

A comparison of emissions and thermal efficiency of three improved liquid fuels



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Preamble



Background

Introduction

Materials and Methodology

- The Heterogeneous Testing Protocol
- Stoves
- Sampling and Analysis
- Quality Control

Results and Discussion

Conclusions

Acknowledgements

Background



- In S.A. more than 87% of households are electrified (DoE, 2013)
- Majority of S.A. low income earners still rely on multiple energy sources to complement their daily needs (Kimemia, 2012)
- Access to electricity alone unfortunately will not solve all energy challenges (Masekameni *et al.*, 2014)
- Diseases related to Household Air Pollutions (HAPs) continue to threaten societies
- Globally, Household Air Pollution claims 4.3% lives, with ambient air pollution responsible for 3.7 deaths (WHO, 2012)

The problem:

“disease, *fires, burns and poisonings*”



- Accidents related to domestic energy use are common in South Africa's low-income households.
- Cause of mortality, diseases (acute & chronic) and economic losses
- Poor disproportionately affected.
- Underlying causes of the diseases not well understood

Questions

- How can the introduction of paraffin alternative fuels in certain communities improve household indoor air quality?

Introduction



- Illuminating paraffin is the commonly sourced and utilised fuel source in the low income urban stratum of South Africa (Makonese *et al.*, 2012).
- An estimated 40-50% of the populace in South Africa still depend on liquid fuels like paraffin to meet their basic daily energy needs (Kruger 2006).
- Faulty and sub-standard paraffin appliances are believed to be the main source of uncontrolled shack fires and indoor air pollution
- 33% of paraffin using households had acute lower respiratory Infection (Mathee *et al.* 2014).
- Children from paraffin using households experienced more respiratory symptoms than those in households using other fuels (Behera *et al.* 1998).

Introduction cont...

- In South Africa, there have been high numbers of harmful domestic, paraffin-related incidences which range from paraffin poisoning to burns, indoor pollution and shack fires



Materials and Methods: Stoves

A New model paraffin
wick stove stove



B Ethanol Gel stove



C Methanol stove



- Emphasis given to stove to fuel combination

Test Method: SeTAR Heterogeneous Testing Protocols



SeTAR Heterogeneous Testing Protocol was employed

Each test was done using 5L pot

Emissions performance followed the 'hood' method as suggested by Ahuja 1987

Testo[®] 350XL/454 flue gas analyser was used for the analysis of stack gases.

Dust track[®] 8530 was used to quantify the emissions of particles

Thermocouples were used to measure temperature

Dilution system was used to cool down particles temperature and regulate mass concentration

All stoves were tested only at high power setting

Stove rating procedure

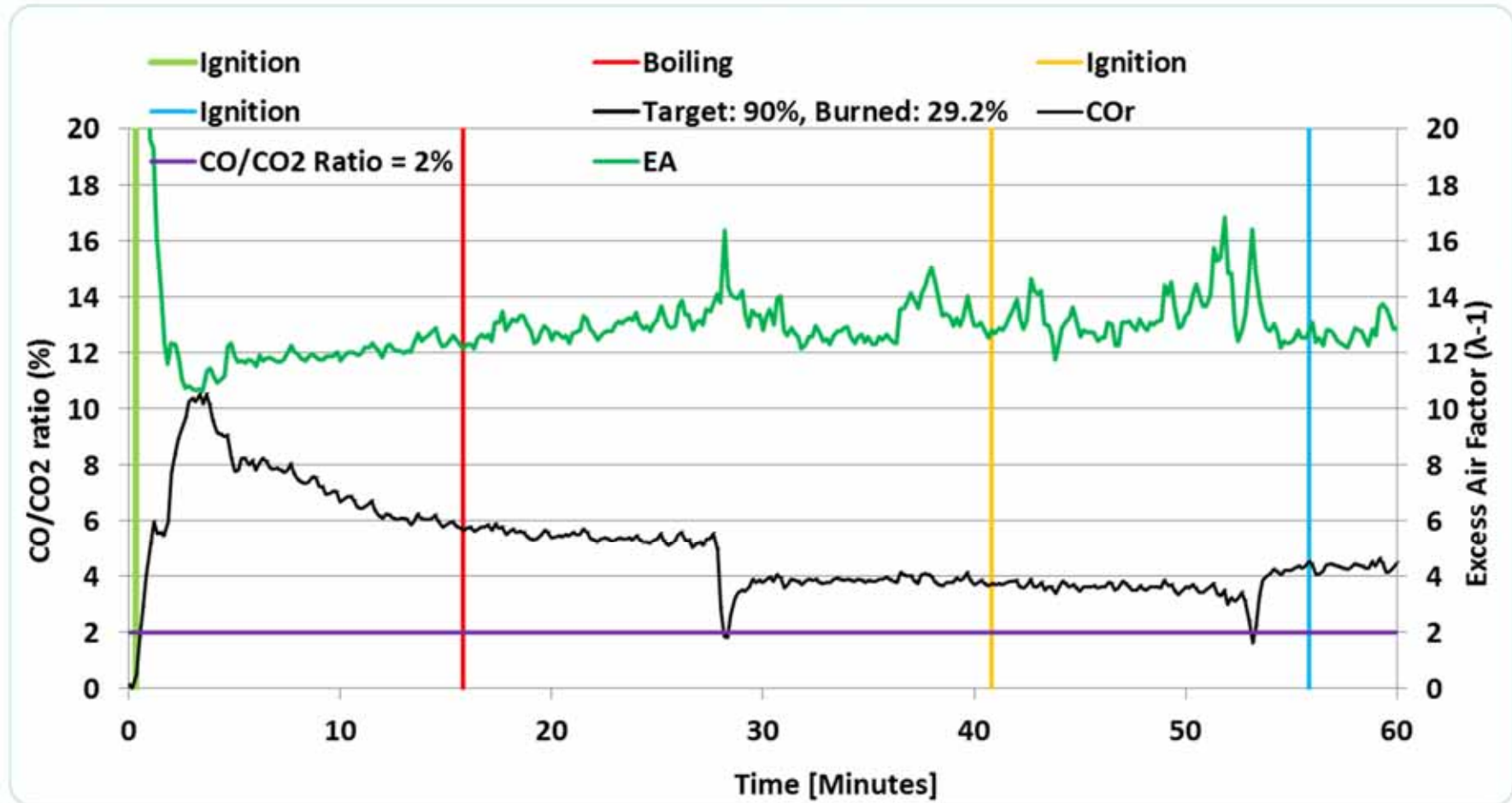
IWA/ISO rating

Tier	Thermal efficiency (%)	CO emission factor (g/MJ)	PM _{2.5} emission factor (mg/MJ)	Fire-power (W)
Tier 0	< 15	> 16	> 979	< 500
Tier 1	≥ 15	≤ 16	≤ 979	≥ 500
Tier 2	≥ 25	≤ 11	≤ 386	≥ 750
Tier 3	≥ 35	≤ 9	≤ 168	≥ 1 000
Tier 4	≥ 45	≤ 8	≤ 41	≥ 1 500

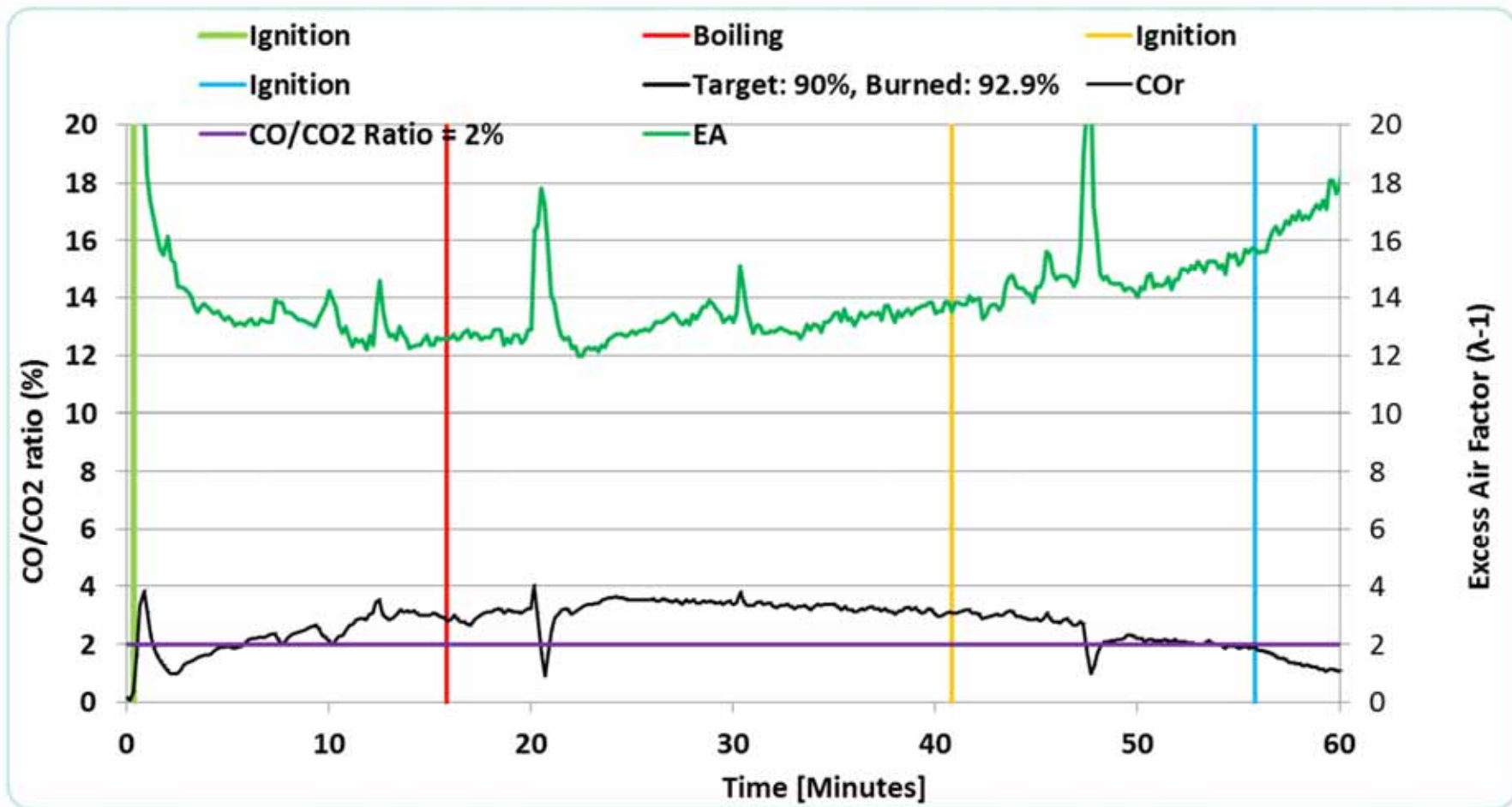
Quality Control

- Series of preliminary experiments were carried out to standardise the burn cycle and minimise the natural variability due to differences in operator behaviour
- All fuels were analysed for determination of their calorific values prior to each test.
- After each fuel/stove combination was tested, the probes were cleaned and the pumps and machines checked and zeroed.
- Steam removed from the combustion flow because it would complicate the analysis of the combustion gases
 - Drier of analyser rendered less effective
 - Overestimation of H₂ and O₂ in the stack

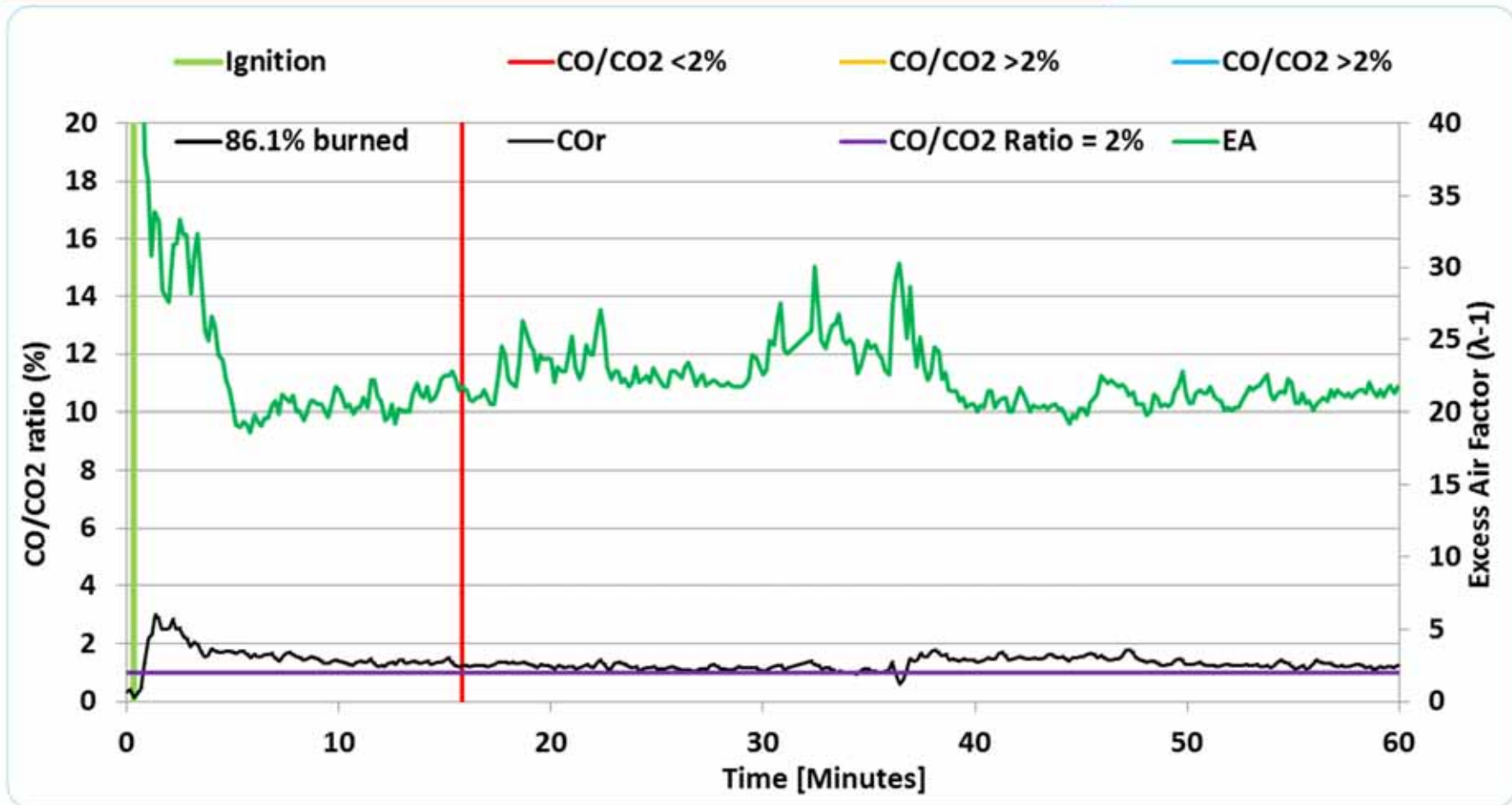
New Paraffin stove combustion efficiency (CO/CO₂)



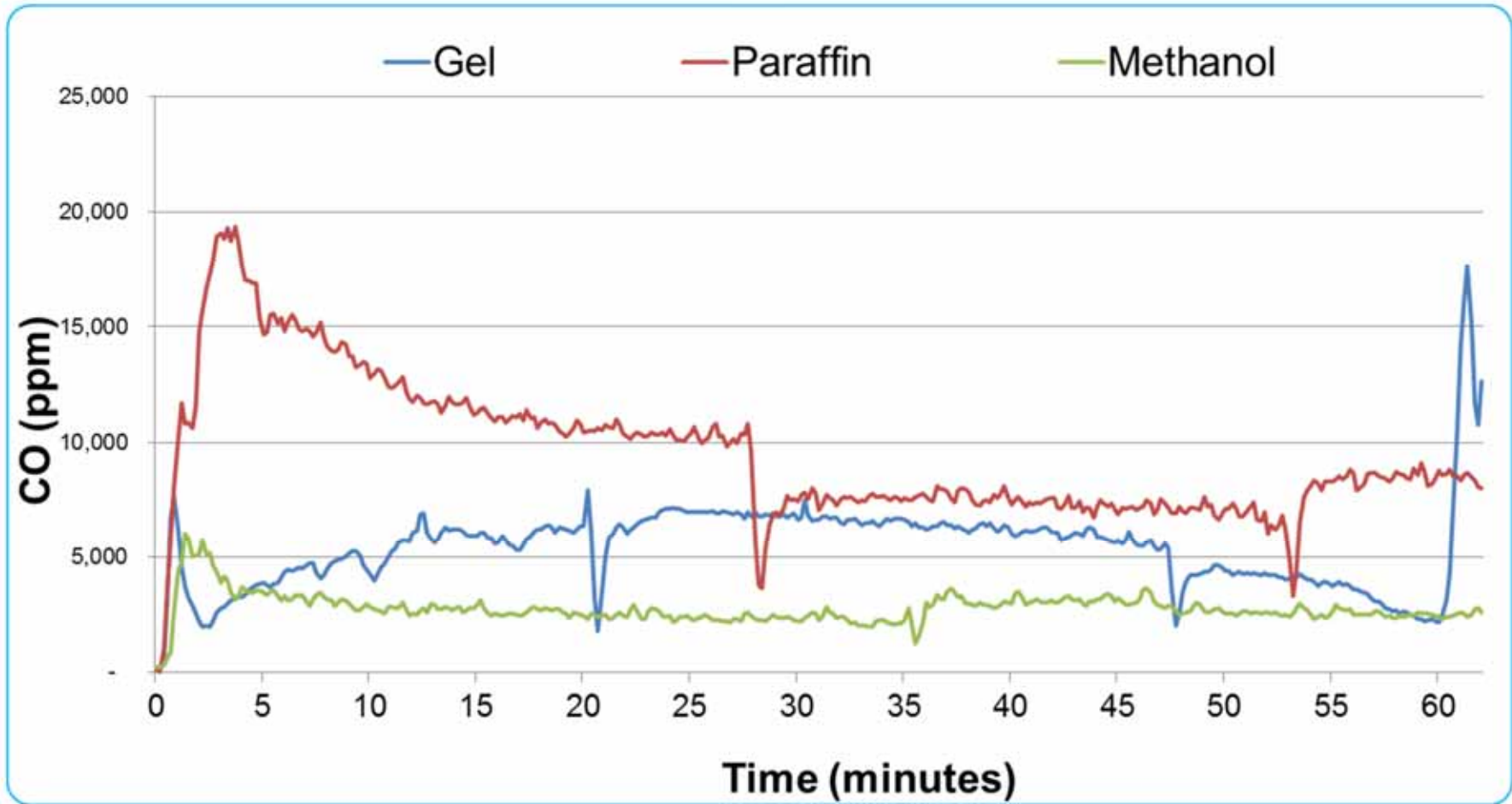
Ethanol Gel stove combustion efficiency (CO/CO₂)



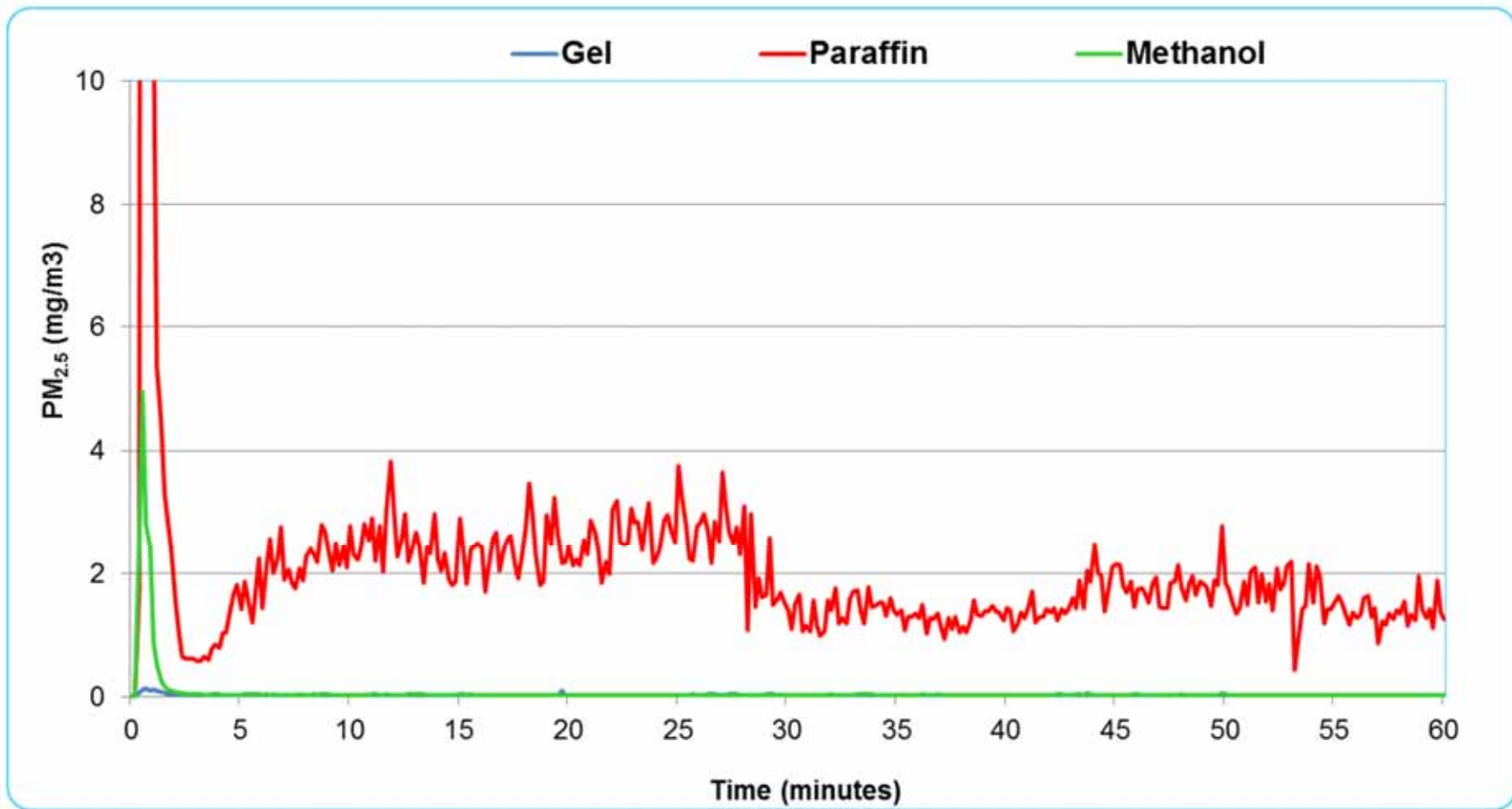
Methanol stove combustion efficiency (CO/CO₂)



CO emission factor



PM_{2.5} emission factor



Results cont...

Test Case	PM 2.5 Emissions per MJ (Fuel) [mg/MJ]	Fire-Power [kW]	CO Emissions per MJ (Fuel) [mg/MJ]	Combustion efficiency (CO/CO ₂) %	Cooking efficiency %
Paraffin	5.1	1.2	2.4	4.7	73
Gel	0.1	1.2	2.2	3.0	73
Methanol	0.3	0.8	1.1	1.7	67

Combustion parameters against fire power of different fuel/stove combinations using big pot

SANS 1906: 2009



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- A cookstove must produce more than 1kW
 - Methanol stove produce about 0.76 kW
 - Paraffin and Gel stove produces same kW but paraffin is high on emissions

Stove rating

☐ IWA/ISO stove rating

Tier	PM _{2.5} emissions	Fire-Power	CO emissions	Thermal efficiency
Tier 2		Methanol		
Tier 3		Ethanol gel, Kerosene		
Tier 4	Ethanol gel, Kerosene, Methanol		Methanol, Kerosene, Ethanol gel	Methanol, Kerosene, Ethanol gel

Conclusions

- Based on the parameters reported in this paper, ethanol gel stove provide a suitable alternative to paraffin stove
- Methanol stove reports a better combustion efficiency looking at the CO/CO₂ ratio but have a poor fire-power
- Gel stove proves to have good overall rating when comparing with the other two stoves
- Methanol stove could also be a great contender if the designer increases the kW output to comply with SANS codes
- Integration of cleaner energy access present a brighter future for South Africa and improved indoor air quality

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