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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

1. Introduction

The CleanCook stove was received at the Aprovecho laboratory in May of 2009 in order to study fuel use and emissions while varying fuels and water contents. Aprovecho conducted standard laboratory testing to determine the relative performance of the stove. Emissions of carbon dioxide, carbon monoxide, particulate matter, and methane were measured. The safety of the stove was also evaluated.

The intention of this testing was to provide a thorough laboratory analysis of the stove model to complement in-field studies in Madagascar.

CleanCook Single Burner Stove

Figure 1.1 The Stove

The fuel used was pure grain alcohol from a local liquor store with varying amounts of water added. Also, an "ideal" soot-free fuel was also used for one test.

2. Testing Methodology

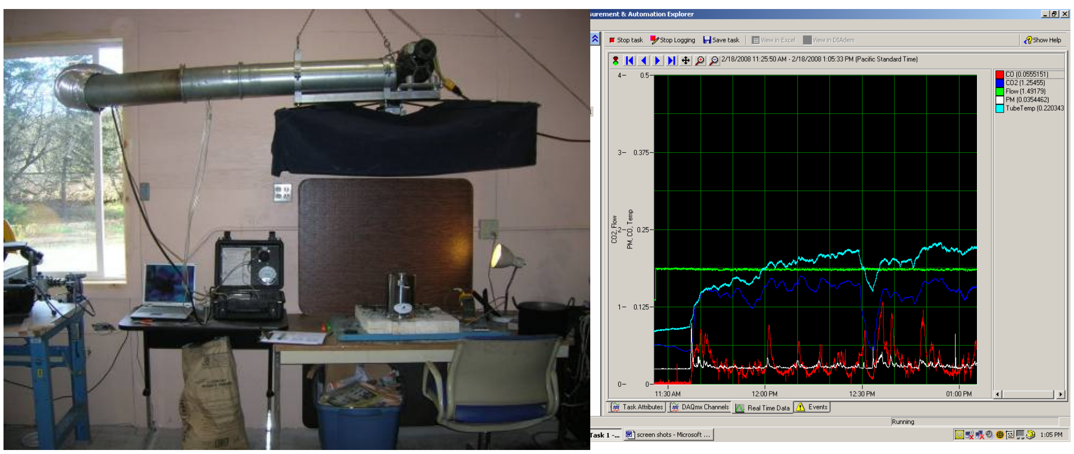
2.1 Testing Protocol

The ethanol stove was tested using the 2003 UCB Water Boiling Test (WBT). The first phase of each test consists of a high-power analysis in which 2.5 or 5 liters of water are brought to a boil in the standard 3 or 7 liter pots. In this case, only the 95% fuel burned in the CleanCook stove produced a high enough firepower to boil the 5 liters, so the other test series were conducted using 2.5 L of water. Each high power test was performed twice with the stove body starting cold and then again when hot. In the low power phase of the test, the 5 liters of water was simmered at about 3 degrees C below the full boiling temperature for 45 minutes.

It is important to note that the Water Boiling Test is not intended to necessarily predict field performance of the stove, as real-world conditions are highly variable.

2.2 Emissions Protocol

The stove was tested using Aprovecho's commercially-available Portable Emissions Measurement System, in which real-time emissions of carbon dioxide (CO_2), carbon monoxide (CO) and particulate matter (PM_{TSP}) were recorded. The system also measured the flow rate of the diluted exhaust gases, enabling mass-based calculations of the emissions.



Emissions Measurement Hood and Emissions Output Screen

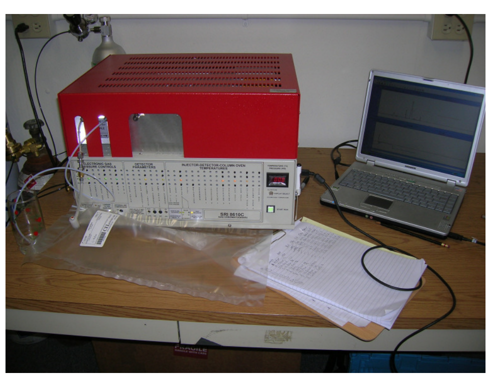


Figure 2.1 – Emissions Equipment

Gas Chromatograph

The Aprovecho gas chromatograph (GC) was used to measure the emissions of carbon dioxide, carbon monoxide, and methane. An integrated Tedlar bag sample was taken from the exit of the emissions collection hood throughout the duration of the test. This sample was then analyzed within 24 hours using the gas chromatograph. A calibration standard was run daily to ensure accurate readings from the GC.

The Aprovecho test protocol suggests that each stove/fuel combination be tested three times for statistical confidence. In this test series, the pure fuel was tested three times as required, but the varying water content levels were tested only once each. So a trend can be observed, but may not account for possible variability.

2.3 Calculation Methodology

2.3.1 Heat Transfer Calculations

Fuel use was calculated in accordance with the standard methods in the Shell Foundation/UCB Water Boiling Test. The prime indicator is that of specific consumption, corrected for starting temperature of the water, moisture content of the fuel, and mass of water remaining in the pot. This provides a measure of fuel used to boil (or simmer) one liter of water.

Fuel used to complete the WBT is reported as the average specific consumption (and emissions) of cold and hot start plus simmer, multiplied by 5 Liters.

2.3.2 Combustion Calculations

Emissions are monitored in real time throughout the duration of the test. The emissions equipment measures both the concentration of each gas and the volumetric flow rate through the system each second. Then the mass of each pollutant emitted during each test phase is calculated.

Because the GC is not real-time, but provides an integrated sample over the duration of the test, the average concentration of the bag sample is applied to each second of the real-time flow data.

This total mass is then normalized and reported as specific emissions to complete the WBT, as corrected for starting temperature of the water, moisture content of the fuel, and mass of water remaining in the pot.

2.4 Fuels and Water Content

The purpose of this test series was to determine the performance of the stove using various fuel stocks. The main base fuel was 95% by volume (190 proof) pure grain alcohol purchased at a local liquor store, with 5% assumed water content. An additional test was run using the special "Soot Free" fuel for boating. It was assumed that the purity of this sample was also 95% with the remainder water, as a detailed ingredient breakdown was not available from the manufacturer.

The Higher Heating Value of the pure ethanol was assumed to be 29.7 MJ/kg as recommended by the NIST Chemistry WebBook.

The experiment involved testing the stove with varying water contents, including 95% ethanol, 90%, 80%, and 60% by volume. To create these varying fuels, the volume of water to add was calculated as follows:

$$VolumeWater_{Added} = \frac{VolumeEthanol_{Present} - Concentration_{End} * TotalVolume_{Present}}{Concentration_{End}} \quad \text{(Eq. 1)}$$

Using this calculation, a calculated volume of distilled water was then added to the 95% pure ethanol fuel stock. The pure fuel stock and 90% concentrations were both verified using laboratory-grade hydrometers and found to be precise.

Figure 2.2 – Laboratory Hydrometer

It is important to note that the calculation of water content by volume is different than the moisture content on a wet mass basis as used in WBT calculations. Give that the density of water is 1 g/mL and the density of pure ethanol is 0.789 g/mL, moisture content on a wet basis is calculated as follows:

$$MC_{wet}\% = \frac{(1*VolumeWater_{Present} + 1*VolumeWater_{Added})}{(1*VolumeWater_{Present} + 1*VolumeWater_{Added} + 0.789 * VolumeEthanol_{Present})} \quad \text{(Eq. 2)}$$

The percent ethanol by volume and corresponding moisture contents on a wet basis are then as follows:

Table 2.1 – Percent by weight and volume

Percent Ethanol by Volume	$MC_{wet}\%$
95%	6.3%
90%	12.3%
80%	24.1%
60%	45.8%

When a different moisture content or type of fuel was used, a brand new fuel canister for the CleanCook was used.

3. Results

3.1 Heat Transfer

Since users in the real world will purchase fuel on a per volume basis, irrespective of actual ethanol content, the gross fuel use is an interesting measure. However, since water does not provide energy to the pot but rather requires energy to be evaporated, actual ethanol used to heat the pot should also be investigated.

Gross fuel consumption, uncorrected for water content, starting temperature, or water remaining, was as follows:

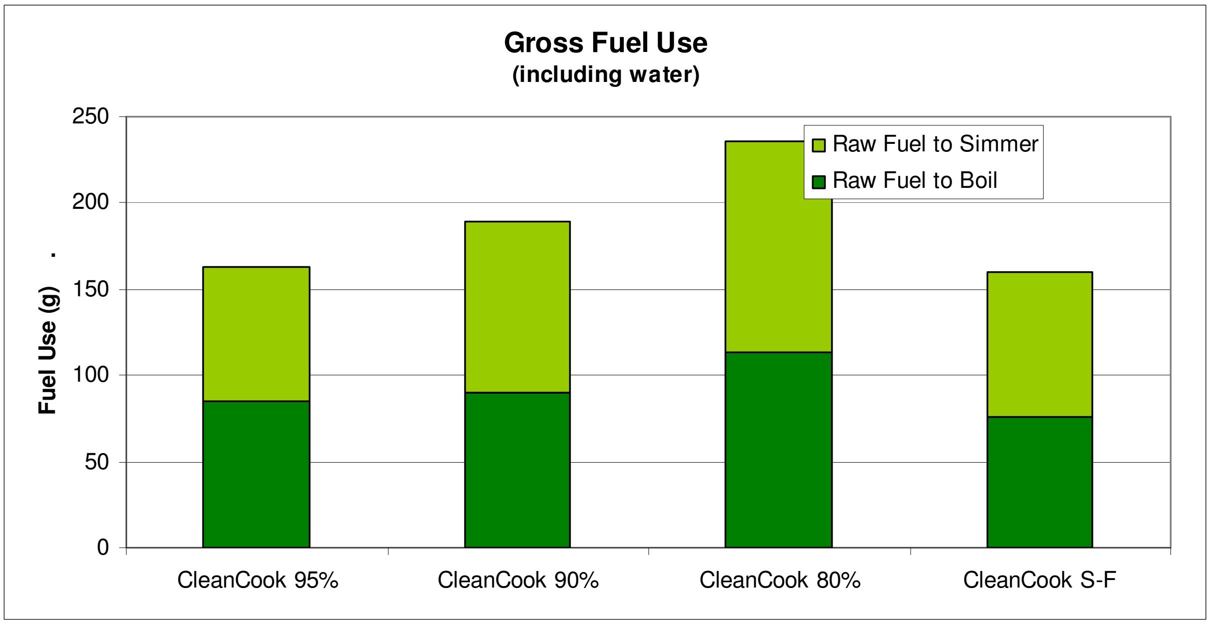


Figure 3.1 – Gross Fuel Use

As expected, the mass of total fuel increased when increasing water content. The fuel use of the special "soot-free" fuel in the CleanCook was similar to that of the 95% ethanol spirits, suggesting similar calorific values for the two fuels.

The results below are based on "Specific Consumption" rather than direct fuel use. Specific consumption is calculated by the fuel used (minus the water and energy required to evaporate the water in the fuel) divided by the liters of water heated, providing a measure of fuel use per useful task completed. This measure is an alternative to calculating the effective calorific value of the fuel containing water. The same "specific" calculation was done for reported emissions. Data is then presented as if each stove had been tested with 5 Liters of water. The following results are the specific fuel use based on the standard measure showing each of the tests conducted on the stove. In theory, when the water content is corrected for, the different fuels should show equal results. So here the differences should show how the water content effects heat transfer, irrespective of the physical removal of the actual water.

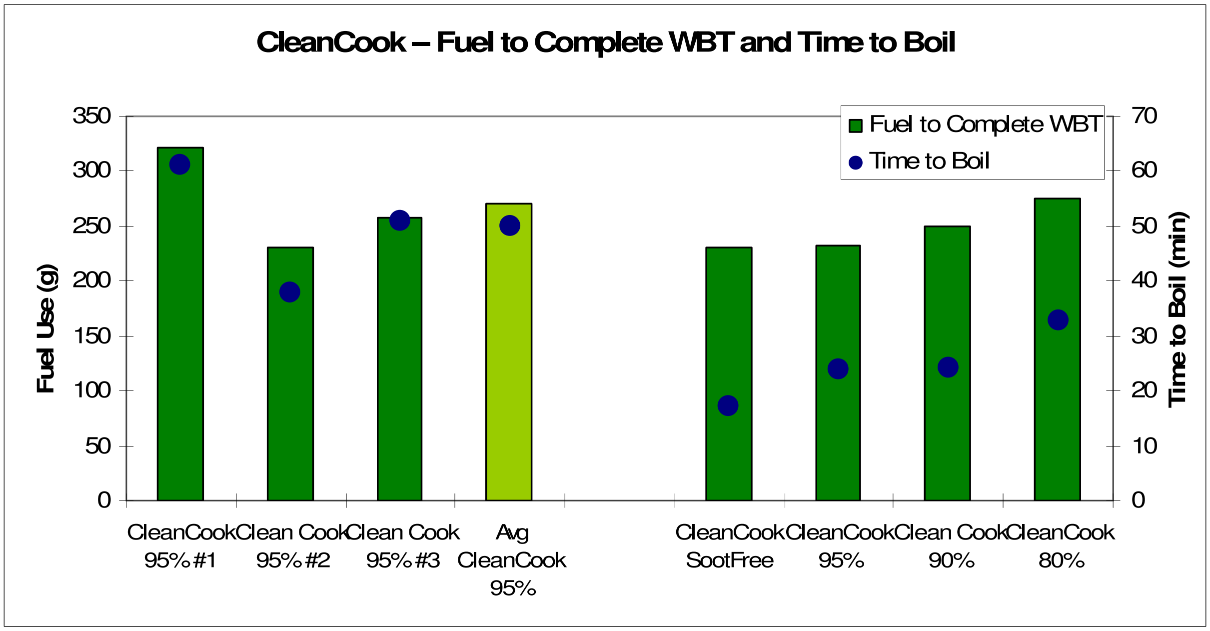


Figure 3.2 – CleanCook, Fuel Use and Time to Boil

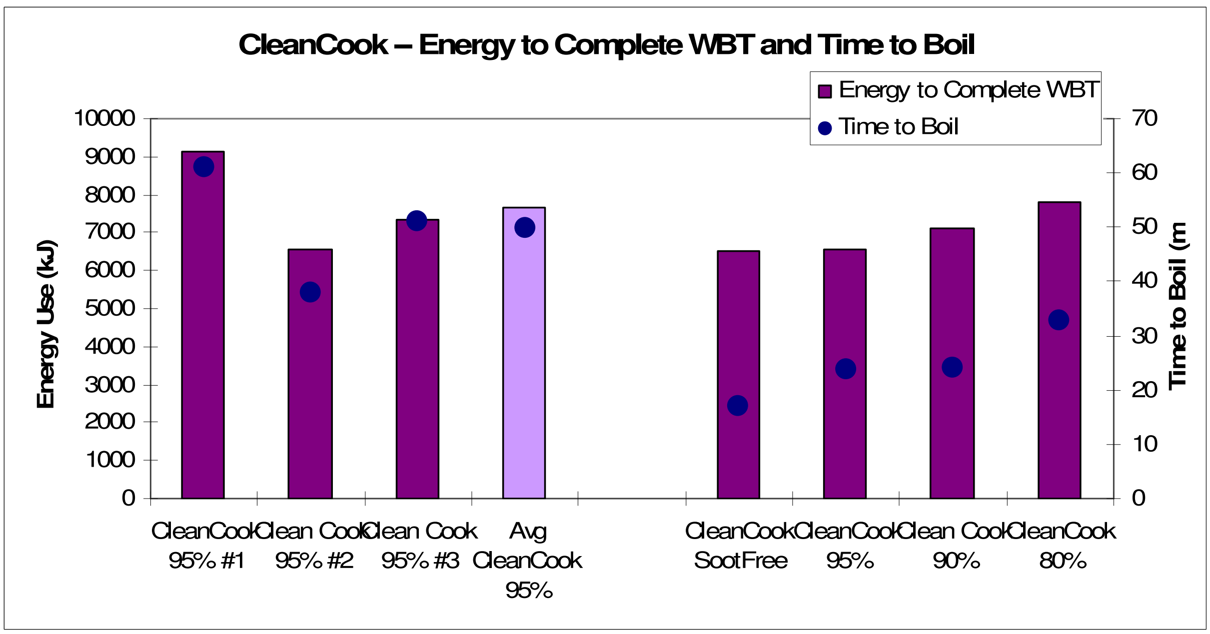


Figure 3.3 – CleanCook, Energy Use and Time to Boil

The first three bars show the three tests with 95% pure fuel and the fourth shows the average of these tests. There is a surprising amount of variability between tests done with the same fuel, likely due to the long time period and high amounts of water evaporation on tests done with 5 liters. Increasing water content in the CleanCook appeared to follow a trend of increasing corrected fuel use, suggesting the presence of water in the CleanCook may affect the function of the stove. However, since only one test per water content was completed, this trend may not be statistically significant. There is also an upward trend in the time to boil with increasing water content.

Note the first 4 tests of the CleanCook were based on 5L tests, while all of the others tests used 2.5L.   This difference will not affect the fuel use measure, but can be clearly seen in the time to boil.

Time to boil increased at a relatively linear rate as the water content of the fuel increased.

The following chart shows the overall results.

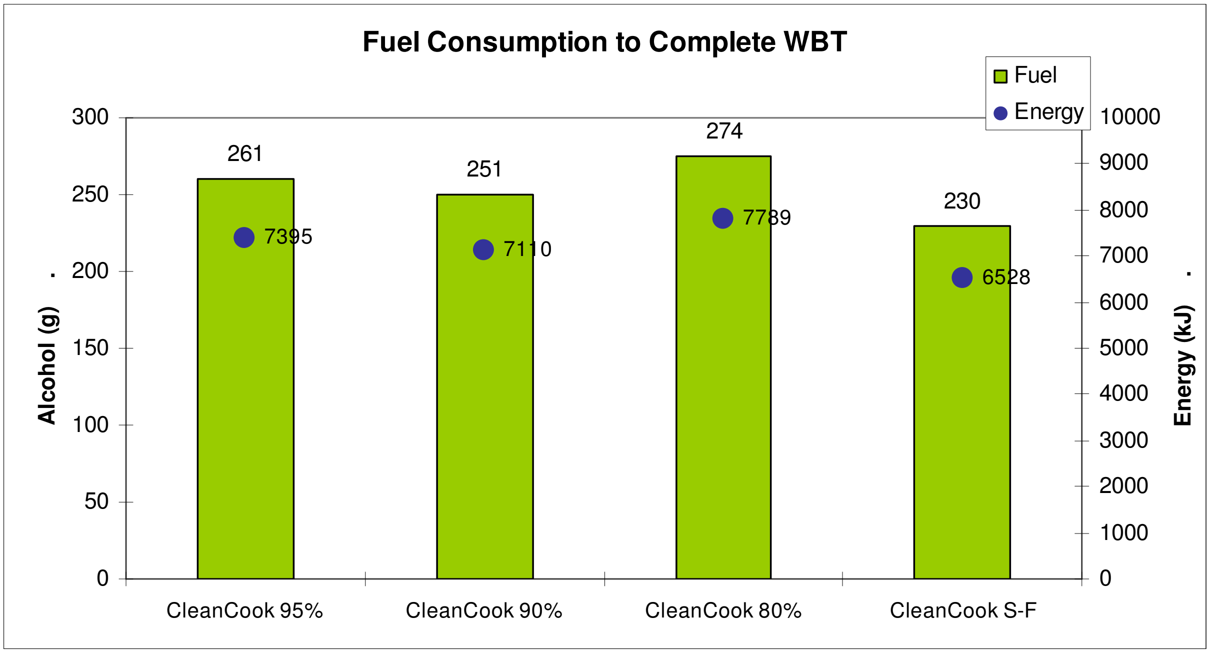
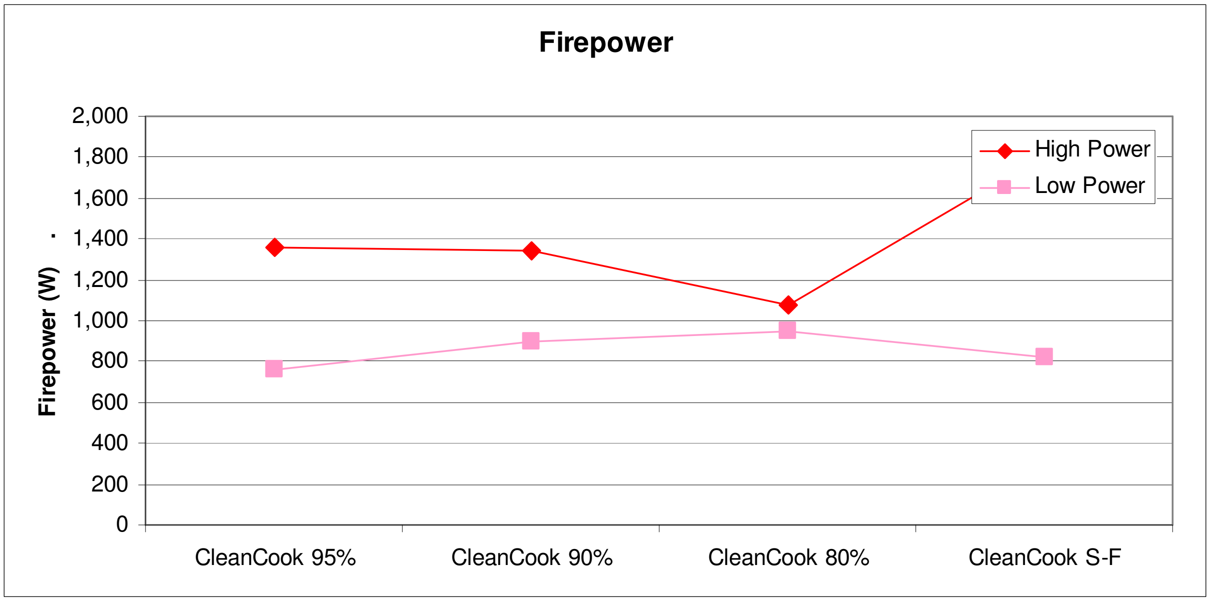


Figure 3.6 – Overall Fuel Consumption

These results show the dry fuel consumption, corrected for water content. The fuel use benchmark as proposed by Aprovecho and Shell Foundation is 15,000 kJ of energy used to boil and simmer the water during the Water Boiling Test. The CleanCook passed this benchmark, requiring only an average of about 50% of the allowable energy use.

On average, the CleanCook used 254 g (7206 kJ) of dry ethanol to complete the WBT.

Firepower, or the burning rate of actual ethanol, decreased with increasing water content at high power. This is as expected, due to the increased time required to boil with increasing water content suggesting slower burning of the ethanol fuel. Firepower at simmer seemed to follow an opposite trend.



Thermal efficiencies were generally independent of water content, as expected. The average thermal efficiency for the CleanCook was 53% at high power and 48% at low power.

Table 3.1 – Thermal Efficiency

	CleanCook 95%	CleanCook 90%	CleanCook 80%	CleanCook S-F
High Power	53%	53%	53%	53%
Low Power	48%	49%	44%	50%

3.2 Total Emissions

It is surprising that the real-time carbon monoxide (CO) emissions were not constant in either stove. Emissions were dependent on how much fuel was in the canister and how long the stove had been burning. For example:

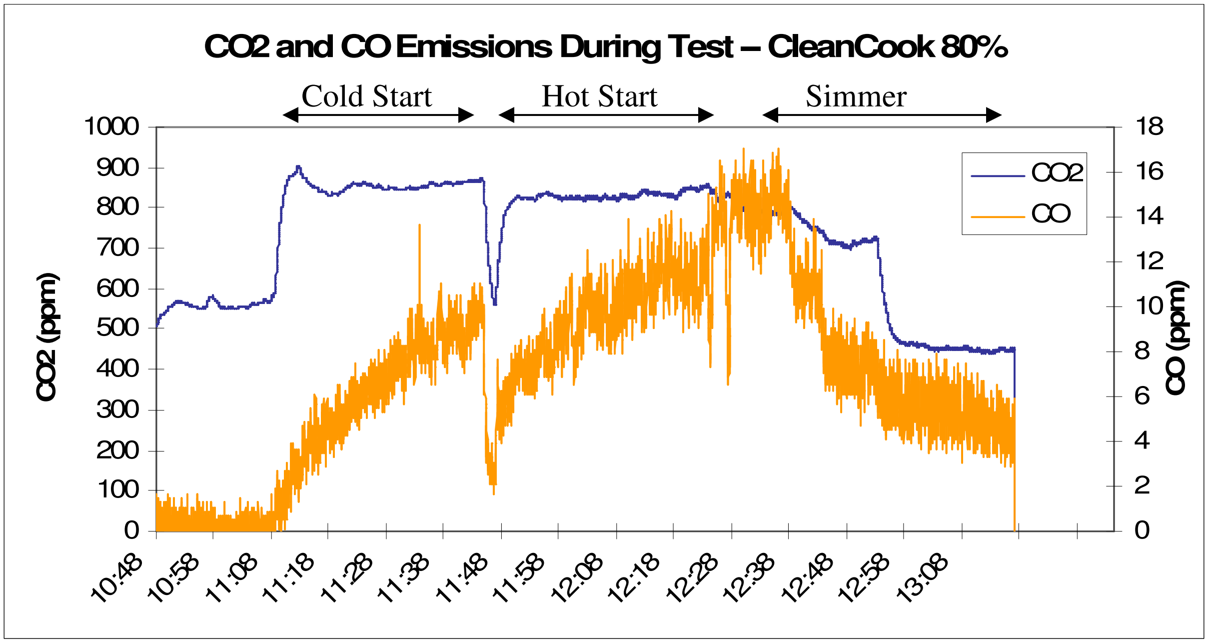


Figure 3.7 – Real-Time CleanCook Data

As the CleanCook heats up, CO emissions increase while CO_2 (firepower) remains fairly constant.

When uncorrected for the amount of fuel required to evaporate the water in the canister, Total CO emissions were as follows:

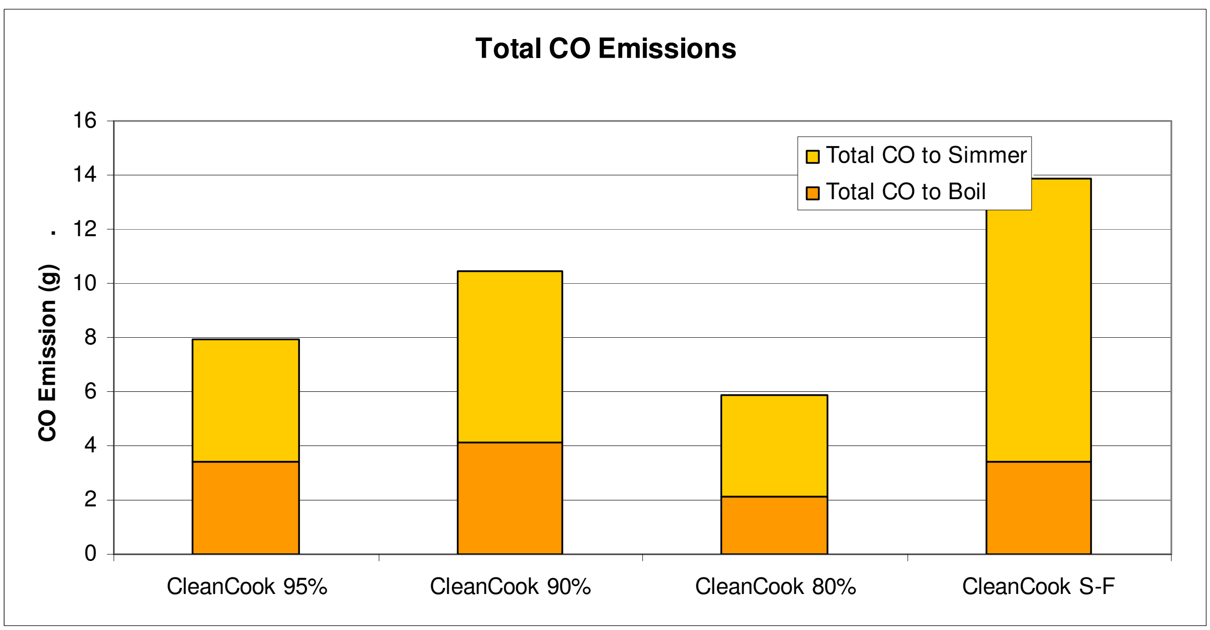


Figure 3.9 – Gross CO Emissions

The Soot-Free fuel seemed to emit high amounts of CO when operated at low power in the CleanCook stove, although emissions are similar to the pure fuel at high power. The water content in the fuel did not seem to have a significant effect on combustion in terms of the total CO production.

As shown in the next chart, when corrected for the emissions produced while evaporating the water in the fuel, and reported as emissions to complete the 5L WBT, CO emissions were:

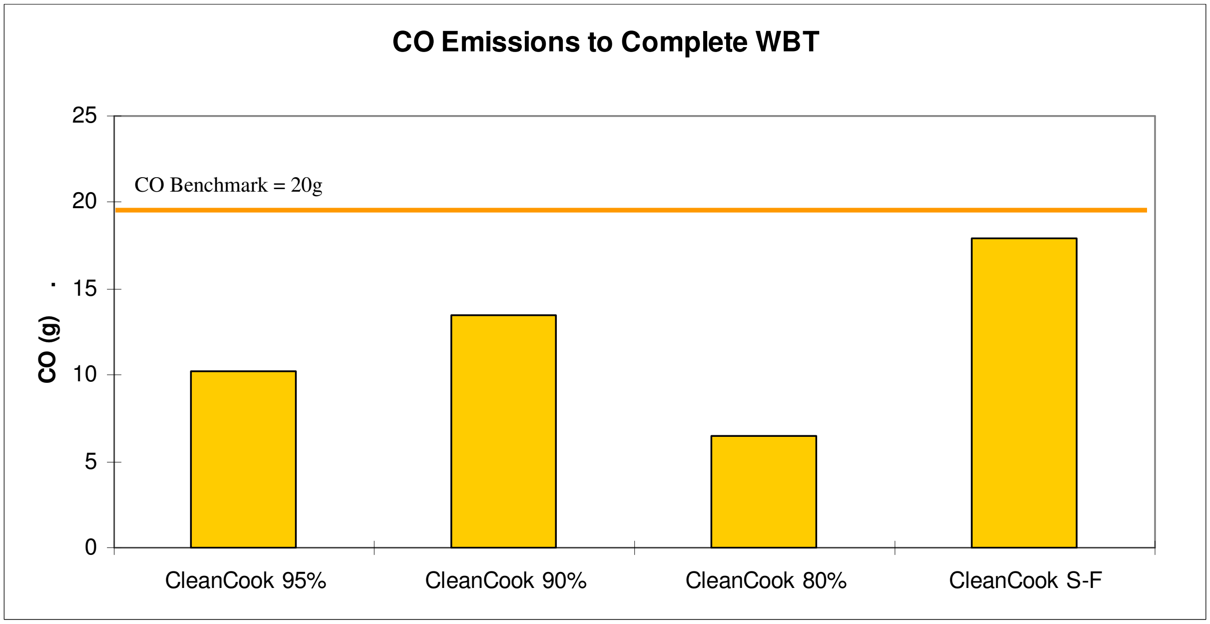


Figure 3.10 – CO Emissions to complete WBT

Note the Shell Foundation/Aprovecho CO benchmark for an improved wood burning cook stove is 20 grams to complete the WBT. The CleanCook stove met this benchmark with all fuels.

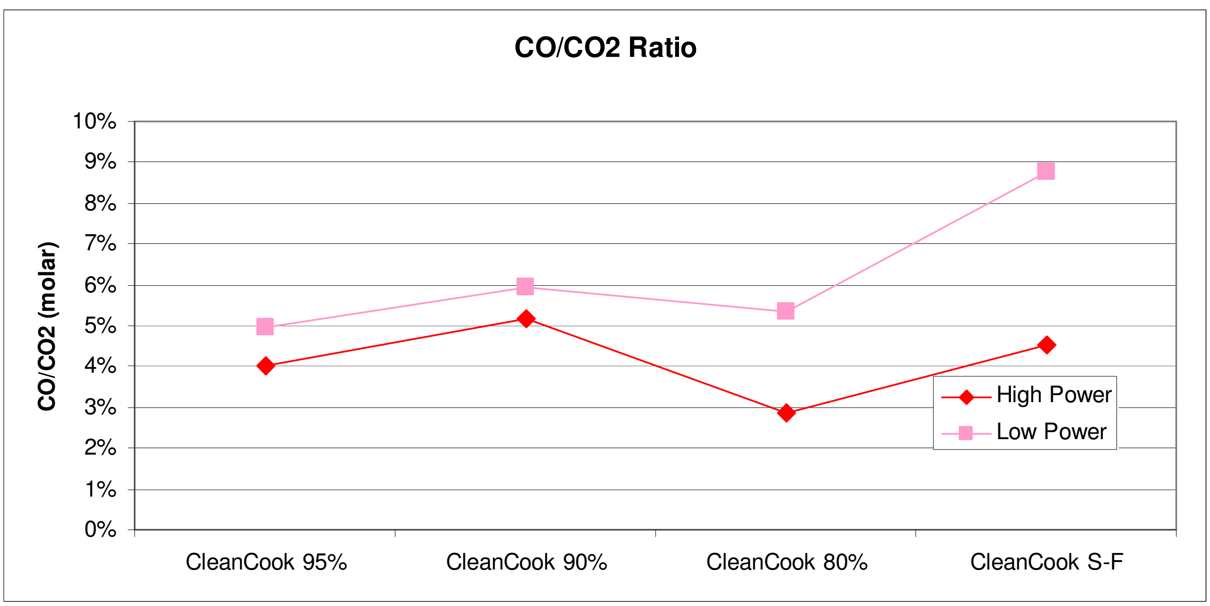


Figure 3.11 – CO/CO_2 Ratio

The CleanCook stove showed an average CO/CO_2 ratio of 4% at high power and 5% at low power in the spirits-based fuel tests.

Particulate Matter ($PM_{2.5}$) Emissions were negligible in all tests.

Methane emissions can be highly variable and difficult to measure, however, the gas chromatograph tests resulted in the following methane emission levels:

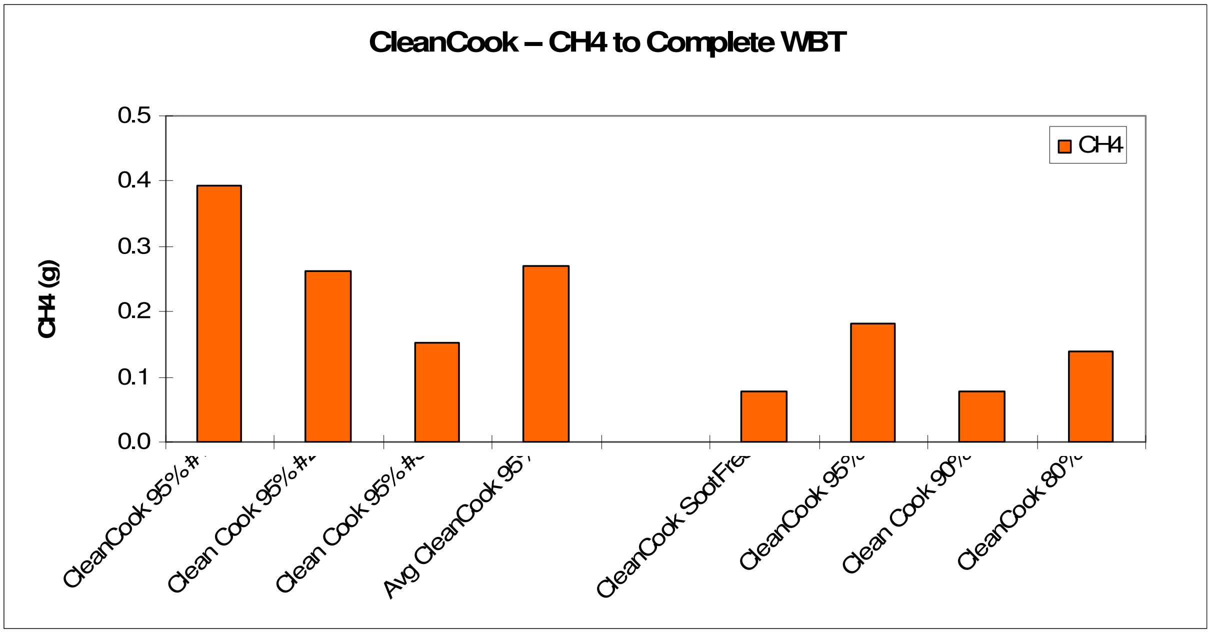


Figure 3.12 – CleanCook Methane Emissions to Complete WBT

The methane/CO_2 ratio ranged from 0.02% to 0.35% in the CleanCook stove.

3.4 Emission Factors and IPCC Defaults

Emission factors per kg and MJ of ethanol combusted:

Table 3.2 – Measured Emission Factors per Fuel Combusted (g and MJ)

		Clean Cook			
		95%	90%	80%	Soot Free
CO High Power	g/kg	36.25	57.14	32.29	50.46
CO Low Power	g/kg	47.00	65.57	59.04	93.97
CO High Power	g/MJ	1.29	1.85	0.86	1.70
CO Low Power	g/MJ	1.84	2.56	1.43	4.68
Methane High Power	g/kg	1.17	0.46	0.53	0.25
Methane Low Power	g/kg	1.00	0.22	0.84	0.52
Methane High Power	g/MJ	0.04	0.02	0.02	0.01
Methane Low Power	g/MJ	0.04	0.01	0.03	0.02
CO2 High Power	g/kg	1776	1744	1783	1648
CO2 Low Power	g/kg	1759	1730	1741	1686

CO2 High Power	g/MJ	63	56	48	54
CO2 Low Power	g/MJ	68	68	42	84

There are default IPCC emission factors in the online database at http://www.ipcc-nggip.iges.or.jp/EFDB/main.php for comparison. However, under fuel combustion activities in the residential energy sector, there are no values available for ethanol in either the 1996 or 2006 guidelines.

For reference, the listed default for *wood* used in residential cooking is 112 g/MJ for CO_2 and 0.3 g/MJ for Methane [IPCC 2006]. In this test series, emission factors for ethanol averaged 64 g/MJ CO_2 and 0.02 g/MJ methane. Thus, the average emission factors for ethanol seem to be 57% of wood for CO_2, and only 5% of methane.

The listed value for kerosene used in residential cooking in wick stoves is available in the IPCC emission factor database:

Table 3.3 – IPCC Default Kerosene Emission Factors

Gas	Fuel 2006	Description	Technologies / Practices	Value	Unit	Data provider	Source of data
METHANE	Other Kerosene	CH4 Emission Factor for Stationary Combustion (kg/TJ on a net calorific basis)		10	kg/TJ	IPCC	2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 2: Energy, Table 2.5
METHANE	Other Kerosene	Residential Source Emission Factor	Other Kerosene Stoves: Wick	2.2 - 23	kg/TJ	IPCC	2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 2: Energy, Table 2.9
CARBON DIOXIDE	Other Kerosene	CO2 Emission Factor for Stationary Combustion (kg/TJ on a net calorific basis)		71900	kg/TJ	IPCC	2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 2: Energy, Tables 1.4 and 2.5
NITROUS OXIDE	Other Kerosene	N2O Emission Factor for Stationary Combustion (kg/TJ on a net calorific basis)		0.6	kg/TJ	IPCC	2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 2: Energy, Table 2.5
NITROUS OXIDE	Other Kerosene	Residential Source Emission Factor	Other Kerosene Stoves: Wick	1.2 - 1.9	kg/TJ	IPCC	2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 2: Energy, Table 2.9

IPCC 2006 Source/Sink Category**:** Energy (1) -> Fuel Combustion Activities (1.A) -> Other Sectors (1.A.4) -> Residential (1.A.4.b)

As seen in the table, default emission factors for kerosene are 71.9 g/MJ for CO_2 and 0.0022 to 0.023 g/MJ combusted for methane, similar to the measured values for ethanol [IPCC, 2006].

In order to investigate emissions per MJ delivered, the emission factor is divided by the thermal efficiency of the stove. The average efficiency of the CleanCook was 53%. Extensive tests at Aprovecho showed efficiency of a kerosene wick stove at 52%, and 20% for the three-stone fire [Still et al, 2009]. All are thermal efficiencies in this analysis were recorded at high power.

Table 3.4 – Emission Factor Summary

	Ethanol Measured		Kerosene Default		Wood Default	
Measured Thermal Efficiency	52.5%		52%		20%	
Per MJ	Combusted	Delivered	Combusted	Delivered	Combusted	Delivered
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 CO_2 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 CO_2 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 CO_2 emission factors based on Carbon balance

Fuel	Molecular Formula	Carbon Fraction	Energy Content (MJ)	Combustion Efficiency (estimated)	Stove Efficiency (reported)	gCO2/MJdelivered
Ethanol	C2H6O	52%	21	95%	64%	133
LPG	C3H8,C4H10	82%	50	98%	57%	103
Kerosene	CnH(2n+2)	85%	43	95%	50%	137

3.5 Flame Quality

It was interesting to note differences in flame characteristics for the various water content fuels. Photos were taken of the flame, but were not able to capture the difference. Notes on flame qualities were taken during the experiments.

Table 3.6 – Flame Quality Observations

	CleanCook
95%	Strong orange flame
90%	Darker orange flame
80%	Blue flame with light orange tips
60%	N/A
SootFree	Clear blue flame with some light orange

The trend in flame quality showed that increasing water content led to increasing blueness of the flame.

4. Recommendations for Improvement

There are no apparent improvements to heat transfer or combustion efficiencies for the stove.

A benchmark certification for the CleanCook stove is provided at the end of this document.

5. Safety Evaluation

The stove was also 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:

Table 4.1 – CleanCook Safety Evaluation

CleanCook Safety Evaluation	Score/4	Comments
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**	

The CleanCook stove was quite safe. Access to the fuel canister is only through the bottom of the stove preventing the danger of refilling from the top and the associated risk of burns. Refilling can only be done with the canister completely removed, and it does not generally remain hot enough to be dangerous.

6. Conclusions

The CleanCook was able to efficiently combust ethanol containing substantial amounts of water. Increasing water content did increase the cooking time, but not generally the actual ethanol use. Up to 40% water content was successfully burned, although the high water content had reduced firepower such that it was not able reach full boiling temperature. Water content did not generally affect products of incomplete combustion in a predictable way.

7. Resources

For questions about this report, please contact Nordica MacCarty at nordica.maccarty@gmail.com.

2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 2: Energy, Chapter 1. 2006.

Bailis, R. "Stove Performance and Evaluation Protocols, Forms, and Guidelines: The Water Boiling Test (WBT)." Center for Entrepreneurship in International Health and Development (CEIHD) and The Shell Foundation. 2006.

Cheremisinoff, N. Properties of Wood. Wood for Energy Production. Ann Arbor, MI, Ann Arbor Science: 31-43. 1980.

IPCC Emission Factor Database, default data presented in the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories and the IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, http://www.ipcc-nggip.iges.or.jp/EFDB/main.php, Accessed November, 2008 and July, 2009.

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Appendix A – Aprovecho/Shell Foundation Benchmarks
September 17th, 2007

Since 2003, Aprovecho Research Center has been testing biomass burning stoves using both the revised UCB Water Boiling Test and the Controlled Cooking Test. The stove evaluation includes monitoring emissions produced during the testing. In 2006, Aprovecho was requested by the Shell Foundation to propose benchmarks of performance that define improved stoves. The suggested definition of an improved stove was based on a library of results from over 50 stoves. Stoves that pass the following benchmarks are defined as improved.

Stoves are benchmark tested using the 2003 UCB Laboratory Water Boiling Test. The 'improved' stove meets the following proposed performance benchmarks:

1.) **Fuel use:** Using the International Testing Pot, a wood burning stove without a chimney should use less than 850 grams (15,000 kJ) of wood to bring to boil 5 liters of 25 degree C water and then simmer it for 45 minutes during the UCB revised Water Boiling Test.
2.) **Emissions:** The wood burning stove without a chimney should produce less than 20 grams of Carbon Monoxide to boil 5 liters of 25 degree C water and then simmer it for 45 minutes during the UCB revised Water Boiling Test.
3.) **Emissions:** The wood burning stove without a chimney should produce less than 1500 milligrams of Particulate Matter to boil 5 liters of 25 degree C water and then simmer it for 45 minutes during the UCB revised Water Boiling Test.
4.) **Chimney Stoves:** Wood burning stoves with chimneys are exempt from the above standard if the stove does not allow more than an average of 50 parts per million of Carbon Monoxide to pollute the air anywhere within 30cm of the stove. A wood burning stove with chimney should use less than 1500 grams (30,000 kJ) of wood to bring to boil 5 liters of 25 degree C water and then simmer it for 45 minutes during the UCB revised Water Boiling Test.

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Appendix B -- Benchmark Certification for the CleanCook Stove
June 29th, 2009

STOVE NAME	CleanCook	
ORGANIZATION	Project Gaia/Dometic	
LOCATION	Madagascar/Ethiopia	
DESCRIPTION	A single-burner stainless steel ethanol stove with fiber-filled enclosed fuel canister.	
IMPROVEMENTS MADE	None necessary.	
MET BENCHMARKS?	**YES**	
	As Received	As Improved
TIME TO BOIL 5L	49.9	
FUEL TO COOK *15 MJ Benchmark*	7.7	
CO EMISSION TO COOK *20 g Benchmark*	10.0	
PM EMISSION TO COOK *1500 mg Benchmark*	Negligible	
SAFETY SCORE	39/40	

Safety Evaluation	Score/4	Comments
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**	

Certified By: Nordica MacCarty, Laboratory Manager

Appendix C – Detailed Test Data, Clean Cook

CleanCook		CleanCook 95% #1 5L	CleanCook 95% #1 5L	CleanCook 95% #1 5L	Average CleanCook 95% 5L	CleanCook SootFree	CleanCook 95	Clean Cook 90	CleanCook 80
Cold Start Time to Boil 5L	min	63	42	53	53	17	24	25	32
Hot Start Time to Boil 5L	min	59	34	49	47	17	24	24	33
Fuel Used to Boil 1L of Water	g/L	38	25	30	31	27	29	29	32
Fuel Used to Simmer for 45min	g/L	26	21	22	23	38	35	43	46
Fuel Used to Cook 1L of Food	g/L	64	46	52	54	65	64	71	78
Energy Used to Boil 1L of water	kJ/L	1,083	716	850	883	772	820	818	908
Energy Used to Simmer 1L of water	kJ/L	743	593	615	650	1,067	991	1,208	1,300
Energy Used to Cook 1L of Food	kJ/L	1,826	1,310	1,465	1,533	1,839	1,811	2,026	2,208
Boil Firepower	Watts	1,309	1,518	1,299	1,375	1,812	1,362	1,341	1,079
Simmer Firepower	Watts	1,116	969	969	1,018	822	763	901	953
Burning Rate High Power	g/min	3	3	3	3	4	3	3	2
Burning Rate Low Power	g/min	2	2	2	2	2	2	2	2
Boil Thermal Efficiency	%	57%	59%	57%	58%	53%	53%	53%	53%
Simmer Thermal Efficiency	%	52%	53%	55%	53%	50%	48%	49%	44%
Turn Down Ratio		1.2	1.6	1.3	1.4	2.2	1.8	1.5	1.1
Emissions									
CO Released to Boil	g/L	1.1	0.9	1.0	1.0	1.2	1.2	1.3	0.6
CO Released to Simmer	g/L	0.5	1.3	1.3	1.0	4.7	2.0	2.7	1.4
CO Released to Cook	g/L	1.5	2.1	2.3	2.0	5.9	3.2	4.0	2.0
Methane Released to Boil	mg/L	0.07	0.04	0.02	0.04	0.01	0.01	0.01	0.01
Methane Released to Simmer	mg/L	0.02	0.02	0.01	0.02	0.02	0.05	0.01	0.03
Methane Released to Cook	mg/L	0.09	0.06	0.04	0.06	0.02	0.06	0.02	0.04
CO2 Released to Boil	g/L	65.0	39.7	56.2	53.6	42.4	45.6	40.4	33.1
CO2 Released to Simmer	g/L	41.6	33.0	48.7	41.1	83.9	64.2	71.7	41.7
CO2 Released to Cook	g/L	106.6	72.7	104.9	94.7	126.3	109.8	112.1	74.8
Emission Factors									
CO/CO2 Ratio High-Power		2.6%	3.4%	2.9%	2.9%	4.5%	4.0%	5.2%	2.9%
CO/CO2 Ratio Low-Power		1.7%	6.0%	4.2%	4.0%	8.8%	4.9%	6.0%	5.3%
CO Emission Factor to Boil	g/kg	29.8	36.4	37.0	34.4	48.1	43.0	52.5	24.3
CO Emission Factor to Simmer	g/kg	18.9	64.0	64.4	49.1	132.8	61.7	72.8	40.7
Methane Emission Factor to Boil	g/kg	1.80	1.42	0.88	1.37	0.25	0.48	0.46	0.53
Methane Emission Factor to Simmer	g/kg	0.99	0.78	0.57	0.78	0.52	1.44	0.22	0.84
Benchmarks									
Energy to Cook 5L (15,000 kJ Benchmark)	kJ	9128	6549	7325	7667	6528	6578	7110	7789
CO to Cook 5L (20 g Benchmark)	g	7.7	10.6	11.7	10.0	17.9	10.9	13.4	6.5
Methane to Cook 5L	mg	0.4	0.3	0.2	0.3	0.1	0.2	0.1	0.1