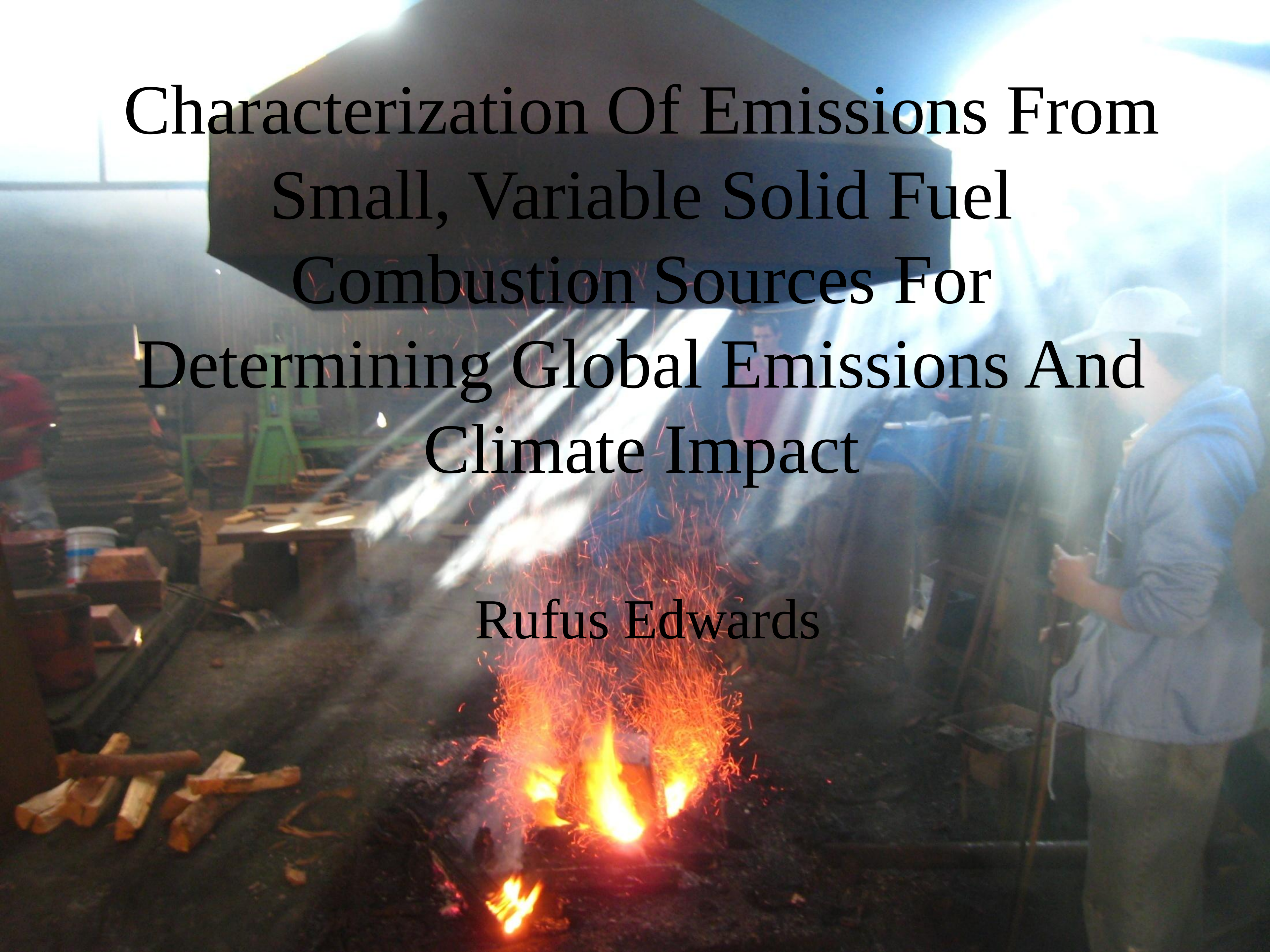
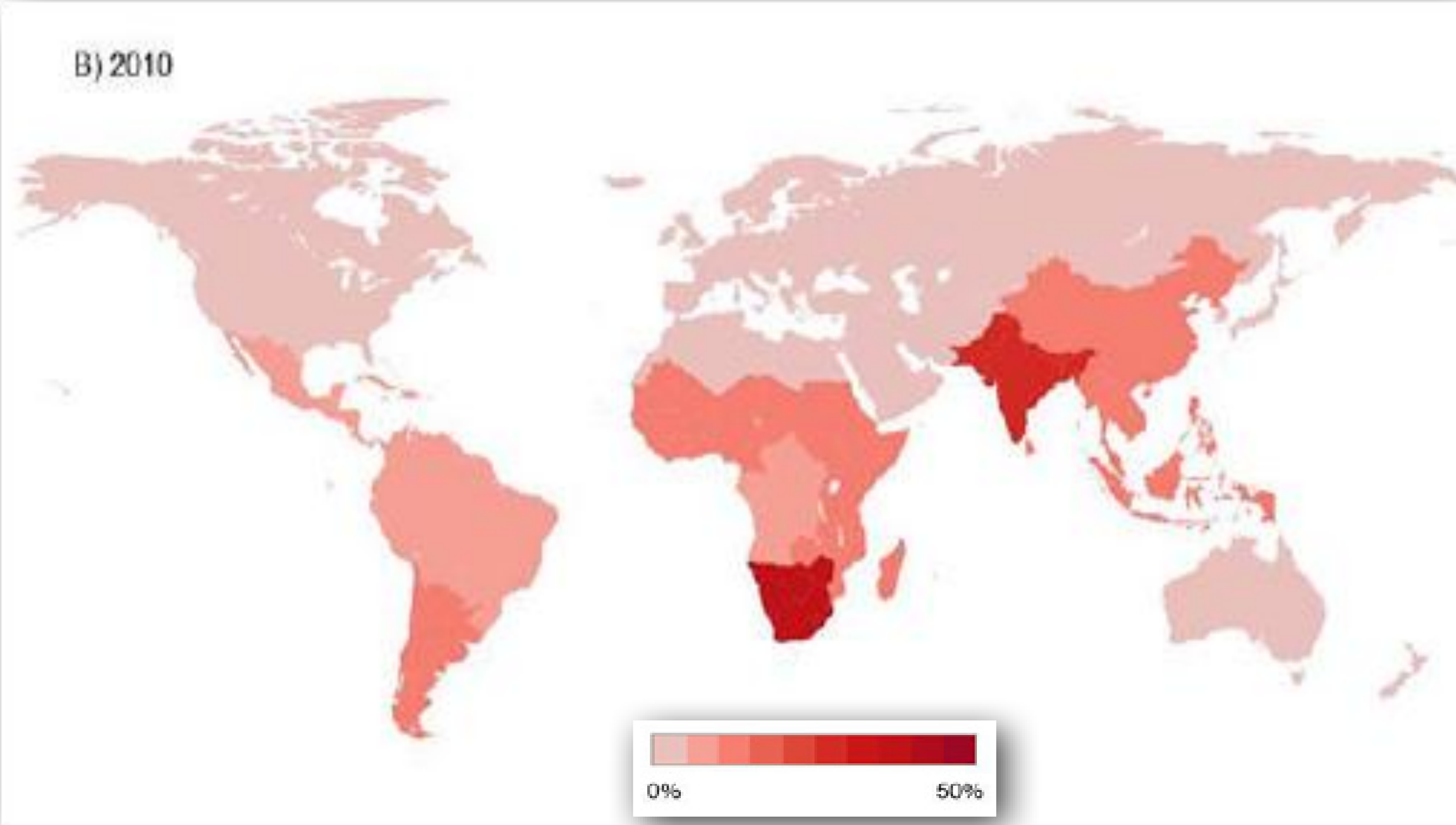


Characterization Of Emissions From Small, Variable Solid Fuel Combustion Sources For Determining Global Emissions And Climate Impact

Rufus Edwards

Where were we when this project started?

- Focus on urban areas
- Systematic under representation of atmospheric PM concentrations by bottom up models
- SPEW (AR5)
- Used in-field EF for BC and OC from one study.
- GAINS
- Used highest PM emission, from heating stove in New Zealand, multiplied by BC fraction.
- EDGAR
- Took emission factors from SPEW. Not clear how technologies are chosen and EFs are translated.

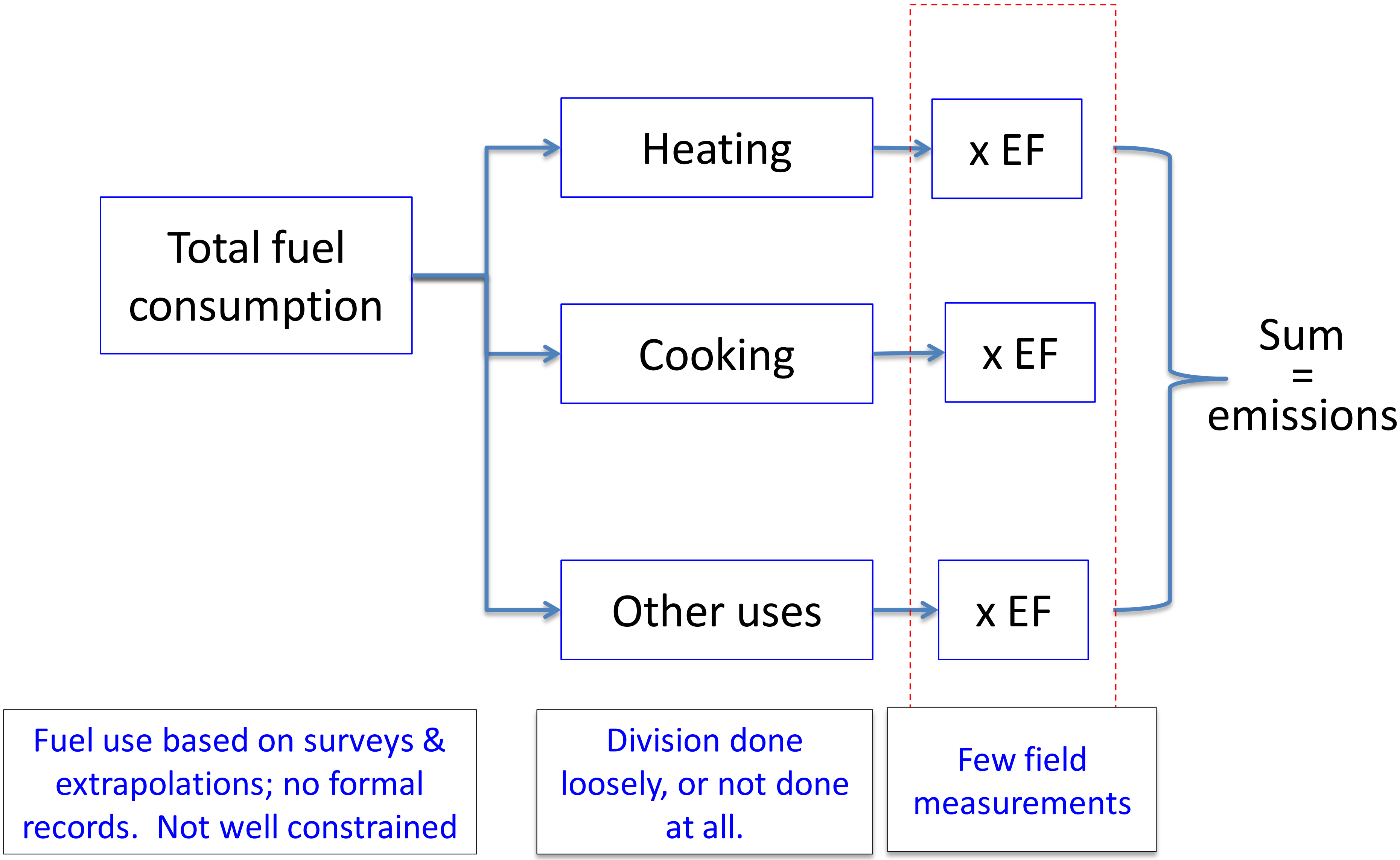


Percent of ambient $PM_{2.5}$ coming from household solid cooking and heating fuels

Chafe et al. Household Cooking with Solid Fuels Contributes to Ambient PM2.5 Air Pollution and the Burden of Disease. Advance Publications Environmental Health Perspectives. http://dx.doi.org/10.1289/ehp.1206340

Emission inventory procedure

and all we need to improve

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Previous state of emissions factors

In field emission factors for household stoves during daily cooking activities.

				Emission factors (g/kg fuel)						
Fuel		Stove classification		CO_2	CO	CH_4	TNMOC	PM	BC	NCE
Biomass-	Wood	Traditional Unvented	Local	1509	87.2	5.0	10.0	7.4	0.7	93.4
				(1672-1267) 6	(145-25.66) 12	(7.4-2.8) 5	(14.85-2.4) 4	(11.7-5) 11	(0.7-0.6) 3	(94-93) 19
		Improved Unvented	Local	1711	74.5			3.3	1.4	93.4
				(1711) 1	(77-72) 2			(5.9-1.2) 6	(2.145-0.8) 5	(93.4) 6
			Natural	1672	74.5	5.1	3.9	4.8	1.5	93.3
				(1711-1633) 2	(88.6-47) 10	1.0	1.0	(13.3-1.2) 14	(2.145-0.8) 6	(93.4-93.1) 14
			Forced	1661	50.0	3.4	8.2	1.9	0.1	95.5
				1	1	1	1	1	1	1
		Improved Vented	Local	1628	40.9	2.5		5.6		93.4
				(1764-1452) 4	(65.33-16.33) 5	(4.4-0.93) 4		1.0		1
	Charcoal	Improved Unvented	Local	2469	311.9	14.7	41.7	15.0		78.4
				(2543-2394) 2	(350.5-273.2) 2	(15.0-14.3) 2	(53.4-29.9) 2	(15.9-14.1) 2		(81.2-75.6) 5
Liquid-	Kerosene	Improved Unvented	Local		11.0				90	
					1				1	
Gas-	LPG/NG	Improved Unvented	gas burner	2848	9.4	0.032				
				(3440-1390) 4	(19.1-0.3) 3	(0.044-0.012) 3				

Number after parentheses indicates number of stoves

WHO Indoor Air Quality Guidelines: Household fuel Combustion.
Chapter 4: Emissions of Health-Damaging Pollutants from Household Stoves

Objective 1

Update emissions inventories with particulate (BC, OM, $PM_{2.5}$) and gaseous (CO_2, CO, CH_4, NMHC, SO_2) species from in field measurements of household stoves and rural small scale industries in 4 sites across the Himalayas:

- Nepal-Mid hills and plains
- China-Tibet
- China-Yunnan
- Haryana, India

Locations

		meals	1 day	3 day	Homes		Industries	
Nepal	Integrated	13	26	7	46	Dung, wood, agricultural residues	17	roadside vendors, pottery kilns
	Real time PSAP	30			16			candy making, kerosene
Tibet	Integrated		34	4	38	Yak dung, wood, agricultural residues		
	Real time PSAP	26			8			
Haryana	Integrated	7	18	2	19	Cow dung, wood, agricultural residues	7	Metal Work, Candy making,
	Real time PSAP	35			35			Pottery kiln, Dhaba (restaurant)
Yunnan	Integrated		33	6	39			
	Real time PSAP	41			41			
					242		24	

Northern India; International Clinical Epidemiology Network (INCLEN) SOMAARTH surveillance site. Palwal District - 51 villages - 200,000+ people
77% use biomass - 94% gather fuel. Almost all outdoor cooking. Predominantly traditional cookstoves using dung, crop residues, and wood, Phillips forced draft advanced combustion stove

China-Tibet; Nam CO high altitude research station; Linzhi. local nomadic populations and communities that primarily use yak dung and wood as fuel. Fuel types measured represent ~ 95% of household energy consumption.

Nepal; CRTN Midhills and plains regions. Fuel use is predominantly wood 74%, dung 8%, and kerosene 3.5 % in Nepal. Fuel types measured represent ~85% of household energy consumption.

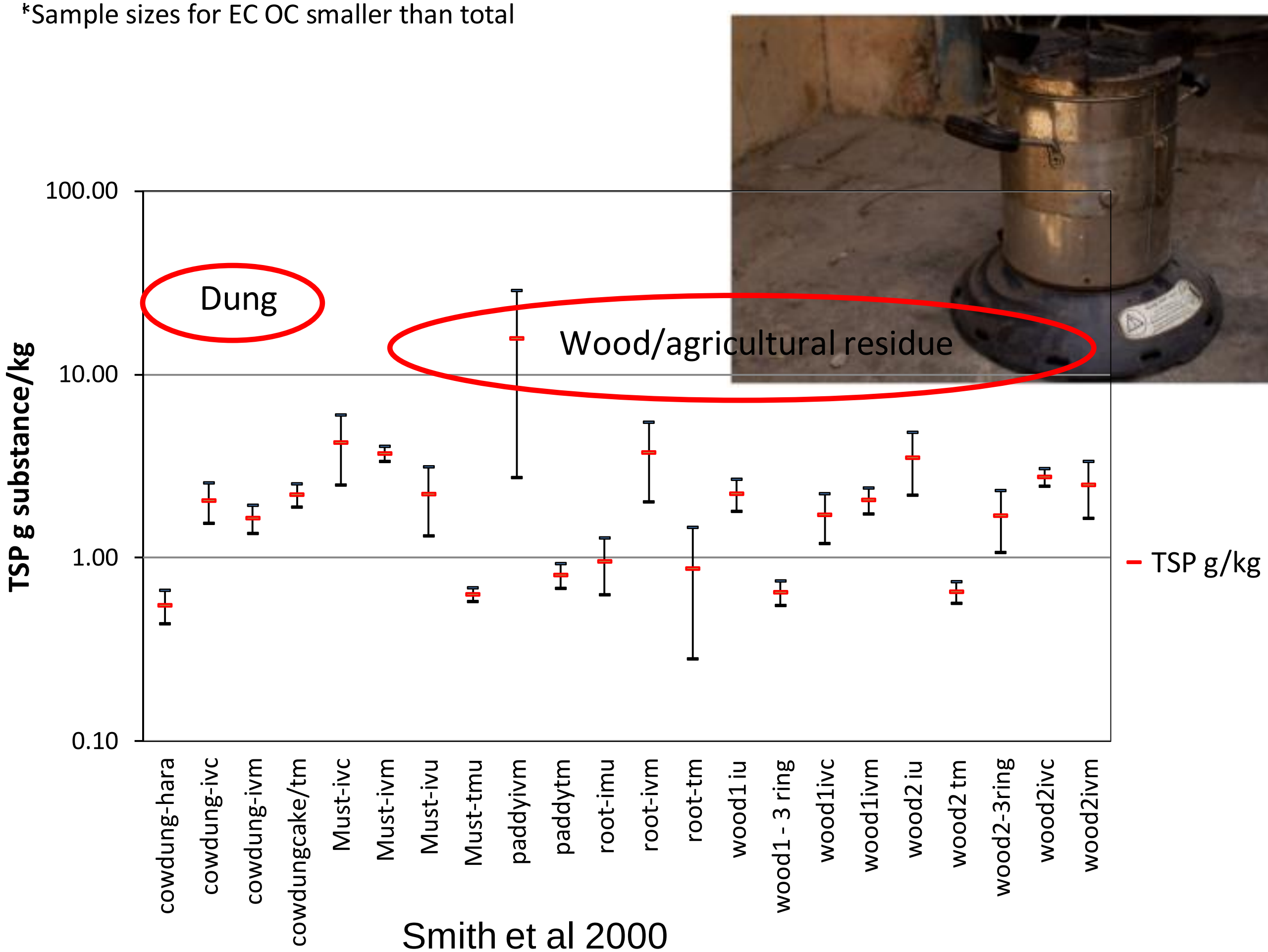
China -Yunnan; Chinese CDC and NCI group working on cancer, coal smoke and gene environment interactions. Fuel types measured represent ~89% of household energy consumption

El Salvador; Evaluate the Turbococina an advanced combustion biomass cook stove used in homes and schools. Wood dominates residential energy consumption in El Salvador

India emissions

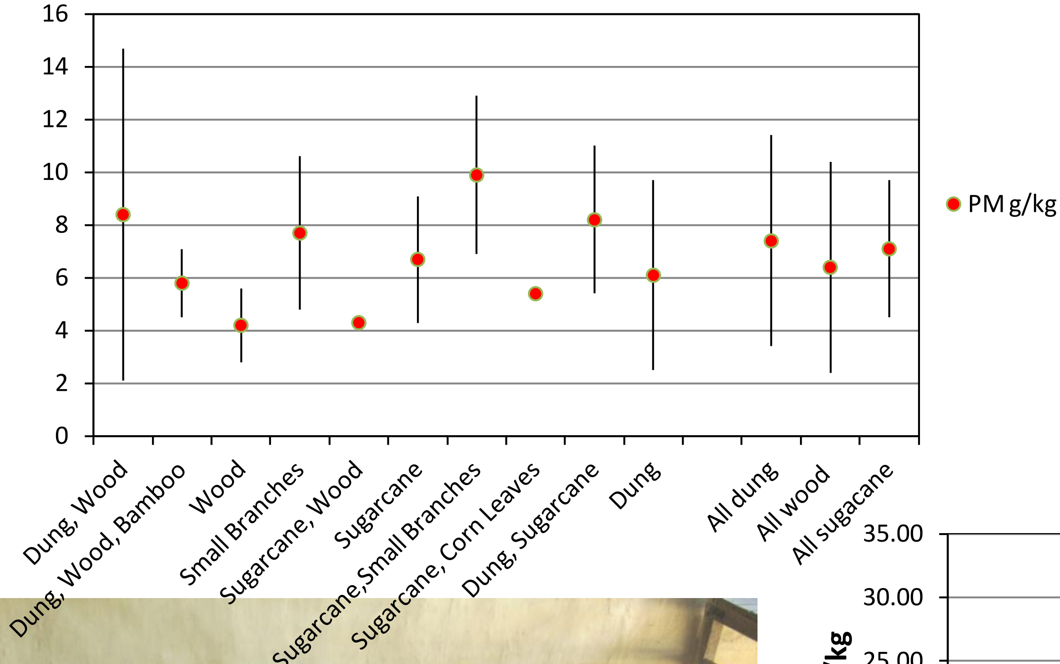
	n	MCE	CO_2	CO	$PM_{2.5}$	EC	OC	TIME (min)
			g substance/ kg fuel					
Fixed Chula w/o Chimney	16	0.92 (±0.01)	1651 (±20.8)	152.2 (±19.0)	12.0 (±8.7)	0.8(±0.9)	10.9(±9.8)	167 (±12)
Phillips	13	0.94 (±0.01)	1704 (±16.2)	100.8 (±13.8)	6.6 (±3.9)	0.9(±0.6)	6.3(±2.2)	216 (±31)
Haro	5	0.89 (±0.02)	1584 (±48.5)	189.9 (±39.8)	44.8 (±32.6)	1.7(±1.8)	41.5(±32.4)	167 (±36)
Angithi	2	0.86 (±0.04)	1541 (±77.9)	243.9 (±69.4)	24.6 (±10.0)	4.8	8.3	111 (±9)

*Sample sizes for EC OC smaller than total

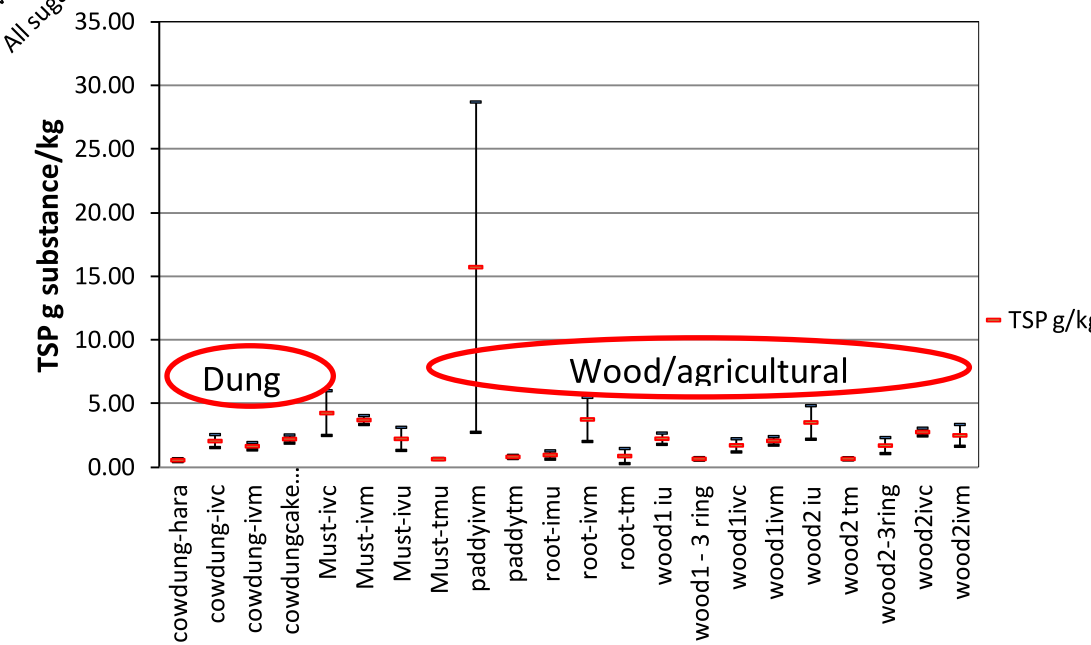


Smith et al 2000

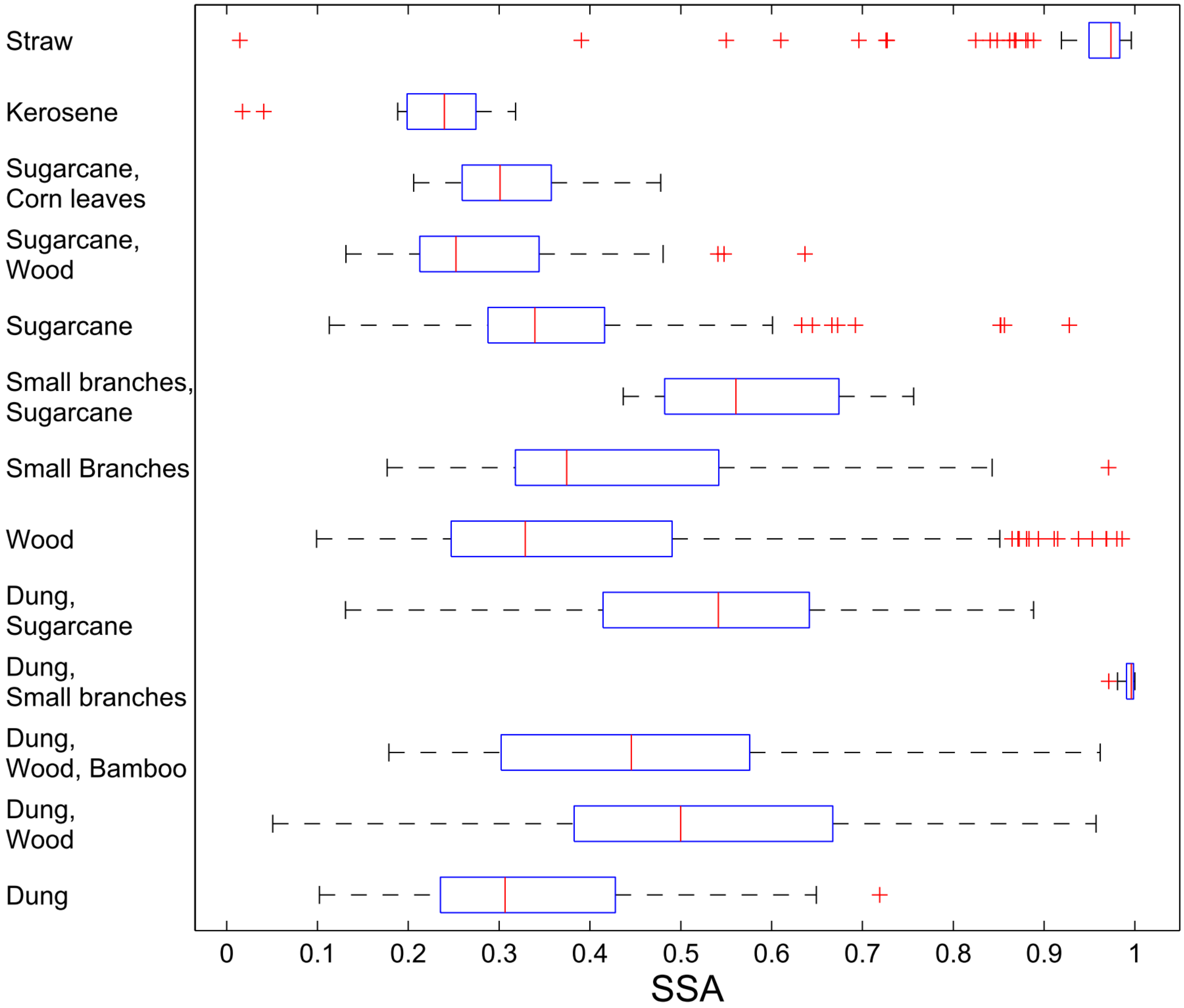
Nepal emissions



Smith et al 2000

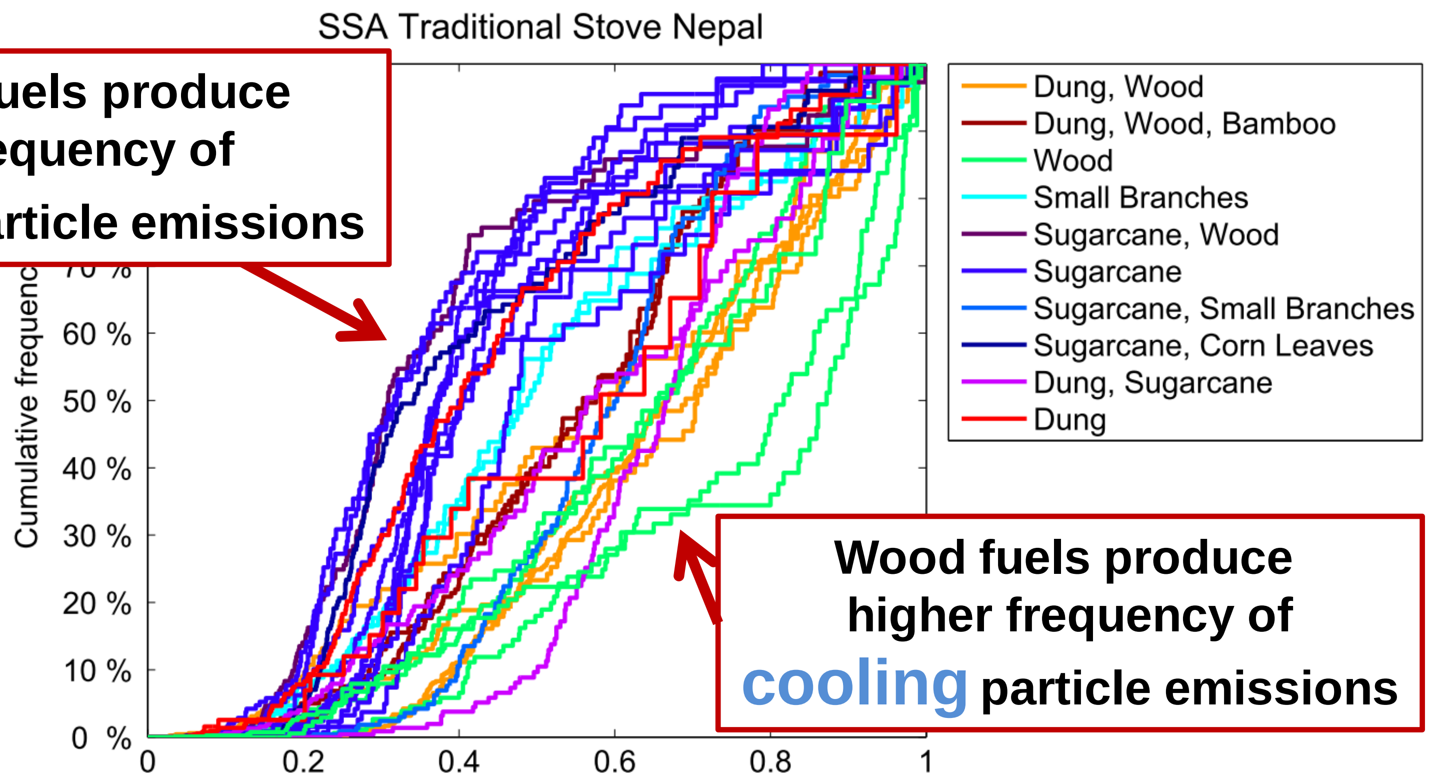


Nepal: Fuel Categorized emissions



Ratio of scattering to absorbing particles is related to fuel.

Sugarcane fuels produce higher frequency of warming particle emissions



Wood fuels produce higher frequency of cooling particle emissions

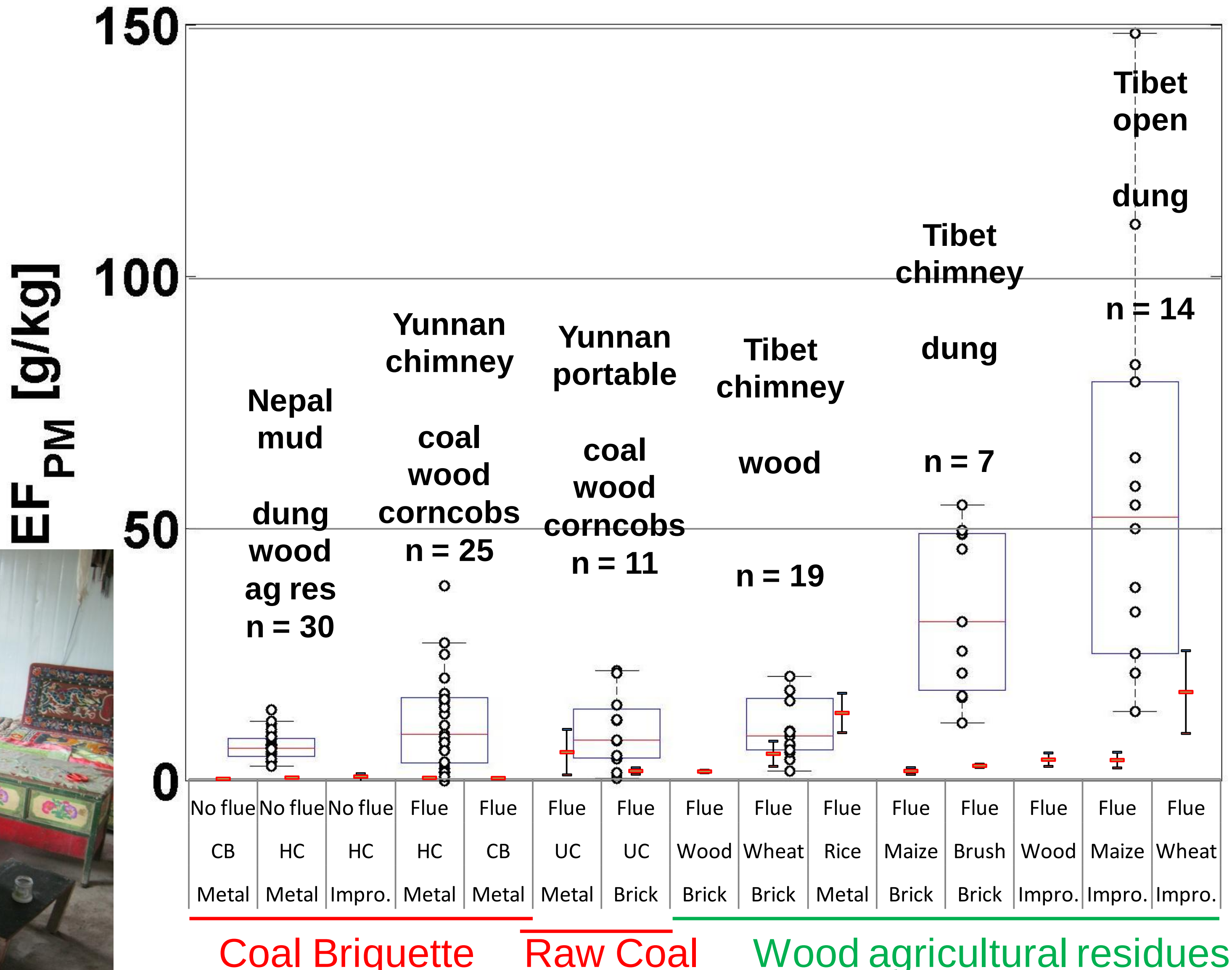
More warming particles ⟷ **More cooling particles**

Yunnan and Tibet Emissions



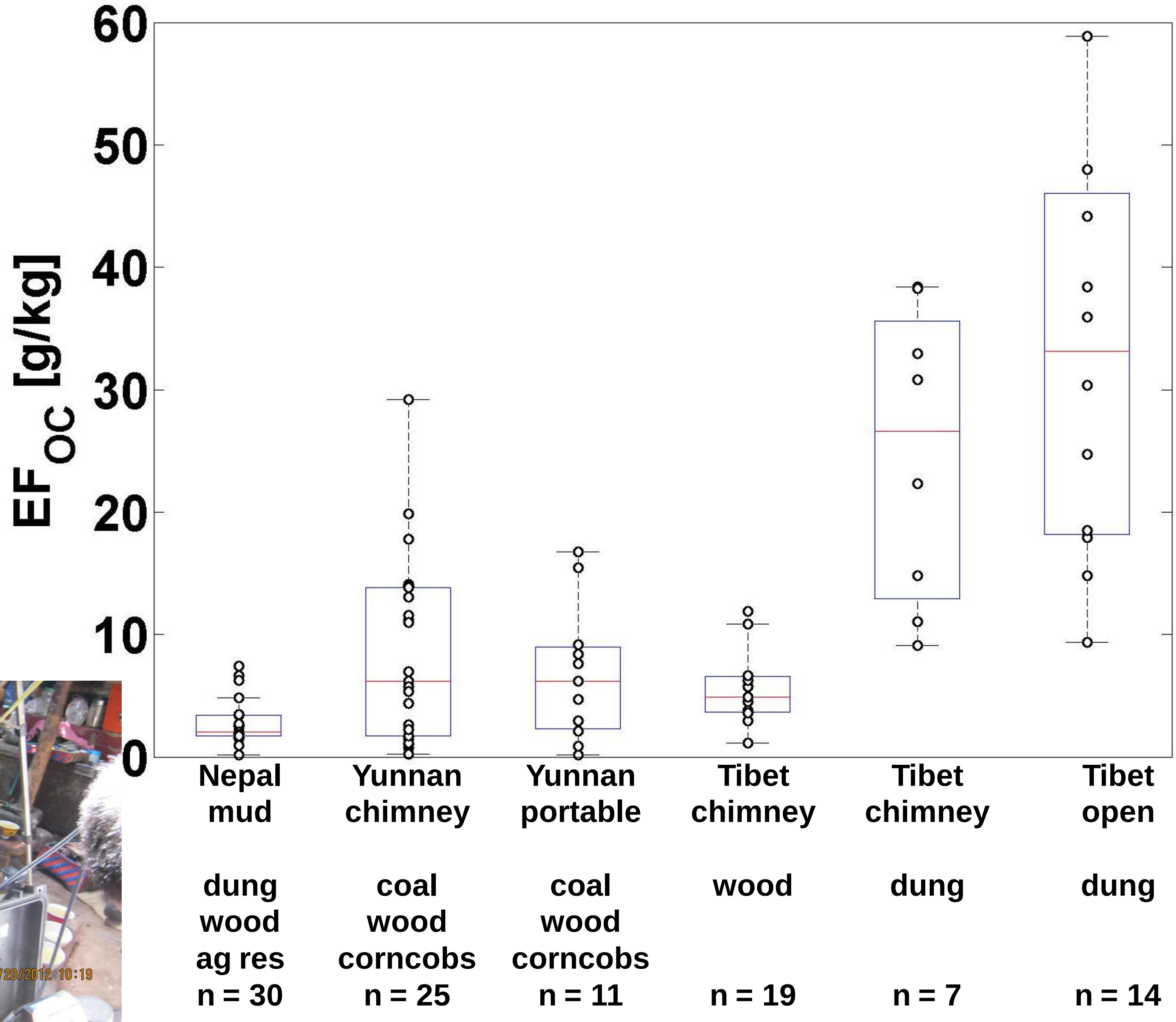


Yunnan and Tibet

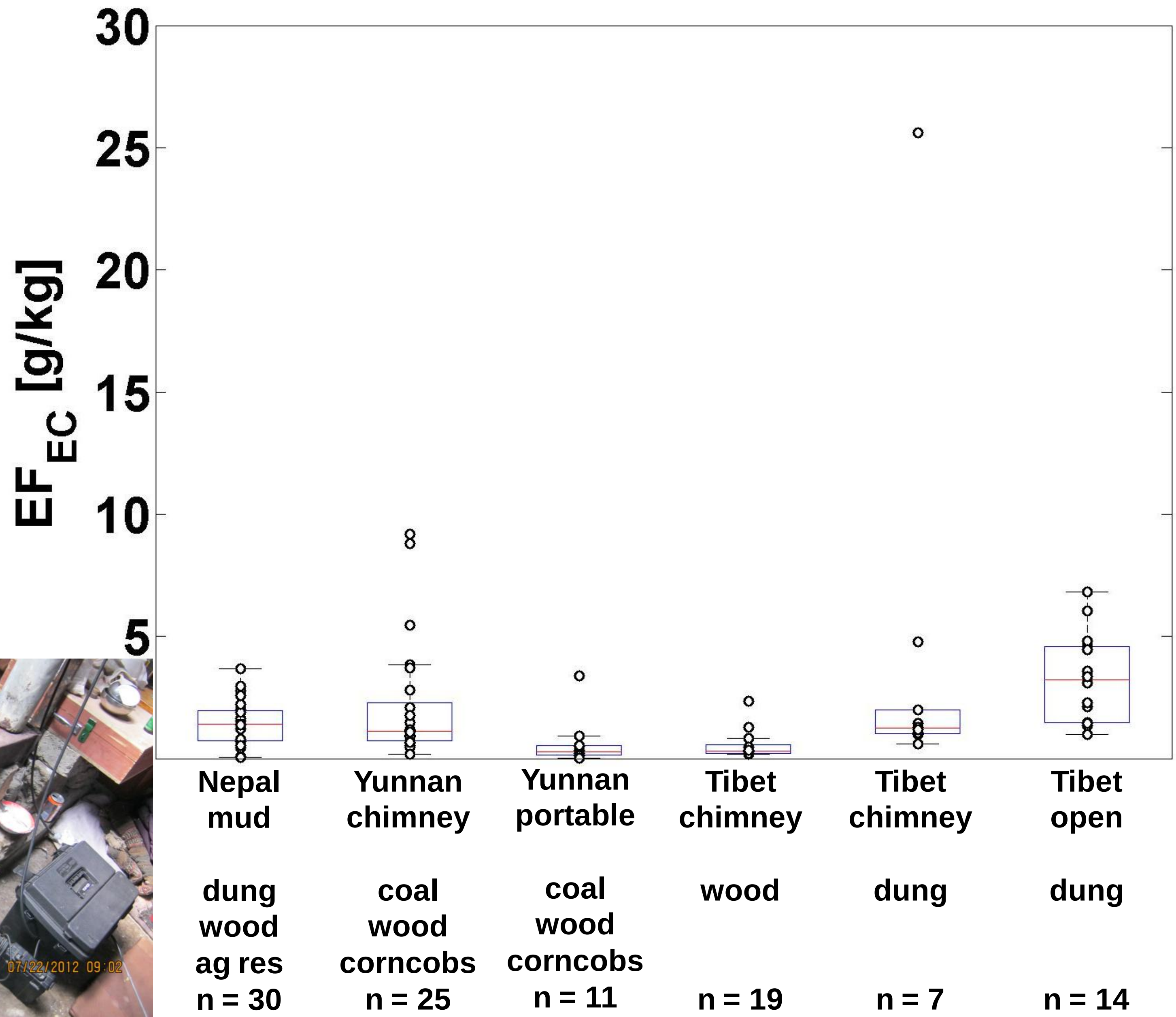


Zhang et at 2000

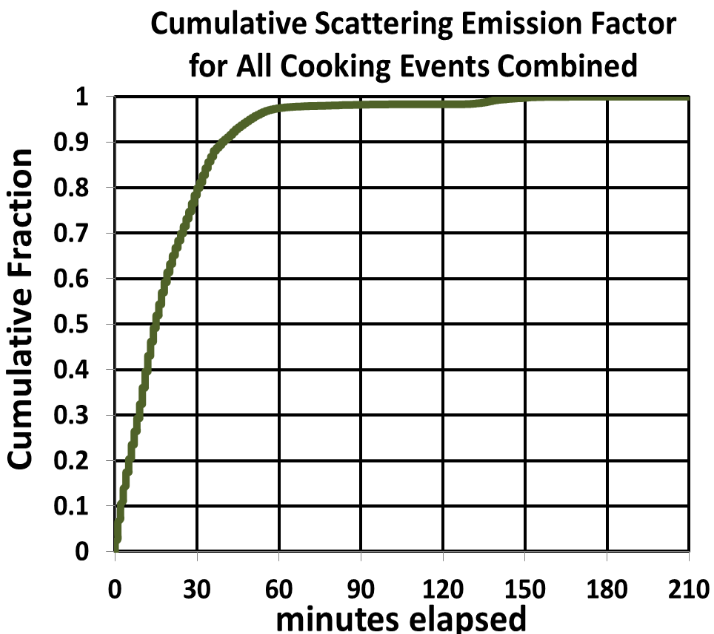
OC Emission Factor

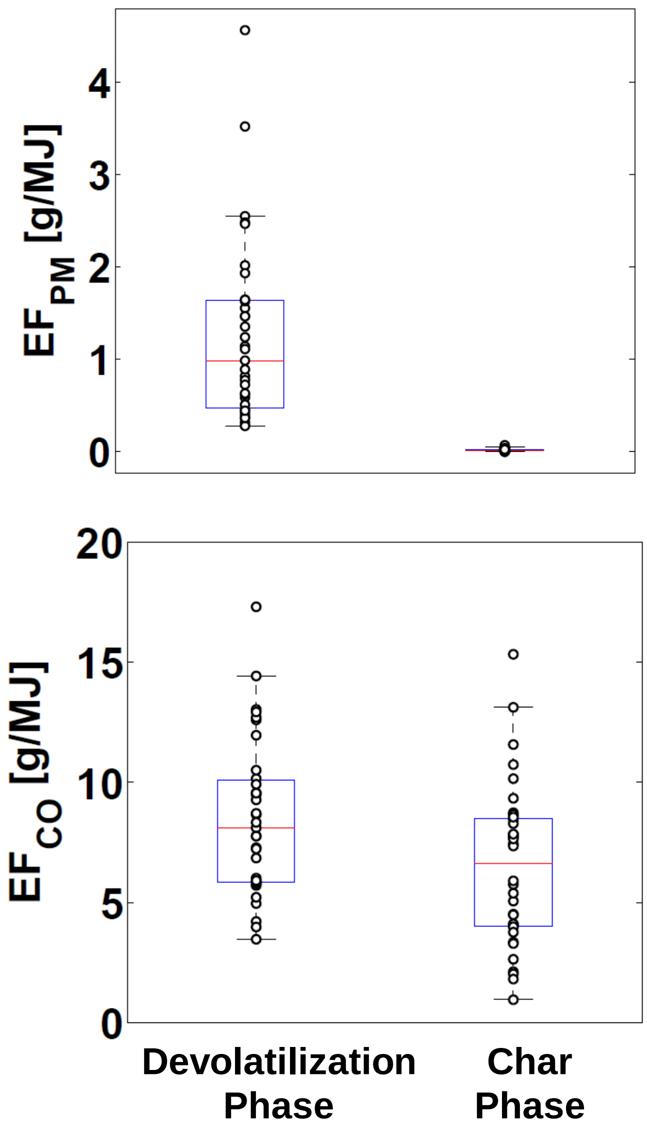


EC Emission Factor



Yunnan Coal stoves





WHO air quality guidelines for indoor air quality: unprocessed coal combustion

Recommendation 3: Household use of coal

Recommendation	Strength of recommendation
Unprocessed[3] coal should not be used as a household fuel.	Strong

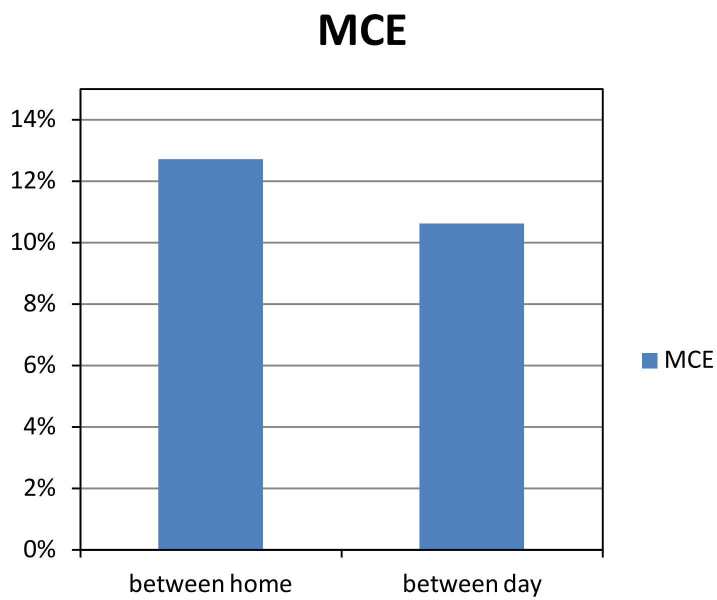
Remarks

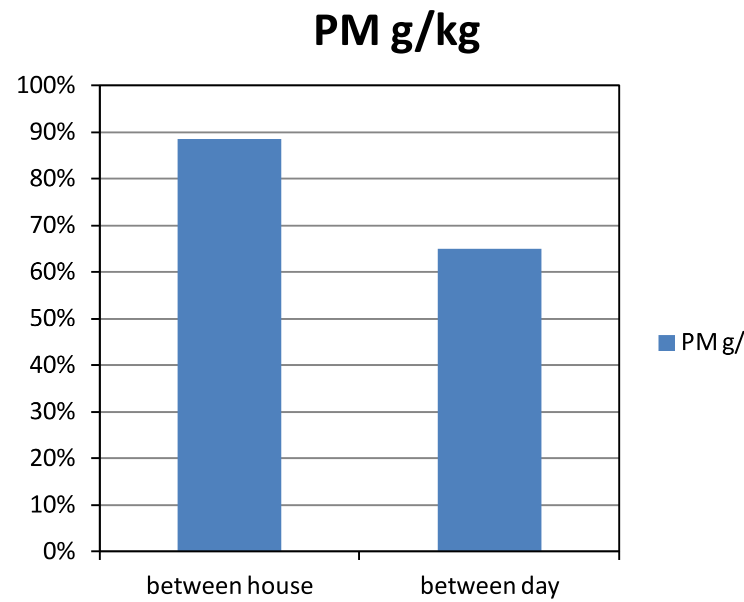
1. This recommendation is made for the following three reasons, over and above the documented health risks from products of incomplete combustion of solid fuels.
   i. Indoor emissions from household combustion of coal have been determined by the International Agency for Research on Cancer (IARC) to be carcinogenic to humans (Group 1).
   ii. Coal – in those parts of the world where coal is most extensively used as a household fuel and the evidence base is strongest – contains toxic elements (including fluorine, arsenic, lead, selenium and mercury) which are not destroyed by combustion and lead to multiple adverse health effects.
   iii. There are technical constraints on burning coal cleanly in households.

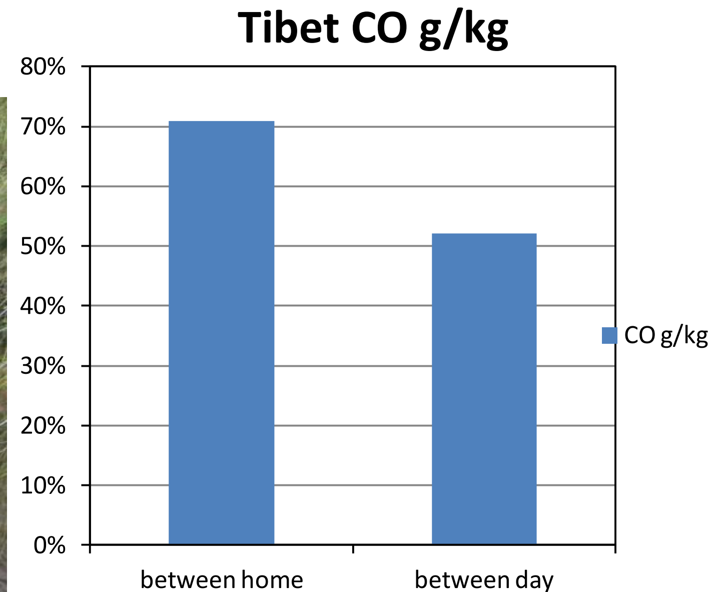
Objective 2

Identify major variability in emissions quantities and properties. Estimate sample sizes needed in future emissions measurements for updating global inventories, and determine how broad in scope our inventories need to be.

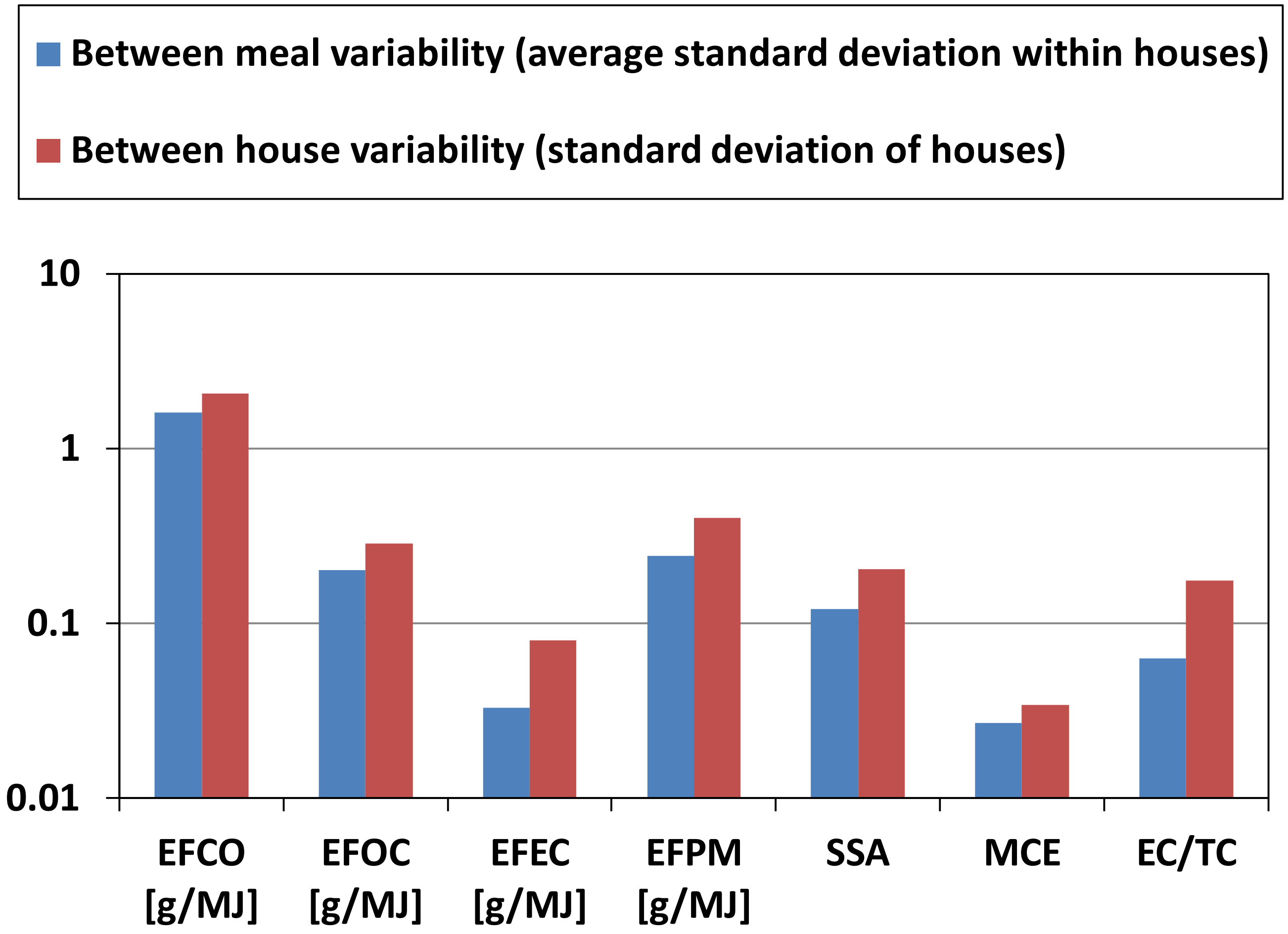
Tibet – between home and between day



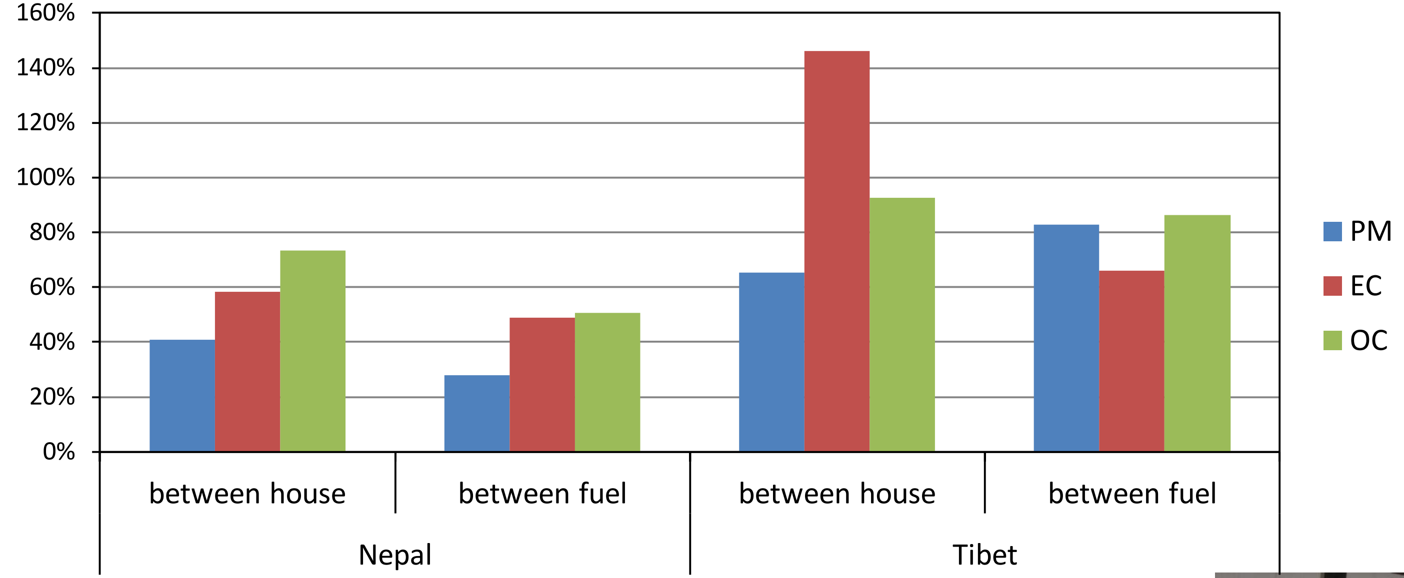




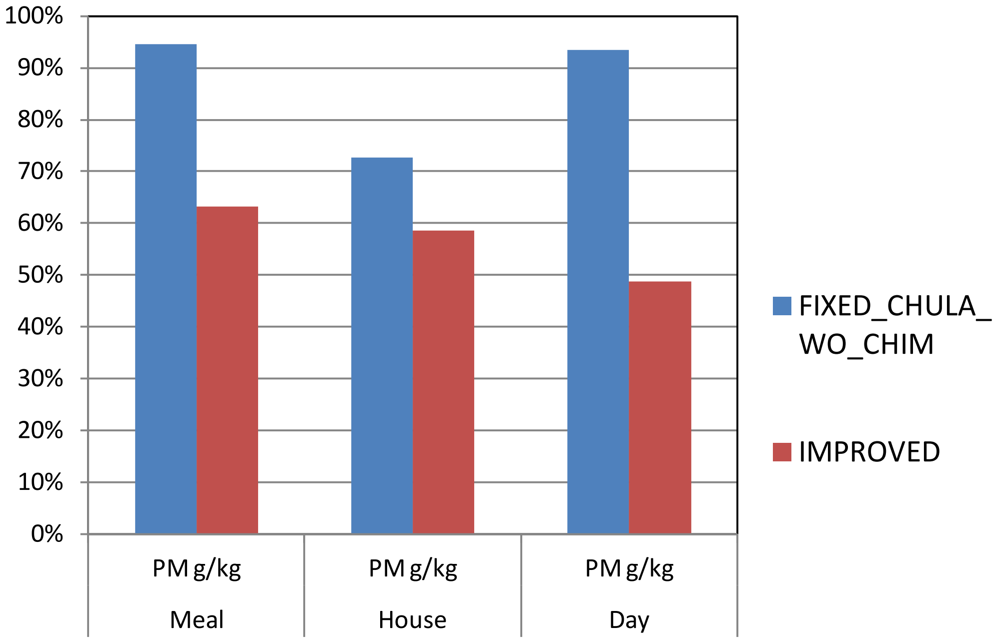
Yunnan: between meal and between house

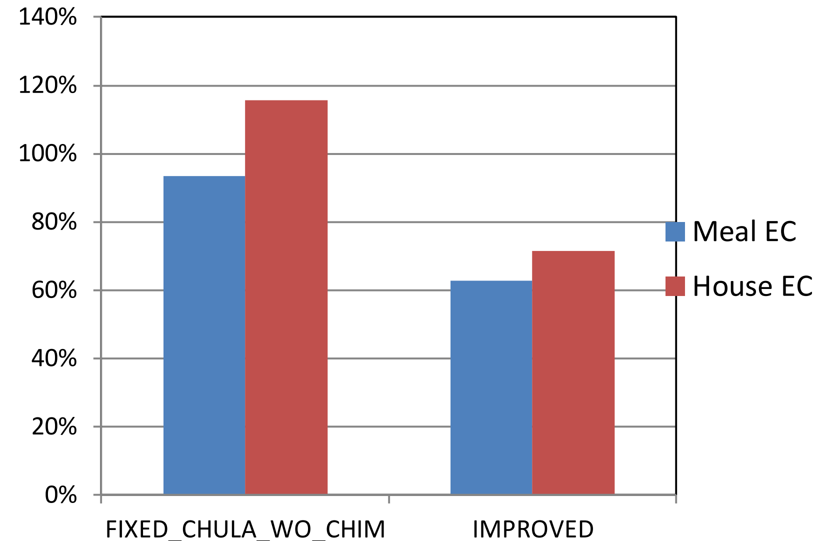


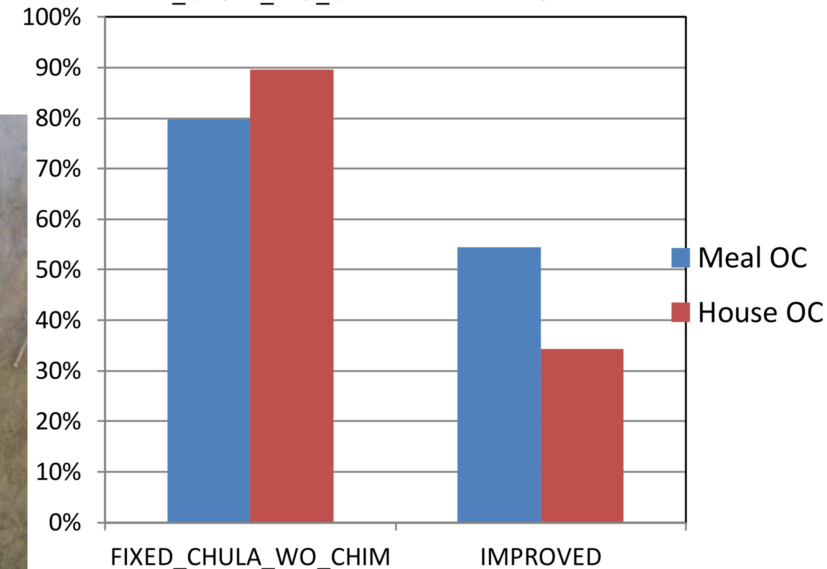
Nepal and Tibet – accounting for variability between fuel/stove combination, and between houses (within fuel)



India – accounting for variability between meal, between days and between houses

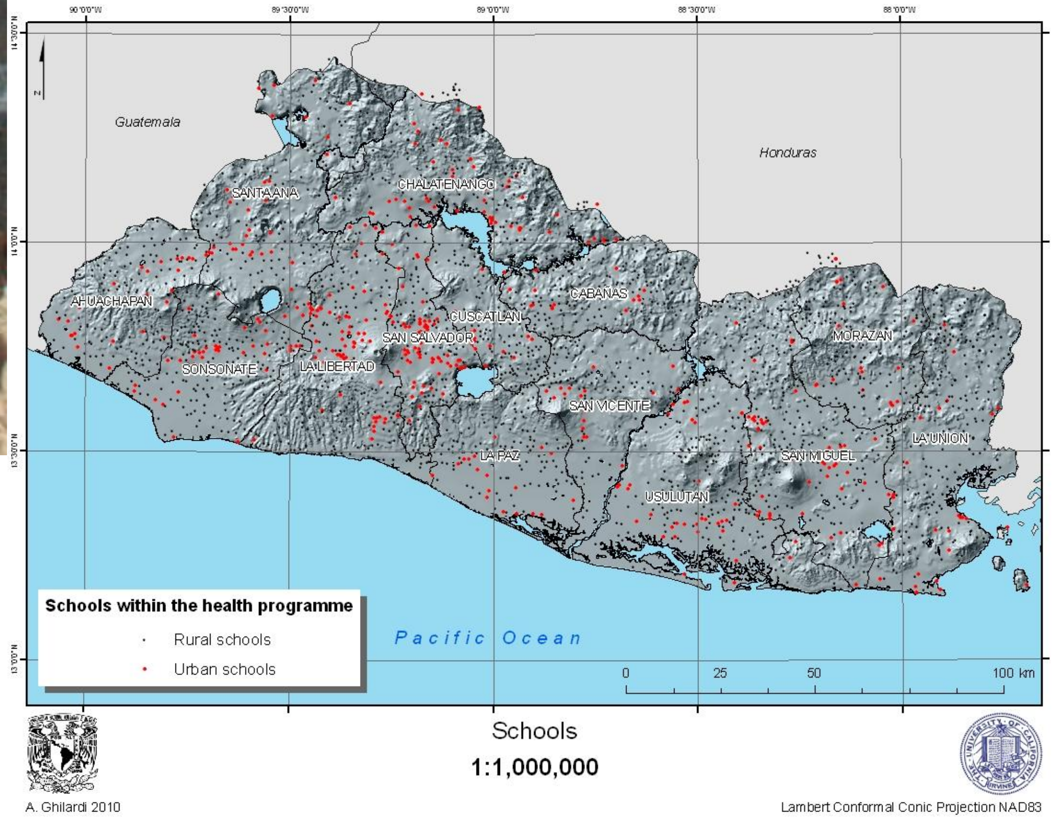






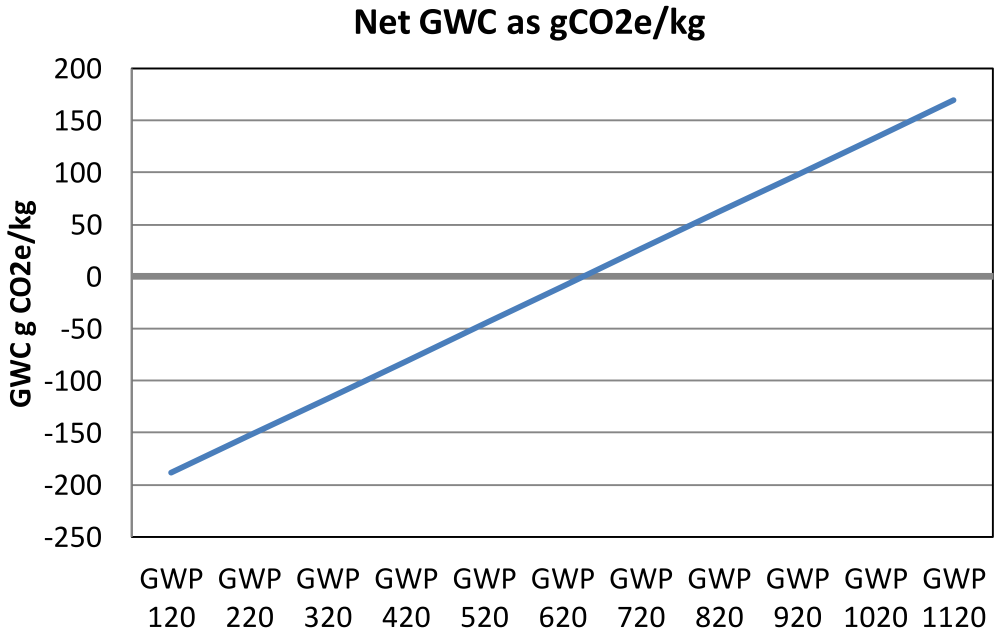
Objective 3

Estimate the potential of advanced combustion biomass stoves to mitigate emissions



Potential for mitigation

	PM g/kg	EC g/kg	OC g/kg	EC/OC	GWC EC	GWC OC	GWC
TRADITIONAL	15.9	0.9	7.9	0.11	789	-276	512
TURBOCOCINA	2.9	0.5	1.3	0.41	466	-45	422
	81%	41%	84%				18%

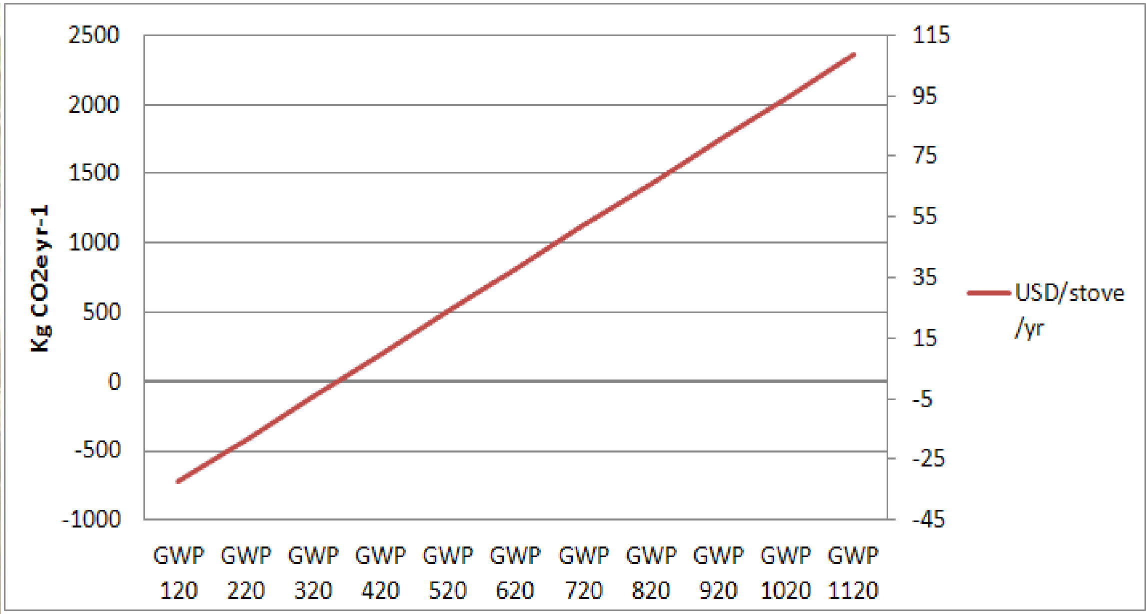


Stove	Homes			Schools		
	N	kg SA^{-1} day^{-1}	t hh^{-1} yr	N	kg $student^{-1}$ day^{-1}	t $school^{-1}$ yr
Traditional	25	2.36±1.12 *(2.93±1.40)*	3.88±1.85 *(4.82±2.30)*	23	0.11±0.05 *(0.14±0.06)*	5.04 ± 2.04 *(6.3±2.55)*
Turbococina	15	0.25±0.10 *(0.31±0.12)*	0.42±0.16 *(0.52±0.19)*	22	0.004±0.003 *(0.005±0.004)*	0.21±0.16 *(0.26±0.20)*
Reduction*		89%	89%		96%	96%

Figures in plain font dry wood and those in italics are wet wood

Potential for mitigation

kg yr-1		PM	EC	OC	GWC	USD/Stove/yr
Homes	Traditional	61	3.1	30.3	1701	
	Turbococina	0.5	0.06	0.24	50	78
		99%	98%	99%	97%	
Schools	Traditional	58	2.9	28.8	1616	
	Turbococina	0.5	0.07	0.24	51	74
		99%	98%	99%	97%	



@ 47 USD (Mg C)$^{-1}$ – equivalent to USD (tonne CO_2)$^{-1}$

Health co-benefits

	PM mg/min
TRADITIONAL	481.8
TURBOCOCINA	15.6

Table R1.2: Emission rate targets for meeting WHO annual mean AQGs for $PM_{2.5}$

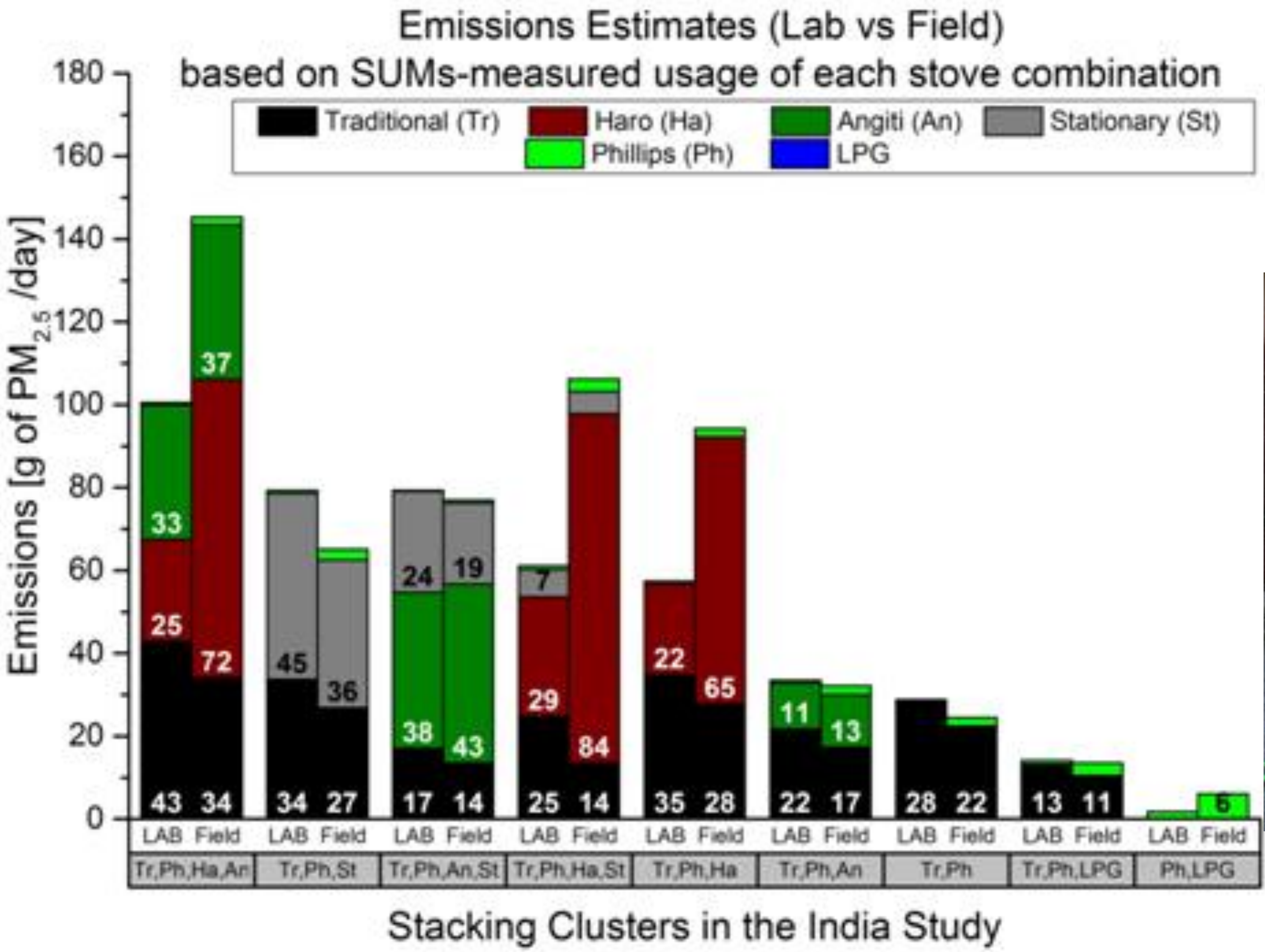
Emissions rate targets (ERT)	Emission rate (mg/min)	Percentage of kitchens meeting AQG (10 μg/m³)	Percentage of kitchens meeting AQG IT-1 (35 μg/m³)
Unvented			
Intermediate ERT	1.75	6	60
ERT	0.23	90	100
Vented			
Intermediate ERT	7.15	9	60
ERT	0.80	90	100

WHO air quality guidelines for indoor air quality: household fuel combustion

Adoption and stacking is important

- Adoption rates are not 100% even when stoves are bought.
- Unless incentives are provided traditional stoves remain in use, especially for longer duration tasks
- Developing mechanisms to completely displace traditional stoves increasingly important
  - ie contract for carbon credits
  - linking stoves to prenatal care programs as has been proposed in India.
  - Linking to social programs as El Salvador and Mexico

Lab and field emissions estimates of stacking clusters in India weighed by daily usage measured with the SUMs.

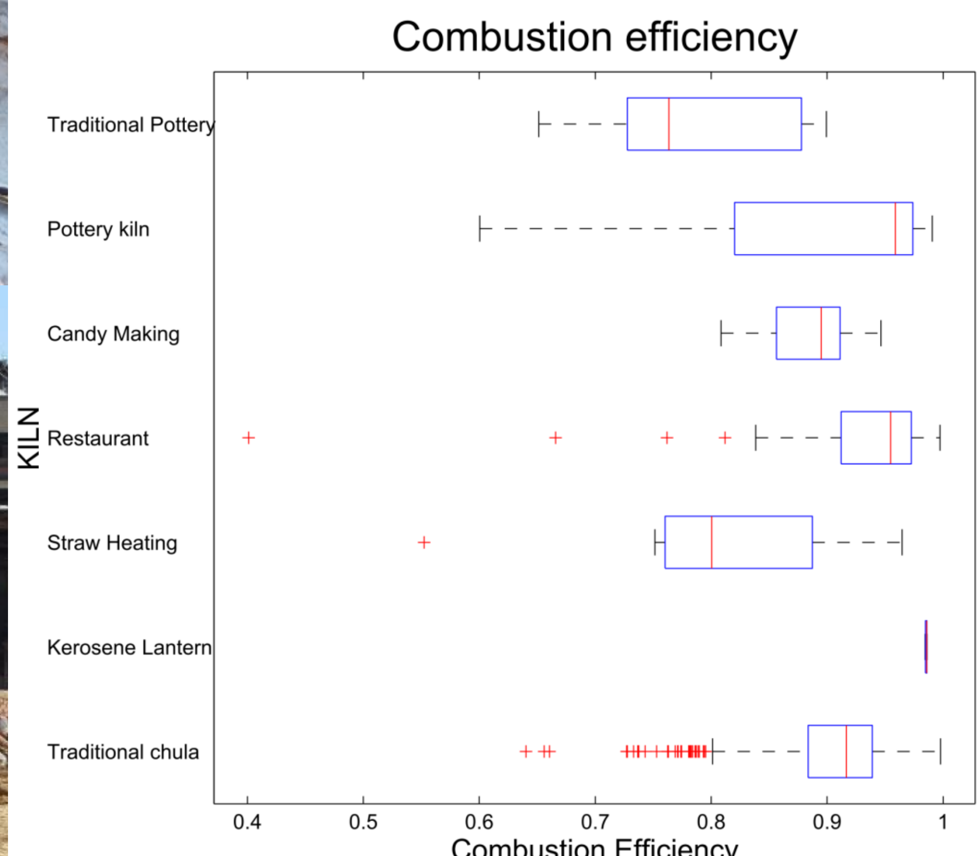


Low levels of displacement of traditional stoves, combined with low usage levels of the Phillips stove led to limited reductions emissions

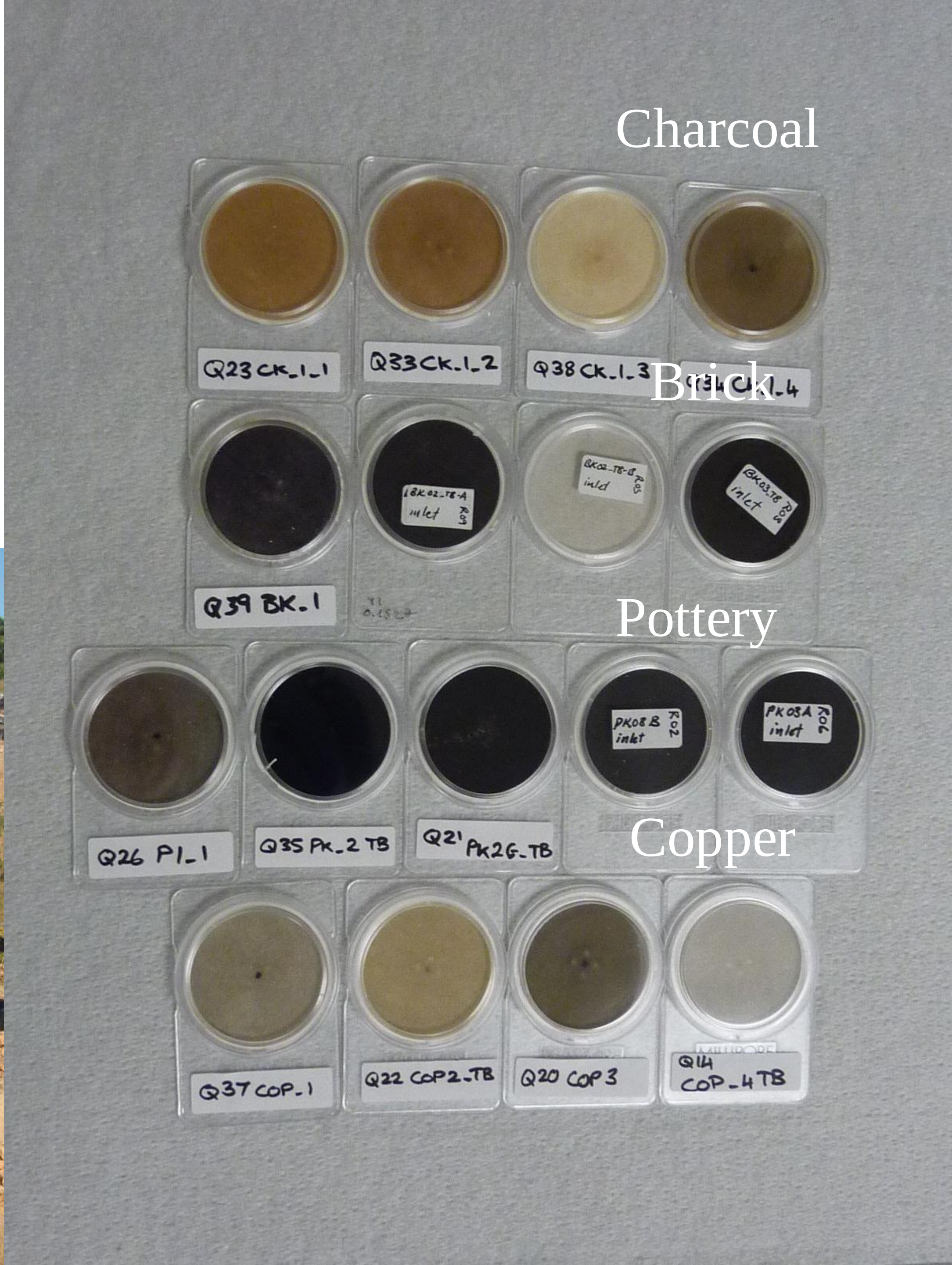
Small scale industries

- Economic and social significance well recognized
- In Africa and Asia small-scale non-farming enterprises provide 20%–45% of full-time employment and 30%–50% of rural household income (Haggblade and Liedholm 1991).
- Latin America has an estimated 50 million micro and small-scale enterprises responsible for 20 to 40% of GDP (Scott A 2000), employing 120 million people (Berger and Guillamon 1996).
- Emissions are practically uncharacterized. We don't know a) how many there are, b) their emissions, or c) what fraction of fuel use they constitute.
- Relatively low combustion temperatures and inefficient technology.
- lack pollution control equipment, labor intensive, often located in poor residential neighborhoods
- Contribute substantially to regional concentrations of climate altering pollutant species and adverse health impacts

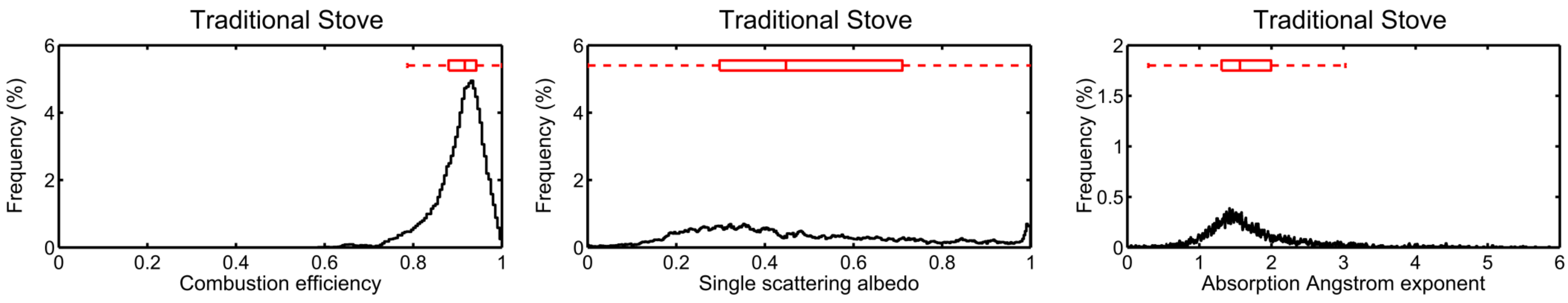
They are not the same as household stoves



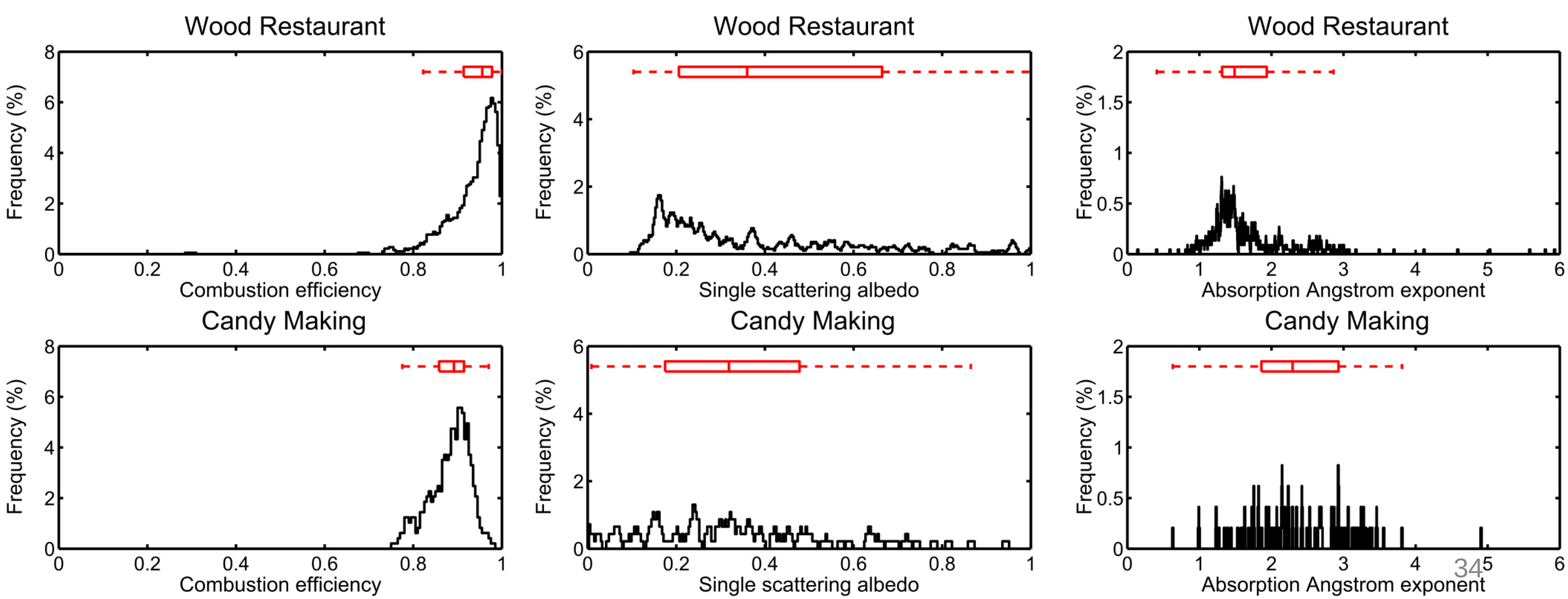
	EC/OC
Brick	0.44
Charcoal	0.01
Copper	0.08
Pottery	2.51



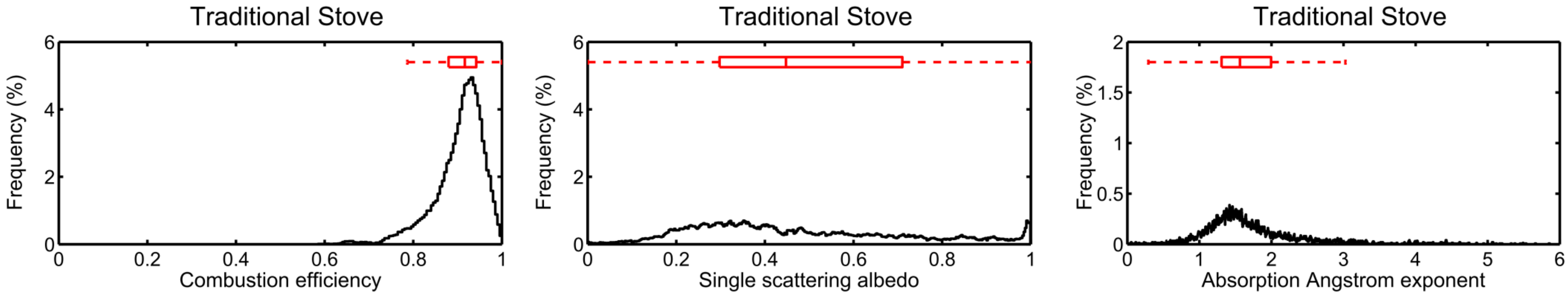
Nepal: In-home stoves



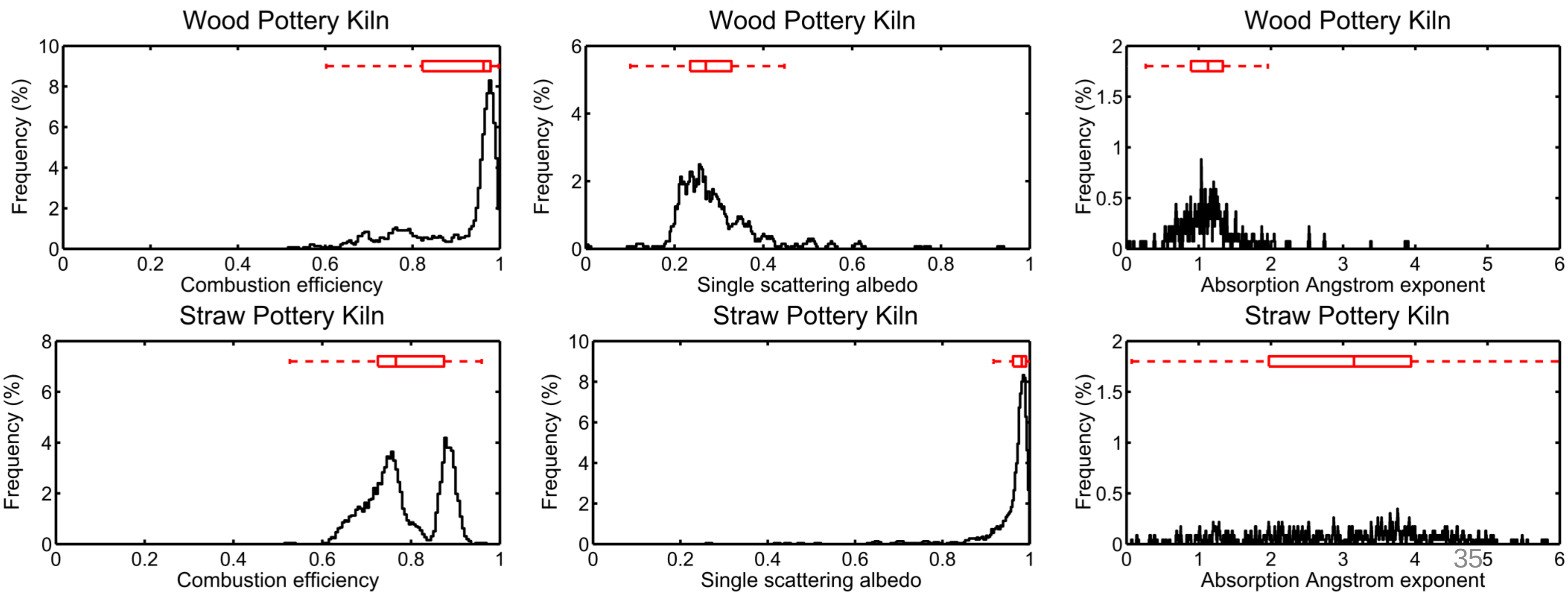
Nepal: Small Industry stoves



Nepal: In-home stoves



Nepal: Small industry pottery kilns

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