Webinar: In-field black carbon emissions of liquid, gas, and high-performing biomass stoves – November 28th, 2018

CLEAN COOKING ALLIANCE

In-field black carbon emissions of liquid, gas, and high-performing biomass stoves

Webinar-November 28th, 2018

This webinar will examine the results of two research studies commissioned by the Clean Cooking Alliance and funded by the Climate & Clean Air Coalition to understand the in-field black carbon emissions from liquid, gas, and high-performing biomass stoves.

This webinar will provide insights and preliminary results from two recently completed field studies in Nepal and Rwanda examining how higher performing stoves and fuels can potentially reduce the climate impacts from black carbon emissions.

- Speakers
  - Donee Alexander, PhD, Senior Director of Evidence & Impact, Clean Cooking Alliance
  - Yekbun Gurgoz, Finance & Household Energy Initiative Coordinator, Climate & Clean Air Coalition
  - Ryan Thompson, Mountain Air Engineering
  - Andy Grieshop, PhD, North Carolina State University
  - Katie Pogue, Manager of Environment & Climate, Clean Cooking Alliance

Overview

- Welcome and overview, Donee Alexander, Clean Cooking Alliance
- Climate and Clean Air Coalition introduction, Yekbun Gurgoz, CCAC
- Nepal research presentation, Ryan Thompson, Mountain Air Engineering
- Rwanda research presentation, Andy Grieshop, North Carolina State University
- Sector implications, Katie Pogue, Clean Cooking Alliance
- Questions and answers
- Thank you and close, Donee Alexander
- Participant survey

The Need

Every day,

3 BILLION PEOPLE

depend on polluting open fires and inefficient stoves to cook their food

Background

- **Black carbon emissions** occur due to the incomplete combustion of biomass and fossil fuels and are a significant source of both climate change and air pollution
- **Up to 25%** of black carbon emissions come from household solid-fuel use
- **Few studies** measure the emissions reduction potential of household use of liquid, gas, or high-performing biomass cookstoves
- **Laboratory data** indicates that consistent use of higher performing cookstoves and fuels, at scale, could have a significant climate benefit
- **Household use**: At the same time, research shows that household use greatly differs from the ideal settings in a lab

Research motivation: commissioned the black carbon emissions studies to answer whether liquid, gas, and high-performing biomass cookstoves provide measurable climate benefits when used in households in Nepal and Rwanda

Background

Rwanda: The study assessed the emissions cookstoves in urban and rural homes in Gisenyi, Rwanda.

- Emissions were sampled in-field during cooking events for:
  - forced-draft pellet-fed semi-gasifier (Mimi Moto),
  - traditional wood (three stone fire),
  - and charcoal (coalpot/Jiko)

Nepal: The study assessed the emissions from cookstoves used by households in Kavre, Nepal.

- Emissions were sampled in-field during cooking events for:
  - biogas
  - LPG
  - and wood cookstoves.

Study objectives

1) measure emission factors from in-home use of the three stove types,
2) compare emission factors to existing lab and field measurements, and
3) characterize the optical properties of the aerosols emitted during cooking.

*Both studies took into account seasonality and fuel quality.

Climate and Clean Air Coalition

Yekbun Gurgoz, Finance & Household Energy Initiative Coordinator, Climate & Clean Air Coalition

CLEAN COOKING ALLIANCE

CLIMATE & CLEAN AIR COALITION
TO REDUCE SHORT-LIVED CLIMATE POLLUTANTS

Climate and Clean Air Coalition

Yekbun Gurgoz,
Coordinator,
Household Energy & Finance Initiatives

UN environment

Key messages

CLIMATE & CLEAN AIR COALITION
TO REDUCE SHORT-LIVED CLIMATE POLLUTANTS

Why is this important?

- Air pollution biggest environmental health risk – **6.5 million premature deaths** per year
- **Welfare losses** – Exposure to air pollution (outdoor & indoor) costs USD 5.11 trillion per year
- **Increase resilience** – impacting climate & extreme weather events

There are solutions – measure governments can take

- Join up **air quality and climate policies/actions**
- **Cleaner and controlled mobility**
- Cleaner **household energy**
- Cleaner **production** processes
- Improved **agriculture** and **waste management** practices
- Banning open burning of **waste**
- **Taxation** ('polluter pays')
- **Awareness** campaigns - policy and public (behaviour)

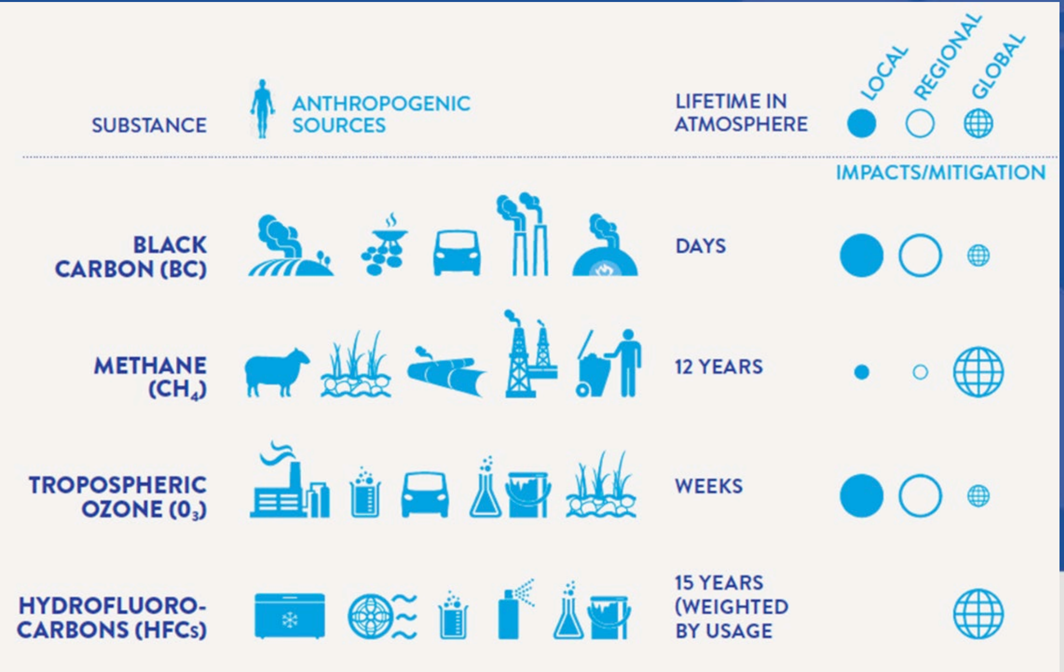
BREATHE LIFE
Clean Air. Healthy Future.

Impact of Air Pollution Emissions

Different scales – all impacting cities. Where are decisions taking on policy on

WHAT ARE SHORT-LIVED CLIMATE POLLUTANTS?

SLCPs are substances with relatively short lifetime in the atmosphere and a warming influence on near-term climate.



They are powerful climate forcers and dangerous air pollutants, detrimental to on human health, agriculture and ecosystems.

WHAT ARE SLCP IMPACTS?

SLCPs have negative impacts on:

- Public health
- Food security
- Global warming
- Ice and Snow melting
- Weather patterns

Which threatens economic security of large populations throughout the world.

Climate & Clean Air Coalition

Methane, Black Carbon & HFC actions

AGRICULTURE BRICKS HOUSEHOLD DIESEL OIL & GAS HFCs WASTE

ASSESSMENTS FINANCE SNAP URBAN HEALTH

Political leadership – partner driven - transformative

FAST ACTION

QUICK RESULTS

CLIMATE & CLEAN AIR COALITION

TO REDUCE SHORT-LIVED CLIMATE POLLUTANTS

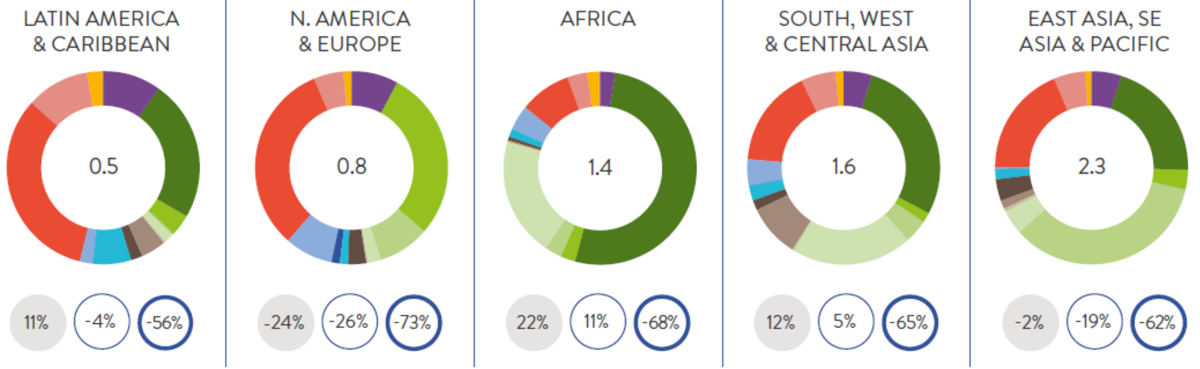
New agreements strengthening the relevance of SLCP reductions

PARIS2015
CONFÉRENCE DES NATIONS UNIES
SUR LES CHANGEMENTS CLIMATIQUES
COP21·CMP11

UNEP/EA.3/L.23 (2017): Preventing and reducing air pollution to improve air quality globally

BLACK CARBON EMISSION TRENDS

2015 Black carbon emissions from main anthropogenic sources (in million tonnes) by region, historical trends and 2030 projections under BAU and full SLCP mitigation scenario



% of change from 2000 to 2015 | Projected % change from 2015 to 2030 under BAU | Projected % change from 2015 to 2030 under mitigation scenario

HOUSEHOLD
58% of 2015 global emissions
- Biomass cookstoves
- Biomass heating stoves
- Coal stoves
- Other residential combustion, incl. kerosene lamps

TRANSPORT
24% of 2015 global emissions
- Transport
- Transport high emitters

INDUSTRIAL PRODUCTION
6% of 2015 global emissions
- Brick production
- Coke production
- Other

AGRICULTURE
5% of 2015 global emissions
- Open burning

FOSSIL FUELS
3% of 2015 global emissions
- Long distance gas transmission
- Oil and gas production incl. flaring

LARGE SCALE COMBUSTION
2% of 2015 global emissions
- Large scale combustion including boilers and furnaces in power plants and industry

WASTE
24% of 2015 global emissions
- Open burning of municipal waste

BLACK CARBON EMISSIONS FROM INEFFICIENT COOKSTOVES

Household energy (cooking, heating and lighting)

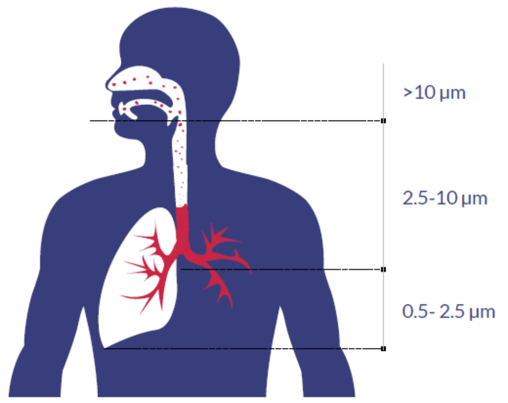
Cookstoves: A Silent Killer

Nearly **3 billion** people rely on open fires and simple stoves to cook wood, animal dung, charcoal, and coal.

Cookstoves: A Silent Killer

Over 4.3 million people a year die prematurely from illness attributable to household air pollution (HAP) from cooking with solid fuels:

- **12%** are due to pneumonia
- **34%** from stroke
- **26%** from ischemic heart disease
- **22%** from chronic obstructive pulmonary disease (COPD)
- **6%** from lung cancer



Also linked to low birth weight, tuberculosis, cataracts, cancer

1/3 of wood harvesting is unsustainable

Contributes to CO_2 emissions

Risk factor for food security

Opportunity to provide to clean energy to 1 billion people

Clean cooking is part of basic services necessary to lead a healthy and productive life. Projects distributing clean cookstoves often serve communities of people living below the poverty line. And by reducing fuel consumption, they can also save households money.

Efficient cookstoves lower the amount of fuel needed to cook, thus reducing the burden on families who would otherwise have to collect it, buy it, or trade their food for it. Emissions of black carbon and other short-lived climate pollutants from inefficient cooking also hamper agricultural productivity.

Reducing smoke emissions from cooking can decrease the burden of disease associated with household air pollution and improves well-being, especially for women and children.

Children, especially girls, are often kept out of school so that they can contribute to household tasks, like cooking and collecting fuel. By reducing the amount of fuel required, efficient cookstoves free up time that would otherwise have been spent collecting or earning money for fuel.

Unpaid work, including collecting fuel and longer hours spent with inefficient cooking, remain a major cause of gender inequality.

Clean cooking and heating is essential to addressing energy poverty and ensuring sustainable energy security for billions of people.

Energy access enables enhanced productivity and inclusive economic growth. The clean cooking sector offers many job opportunities through local production, distribution and other project support activities.

The use of inefficient stoves increases fuel consumption, releasing CO2 and other greenhouse gases into the atmosphere. In addition, up to 25% of black carbon emissions come from burning solid fuels for household energy needs. Clean cooking thus delivers a dual-impact of climate benefits.

Up to 34% of wood fuel harvested is unsustainable,[1] contributing to forest degradation, deforestation, and climate change.

1. Bailis et al. The carbon footprint of traditional woodfuels. Nature Climate Change 5, 266–272 (2015)

Clean Cooking and Heating and the SDGs

In 2015, 193 countries worldwide adopted 17 Sustainable Development Goals (SDGs) to tackle major issues the world faces, from ending poverty, to protecting the planet, to ensuring prosperity for all.

Clean cooking and heating interventions deliver against a wide range of these SDGs, helping improve livelihoods, providing access to clean energy, contributing to gender equality, improving health, conserving natural ecosystems, and more.

Brief overview of vision and purpose of Initiative

The Household Energy Initiative aims to speed up reductions in SLCP emissions through:

- High-level advocacy and government engagement
- Support for new finance mechanisms
- Targeted research to further the understanding of the emissions reductions that can be achieved by various technologies
- Development of standards and testing protocols to provide clear criteria for evaluating emissions reductions for improved cookstoves, heatstoves and fuels

Thank you!

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Nepal

Ryan Thompson, Mountain Air Engineering

Biogas Stove Emissions in Kavre, Nepal

Cheryl Weyant, Ryan Thompson, Nicholas L. Lam, Basudev Upadhyay,

Amod Pokhrel, Prabin Shrestha, Shovana Maharjan, Kaushila Rai, Chija Adhikari, Maria C. Fox

preliminary results

Mountain Air

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CLIMATE & CLEAN AIR COALITION

Objectives

Measure emission factors of health and climate relevant emissions

- Including black carbon (BC), organic carbon (OC), particulate matter ($PM_{2.5}$) , and carbon monoxide (CO)
  Note: BC is measured as elemental carbon (EC)

- From biogas, LPG, and wood stoves

- During uncontrolled field settings

Project Partners

- Mountain Air Engineering – Ryan Thompson
- University of Illinois – Cheryl Weyant, Tami Bond, Maria Fox
- Basudev Upadhyay (Independent contractor)
- Humboldt State University – Nicholas Lam
- LEADERS Nepal – Amod Pokhrel
- Center for Rural Technology, Nepal (CRT/N) - Prabin Shrestha, Shovana Maharjan, Kaushila Rai, Chija Adhikari
- Climate and Clean Air Coalition
- Clean Cooking Alliance

Why Biogas?

- Biogas benefits
  - Clean, local, renewable fuel
  - Source of organic fertilizer

- Long-term adoption (20yrs)

- Wide-spread use

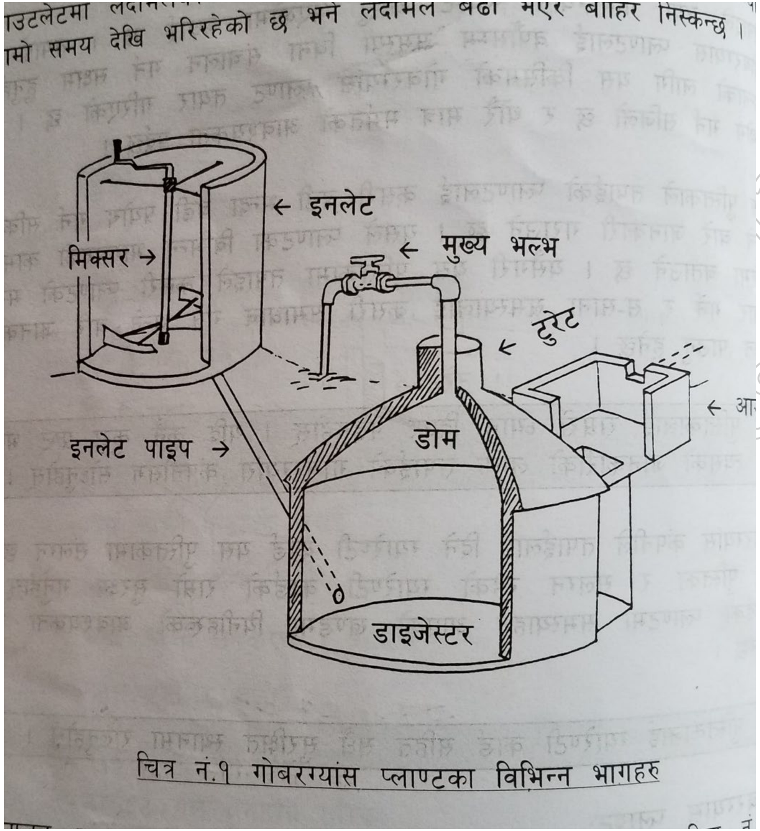
Region: Panchkhal, Nepal

Kavrepalenchok District

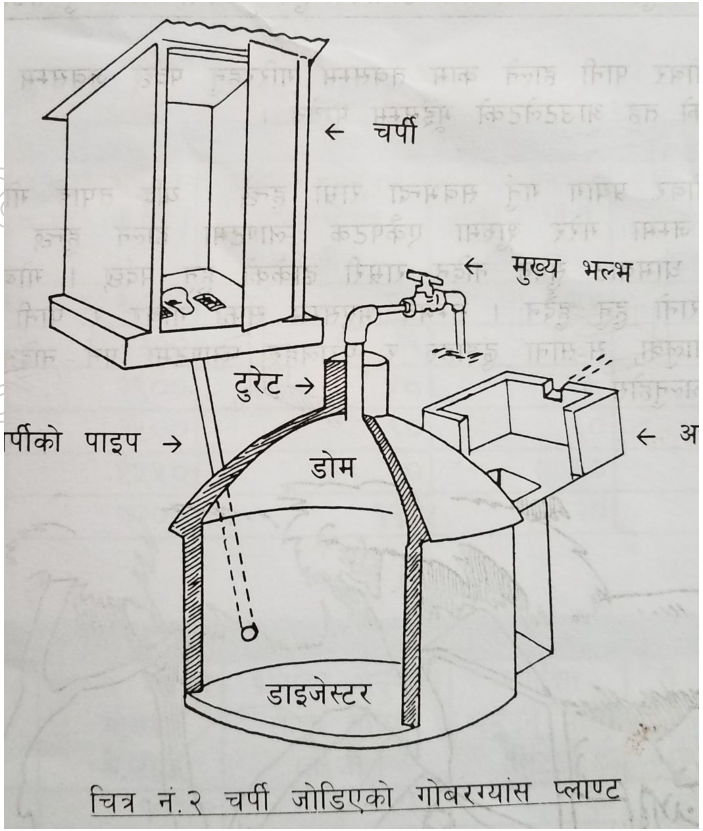
Stoves: Wood

Stoves: Biogas and LPG

Biogas System



चित्र नं.१ गोबरग्यांस प्लाण्टका विभिन्न भागहरु



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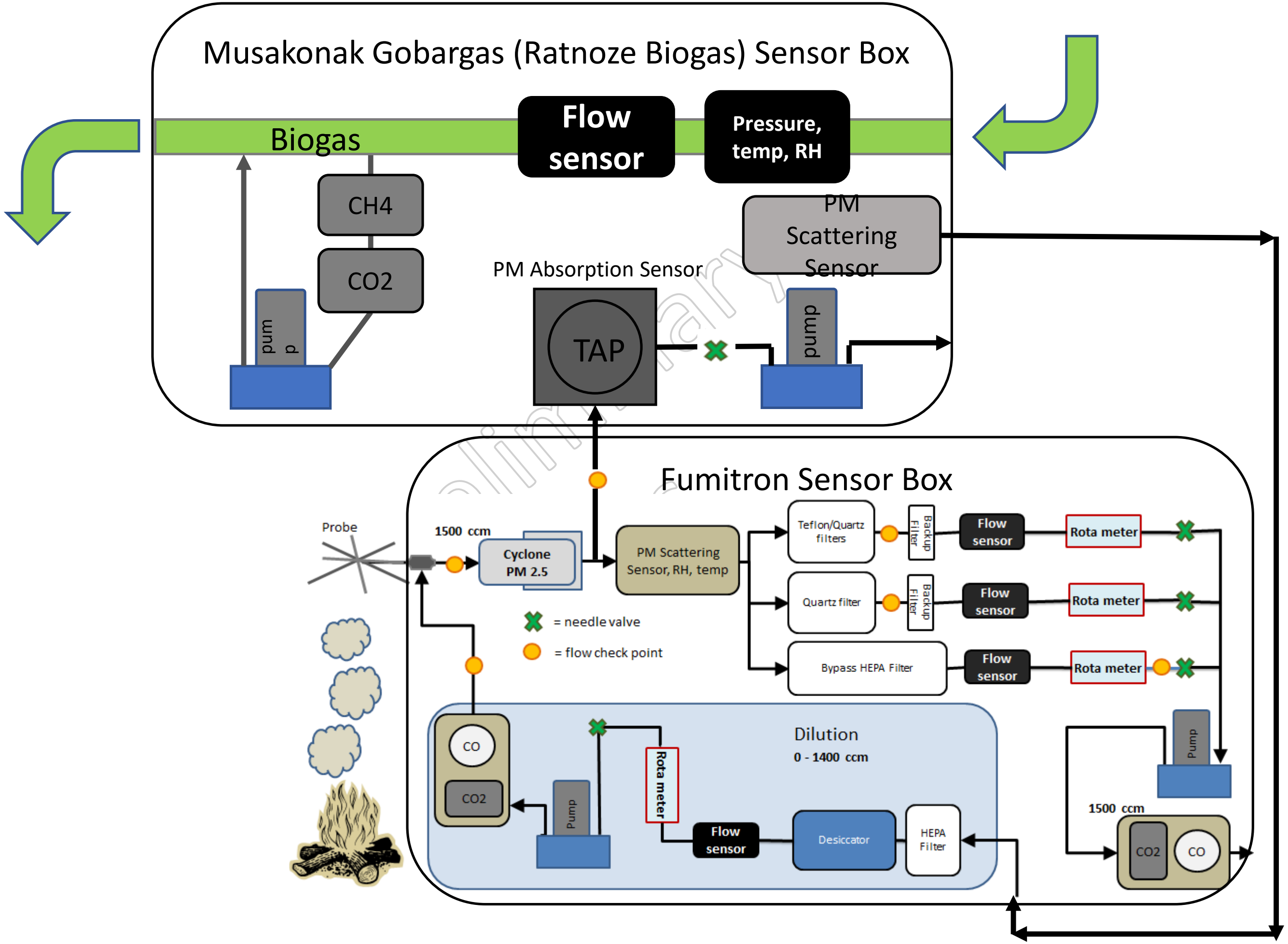
Biogas System

Measurement Equipment



Equipment

Sampling Plan

- 3 seasons (Monsoon, Spring, Winter)
- 20 homes

- 79 Cooking events measured:
  - 57 biogas
  - 16 wood
  - 6 LPG

- Variety of cooking tasks: rice, lentils, tea, boiling milk, heating water, frying vegetables, etc.

Results: Biogas Properties

	mean	standard deviation
CH_4 (%vol)	59.0	3.3
CO_2 (%vol)	26.7	4.1
CH_4massfrac (g/g)	0.38	0.03
Cmassfrac (g/g)	0.41	0.02
LHV (MJ/kg)	20.9	1.8

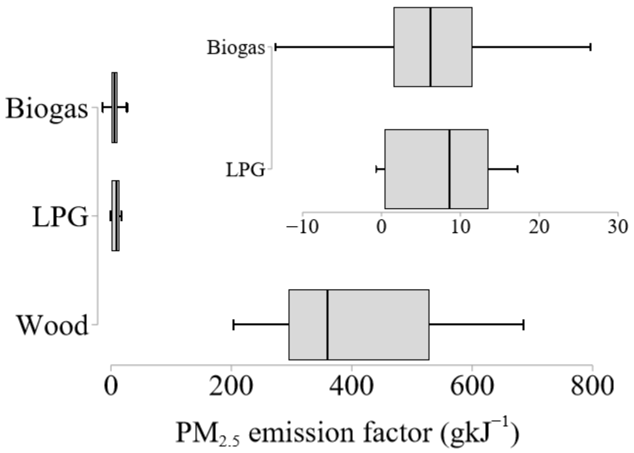
n = 57 (3 seasons, 19 samples per season)

Biogas properties were not significantly different between seasons

Results

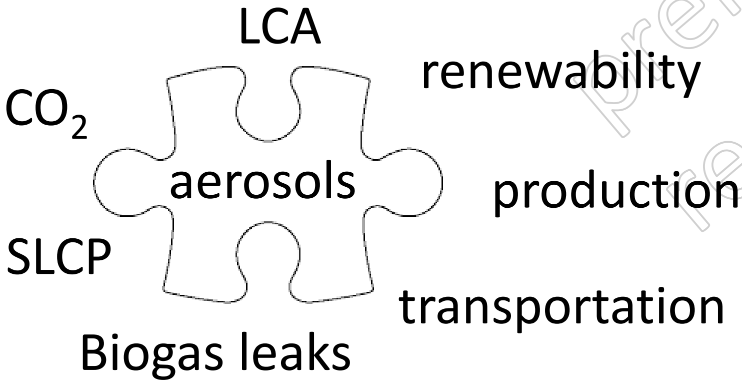
- $PM_{2.5}$ emission factors of gas cooking events are 50 times lower than wood cooking events
- Seasonal variability – no significant difference

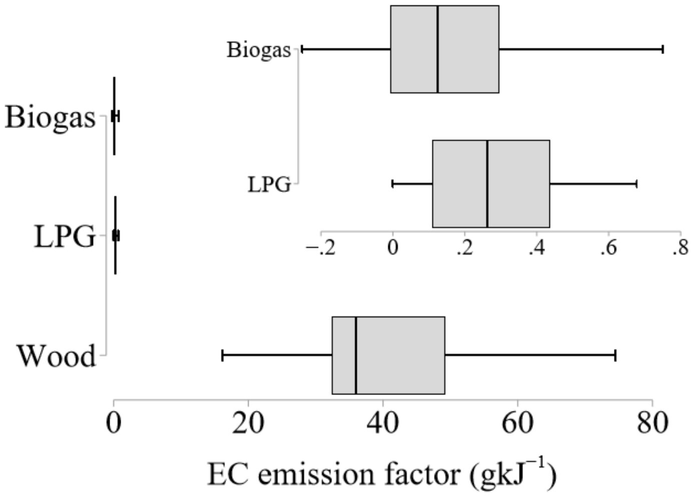
Fuel	N	EF_{CO} gMJ^{-1}	EF_{PM} gkJ^{-1}	EF_{EC} gkJ^{-1}
Biogas	57	1.1 (0.5)	7.4 (10.9)	0.19 (0.30)
LPG	6	0.4 (0.2)	9.5 (6.8)	0.29 (0.25)
Wood	16	5.1 (1.3)	408 (160)	45.6 (24.5)



Results: Climate Impact

- The climate impact of aerosols from gas cooking is cooling and very small
- Black carbon is a small fraction (3%) of particle emissions
- EC emission factors of gas cooking events are 200 times lower than wood cooking events

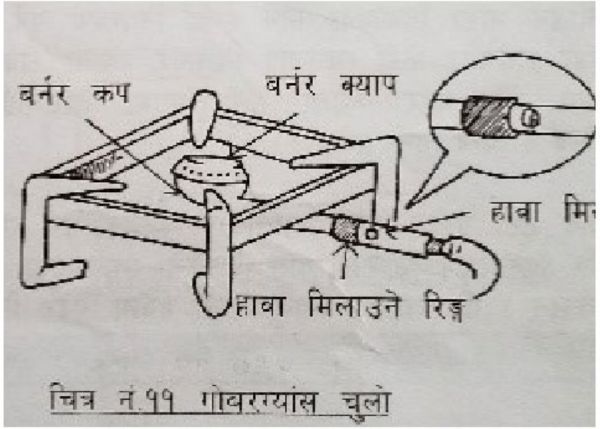




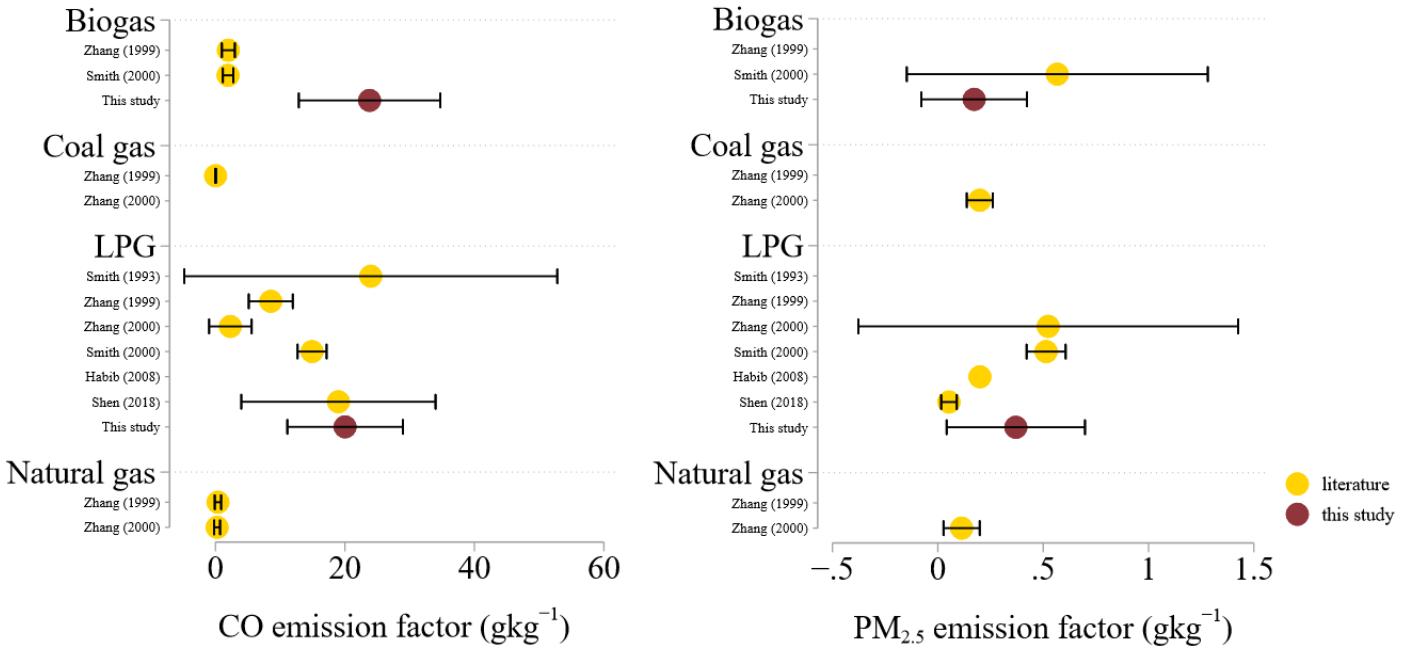
Results: CO Emissions

- Biogas stove CO emissions were approximately double LPG (not significant)
- Biogas stove CO emissions were influenced by primary air adjustment: more air = lower CO
- During a controlled lab test, CO emissions were 3 times higher when the primary air valve was closed

CO emission factor (g/kg)	mean	standard deviation
Biogas – valve open	16	4.0
Biogas – valve half open	17	4.1
Biogas – valve closed	33	9.0



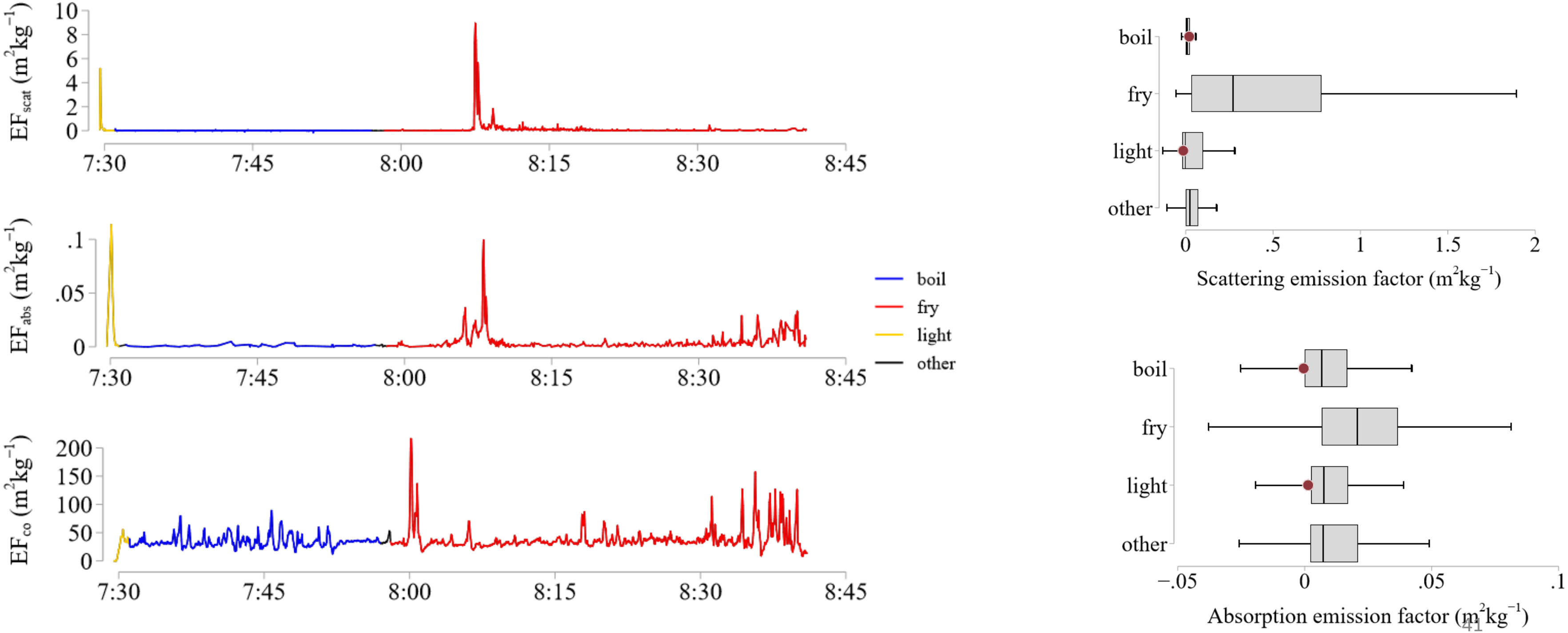
Results: Comparison with literature



Previously published results are water boiling tests

Results: Cooking Emissions

- About 90% of $PM_{2.5}$ emissions were attributed to frying
- About 30% of EC emissions were attributed to frying



Detection Limits and Measurement Uncertainty

- Two types of particle ($PM_{2.5}$, EC, and OC) detection limits
  1. Filter loading (minimum detectable particle mass on filter)

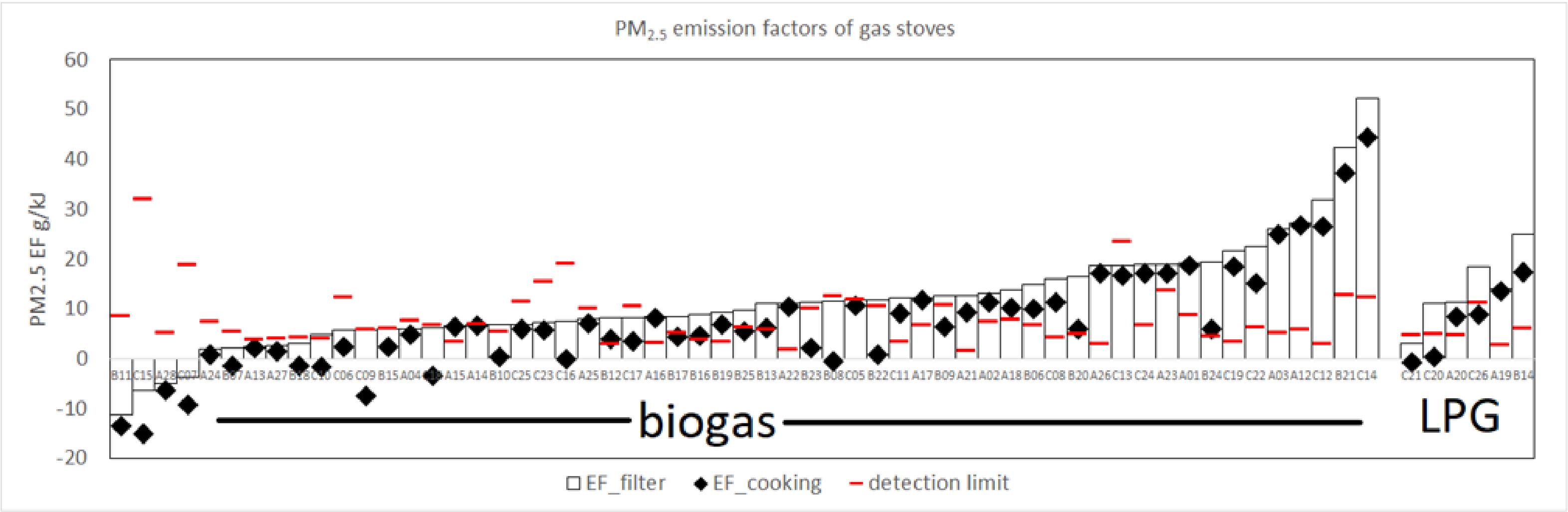
     LOD = 3 * standard deviation of field blanks

  2. Background concentrations

     $C_{emission} = C_{plume} – C_{bkg}$

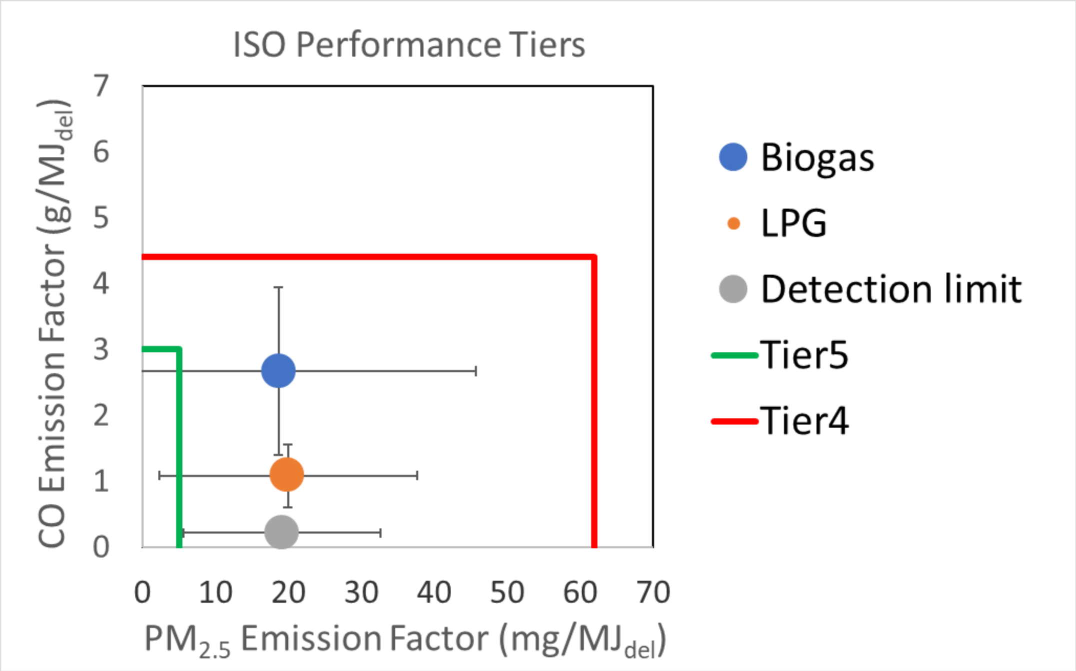
- Background concentration has relatively high uncertainty because of temporal and spatial variability
- Clean background air is required to better quantify pure gas stove emissions

Propagated Detection Limits for Gas Stoves



- Average detection limit ≈ average emission factor
- Data censoring does not significantly change the results

Comparison with ISO Performance Targets



Performance Tiers from (International Standards Organization) ISO/TR 19867-3:2018 Clean cookstoves and clean cooking solutions -- Harmonized laboratory test protocols -- Part 3: Voluntary performance targets for cookstoves based on laboratory testing

Assumption: Thermal Efficiency of biogas and LPG stoves = 0.5

Conclusions

- Biogas and LPG stoves are clean in real-world settings
- Biogas and LPG cooking aerosol emissions are slightly climate cooling
- Majority of $PM_{2.5}$ emissions are from frying food, not from the fuel
- Gas stoves do not meet all household energy needs – wood remains a major household energy source

Future research directions

- Comparative household emission rates
  - Including all household stoves
- Total climate impacts
  - Life cycle analysis
  - Biogas leakage
- Biogas system maintenance and repair
- Biogas system design

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Thanks

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Rwanda

Andrew Grieshop, North Carolina State University

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Pellet-fed gasifier stoves approach gas-stove like performance during in-home use in Rwanda

Wyatt M. Champion*, **Andrew P. Grieshop**
Environmental Engineering, North Carolina State University
go.ncsu.edu/grieshop_lab
*now an ORISE postdoctoral researcher at US EPA

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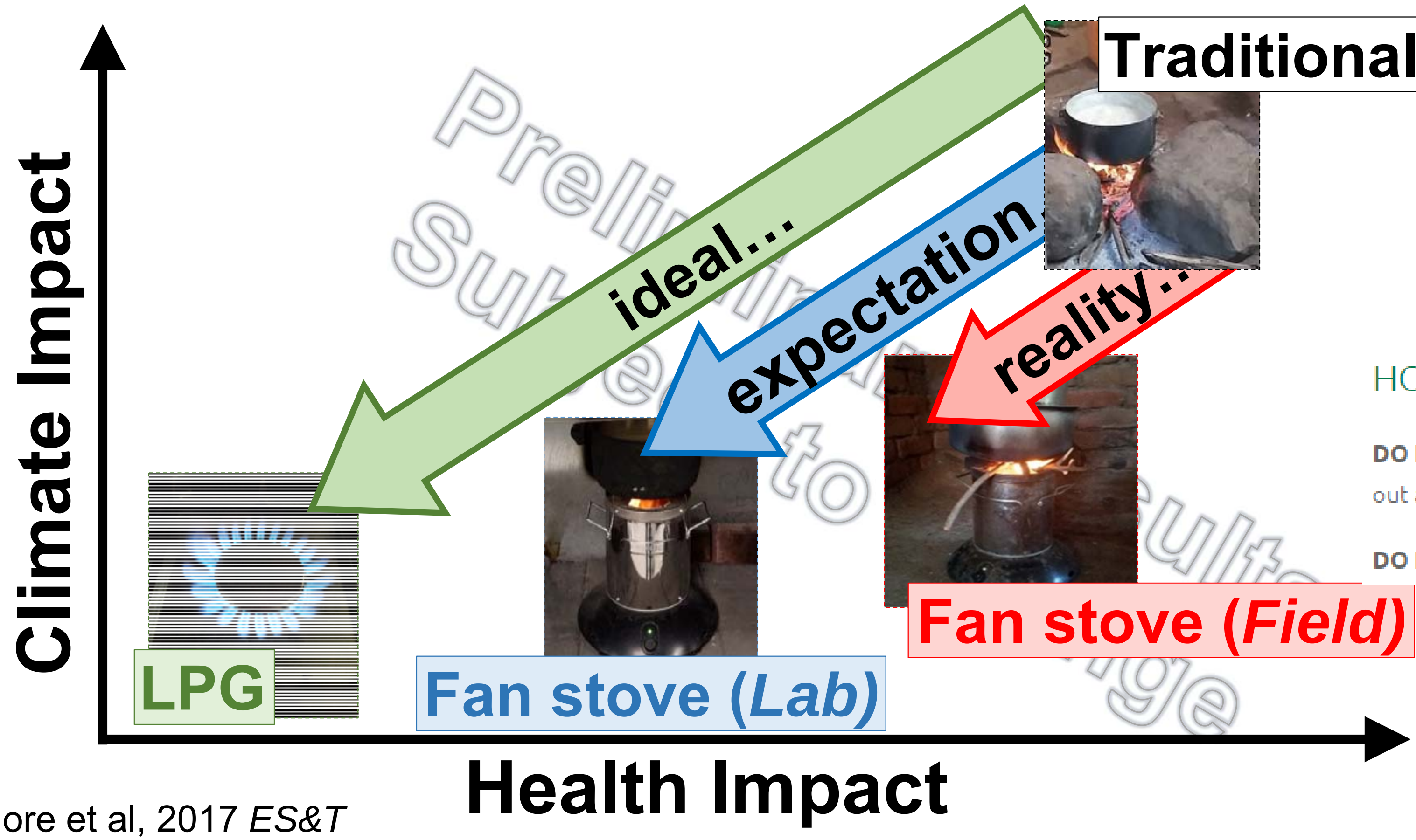
28 November 2018 -- Clean Cooking Alliance Webinar

Roadmap for talk

- Why a pellet + gasifier stove?
- Why Rwanda?
- What did we do?
  - In-home testing of baseline and pellet-fed gasifier stoves
- What did we find?
  - Emission factors and emission rates
  - Optical properties of particles (climate relevant)
  - Distribution of emission performance *across* and *within* tests
- What are implications?
  - Co-benefits from use of pellet-fed gasifiers versus baseline and modern fuels

Ultra-low cooking emissions required for health and climate benefits, but not seen in ‘real-world’ use of biomass stoves



Wathore et al, 2017 *ES&T*

Inyenyeri: addressing the fuel, stove <u>and</u> household

Implementer: Inyenyeri, a Rwandan Social Enterprise

- Mimi Moto stoves and **locally-produced biomass fuel pellets**
- Innovative business model: **Pay for pellets, get free stove**
- **Pellets compete with charcoal (purchased) and fuelwood (gathered)**
- Large **emphasis on customer service** and follow-up
- See Jagger and Das, 2018, *ESD* for more…

Stove: Mimi Moto

- Pellet-fed forced-draft cookstove
- Lab tests: Tier-4 for emissions and efficiency measurements (CSU)

Location: Gisenyi, Rwanda (small city)

- Headquarters and pilot roll-out

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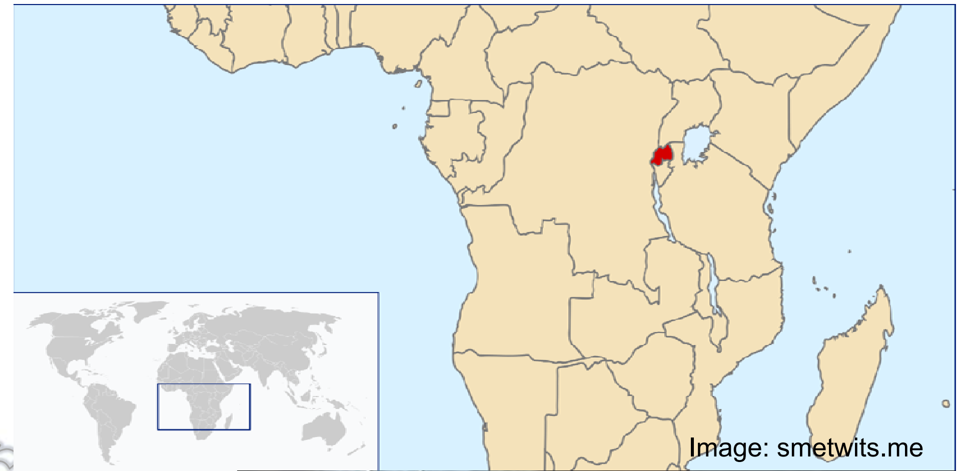
Photo: trendhunter.com

Rwanda, the land of a thousand hills and a million smiles

- Located in East Africa
- Most densely populated nation on the continent
- 95% of population relies on solid biomass for cooking.[3]
  - Wood is dominant in rural
  - Wood and charcoal split in urban
- Lower respiratory infection is the leading cause of disability-adjusted life years lost (DALYs) in Rwanda[4].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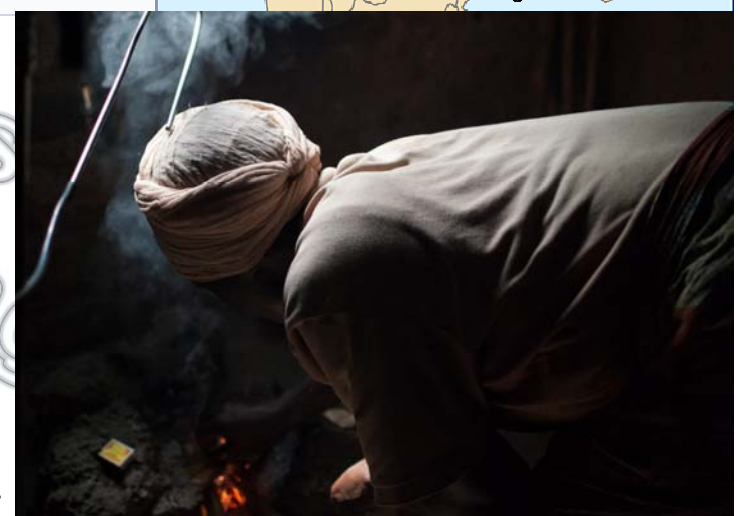
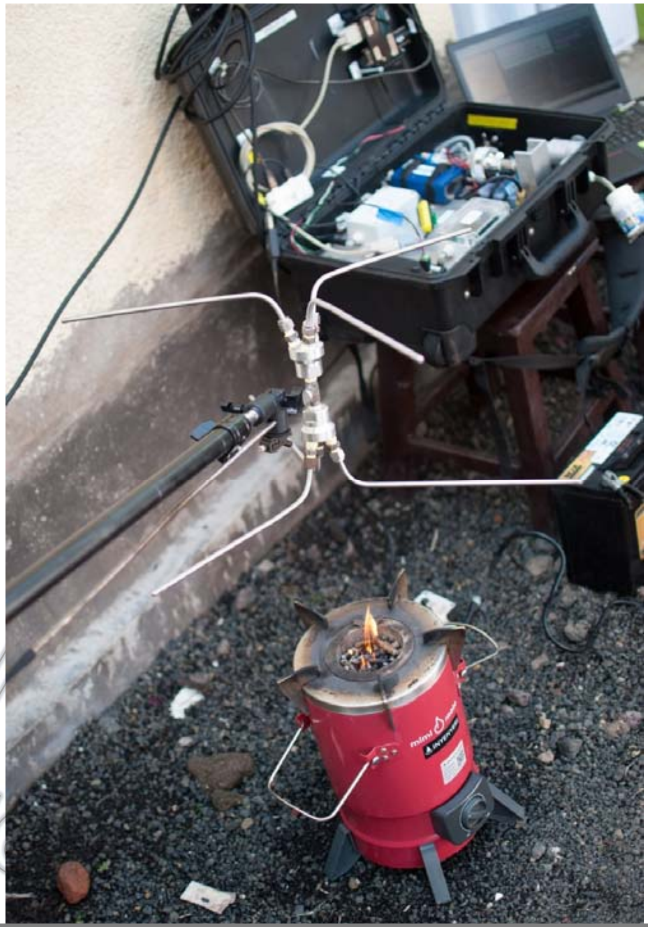


1. Global Alliance for Clean Cookstoves, 2012; 2. Institute for Health Metrics and Evaluation, 2018

In-home measurements of Mimi Moto and baseline stoves

- ‘Randomized’ Household Selection
  - Pellet (~70% urban, ~30% rural)
  - Wood (100% rural)
  - Charcoal (100% urban)
  - 2 ‘seasons’, testing same households (Dec ‘17, May ‘18)
- Sampling Equipment
  - Stove Emission Measurement System (STEMS)
  - Plume-sampling probe
  - Real-time:
    - CO and CO_2
    - $PM_{2.5}$ Scattering and Absorption (Aethlabs µAeth)
  - Integrated $PM_{2.5}$ filter samples:
    - Mass, and Organic and Elemental Carbon (OC/EC)
- Carbon-balance method for emission factors
- Uncontrolled Cooking Test (UCT)
  - Participant cooks a meal of their choice with (ideally) minimal disruption

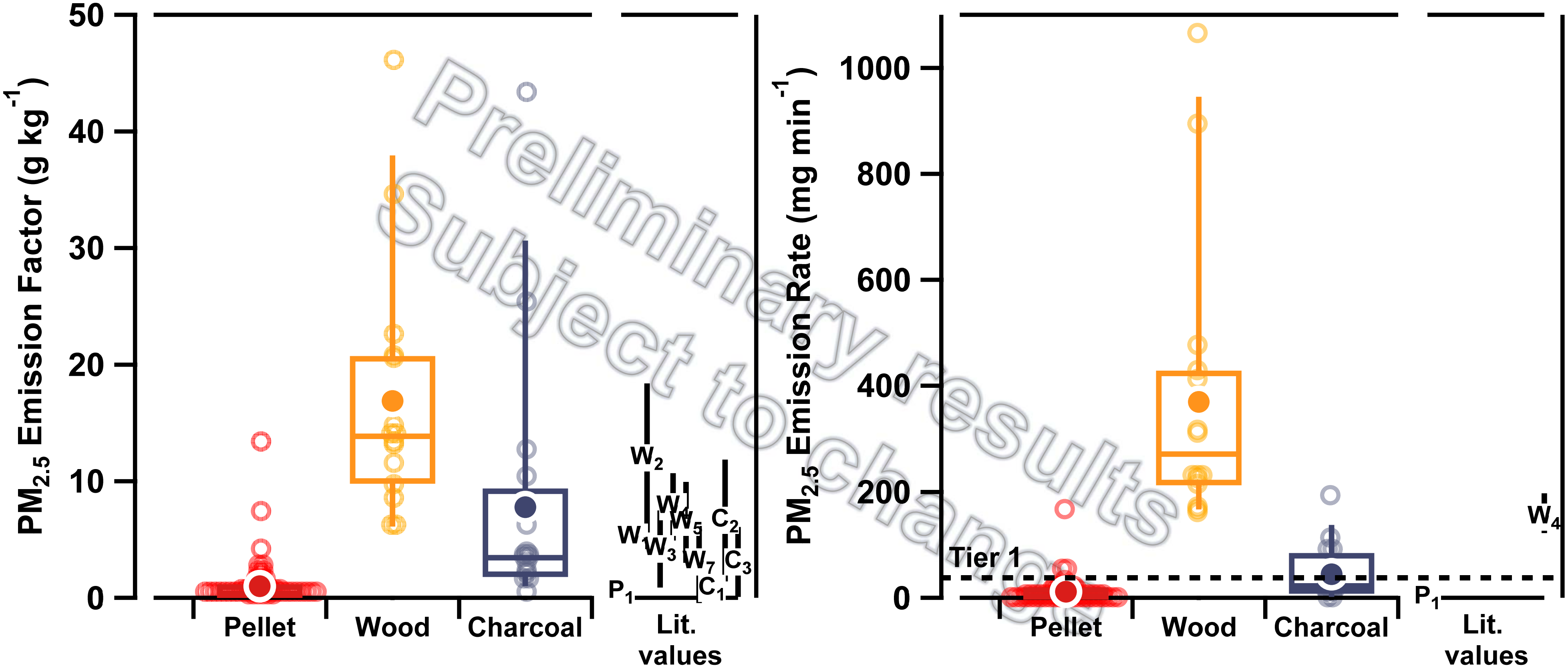


Mimi Moto and Sampling Equipment

STove Emissions Measurement System (STEMS)


Pellet
n=59
Wood
n=16
Charcoal
n=16

Pellet stoves reduce $PM_{2.5}$ emissions by 97% compared to Wood, and 88% compared to Charcoal



3. Global Alliance for Clean Cookstoves, 2018; 4. Garland et al., 2017; 5. Roden et al., 2009; 6. Coffey et al., 2017; 7. Wathore et al., 2017; 8. Rose Eilenberg et al., 2018; 9. Lefebvre 2016; 10. Grieshop et al., 2017

Implications for the Sector

Katie Pogue, Clean Cooking Alliance

Sector Implications

- **Adding to the evidence base:** the Nepal study is the first study to measure emissions from biogas and LPG emissions under typical household-use settings and the Rwanda study is the first to measure emissions from the MimiMoto under typical household-use.
  - The Nepal study added 57 new tests for biogas stoves and six for LPG over three seasons. The Rwanda study added 59 uncontrolled cooking tests for the MimiMoto.
  - There is an ongoing, global transition to clean fuels (particularly gas fuels and electric stoves), and these studies begin to provide data for assessments of the health and climate impacts of this transition, as well as building the case for interim biomass options.
- **Affordability:** affordability is a key concern for higher-performing technologies, and biogas and high-performing biomass stoves may offer a more affordable option with the right business model or program.
- **Suite of clean cooking options:** not only LPG, but also biogas and high-performing biomass stoves should be considered a viable step for household transitions towards cleaner energy.
- **Long-term sustainability:** need for sustainable maintenance and customer support programs for clean cooking interventions.
  - In the Nepal case, a biogas maintenance program could have a large benefit to cost ratio and could help foster new users. In the Rwanda case, the Inyenyeri business model emphasizes customer service.
  - Both public and private initiatives should consider sustainability.

Q&A

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Thank you for attending

Please take a few moments to complete the survey