Stoves, Health, and Climate
Where are we now?

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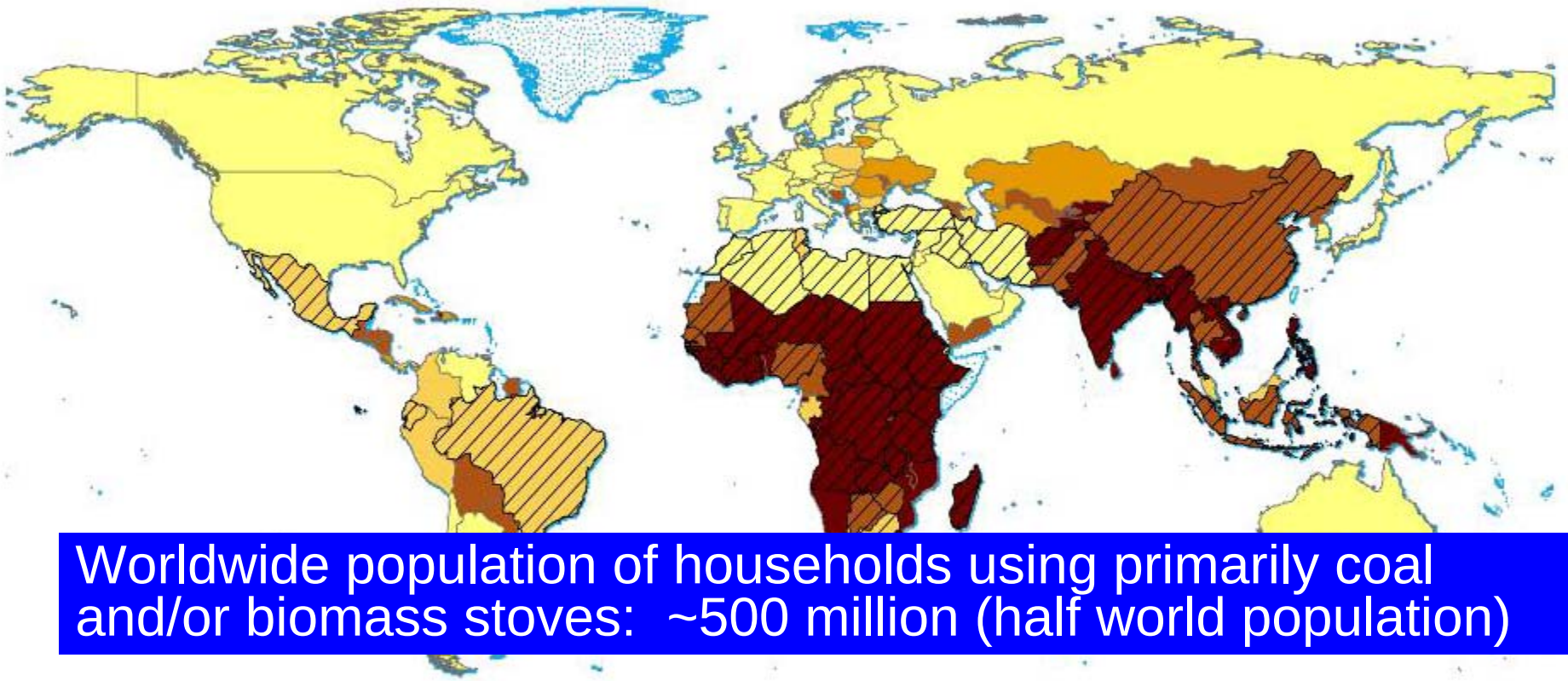
Outline of Briefing

- Overview of issue
- Climate Connection
- Need for and State of Monitoring Technology (slides prepared by Ilse Ruiz-Mercado)

Biomass fuel

- The poorest half the people in the world use simple biomass fuels for cooking and space-heating
- It accounts for about 10% of human energy use
- Perhaps one-third is in the form of agricultural wastes
- The rest in the form of woody biomass
- Harvesting is largely done on a renewable basis, but there are many areas where it puts pressure on local forests
- Household time use for fuel gathering is high in some areas, but this substitutes for having to pay for fuel.

National Household Solid Fuel Use, 2000



Worldwide population of households using primarily coal and/or biomass stoves: ~500 million (half world population)

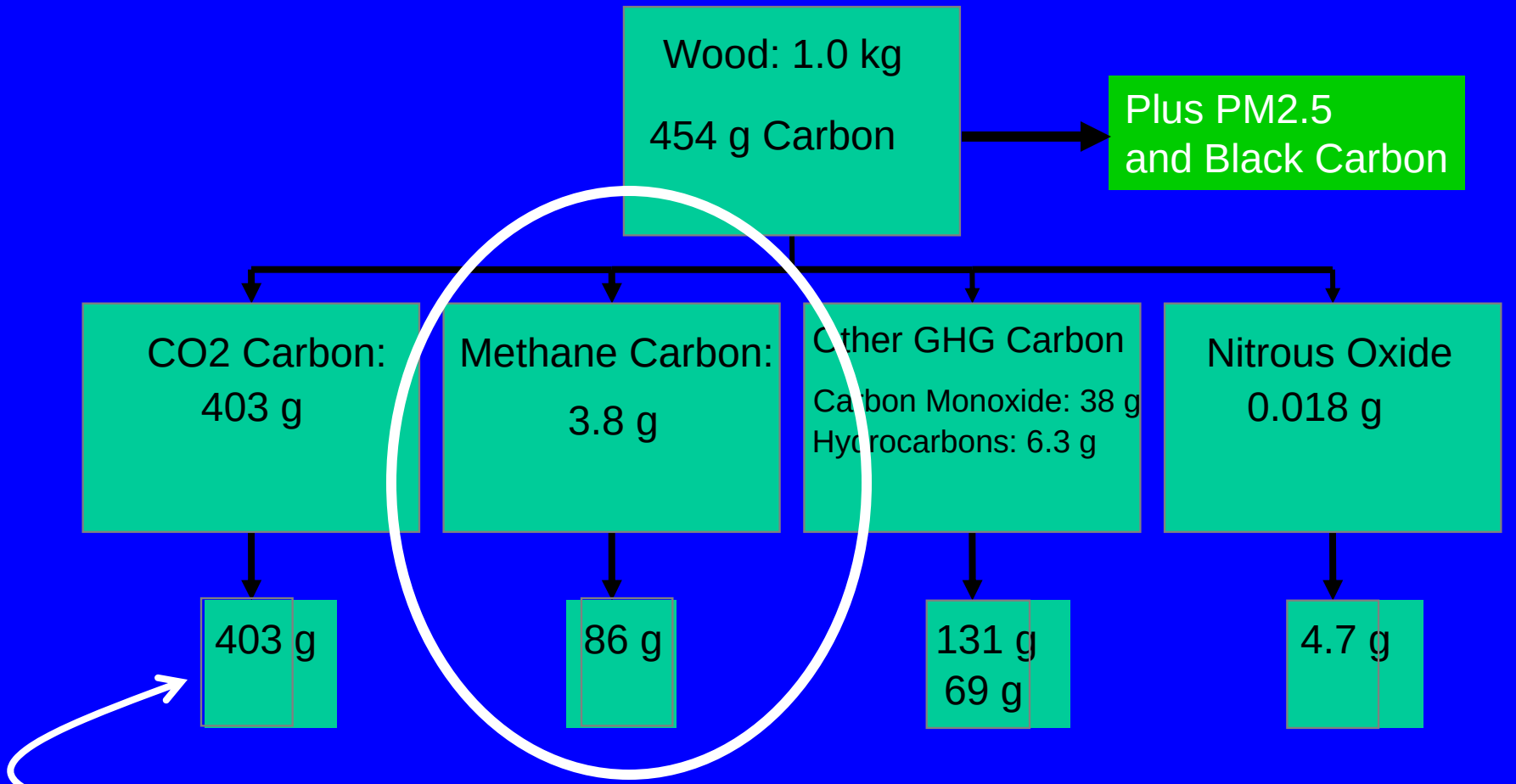
Fuel Combustion

- Nearly all traditional biomass stoves are inefficient by modern standards: <20% of fuel energy enters pot: two factors
- Poor conversion of fuel energy to heat (80-95%) due to poor combustion conditions and variable fuel quality
- Poor transfer of heat to pot (<20%) due to poor insulation and lack of contact of hot gases with pot

Smoke Production

- Biomass has nearly no intrinsic contaminants, i.e., can be burned cleanly to CO2 and water
- Poor combustion creates large volumes of products of incomplete combustion (PIC), nearly all of which are hazardous to health
- Main constituent (90%) is carbon monoxide (CO)
- Small particles also created
- Nearly all remainder is in the form of toxic organic gases

Greenhouse warming commitment per meal for typical wood-fired cookstove in India



Global warming commitments of each of the gases as CO_2 equivalents

Smith, et al., 2000

Exposure Conditions

- Large, but unknown, proportion of all stoves emit smoke directly into living area
- As cooking is done when people are present, substantial exposure occurs
- Even when kitchen is separate from house
- Even when cooking done outdoors
- Mostly to women and their youngest children because of their role in cooking

Chimneys

- Chimneys or other venting arrangements can lower indoor levels substantially
- But work best if made of good materials and regularly maintained
- Without reducing emissions by improving combustion efficiency, however, the degree of exposure reduction by a chimney is limited – perhaps to two-thirds because smoke not reduced, just moved
- Lowering emissions also extends life and function of chimneys and reducing need for maintenance

Health Hazard of Smoke

- Although smoke contains many pollutants with well-understood properties, the total impact of such mixtures cannot today be estimated by combining the effect of separate toxins
- Need to look at mixture as a whole, but then need indicators
- Best indicators are probably small particles and CO, which have come to be used in studies of tobacco burning
- These may not, however, do as well for some diseases, for example cataracts and cancer, which may be triggered by specific chemicals
- On the other hand, although the relative amounts of the different chemicals vary by fuel and combustion conditions, even if we understood this variation, it would not lead to any obvious interventions separate from those being pursued now

Human Studies: Epidemiology

- Dozens of studies have shown consistent relationships between household solid fuel use (SFU) and
  - Pneumonia in young children
  - Chronic obstructive lung disease (COPD) in women
- A few studies have shown
  - TB, lung cancer, low birthweight, stillbirth, cataracts, asthma
- One study has shown an effect on blood pressure – a major indicator of heart disease
- Animal data and physiology would indicate impact on child cognitive function (learning ability)
- Animal data would indicate an effect on birth defects, i.e., cleft

Health Effects: Comparison

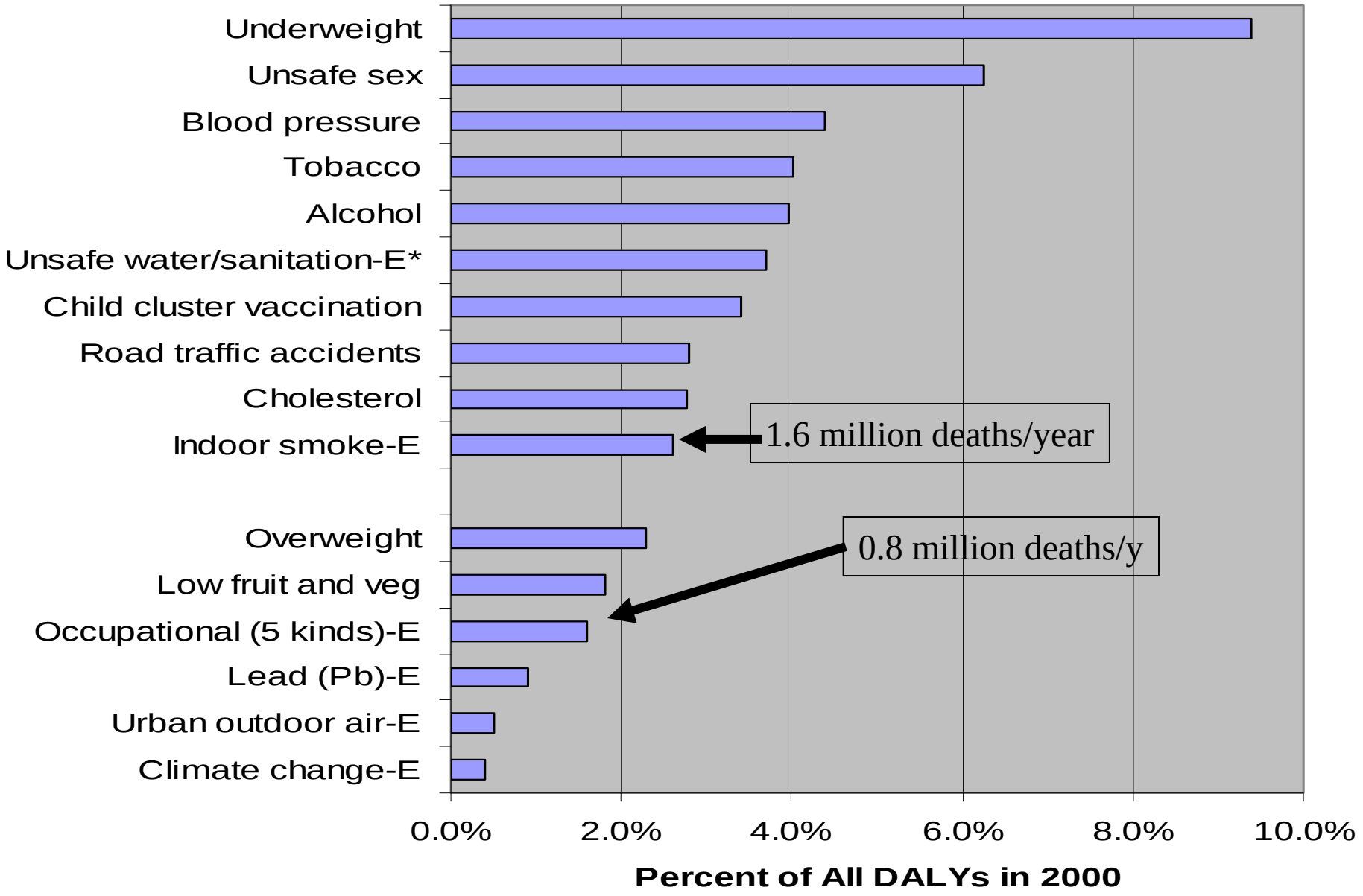
- Passive smoking, another form of biomass smoke exposure, clearly enhances several important diseases in women and children
- Household particle exposures from solid fuel typically above the levels in these studies
- Outdoor air pollution studies find effects at levels of particles an order of magnitude lower than typical indoor levels – e.g., at 10s compared to 100s of ug/m2
- Even accounting for some differences in the kinds of particles and effects at high exposures, current health effects of household biomass smoke are thus likely underestimated

Burden of Disease

- Current estimates put SFU 10th among major risk factors for ill-health globally
- Third in India, after malnutrition and poor water/sanitation
- 1.6 million premature deaths in 2000, two-thirds in children
- 420,000 in India
- Only pneumonia and COPD counted

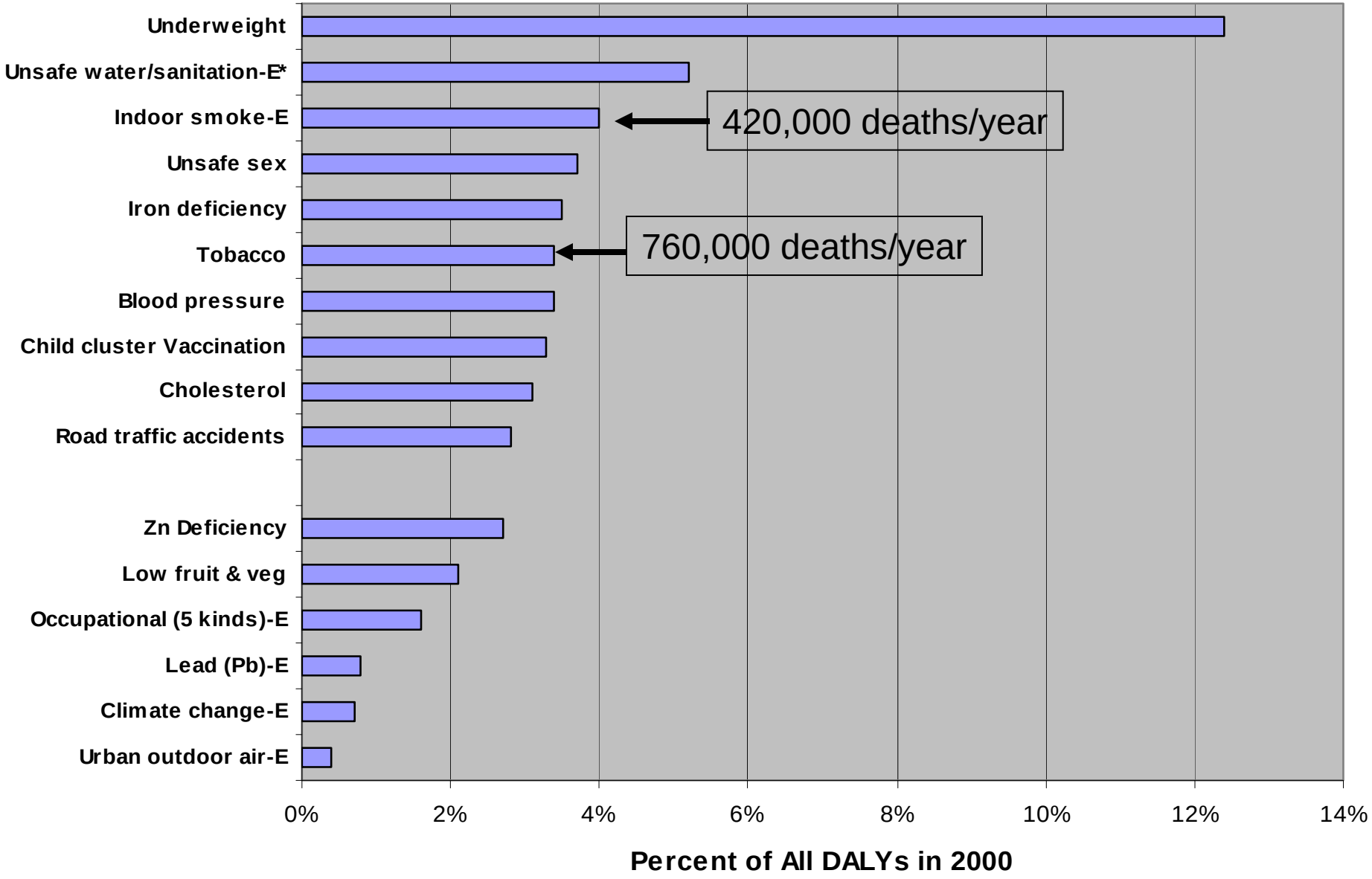
Global Burden of Disease from Top 10 Risk Factors

plus selected other risk factors



Indian Burden of Disease from Top 10 Risk Factors

and Selected Other Risk Factors



Burden of Disease, cont.

- New burden of disease study being done for SFU – finished in 2010
- Preliminary indication is that effect on pneumonia will be lower than before
- COPD will be similar
- But information on other diseases will be sufficiently improved to include them
- Overall effect on total still unclear

Strategic Health Research:

- One good lung cancer study would probably tip cancer into the top evidence category
- Need heart disease studies, since it is so important for outdoor air pollution and tobacco smoke
- TB effect nearly demonstrated, but one or two more positive studies would do so.
- Birth defects and child cognitive function would also have public relations impact

New health research: CO

- *In utero* exposures
  - Cognitive function
  - Birthweight
  - Adverse pregnancy outcomes – stillbirth, early infant death, etc.
  - Birth defects
- Daily average CO exposures similar to ambient pollution in many cities
- Peaks during cooking are much higher, however.

Stove Research

- Best stoves achieve high combustion efficiency and have a chimney
- Must use good materials (metal or ceramic)
- Will be more sensitive to fuel quality, i.e., size, density, and moisture
- Hybrid stoves (with blower) are more tolerant of fuel variations
- And can obtain high cooking power with low density fuel such as crop wastes

Exposure Research

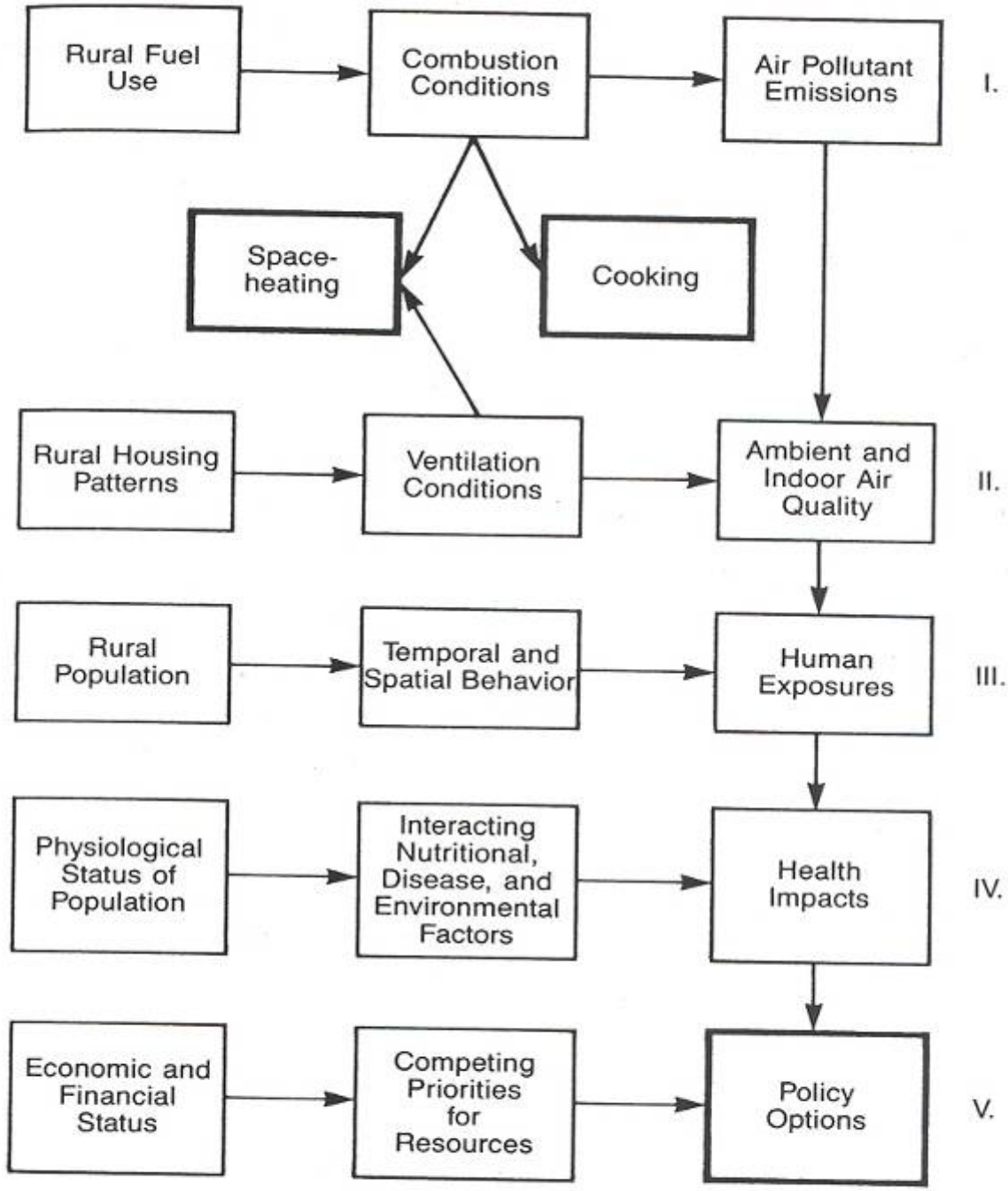
- CO is very promising as indicator and as a health hazard itself – more validation needed
- Work still needed to reliably measure personal particle levels in a cost-effective manner without pumps
- Some new biomarkers show promise, but research is expensive and results are often difficult to interpret for health – still in the realm of basic science

Perfect Storm

- Poorest half of humanity with high vulnerability to disease
- Largely women and children, the most vulnerable subgroups
- High emissions of pollutants directly into living space during times people are present
- Greatest greenhouse impact per unit energy
- Part of the storm, unfortunately, is that it is not easily fixed.
  - Poverty is the problem
  - But poverty alleviation is too slow as an answer

What Can be Done?

Smith, 1983

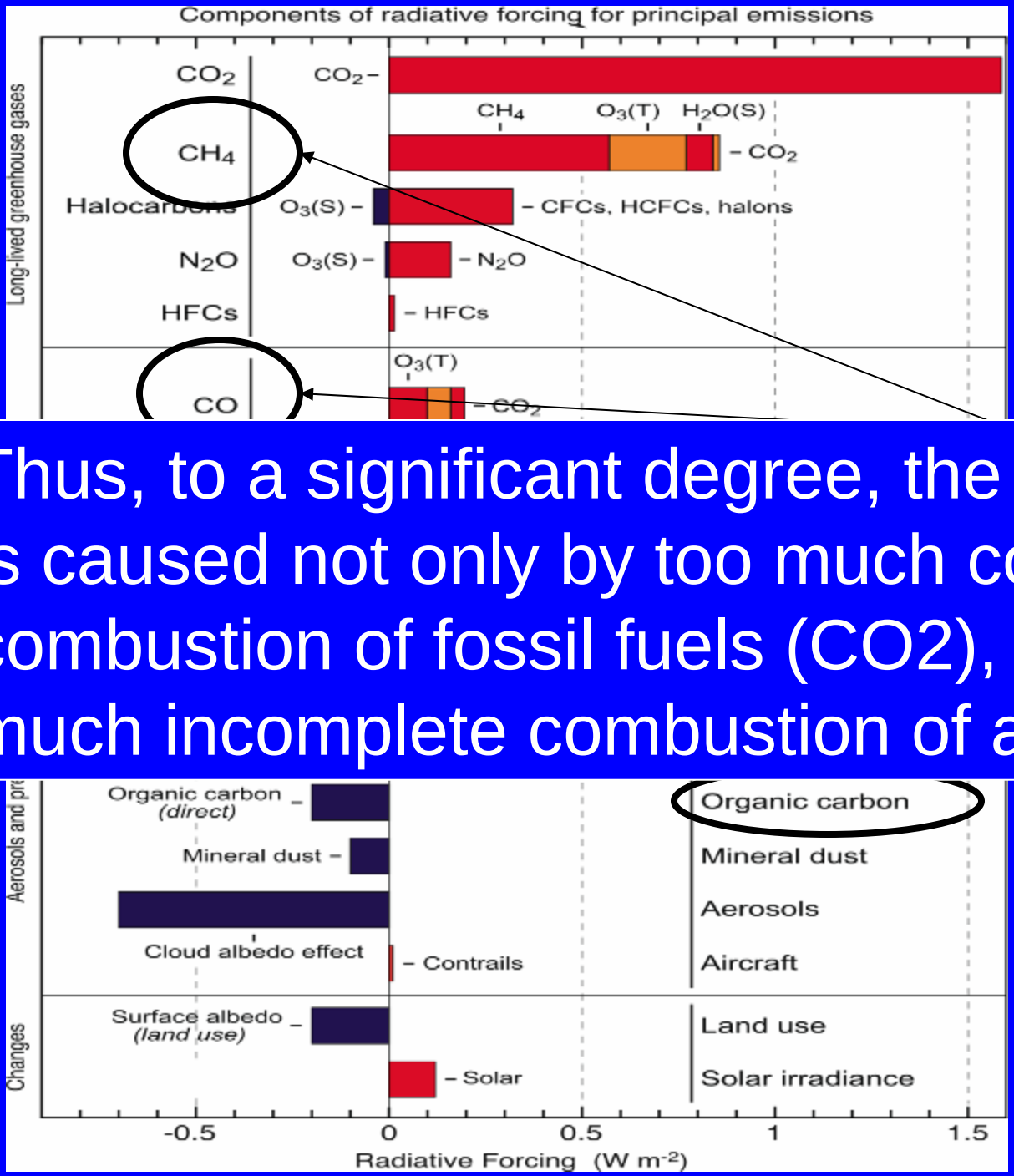


Engineering Interventions to Reduce Health Burden from Household Solid Fuel Use

- Ventilation changes (put smoke outside)
  - More windows/openings
  - Chimneys on stoves
- Stoves with better combustion (low emissions)
  - Using existing biomass fuels, e.g., “gasifier” stoves
  - Using processed biomass, e.g., pellet stoves
  - Better energy efficiency alone may not help
- Liquid/gaseous fuels (much easier to burn cleanly)
  - Made from biomass, e.g., biogas, alcohol, DME
  - Fossil fuels, e.g., LPG

Climate connection

- SF PIC contain important greenhouse pollutants (GHPs) including
  - Methane – second most important GHP after CO2
  - Black carbon – extremely powerful GHP
- Making HH SFU probably the most GH intensive energy system in the world per unit useful energy
- HH stoves produce a few percent of global methane and >50% of global black carbon
- Major opportunities for co-benefits, i.e., tap international carbon market to pay for stove/fuel improvements

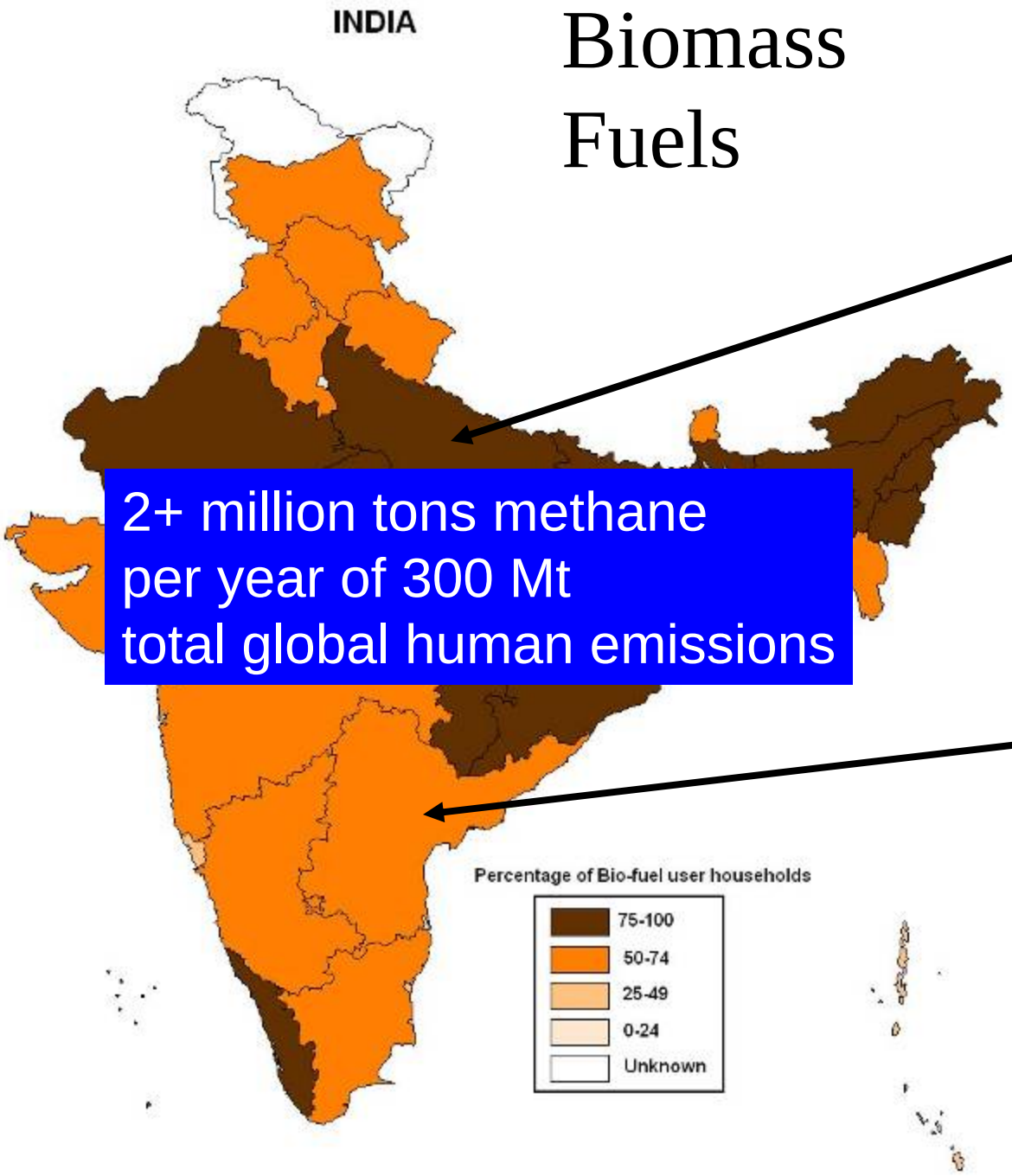


Warming in 2005 from emissions since 1750

Thus, to a significant degree, the problem is caused not only by too much complete combustion of fossil fuels (CO2), but also by too much incomplete combustion of all fuels (PIC)

IPCC, 2007

Biomass Fuels



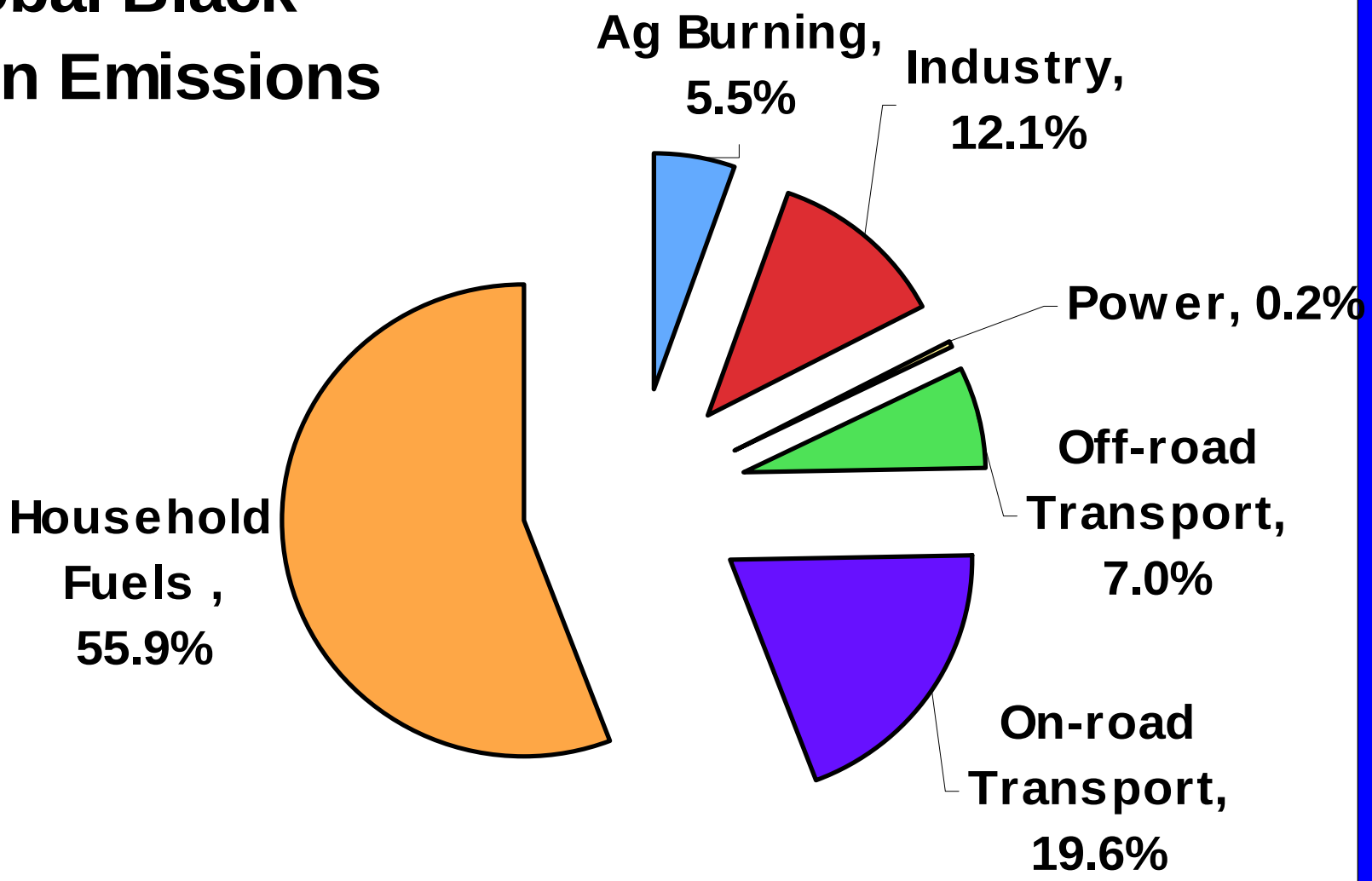
2+ million tons methane per year of 300 Mt total global human emissions

More than 75% of households

50-74% of households

2000 Census

Global Black Carbon Emissions



No forest fires

Total 6600 gigagrams in 2000

BC Campaign Data

China National Stove Contest - 2007

Luoyang-gasifier stove compared to traditional stove

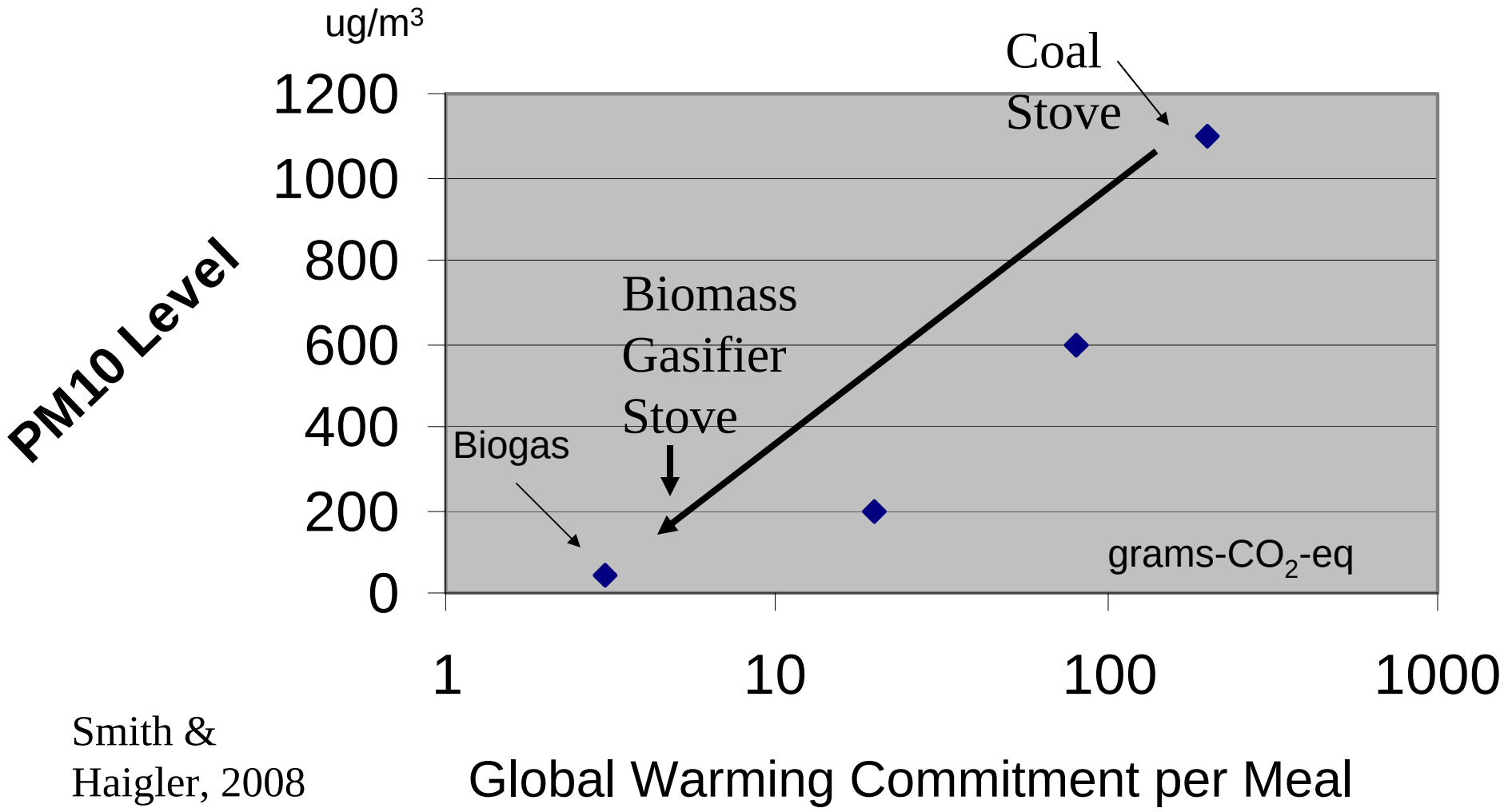
Reduce fuel use + reduce PM emissions per unit fuel:
Total ~15x reduction – 7%

			PM g/kg
Coal#			1.6
Traditiona			2.0
Biomass			
Daxu			0.28
Luoyang			0.24
Xintai	0.025	32.6*	0.36
Zhenghong	0.019	35.9	0.24

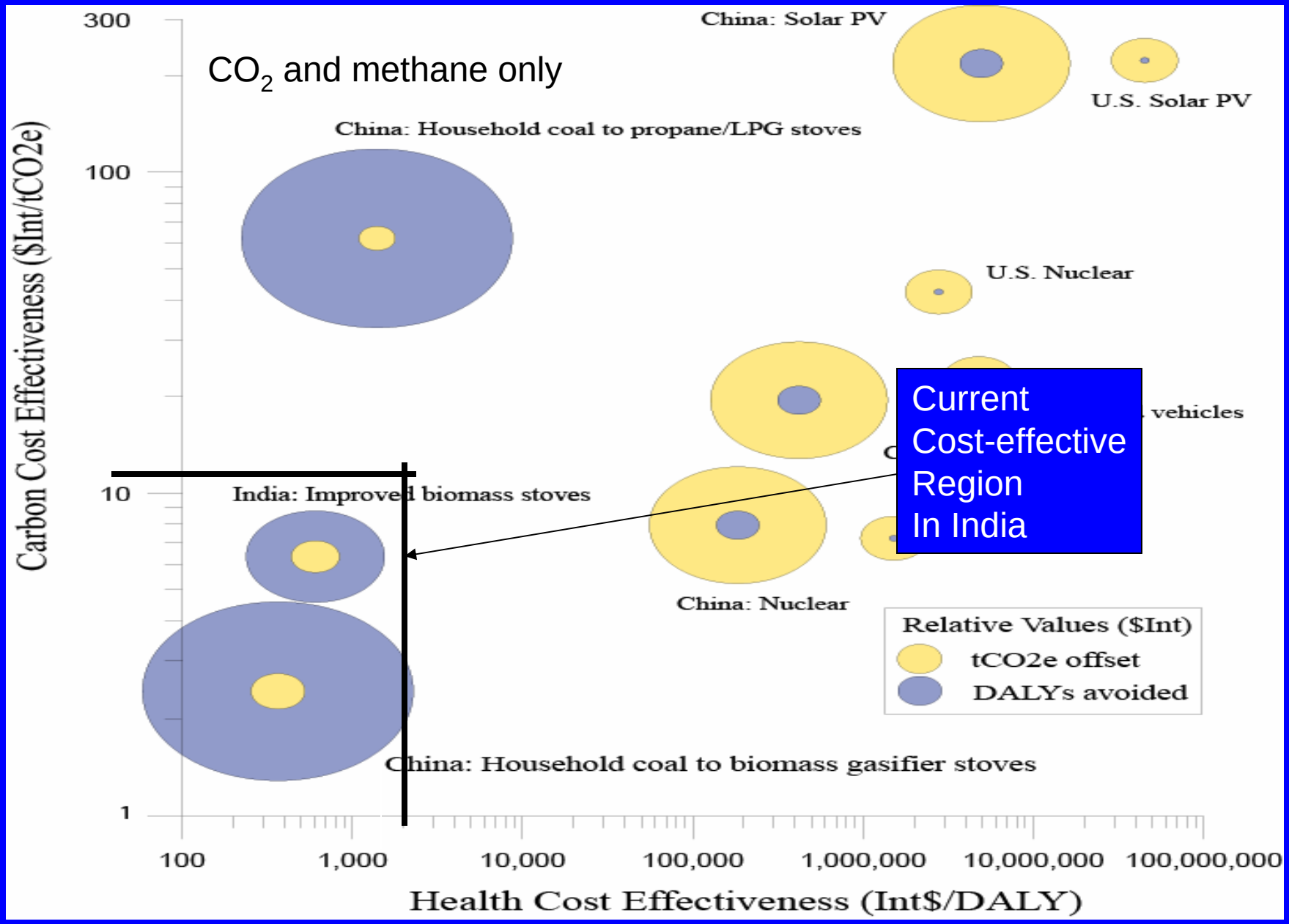
Zhang, et al., 2000

*Not including water heating function

Health and Greenhouse Gas Benefits of Biomass Stove Options



Smith & Haigler, 2008



Smith & Haigler, 2008

Paying for Rural Energy Development

High-efficiency low-emissions rural energy technology is too expensive for local markets

Why M&E?

You don't get what you expect, but what you inspect

Abandoned improved stove, *Guatemala*

Misplaced self-polluting chimney, *Guatemala*

Standard Methods are too slow, too imprecise, too labor intensive, and too expensive for use with millions of stoves

Fuel savings *estimation through KPT (kitchen performance test) and sales records*

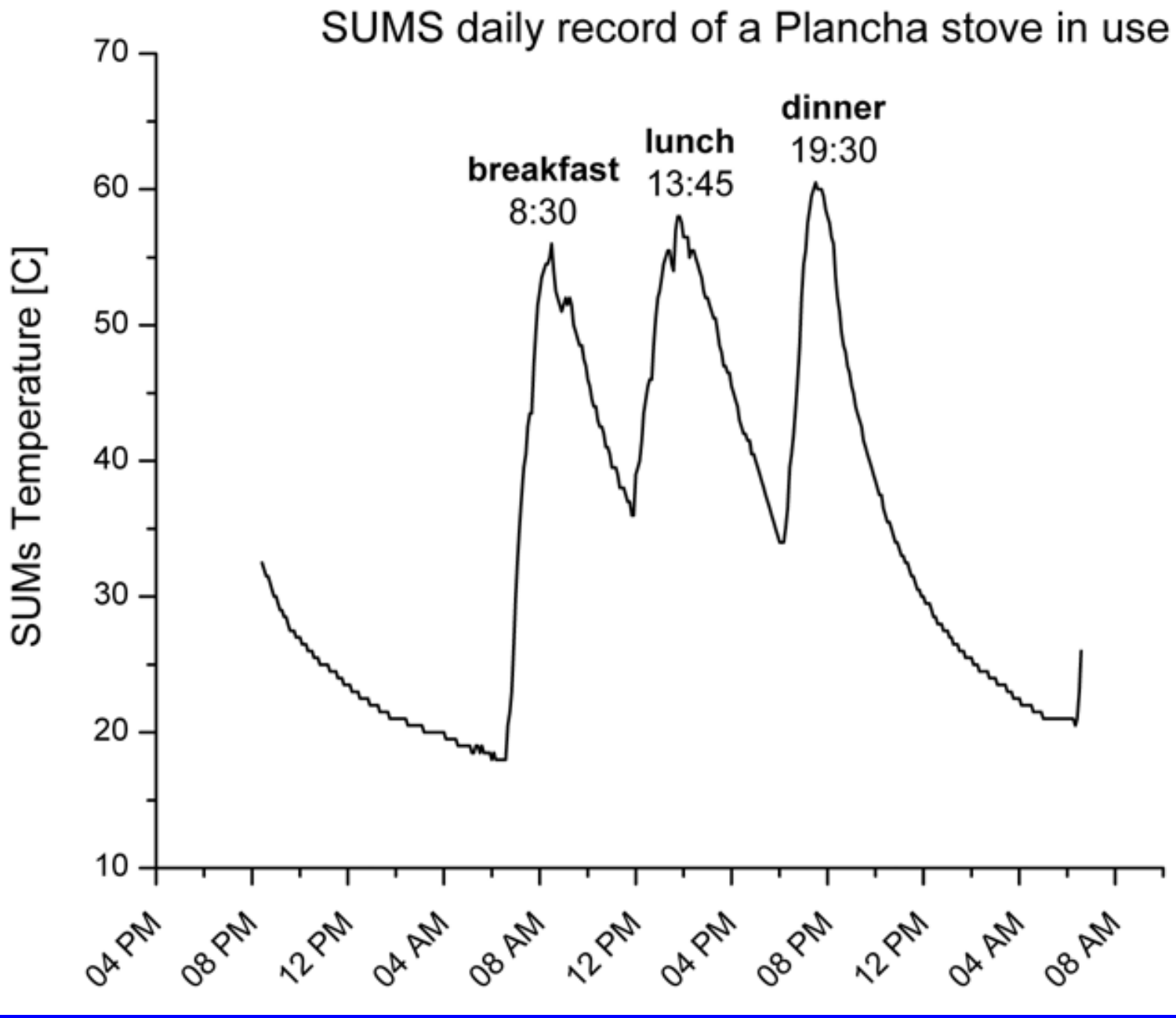
Tracking ***drop out rates*** *through surveys, visits and phone interviews*

Monitoring ***reductions in indoor air pollution and black carbon emissions***

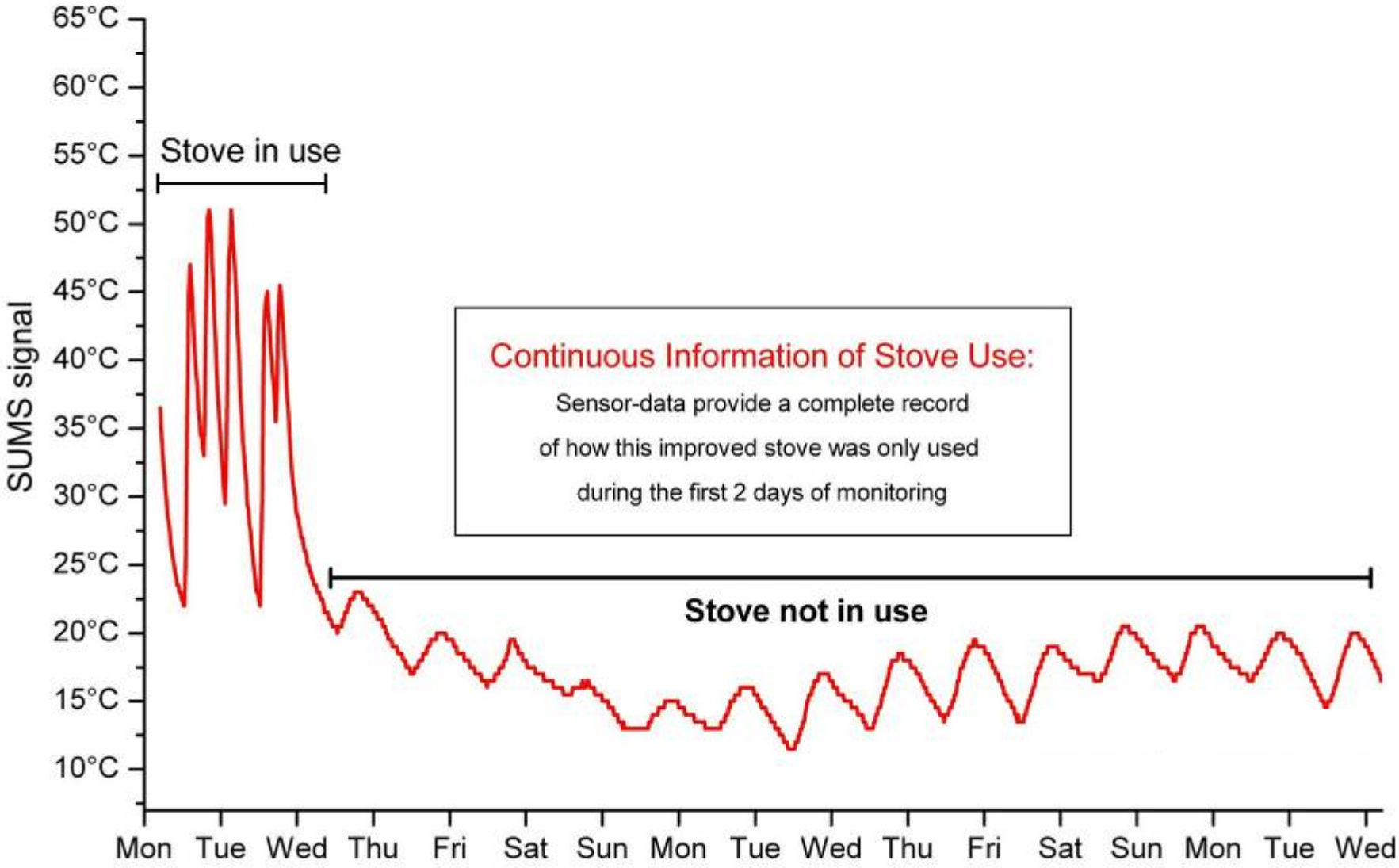
UCB-SUMS:
The Stove Use Monitoring System

Fuel savings *quantification using the SUMS system*

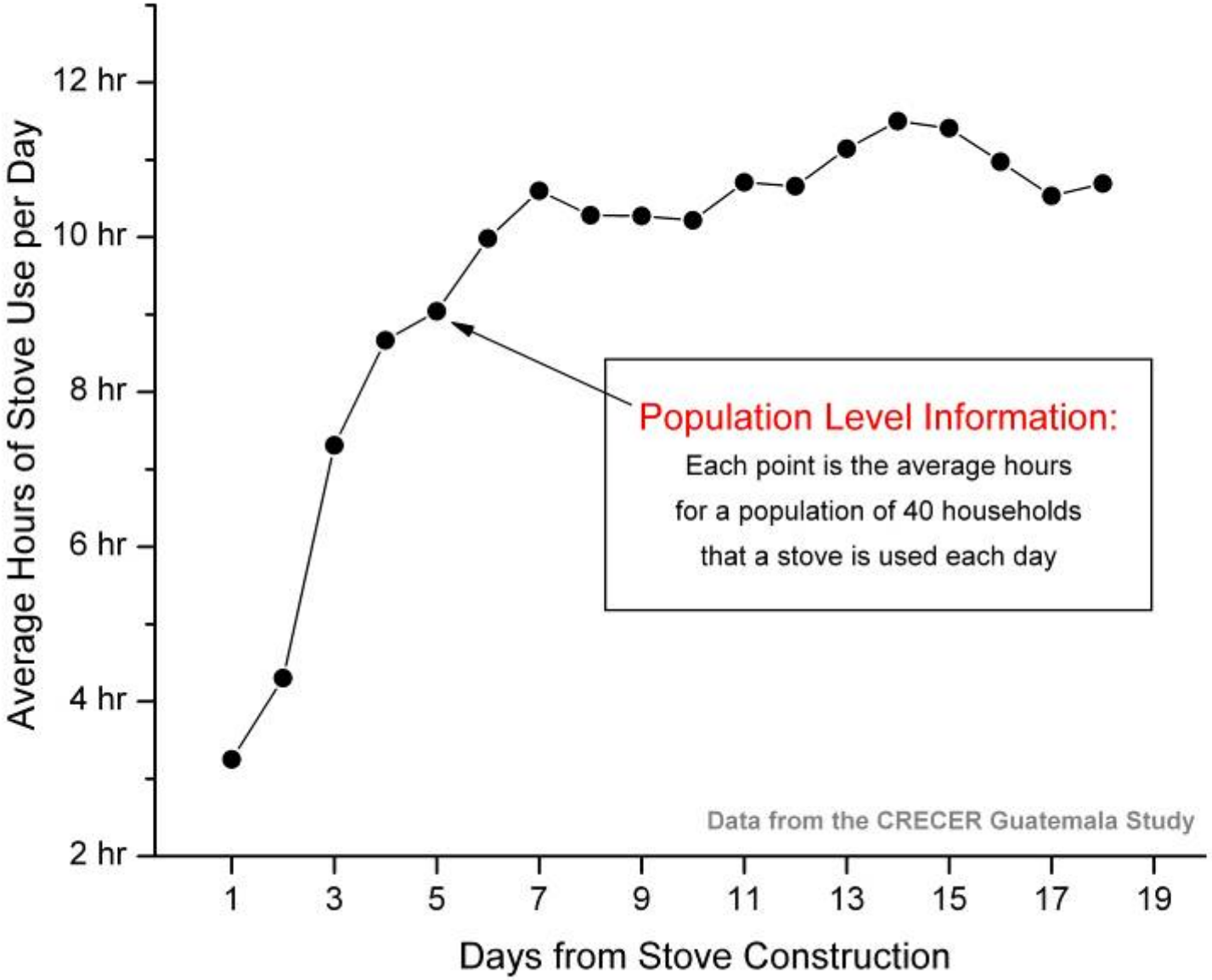
Monitoring ***drop out rates*** *and* ***patterns of use*** *with the SUMS system*

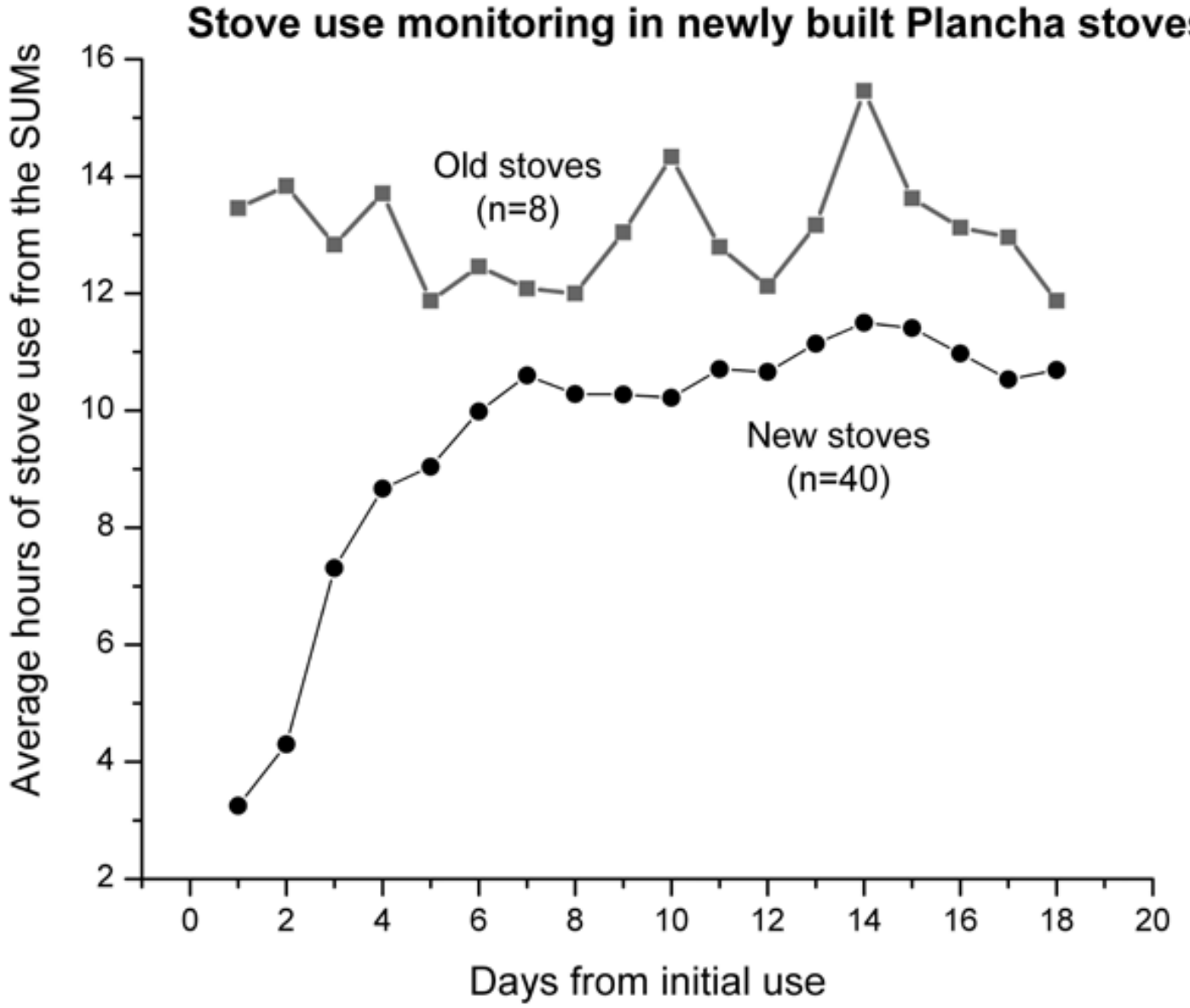

SUMS daily record of a Plancha stove in use
SUMs Temperature [C]
70
60
50
40
30
20
10
breakfast
8:30
lunch
13:45
dinner
19:30
04 PM
08 PM
12 PM
04 AM
08 AM
12 PM
04 PM
08 PM
12 PM
04 AM
08 AM

Objective Monitoring with the UCB-SUMS System



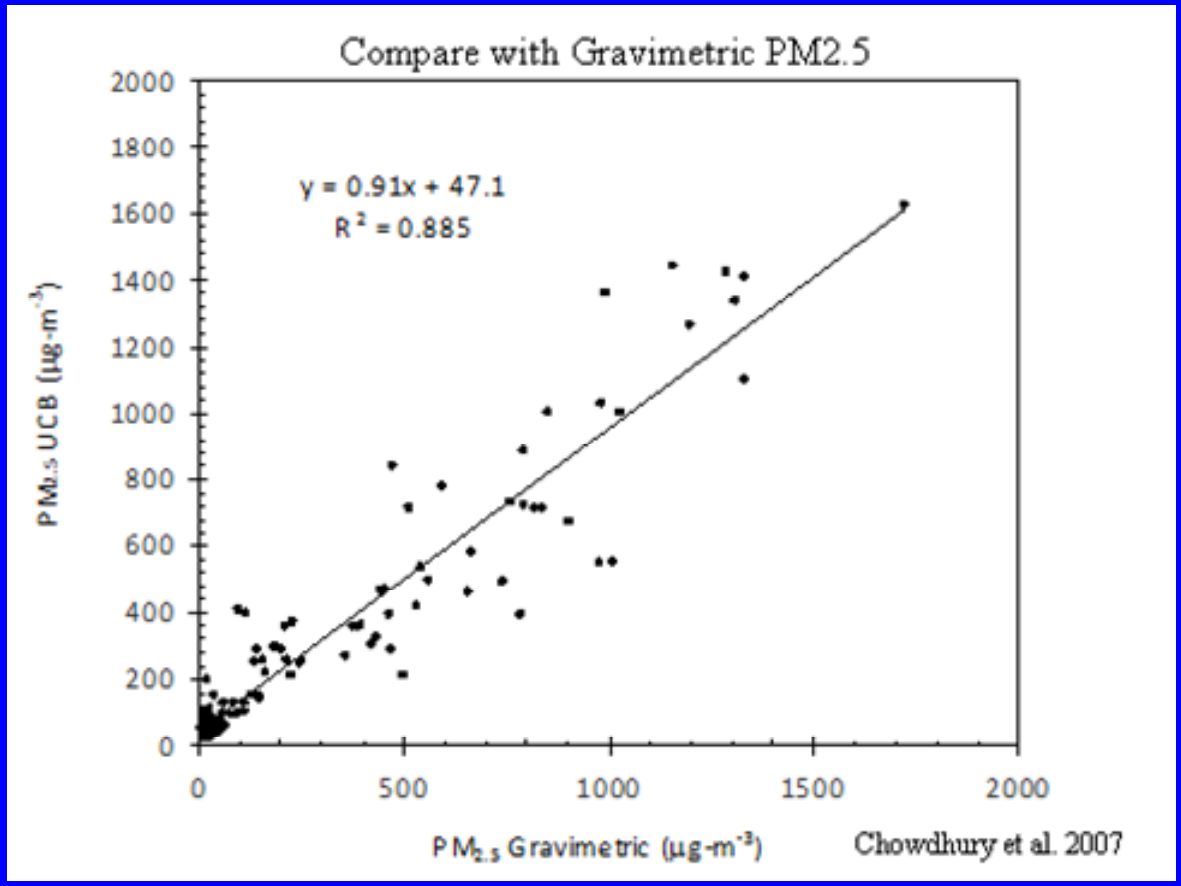
Measuring Adoption Dynamics with the UCB-SUMS



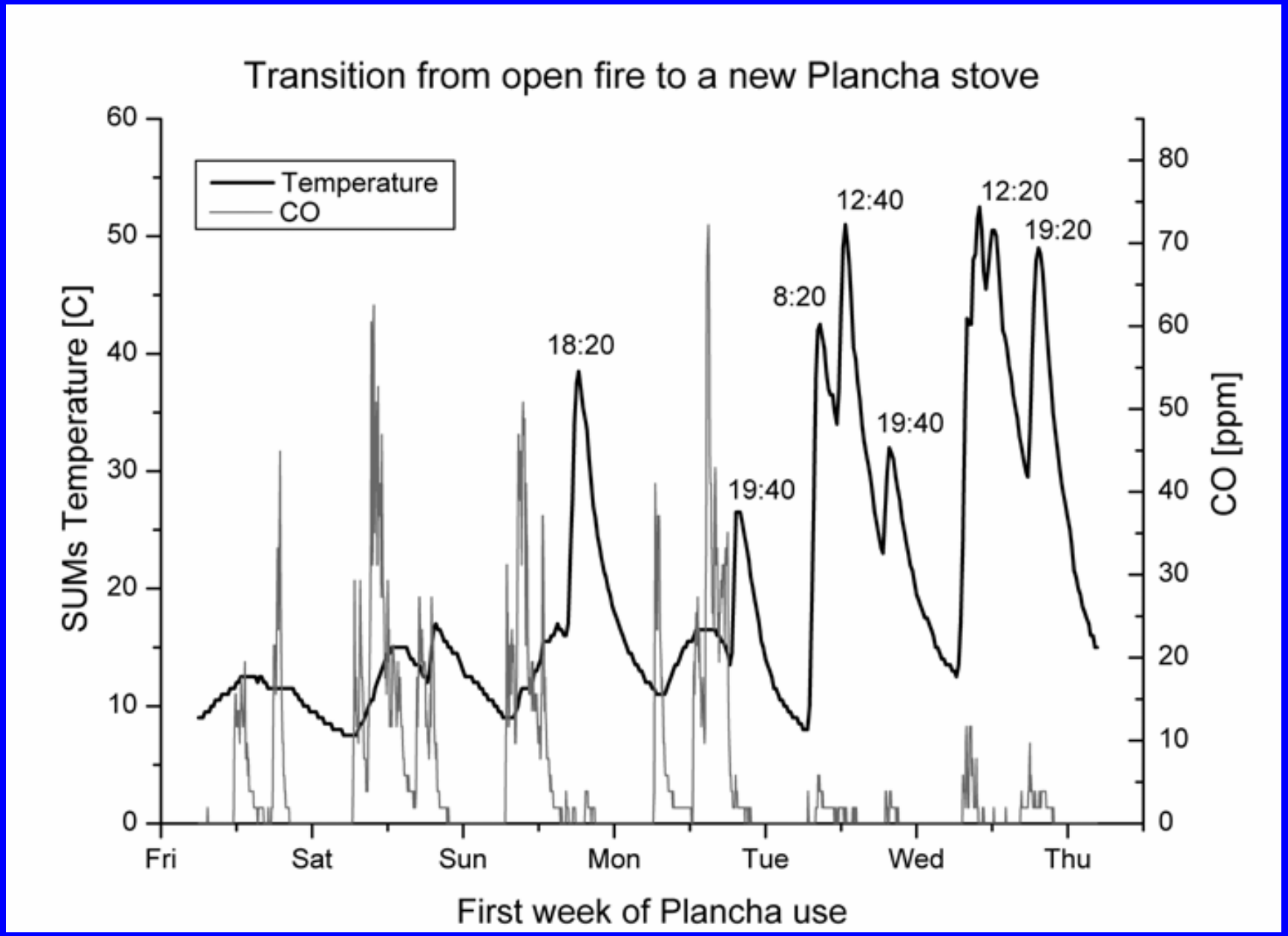

Stove use monitoring in newly built Plancha stoves
Average hours of stove use from the SUMs
Days from initial use
Old stoves
(n=8)
New stoves
(n=40)
16
14
12
10
8
6
4
2
0
2
4
6
8
10
12
14
16
18
20

Monitoring: Indoor Air Pollution

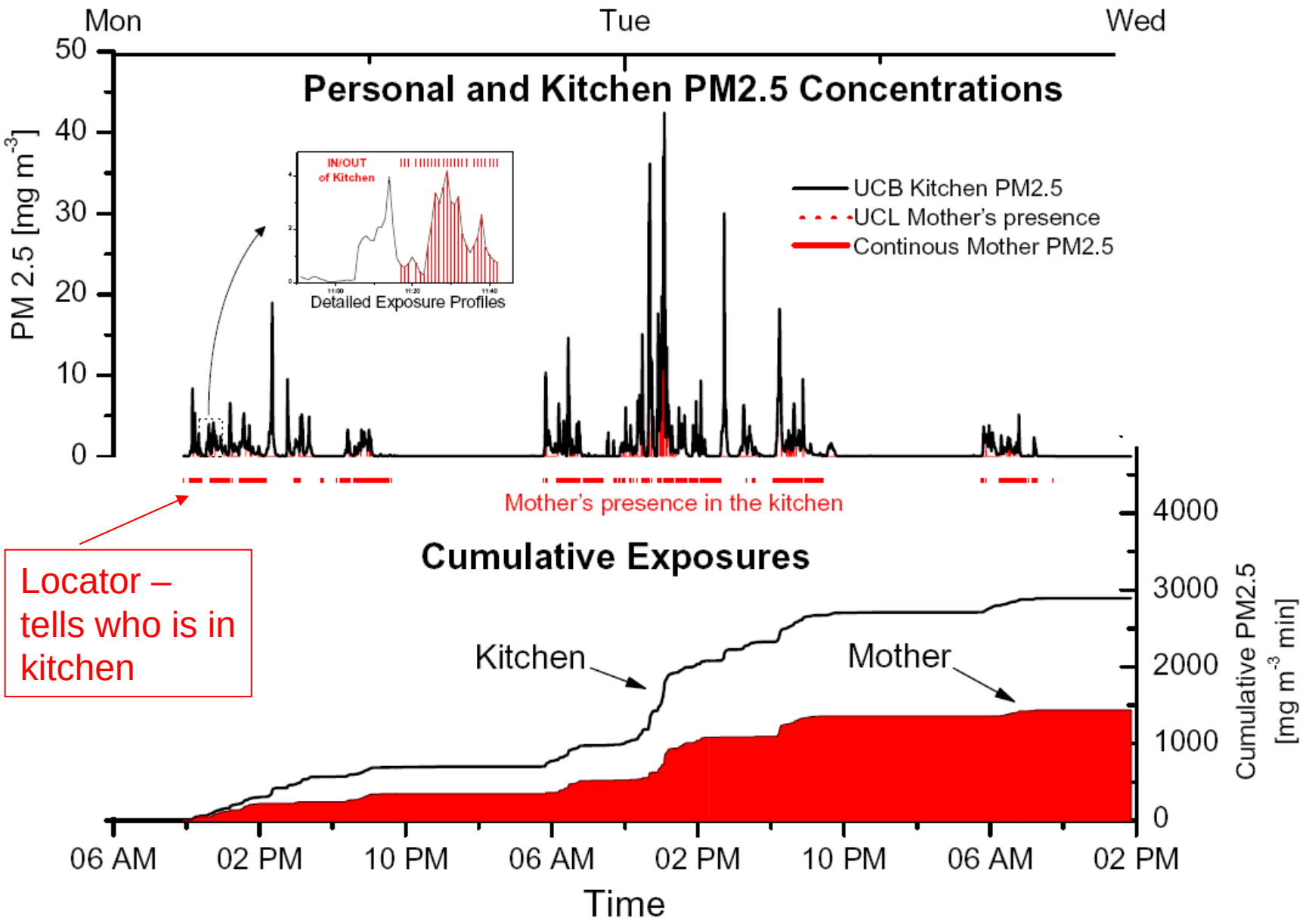
- $PM_{2.5}$: Pump/filter is standard method, but cumbersome, slow, and poor resolution
- Need new method: Small, smart, fast, and cheap
- UCB Monitor using smoke detector technology is an example



Source: Chowdhury, Z., R. D. Edwards, et al. (2007). "An inexpensive light-scattering particle monitor: field validation." Journal of Environmental Monitoring **9**(10): 1099-1106.


Transition from open fire to a new Plancha stove
Temperature
CO
SUMs Temperature [C]
CO [ppm]
0
10
20
30
40
50
60
0
10
20
30
40
50
60
70
80
18:20
19:40
8:20
12:40
19:40
12:20
19:20
Fri
Sat
Sun
Mon
Tue
Wed
Thu
First week of Plancha use

Measuring Personal Exposure to PM2.5 from Woodsmoke with the UCB-Particle Monitor and the UCB-Personal Locator

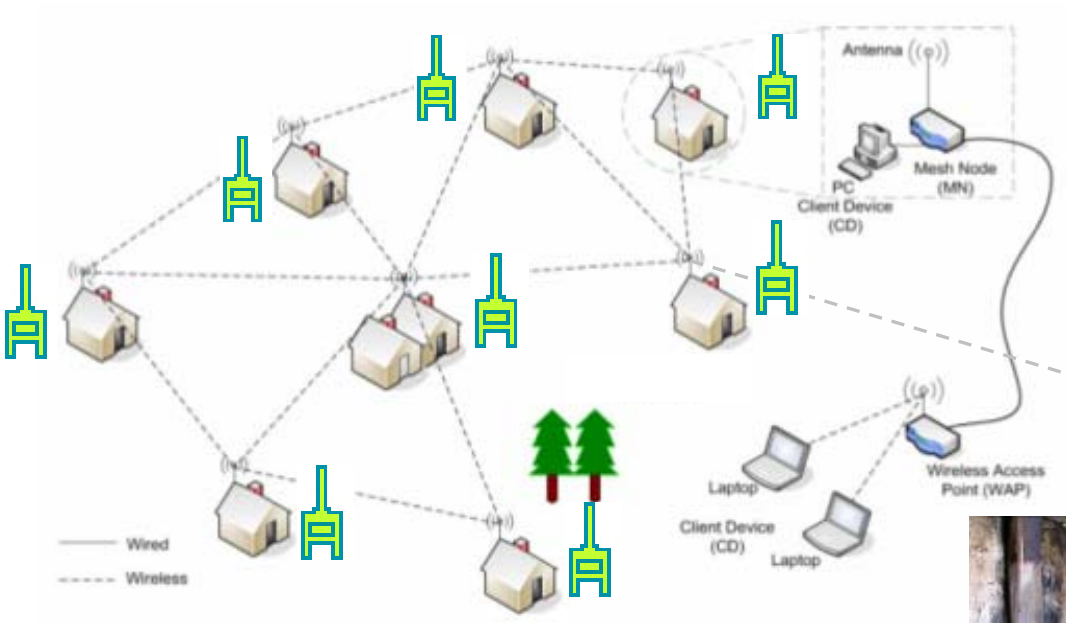


Measuring Reductions in Black Carbon Emissions During Use in Real Households

Portable Black Carbon Monitor

Next Generation of M&E Systems

Wireless networks of sensors using cell phone communication



Data Collection:
Smart phones, cell phones, RFID, bar codes, PDAs, tablet PCs

Sensors:
Wireless-SUMS, portable black carbon monitor,

Publications and presentations available at

http://ehs.sph.berkeley.edu/krsmith/

Thank you