Cooking Outdoors: A Safer Alternative

Sam Bentson, Kelley Grabow, Dean Still, and Ryan Thompson

Aprovecho Research Center

Introduction

- What is indoor air pollution (IAP)?
- How do stoves affect IAP?

- Why is indoor cooking a problem?
  - 1,500,000 deaths per year[1]

1. http://www.who.int/indoorair/publications/nationalburden/en/index.html

Background

- WHO standards updated in 2010
- Johnson, Monte Carlo box model
- Smith, RESPIRE study
- Seen in literature:
  - "[IAQ] ranks second only to poor water/sanitation/hygiene among environmental health risk factors."[1]
  - "Improved ventilation of the cooking and living area can contribute significantly to reducing exposure to smoke."[2]
  - But also: "The largest reductions in indoor air pollution can be achieved by switching from solid fuels (biomass, coal) to cleaner and more efficient fuels…"[2]

1. Naeher, L. P., Smith, K. R., et al., Critical Review of the Health Effects of Woodsmoke, 2005.
2. http://www.who.int/indoorair/interventions/en/, accessed 25 January, 2011.

Project Objectives

- Goal:
  - Compare emissions of traditional & improved biomass stoves, both inside & outside
  - Show basic methods of reducing emissions exposure

Project Objectives

- Why?
- Get solid scientific support
  - Cooking location recommendations
  - Funding projects
- Demonstrate use of IAP in field

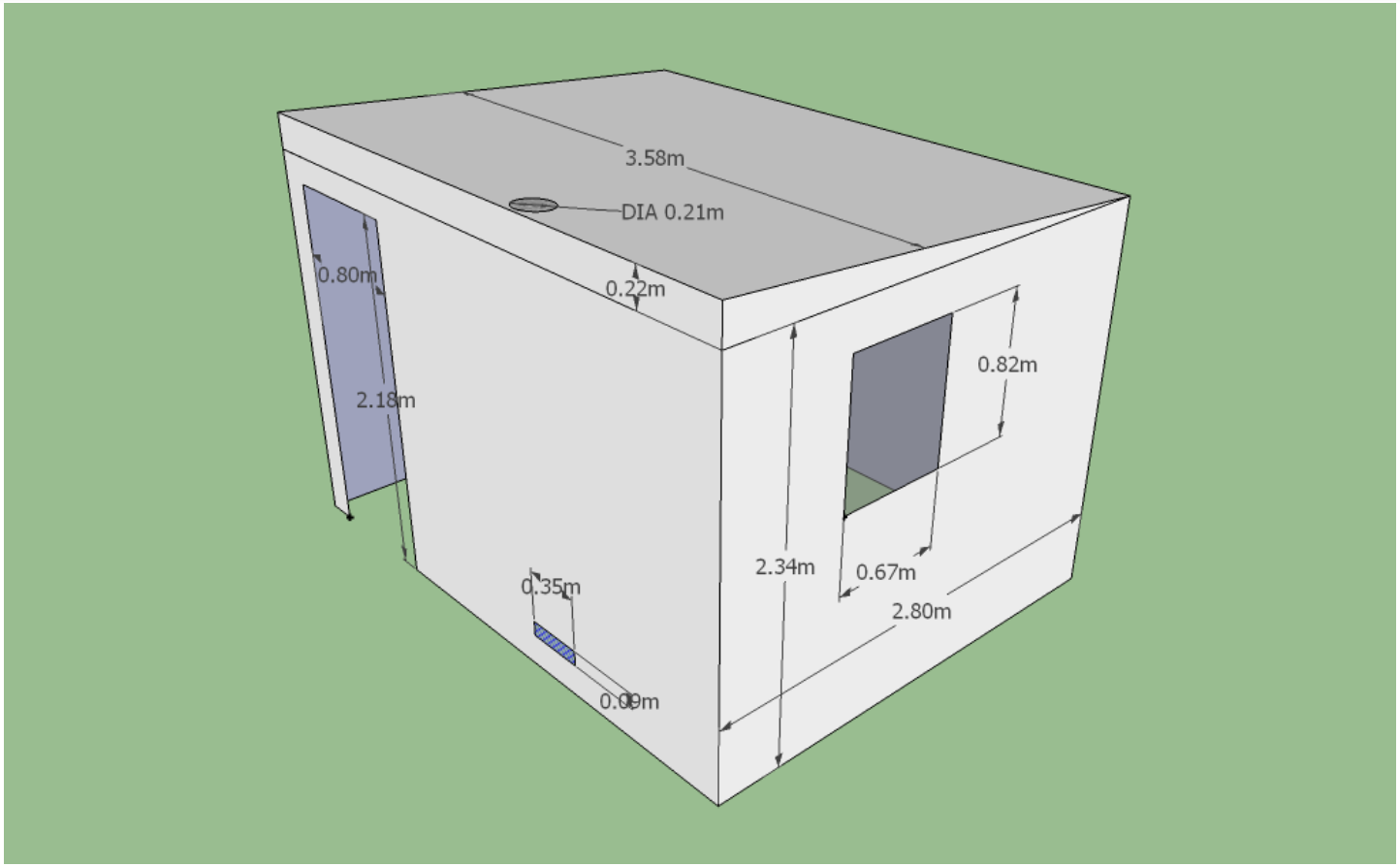
Methodology

- IAP meter
- Technical specifications
  - CO detector
  - PM detector

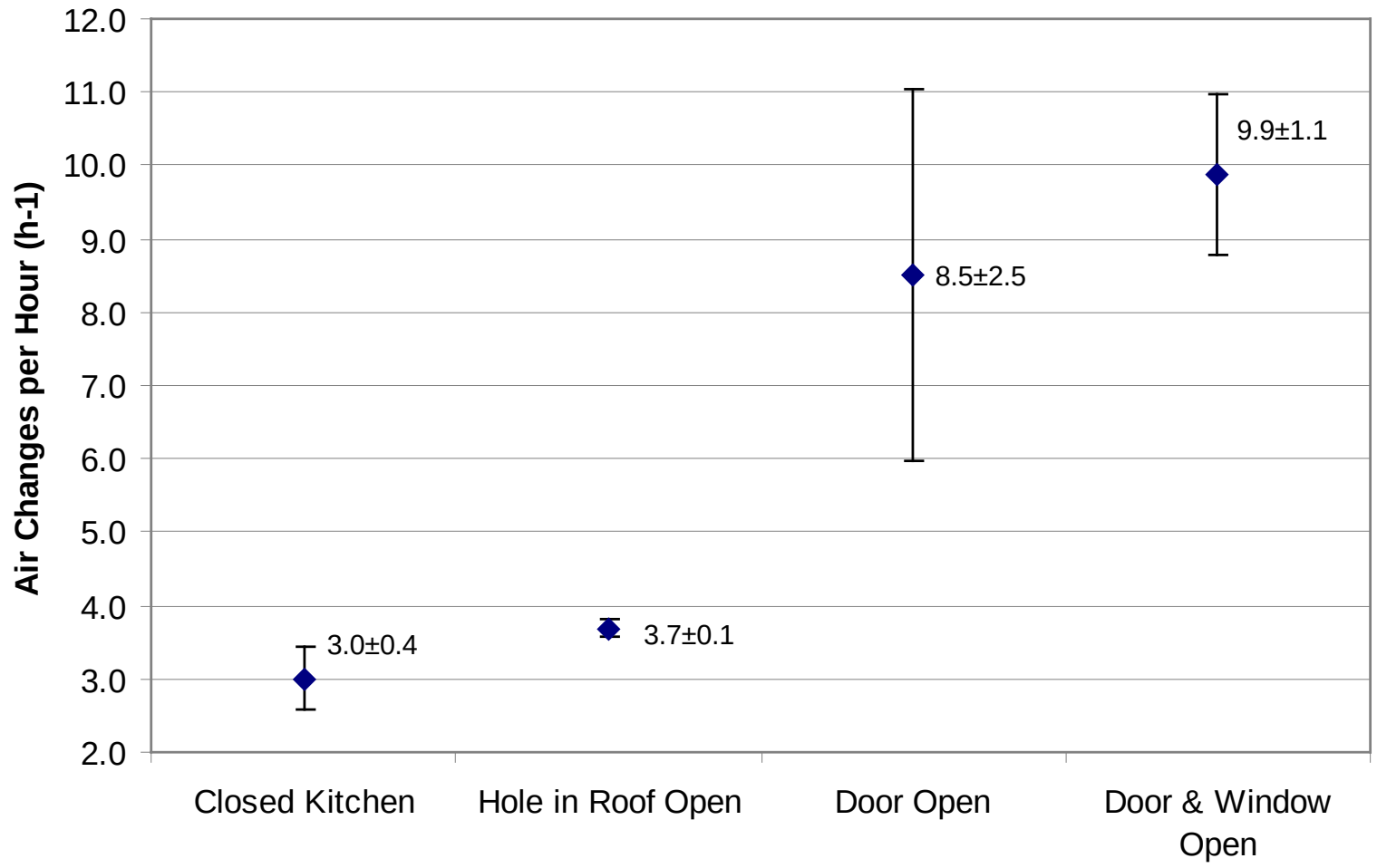
Methodology

- Written protocol
  - Based on typical cooking task
  - Collect data for 60 minutes
- Experimental setup
  - Test kitchen volume ~10 m^3
  - IAP monitor ~1 m horizontally and ~1 m vertically from stove center
  - Open fire
  - TLUD

Experimental



Results


Air Changes per Hour (h-1)
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
3.0±0.4
3.7±0.1
8.5±2.5
9.9±1.1
Closed Kitchen
Hole in Roof Open
Door Open
Door & Window Open

Findings

- Indoor performance
  - Open fire
  - TLUD

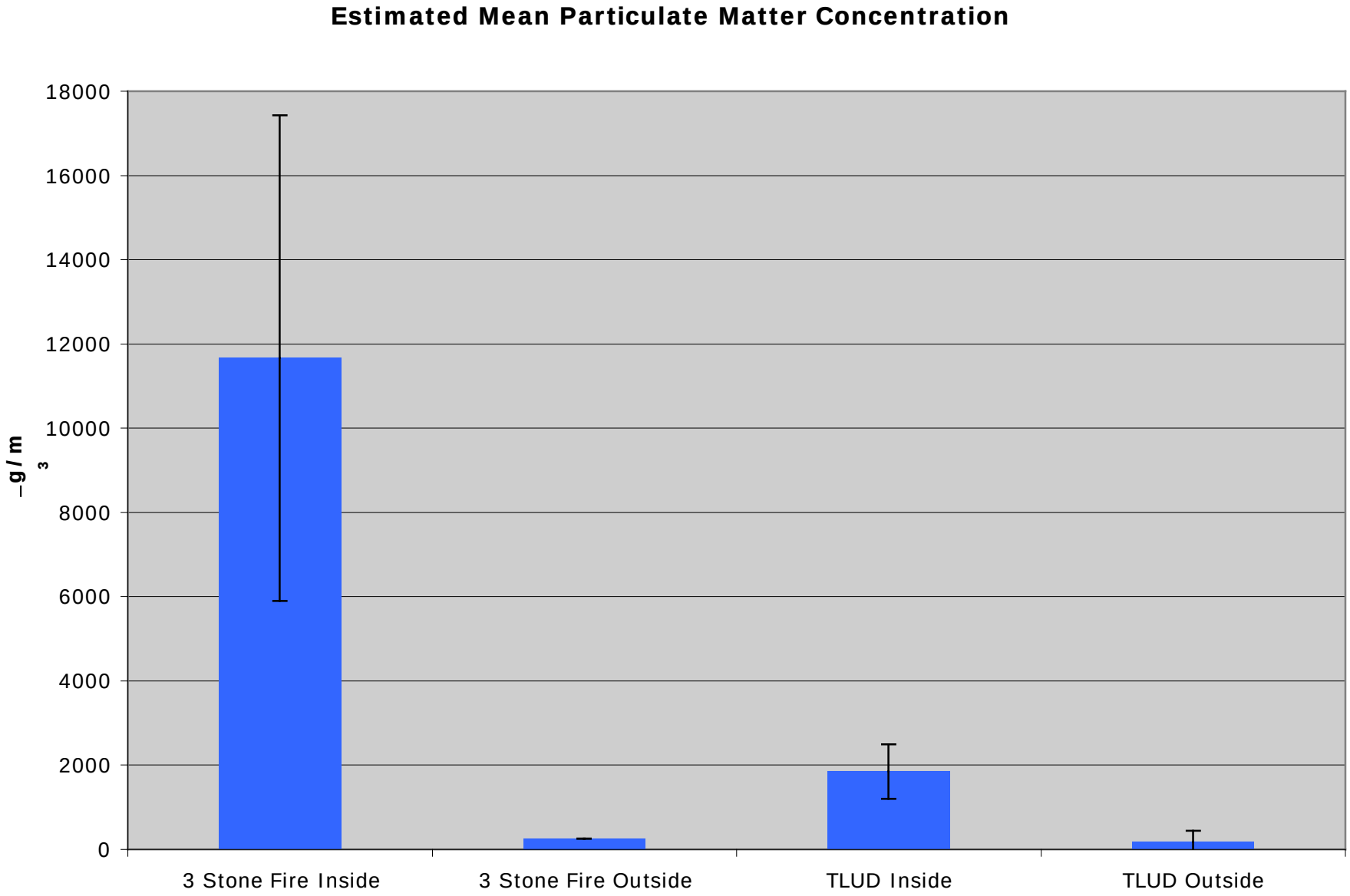
Stove	Measurement	Units	Estimated mean	t value * estimated standard deviation of the mean
3 Stone Fire Inside	Average PM concentration	ug/m3	11664.7	5760.4
TLUD Inside	Average PM concentration	ug/m3	1848.6	643.4
3 Stone Fire Inside	Average CO concentration	ppm	85.9	36.9
TLUD Inside	Average CO concentration	ppm	17.6	13.6

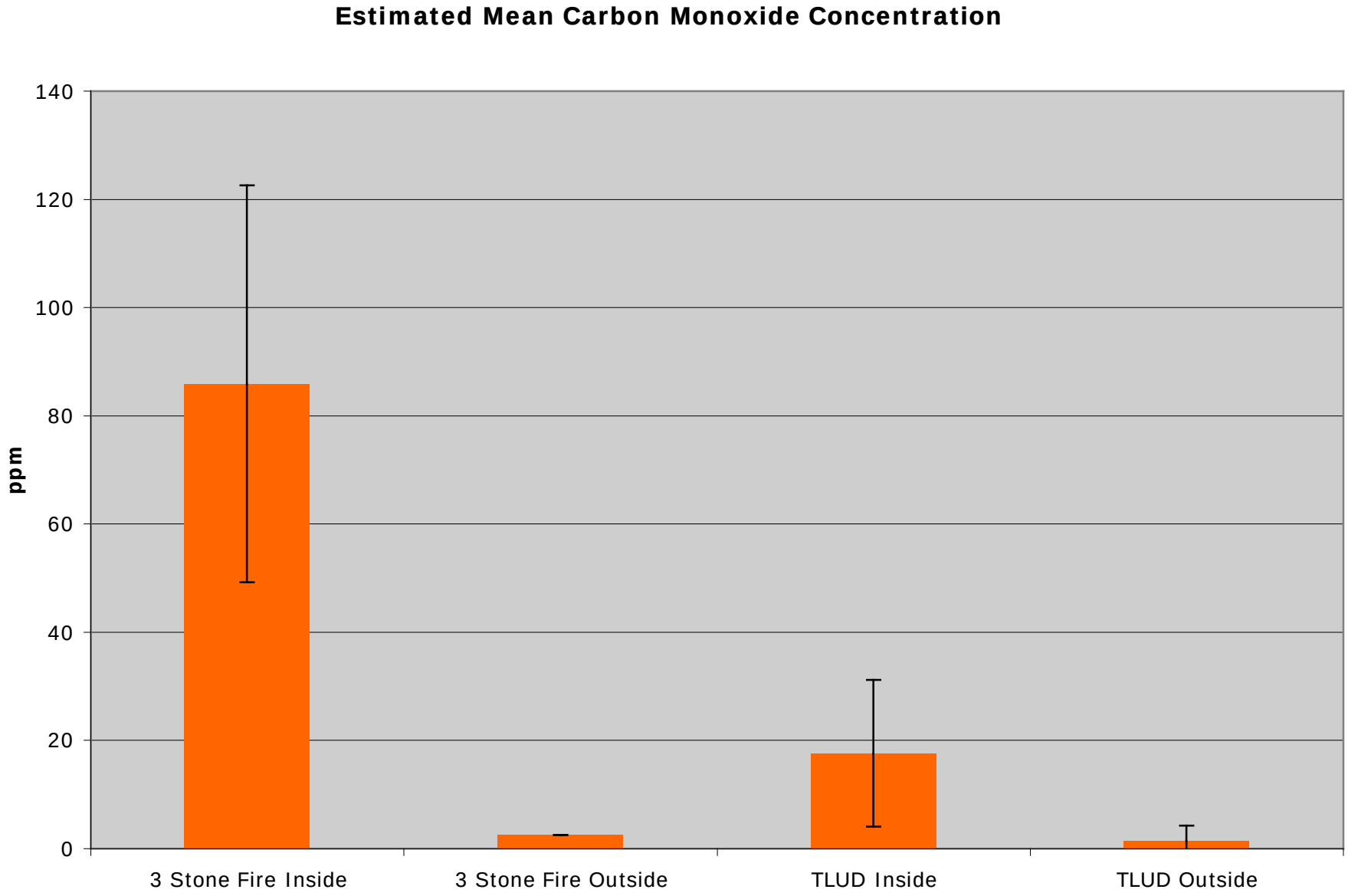
Findings

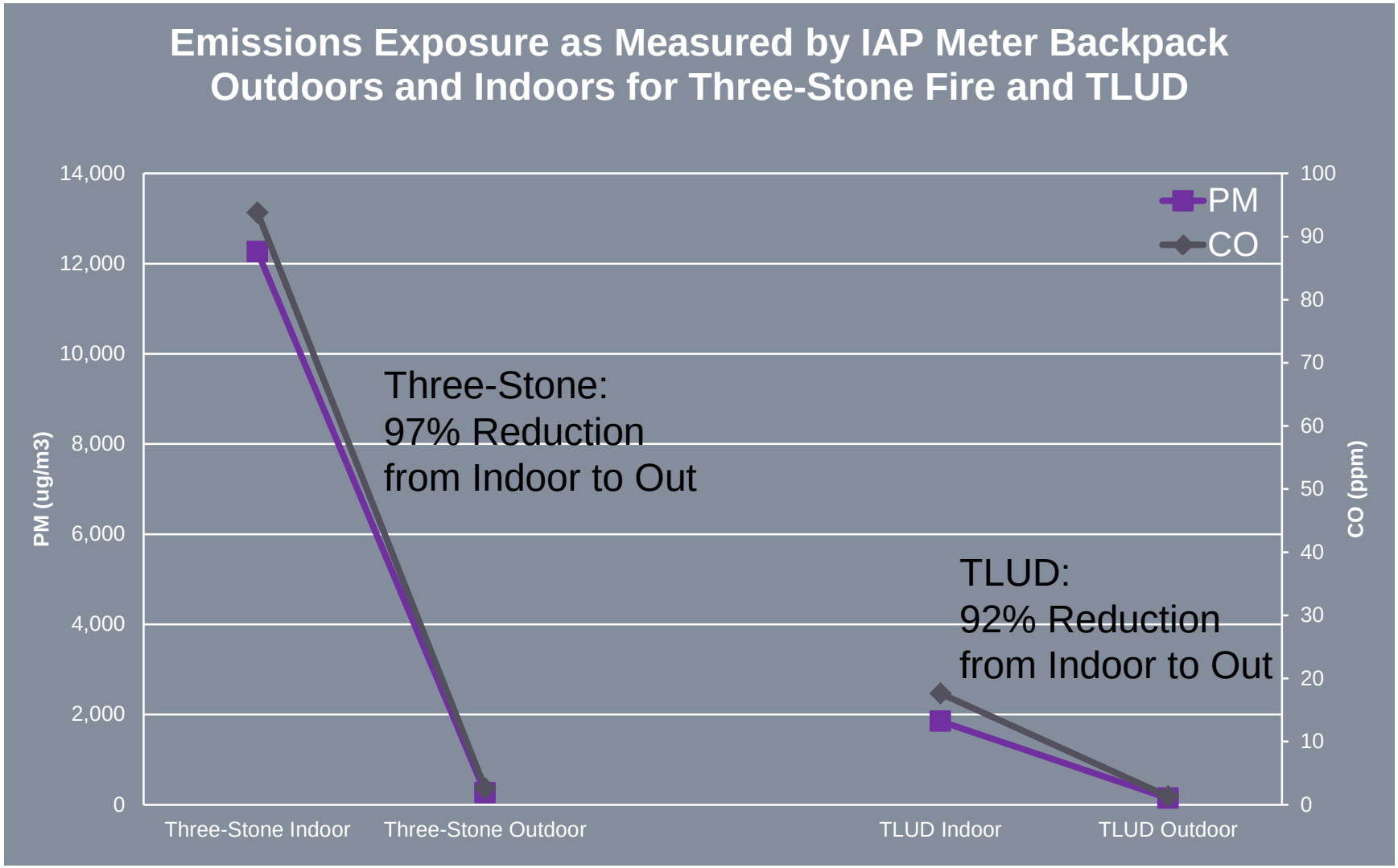
- Outdoor performance
  - Open fire
  - TLUD

Measurement	Units	Estimated mean	t value * estimated standard deviation of the mean
Average PM concentration	ug/m3	261.9	6.80E-08
Average PM concentration	ug/m3	170.5	267.1
Average CO concentration	ppm	2.6	4.30E-10
Average CO concentration	ppm	1.5	2.8

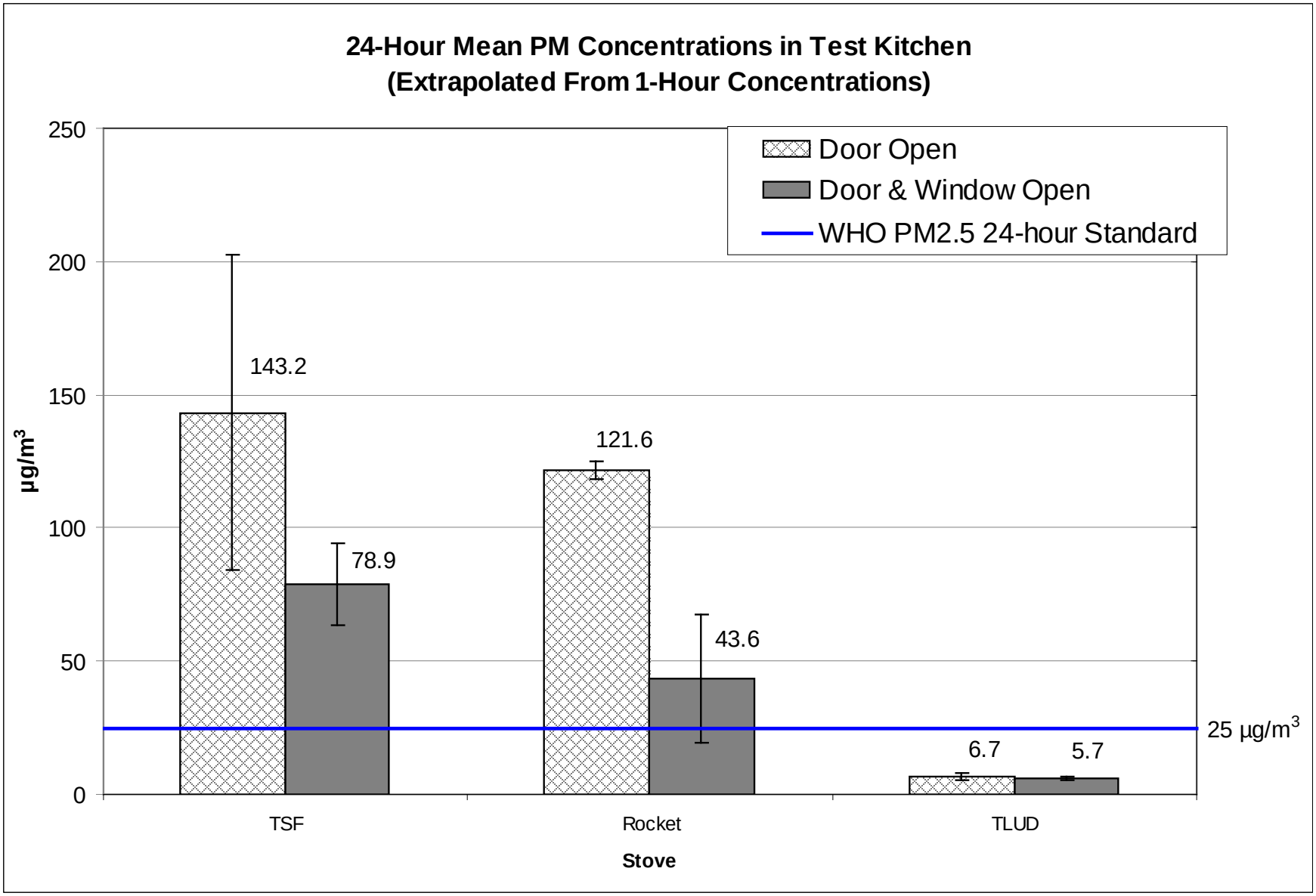
More detailed information about how data were processed may be seen on the penultimate slide “Data Processing”.


Estimated Mean Particulate Matter Concentration
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
_g / m 3
3 Stone Fire Inside
3 Stone Fire Outside
TLUD Inside
TLUD Outside

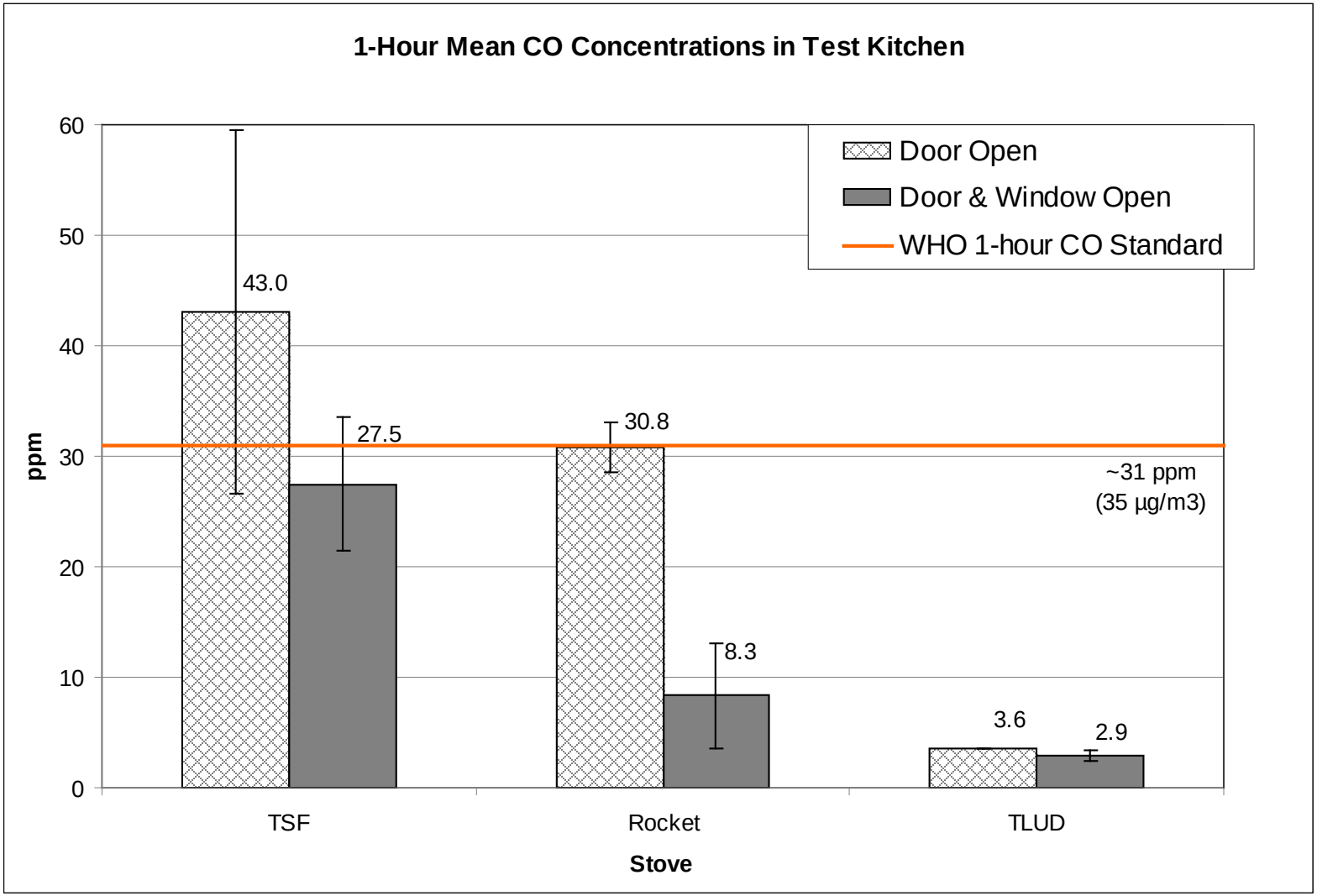

Estimated Mean Carbon Monoxide Concentration
140
120
100
80
60
40
20
0
ppm
3 Stone Fire Inside
3 Stone Fire Outside
TLUD Inside
TLUD Outside


Emissions Exposure as Measured by IAP Meter Backpack
Outdoors and Indoors for Three-Stone Fire and TLUD
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
PM (ug/m3)
100
90
80
70
60
50
40
30
20
10
0
CO (ppm)
PM
CO
Three-Stone:
97% Reduction
from Indoor to Out
TLUD:
92% Reduction
from Indoor to Out
Three-Stone Indoor
Three-Stone Outdoor
TLUD Indoor
TLUD Outdoor

Results


24-Hour Mean PM Concentrations in Test Kitchen
(Extrapolated From 1-Hour Concentrations)
Door Open
Door & Window Open
WHO PM2.5 24-hour Standard
µg/m³
250
200
150
100
50
0
143.2
78.9
121.6
43.6
6.7
5.7
25 µg/m³
TSF
Rocket
TLUD
Stove

Results


1-Hour Mean CO Concentrations in Test Kitchen
60
50
40
30
20
10
0
ppm
43.0
27.5
30.8
8.3
3.6
2.9
~31 ppm
(35 µg/m3)
Door Open
Door & Window Open
WHO 1-hour CO Standard
TSF
Rocket
TLUD
Stove

Conclusions and Discussion

- Improvement of TLUD over open fire
- What was statistically significant?
- What was not statistically significant?
- Why is that important?

Recommendations

- Is it better to cook outdoors on a traditional fire, or to cook on a TLUD, in terms of:
  - Health?
  - Deforestation?
  - Climate change?

Issues yet to be addressed

- Will more stoves be tested?
- What if a cook cannot cook outside?
- What about outdoor air pollution?

Looking forward

- Continue testing
- Key points to remember for future
  - Emissions
  - Ventilation
  - Location
  - Stove
  - End user

Sources Referenced and Cited

- Aprovecho Research Center, Shell Foundation, et al. *Comparing Cook Stoves*.
- Dasgupta, S., Huq, M., et al. *Indoor Air Quality for Poor Families: New Evidence from Bangladesh*. Development Research Group, World Bank Policy Research Working Paper 3393, 2004.
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- Rubinson, K. A., & Rubinson, J. F. *Contemporary Instrumental Analysis*, Prentice Hall, 2000.

Data Processing

- Error Analysis
  - Standard format
    - True mean (μ)
    - Estimated mean (m)
    - Estimated standard deviation of mean (s_m)
    - Student's t at 95% ($t_{(N-1,95)}$)
  - Reporting and display
    - $\mu = m \pm t_{(N-1,95)} \bullet s_m$
    - Bar graphs display m
    - Error bars display $\pm t_{(N-1,95)} \bullet s_m$

Acknowledgements

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