Comparative Evaluation of Emissions from Selected Paraffin Lamps and a Paraffin Thermoelectric Generator

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Presentation outline

- Introduction
- Materials and test procedures
  - Experimental lighting devices
  - Test procedures
- Results
- Discussion and conclusion

Introduction

- Energy services for cooking and lighting a necessity
- Energy poverty afflicts many households in dev countries
- Energy-poor rely on traditional biomass and paraffin lamps
- Products of incomplete combustion (McCarty *et al*., 2008)
- CO, $PM_{2.5}$ - cause of health losses (Lim *et al*., 2012)
- Black carbon (BC) - forcing mechanism in global warming (Bond *et al*., 2013)
- We focus on PM emissions from paraffin lamps

Introduction , cont'd

- About 620 million people in sub-Saharan Africa lack electricity (IEA, 2014)
- PM emissions from paraffin lamps underestimated (Arne *et al*., 2013)
- Lamps emit 20 times more PM (BC) than previously thought
- Even with adoption of clean stoves, households still exposed (WHO, 2014) (Lam *et al*., 2012)
- Mitigation – LED lamps by solar or thermoelectric generator

Introduction, cont’d

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- Paper addresses knowledge gap on domestic lighting services
- Reports on evaluation of CO and $PM_{2.5}$ for two paraffin lamps and prototype thermoelectric generator
- Thermoelectric gen/LED (iHarvey ™) designed to provide higher light intensity
- …also has a USB plug point for media power
- We compare fuel consumption and emission rates of the 3 devices
- Tests conducted at SeTAR Centre stove-testing laboratory, UJ

Materials and test procedures

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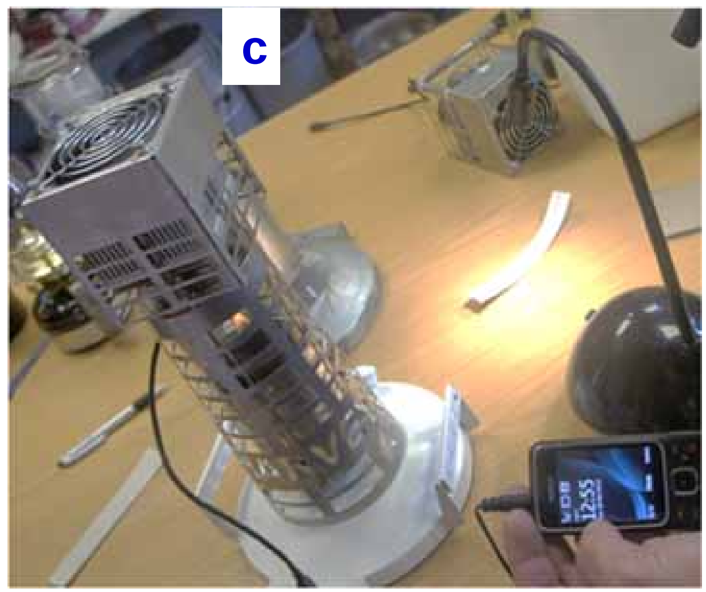
Experimental lighting devices

- Two paraffin wick lamps: a) standard lantern and b) glass lamp
- c) iHarvey™ thermoelectric generator



Source: SeTAR photos 2014

Materials and Test Procedures, cont'd

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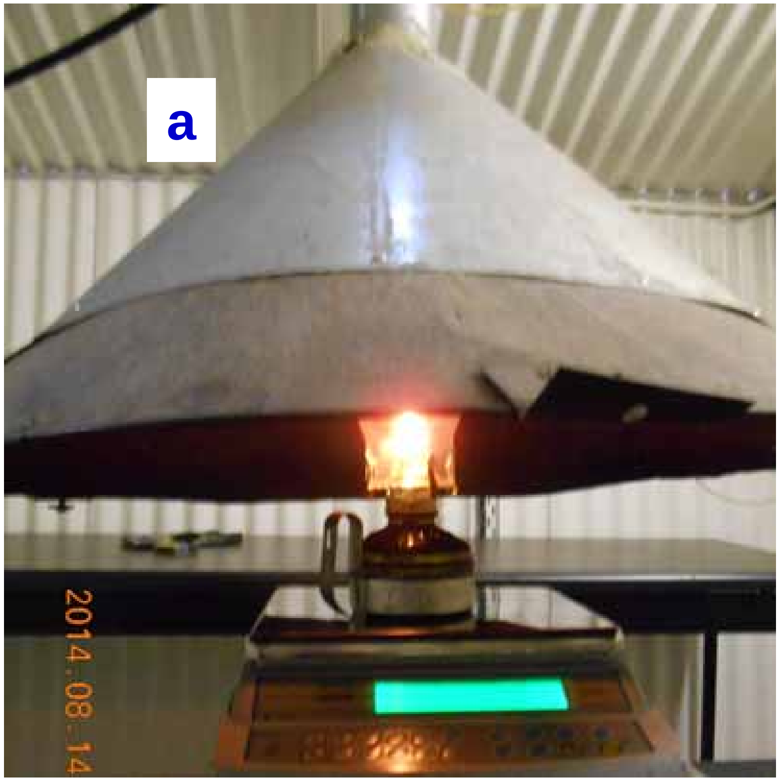
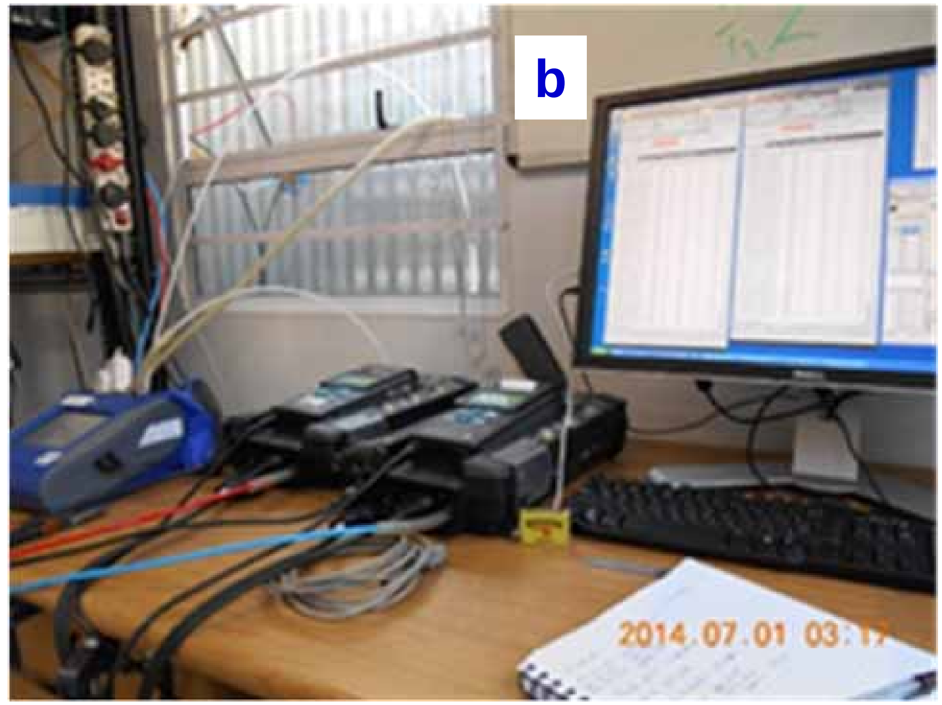
Testing rig: Emissions collection hood; flue gas analyser (Testo™), particle counter (Dust trak™), computer, mass balance

Test procedure:

- Device fuelled, weighed and ignited under the hood
- Left on mass balance to track fuel consumption
- Gas sample collected by two probes and channelled to flue gas analyser and particle counter
- Data logged every 10 seconds; Test duration 25 minutes
- SeTAR HTP adapted for the suite of tests (www.setarstoves.org)

Test equipment set-up at SeTAR lab:
a) Combustion room; b) data capture room





Source: SeTAR photos 2014

Calculation and determination of CO and $PM_{2.5}$ emission factors

Calculation of the emission factors is made in this manner:

$$CO_{EF} = \frac{CO[g]}{H_{NET}[MJ]}$$

$$PM2.5_{EF} = \frac{PM2.5[mg]}{H_{NET}[MJ]}$$

$$\%\, reduction = 100 \cdot \frac{(Hr - Lr)}{Lr}$$

Results

Emissions

- iHarvey has 83% less $PM_{2.5}$ emissions compared to p-lamps
- 90% of iHarvey PM emissions produced in first five minutes
- CO and CO/CO_2 ratio for the 3 devices have no statistical diff

Fuel consumption and illumination

- iHarvey and glass lamp similar fuel consumption rate (~30g/h)
- Manufacturer data – iHarvey has light output of 5 lanterns
- Implies iHarvey provides better illumination for less fuel consumption, with lower $PM_{2.5}$ emissions, lower risks of injury

PM2.5 emissions profile for the paraffin lantern, glass lamp, and thermoelectric gen

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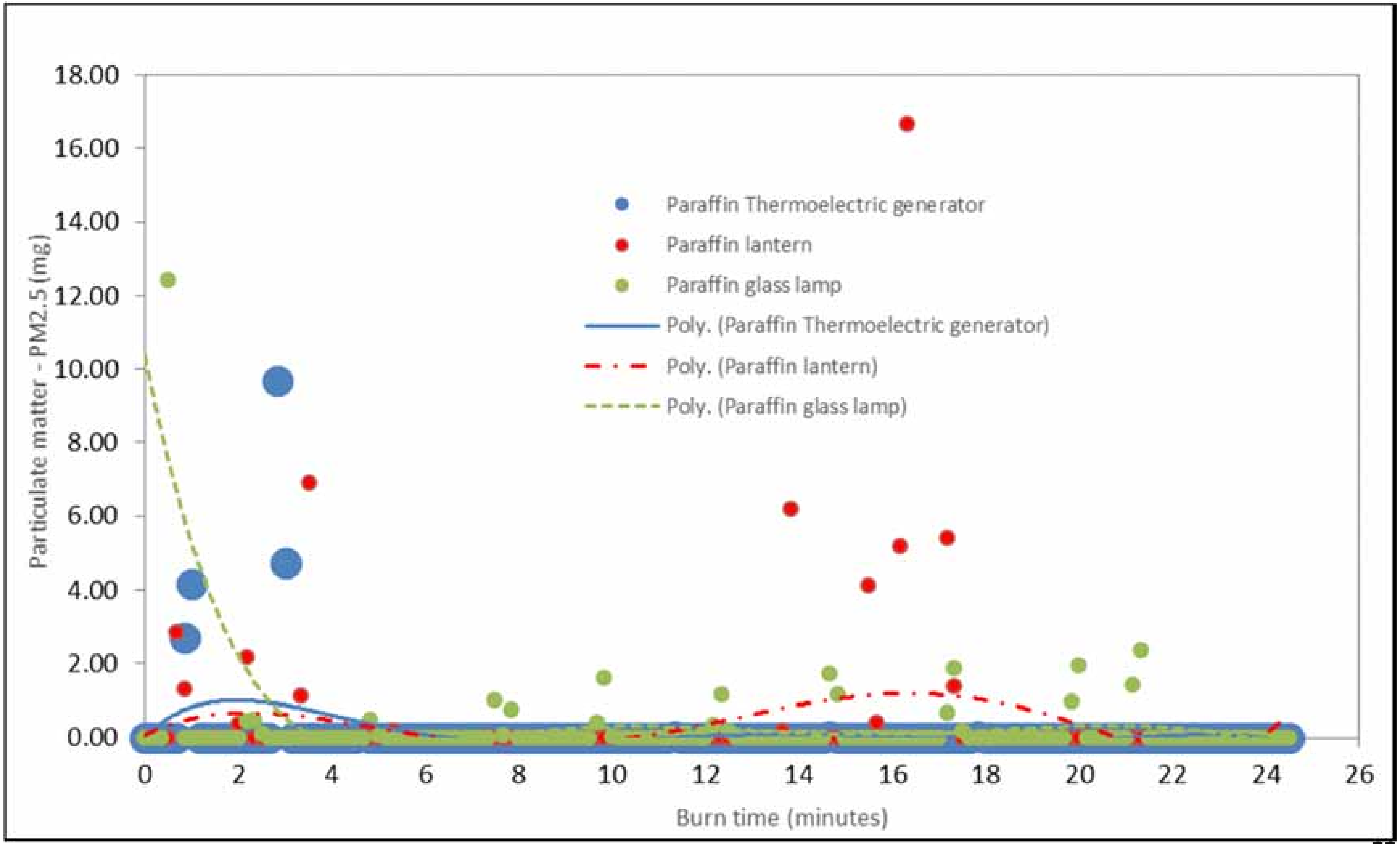

Pair-wise comparisons

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Test Device	Fuel cons. (g/h).	COEF (g/MJ)	PM2.5 EF (mg/MJ)	CO (g/h)	PM2.5 (mg/h)	CO/CO2 (%)
Paraffin thermoelectric generator	30 ± 3	0.17 ± 0.02	48 ± 0.25	0.18 ± 0.01	21 ± 0.27	0.41 ± 0.02
Paraffin lantern	40 ± 0.58	0.14 ± 0.02	85 ± 0.26	0.16 ± 0.02	127 ± 0.29	0.34 ± 0.04
% reduction	-25%	27%	-44%	13%	-83%	21%
p-value	0.01	0.10	0.00	0.06	0.00	0.09
Sig. at 95% confidence ($p<0.05$)	Yes	No	Yes	No	Yes	No
Paraffin thermoelectric generator	30 ± 3	0.17 ± 0.02	48 ± 0.25	0.18 ± 0.01	21 ± 0.27	0.41 ± 0.02
Paraffin glass lamp	30 ± 2	0.15 ± 0.01	212 ± 13	0.16 ± 0.01	127 ± 1.0	0.23 ± 0.12
% reduction	0%	16%	-77%	13%	-83%	78%
p-value	1.00	0.21	0.00	0.07	0.00	0.07
Sig. at 95% confidence ($p<0.05$)	No	No	Yes	No	Yes	No

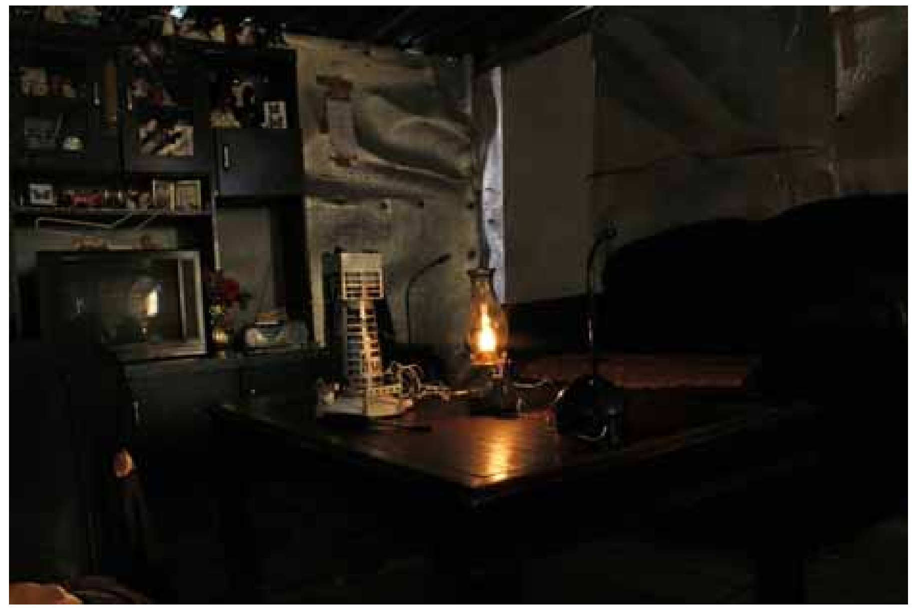
Discussion and conclusion

- PM emissions still significant in households with clean stoves
- Remaining source of the PM emissions is paraffin lamps
- Paraffin thermoelectric gen/LED a suitable intervention
- …iHarvey provides 5 times better light than lanterns and powers media
- …demonstrates 83% reduction on $PM_{2.5}$ emissions, safer.
- Unlike solar, iHarvey thermoelectric gen provides power on demand – irrespective of time of day or night.

Images of iHarvey and Glass Lamp lighting a shack

iHarvey in a room

Glass lamp in a room



References

International Energy Agency, "Modern Energy for All," in *World Energy Outlook 2014*. 2014, Paris: IEA. Available from www.iea.org.

WHO, "Reducing the health burden from household air pollution: towards the development of a national strategy for Kenya". Minutes of a workshop held on 11-12 February in Nairobi, Kenya. Geneva, WHO, 2014.

J. Arne, T.C. Bond, L.N. Lam, H. Nathan, "Black carbon and paraffin lighting: an opportunity for rapid action on climate change and clean energy for development," Policy Paper No. 2013-3, 13 pp., 2013, Washington D.C.: The Brookings Institution.

L. Lam, Y. Chen, C. Weyant, C. Venkataraman "Household light makes global heat: high black carbon emissions from paraffin lamps," *Environ. Sci. Technol*. vol. 46, pp. 13531–13538, 2012.

T. C. Bond, S. J. Doherty, D. W. Fahey, P. M. Forster *et al.*, "Bounding the role of black carbon in the climate system: A scientific assessment," *Journal of Geophysical Research: Atmospheres*, vol. 118, pp. 5380–5552, doi:10.1002/jgrd.50171, 2013.

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