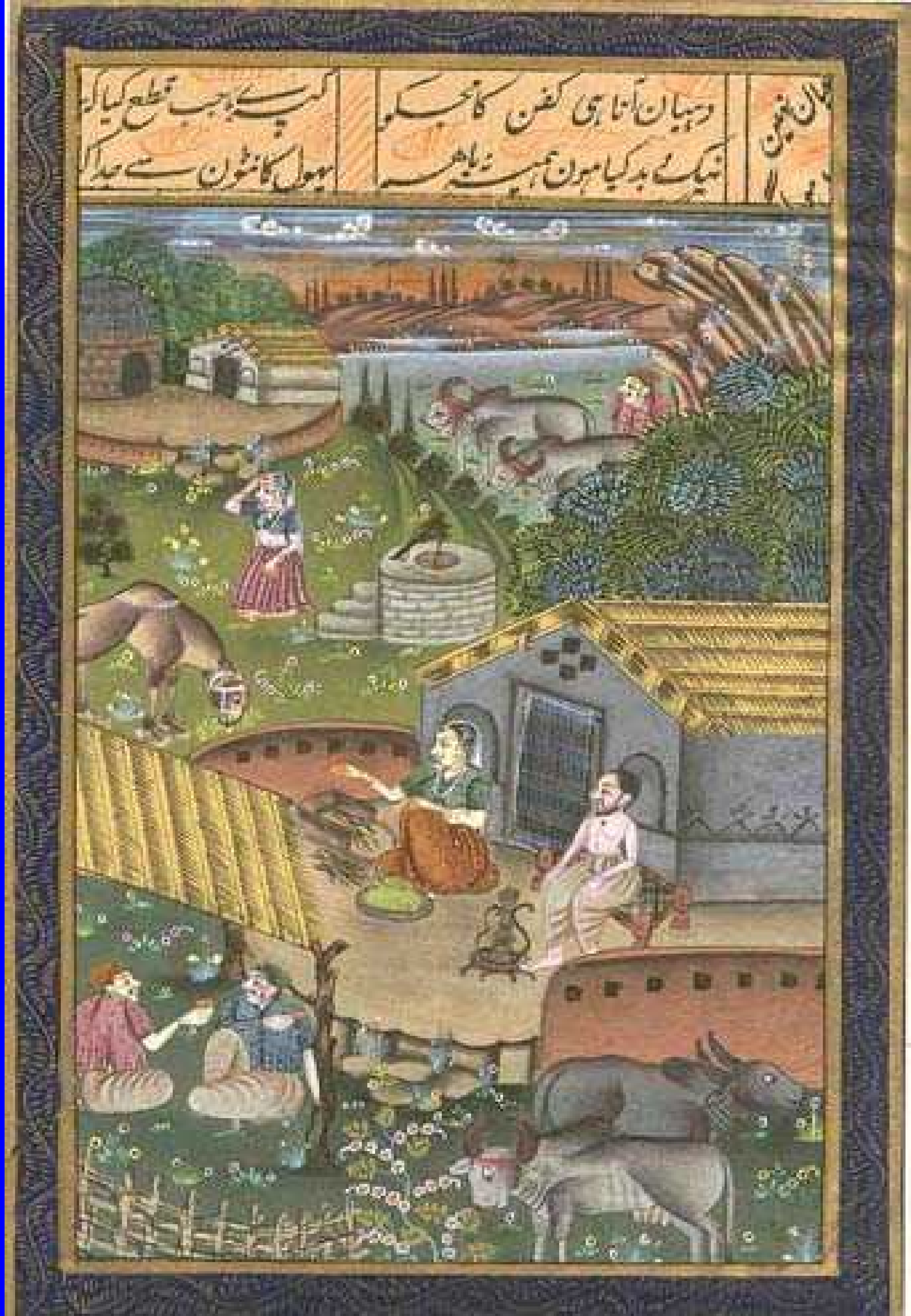
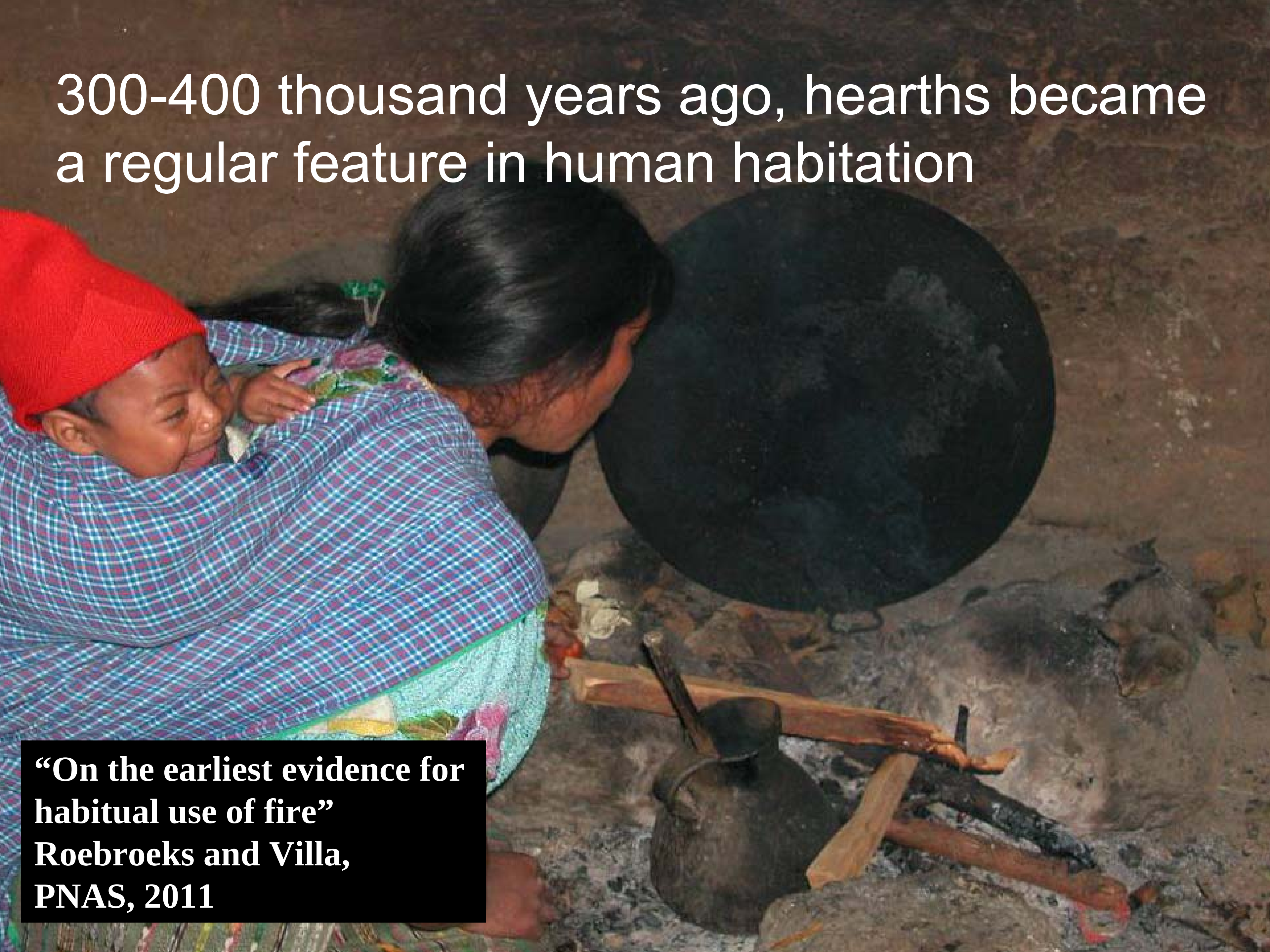
Household Air Pollution: the Scope of the Problem

The Health Impacts of Humanity's Oldest Occupation

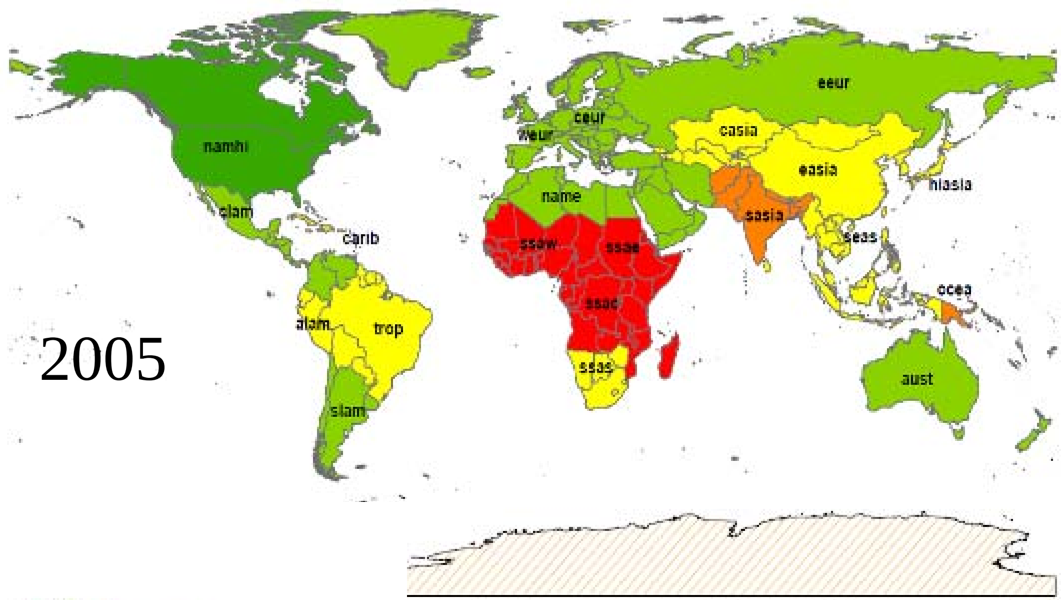
Kirk R. Smith
Professor of Global Environmental Health
University of California Berkeley

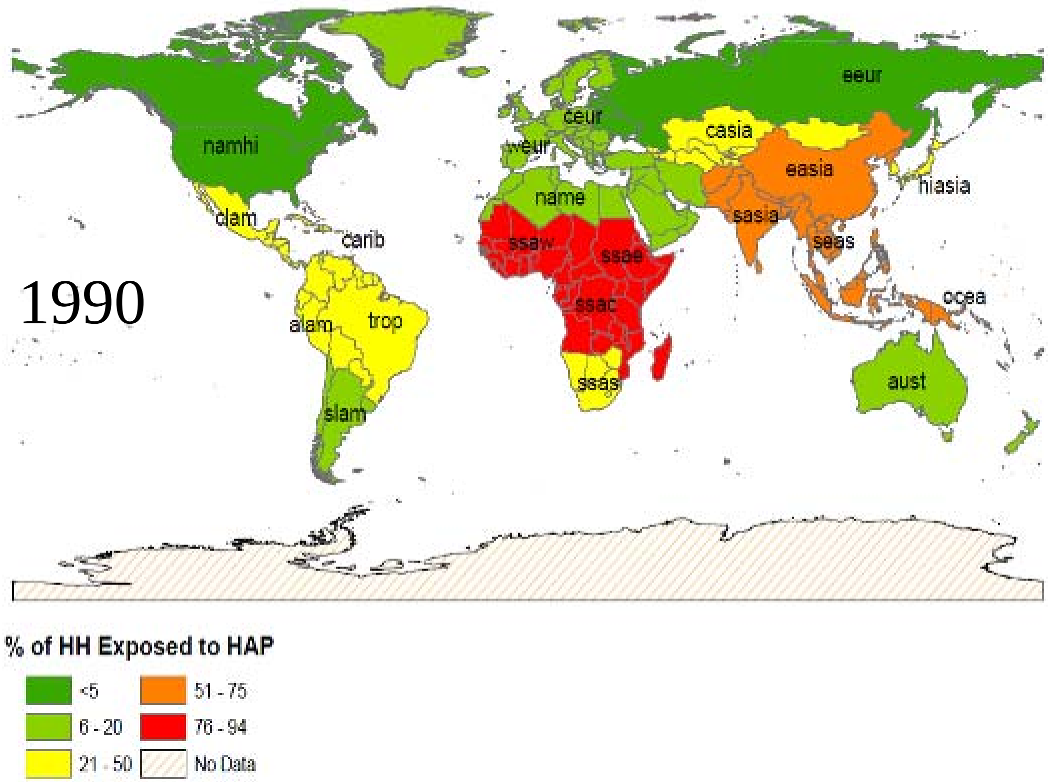
NIH Workshop on Indoor Air Pollution, Washington DC
May 10, 2011




300-400 thousand years ago, hearths became a regular feature in human habitation
“On the earliest evidence for habitual use of fire”
Roebroeks and Villa,
PNAS, 2011

Households using biomass or coal to cook





Comparative Risk Assessment (CRA) 2011- preliminary, Adair, et al.

Biomass Cooking in History

- **Only quite recently in human history did more than half of households use non-solid fuels for cooking – perhaps around 1980.**
- **Today, ~43% use solid fuels, about 3 billion people**
- **Although the percentage is dropping, the absolute number is still rising.**
- **Perhaps 20 million people a year are added to the total each year.**
- **Indeed, there are more people using solid fuels today for cooking than the total world population in 1950**
- **Or any year previously**

A problem that has lasted one-third of a million years and is showing no sign of quickly going away by itself.


The three major solid fuels

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

Into Pot	In PIC	Waste Heat
2.8 MJ	1.2 MJ	11.3 MJ
18%	8%	74%

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

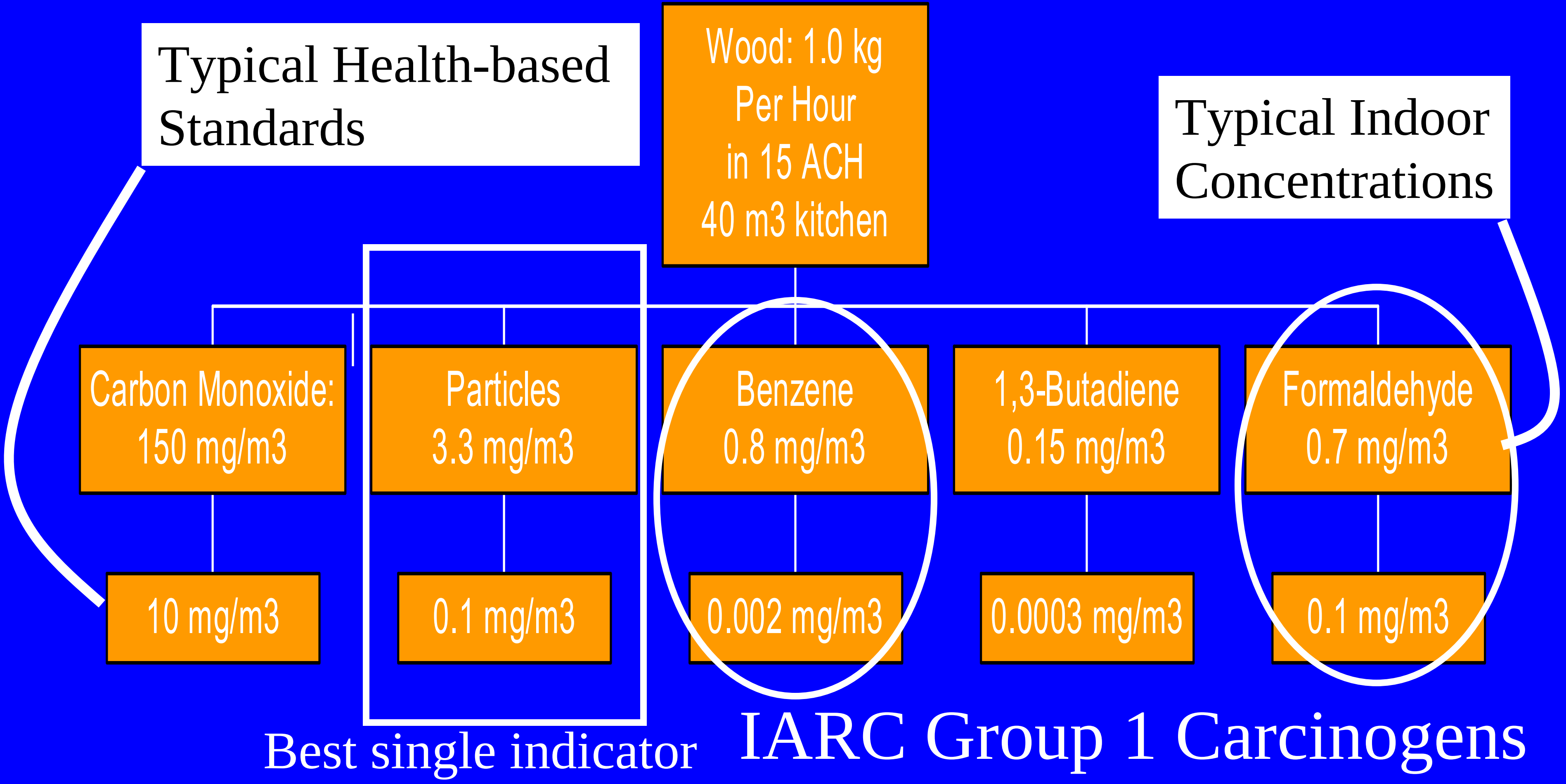
Source: Smith, et al., 2000

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

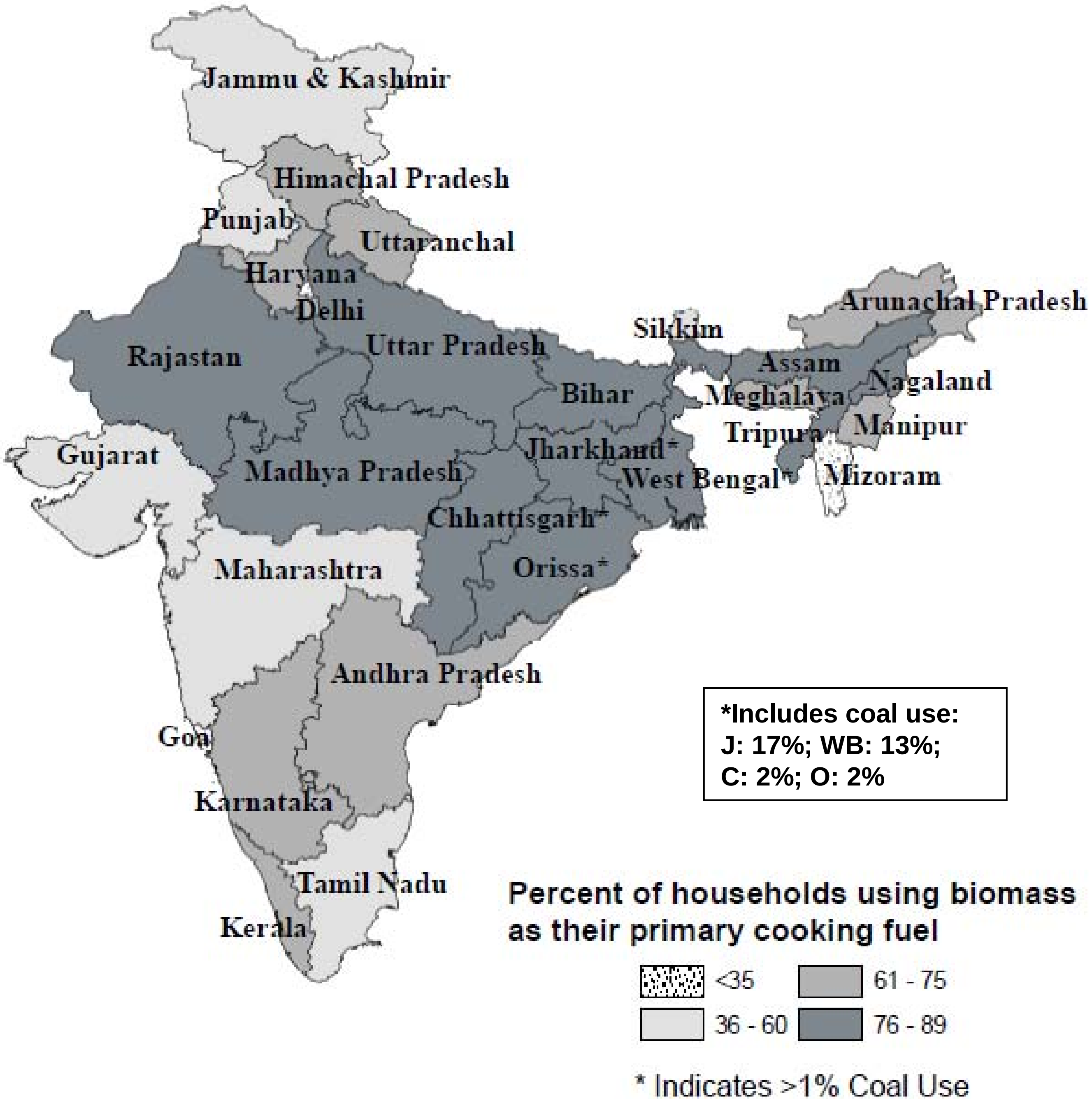
- Small particles, CO, NO_2
- Hydrocarbons
  - 25+ saturated hydrocarbons such as *n-hexane*
  - 40+ unsaturated hydrocarbons such as *1,3 butadiene*
  - 28+ mono-aromatics such as *benzene & styrene*
  - 20+ polycyclic aromatics such as *benzo(α)pyrene*
- Oxygenated organics
  - 20+ aldehydes including *formaldehyde* & *acrolein*
  - 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*

Source: Naeher et al, *J Inhal Tox*, 2007

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
How much exposure?
Kheda District, Gujarat, 1981

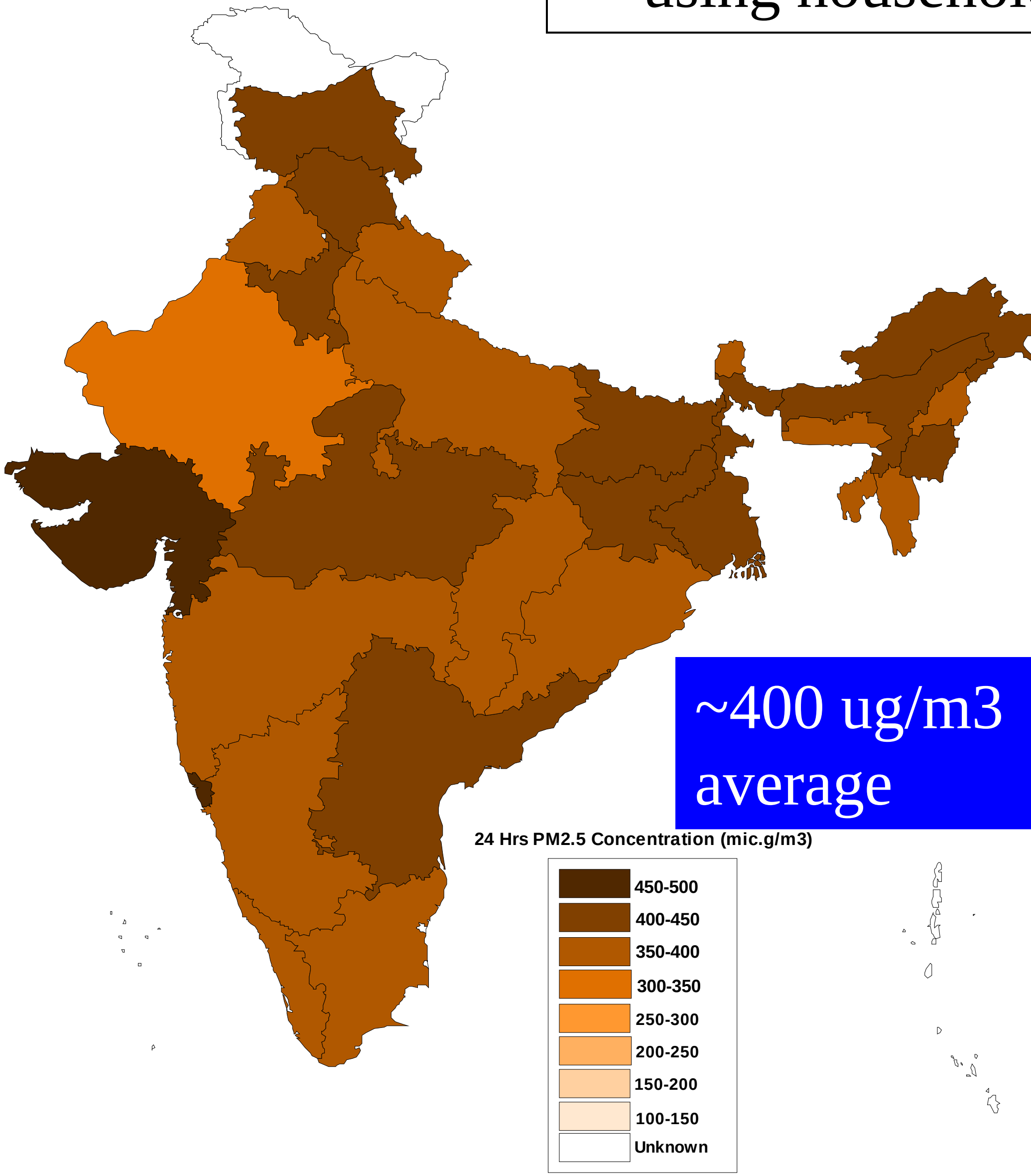


India in 2005

71% households use solid fuel for cooking

Venkataraman et al. 2010

Estimated PM2.5 for solid fuel using households in India



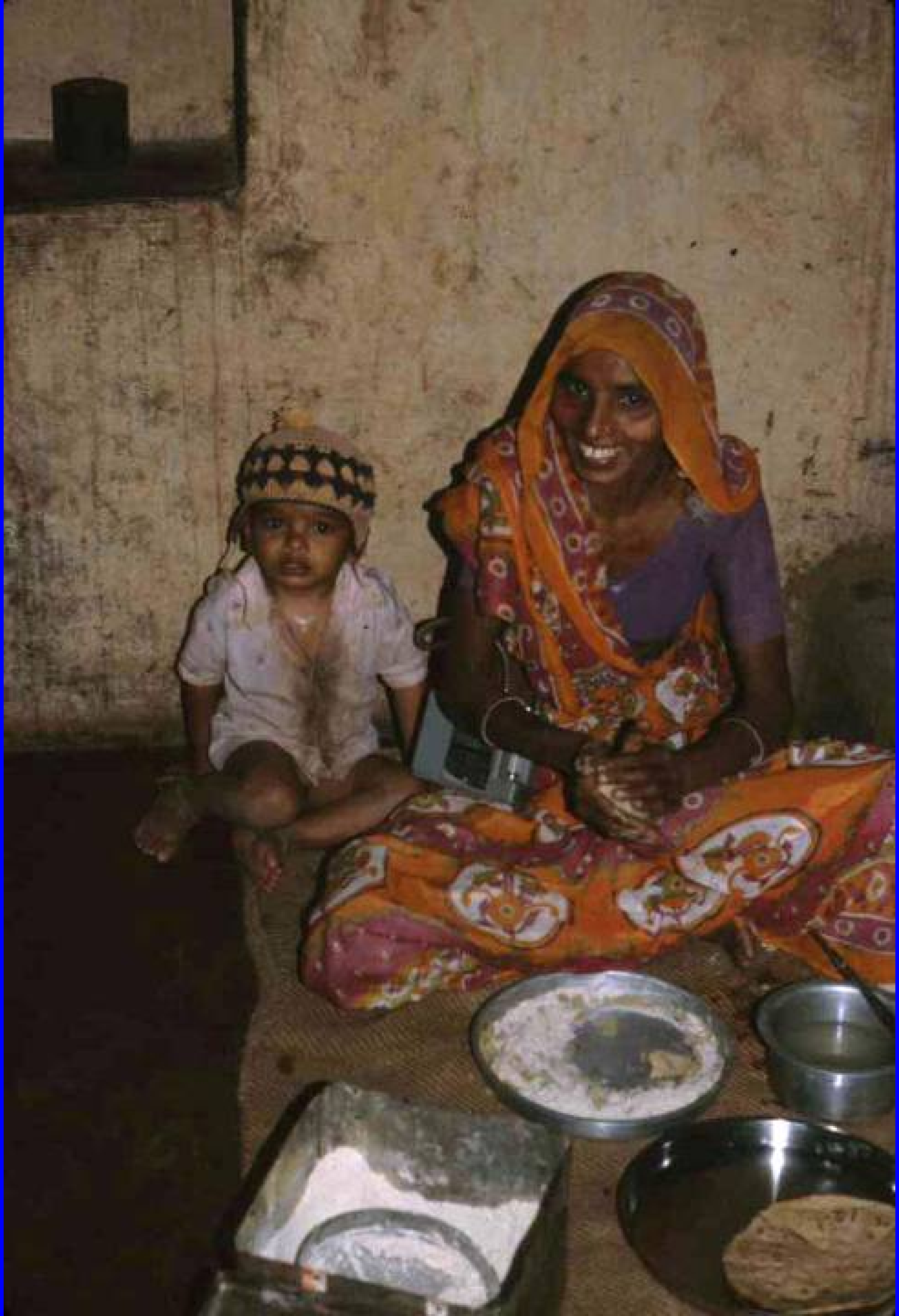
~400 ug/m3 average

USEPA Standard 15 ug/m3

WHO Guideline 10-35 ug/m3

Preliminary result from CRA

Balakrishnan et al.

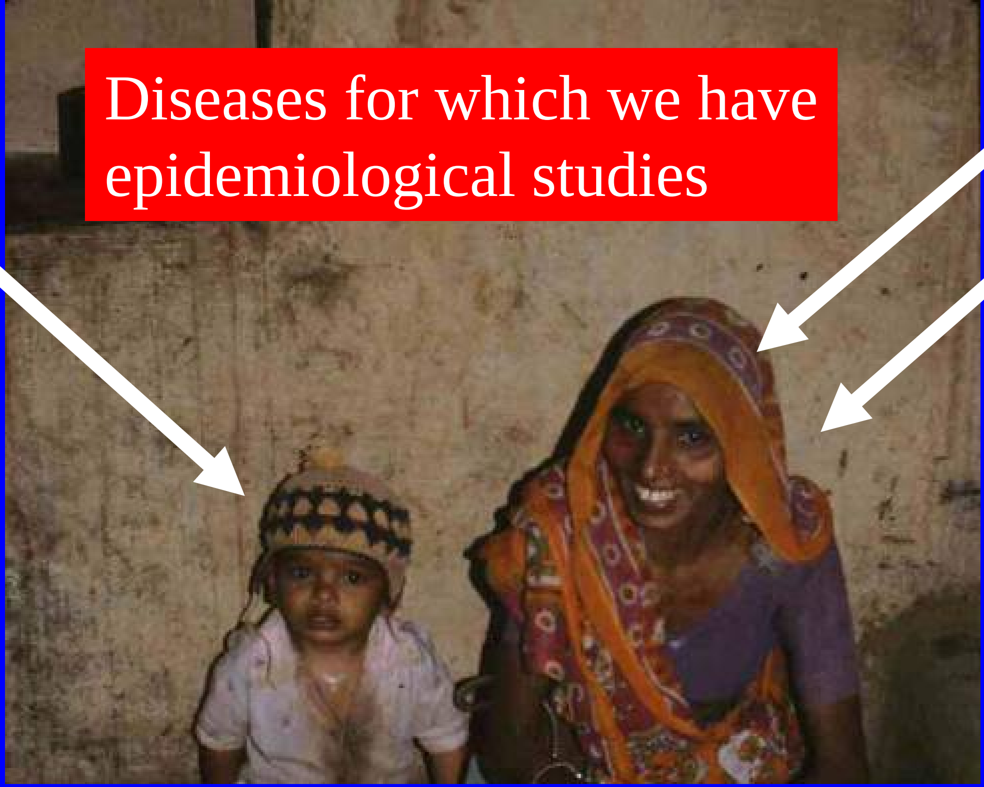


How much
Ill-health?

ALRI/
Pneumonia

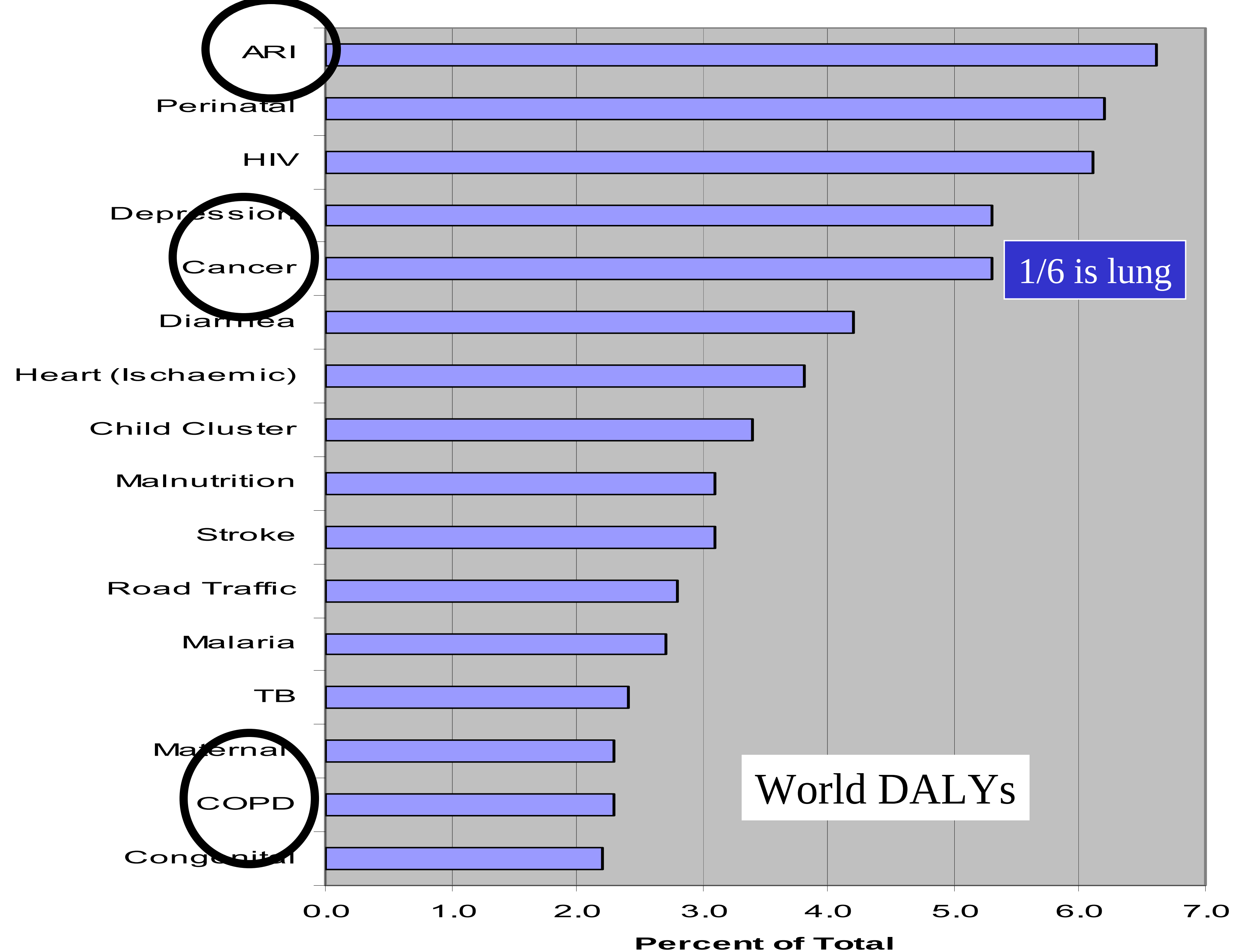
COPD

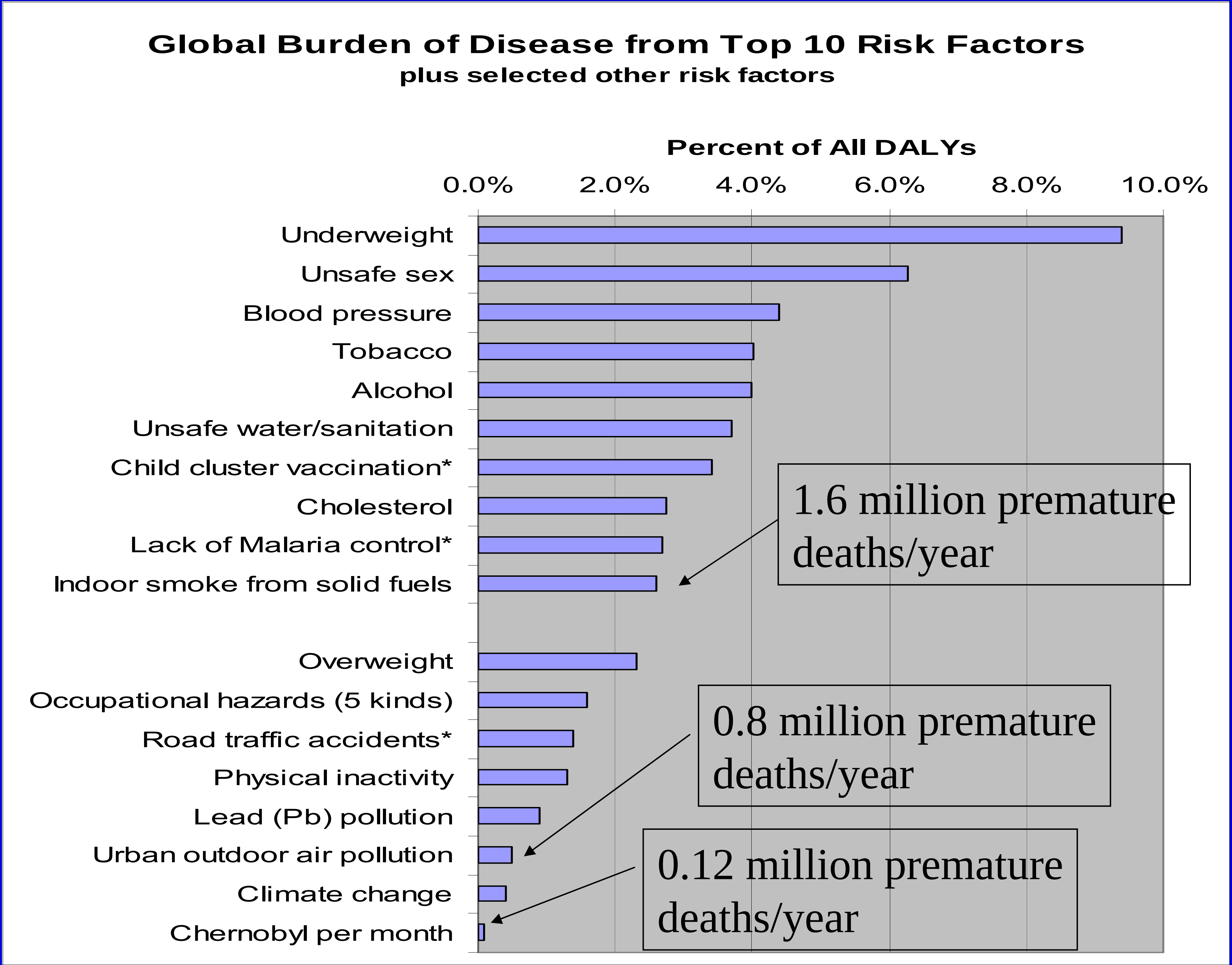
Lung cancer
(coal)



These three diseases were included in the
2004 Comparative Risk Assessment
Managed and published by WHO

First ever comprehensive risk assessment
with consistent rules of evidence
and common databases


ARI
Perinatal
HIV
Depression
Cancer
Diarrhea
Heart (Ischaemic)
Child Cluster
Malnutrition
Stroke
Road Traffic
Malaria
TB
Maternal
COPD
Congenital
1/6 is lung
World DALYs
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
Percent of Total


Global Burden of Disease from Top 10 Risk Factors
plus selected other risk factors
Percent of All DALYs
0.0%
2.0%
4.0%
6.0%
8.0%
10.0%
Underweight
Unsafe sex
Blood pressure
Tobacco
Alcohol
Unsafe water/sanitation
Child cluster vaccination*
Cholesterol
Lack of Malaria control*
Indoor smoke from solid fuels
Overweight
Occupational hazards (5 kinds)
Road traffic accidents*
Physical inactivity
Lead (Pb) pollution
Urban outdoor air pollution
Climate change
Chernobyl per month
1.6 million premature deaths/year
0.8 million premature deaths/year
0.12 million premature deaths/year

Global Burden of Disease Database
and Comparative Risk Assessment
World Health Organization

Being completely updated
For 2011 release

For household air pollution:
New exposure assessment modeling
New outcome estimates based on meta-analyses
ALRI, COPD, Lung Cancer
Low birth weight, cataracts, cardiovascular

Population (thousands): 6224984.81 | 317077.27 | 622741.70 | 817442.87 | 663966.38 | 427071.29 | 166160.20 | 80443.11 | 26143.24 | 3131052.05 | 301091.79 | 588228.34 | 782026.21 | 646519.90 | 427846.34 | 181906.42

GBD 2002: DALYs by age, sex and cause for the year 2002

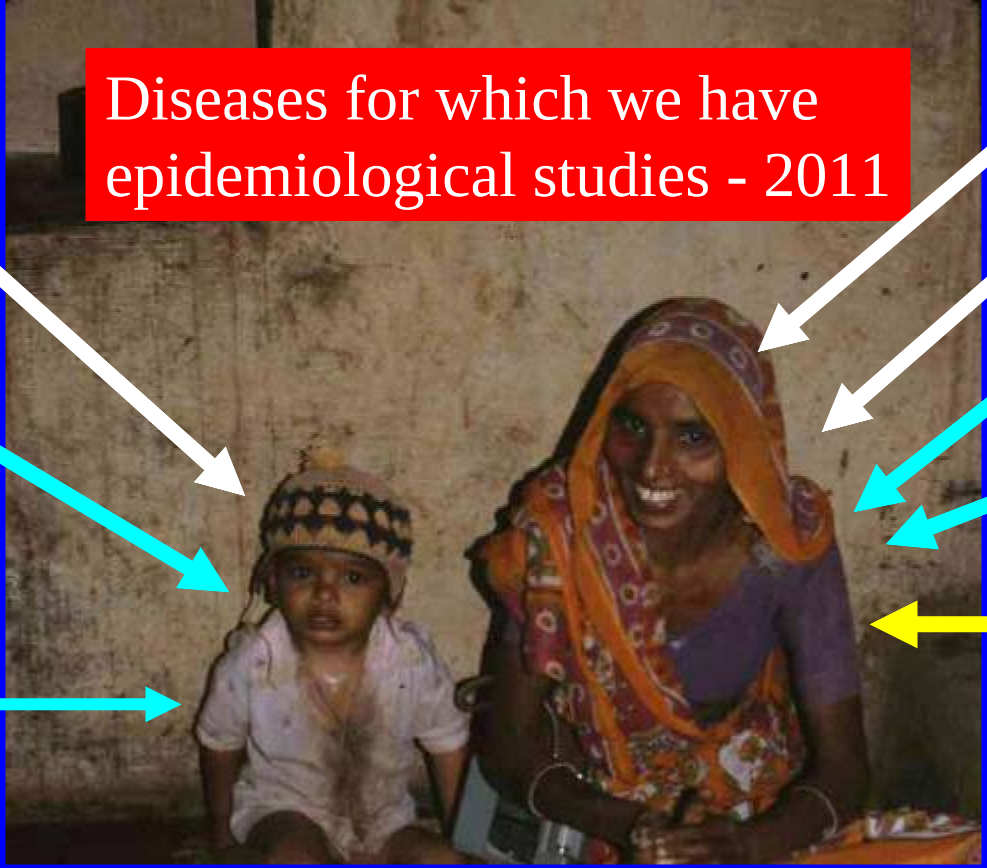
WORLD

			Male									Female					
Code	**Cause**	**Total**	**0-4**	**5-14**	**15-29**	**30-44**	**45-59**	**60-69**	**70-79**	**80+**	**Total**	**0-4**	**5-14**	**15-29**	**30-44**	**45-59**	**60-69**
U000	**All Causes**	1490125643	222552079	56142418	141637847	130501742	115374678	60641455	36229210	9832834	772912264	211279454	54559890	141633214	108257333	90621463	53460940
U001	I. *Communicable, maternal, perinatal and nutritional conditions*	610319230	########	20979812	29721889	36148773	16631072	5676094	2913759	849889	########	########	23248712	59740290	35979204	11499502	4476964
U002	A. **Infectious and parasitic diseases**	350332571	87977510	12810197	25516201	33372707	14085712	3710016	1519252	315539	179307135	89749119	13534884	31549467	23070592	8616676	2658113
U003	1. **Tuberculosis**	34735908	839261	782431	5497848	7335503	4868489	1832663	658401	90612	21905208	738745	821735	4163278	3822011	2041939	833205
U004	2. **STDs excluding HIV**	11347067	1521528	26245	1080828	660600	423721	103004	31641	7415	3854983	1726606	97221	4158088	1147558	260537	71612
U005	a. Syphilis	4200039	1039452	2292	151945	285546	354596	99162	30394	6987	1970375	1265722	3432	521758	262487	107605	42492
U006	b. Chlamydia	3571404	1199	7209	241593	50929	1169	136	0	0	302234	1152	69338	2635460	439449	109658	14084
U007	c. Gonorrhoea														422675	6262	1616
U008	d. Other STDs														22947	37012	13420
U009	3. **HIV/AIDS**														13746555	2624463	230670
U010	4. **Diarrhoeal diseases**														545936	373258	201900
U011	5. **Childhood-cluster dise**														53966	19174	4837
U012	a. Pertussis														0	13	0
U013	b. Poliomyelitis														16931	3822	615
U014	c. Diphtheria														386	572	29
U015	d. Measles														29	30	0
U016	e. Tetanus														36620	14737	4192
U017	6. **Meningitis***														167759	110215	48775
U018	7. **Hepatitis B**														115391	110437	36630
U019	**Hepatitis C**														53705	61307	30322
U020	8. **Malaria**														453207	280704	99111
U021	9. **Tropical-cluster diseas**														593336	496341	75537
U022	a. Trypanosomiasis														79329	46509	3694
U023	b. Chagas disease														51644	48058	15987
U024	c. Schistosomiasis														128589	58850	17056
U025	d. Leishmaniasis														67203	30097	11647
U026	e. lymphatic filariasis														206680	266630	15772
U027	f. Onchocerciasis														59892	46198	11380
U028	10. **Leprosy**														15828	9135	4389
U029	11. **Dengue**														10408	6396	2644
U030	12. **Japanese encephalitis**														26926	7282	2513
U031	13. **Trachoma**														517423	559520	344796
U032	14. **Intestinal nematode i**														5192	5921	3469
U033	a. Ascariasis														161	21	111
U034	b. Trichuriasis														388	433	238
U035	c. Hookworm disease														4212	4859	2723
U036	Other intestinal infectio														432	607	397
U037	Other infectious disease														1795391	1650048	667703
U038	B. **Respiratory infections**														1481589	1357246	1460806
U039	1. Lower respiratory infect														1434738	1329549	1425397
U040	2. Upper respiratory infec														45228	26339	34405
U041	3. Otitis media														1622	1358	1004
U042	C. **Maternal conditions**														9947305	403615	19
U043	1. Maternal haemorrhage														1944088	133887	0
U044	2. Maternal sepsis														1625431	72999	0
U045	3. Hypertensive disorders*														722909	40216	0
U046	4. Obstructed labour	3048291	0	0	0	0	0	0	0	0	0	0	0	2241561	794568	12162	0
U047	5. Abortion	4652171	0	0	0	0	0	0	0	0	0	0	223411	3721304	705860	1596	0
U048	Other maternal conditions	12427759	0	0	0	0	0	0	0	0	0	0	1970	8128555	4154451	142755	19
U049	D. **Perinatal conditions***	97335086	53209265	1343	1031	347	89	12	9	0	53212095	44121066	1195	498	158	34	29
U050	1. Low birth weight	46334234	25061999	52	13	20	0	9	0	0	25062092	21272111	31	0	0	0	0
U051	2. Birth asphyxia and birth trauma	34445758	19353003	790	302	73	33	3	0	0	19354204	15090851	573	107	0	15	0
U052	Other perinatal conditions	16555094	8794262	502	716	253	56	0	9	0	8795799	7758104	591	392	158	19	29
U053	E. **Nutritional deficiencies**	34416632	10258276	1921013	1793247	1025783	698252	230984	132831	39983	16100369	10385030	2582483	2149411	1479558	1121930	357998
U054	1. Protein-energy malnutrition	16910328	7556012	560106	156056	69278	103279	71114	45451	18671	8579966	7350453	620870	66437	68728	81418	70683
U055	2. Iodine deficiency	3519322	1283895	471857	528	748	1215	641	236	50	1759171	1305105	450178	1681	1046	1287	439
U056	3. Vitamin A deficiency	792562	257306	84825	3330	6358	7864	3519	983	100	364284	320394	84034	10506	3807	6687	

ALRI/
Pneumonia

Low birth
weight

Stillbirth



COPD

Lung cancer
(coal)

Lung cancer
(biomass)

Blindness
(cataracts, opacity)

CV disease
Blood pressure
ST-segment

These additional diseases will be included in the
2011 Comparative Risk Assessment

In addition, using evidence from other
exposure sources, CVD will be included

There is epi evidence for these other diseases, but considered insufficient to include in the 2011 Comparative Risk Assessment

Cognitive Impairment

Birth defects

Asthma?

Tuberculosis

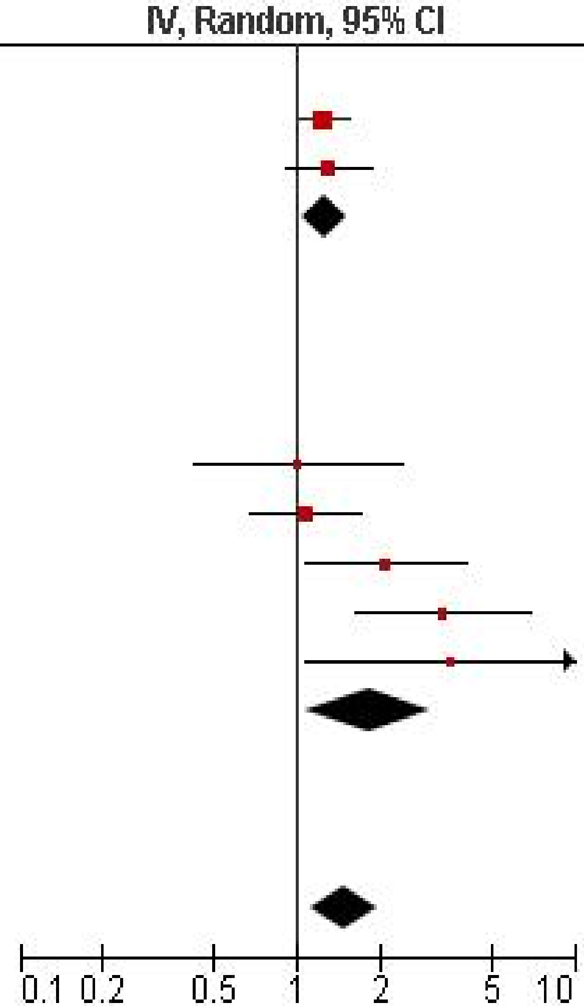
ALRI

Other cancers
(cervical, NP,
upper airway)

Burns and the health/safety impacts of fuel gathering

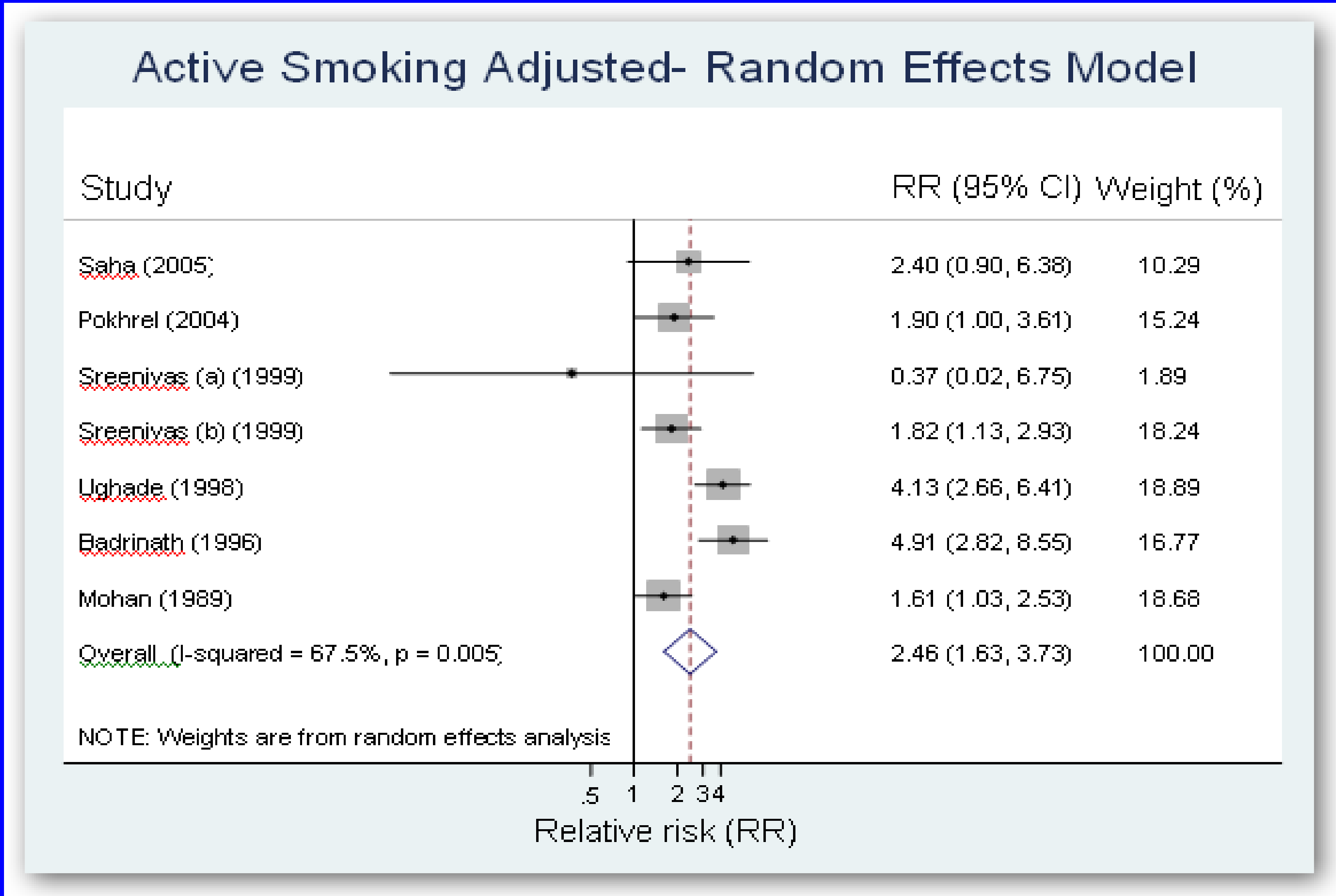
Lung Cancer: Biomass vs. clean fuel

Study or Subgroup	IV, Random, 95% CI
2.7.1 Male	
Lissowska2005	1.24 [1.00, 1.54]
Sapkota2008	1.30 [0.90, 1.87]
Subtotal (95% CI)	**1.26 [1.04, 1.52]**
Heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 0.05$, df = 1 (P = 0.83); $I^2 = 0\%$	
Test for overall effect: Z = 2.37 (P = 0.02)	
2.7.2 Female	
Sapkota2008	1.01 [0.42, 2.41]
Lissowska2005	1.07 [0.67, 1.71]
Ko1997	2.08 [1.06, 4.07]
Lee2001	3.36 [1.62, 6.96]
Behera 2005	3.59 [1.08, 11.97]
Subtotal (95% CI)	**1.81 [1.07, 3.06]**
Heterogeneity: $Tau^2 = 0.21$; $Chi^2 = 10.21$, df = 4 (P = 0.04); $I^2 = 61\%$	
Test for overall effect: Z = 2.20 (P = 0.03)	
Total (95% CI)	**1.48 [1.12, 1.97]**
Heterogeneity: $Tau^2 = 0.06$; $Chi^2 = 12.14$, df = 6 (P = 0.06); $I^2 = 51\%$	
Test for overall effect: Z = 2.75 (P = 0.006)	
Test for subgroup differences: $Chi^2 = 1.89$, df = 1 (P = 0.17), $I^2 = 47.1\%$	



CRA, Imran et al. preliminary

Cataracts and Biomass Cooking Smoke*



* Adjusted for UV

CRA Preliminary, Adair et al.

Pooled birth weight difference (low minus high exposure):

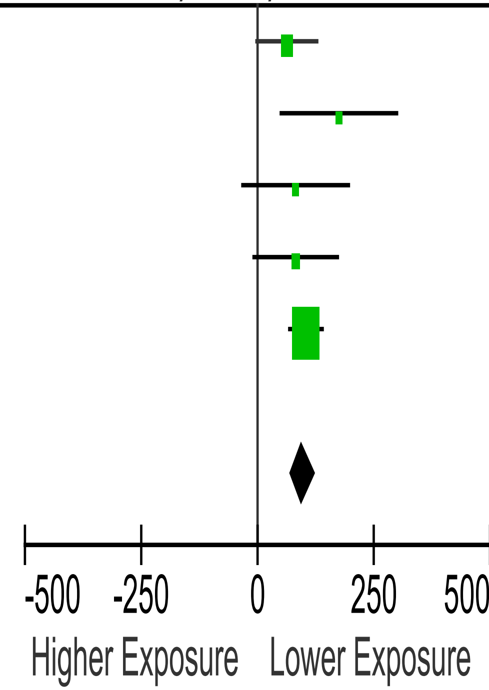
Adjusted estimates (Boy and Tielsch have GA)

Study or Subgroup	Lower Exposure Mean	Lower Exposure SD	Lower Exposure Total	Higher Exposure Mean	Higher Exposure SD	Higher Exposure Total	Weight	Mean Difference IV, Fixed, 95% CI
Boy 2002	2,835	533	357	2,772	525	871	18.5%	63.00 [-2.36, 128.36]
Mishra 2004	3,271	1,448	766	3,096	1,429	1535	5.0%	175.00 [50.00, 300.00]
Siddiqui 2008	2,812	404	80	2,730	385	108	6.0%	82.00 [-32.50, 196.50]
Thompson 2005	2,805	579	366	2,723	573	268	9.6%	82.00 [-8.69, 172.69]
Tielsch 2009	2,819	453	646	2,715	420	8958	60.9%	104.00 [68.00, 140.00]
Total (95% CI)			**2215**			**11740**	**100.0%**	**96.58 [68.49, 124.67]**

Heterogeneity: $Chi^2 = 2.85$, $df = 4$ ($P = 0.58$); $I^2 = 0\%$

Test for overall effect: $Z = 6.74$ ($P < 0.00001$)

Mean Difference IV, Fixed, 95% CI



All estimates: +96.6g (68.5, 124.7)

Excluding self-reports +93.1g (64.6, 121.6)

CRA: Pope et al., 2010

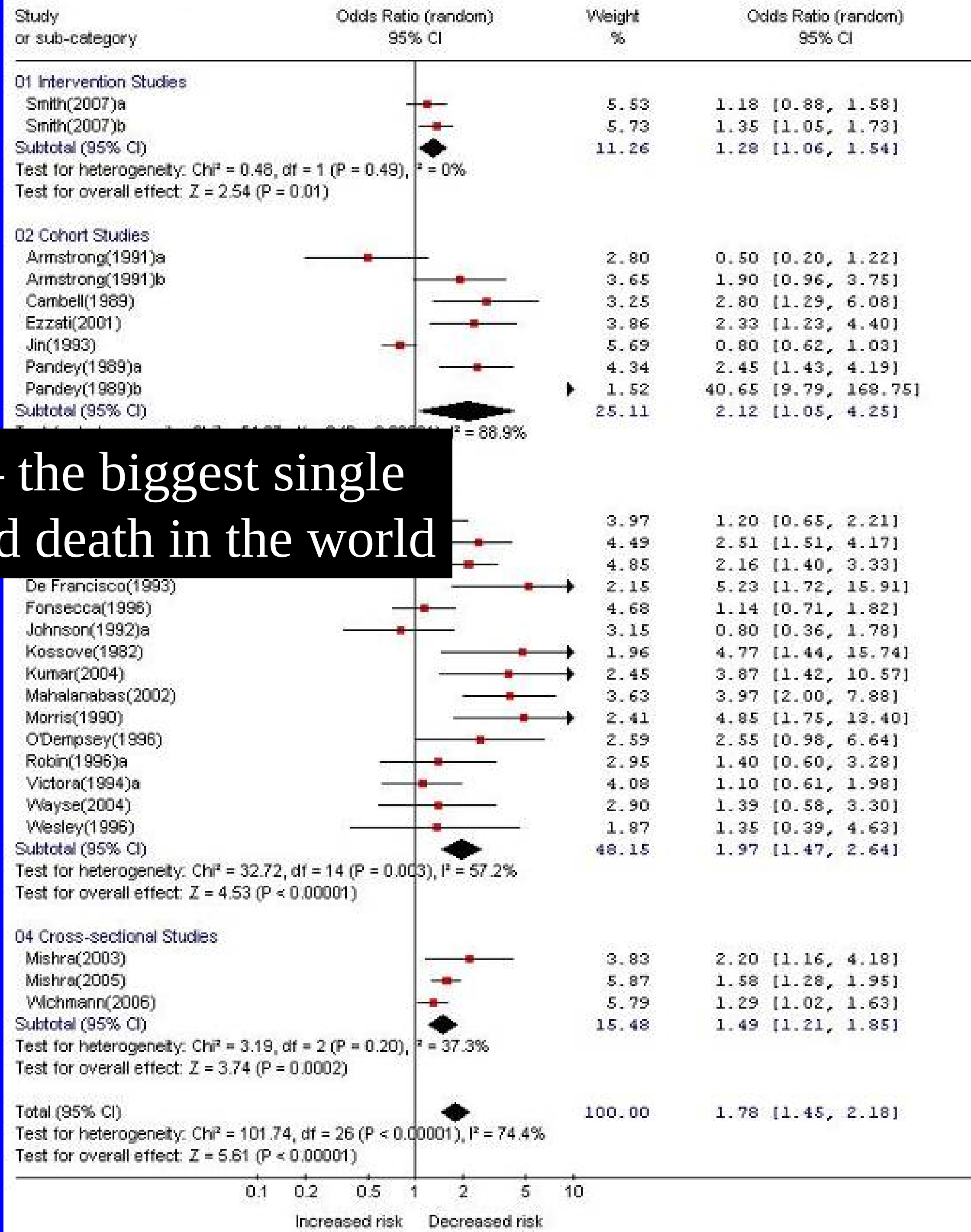
Preliminary CRA Effect Estimates

Health Outcome	Sex	Age	Level of Outcome	Risk Estimate
ALRI	M & F	< 60 mo	Ia	1.78 (1.45 to 2.18)
ALRI: exposure/response	M&F	< 60 mo	Ib	2.3 (95% CI ?)
COPD	F	>15 yr	Ia	2.7 (1.95 to 3.75)
COPD	M	>15 yo	Ia	1.9 (1.15 to 3.13)
Lung Cancer (coal)	F	> 15 yr	Ia	1.98 (1.16 to 3.36)
Lung Cancer (coal)	M	> 15 yr	Ia*	1.38
Cataract	F	> 30 yr	Ia	2.45 (1.61 to 3.73)
Cataract	M	> 30 yr	Ia	?
LBW (OR)	M & F	Perinatal	Ia	1.52 (1.25 to 1.80)
LBW (mean weight)	M & F	Perinatal	Ia	93.1g (64.6, 121.6)
Lung Cancer (biomass)	F	> 15 yr	Ia	1.81 (1.07 to 3.06)
Lung Cancer (biomass)	M	> 15 yr	Ia	1.26 (1.04 to 1.52)
CVD	F	> 30 yr	Ib	1.3 to 1.4 (95% CI)
CVD	M	> 30 yr	Ib*	1.16

Study design	N*	OR	95% CI
Intervention	2	1.28	1.06, 1.54
Cohort	7	2.12	1.06, 4.25
Case-control	15	[illegible]	[illegible]
Cross-sectional	3	1.49	1.21, 1.85
All	26	1.78	1.45, 2.18

Dherani et al Bull WHO (2008)

Pneumonia – the biggest single cause of child death in the world



Story of Two Conferences

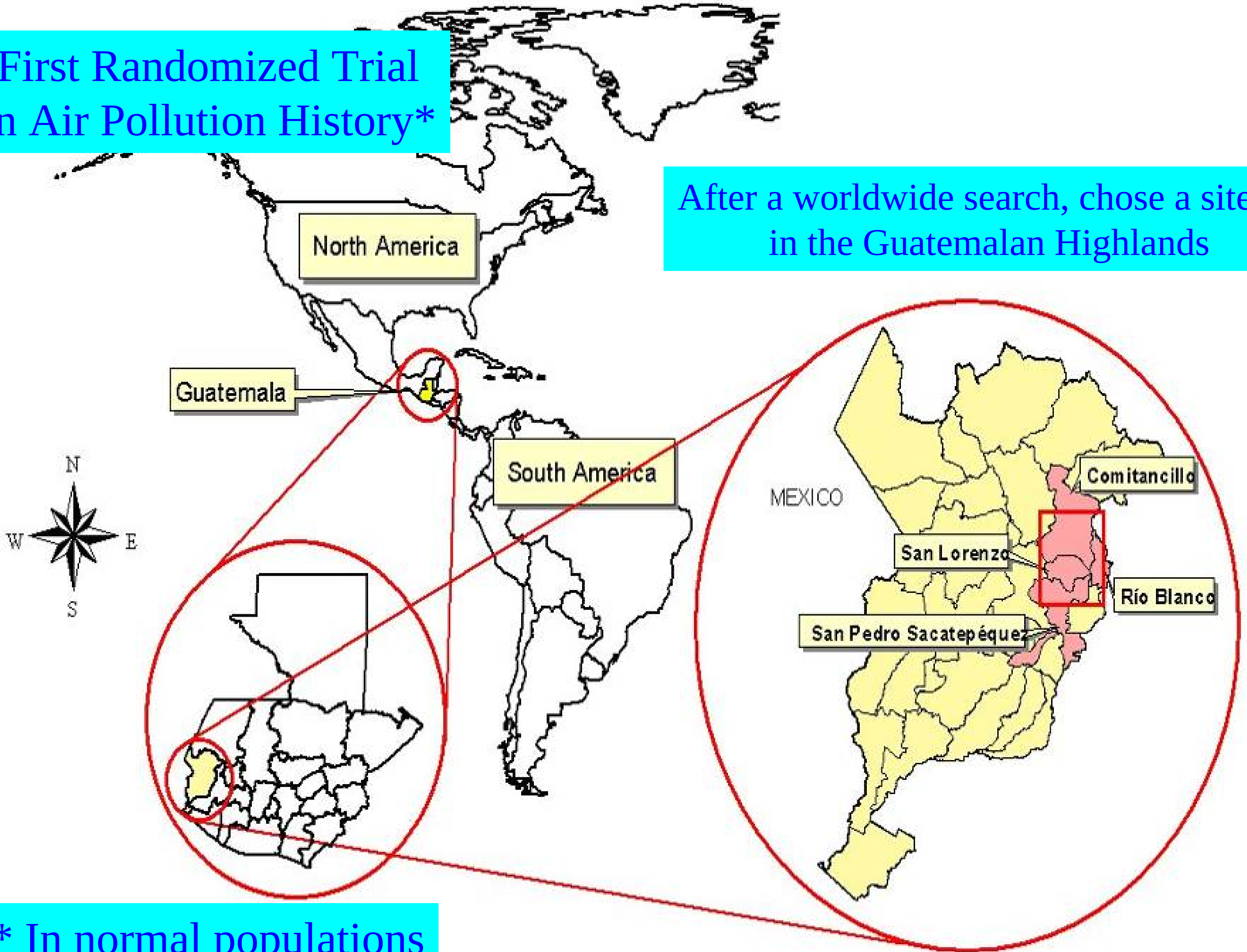
- Air pollution conference
  - High exposures to large vulnerable population
  - No more health effects work needed
- International health conference
  - Still doubt about causality
  - Need to know exact benefit to be expected
- Where are your randomized controlled trials?

History of an RCT

- ~1980: Case reports of health effects in South Asia
- 1981: First measurements of pollution levels in India
- 1984: International meeting to decide on needed research
  - Chose randomized controlled 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 – does stove work and do people use it?
- 1996-1999: Unfunded proposals
- 2001: NIEHS funding secured
- 2002-2006: Fieldwork completed
- 2011: Main results published (we hope)
- 25+ years from deciding to conduct RCT to results!

First Randomized Trial In Air Pollution History*

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



* In normal populations

RESPIRE – Randomized trial (n=518)
Impact on pneumonia up to 18 months of age

Traditional open 3-stone fire: kitchen 48-hour $PM_{2.5}$ levels of 600 - 1200 $\mu g/m^3$

Chimney wood stove, locally made and popular with households

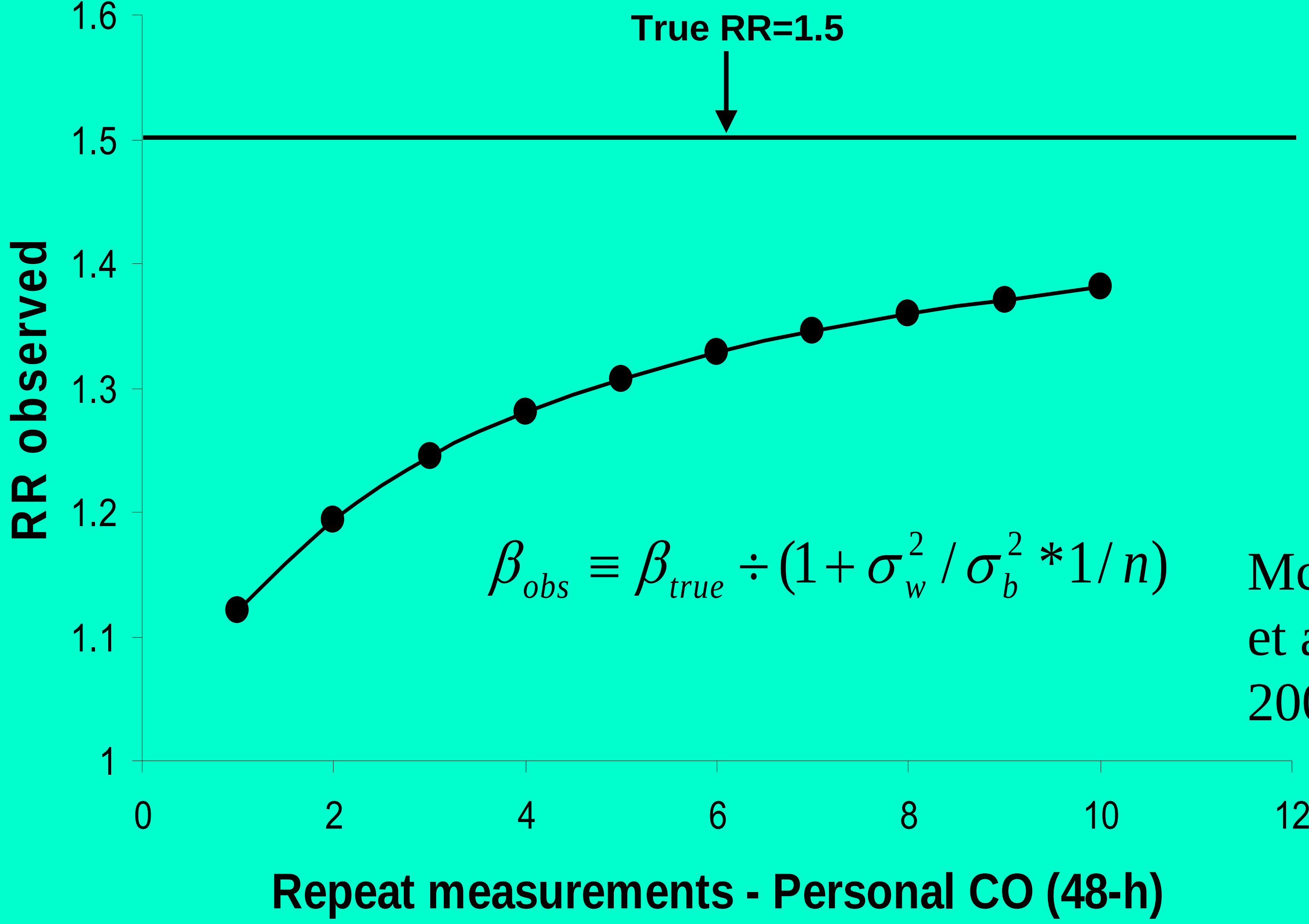
RESPIRE Results

(Randomized Exposure Study of Pollution Indoors and Respiratory Effects)

- Intention-to-Treat analysis of the RCT under journal review
- Will present preliminary results of the exposure-response analysis, which is most relevant to this audience


Tubito
Tubito

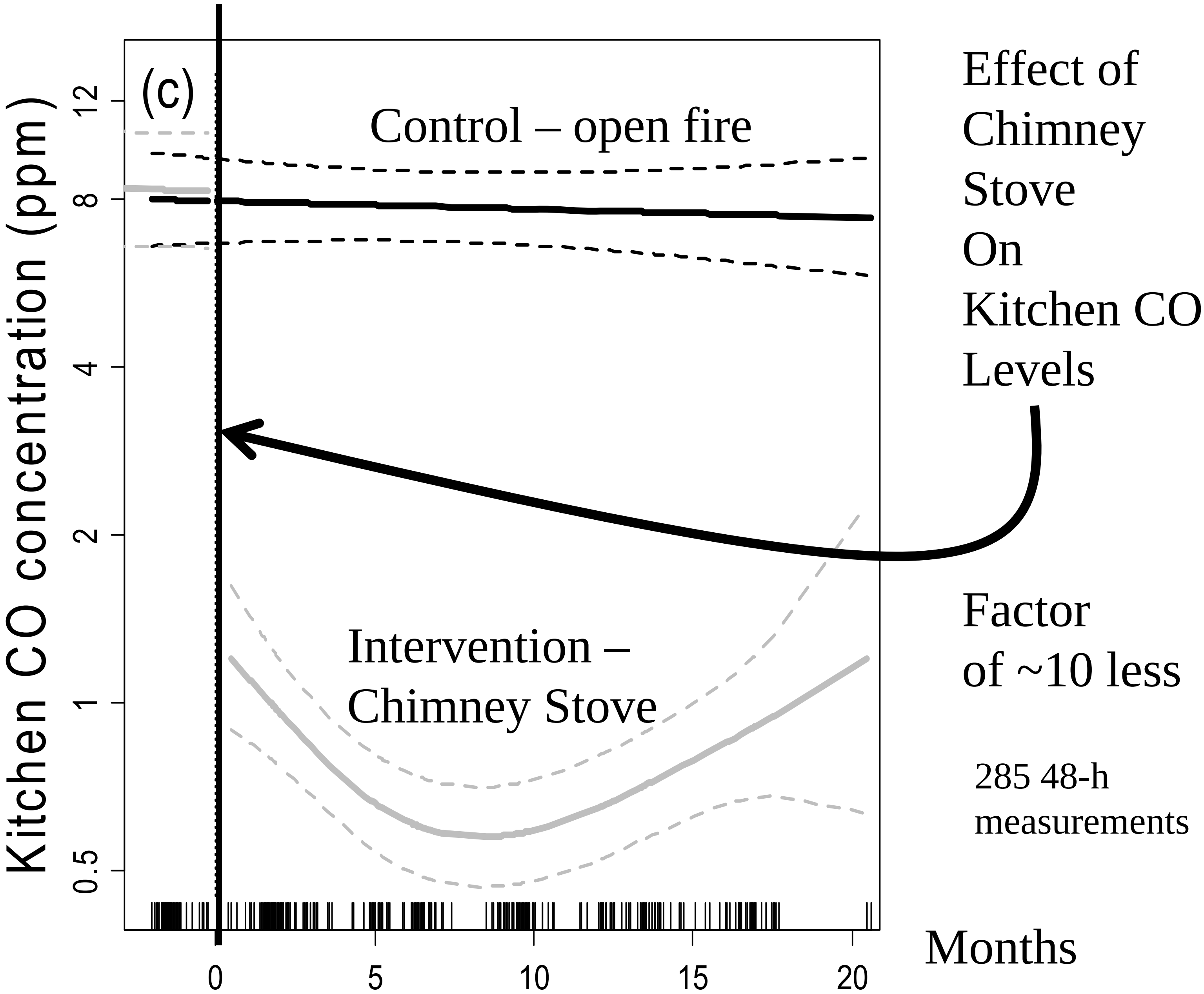
Attenuation Bias in Measurement Error



$$\beta_{obs} \equiv \beta_{true} \div (1 + \sigma_w^2 / \sigma_b^2 * 1/n)$$

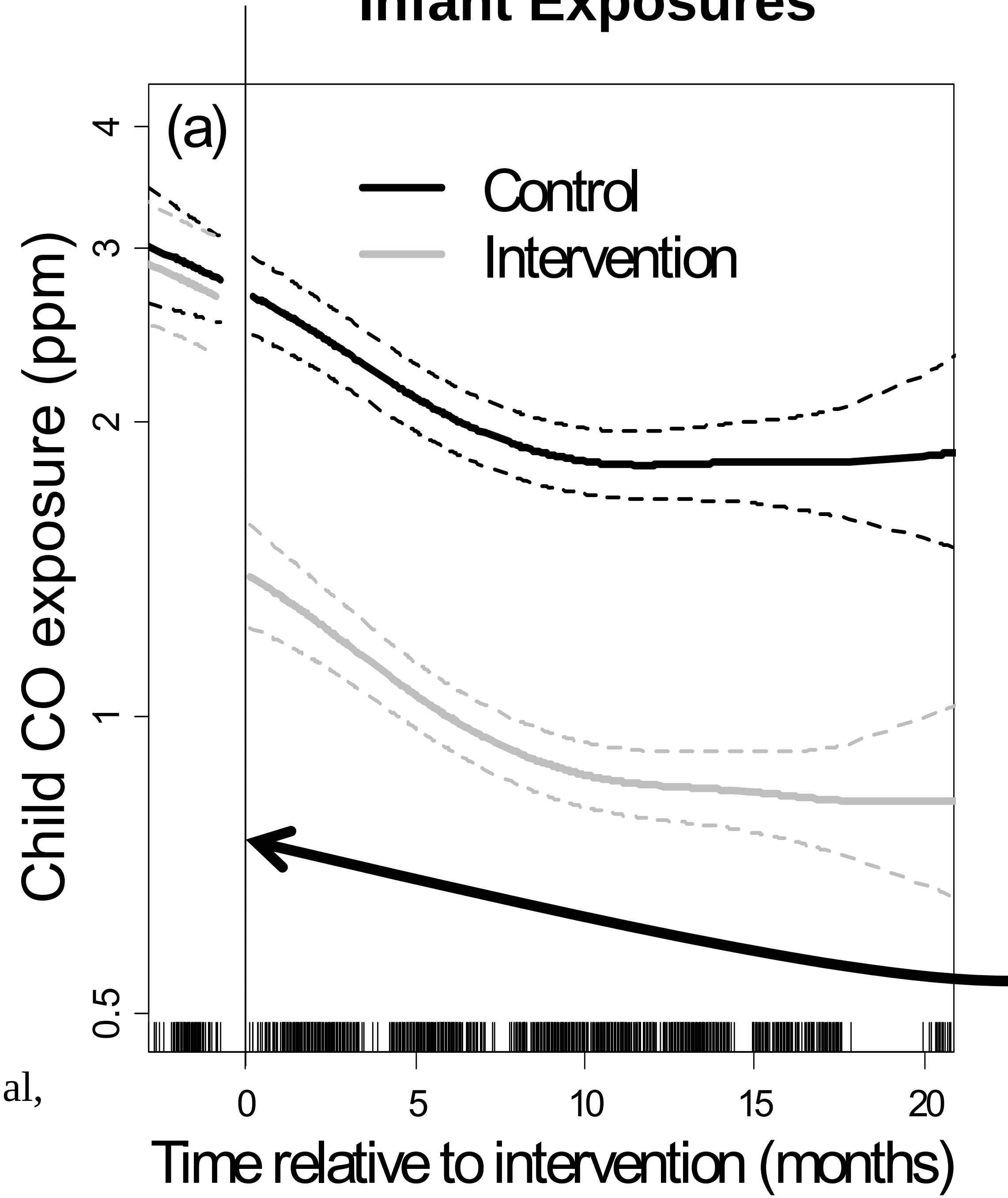
McCracken et al. 2009

Guatemala RCT: Kitchen Concentrations



Smith, et al, 2010

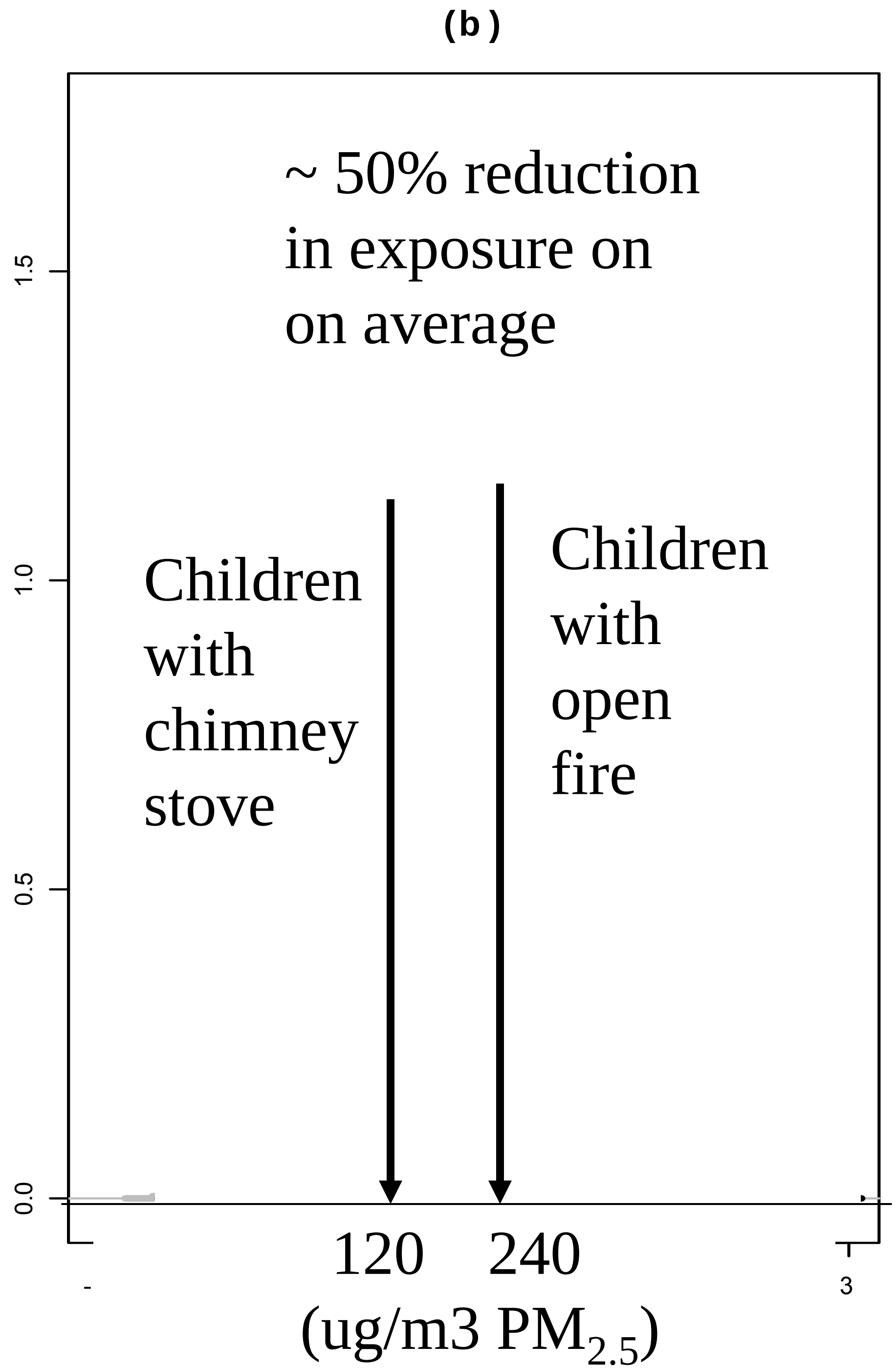
Infant Exposures



1888 48-h measurements

Effect of Chimney Stove On Infant Exposures - 2x less

Smith, et al, 2010

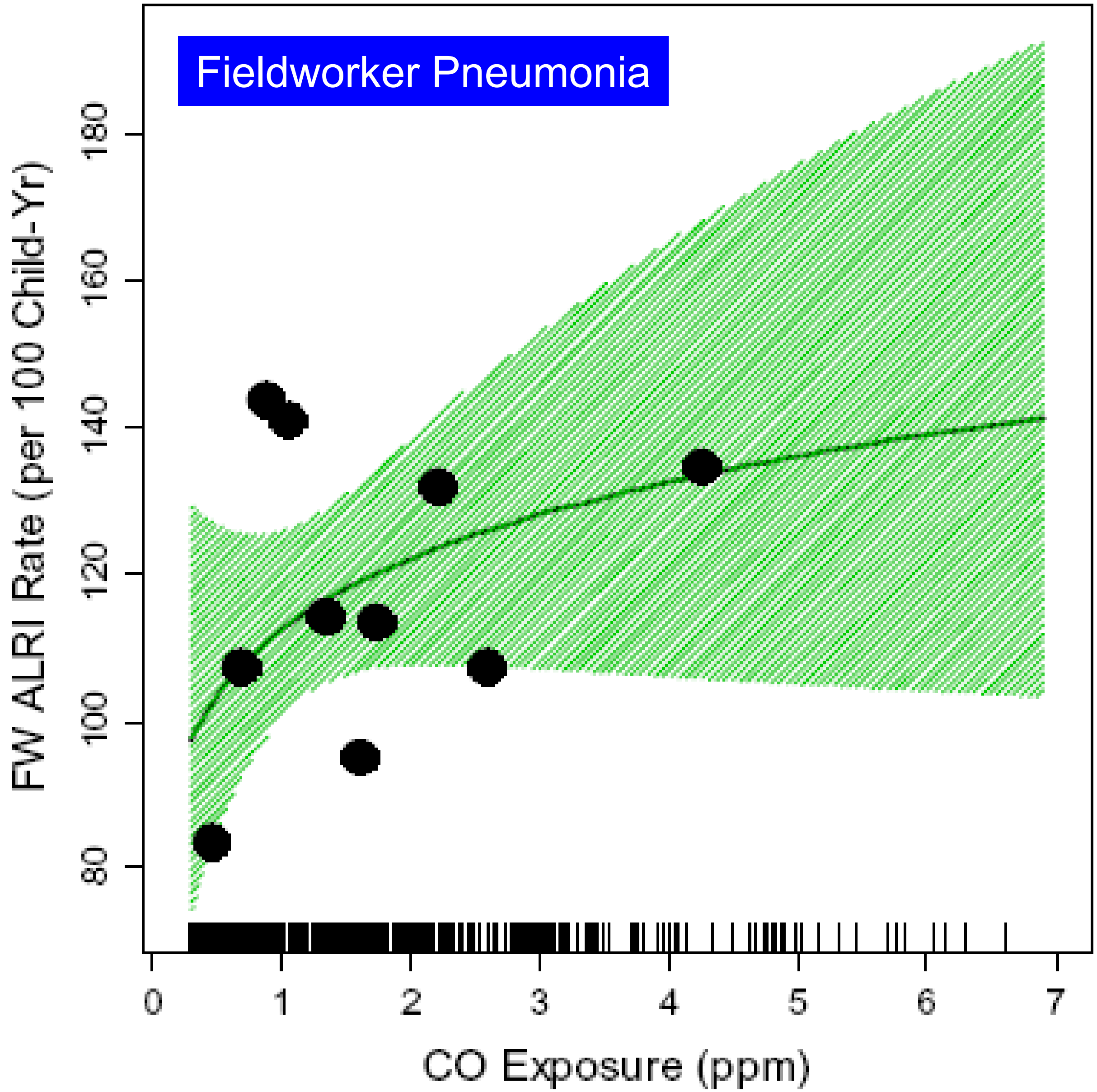


Chimney stove did not protect all children

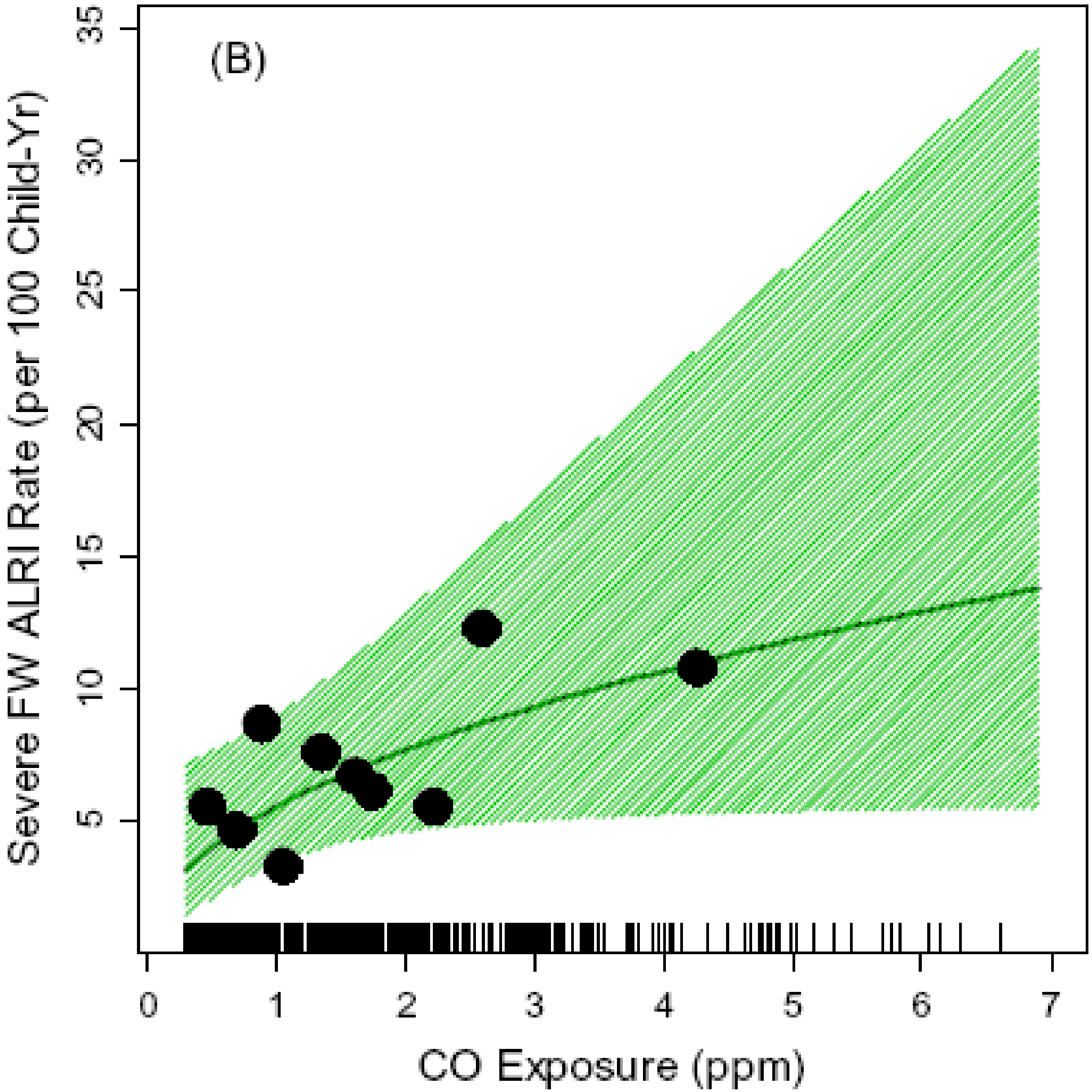
Preliminary Adjustments for Exposure-Response Model

- Adjusted for child's age (quadratic), sex, birth interval less than 2 yr (yes/no), mother's age (quadratic), maternal education and paternal education (none/primary/ secondary), secondhand tobacco smoke exposure (yes/no), latrine (yes/no), piped water (yes/no), electricity (yes/no), kerosene lamp (yes/no), wood-fired sauna (yes/no), bedroom in kitchen (yes/no), roof type (metal sheet/tiles/straw), earth floor (yes/no), asset index (linear over range 0 to 6), animal ownership index (linear over range 0 to 4), crowding index (people per room), altitude (5 categories), occupation (farm other land/farm own land/other), and season (cold dry, warm wet, warm dry).

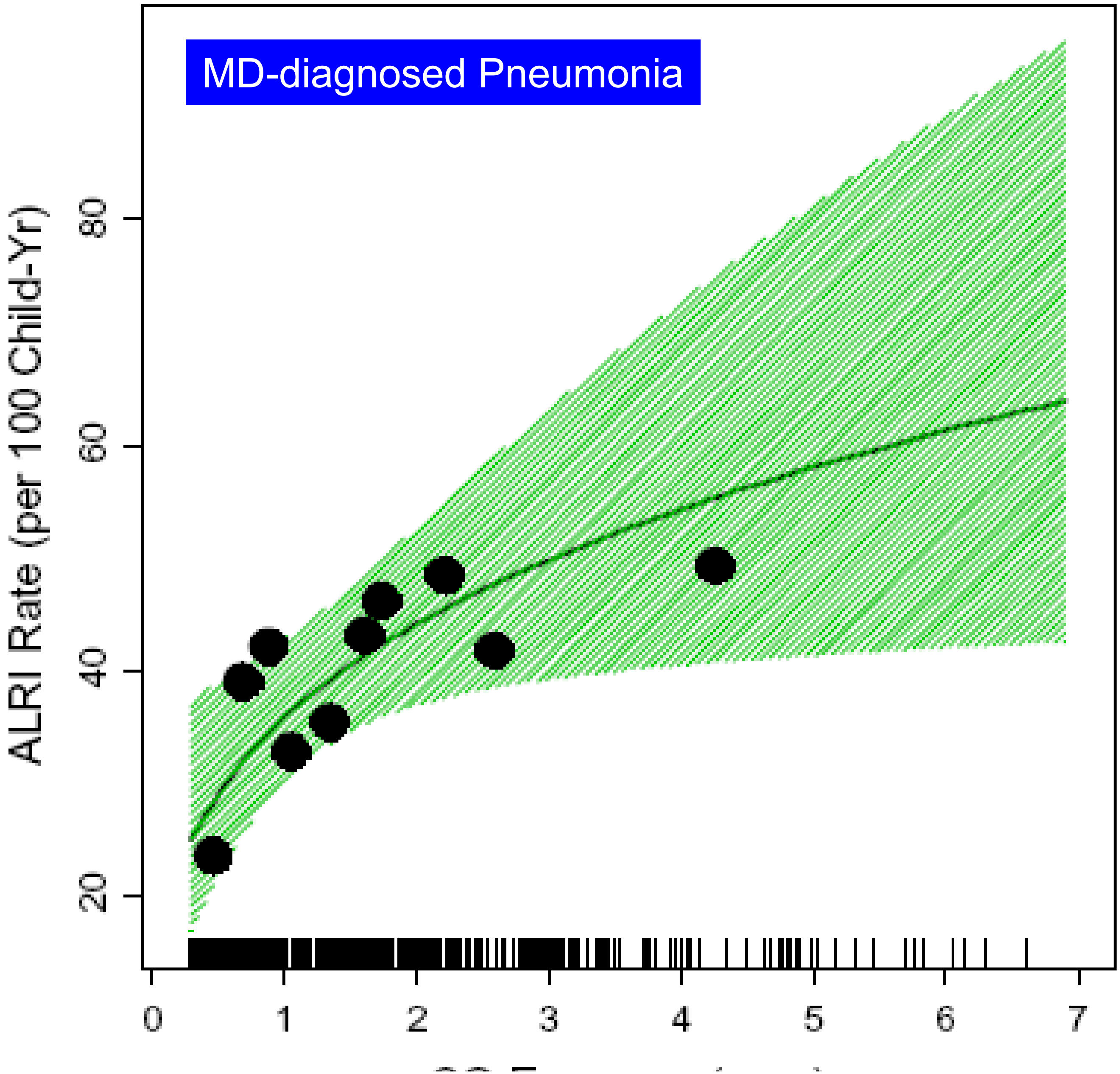
Preliminary



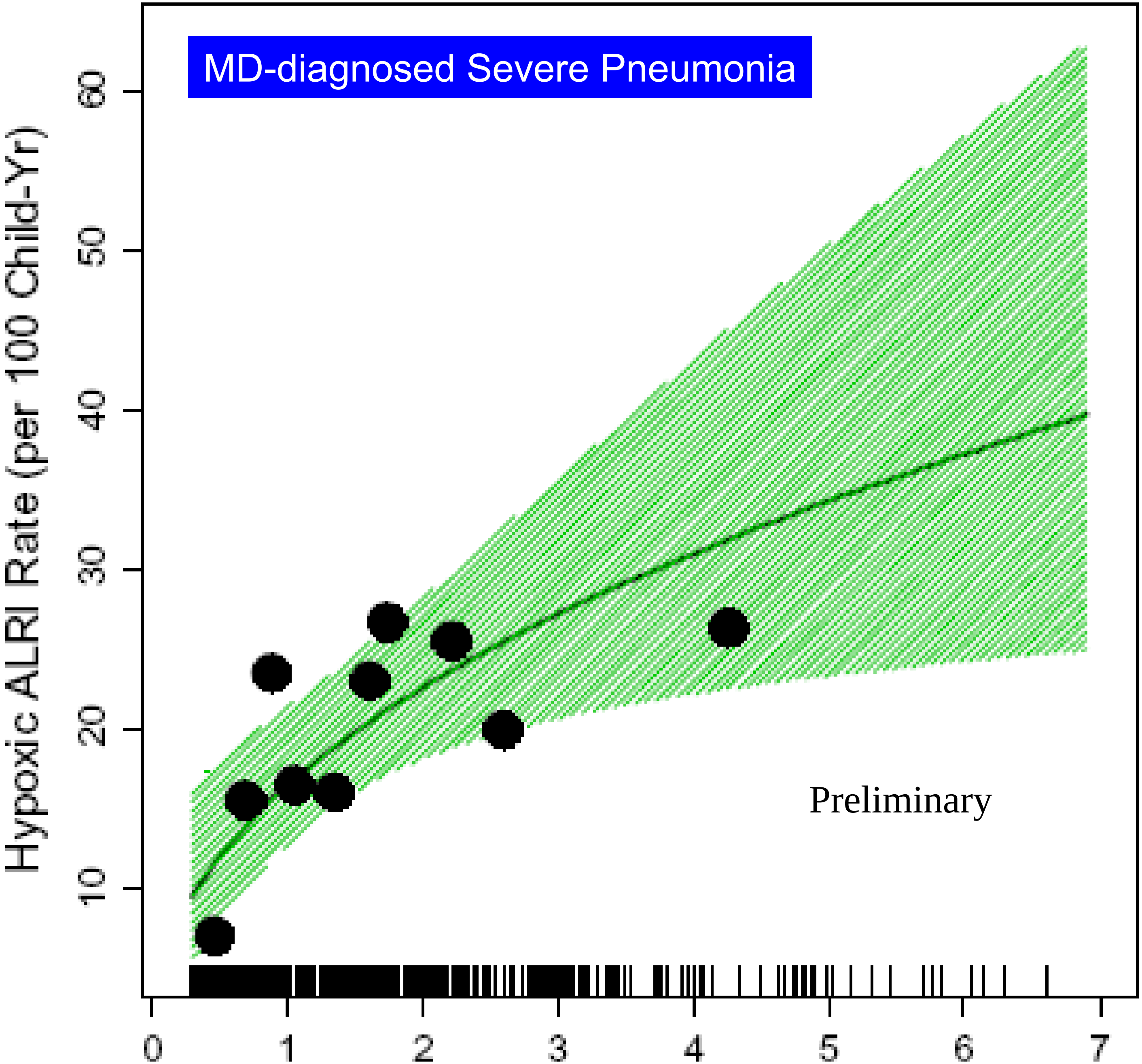
Preliminary



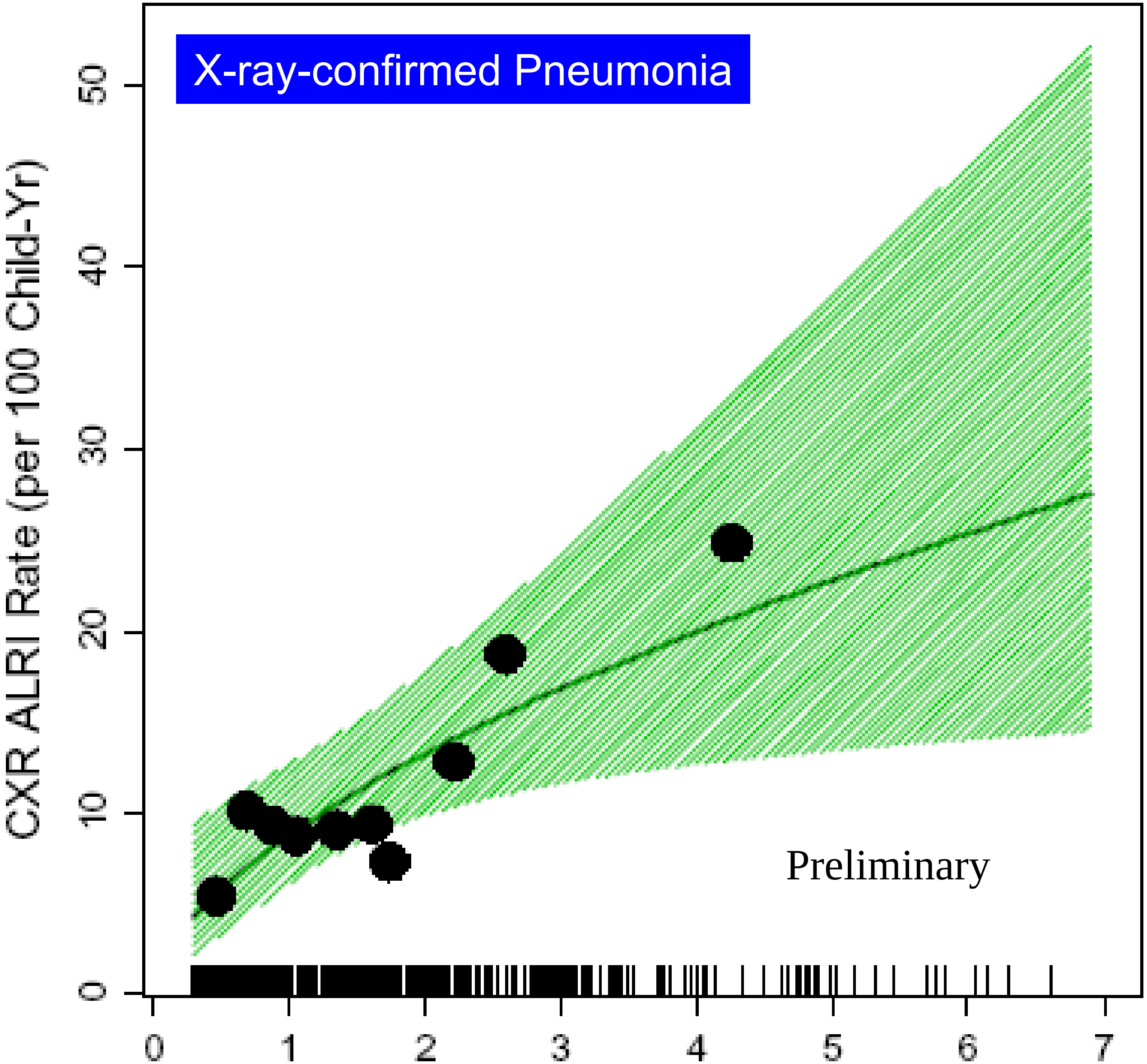
Preliminary



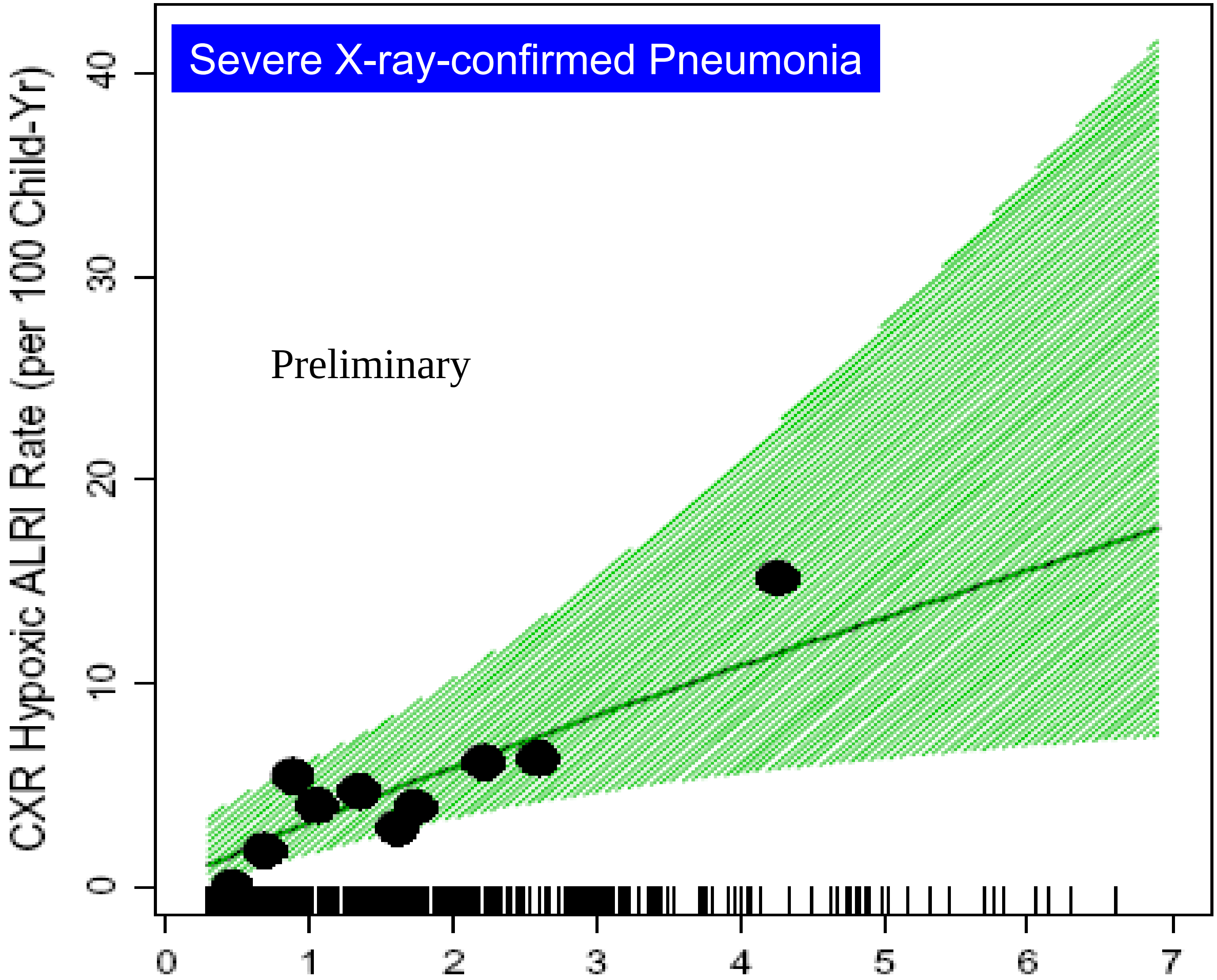
Approximate Mean PM2.5 exposure in 100s of ug/m3



Approximate Mean PM2 5 exposure in 100s of ug/m3



Approximate Mean PM2.5 exposure in 100s of ug/m3



Approximate Mean PM2.5 exposure in 100s of ug/m3

RESPIRE: Pneumonia Reductions with Exposure Reduction
Preliminary Results

Exposure reduction	Overall MD-pneumonia	Severe (hypoxic) MD-pneumonia	CXR pneumonia	Severe (hypoxic) CXR pneumonia
25%	0.92 (0.86, 0.99)	0.88 (0.80, 0.97)	0.84 (0.74, 0.96)	0.79 (0.69, 0.95)
50%	0.82 (0.70, 0.98)	0.73 (0.59, 0.92)	0.66 (0.49, 0.91)	0.56 (0.40, 0.88)
75%	0.67 (0.50, 0.96)	0.53 (0.35, 0.84)	0.44 (0.24, 0.83)	0.31 (0.16, 0.78)
90%	0.51 (0.31, 0.93)	0.35 (0.17, 0.76)	0.26 (0.09, 0.74)	0.15 (0.05, 0.67)

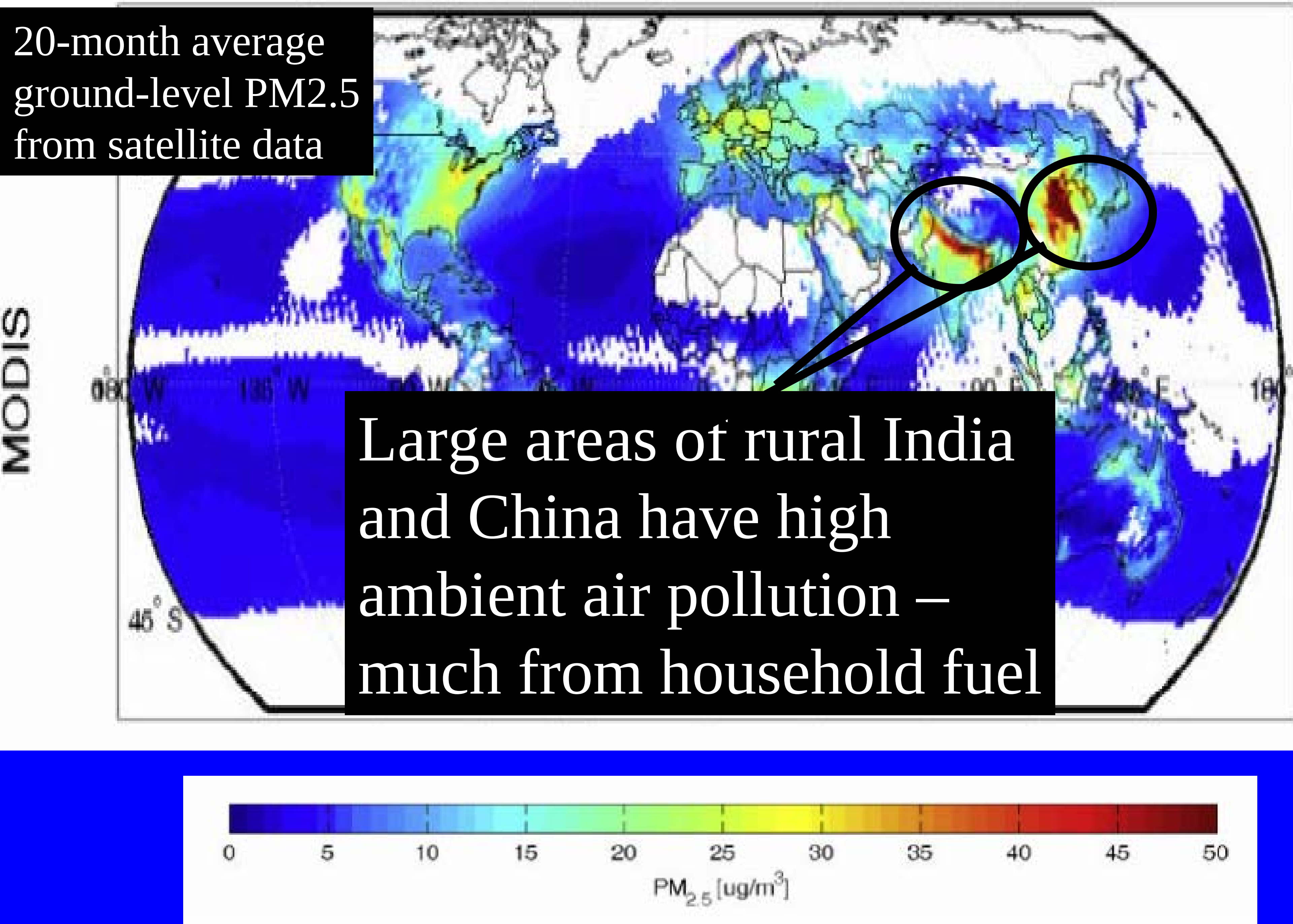
Kitchens down by 10x, but children exposure down by only 2x, because

--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

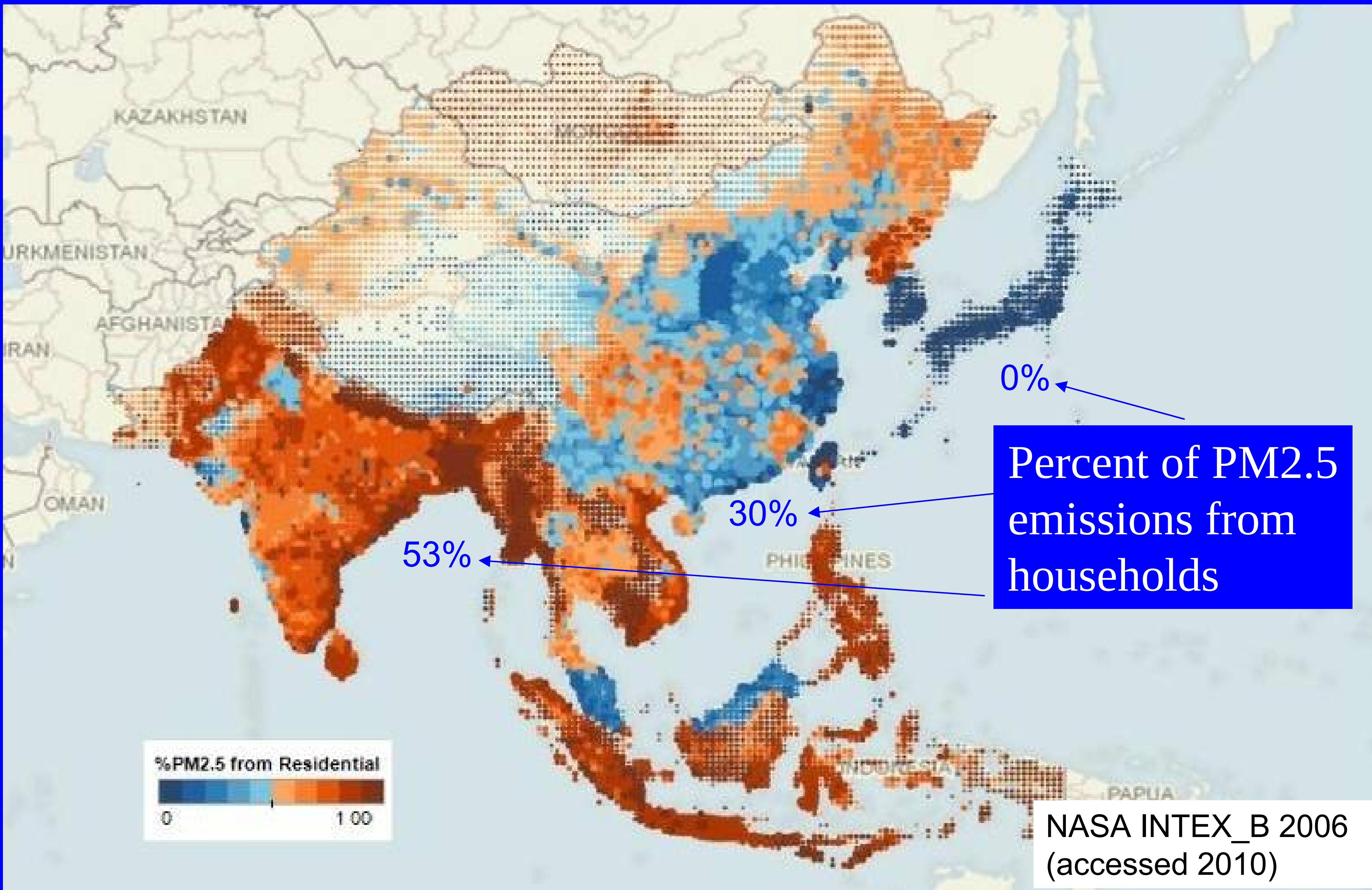
--No significant difference in bedrooms

20-month average ground-level PM2.5 from satellite data

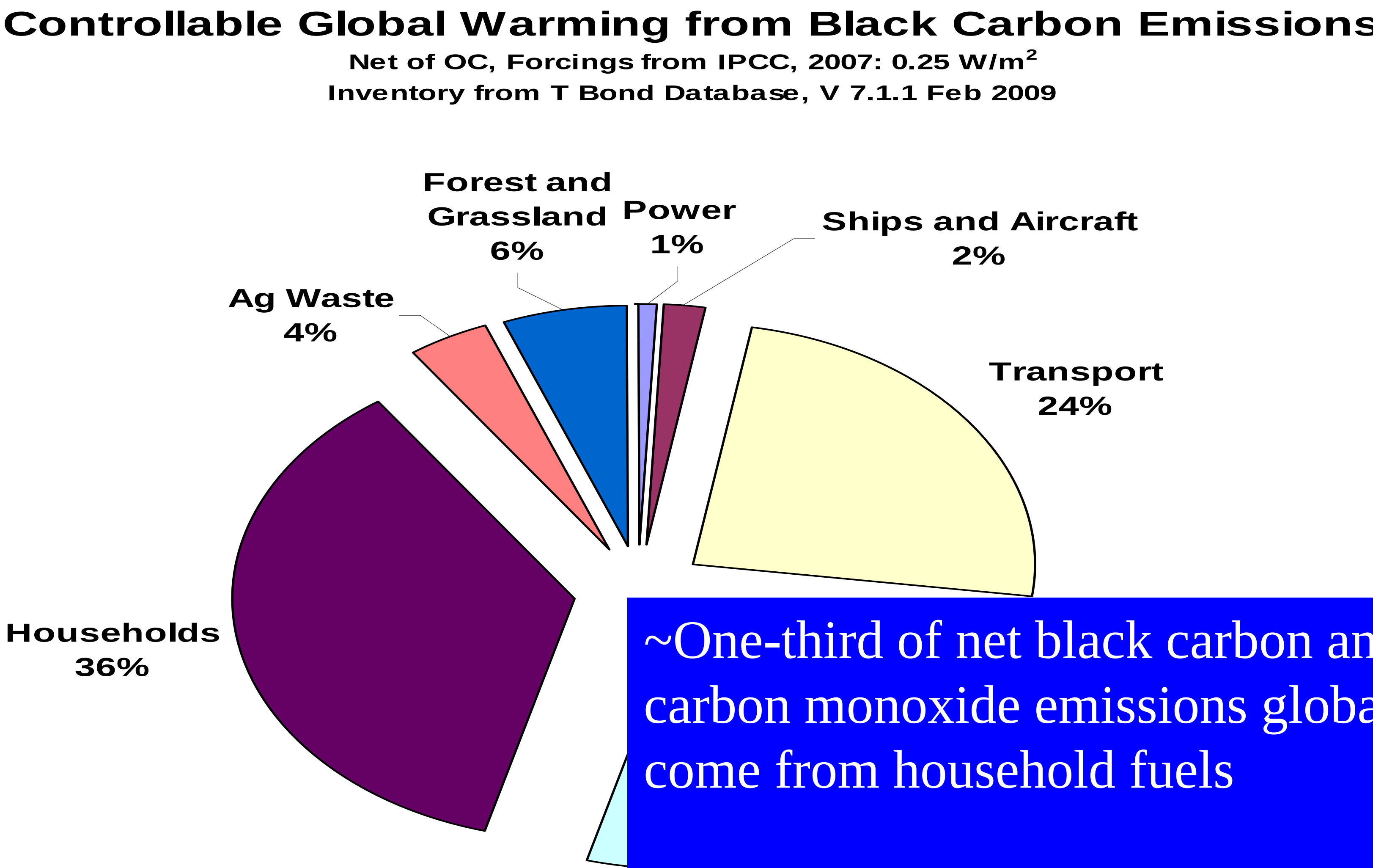


Large areas of rural India and China have high ambient air pollution – much from household fuel

NASA INTEX_B Database
Percent $PM_{2.5}$ emissions from households



NASA INTEX_B 2006 (accessed 2010)

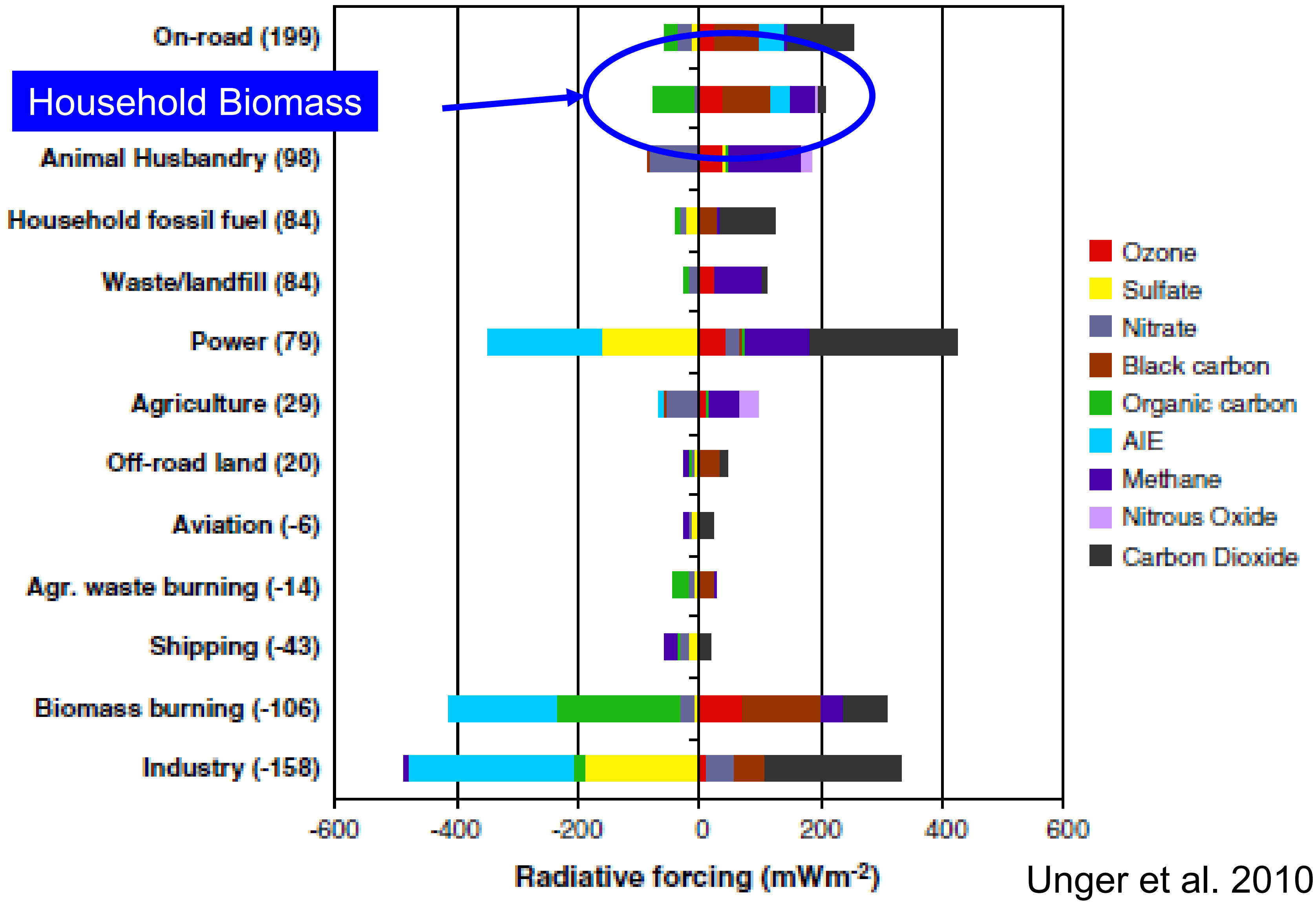


~One-third of net black carbon and carbon monoxide emissions globally come from household fuels

~One-sixth of ozone causing pollutar

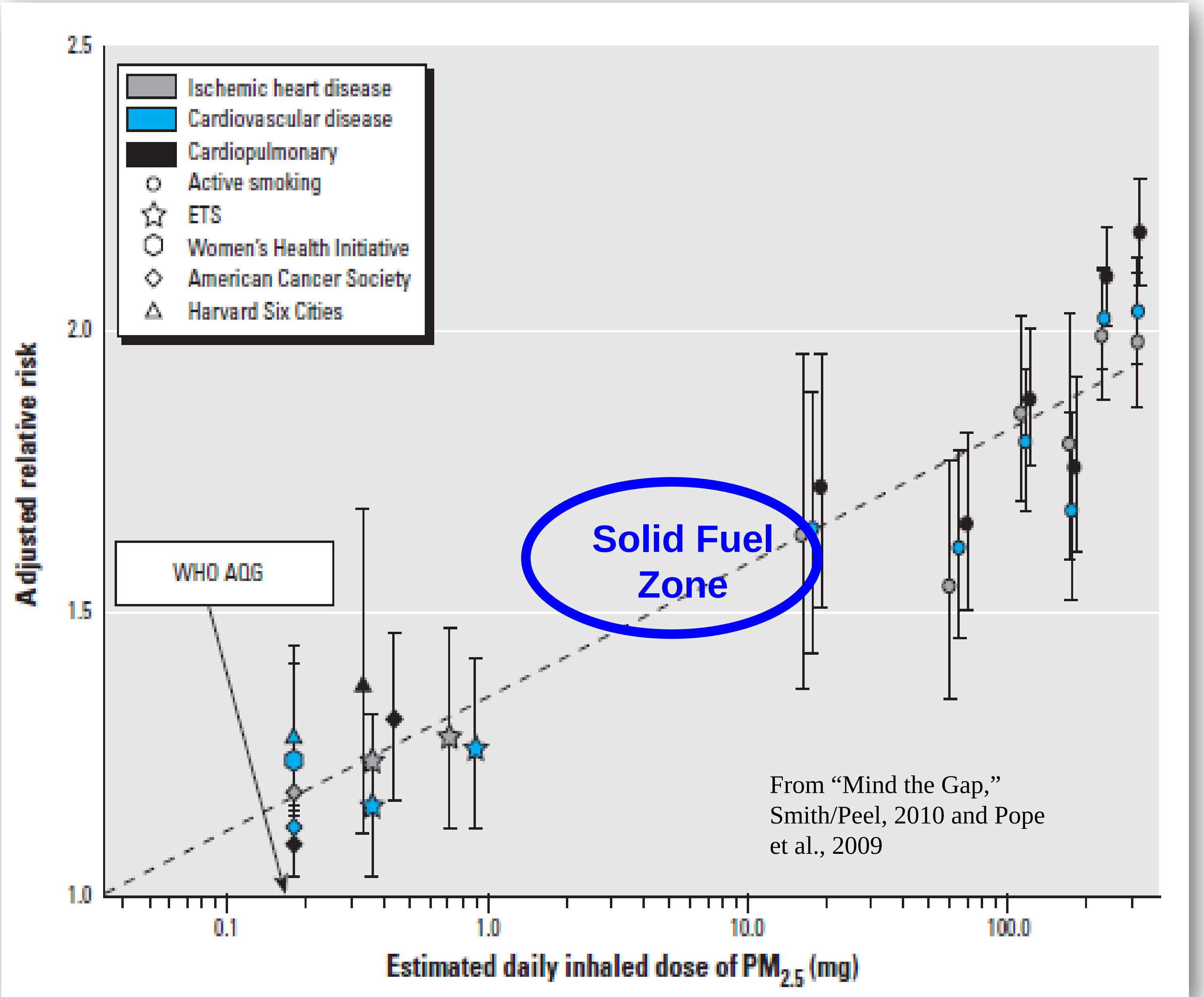
~One-twentieth of methane

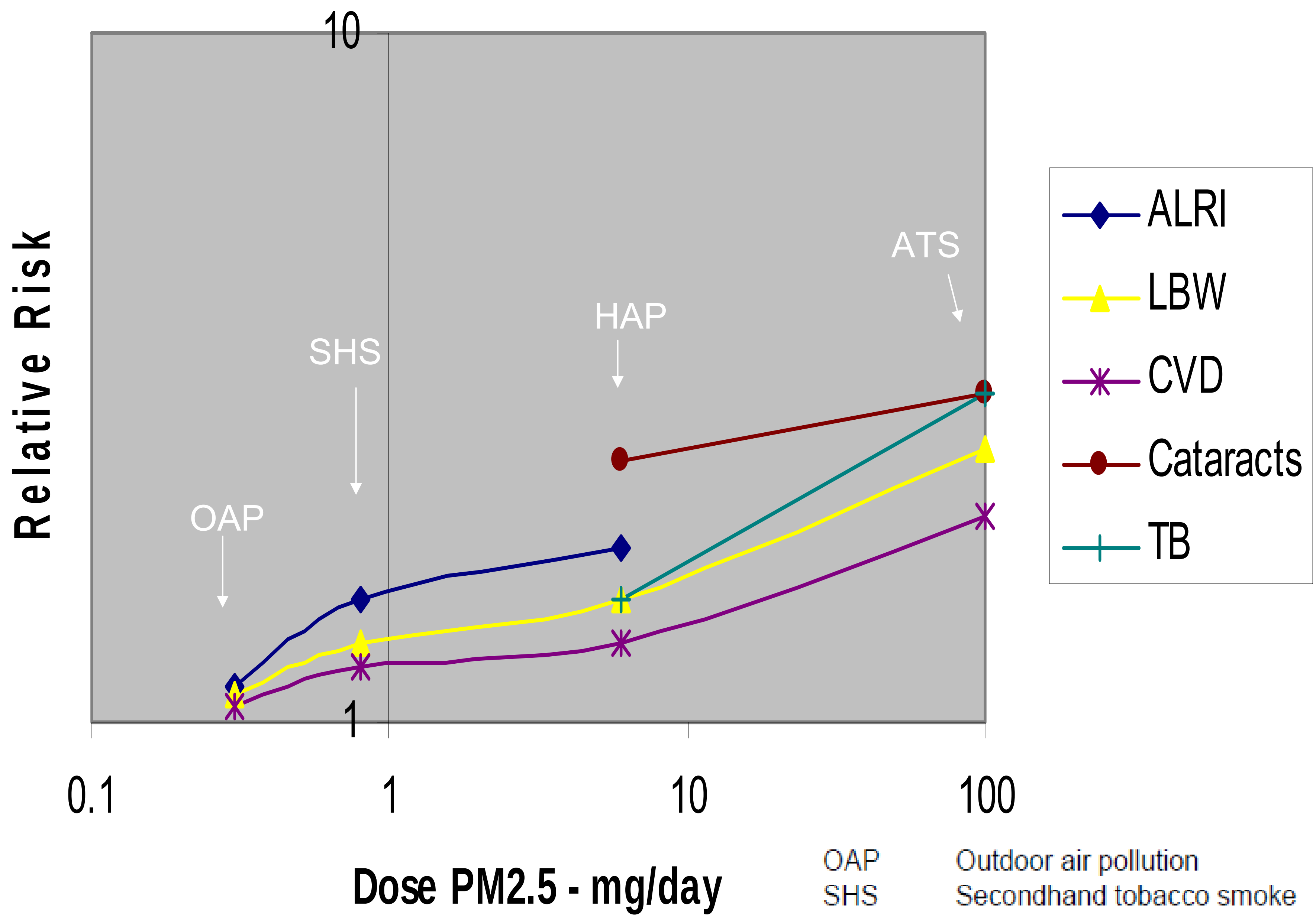
Climate Warming in 2020 Under Present Trends



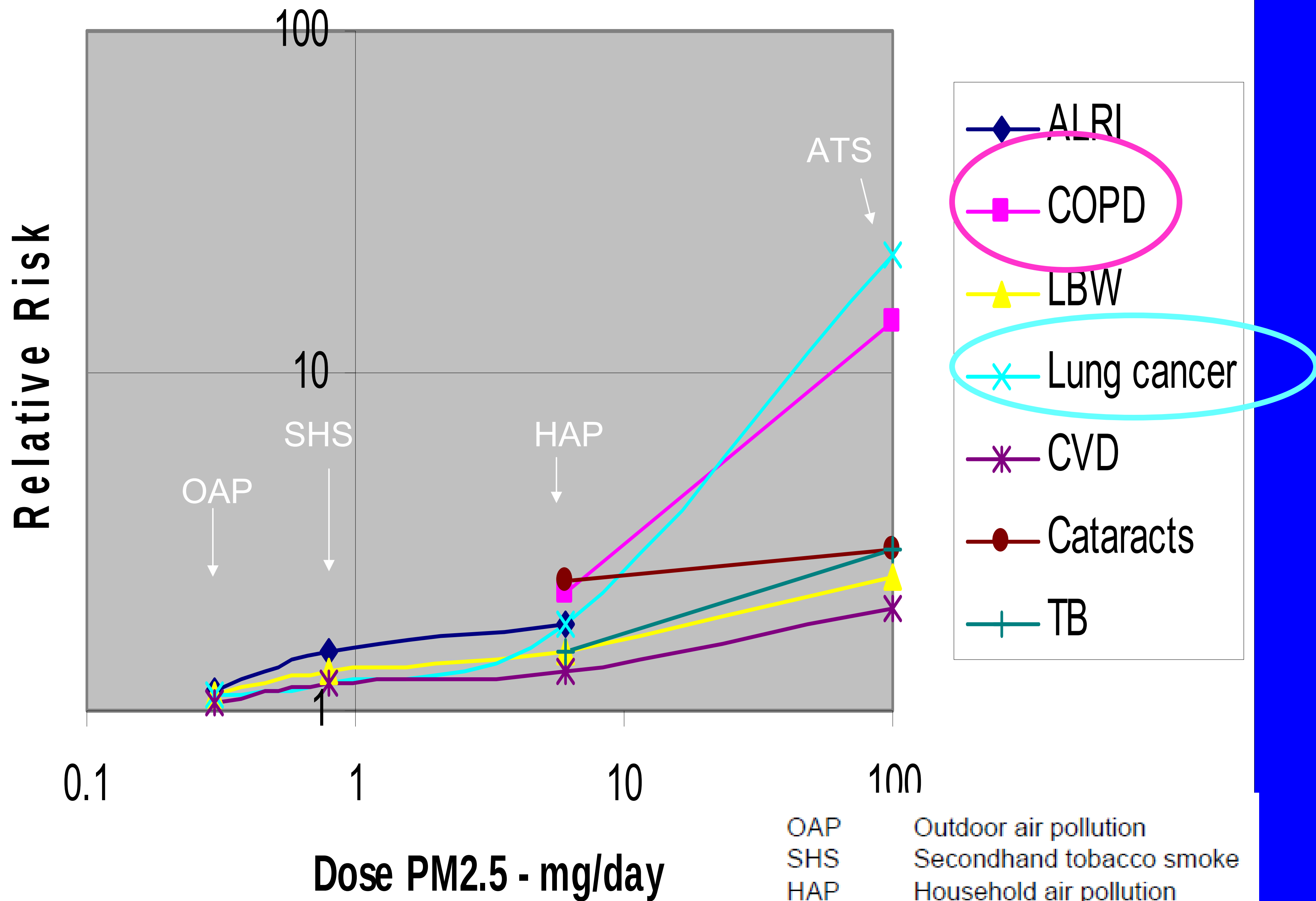
Unger et al. 2010

Heart Disease and Combustion Particle Doses



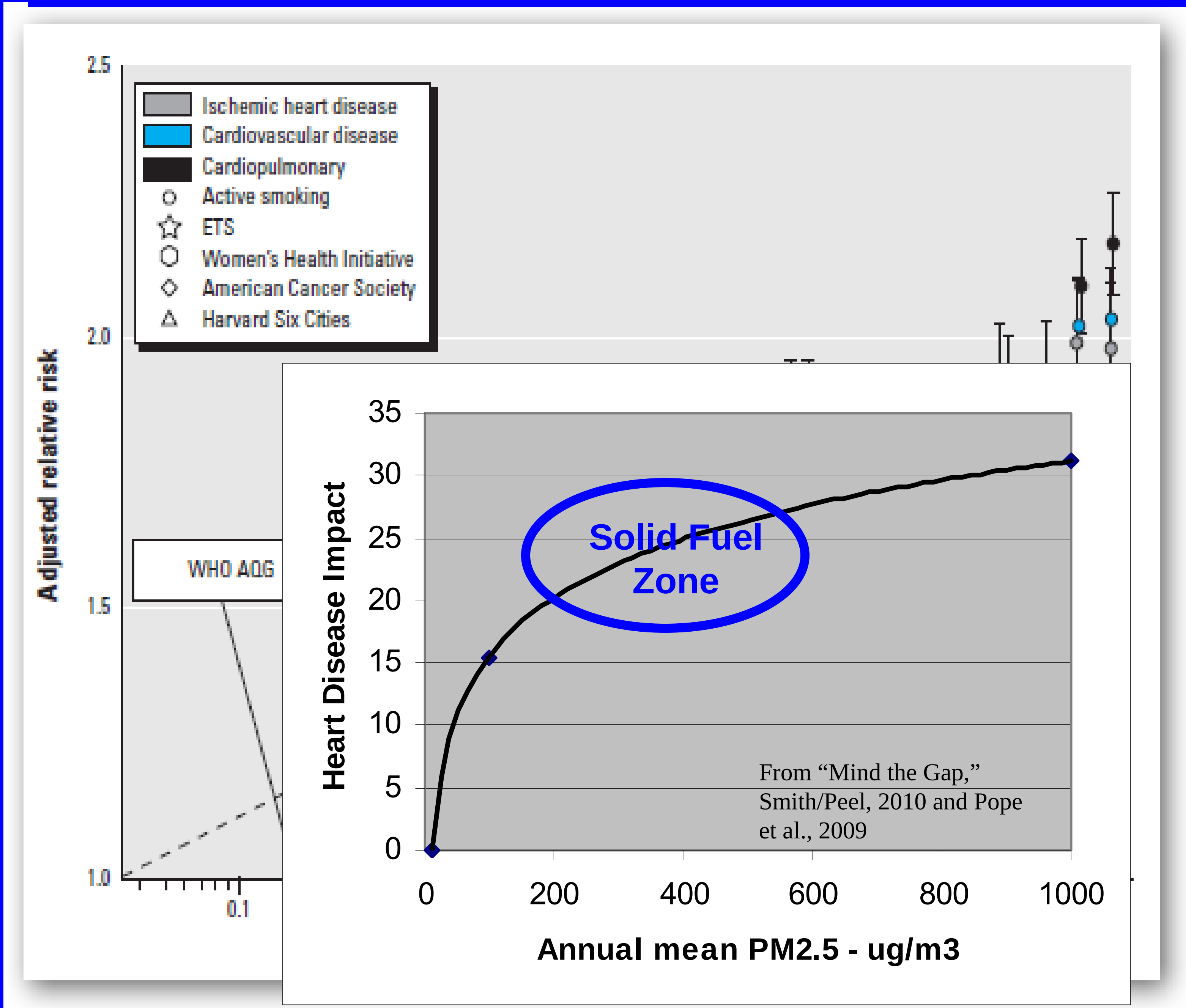


OAP	Outdoor air pollution
SHS	Secondhand tobacco smoke
HAP	Household air pollution
ATS	Active tobacco smoking

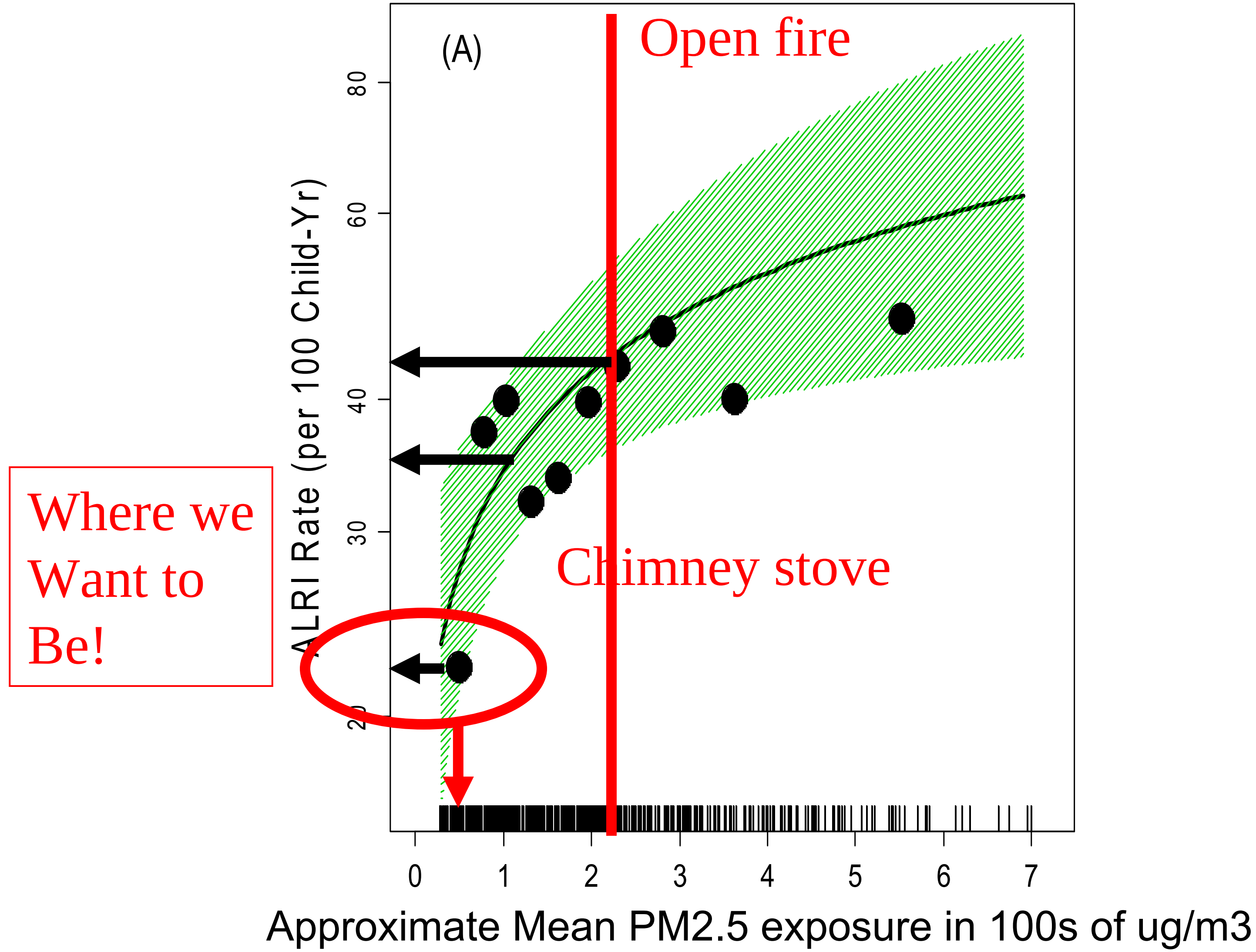


OAP Outdoor air pollution
SHS Secondhand tobacco smoke
HAP Household air pollution
ATS Active tobacco smoking

Heart Disease and Combustion Particle Doses



MD-diagnosed Acute Lower Respiratory Infection



RESPIRE-Guatemala

Indian National Cookstove Initiative

- **“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.”**

- **Shyam Saran, Dec 9. 2009**

Other issues

- Space heating
- Lighting and kerosene
- Measurement insights
  - Exposure
  - Stove Use
- Non-communicable diseases of the poor

Recent TB case-control study in Nepal

Table 2. Multivariate logistic regression model for fuel use in relation to TB in women in Pokhara, Nepal (log likelihood = –118.73, $R^2 = 0.44$).

Variable		OR (95% CI)[a]
Fuel stove		
GFS	**Gas**	.00
BFS	**Biomass**	.21 (0.48–3.05)
KFS	**Kerosene**	.36 (1.01–11.22)
Heating fuel		
No heating fuel use or electricity		1.00
Biomass, coal, or kerosene		3.45 (1.44–8.27)
Main light source in the house		
Electricity		1.00
Kerosene lamp		9.43 (1.45–61.32)

[a]Adjusted for age, religion, income, residence locality, residence district, literacy, type of present house construction, always lived in the present house, pack-years of smoking, number of family members who smoked indoors, alcohol consumption, taking vitamin supplements, family history of TB, and ventilation in the kitchen.

Pokhrel et al. 2010

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 ehs.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 enviromental 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

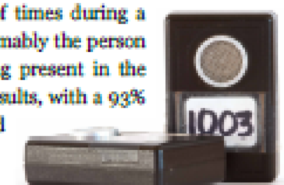
The ability to measure concentrations of small airborne particles is vital in understanding adverse health effects from combustion-derived air pollution. Available instrumentation to conduct such measurements is complex and expensive. Such devices are appropriate for developed countries and ambient air 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.

TIME-ACTIVITY MONITORING LOCATION

Measurement of exposure to pollutants is vital to the field of environmental health. The significance of a hazard depends on the amount of time a person is in contact with it. For instance, high indoor air pollution levels have been found in many homes globally. The risk of respiratory disease depends on the amount of time people spend in the presence of this pollution.

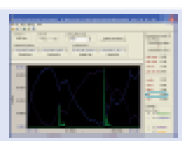
Time-Activity Monitoring System (TAMS) detects the presence or absence of individuals in an enclosed space. The system consists of one to five small ultrasound emitting devices worn on an individual's clothing. Each produces a distinct pattern that is emitted every few seconds. An ultrasound receiver is mounted on the wall of a room and detects the unique pattern from the device worn by an individual.

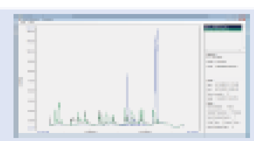
If the identifying signal pattern emitted from a particular locator is received a certain number of times during a minute, that locator, and presumably the person wearing it, is recorded as being present in the room. Field trials show good results, with a 93% accuracy rate as measured against direct observation.

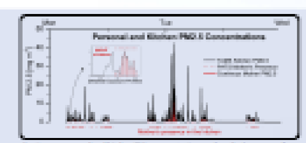


Device Software & Sample Output

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

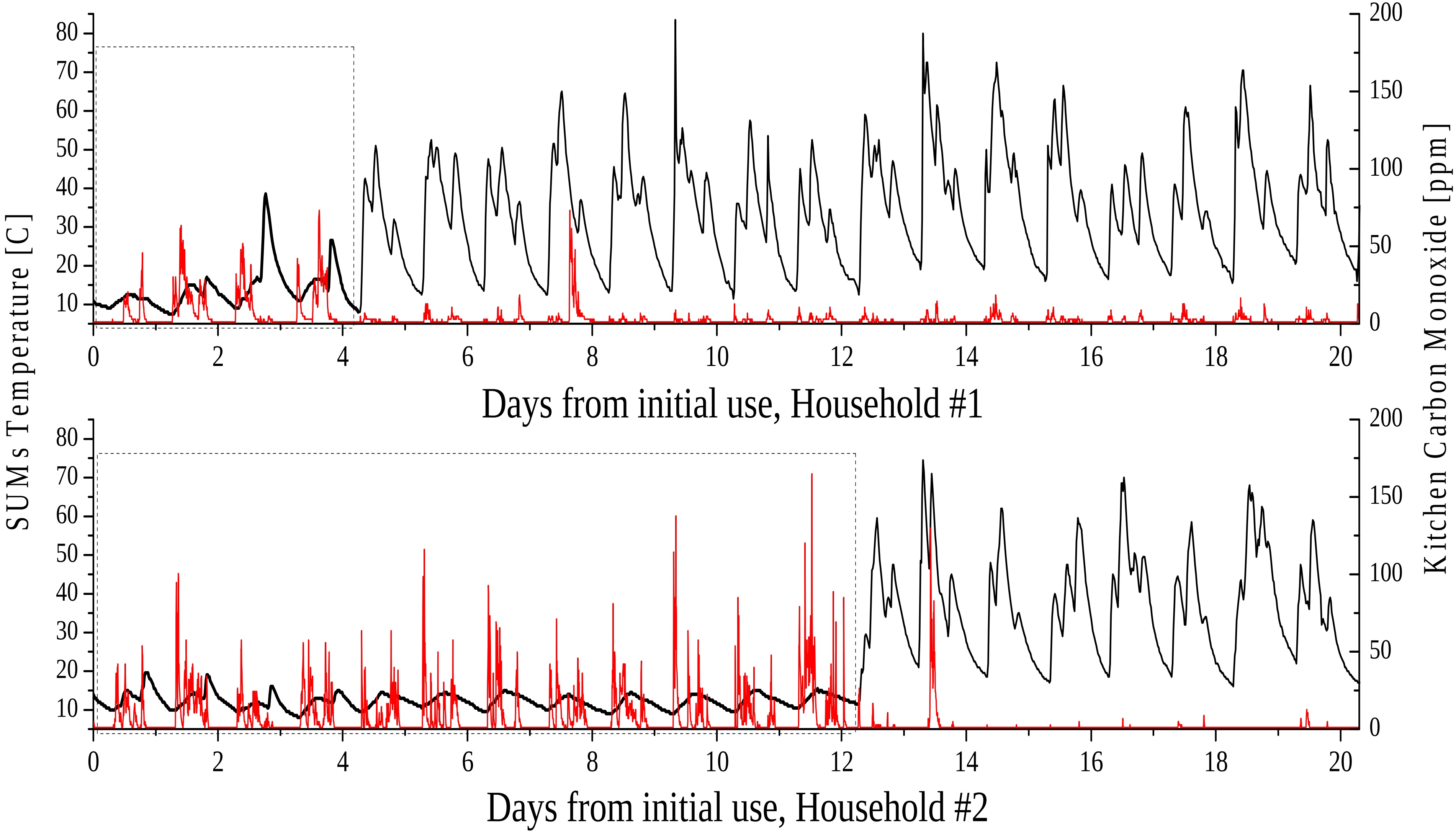




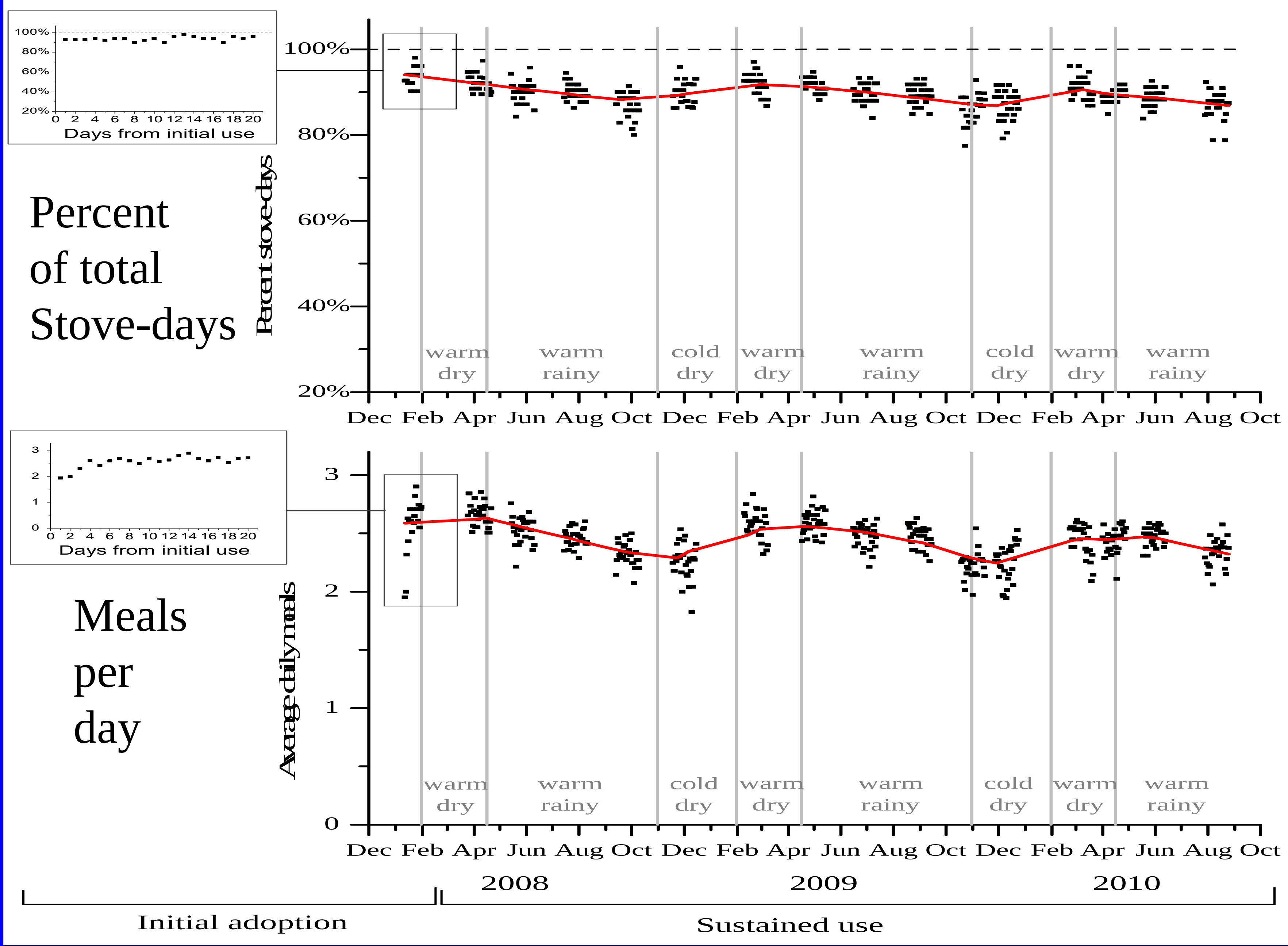


For more information, google "Kirk R Smith" • To acquire devices, visit berkeleyair.com

Stove Use Monitors (SUMs) in Action



Ruiz et al., submitted

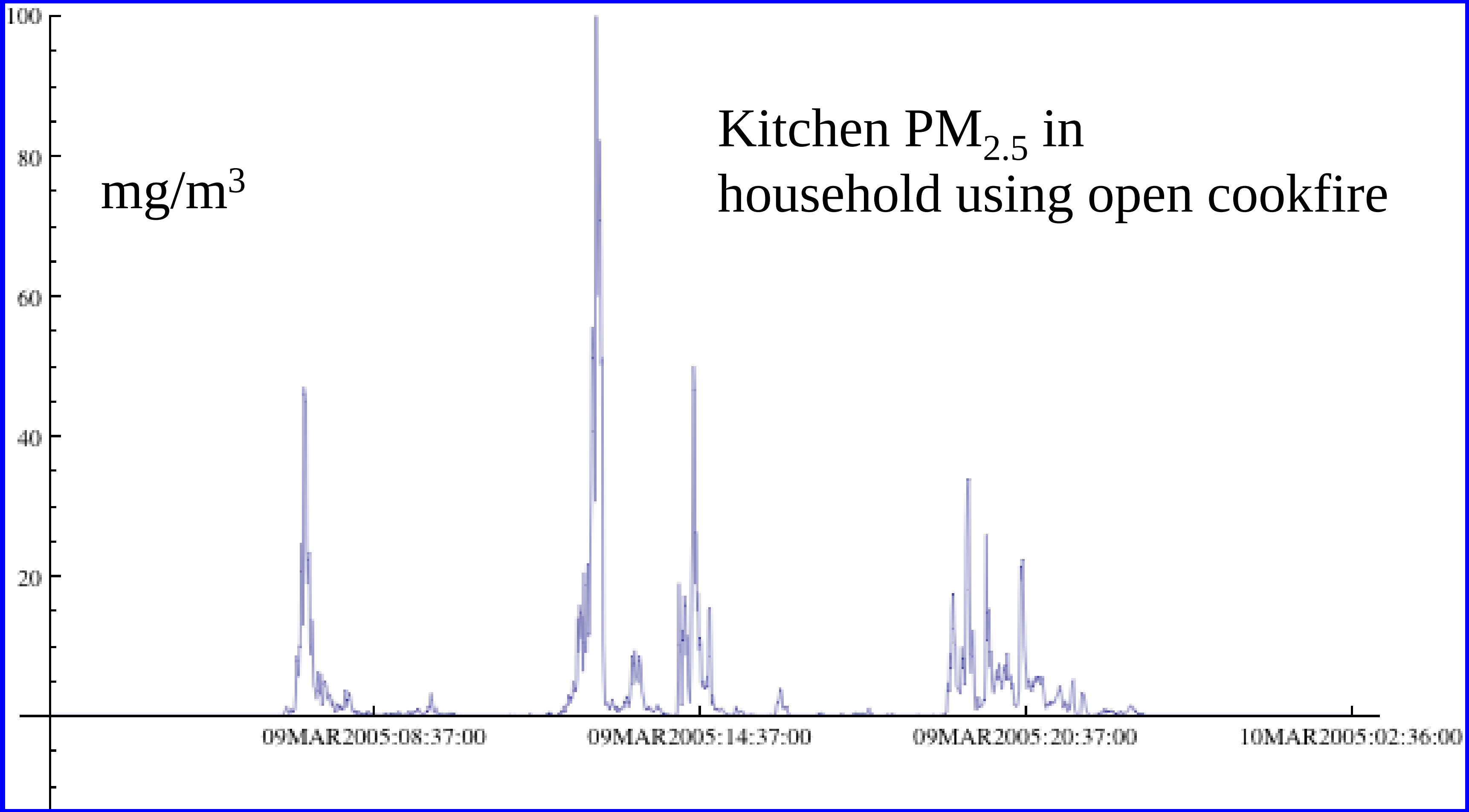


Ruiz et al., submitted

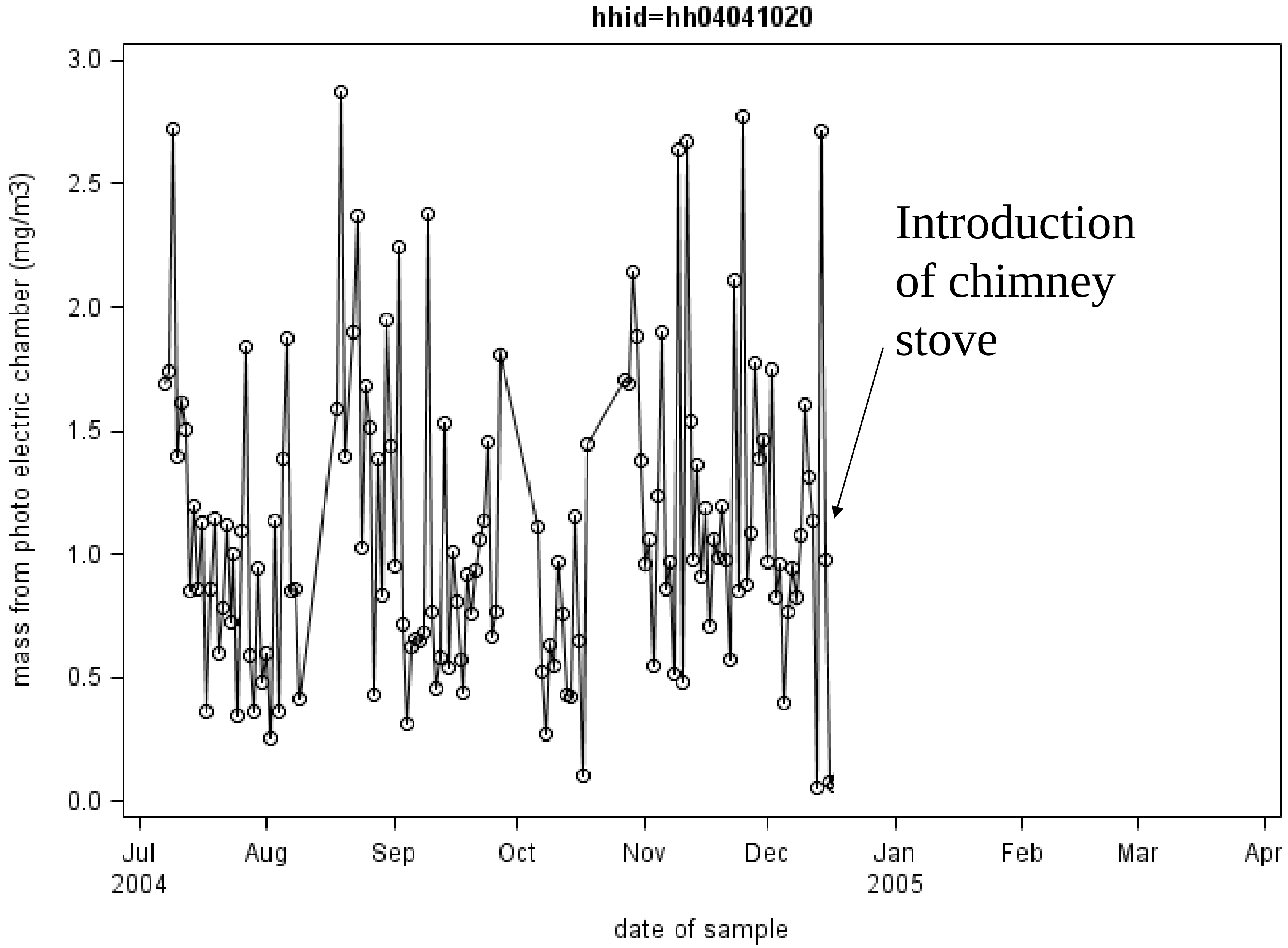
Inter-instrument Comparison: 30 UCB-PATS
UCB Particle and Temperature Monitoring System
(custom PM monitor using smoke alarm technology)

UCB Particle Monitor

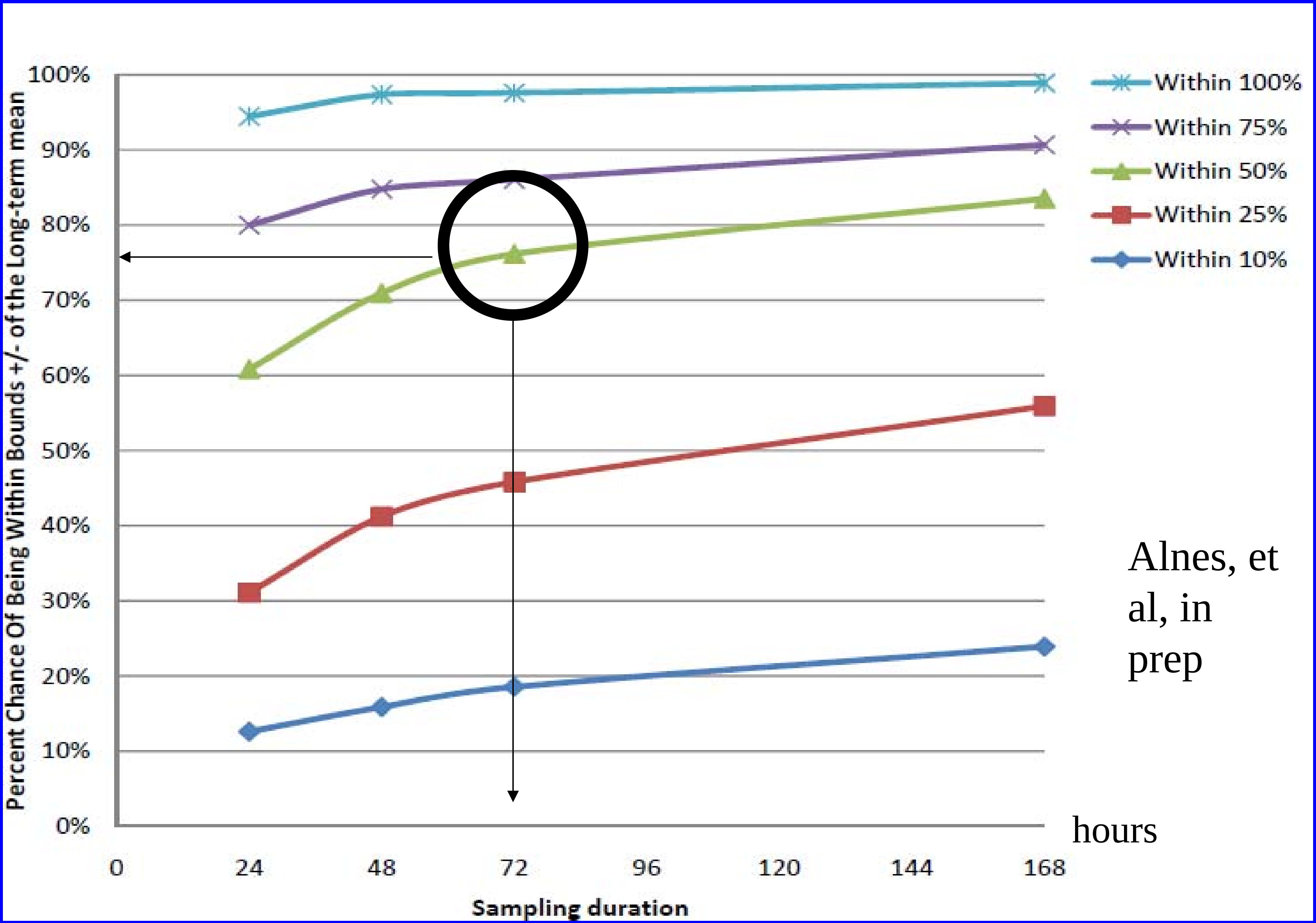
<u>How many hours should we measure to obtain good estimate of the long-term mean?</u>



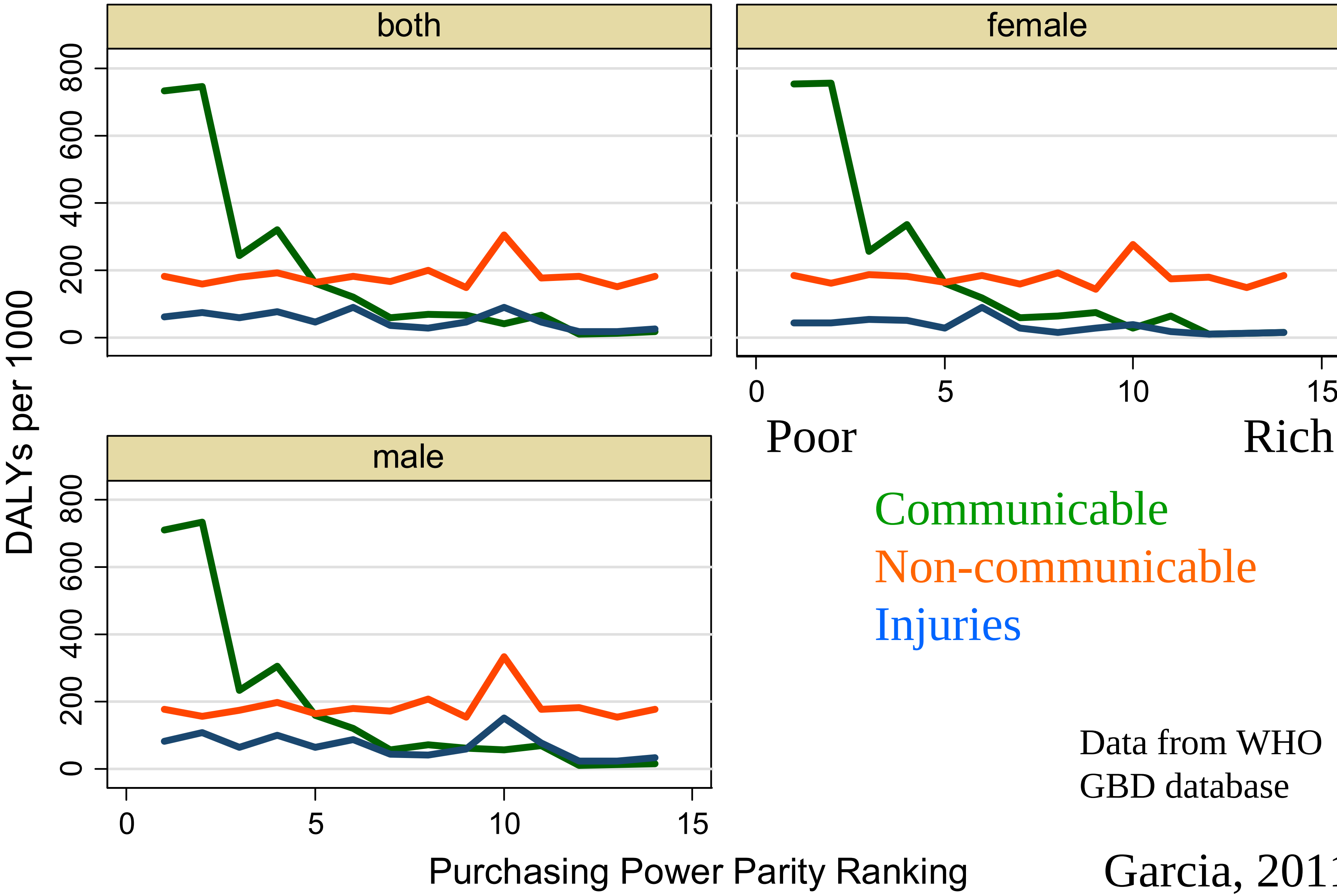
Long-term Household Measurements



How Close to the True Mean With One Measurement?



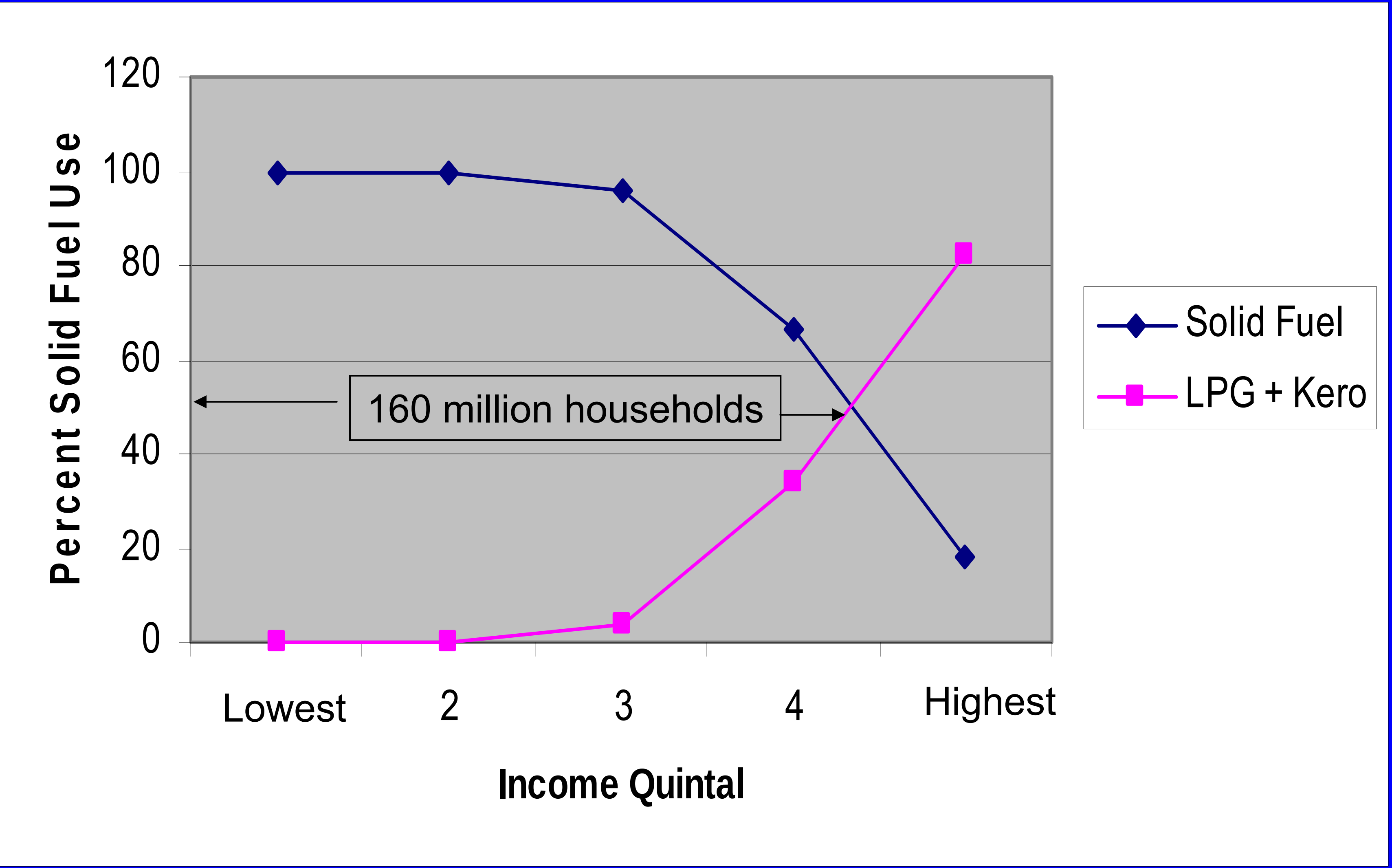
Epidemiological Transition: All Ages



Data from WHO
GBD database

Garcia, 2011

Distribution of Household Cooking Fuel by Income in India



NFHS, 2006

Combustion Particles (and their accompanying toxic side-kicks) cause more health damage than any other environmental contaminant

- Worst thing to do is stick burning stuff in your mouth ~5 million deaths
- Not so great to have other people sticking in their mouths nearby ~ 300k deaths
- Bad even to have poorly burning stuff in your city ~ 1 million deaths
- The oldest of burning practice, however -- poorly combusted fuels in the home -- is still the cause of more ill-health than any other particle source except smoking ~ 1.6 million deaths

If it doesn’t take fifty years, it isn’t worth doing.*

- First Royal Commission on Air Pollution in London in 1315; recommendation (ban coal burning) taken up in 1955.
- John Snow in 1854; still one-third of world population without adequate sanitation/water
- Surgeon General’s Report in 1964; Framework Convention on Tobacco Control came into force in 2005 (still not all countries signed up)

*Attributed to Albert Einstein

Many thanks to colleagues and funders here today:

- Adair, Balakrishnan, Balmes, Bates, Bruce, Charron, Edwards, Jack, Kinney, McCracken, Mehta, Naeher, Peel, Pennise, Pope

- CDC, NIEHS, Shell Foundation, USEPA, WHO, Winrock, World Bank

- And all the others not here

- Publications and presentations on website – easiest to just "google" Kirk R. Smith