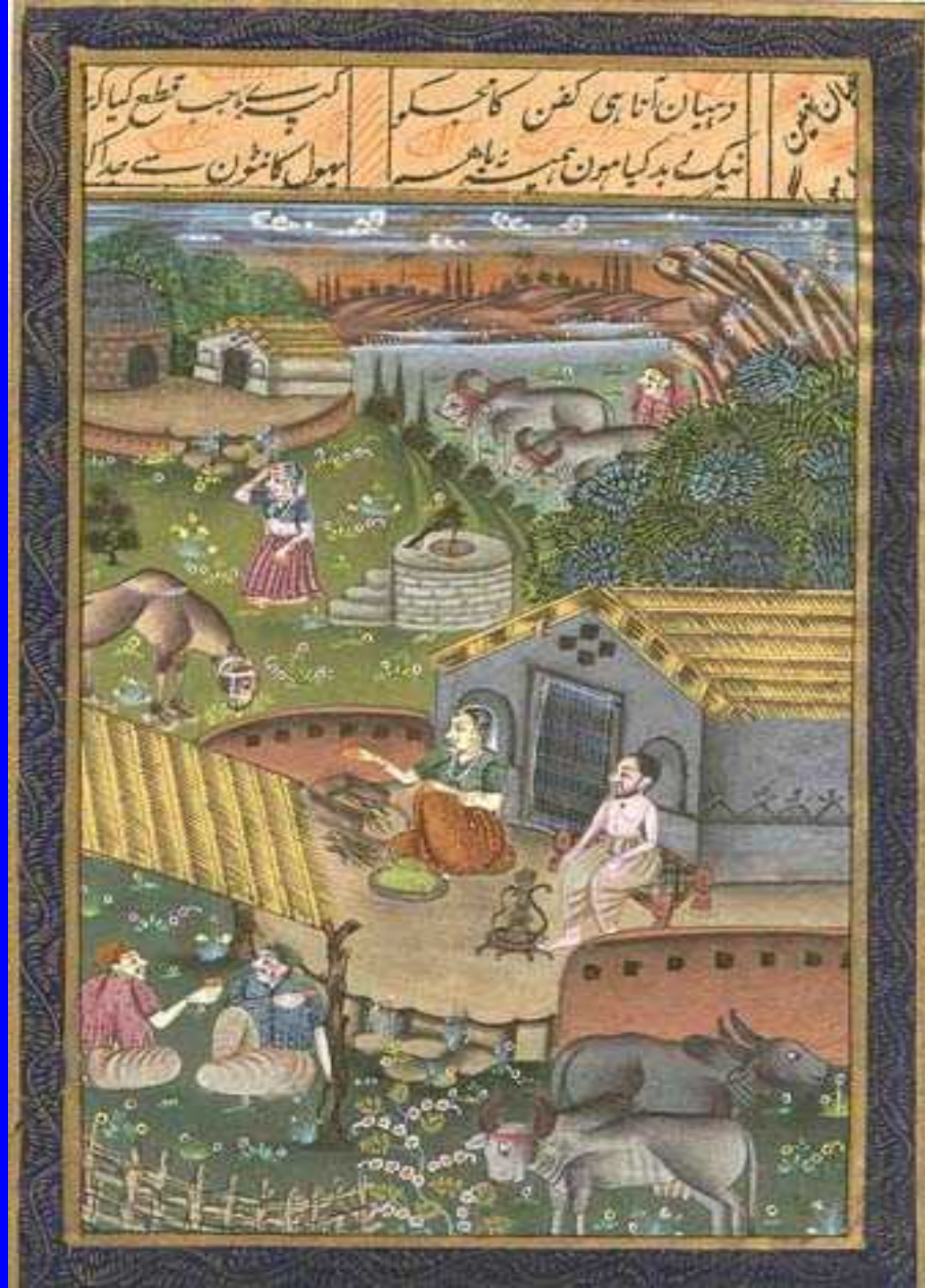


COOKFIRES, CLIMATE, AND HEALTH:

THE UNFINISHED AGENDA OF INCOMPLETE COMBUSTION

Kirk R. Smith
Professor of Global
Environmental Health
University of California
Berkeley

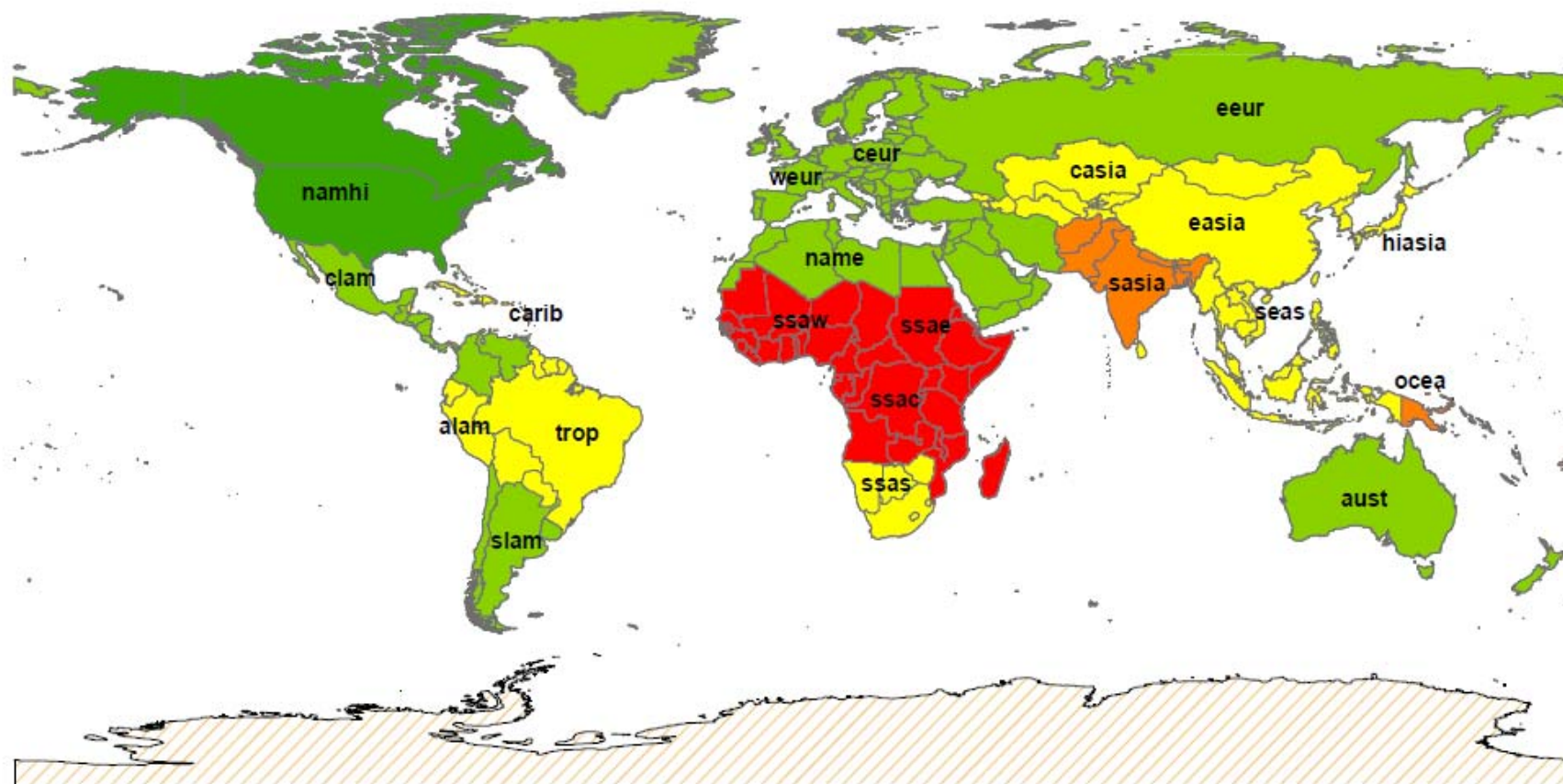
**Indian Institute of
Technology, Delhi**
March 28, 2011



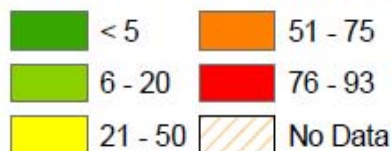
Road Map

- Why a problem?
- What health effects are found?
- What are climate implications?
- What is India doing?
- What engineering is involved, besides designing new stoves?

Households Using Solid Cooking Fuels

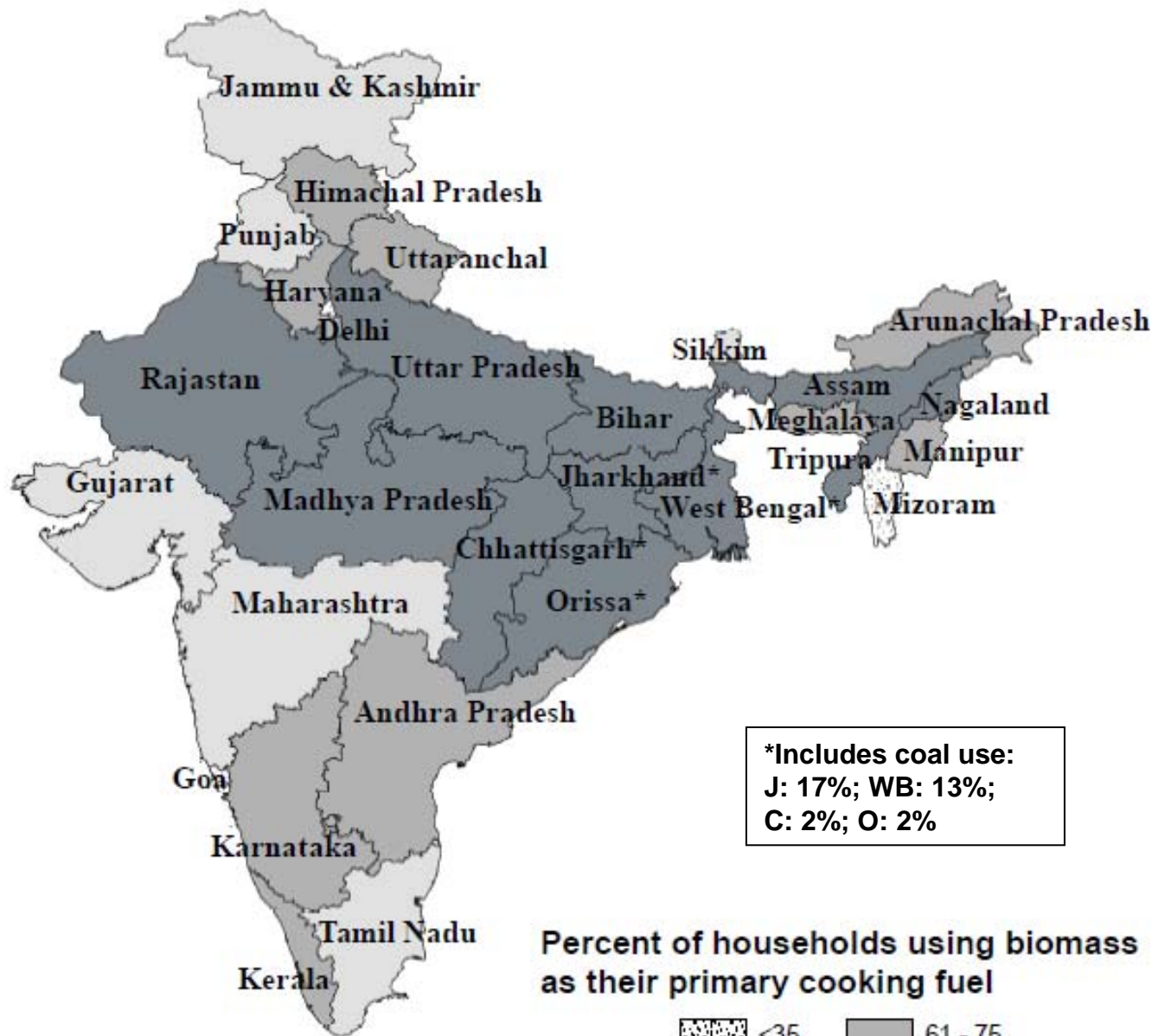


% of HH Exposed to HAP



For 2005, CRA-10 preliminary

India in 2005



Venkataraman
et al. 2010

Woodsmoke is natural – how can it hurt you?

Or, since wood is mainly just carbon, hydrogen, and oxygen, doesn't it just change to CO_2 and H_2O when it is combined with oxygen (burned)?

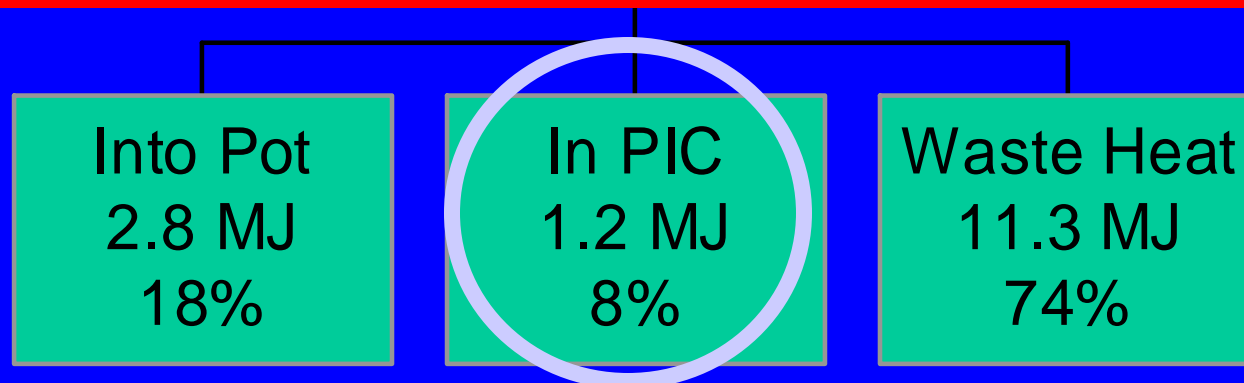


Reason: the combustion efficiency is far less than 100%

Energy flows in a well-operating traditional wood-fired Indian cooking stove

A Toxic Waste Factory!!

Typical biomass cookstoves convert 6-20% of the fuel carbon to toxic substances



PIC = products of incomplete combustion = CO, HC, C, etc.

Source:
Smith,
et al.,
2000

Toxic Pollutants in Biomass Fuel Smoke from Simple (poor) Combustion

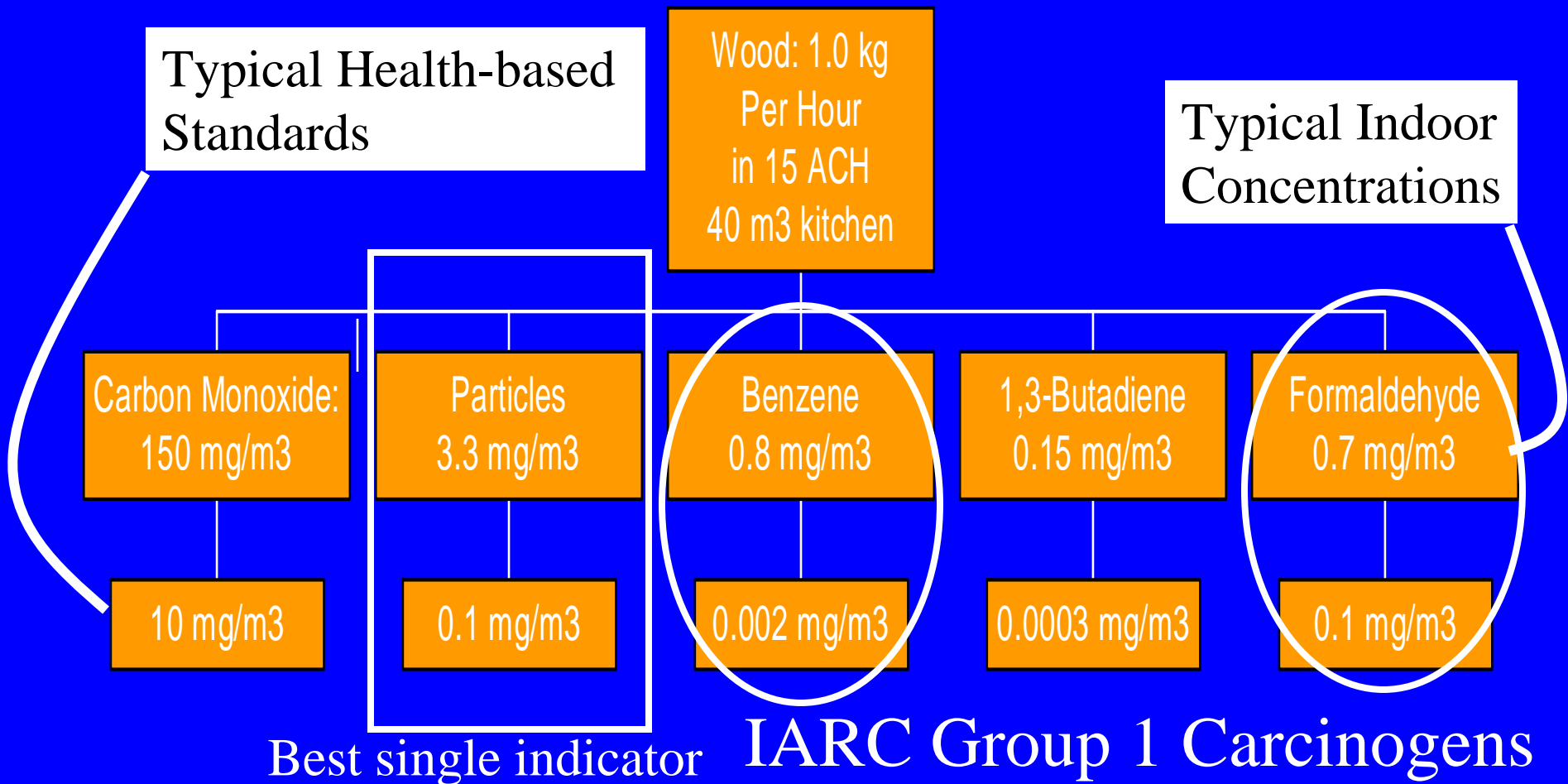
Organics known to be mutagens, immune system suppressants, severe irritants, inflammation agents, central nervous system depressants, cilia toxins, endocrine disrupters, or neurotoxins.

Several chemicals firmly established as human carcinogens.

Other toxic inorganic chemicals.

- 25+ alcohols and acids such as *methanol*
- 33+ phenols such as *catechol* & *cresol*
- Many quinones such as *hydroquinone*
- Semi-quinone-type and other radicals
- Chlorinated organics such as *methylene chloride* and *dioxin*

Health-Damaging Air Pollutants From Typical Woodfired Cookstove in India.



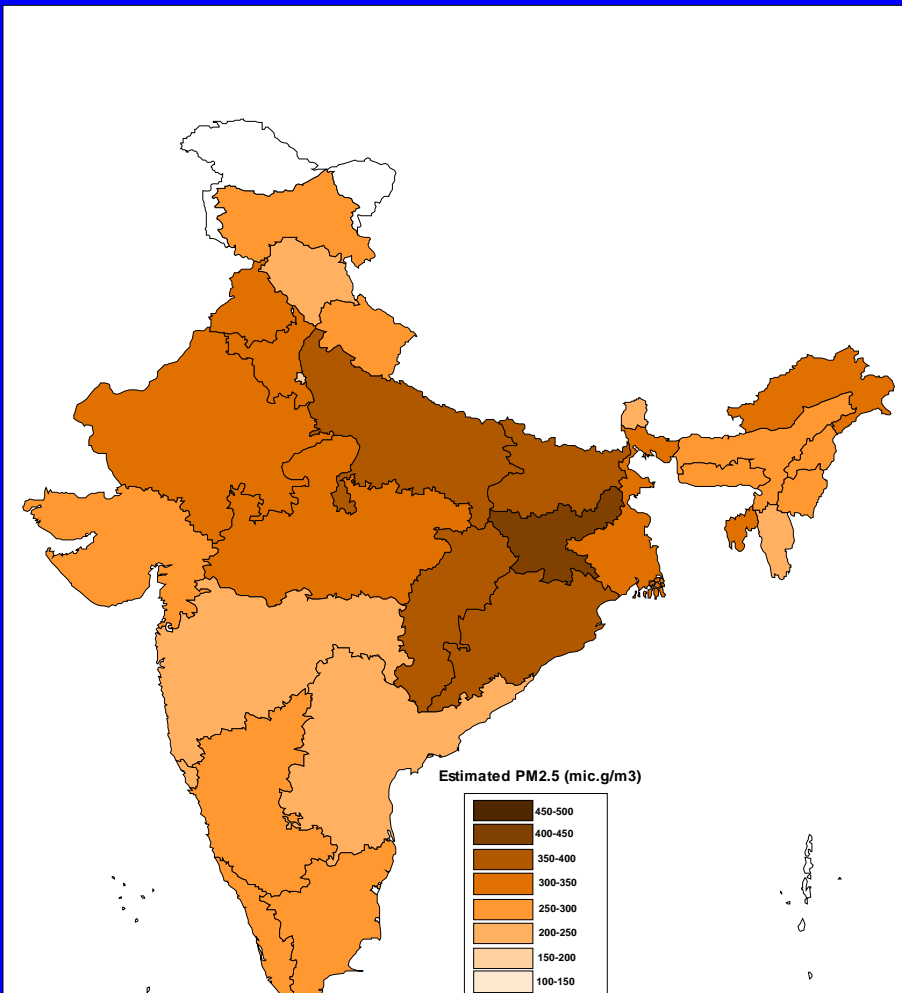
First person in human history to have her exposure measured doing the oldest task in human history

Emissions, yes,
but what about
exposures?

Kheda District,
Gujarat, 1981

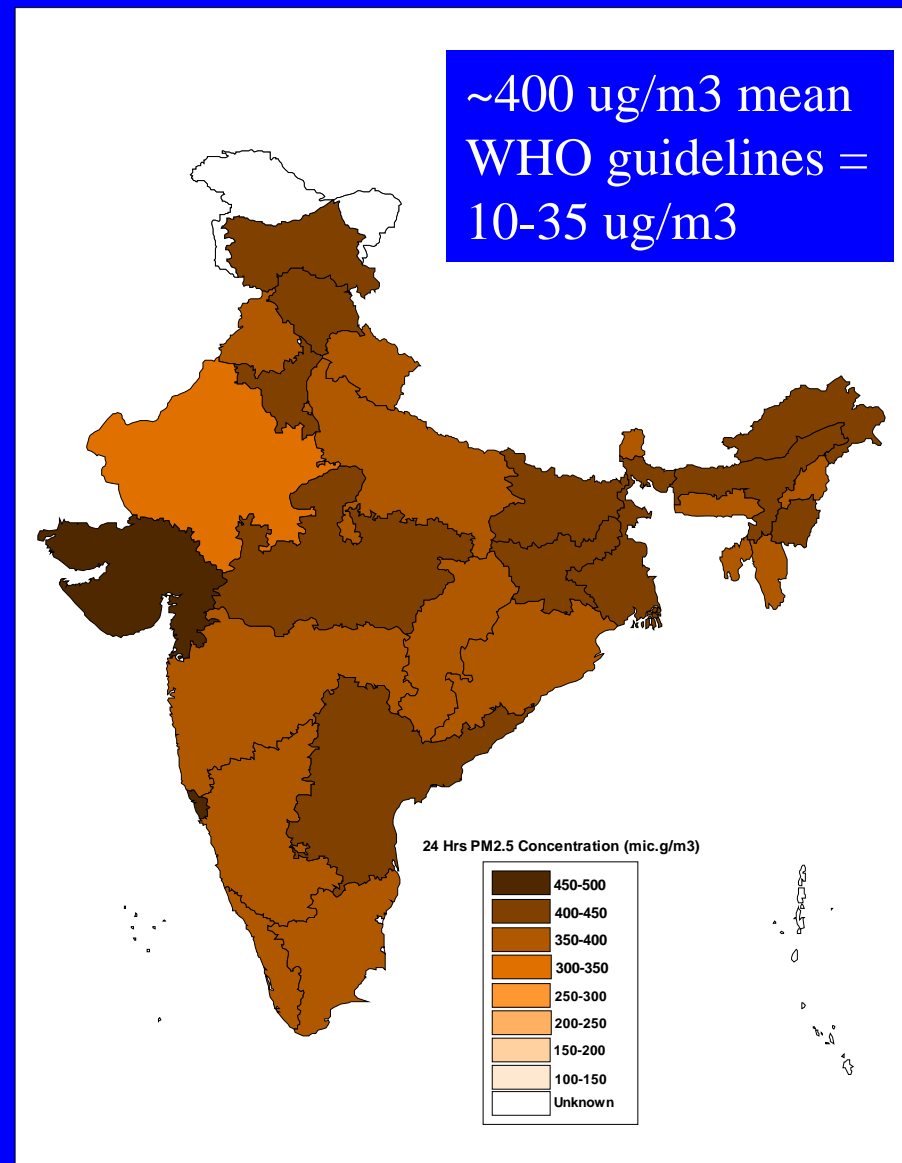


Estimated PM2.5 indoors for all households

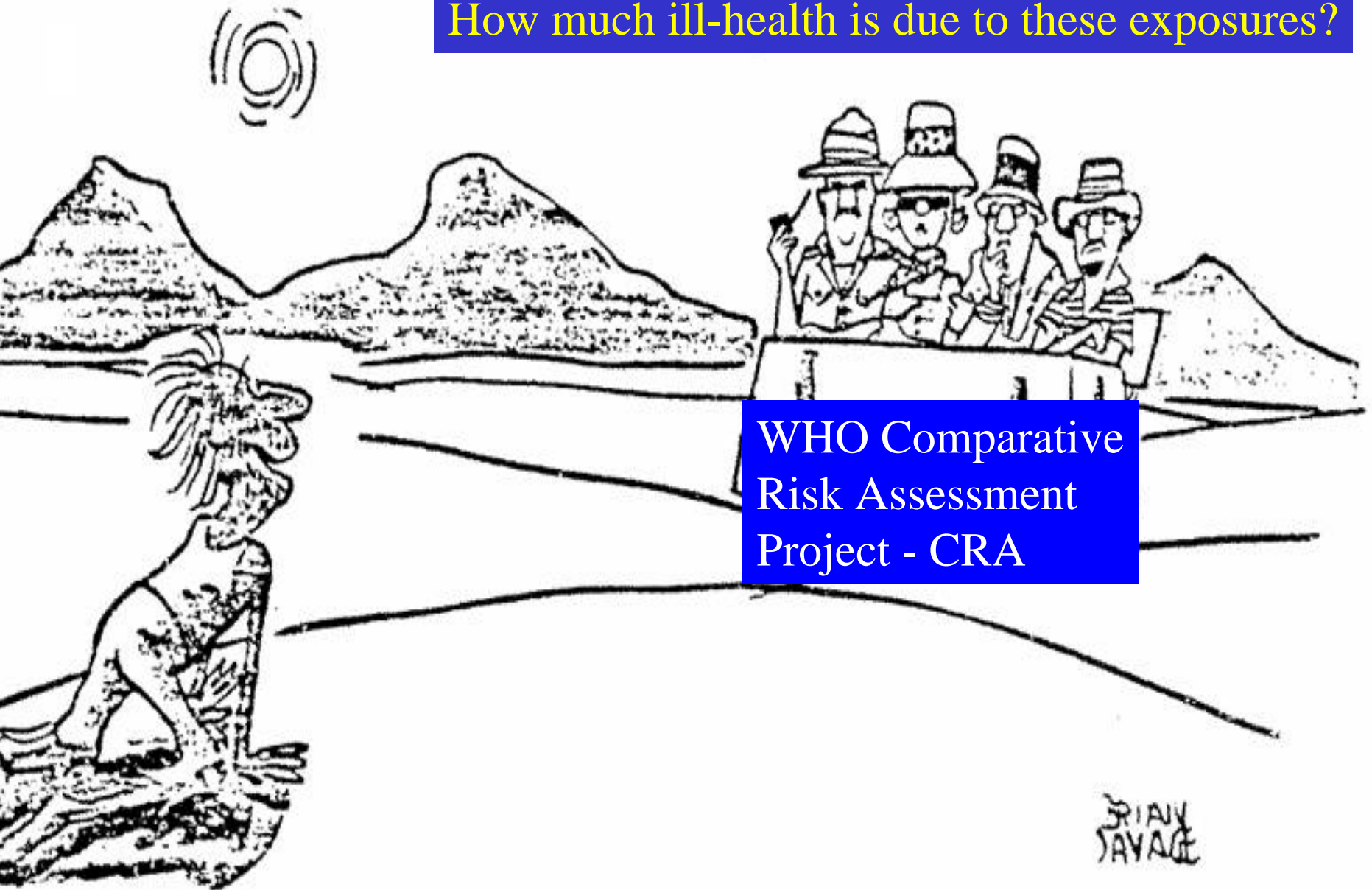


Preliminary results from the Household Air Pollution Comparative Risk Assessment, 2011

Estimated PM2.5 for only solid-fuel-using households



How much ill-health is due to these exposures?



WHO Comparative
Risk Assessment
Project - CRA

"Thank God! A panel of experts!"

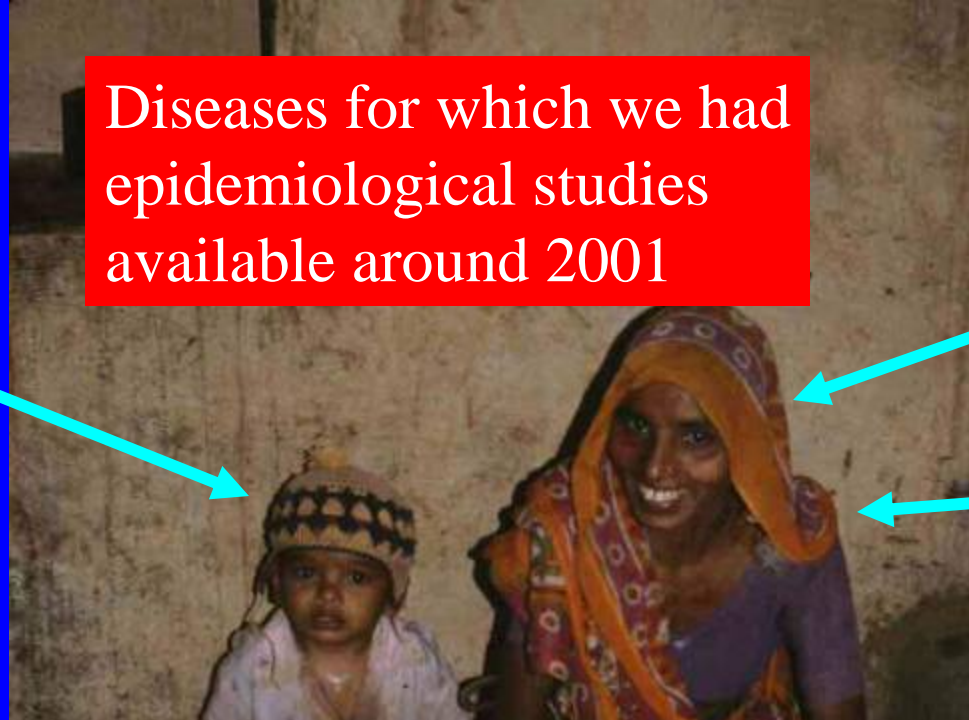
Courtesy of Ross Anderson

Diseases for which we had
epidemiological studies
available around 2001

ALRI/
Pneumonia

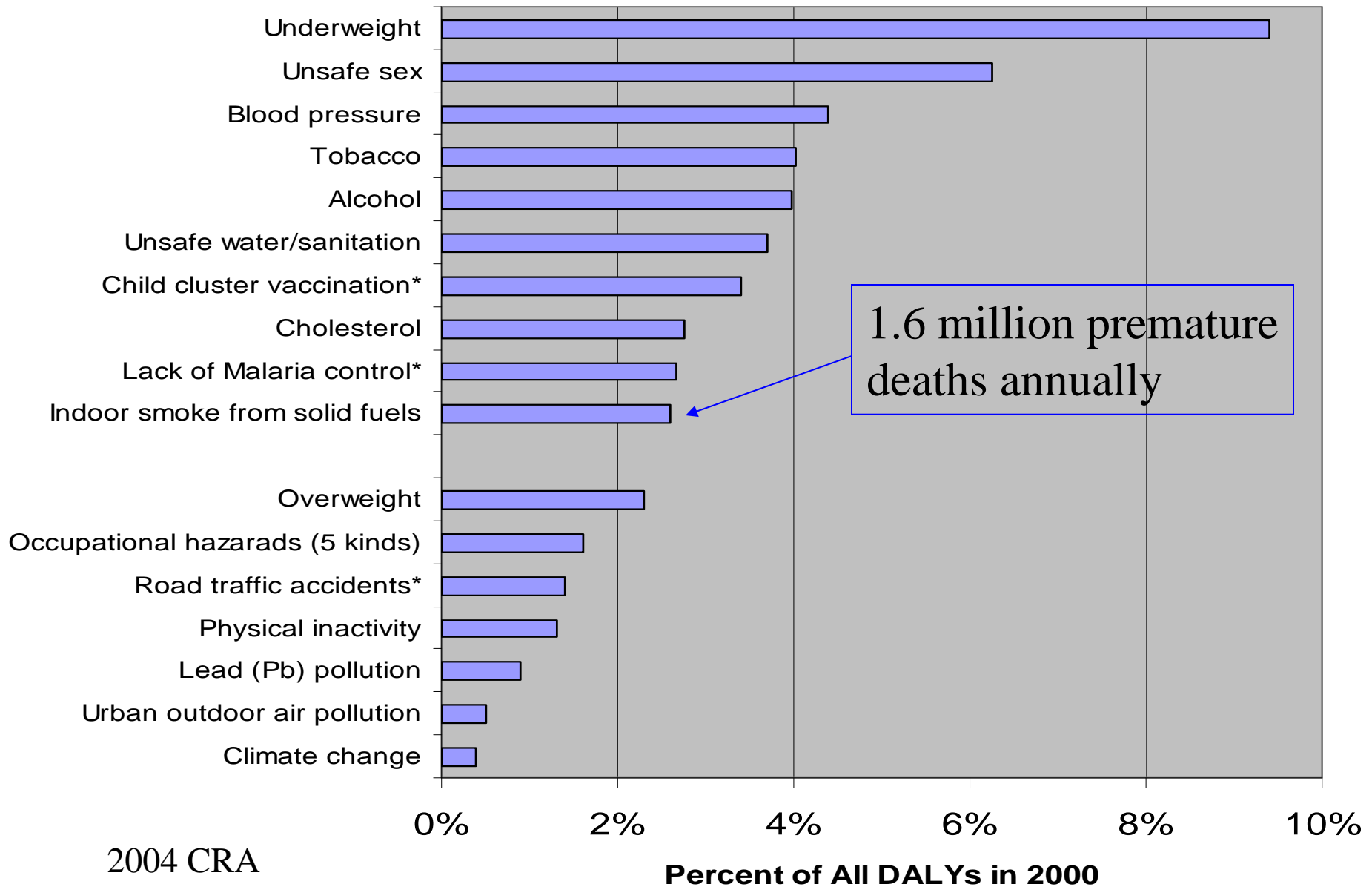
Chronic
obstructive
lung disease

Lung cancer
from coal only

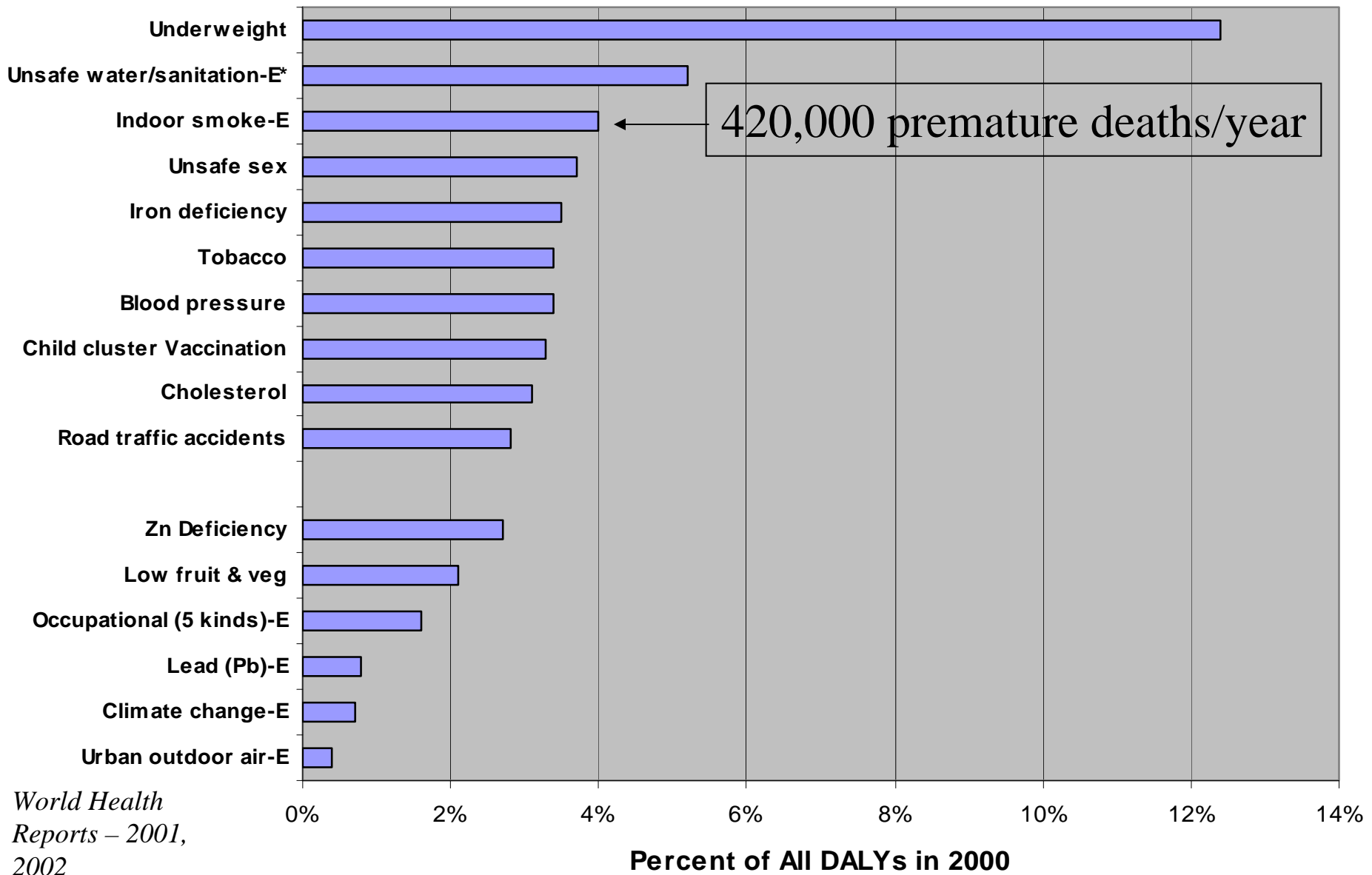


Three outcomes qualified
with sufficient evidence to be
included in the WHO CRA
of 2004

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



Global Burden of Disease Database
and Comparative Risk Assessment

Being completely updated
for late 2011 release

Diseases for which we have
epidemiological studies - 2010

ALRI/
Pneumonia
(meningitis)

Low birth
weight

Stillbirth

Cognitive
Impairment

Birth defects?

Asthma?

Chronic
obstructive
lung disease

Interstitial lung
disease

Cancer
(lung, NP, cervical,
aero-digestive)

Blindness
(cataracts, opacity)

Tuberculosis

Heart disease?
Blood pressure
ST-segment

Burns, health and safety
impacts of fuel gathering?



Summary of Endpoints in New CRA for Household Air Pollution

- New estimates for diseases in previous CRA
 - Pneumonia in children
 - COPD in adults (male and female)
 - Lung cancer in adults (male and female)
- Diseases now included
 - Low birth weight
 - Cataracts
 - Heart disease
- Still unclear – not included
 - TB
 - Asthma
 - Other cancers

Story of Two Conferences

- Air pollution conference
 - High exposures to large vulnerable population
 - No more health effects work needed
- International health conference
 - Still doubt about causality
 - Need to know exact benefit to be expected
- Where are your randomized controlled trials?

History of an RCT

- ~1980: Early studies of health effects in Nepal and elsewhere
- 1981: First measurements of pollution levels in India
- 1984: International meeting to decide on needed research
 - Chose randomized control trial (RCT) of ALRI
- 1986-89: Unfunded proposals to do RCT in Nepal
- 1990: WHO establishes committee to find best sites
- 1990-1992: Criteria established and site visits made
- 1992: Highland Guatemala chosen
- 1991-1999: Pilot studies to establish data needed for proposal
- 1996-1999: Unfunded proposals
- 2001: NIEHS funding secured
- 2002-2005: Fieldwork completed
- 2011: Main results published
- 25+ years from deciding to conduct RCT to results!

First Randomized Trial
In Air Pollution History*

After a
in

North America

Guatemala

South America

N
W E
S

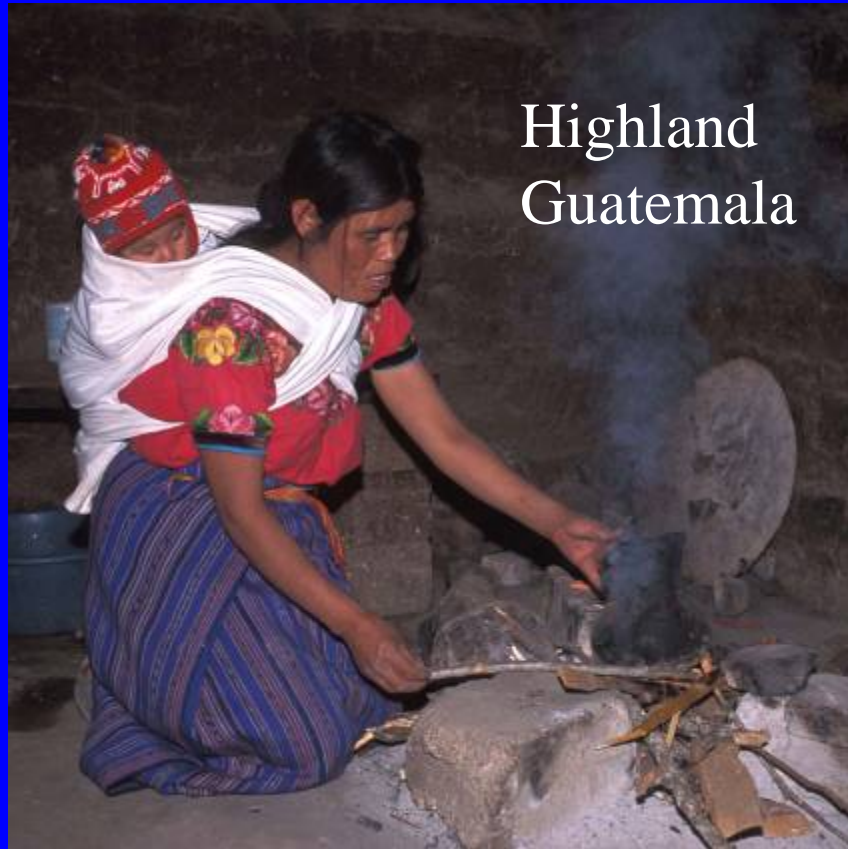
* In normal populations

After a worldwide search, chose a site in
in the Guatemalan Highlands



- * In normal populations

RESPIRE: (Randomized Exposure Study of Pollution Indoors and Respiratory Effects)



Traditional 3-stone open fire



Chimney woodstove



Tubito

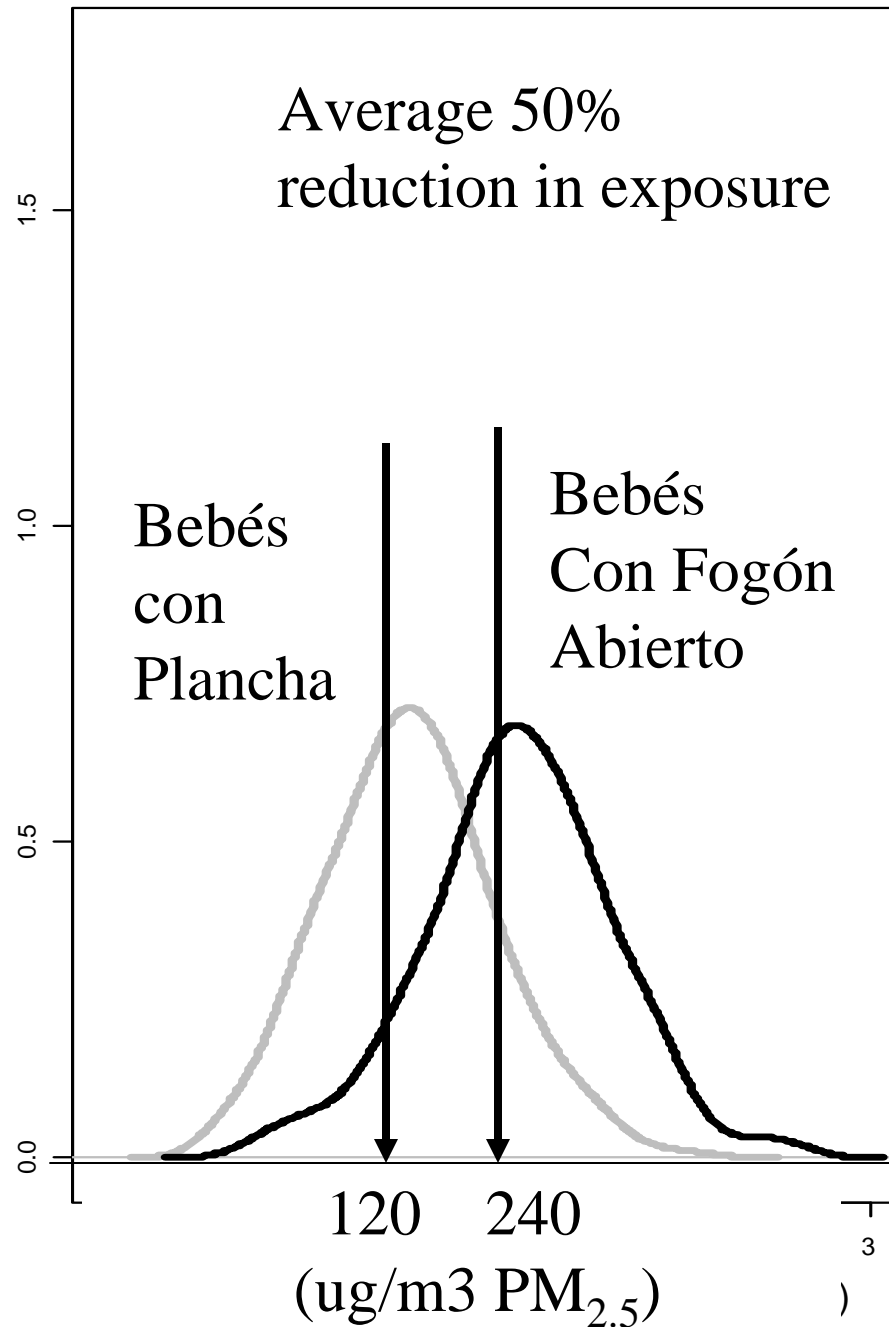
Tubito

Unpublished results from RESPIRE have been removed

Watch the website below where they will be
posted as soon as they are published.

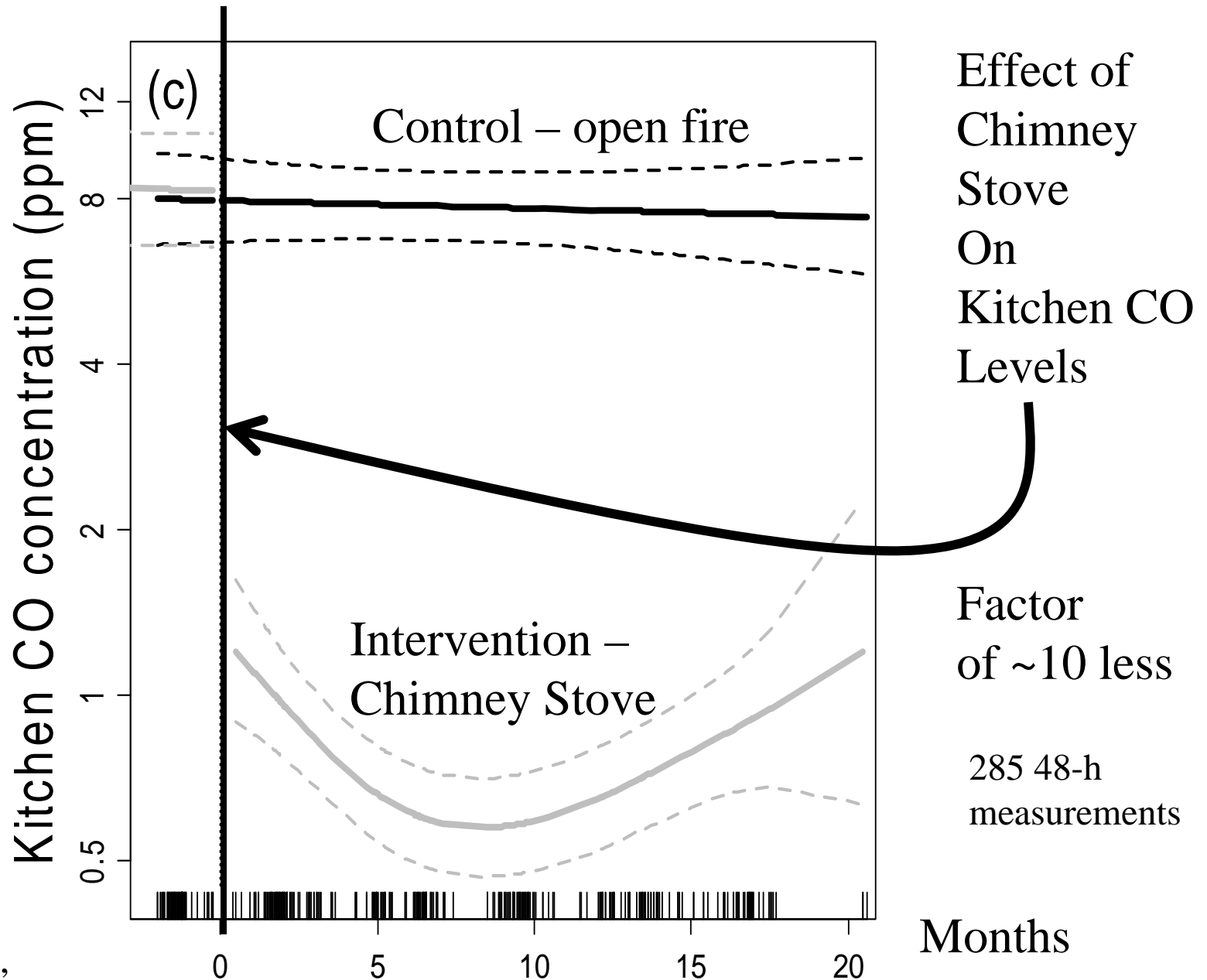
<http://ehs.sph.berkeley.edu/krsmith>

(b)

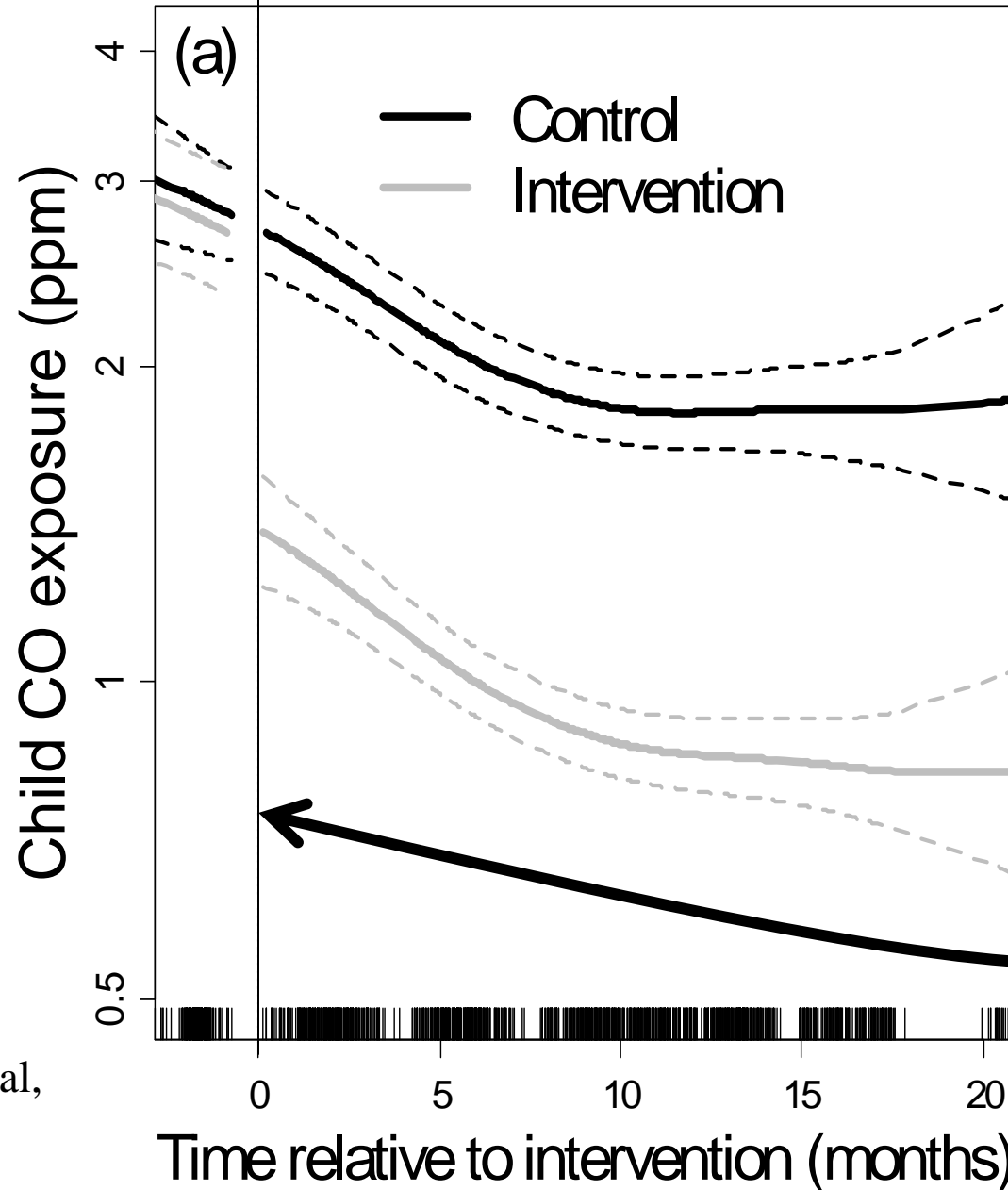


Chimney
stove did
not protect
all children

Guatemala RCT: Kitchen Concentrations



Infant Exposures

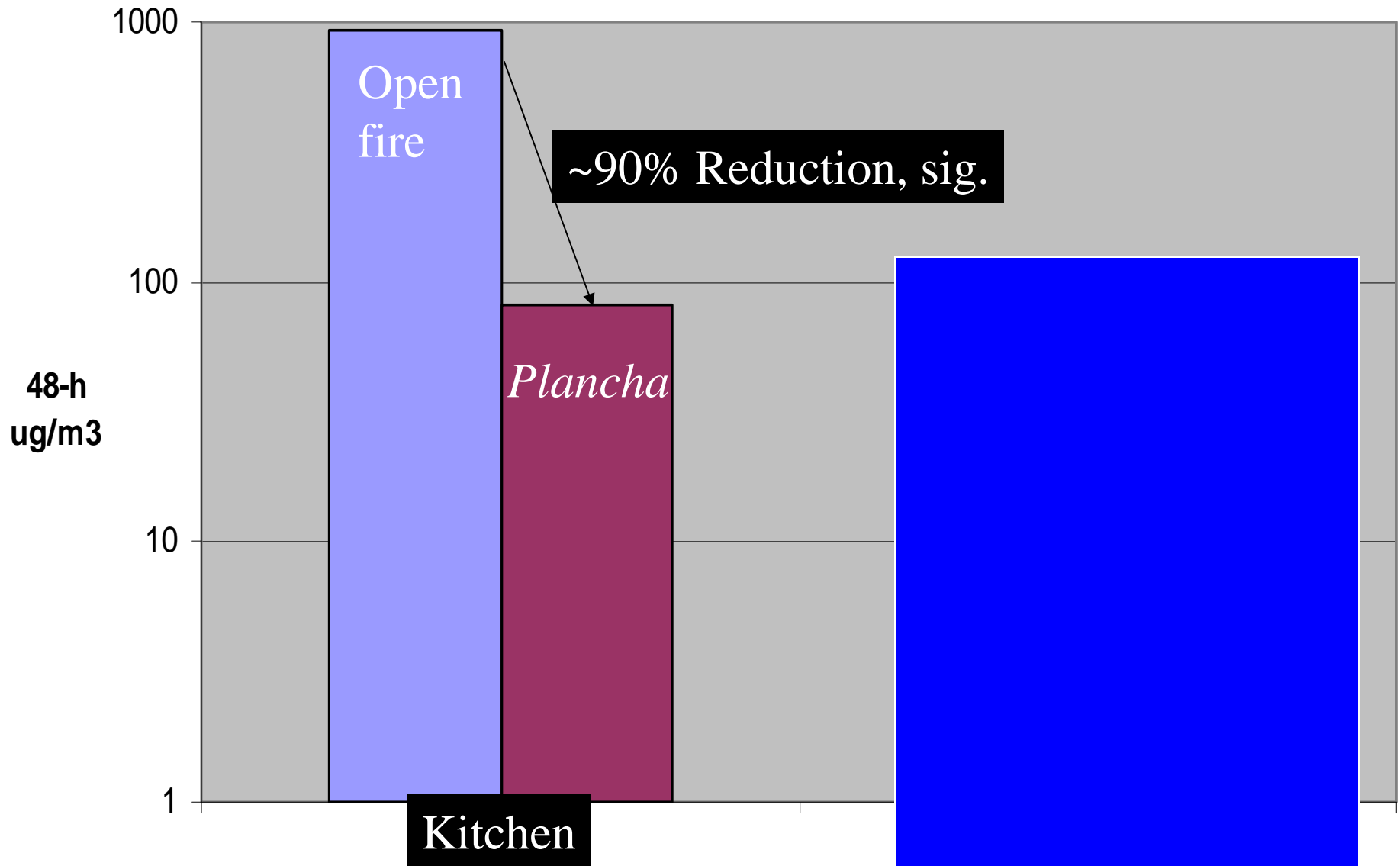


1888 48-h
measurements

Effect of
Chimney
Stove
On
Infant
Exposures
- 2x less

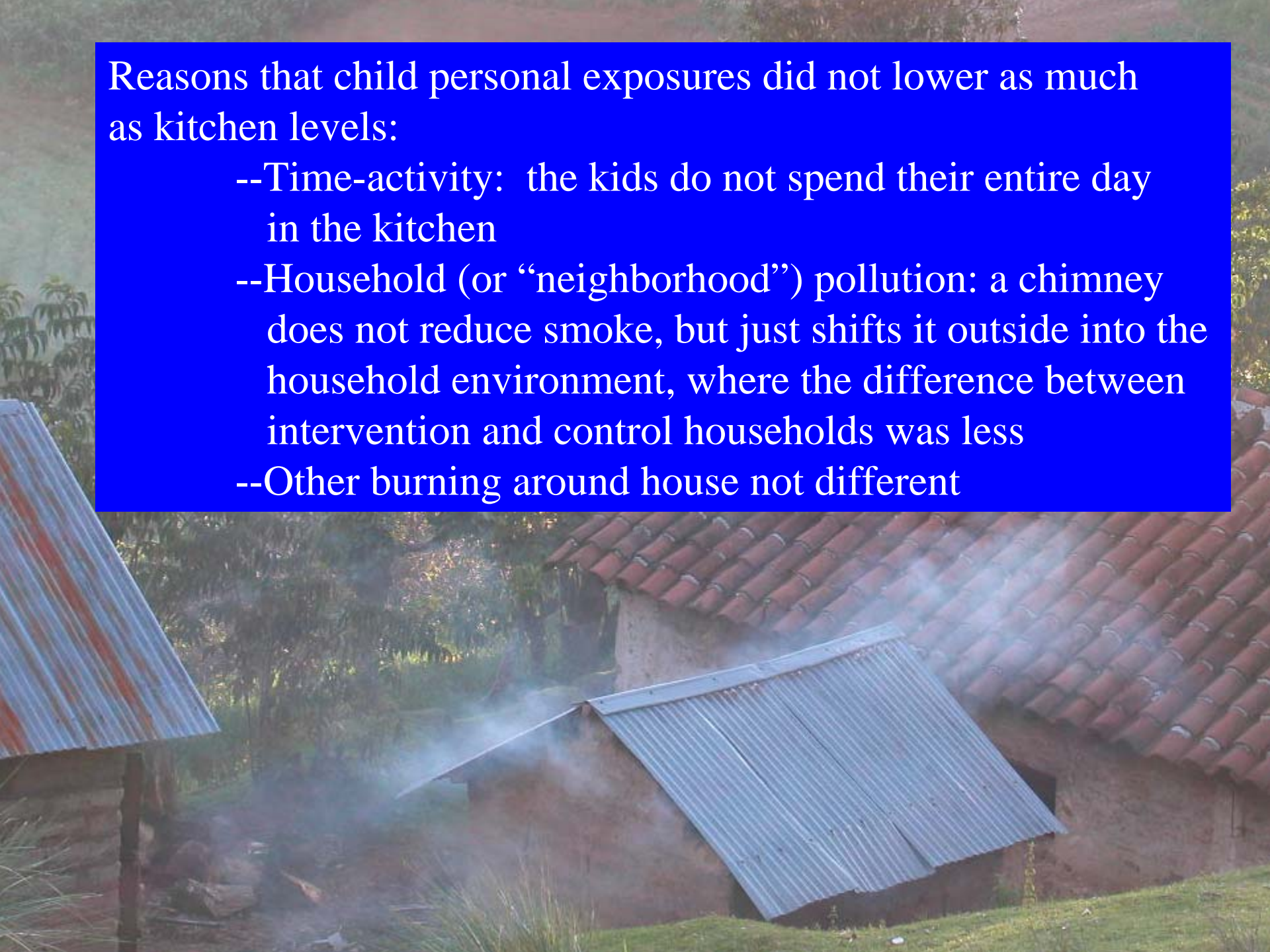
Effect of Plancha on PM2.5

Log Scale



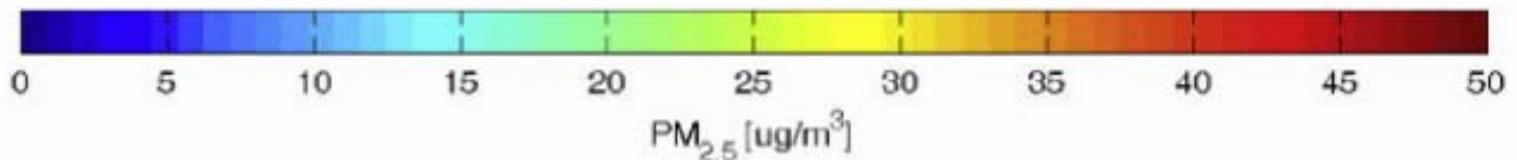
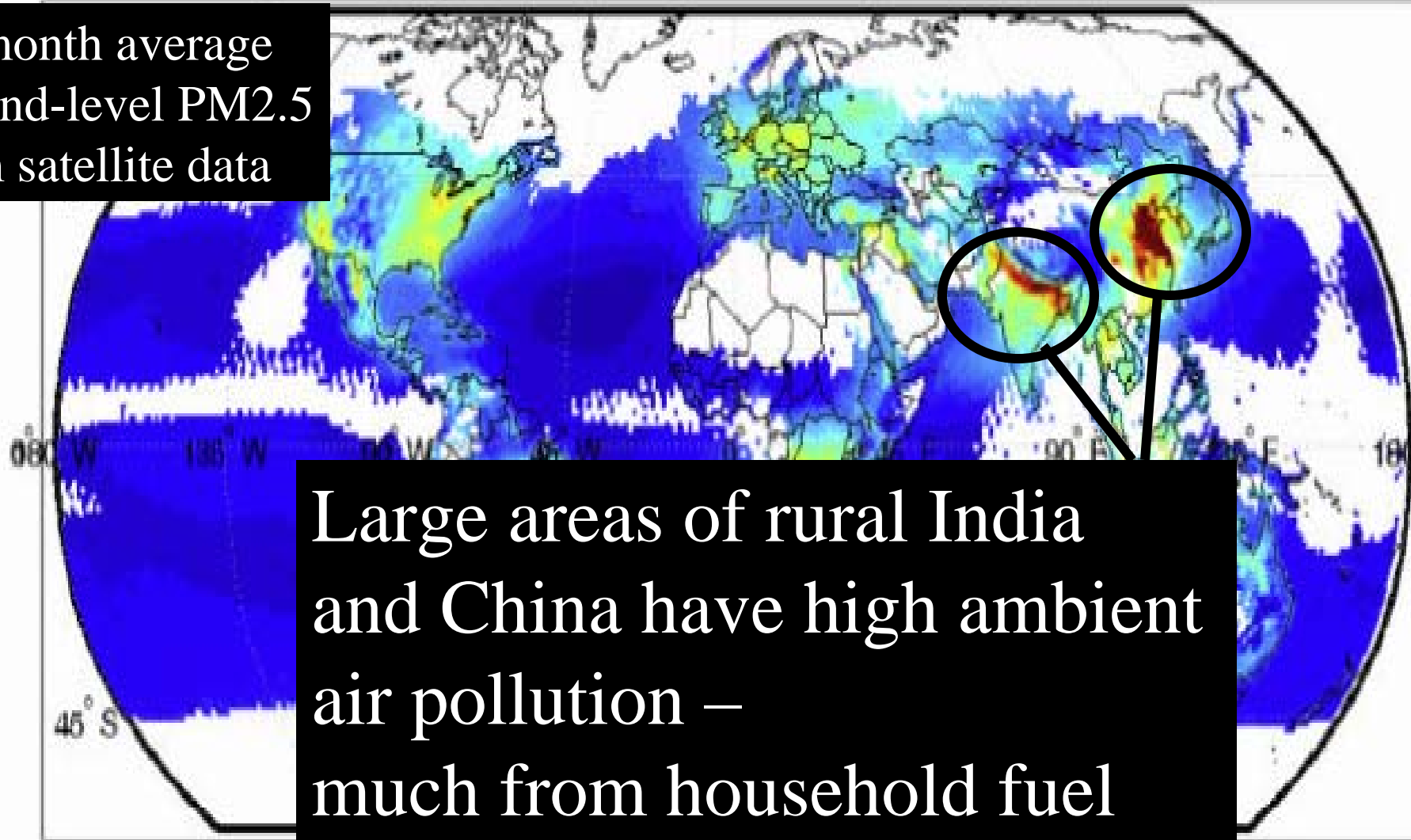
Reasons that child personal exposures did not lower as much as kitchen levels:

- Time-activity: the kids do not spend their entire day in the kitchen
- Household (or “neighborhood”) pollution: a chimney does not reduce smoke, but just shifts it outside into the household environment, where the difference between intervention and control households was less
- Other burning around house not different



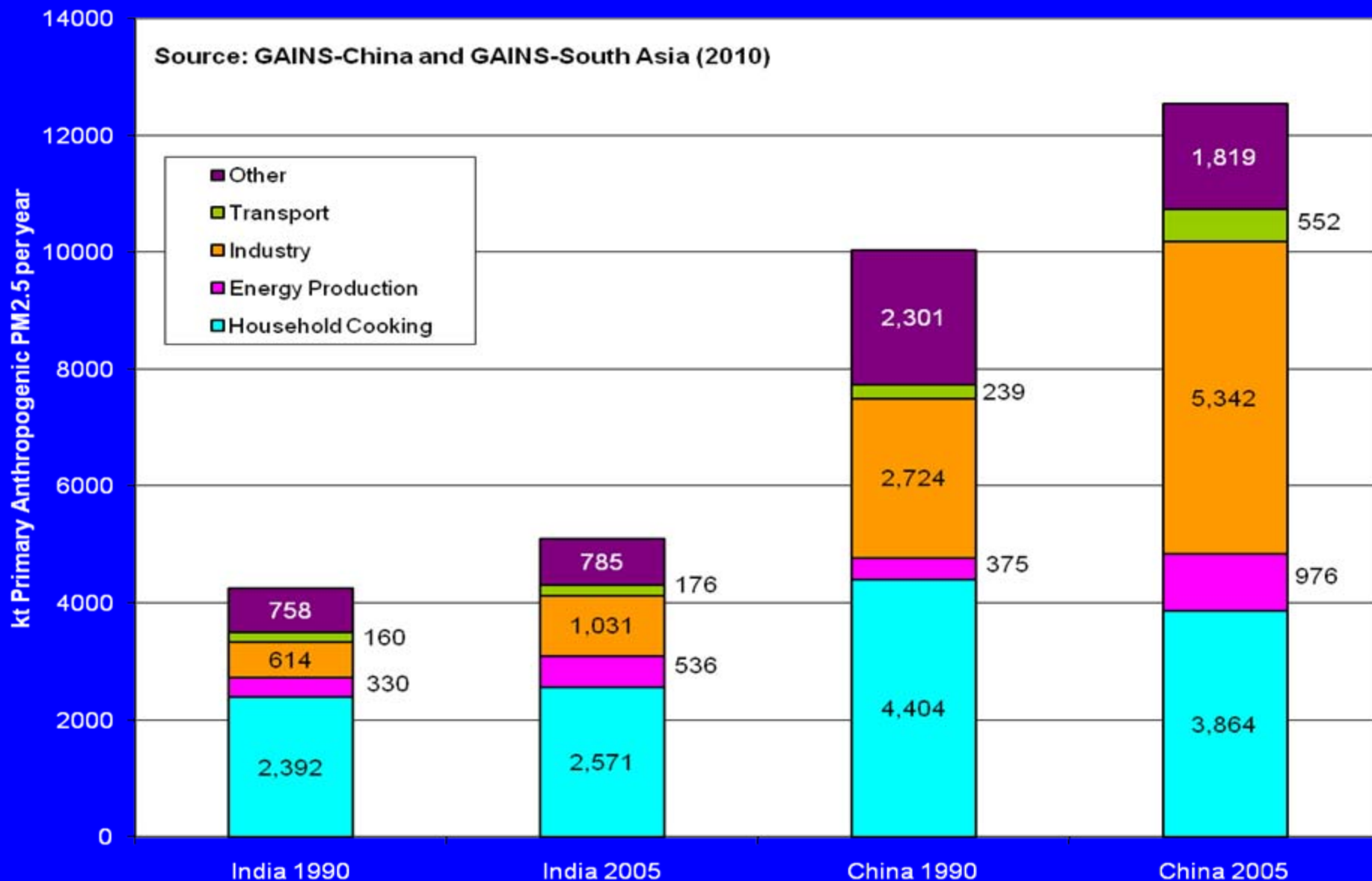
20-month average
ground-level PM_{2.5}
from satellite data

MODIS



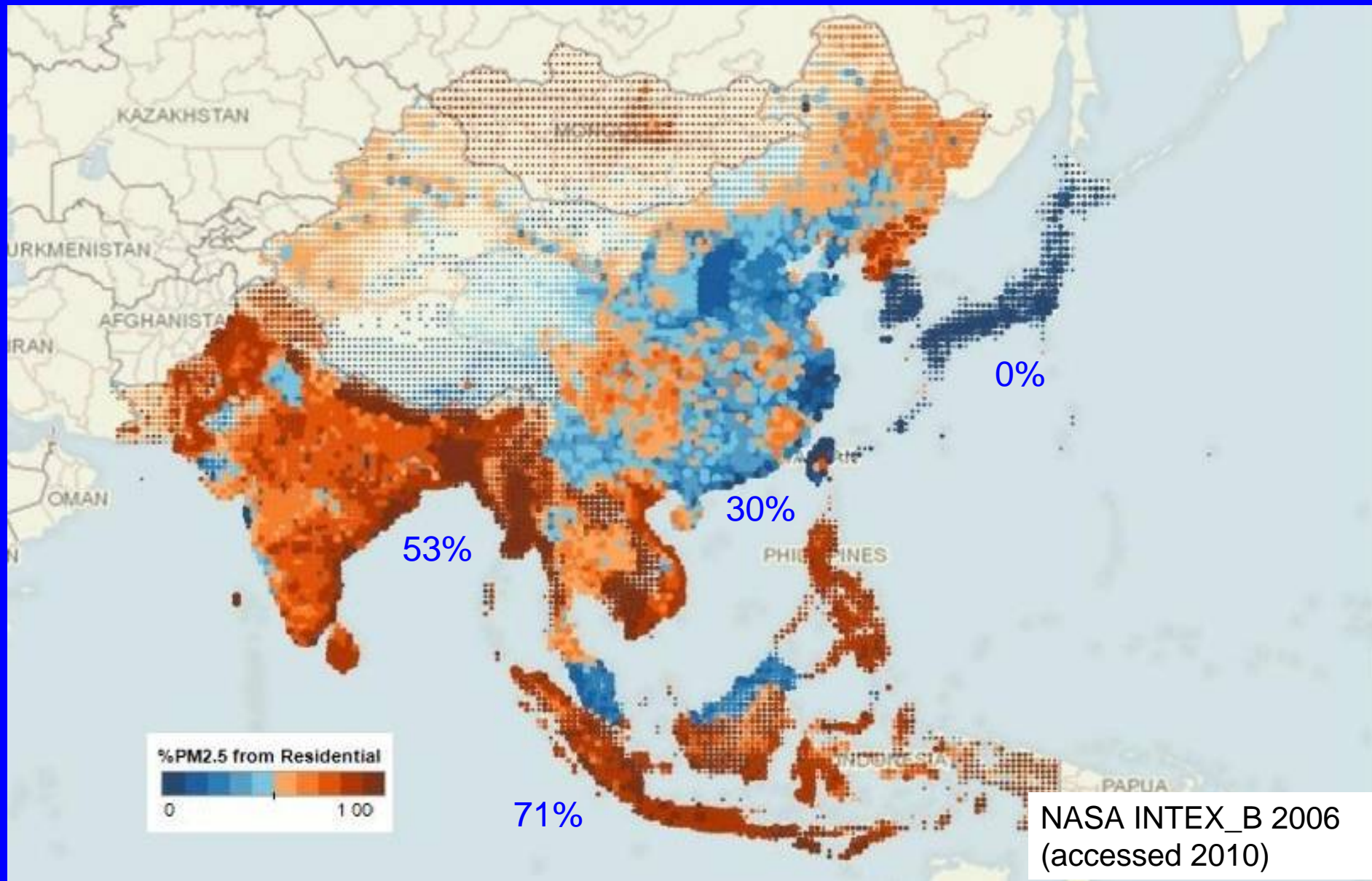
Sources of Primary PM_{2.5}: India and China

Source: GAINS-China and GAINS-South Asia (2010)

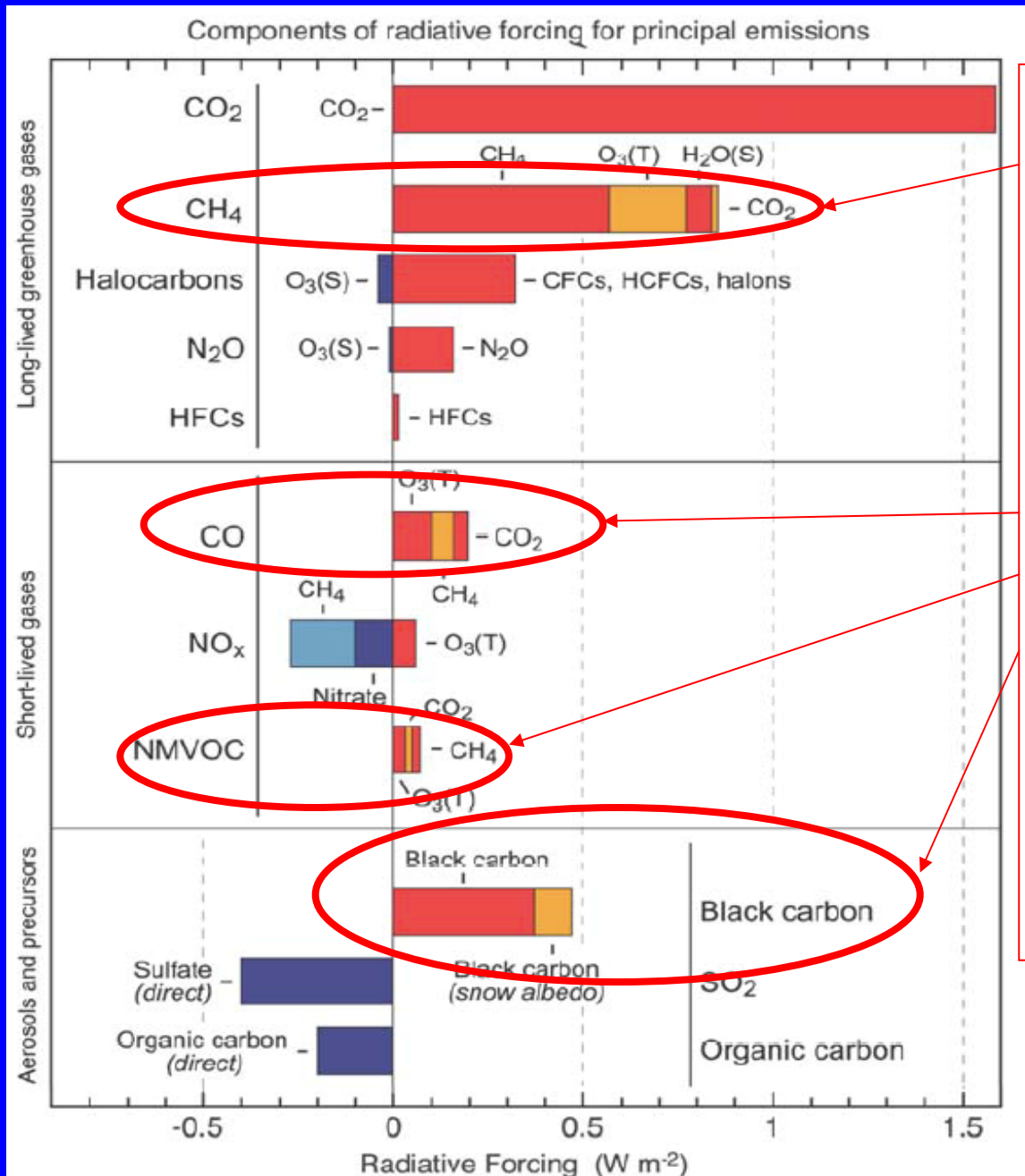


NASA INTEX_B Database

Percent PM_{2.5} emissions from households

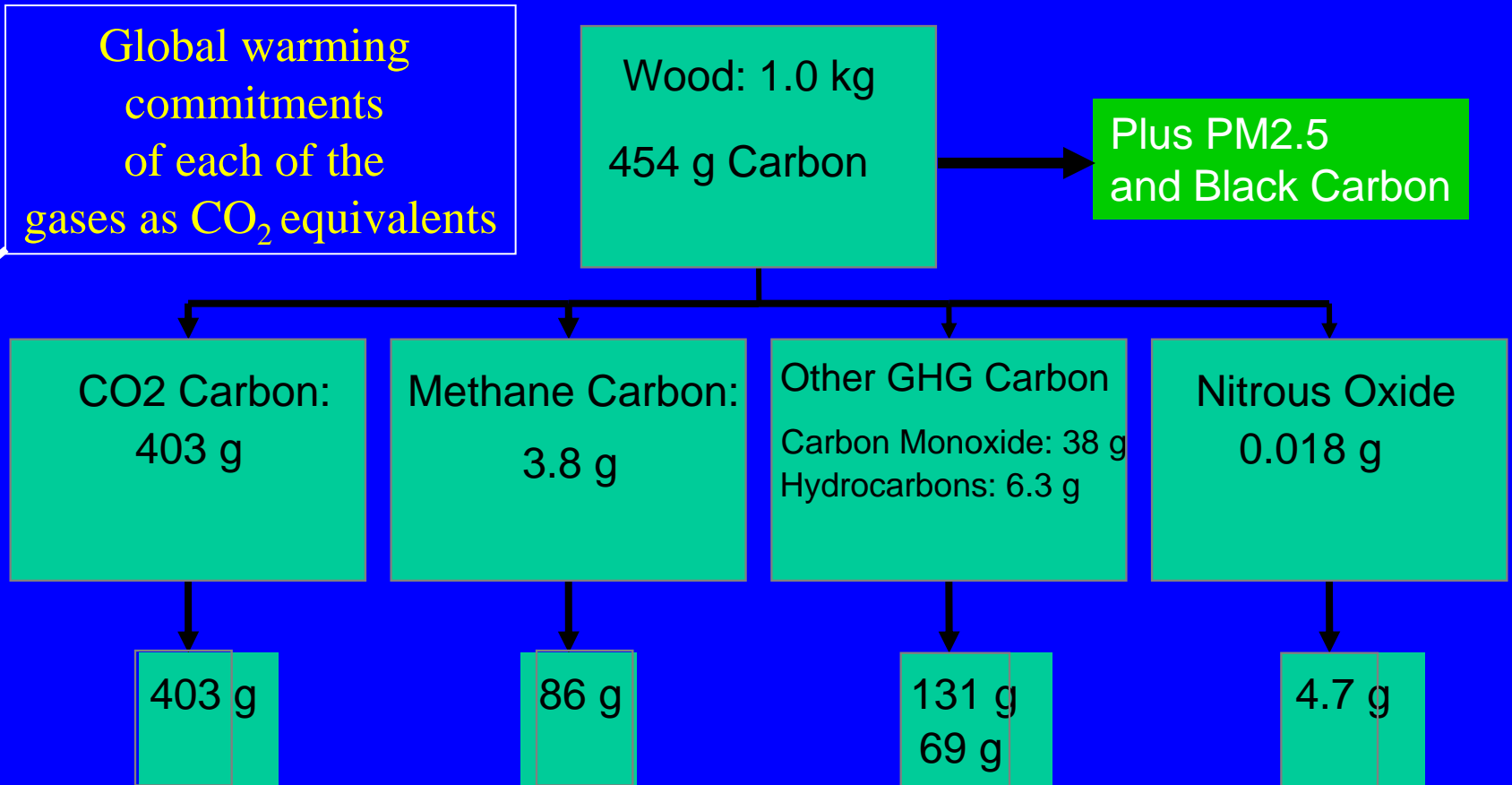


Global warming in 2005 due to all human emissions since 1750



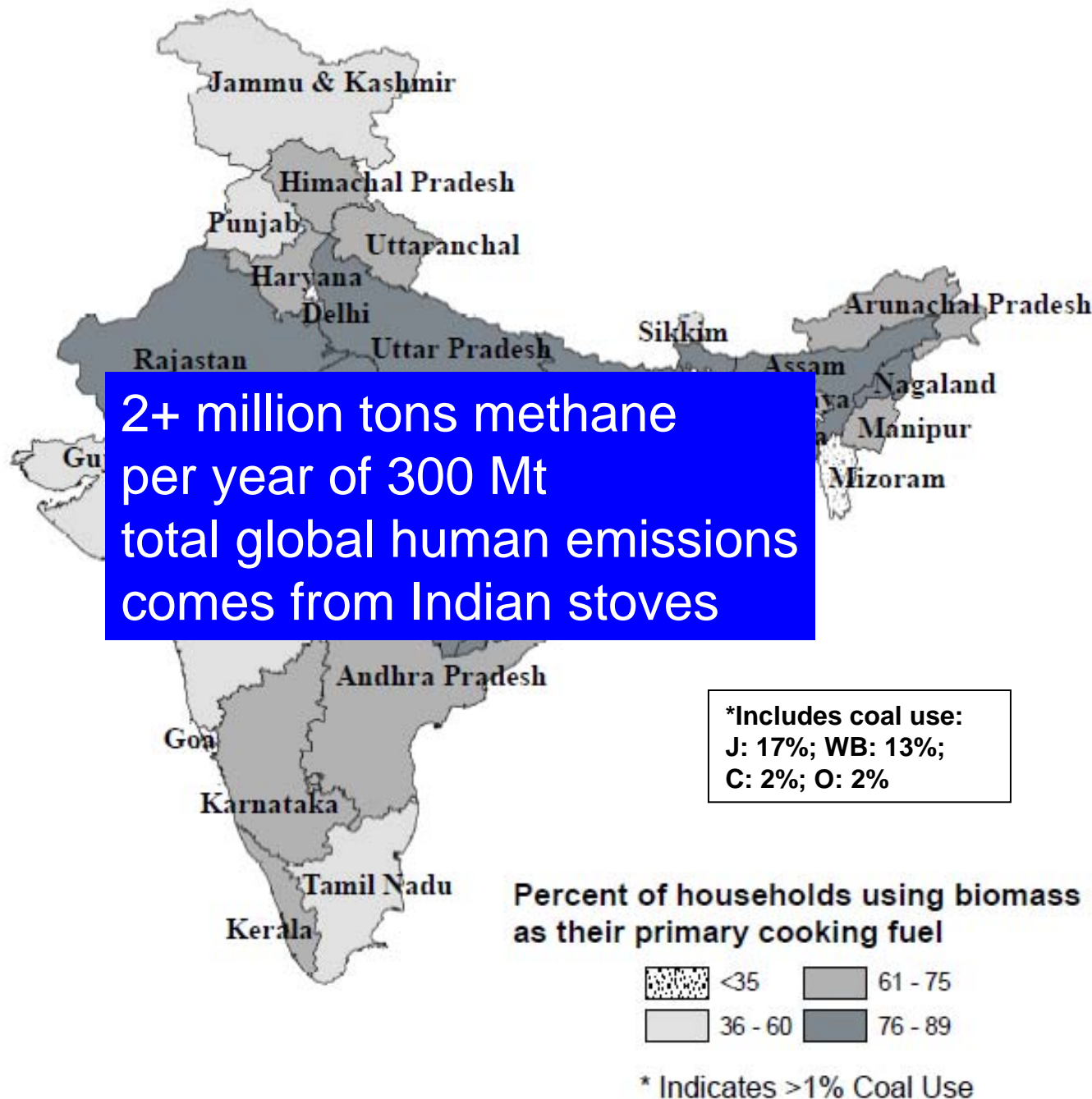
CO_2 is important for climate, but so are many other pollutants, including the ones circled that, unlike CO_2 , also have significant health as well as climate impacts. All of these are products of incomplete combustion, in some cases the only source

Greenhouse warming commitment per meal for typical biomass-fired cookstove in China



India in 2005

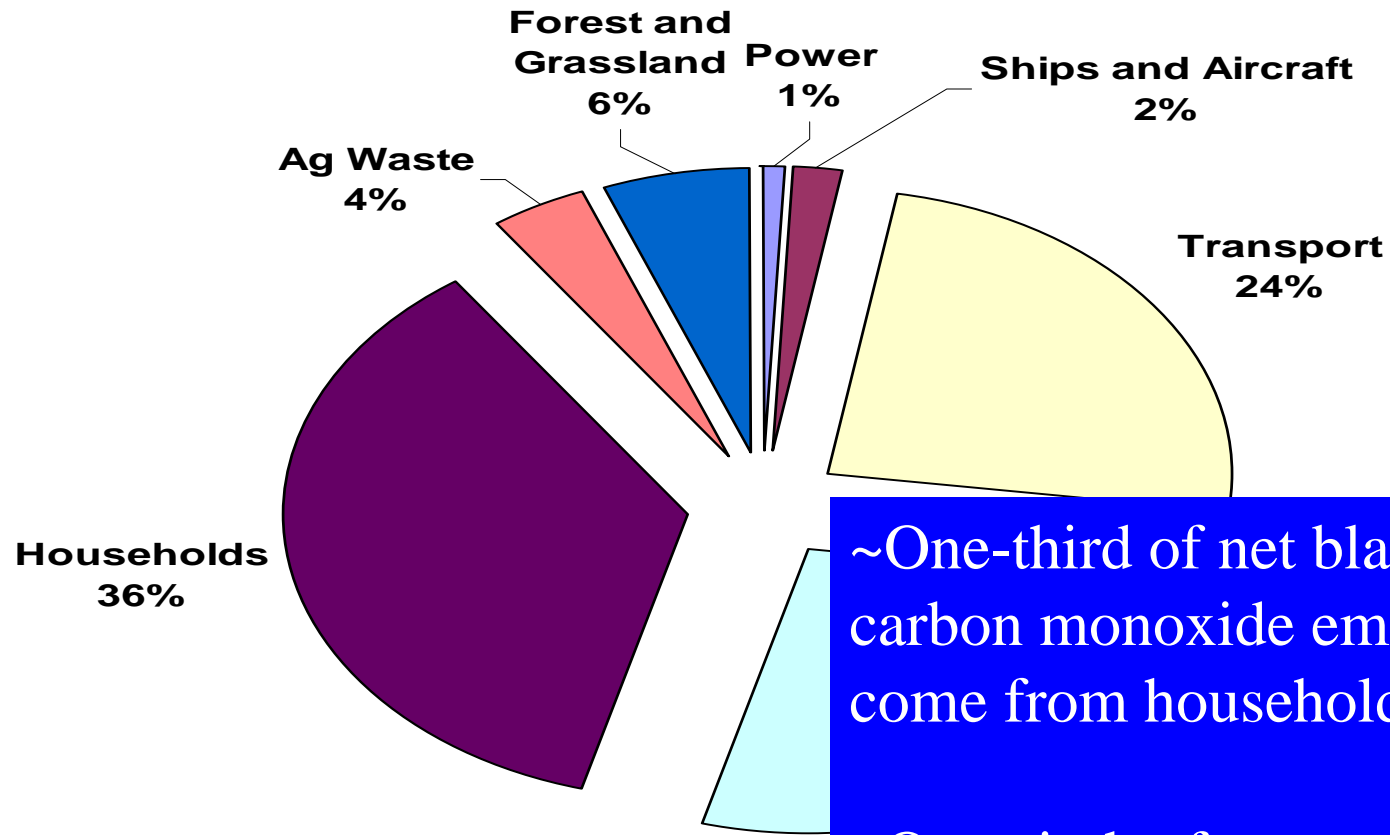
2+ million tons methane
per year of 300 Mt
total global human emissions
comes from Indian stoves



Venkataraman
et al. 2010

Controllable Global Warming from Black Carbon Emissions

Net of OC, Forcings from IPCC, 2007: 0.25 W/m^2
Inventory from T Bond Database, V 7.1.1 Feb 2009

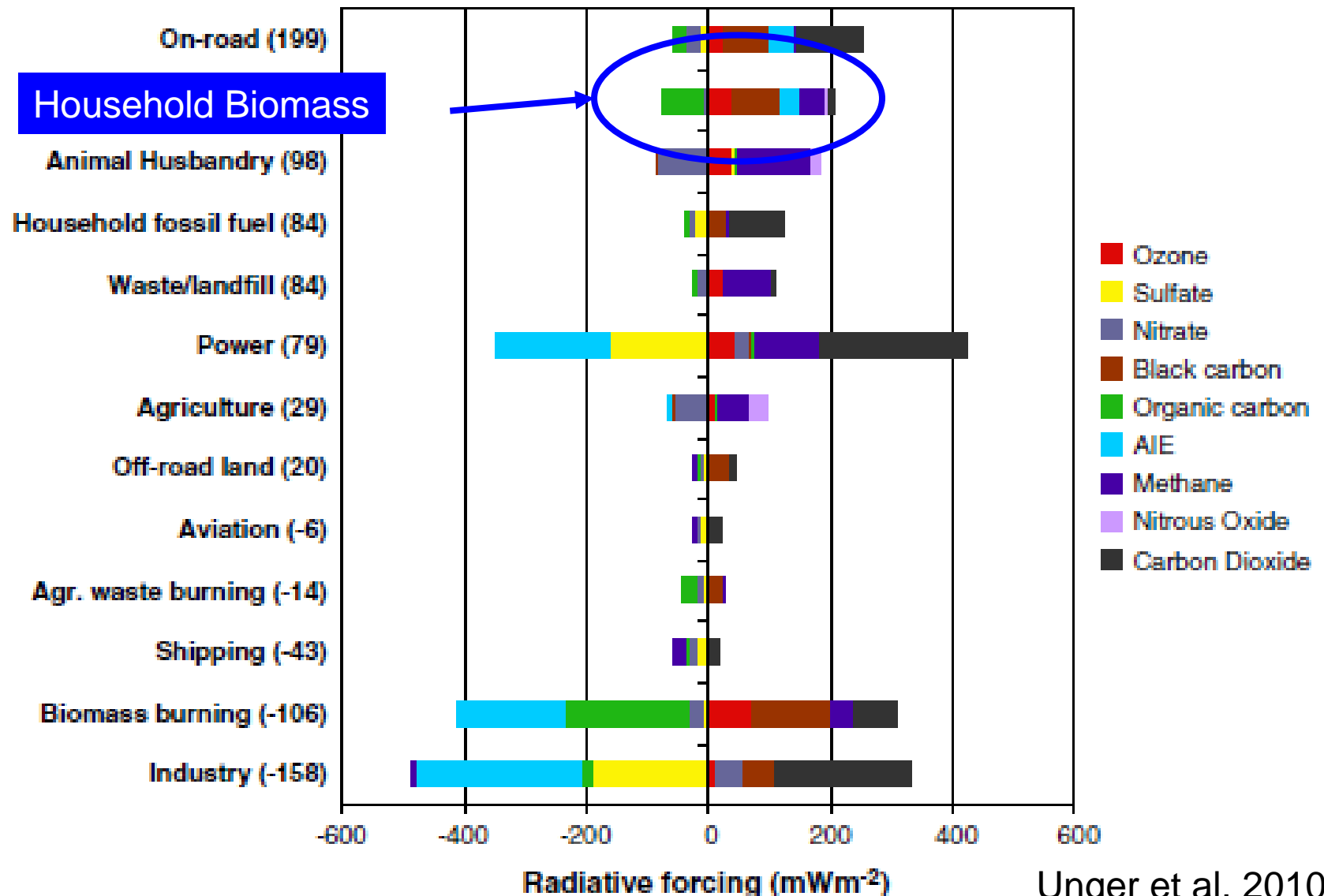


~One-third of net black carbon and carbon monoxide emissions globally come from household fuels

~One-sixth of ozone causing pollution

~One-twentieth of methane

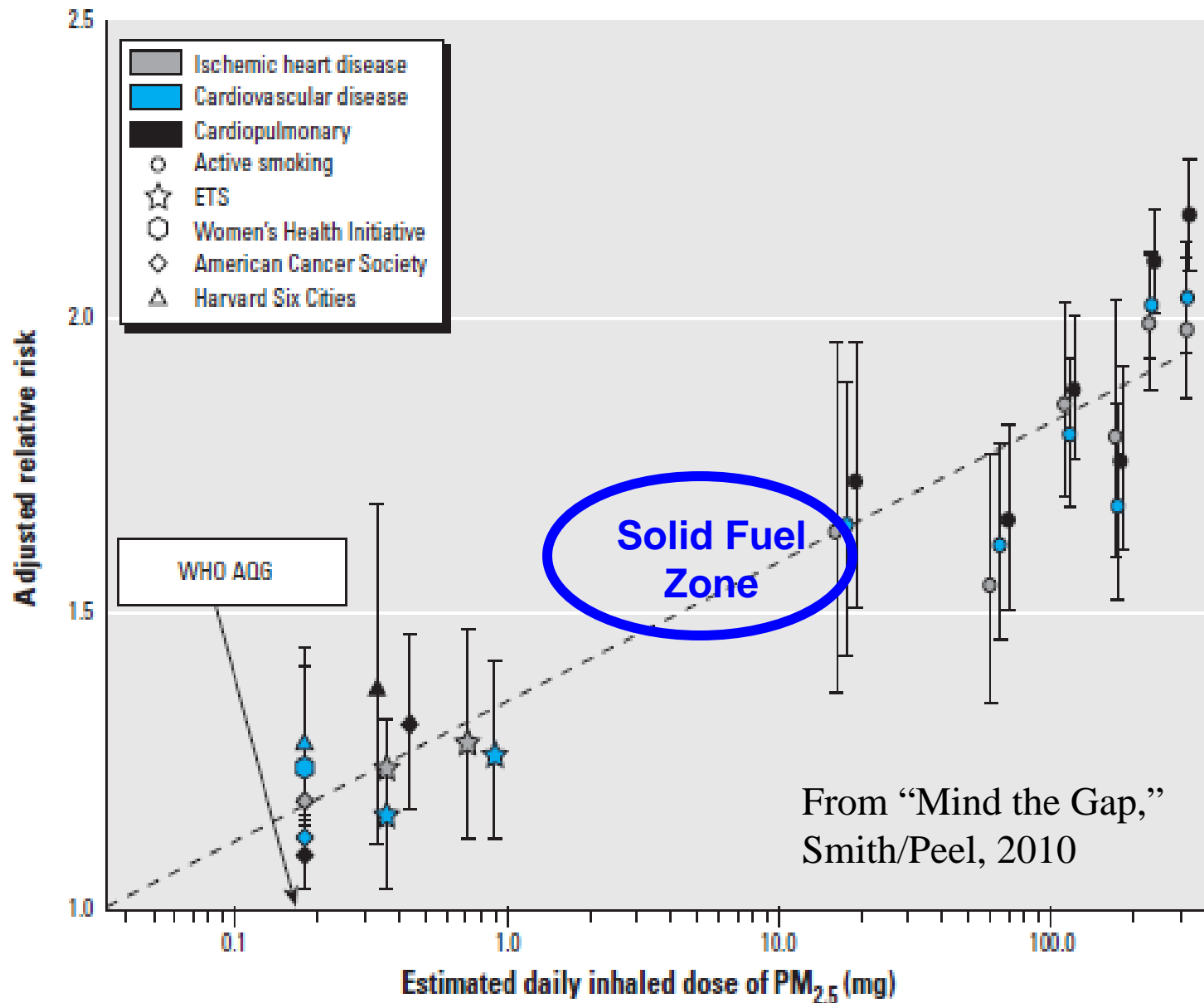
Climate Warming in 2020 Under Present Trends



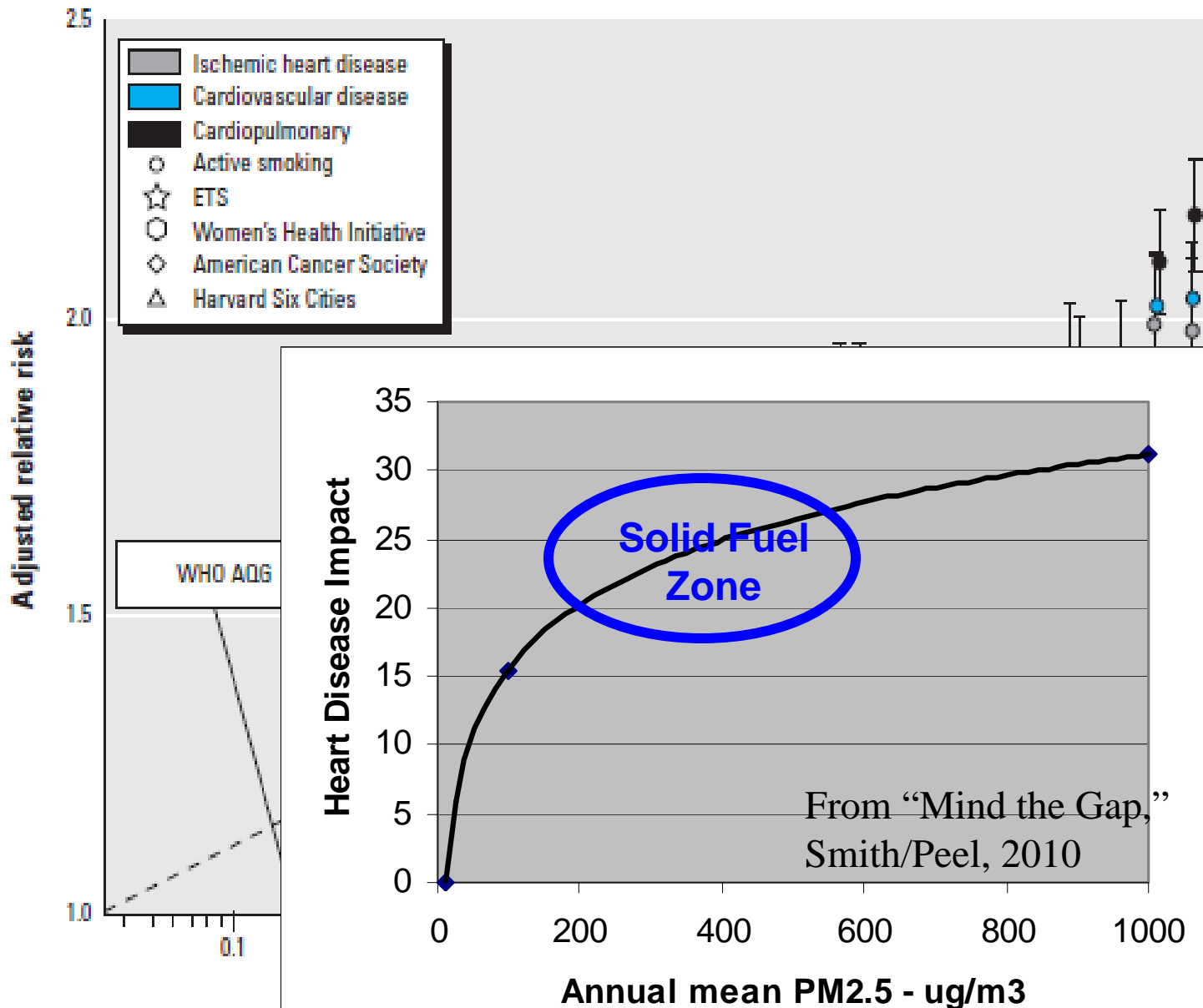
Household Fuels and Climate

- Climate impacts come from non-renewable wood, i.e., from net CO₂ emissions due to deforestation
- Poor combustion also leads to other emissions such as the relatively well-understood GHGs – methane and nitrous oxide – which are “Kyoto” GHGs
- In addition, a wide range of less well-understood short-lived GH-related emissions are emitted including
 - CO and black carbon – warming agents
 - Ozone precursors – warming But also cooling agents such as sulfates and organic carbon particles
- There are also indirect climate impacts of these pollutants including
 - Reducing carbon capture of forests by ozone damage
 - Darkening of snow/ice by black carbon

Heart Disease and Combustion Particle Doses



Heart Disease and Combustion Particle Doses



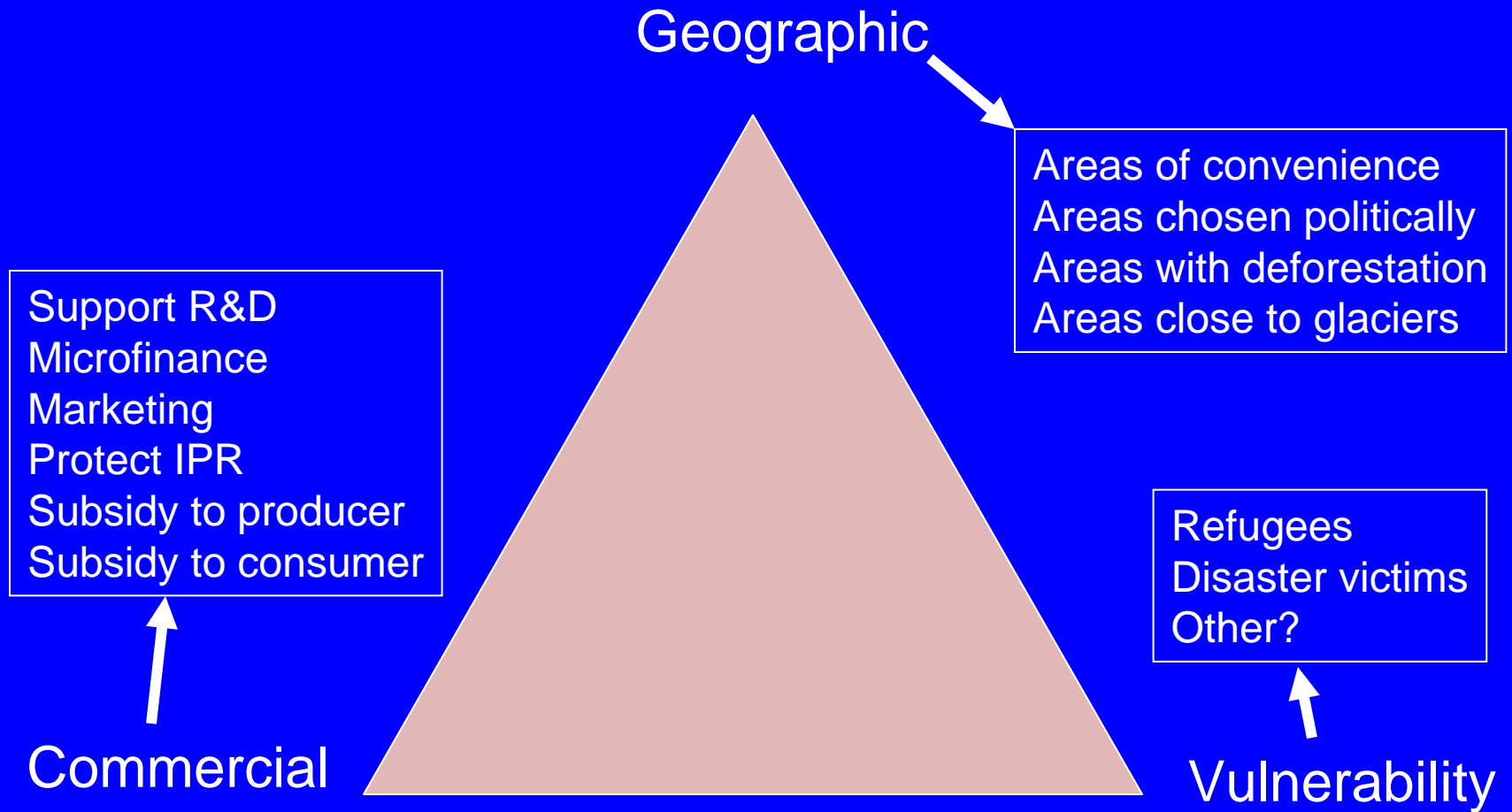
Indian National Biomass Cookstove Initiative (NCI)

- **Saran Criterion: “Our aim is to achieve the quality of energy services from cookstoves [for all Indian households] comparable to that from other clean energy sources such as LPG.”** Dec 2, 2009
- Major innovations to be encouraged in technology, dissemination modes, and M&E – global innovation prizes and perhaps guaranteed sales – X Prize Foundation with MNRE and IITD
- Government backup of private sector in terms of testing, standards, benchmarks, smart subsidies, etc.
- Development of an “Indian Cooking Cycle” for testing
- Work on biomass processing and institutional stoves
- Role for public sector for reaching vulnerable groups

XPF/GOI/IITD Innovation Prize

- Global – engage combustion engineering labs everywhere
- Perhaps not for stove *per se* – stove is phenotype
- Perhaps for combustion unit – with common dimensions that can be used locally to create stoves that fit local needs
- Very low emissions, very long lifetime, and reasonable cost – a serious challenge

Modes of Dissemination

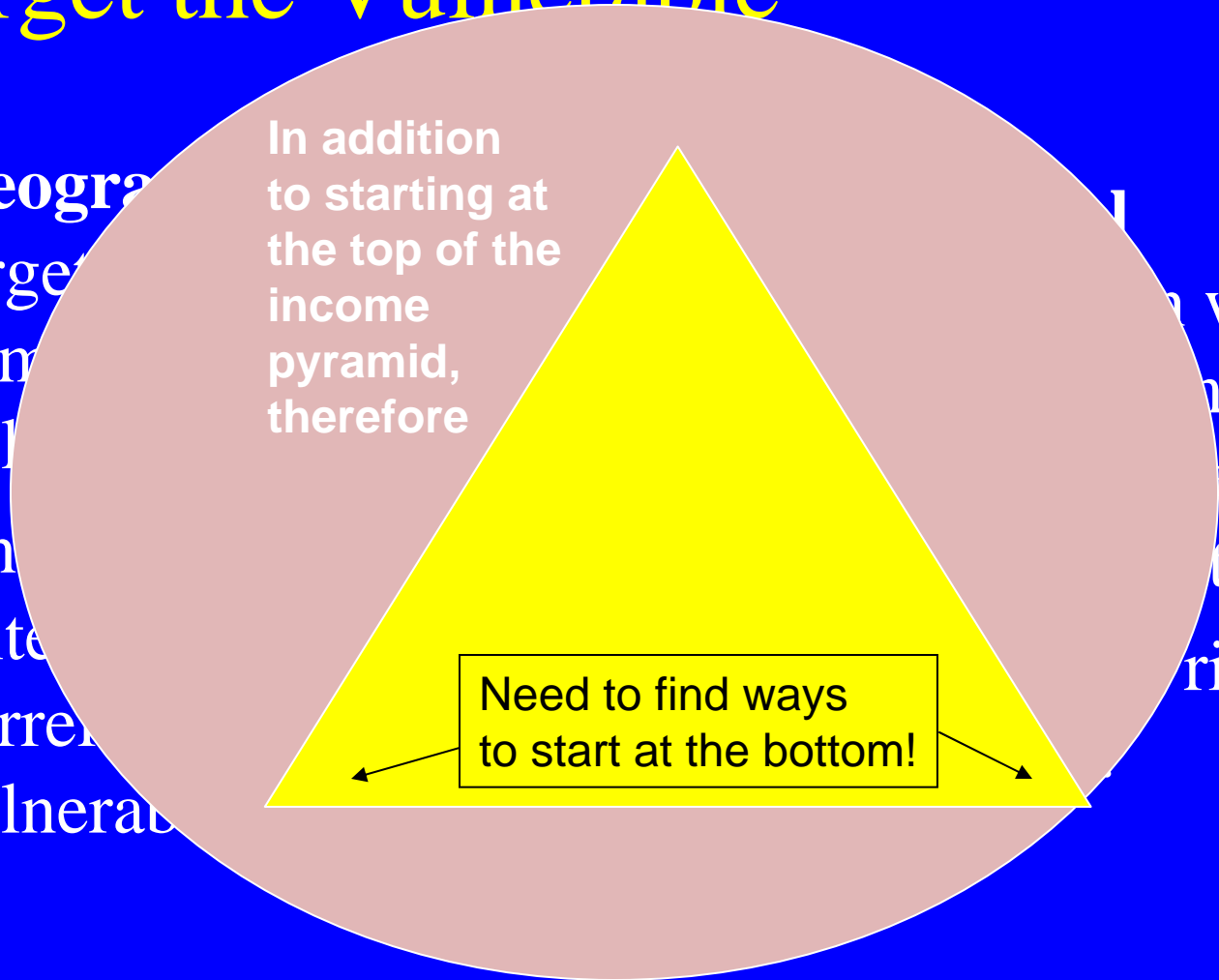


Why Vulnerability?

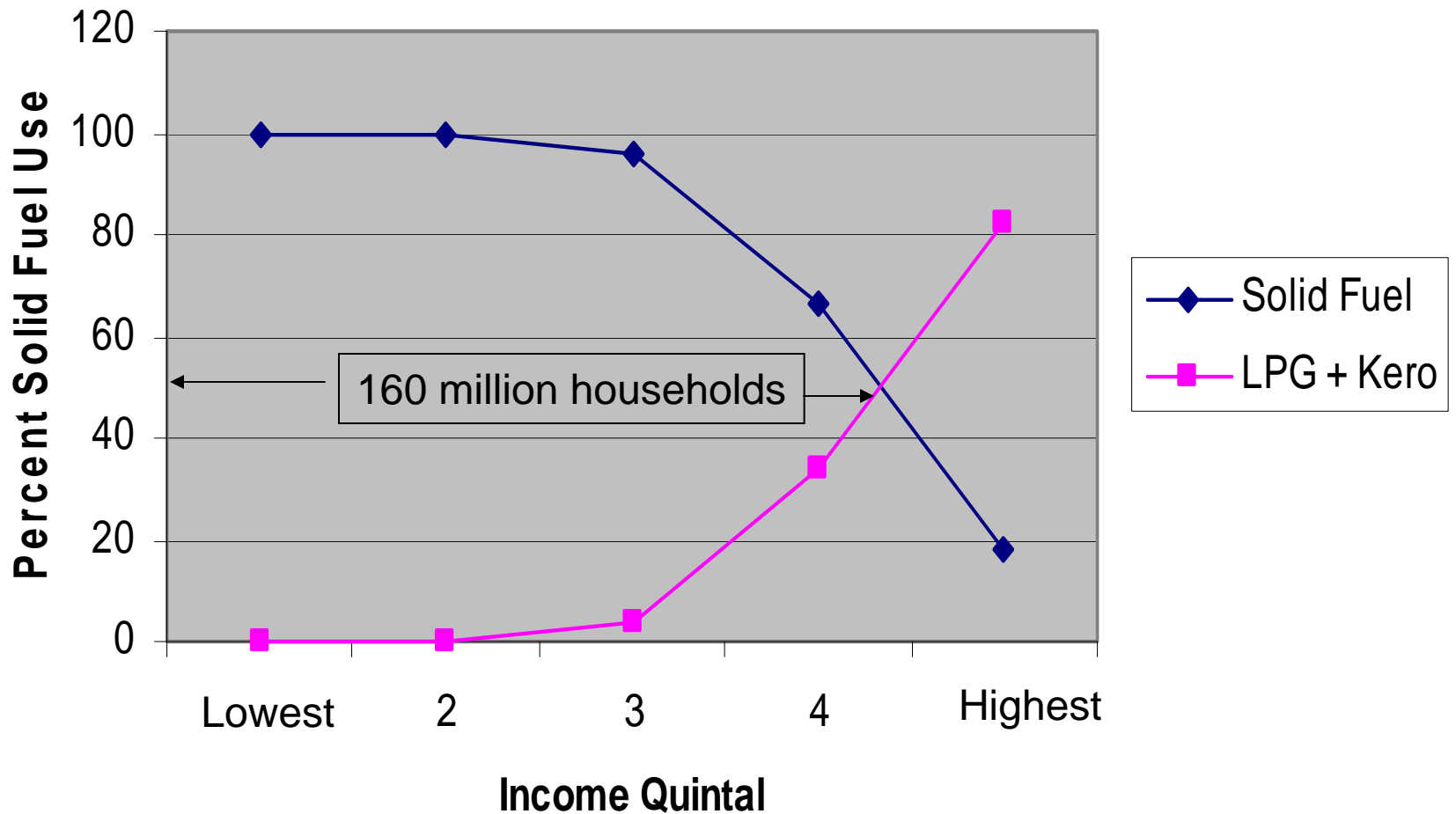
- Every house not the same for health impacts.
- Number of young children different
- Background disease rate different
- Interacting risk factors different, particularly poverty
- With limited resources, why not start with the most vulnerable first?

Alternative Approaches Do Not Target the Vulnerable

- **Geographic** targeting starts with the most vulnerable, but then moves to the most educated and rich, therefore
- **Any** criterion for targeting the vulnerable is flawed



Distribution of Household Cooking Fuel by Income in India



**Rural Housing
Program**

**Rajiv Gandhi
Scheme –
rural electrification**

**Vulnerable populations
in India now being reached
by national programs**

**Women's
Literacy
Program**

**Antenatal
Care
System**

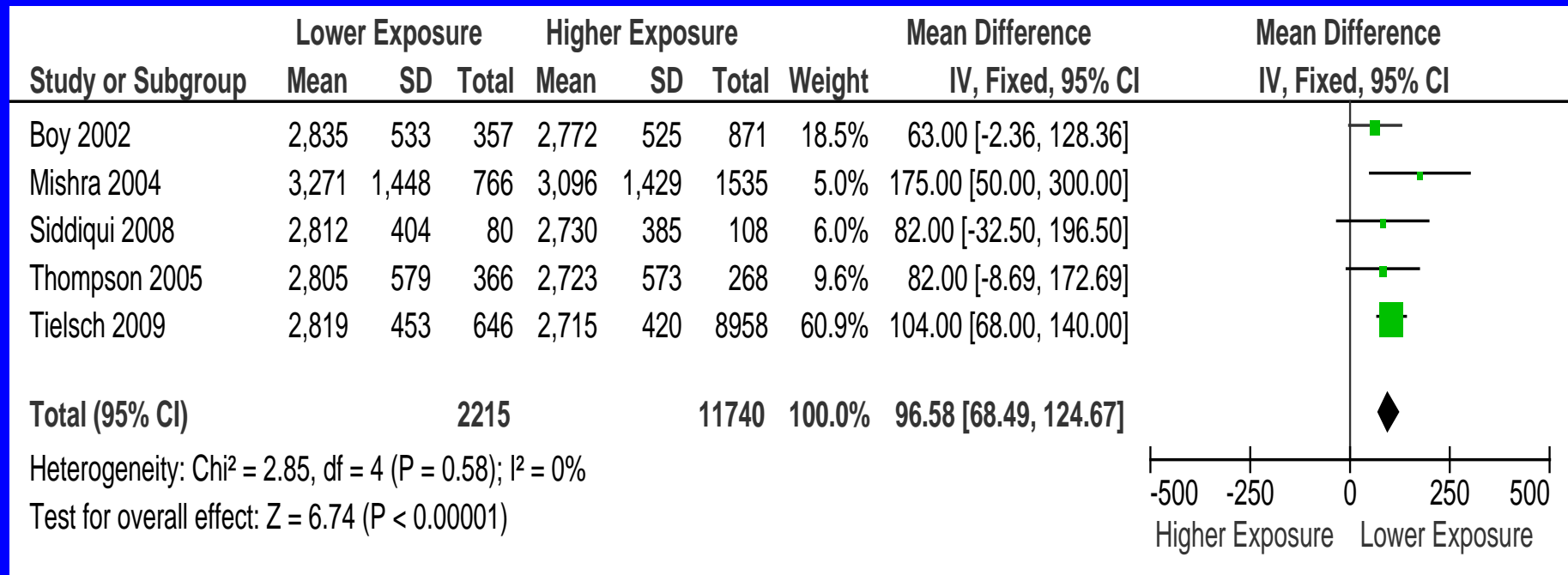
Antenatal Care System

- ANC centers run through public health system with village nurses and Asha workers
- Covered ~25% of all pregnancies in 2006 – risen since
- Coverage varies nationally, but highest coverage in poorest groups (middle income and rich go to doctors)
- In the stove world, there could be no more vulnerable group than pregnant women attending a public antenatal clinic.
- Targets vulnerable group without raising issues of equity

The Newborn Stove (NBS) Program

- Pregnant women going to public pre-natal clinics are among the most vulnerable groups
- Already in the system and receiving iron/FA tablets, hygiene/nutrition education, etc.
- Potential for dealing with neo-natal mortality, which is refractory partly because of lack of viable interventions at that age
- Feasibility studies being planned in Haryana for informing major NBS Trial

Birth weight difference (low minus high exposure) – analysis of studies



All estimates: +96.6g (68.5, 124.7)
Excluding self-reports +93.1g (64.6, 121.6)



SMALL, SMART, FAST, & CHEAP

monitoring devices for household energy & health

Ajay Pillarisetti, Ilse Ruiz-Mercado, and Nick Lam on behalf of Prof. Kirk R. Smith's Research Group at University of California, Berkeley
Visit obs.sph.berkeley.edu/krsmith for more information



STOVE USE MONITORS UTILIZATION

Time-of-use measuring devices allow more accurate estimations and objective definitions of usage patterns including cooking periods, meal times, and technology adoption rates.

Stove Use Monitors (SUMS) quantify utilization of cookstoves to improve estimates of personal exposure and environmental benefits related to household energy use. SUMS are based on commercially available, low-cost, small temperature loggers.



The stainless steel temperature sensors are the size of a coin and can record time, date, and temperature. Programming and downloading data can be easily performed in the field. They are easy to use, unobtrusive, waterproof and tamper-resistant. They come with algorithms and software to systematically assess stove use patterns.

Measurements of stove surface temperature can be used to test the effectiveness of behavioral interventions on stove use. Because they give precise, unbiased measures of a simple physical parameter, statistically reliable information is provided using smaller sample sizes than required for a household survey.

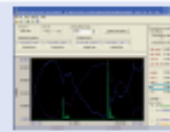
PARTICLE AND TEMP SENSOR CONCENTRATION

The ability to measure concentrations of small airborne particles is vital in understanding adverse health effects from combustion-derived air pollution. Available instrumentation to conduct such measurements is complex and expensive. Such devices are appropriate for developed countries and ambient air monitoring stations. However, their routine use in real-world household environments is expensive & cumbersome. Monitoring locations may also be remote, where security is questionable and electrical power not available, limiting the applicability of conventional instruments. In an effort to fulfill the needs for small, smart, fast, and cheap particle monitors that could be deployed easily in remote settings, a commercial smoke detector that uses optical scattering was identified and modified so that real-time signals could be logged continuously. This modified particle and temperature sensor is dubbed the UCB-PATS. Customized software handles data importing, graphing, and manipulation.

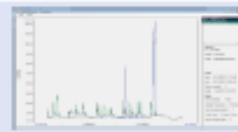


Device Software & Sample Output

Each device is controlled by software allowing equipment launch, data download and manipulation, and reporting of data files for further analysis. Devices connect with the software over a serial port or via an USB to Serial converter.

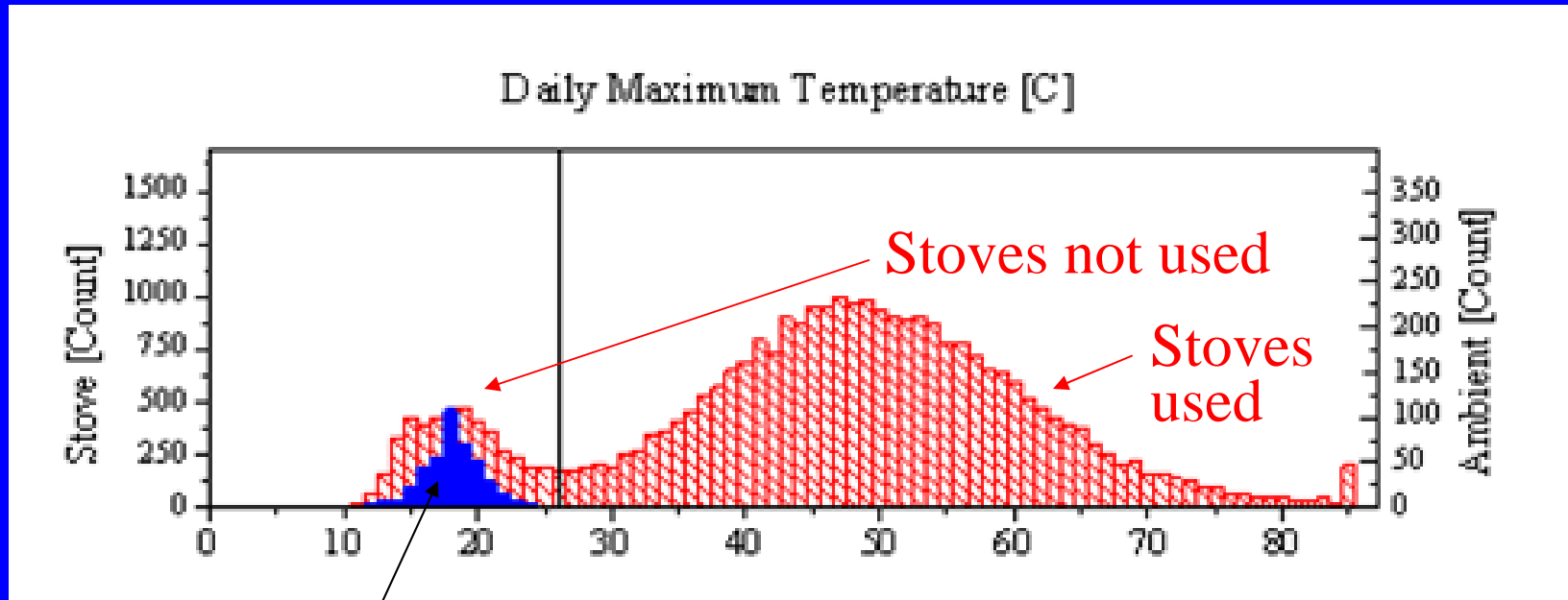


Working and processing downloaded data in the UCB-PATS data browser.



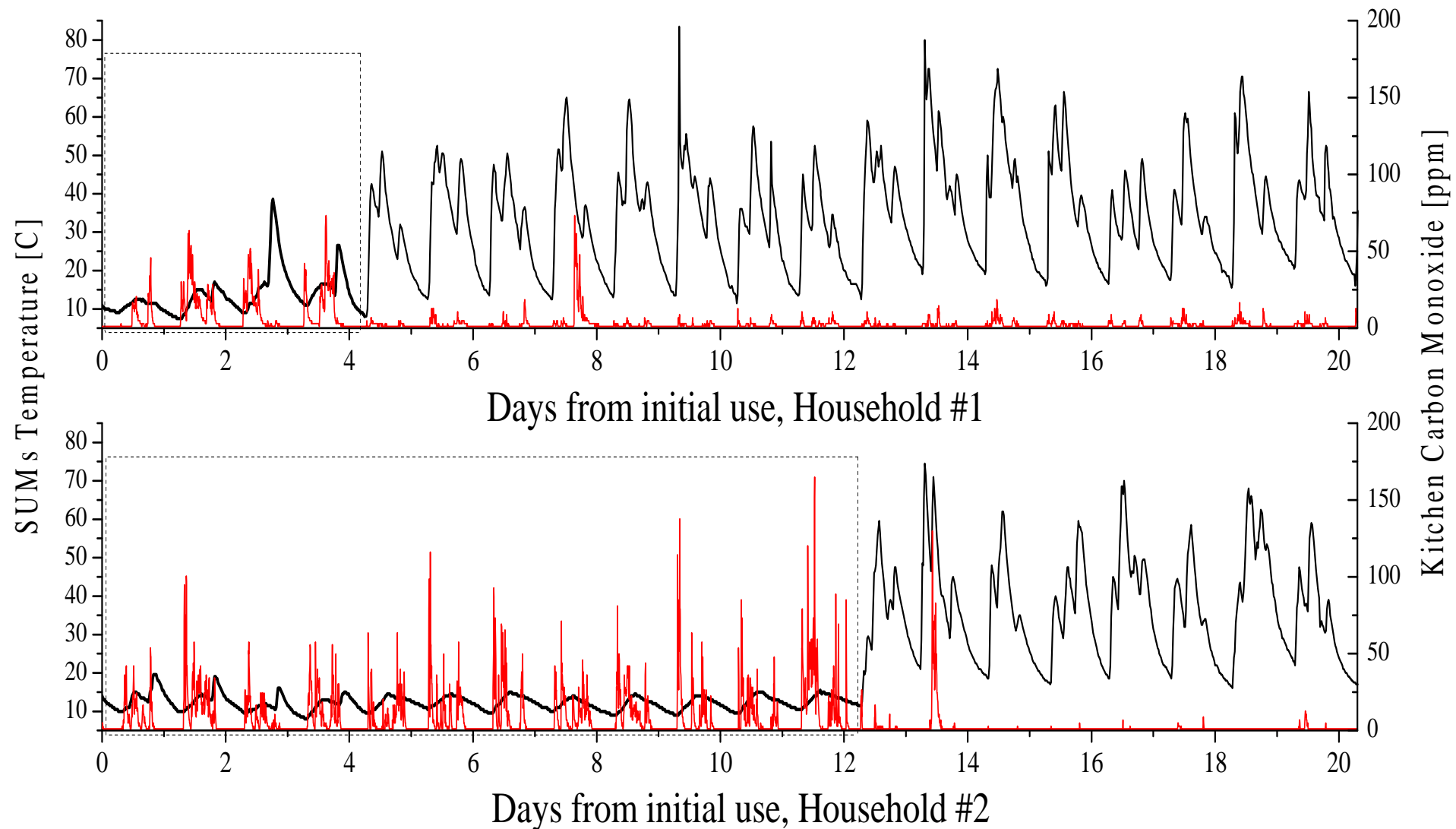
Stratified time of activity in Room 1003 - 1004, 1005, 1006, 1007, 1008, 1009, 1010, 1011, 1012, 1013, 1014, 1015, 1016, 1017, 1018, 1019, 1020, 1021, 1022, 1023, 1024, 1025, 1026, 1027, 1028, 1029, 1030, 1031, 1032, 1033, 1034, 1035, 1036, 1037, 1038, 1039, 1040, 1041, 1042, 1043, 1044, 1045, 1046, 1047, 1048, 1049, 1050, 1051, 1052, 1053, 1054, 1055, 1056, 1057, 1058, 1059, 1060, 1061, 1062, 1063, 1064, 1065, 1066, 1067, 1068, 1069, 1070, 1071, 1072, 1073, 1074, 1075, 1076, 1077, 1078, 1079, 1080, 1081, 1082, 1083, 1084, 1085, 1086, 1087, 1088, 1089, 1090, 1091, 1092, 1093, 1094, 1095, 1096, 1097, 1098, 1099, 1100, 1101, 1102, 1103, 1104, 1105, 1106, 1107, 1108, 1109, 1110, 1111, 1112, 1113, 1114, 1115, 1116, 1117, 1118, 1119, 1120, 1121, 1122, 1123, 1124, 1125, 1126, 1127, 1128, 1129, 1130, 1131, 1132, 1133, 1134, 1135, 1136, 1137, 1138, 1139, 1140, 1141, 1142, 1143, 1144, 1145, 1146, 1147, 1148, 1149, 1150, 1151, 1152, 1153, 1154, 1155, 1156, 1157, 1158, 1159, 1160, 1161, 1162, 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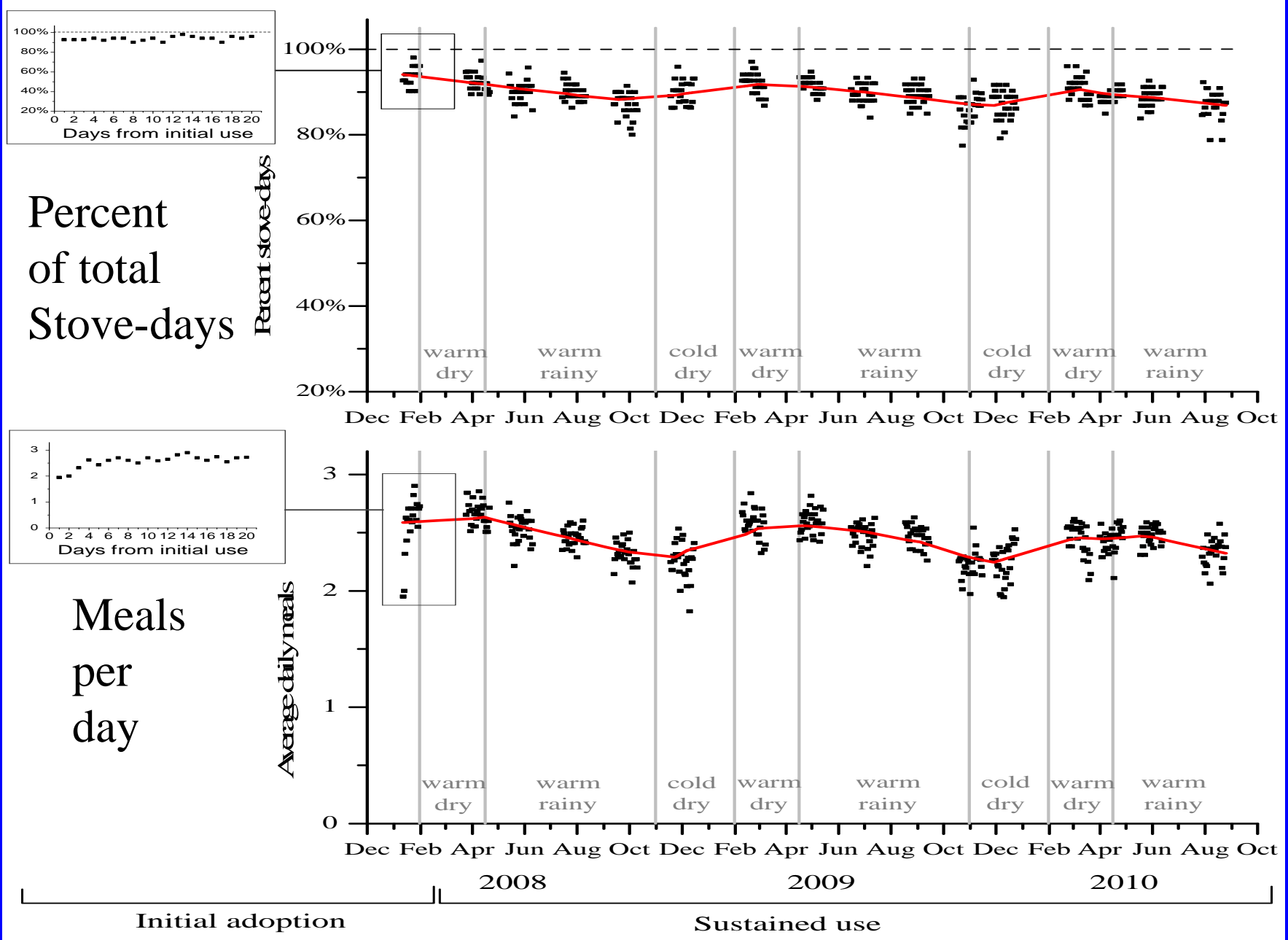
30,122 stove-days in 80 chimney stoves in the Guatemalan highlands



Ruiz et al, submitted

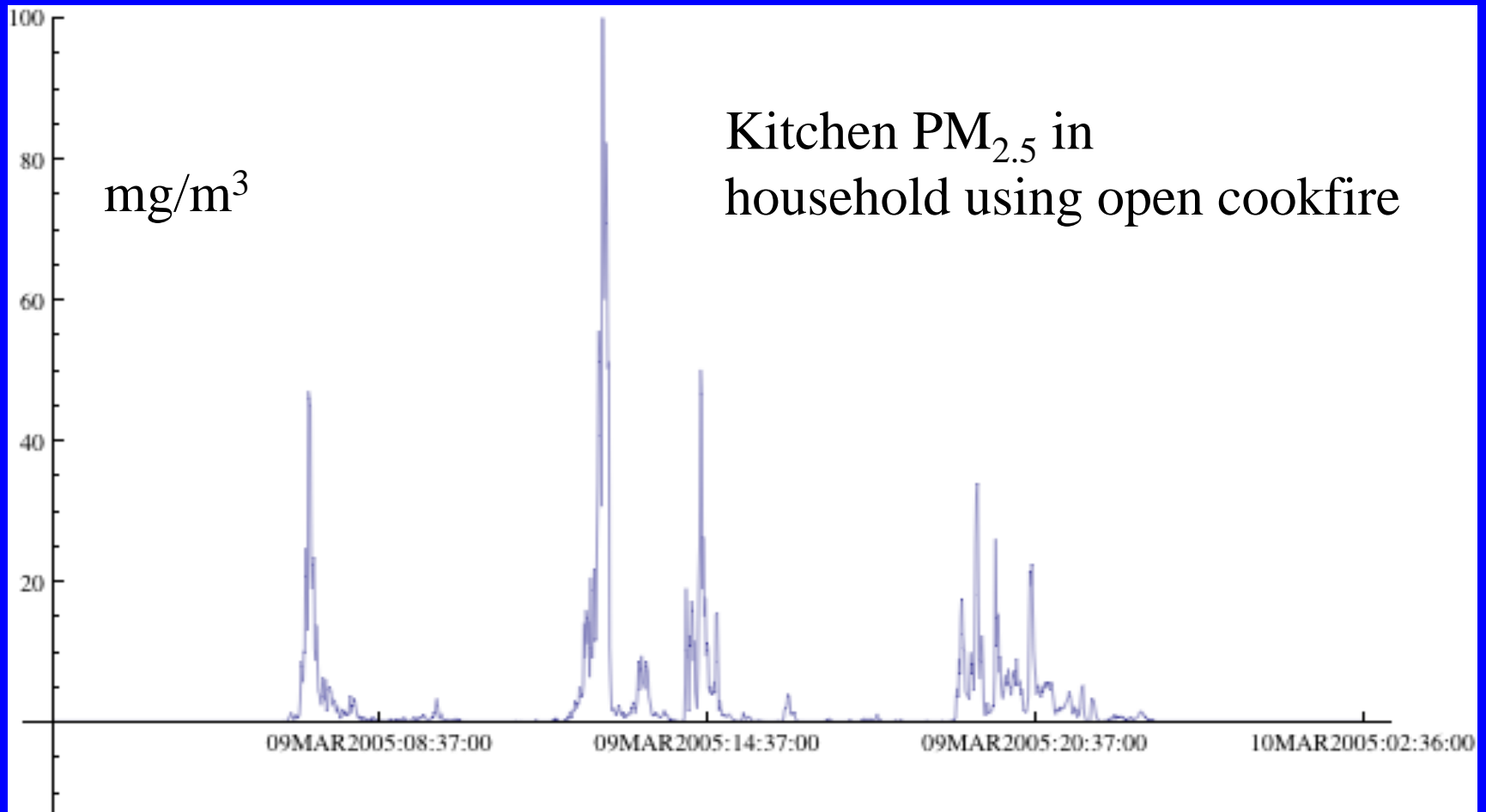
Stove Use Monitors (SUMs) in Action





UCB Particle Monitor

How many hours should we measure to obtain good estimate of the long-term mean?



Inter-instrument Comparison: 30 UCB-PATS

UCB Particle and Temperature Monitoring System (custom PM monitor using smoke alarm technology)

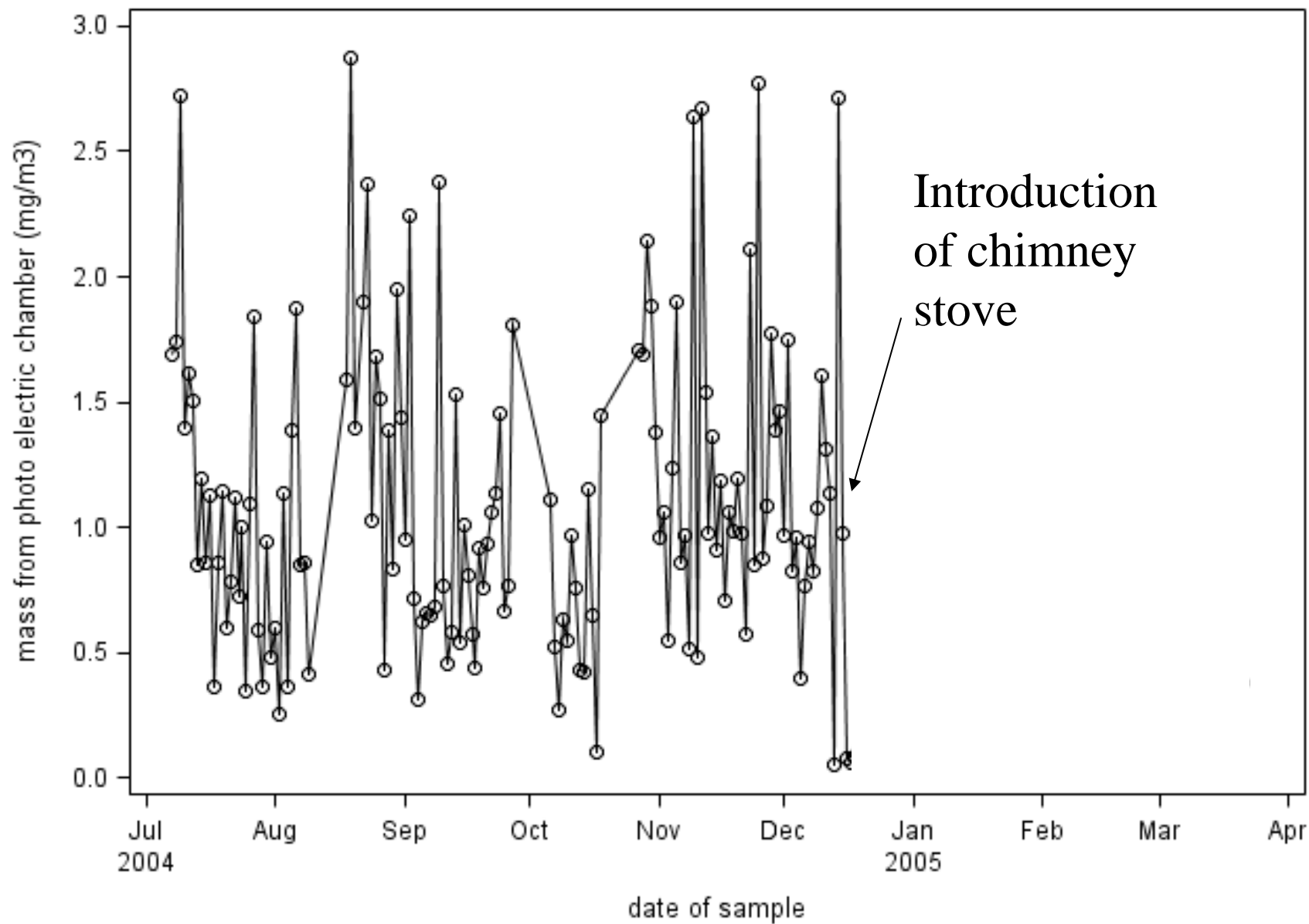


Lopez Kitchen
La Cienaga
Plancha with chimney

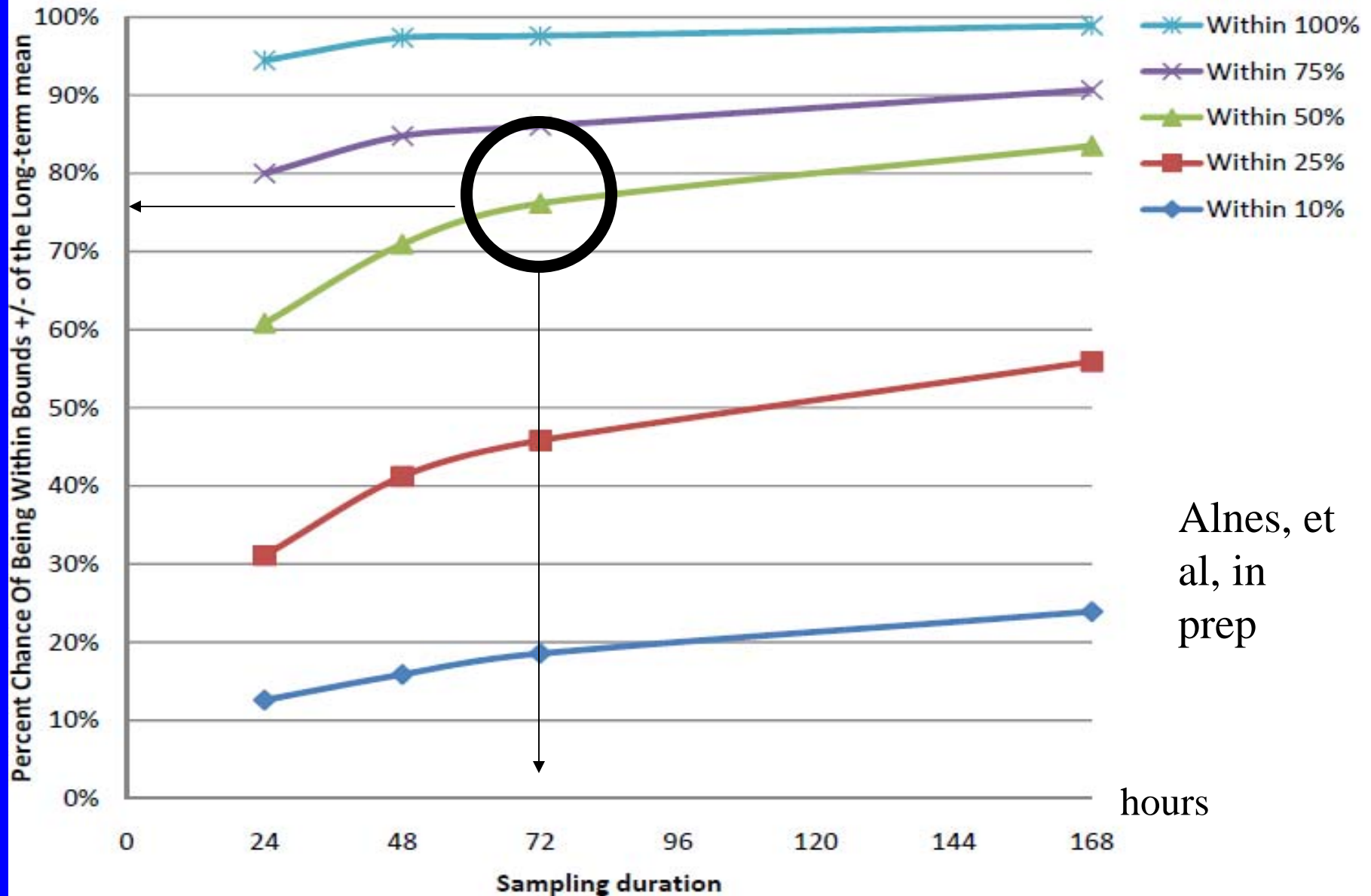
5 PM Sept 24 to 10 AM Sept 25, 2004.

Long-term Household Measurements

hhid=hh04041020



How Close to the True Mean With One Measurement?



Wood is the fuel that

- Heats you twice as is said?
 - Once when you chop it and
 - Once when you burn it
- Or four times?
 - The fever from respiratory infection and
 - Global warming
- Better combustion will get rid of the second pair

Many thanks

Publications and presentations available at my
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