SNV

Narrative testing report on the SPIN forced draft gasifier stove

25 December 2014

by SNV Laos

1. Introduction

As a spin-off of the EU funded SPIN project, a new, smaller gasifier has been developed by the Centre for Creativity and Sustainability (CCS) in Vietnam; Delft University of Technology (TUD), the Netherlands; and the Elegance Co.Ltd, Vietnam. SNV Laos was requested to test the SPIN stove based on the IWA protocol with the purpose of independently validating its performance.

2. Stoves test laboratory

The tests were conducted at the stove test laboratory at the Renewable Energy and New Materials Institute under the Ministry of Science and Technology in Vientiane Capital. Since its establishment in 2013, dozens of stove tests have been conducted here by staff who have been trained by international recognised testing institutes (Aprovecho, GERES Cambodia). The laboratory was set up under the Improved Cookstoves Programme (see www.icslao.info).

Equipment used include the Portable Emission Measuring System (PEMS #2026) that monitors temperature, CO, CO2 and PM; a moisture meter to measure the moisture content of the fuel used; and a digital weight to measure the quantity of fuel and water and a thermo couple.

3. Conclusion

The SPIN stove is a compact and attractive-looking stove, which, in combination with wood pellets, is highly efficient and very clean. The burner on the top of the stove mimics flames from LPG that are equally blue and emit very low levels of emissions. The SPIN stove-pellet combination has the potential to drastically reduce smoke exposure and minimise related health risks when compared to normal kitchen settings.

On the other hand, the flame is not very stable, especially when re-filling the stove during cooking, or during simmering. Reigniting the stove is not that convenient and creates smoke.

SNV Laos recommends piloting the stoves on a sample of households, using SUMS devised to objectively assess the functionality in households and to receive qualitative feedback that will help to adjust the stove to practical needs.

4. Testing objective

1. Assess the efficiency and emissions of the SPIN stove according to IWA protocol,
2. Compare the performance between the SPIN and Philips stoves using the Adapted Water Boiling Test protocol.

5. Testing methodology

The Water Boiling Test (WBT) 4.2.3 has been used for this testing, see the reference website at the link below:
http://www.aprovecho.org/lab/emissionsequip/software/category/46

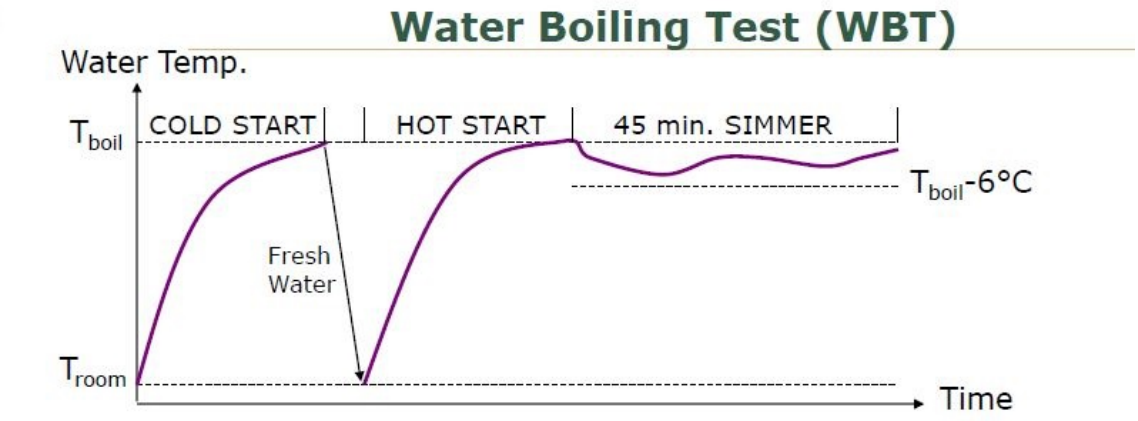
- 500g of pellets were used for each phase of testing (hot start, cold start, simmering).

- As a starter we used 40g of rice husk and 5g of paper.

- The stove was filled in four layers: first 450g of wood pellets and then 20g of rice husk, after that the remaining 50g of wood pellets, and then 20g of rice husk on the top.

- We ignited the stove with paper then turned the button to mid-range middle speed, and gradually increased the speed of the fan.

- After 3 to 5 minutes the burner was put on the stove.
- New fuel was prepared according to the process above for each of the test phases (hot start, cold start, simmering).
- The WBT4.2.3 protocol is comprised of the following steps:



6. Testing date and venue

- The chief tester was Mr. Bounthavy Sengtakoun, technical advisor of SNV Laos to the ICS programme in Lao PDR.
- Testing was carried out from 5 to 9 December 2014.
- The venue was the stove test laboratory of the Renewable Energy and New Materials Institute in Vientiane.

7. Fuel used

The pellets used were made of 80% acacia sawdust and 20% pine, cinnamon and eucalyptus.

An average soft wood was selected to identify the gross calorific value in the calculation format, as can be seen in the table below.

Data	value	units	label
Air temp	23.0	°C	
Average dimensions of fuel	1	cm x cm x cm	
Gross calorific value (dry fuel)	20,817	kJ/kg	HHV
Net calorific value (dry fuel)	19,497	kJ/kg	LHV
Wood moisture content (% - wet basis)	6.0%	%	MC
the fuel)	18,173	kJ/kg	EHV
Net calorific value charcoal (dry fuel)	29,500		LHV

The moisture content of the pellet in wet-basis is 6%, see in below table.

Test-1	Instrument reading (% dry basis)		
	1	2	3
Piece 1	7.0%	8.0%	9.0%
Piece 2	4.0%	6.0%	7.0%
Piece 3	5.0%	6.0%	7.0%
Average moisture content (%)			
dry-basis	7%	wet-basis	6%

Test-2	Instrument reading (% dry basis)		
	1	2	3
Piece 1	7.0%	8.0%	9.0%
Piece 2	4.0%	6.0%	7.0%
Piece 3	5.0%	6.0%	7.0%
Average moisture content (%)			
dry-basis	7%	wet-basis	6%

Test-3	Instrument reading (% dry basis)		
	1	2	3
Piece 1	7.0%	8.0%	9.0%
Piece 2	4.0%	6.0%	7.0%
Piece 3	5.0%	6.0%	7.0%
Average moisture content (%)			
dry-basis	7%	wet-basis	6%

Test-4	Instrument reading (% dry basis)		
	1	2	3
Piece 1			
Piece 2			
Piece 3			
Average moisture content (%)			
dry-basis		wet-basis	

8. Tested stove

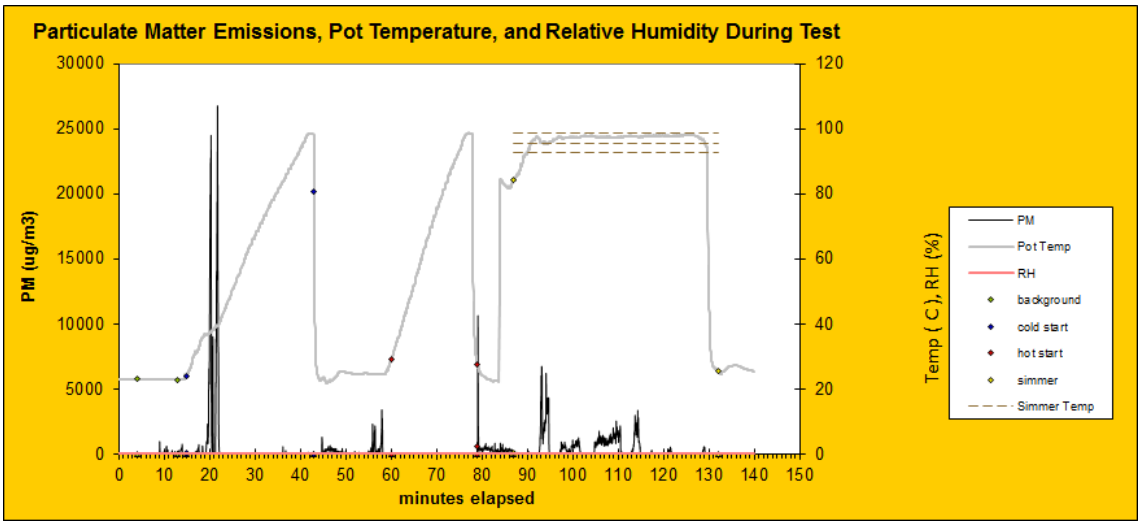
There are three main parts of the Vietnam gasifier stove: the burner, the combustion chamber and the stove body with the fan. The total weight of the stove is 3,170g, with a maximum load of 948g of pellets.

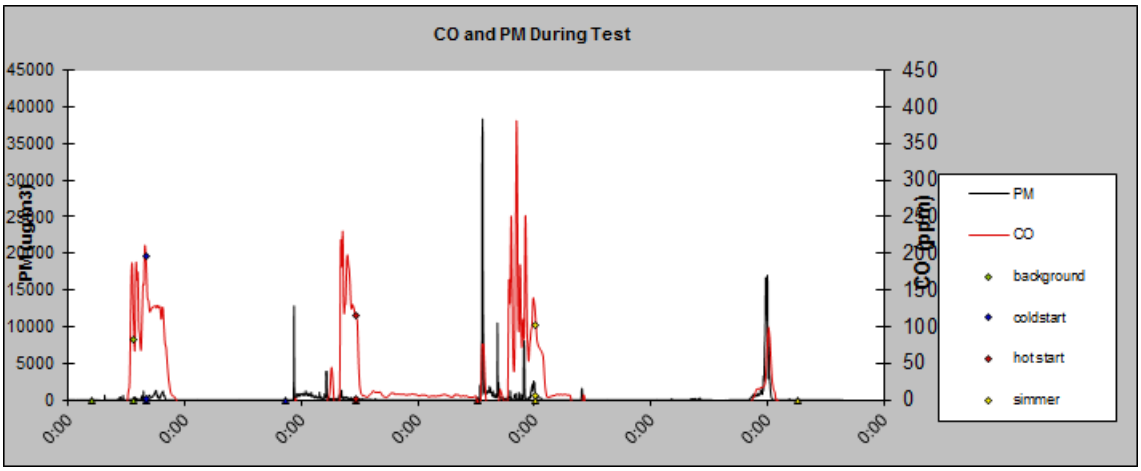
9. Outcome of the testing

9.1. Key observations about the SPIN stove

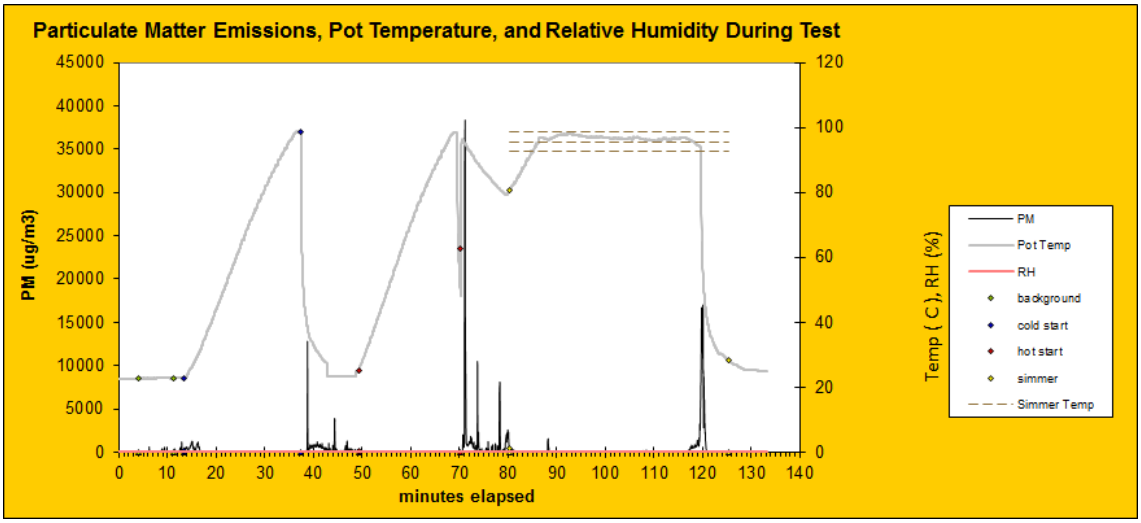
The graphs below show the emissions recorded by the PEMS.

- *Test 1:*


Particulate Matter Emissions, Pot Temperature, and Relative Humidity During Test
PM (ug/m3)
Temp (C), RH (%)
minutes elapsed
PM
Pot Temp
RH
background
cold start
hot start
simmer
Simmer Temp


CO and PM During Test
PM (ug/m3)
CO (ppm)
PM
CO
background
coldstart
hot start
simmer

- *Test 2:*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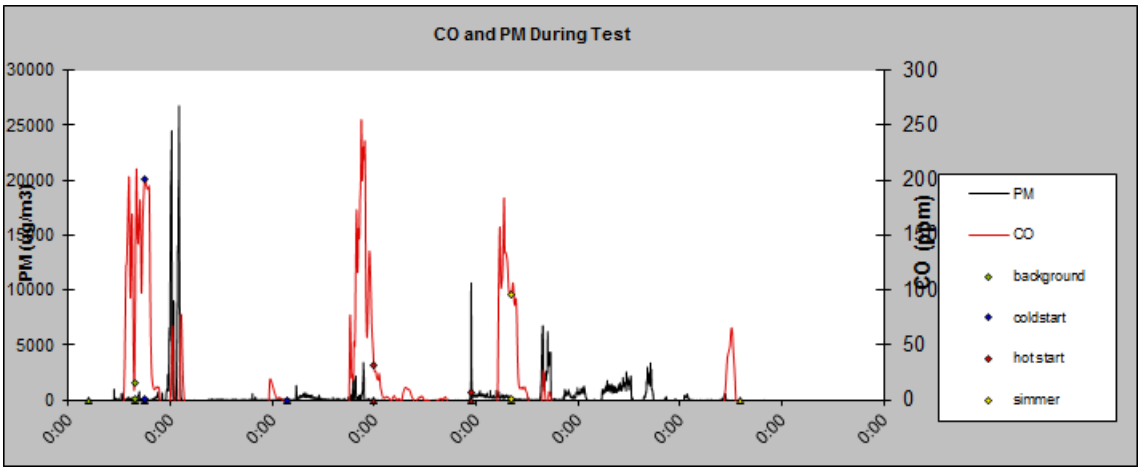
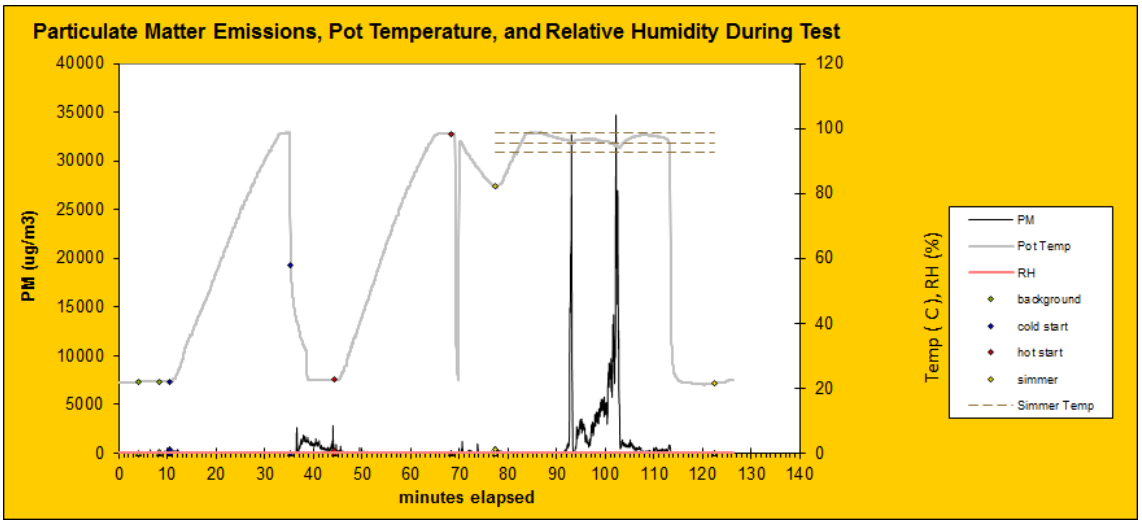
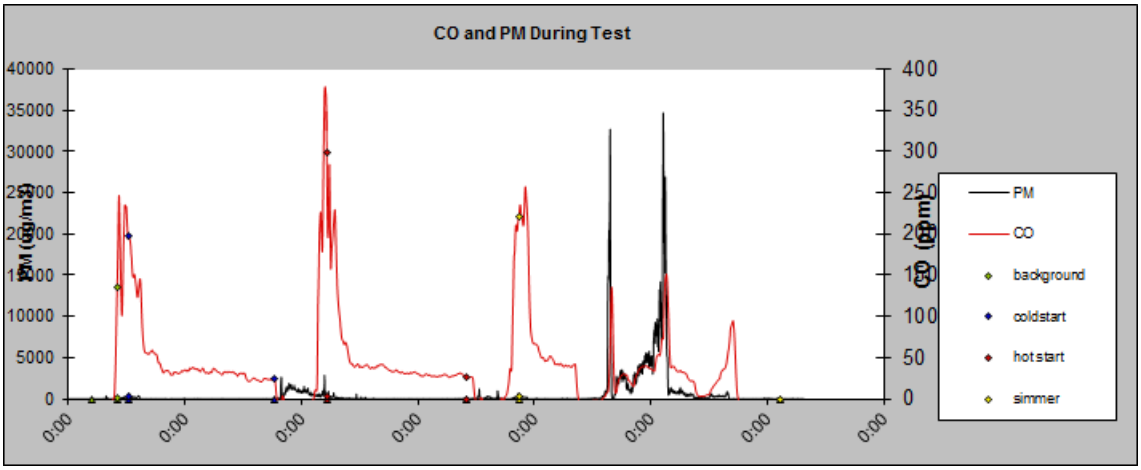
PM (ug/m3)
Temp (C), RH (%)
minutes elapsed
PM
Pot Temp
RH
background
cold start
hot start
simmer
Simmer Temp


CO and PM During Test
PM (ug/m3)
CO (ppm)
PM
CO
background
coldstart
hot start
simmer

- *Test 3:*


Particulate Matter Emissions, Pot Temperature, and Relative Humidity During Test
PM (ug/m3)
Temp (C), RH (%)
minutes elapsed
PM
Pot Temp
RH
background
cold start
hot start
simmer
Simmer Temp


CO and PM During Test
PM (ug/m3)
CO (ppm)
PM
CO
background
coldstart
hot start
simmer

- The photo below shows the little remaining charcoal after the simmering phase (45 min).

9.1.1. Summary of test results

The efficiency of the stove is 35.44%, it was in Tier3.

IWA PERFORMANCE TIERS	Tier
High Power Thermal Efficiency	3
Low Power Specific Fuel Consumption	1
High Power CO	4
Low Power CO	4
High Power PM	4
Low Power PM	3
Indoor CO Emissions	4
Indoor PM Emissions	3

The time it took to boil 5 litres of water from a cold start was 25.67min and from a hot start was 21.33min.

	Test length (mn)	
	Cold start	Hot start
Test1	28	19
Test2	24	21
Test3	25	24
Average	25.67	21.33

The table below shows the details of each testing result and the summary of the three tests.

WATER BOILING TEST - VERSION 4.2.3 | TEST # | Test1,2,3

All cells are linked to data worksheets, no entries are required

Stove type/model	Vietnam gasifier stove
Location	RENMI
Fuel description	Pellet Average Softwood (Conifer)
Wind conditions	No wind; No wind; No wind; (Select from list); (Select from list); (Select from list); (Select from list); (Select from list); (Select from
Ambient temperature	23; 22.6; 21.7

1. HIGH POWER TEST (COLD START)	units	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9	Test 10	Average	St Dev	COV
Time to boil Pot # 1	min	28	24	25								25.666667	2.1	8.1%
Temp-corrected time to boil Pot # 1	min	28	24	24								25	2.1	8.4%
Burning rate	g/min	11	11	13								12	1.2	9.9%
Thermal efficiency	%	34%	38%	33%								0.3498976	2%	7.1%
Specific fuel consumption	g/liter	65	57	69								64	6.4	10.0%
Temp-corrected specific consumption	g/liter	64	56	68								63	6.0	9.6%
Temp-corrected specific energy cons.	kJ/liter	1,252	1,093	1,321								1222	116.9	9.6%
Firepower	watts	3,589	3,693	4,294								3858.6699	380.3	9.9%

2. HIGH POWER TEST (HOT START)	units	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9	Test 10	Average	St Dev	COV
Time to boil Pot # 1	min	19	21	24								21.333333	2.5	11.8%
Temp-corrected time to boil Pot # 1	min	19	21	24								21	2.5	11.6%
Burning rate	g/min	15	13	14								14	1.1	8.0%
Thermal efficiency	%	36%	38%	34%								0	2%	5.3%
Specific fuel consumption	g/liter	59	56	74								63	9.6	15.3%
Temp-corrected specific consumption	g/liter	58	56	73								62	9.3	14.9%
Temp-corrected specific energy cons.	kJ/liter	1,133	1,085	1,419								1212	180.4	14.9%
Firepower	watts	4,843	4,148	4,675								4555	362.6	8.0%

3. LOW POWER (SIMMER)	units	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9	Test 10	Average	St Dev	COV
Burning rate	g/min	8	9	8								8	0.8	9.0%
Thermal efficiency	%	36%	25%	32%								0.3120752	6%	18.0%
Specific fuel consumption	g/liter	98	105	92								98	6.5	6.6%
Temp-corrected specific energy cons.	kJ/liter	1,904	2,054	1,802								1920	126.6	6.6%
Firepower	watts	2,655	3,016	2,546								2739	245.9	9.0%
Turn down ratio	--	1.35	1.22	1.69								1	0.2	16.8%

BENCHMARK VALUES (for 5L)		Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9	Test 10	Average	St Dev	COV
Fuel Use Benchmark Value	g	794	806	813								804	9.7	1.2%
Energy Use Benchmark Value	kJ	15,482	15,711	15,857								15683	188.9	1.2%
Carbon Monoxide Benchmark Value	g	21.5	21.4	31.4								24.8	5.8	23.4%
Particulate Matter Benchmark Value	g	0.295	0.128	0.744								0.389	0.319	81.9%

IWA PERFORMANCE METRICS	units	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9	Test 10	Average	St Dev	COV
High Power Thermal Efficiency	%	35.4%	37.6%	33.3%								0.3544684	2.2%	6.1%
Low Power Specific Fuel Consumption	MJ/(min·L)	0.042	0.046	0.040								0.043	0.003	6.6%
High Power CO	g/MJ	0.7	1.2	5.1								2.3	2.4	103.2%
Low Power CO	g/(min·L)	0.089	0.084	0.087								0.087	0.002	2.7%
High Power PM	mg/MJ	41	3	2								16	22	143.7%
Low Power PM	mg/(min·L)	0.9	0.5	3.3								1.6	1.5	94.3%
Indoor CO Emissions	g/min	0.334	0.334	0.455								0.374	0.070	18.7%
Indoor PM Emissions	mg/min	3.4	2.1	12.5								6.0	5.7	93.8%

IWA PERFORMANCE TIERS	Tier
High Power Thermal Efficiency	3
Low Power Specific Fuel Consumption	1
High Power CO	4
Low Power CO	4
High Power PM	4
Low Power PM	3
Indoor CO Emissions	4
Indoor PM Emissions	3

10. Adapted Water Boiling Test

10.1. As a simple method of comparison, an adapted water boiling test (AWBT) was conducted.

10.2. In this case we conducted the AWBT with the Philips stove, and used similar fuel (500 grams of wood pellets).

10.3. The AWBT tests how long it takes to boil 3 L of water and how long the water stays at a boiling temperature (until the temperature drops 3 degrees). For details of the protocol see: http://www.cleancookstoves.org/our-work/standards-and-testing/learn-about-testing-protocols/protocols/downloads/awbt-protocol.pdf

10.4. This test was conducted only once but gives an indication of the difference in time to boil (TTB) of each stove and total time of test (TTT) by using the same quantity of pellets (500 grams).

10.5. The table below shows that the results are comparable, though the TTB is a bit faster for the Philips, and the SPIN stove seems to be able to maintain the heat transfer for 7 minutes longer.

Stove	Time to boil 3 L water (mn)	Total Test Time (mn)
SPIN stove	16	45
Philips stove	13	38

11. Strong points of the SPIN

- The stove is sturdy, compact and attractive.
- The burner holes on top simulate cooking with gas.
- When using wood pellets the stove is very clean and produces very low amounts of PM and CO, CO2 and will have the potential to positively impact health risks compared to baseline stoves.
- It demonstrated a high power, which could be valued by cooks as it reduces cooking time.
- It is easy to light at the start.
- The stove seems to perform similarly to the Philips stove, but might be more price competitive.

12. Possible improvements of the SPIN

- It takes some effort to properly install the burner on the stove.
- Putting the burner on the stove when in operation runs the risk to kill the flame.
- Changing the speed of the fan from high to low can kill the flame as well.
- It was difficult to keep the flame stable at the low fan speed during simmering.
- Connection to electricity is required during the whole cooking session as there are no batteries in the stoves. This impacts functionality during blackouts.

13. Recommendations and suggestions

- Number and size of the burners could be considered in an attempt to make the flame more stable.
- An acceptability study with the target households is required to get useful feedback on stove improvements such as: size, capacity of the stove to serve one cooking session, and the convenience for the user.
- Install a battery into the stove to keep the power to run the fan for households without a grid connection.
- Trial the stove for other biomass fuels than pellets.

SNV

This is to testify that the report "*Narrative testing report on the SPIN forced draft gasifier stove*" of 25 December 2014, provides testing results and interpretations of the SPIN stove by SNV Laos. SNV Laos is unbiased, independent free of any interest.

Bastiaan Teune

Sector Leader Renewable Energy

SNV Laos PDR

Vientiane, 16 January 2015