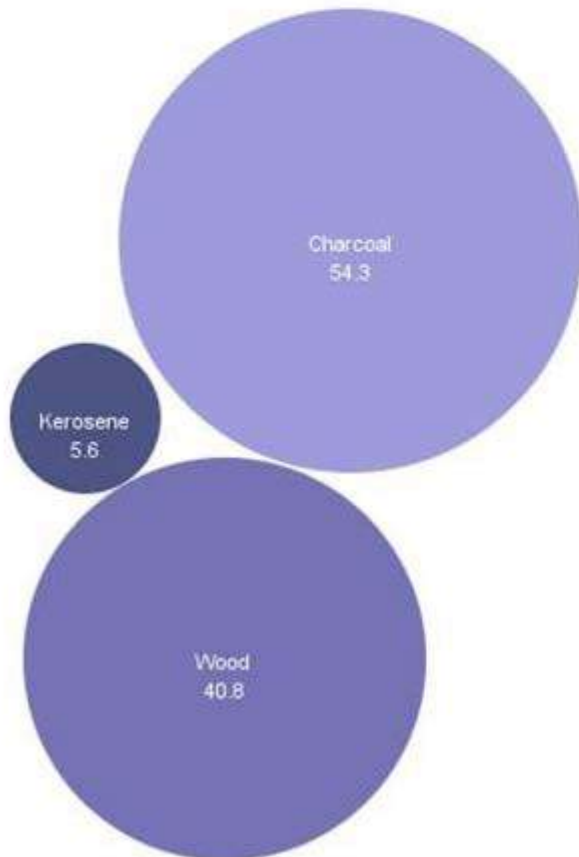
**based on a conservatively estimated 10-year stove life*

Potential Carbon Revenues for Stainless Steel CleanCook Stove over 10 Year Lifespan



Type of fuel displaced	CO ₂ displaced	\$5 credit per ton	\$10 credit per ton	\$15 credit per ton
Charcoal	90.4 tons	\$452	\$904	\$1,356
Wood	68 tons	\$340	\$680	\$1,202
Kerosene	9.4 tons	\$47	\$94	\$141

Tons of CO₂-equivalent Displaced by the Aluminum CleanCook Stove Over a 6 Year Lifespan



CARBON SAVINGS ESTIMATES SHOWN IN TONS OF CO₂ EMISSIONS DISPLACED PER STOVE PER YEAR:

Charcoal: 9.043

Wood: 6.8

Kerosene 0.944

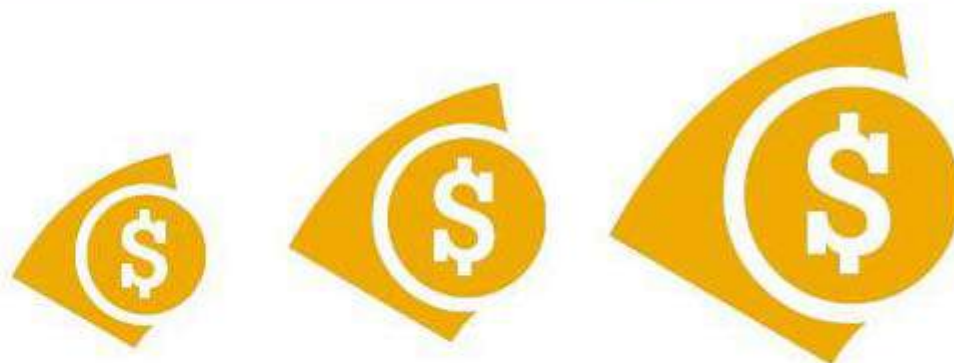
Calculations made by Impact Carbon and Project Gaia, Inc. from data gathered from Ethiopian project sites, 2004-2011



Dometic single burner Aluminum-bodied stove: runs on ethanol or methanol

**based on a conservatively estimated 6-year stove life*

Potential Carbon Revenues for Aluminum CleanCook Stove over 6 Year Lifespan



Type of fuel displaced	CO ₂ displaced	\$5 credit per ton	\$10 credit per ton	\$15 credit per ton
Charcoal	54.25 tons	\$271	\$542	\$813
Wood	40.8 tons	\$204	\$408	\$612
Kerosene	5.64 tons	\$28	\$56	\$84

The CleanCook stove has been designed around the properties of the simple alcohols. Here is how it works:

- Alcohol has low surface tension. The CC stove's fuel canister adsorbs alcohol fuel onto a refractory mass, holding the fuel as if it were a solid. It will not leak or spill out. Result: **safety**.
- Alcohol is volatile. It evaporates easily. The CC stove allows the alcohol to evaporate from the fuel canister into a chimney that controls fuel-to-air ratio for ideal combustion and a hot flame. Under optimal conditions, alcohol has a flame temperature similar to propane. Result: **performance**.
- Alcohol is a liquid at room temperature. As a result, the stove is fueled with a liquid fuel, not with gas that must be pressurized. Ethanol handles with the convenience of kerosene, and can be transported like kerosene. But since it is water-soluble, it does not pose a hazard to the environment. Result: **convenience**.

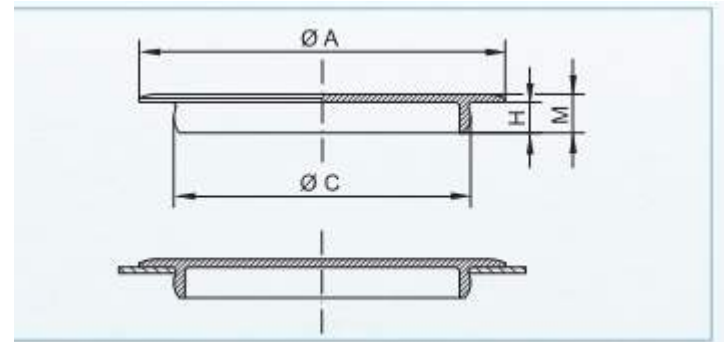
Safety, performance, convenience . . .

- The CleanCook stove is not pressurized.
- The CleanCook stove burns hot (~1.5 kW at full power).
- The CleanCook stove refuels easily, burns for an extended period (4 ½ hrs) between refueling, and burns efficiently, therefore cleanly (low CO and very low PM).
- To sum up, the CleanCook stove uses a **liquid** fuel, but stores it as if as a **solid**, and burns it as a **gas**. The expense and inefficiency of gelling alcohol and the difficulty of burning gel has been eliminated.

The CleanCook fueling system: The fuel is poured into the canister as a liquid and *adsorbed* onto a fiber filling. It volatilizes into a combustion chimney. The fuel will not spill and cannot explode. The result it is a very safe stove.



Gaia Assoc. Addis Ababa



Fuel canister is open and un-pressurized.

Cross-section shown.

Canister with snap-on cap in place is shown.

Cross-section of cap design is shown.



The fuel container may serve as a fuel distribution system. The canister is filled and sealed for distribution. Once empty it is returned for refilling.



Re-usable plastic cap

Totes are designed to carry 6 canisters at a time, weighing < 7.75 kg full and ~3.0 kg empty.

Capacity is 1.2 liters. Larger canisters may be made on order (holding 3 liters).





New snap-on canister lids for storage and transport of fuel in the canister



The CleanCook stove comes as a very durable and long-lived all-stainless-steel stove or with an aluminum body with galvanized and stainless steel parts. Both are robust and durable. Shown here—aluminum-bodied stoves.

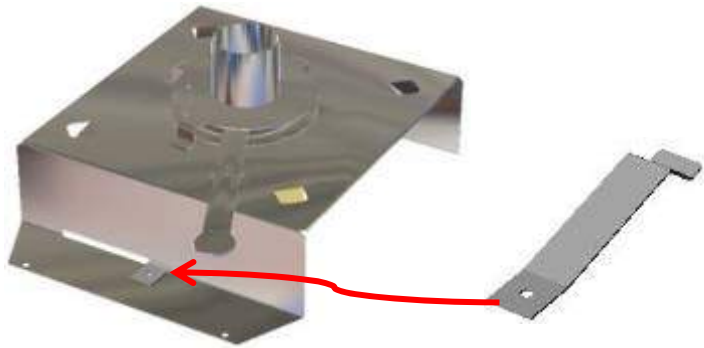




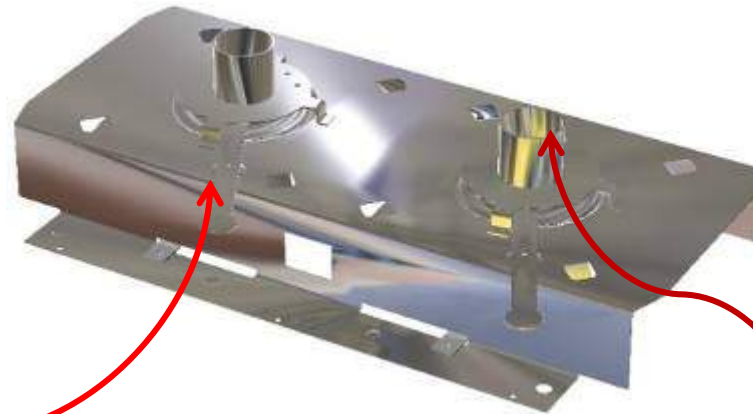
Aluminum-bodied stoves
come in colors.



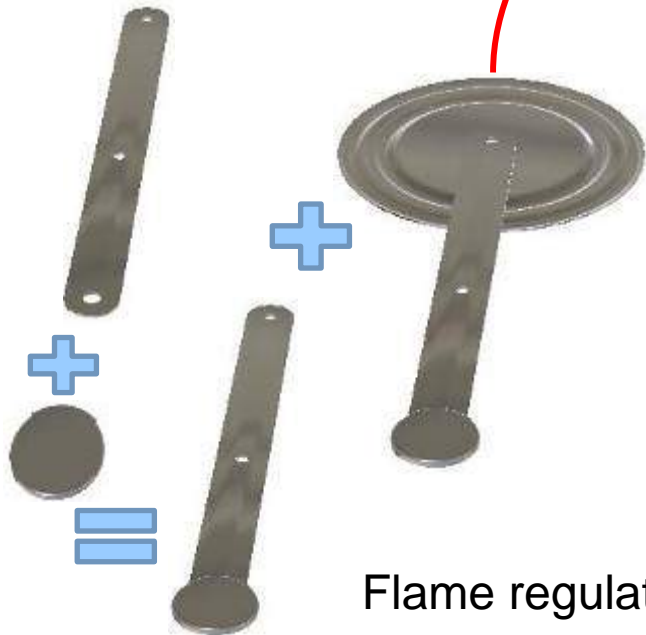
Parts for the two-burner stove. Body manufactured in all-stainless or in aluminum with stainless steel burner, regulator and pot support and galvanized steel heat shield.



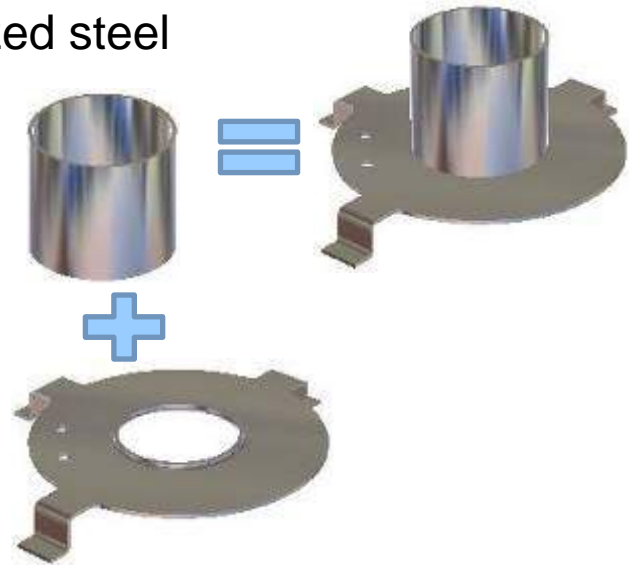
Fuel container clamp



Heat shield can be made of galvanized steel



Flame regulator



Flame chimney

Burner parts, flame regulator and pot support must be made of stainless steel



This aluminum stove withstood a 100 kg deformation test.

Temperatures Testing Origo M1 - Aluminium

DOMETIC Slovakia s.r.o.
26.03.2009
Air temperature: 19°C
Fuel: denaturated alcohol:
ethanol > 80%
methanol < 10%



187°C
115°C
92°C
51°C
19°C



128°C
92°C
51°C
19°C

The stove burns cool. Children are safer around this stove.



Project
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**Simplified stove
for easy local
manufacture**

 **Dometic**
GROUP

