Combustion Particles

The World's Oldest Newest, and Largest Environmental Health Hazard

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Combustion Particles:
The Oldest and Newest of Pollutants

- Oldest: first measured and regulated
  - First Royal Air Pollution Commission in history
    - Appointed in 1265, completed its report in 1306
    - (setting the standard for expert committees)
    - Recommended banning coal burning in London
    - Duly taken up 650 years later by the authorities (1956)
    - (setting the standard for policy response)
  - First systematic measurements in London in 1800s: on fire stations (dust fall)
  - First exposure response relationships for air pollutants

PM: The Newest Pollutant

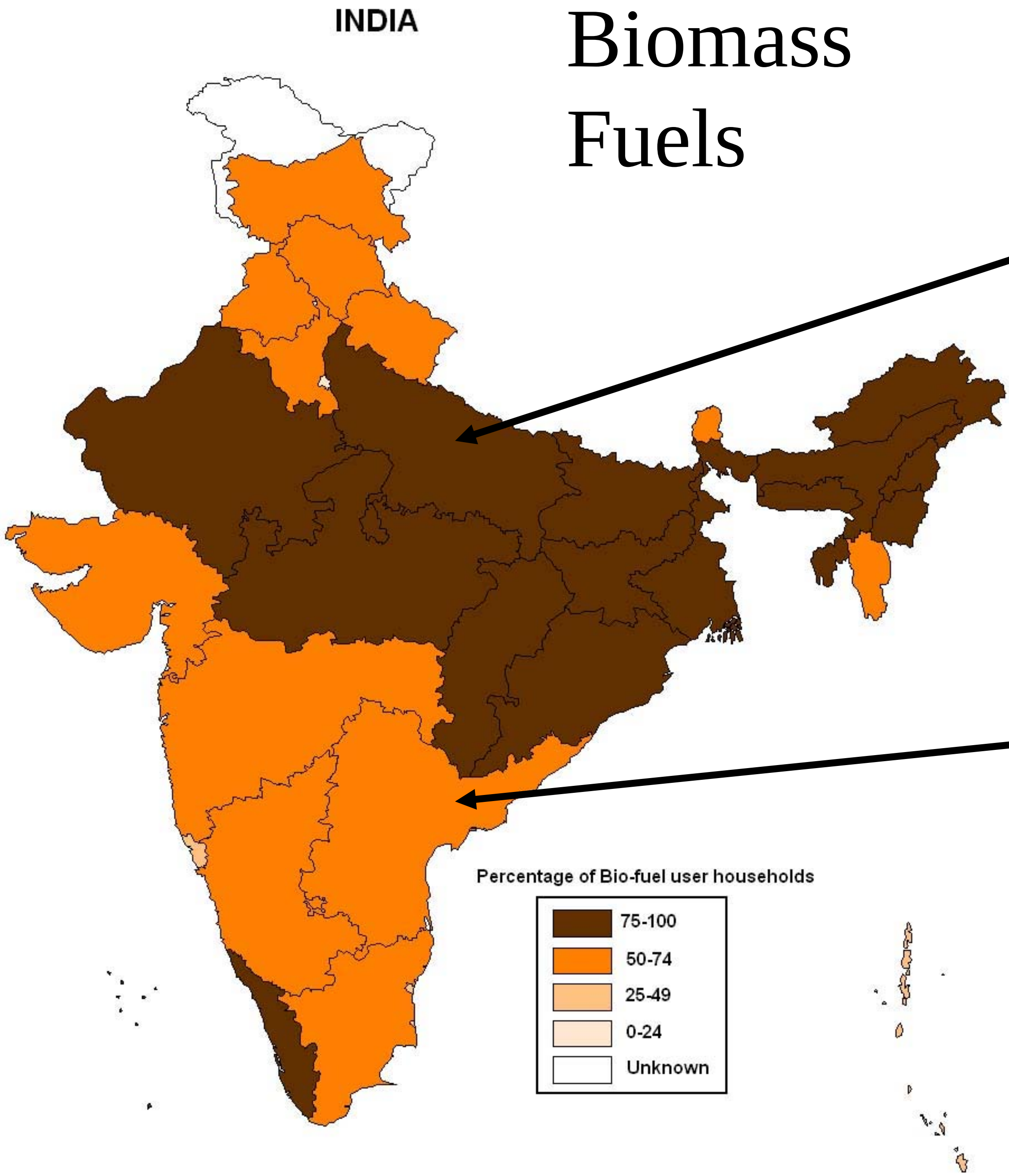
- mechanisms of creation and impact are still not clear,
- new health standards being implemented,
- thresholds of effect essentially have disappeared
- new measurement methods being developed,
- even basic metrics in some doubt
- major impacts on regional and global climate now recognized
- difficult tradeoffs now discussed between climate and health goals

Road Map for this Presentation

- What are major sources of exposure to combustion particles?
- How do we calculate the burden of disease from different risk factors in a compatible manner?
- How was this done globally for outdoor and indoor sources of combustion particles?
- How do the results compare with other major risk factors?
- How does this relate to climate change?

Oldest Pollution Source in Human History
By definition

Biomass Fuels



More than 75% of households

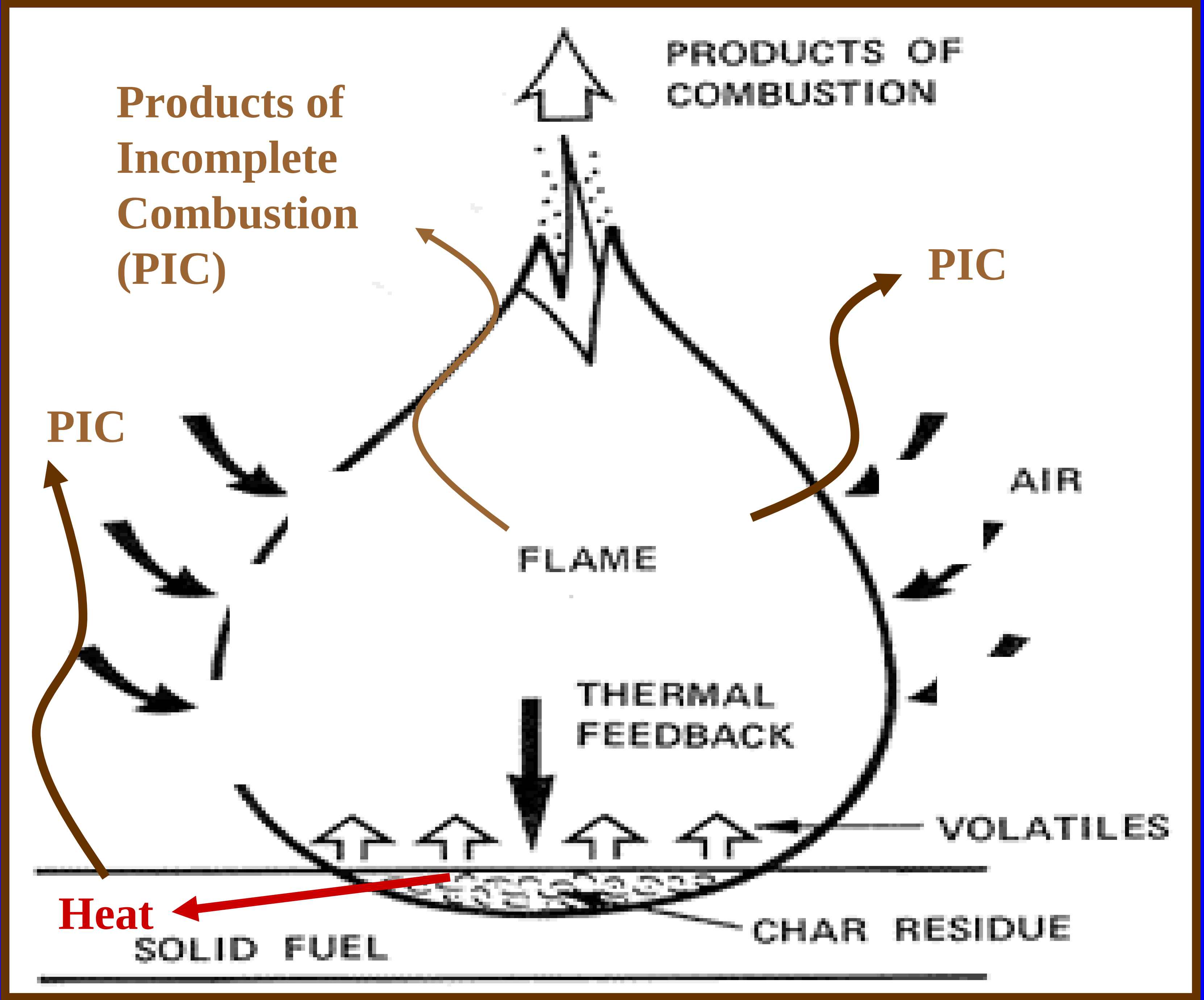
50-74% of households

2000 Census

Woodsmoke is natural – how can it hurt you?

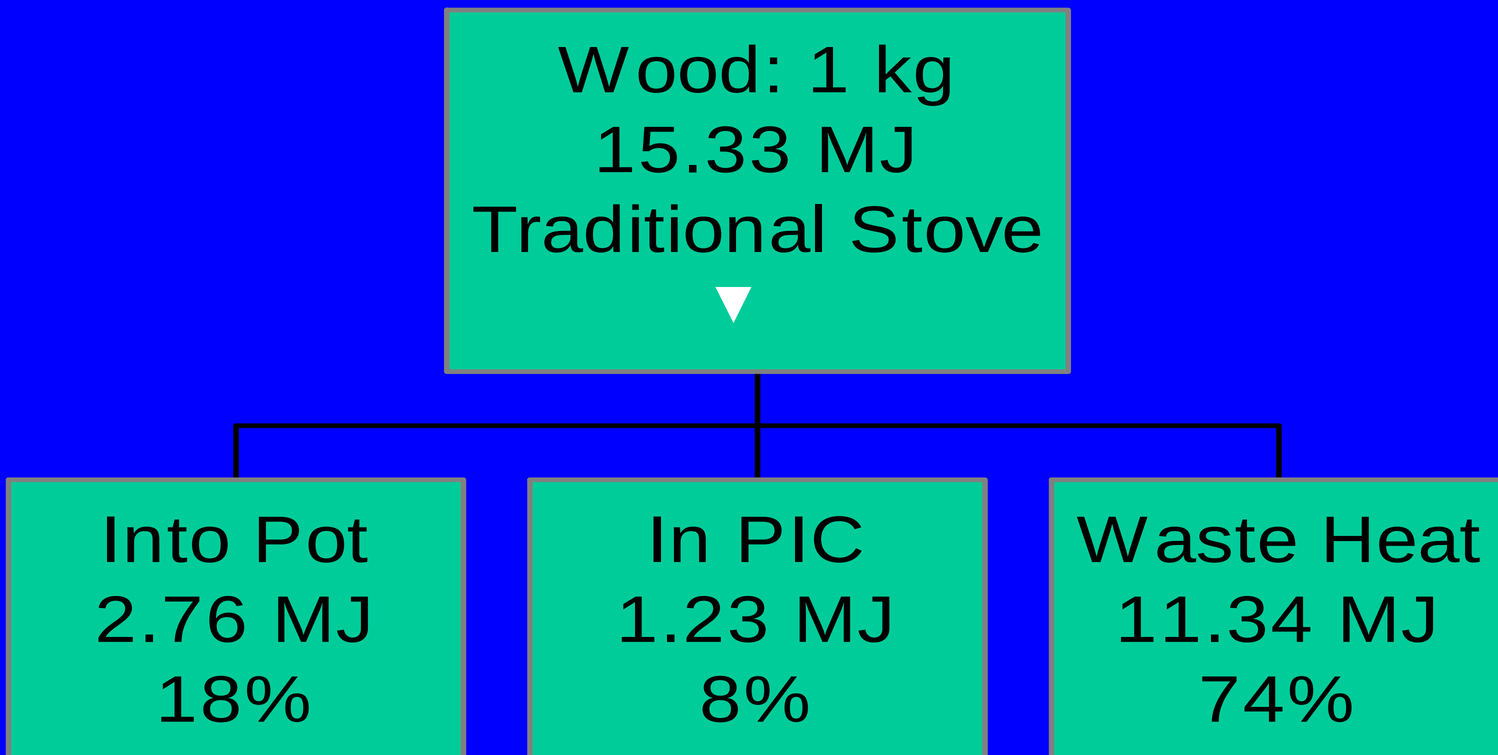
Or, since wood is mainly just carbon, hydrogen, and oxygen, doesn't it just change to CO_2 and H_2O when it is combined with oxygen (burned)?

Reason: the combustion efficiency is far less than 100%


PRODUCTS OF
COMBUSTION
Products of
Incomplete
Combustion
(PIC)
PIC
PIC
AIR
FLAME
THERMAL
FEEDBACK
VOLATILES
Heat
SOLID FUEL
CHAR RESIDUE

Energy flows in well-operating traditional Indian woodfired cookstove

PIC = products of incomplete combustion.



Smith et al., 2000

Indian Cookstoves

	Nominal Combustion Efficiency	Approximate % of Households -
• Gas: `	99% (98-99.5)	[18%]
• Kerosene:	97 (95-98)	[7]
Solid Fuels		
• Wood:	89 (81-92)	[53]
• Crop resid:	85 (78-91)	[10]
• Dung:	84 (81-89)	[10]
• Coal	(variable)	[2]

Source: Smith, et al, 2000
Census, 2001

A Toxic Waste Factory!!

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

454 g Carbon

CO_2 Carbon: 295.8 g

PIC Carbon:
CO: 18.5 g
CH_4: 2.8
TNMOC: 5.2 g

Char/Ash: 161 g
130 g Carbon

TSP Carbon: 1.7 g

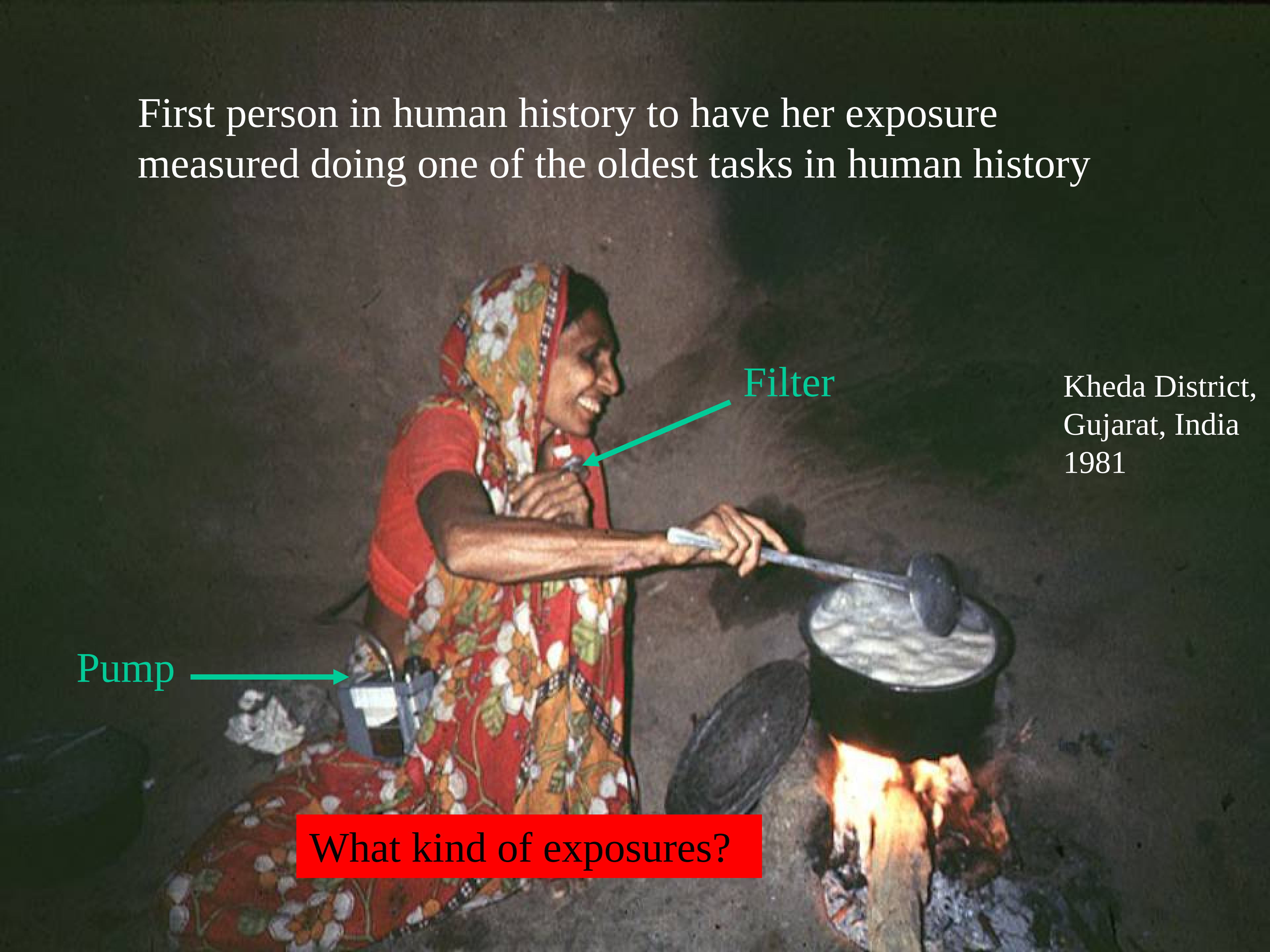
Nominal Combustion Efficiency = 1/(1+k) = 89%

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

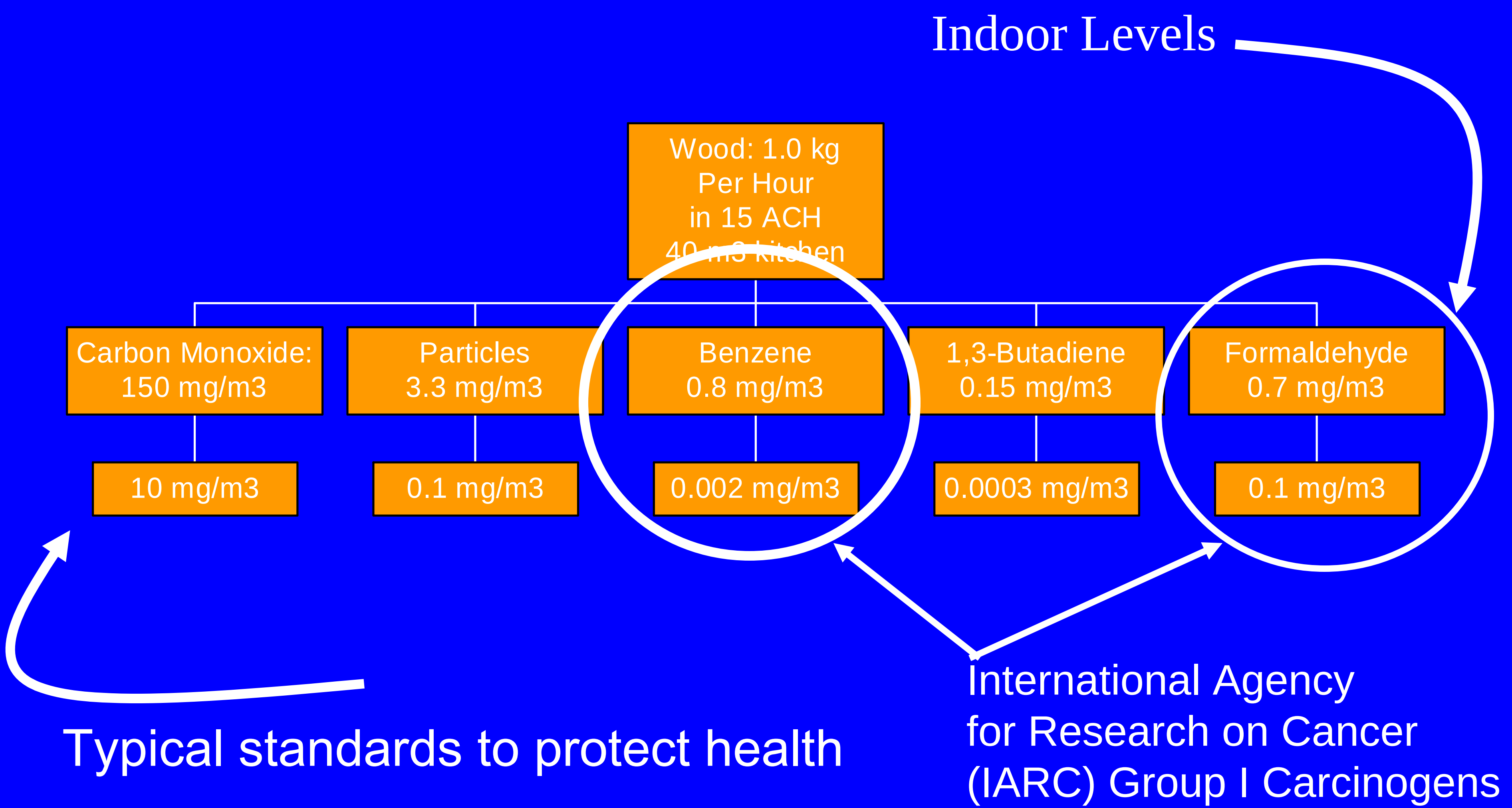
- Small particles,
- Hydrocarbons
  - 25+ saturated hydrocarbons such as *n-hexane*
  - 40+ unsaturated hydrocarbons such as *1,3 butadiene*
  - 28+ mono-aromatics such as *benzene & styrene*
  - 20+ polycyclic aromatics such as *benzo(α)pyrene*
- Oxygenated organics
  - 20+ aldehydes including *formaldehyde*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

Best measure of risk
~ 0.1-0.4% of fuel weight

Naeher et al. 2007, JIT


First person in human history to have her exposure measured doing one of the oldest tasks in human history
Filter
Kheda District, Gujarat, India 1981
Pump
What kind of exposures?

Indoor pollution concentrations from typical woodfired cookstove during cooking



Size Distribution of Biomass Smoke Particles

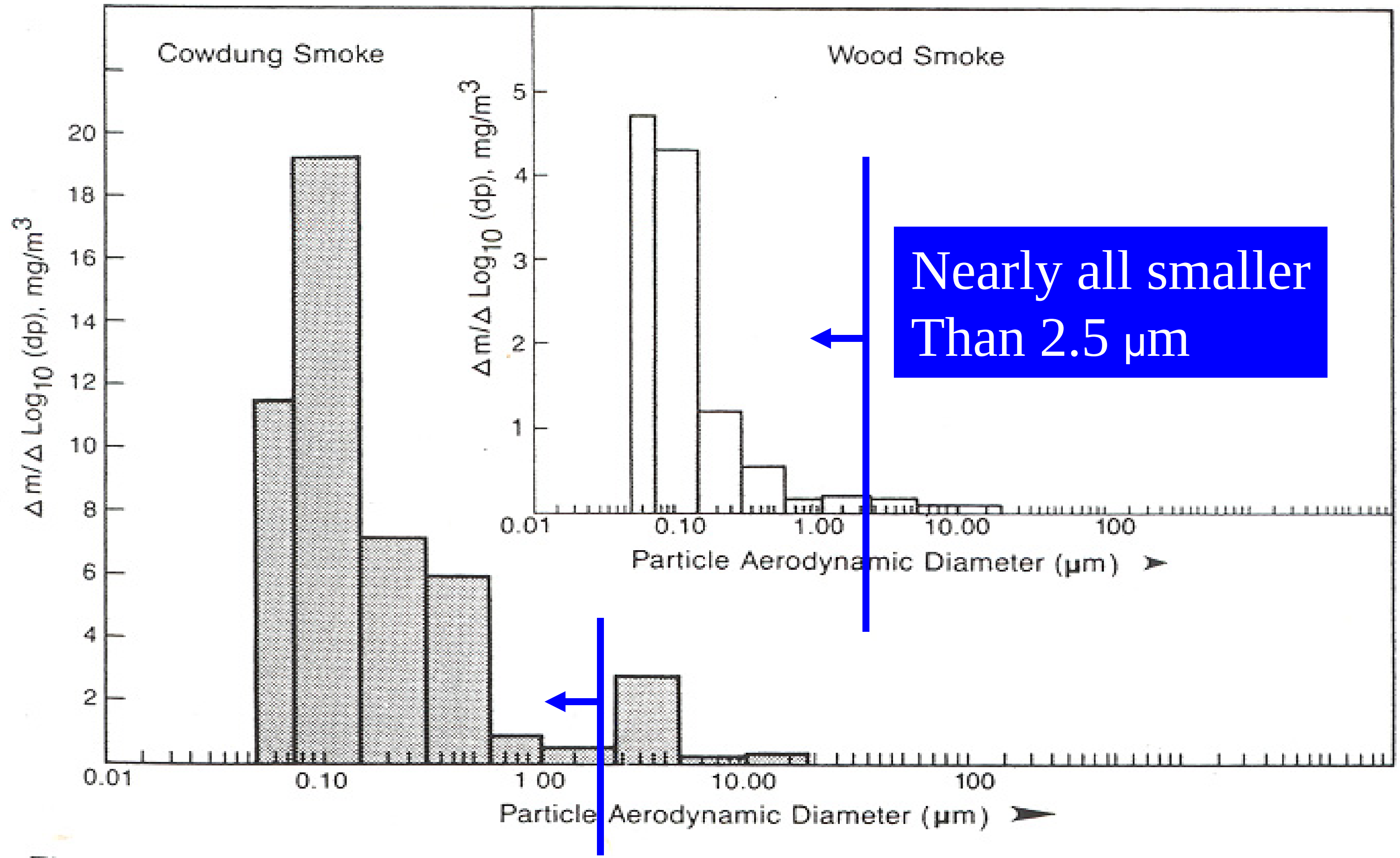
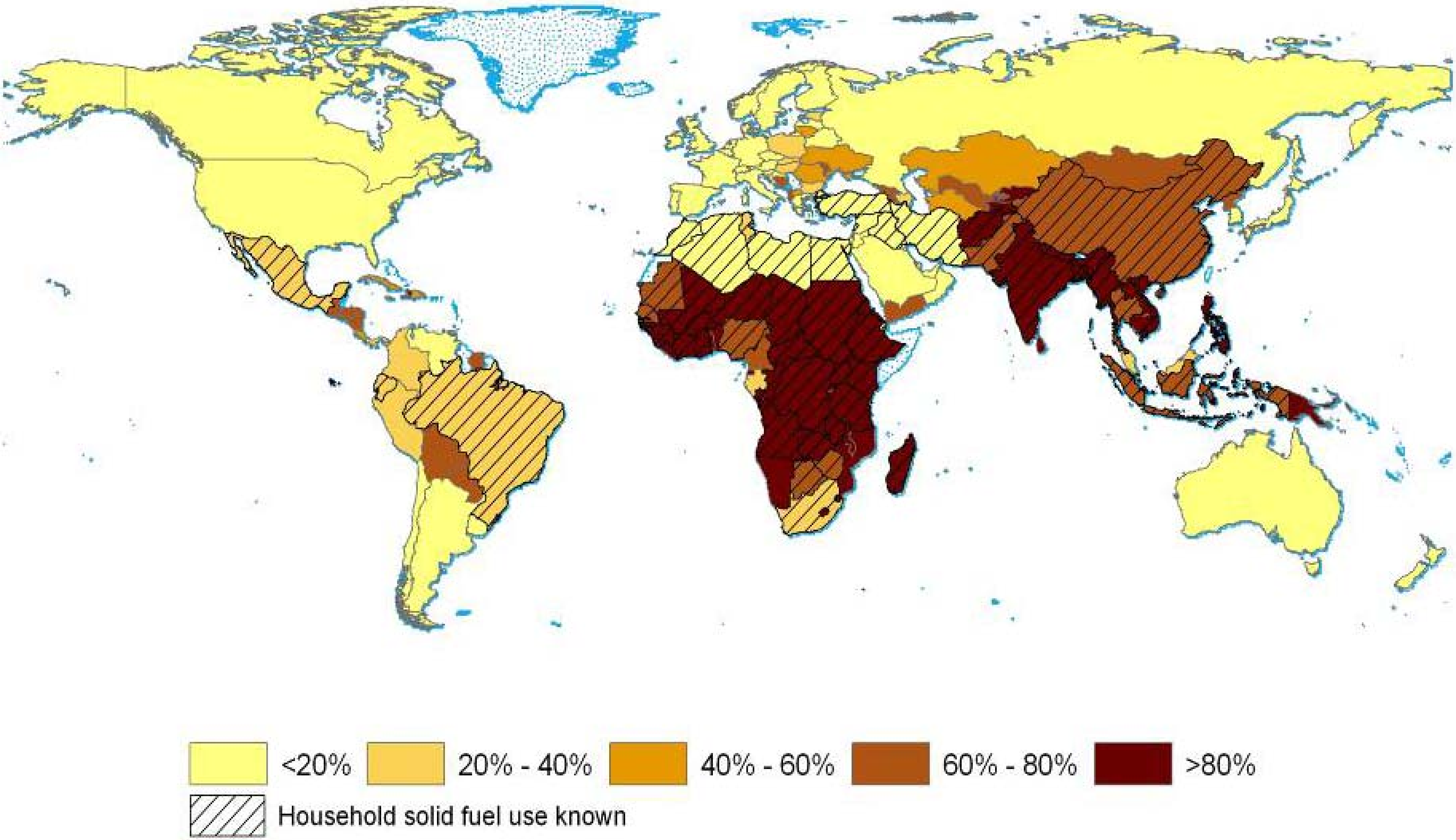


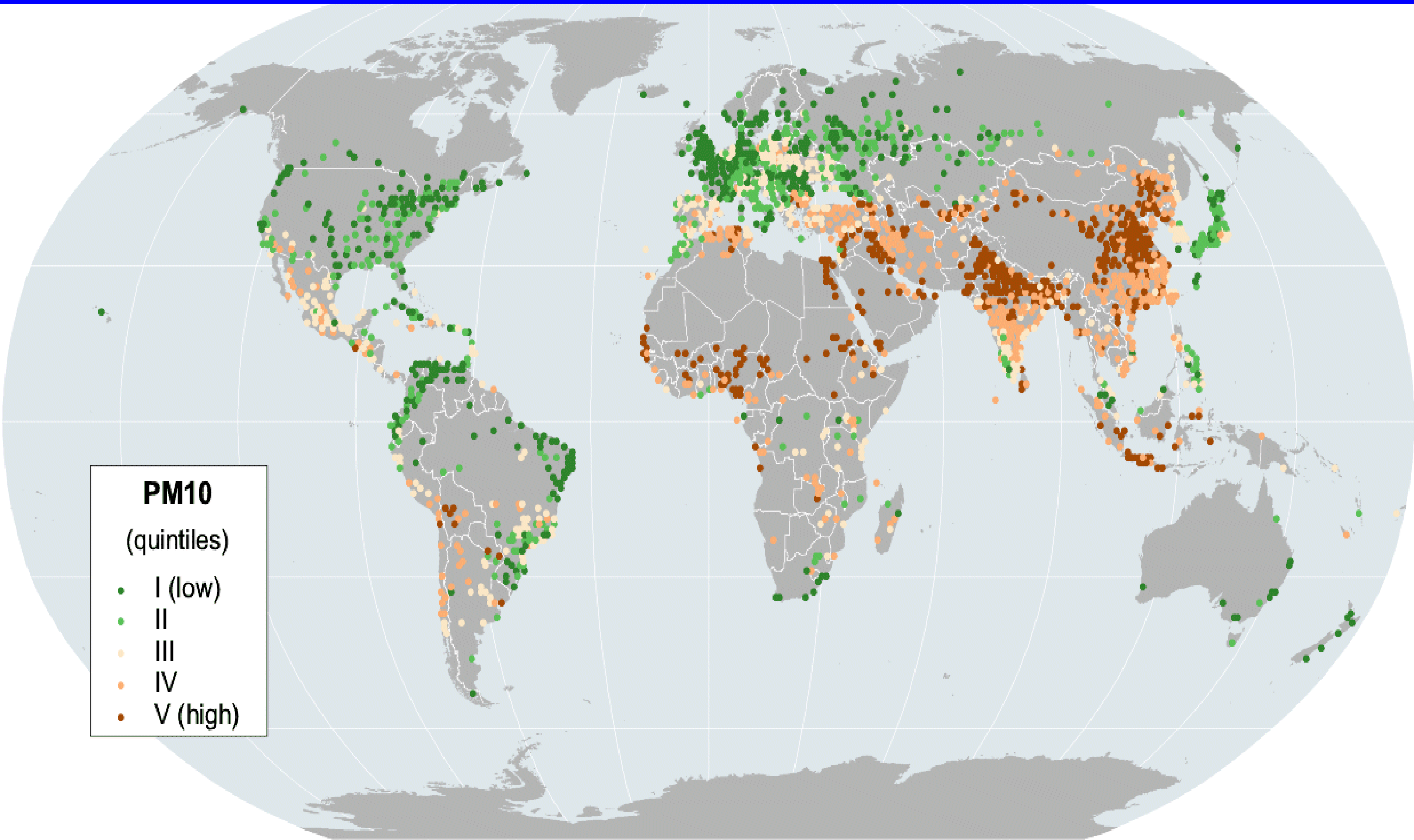
Figure 2.2. Size distribution of woodsmoke and dungsmoke particles. Measurements taken in the East–West Center simulated village house as reported in Smith *et al.* (1984b). (Figure prepared by Premlata Menon.)

Source: Smith, Apte et al. 1984

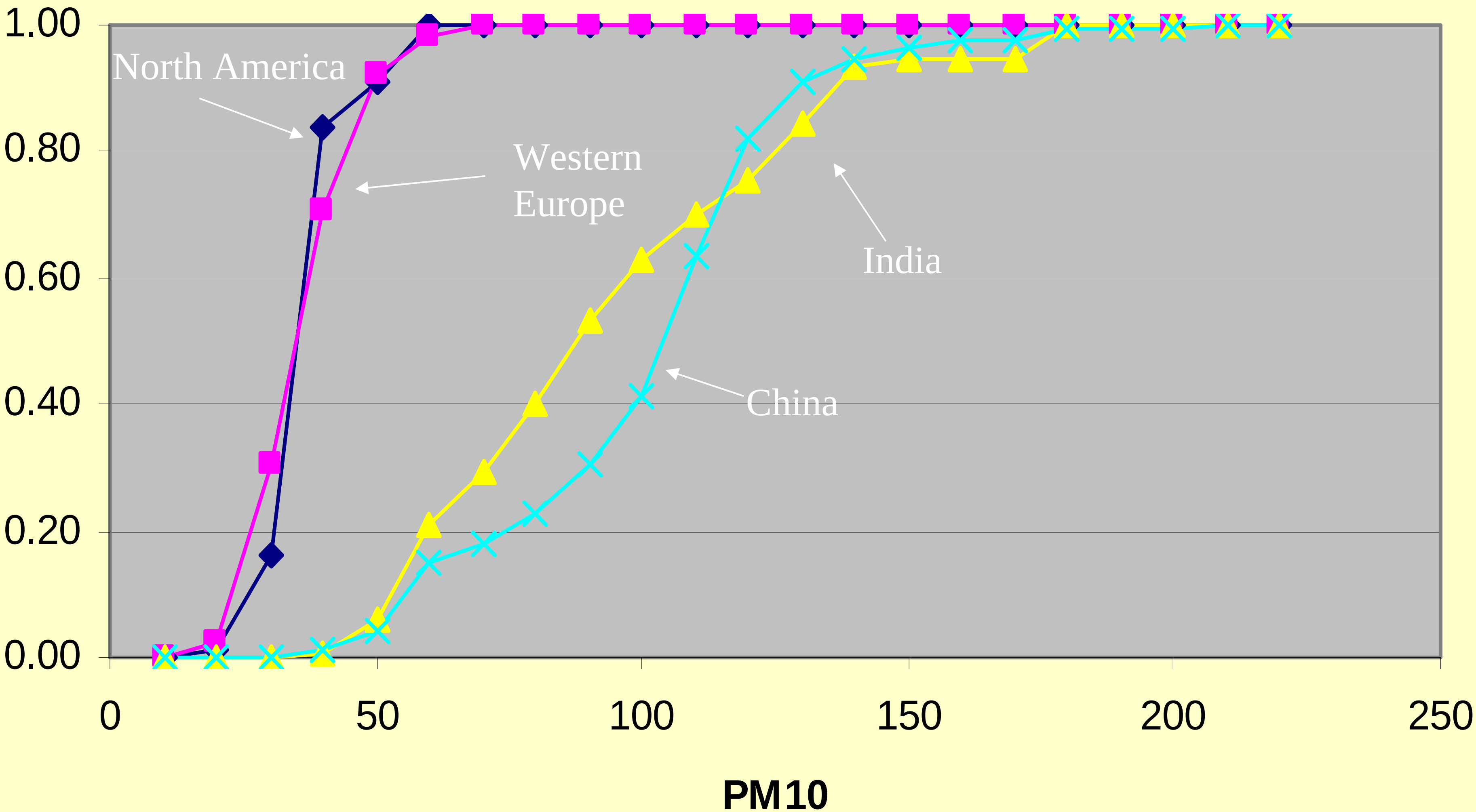
National Household Solid Fuel Use, 2000



Estimated PM10 Concentration in World Cities (pop=100,000+)



Cumulative distribution of urban pollution ($\mu g/m^3$)



How would we answer these questions?

- What is the total impact of disease and injury in the population? -- the overall target for public health interventions?
  - Which diseases are most important for which groups?
  - Are things getting better or worse?
- How do we compare the impacts of different risk factors and potential interventions that affect different populations?
  - For example, what is the burden of disease from particle air pollution?
  - How does the impact of tobacco smoking compare to that from air pollution?

Environmental Health Effects

- Example of results from outdoor particle studies
  - Asthma attacks
  - Missing workdays
  - Missing school days
  - Days with cough
  - Emergency room visits
  - Hospital admissions
  - Physician visits
  - Medication use
  - Daily death rate
  - Lung function
  - Self-reported health status
  - Etc.
- How can these be compared across time, cities, countries, age groups, sectors (e.g., transport versus power plants), etc.?
- Let alone compared with the health impacts from completely different risk factors, such as water pollution, lead exposure, high cholesterol, unsafe sex, etc.?

Ultimate Measure of Ill-health?

- Death is most common
  - Easy to determine
  - Commonly tabulated
- Severe problems as a measure
  - Everyone dies
  - Health never achieved
  - Age is clearly important
- Deaths + Illness = ?

First C^4 Database in Health

(Which we have had in many other fields for long periods)

- Combined mortality and morbidity – lost time
- Complete
  - Much of the world unrepresented in past databases
  - Many important disabilities unaccounted
- Consistent definitions of disease states
- Coherent
  - Deaths by disease need to add to total
    - By age and sex
    - Match with demographic stats
  - No natural discipline, i.e. no import stats from the afterlife tabulating how many died of what

Basic Principles

- C4: Combined, complete, consistent, and coherent
- Like is like
  - The only differences in effects is due to age and sex, not to nation, income, race, social class, etc.
- All are equal
  - All people have the potential for the highest life expectancy in the world, there are no intrinsic differences by genetic or other reasons.

Population (thousands)

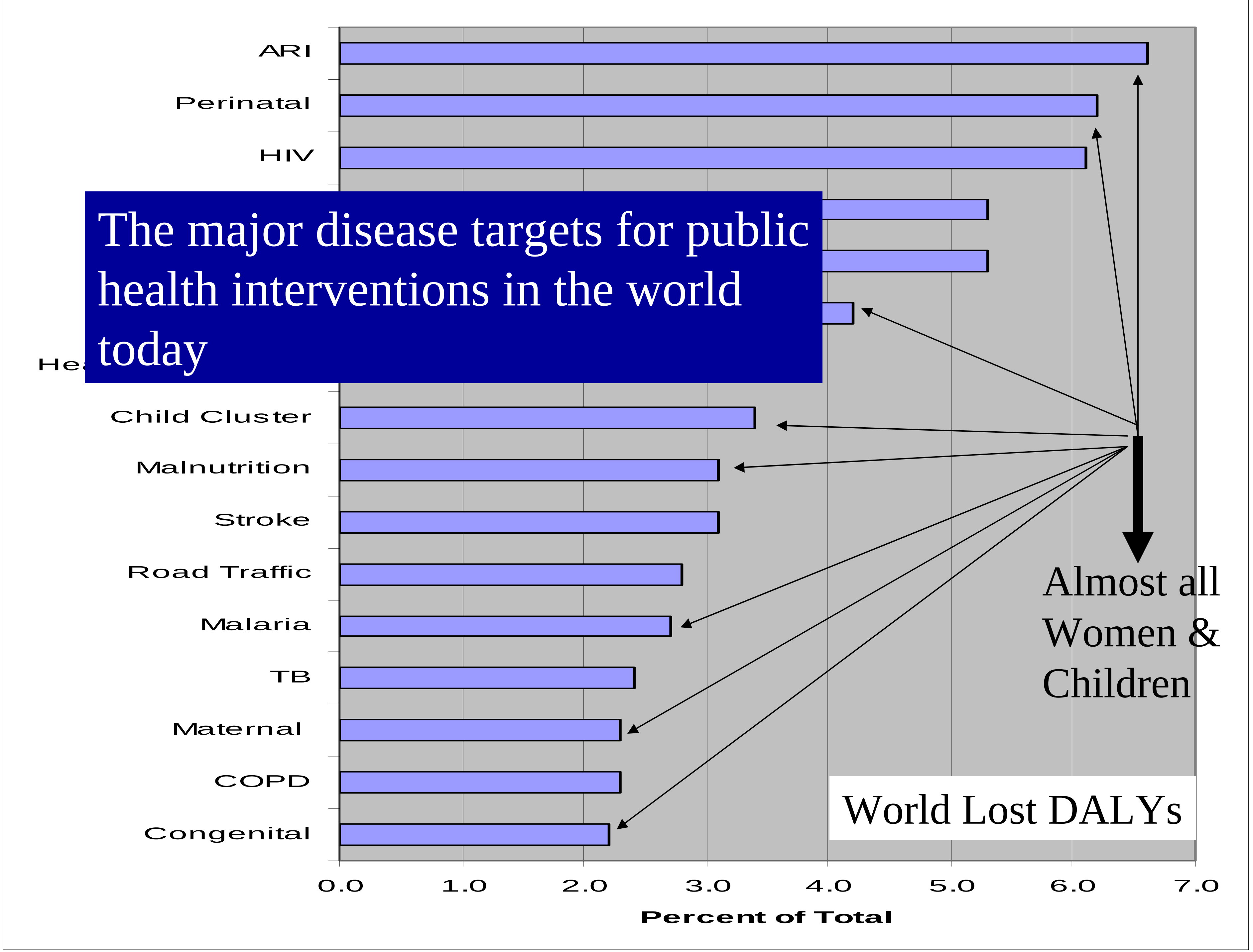
GBD 2002: DALYs by age, sex and cause for the year 2002

WORLD

Code	Cause	Total	Male 0-4	Male 5-14	Male 15-29	Male 30-44	Male 45-59	Male 60-69	Male 70-79	Male 80+	Male Total	Female 0-4	Female 5-14	Female 15-29	Female 30-44	Female 45-59	Female 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	3365159	463945	16559	683964	301215	6664	719	91	3	1473160	447789	24323	989323	422675	6262	1616
U008	d. Other STDs	210465	16932	185	3327	22911	61292	2987	1157	425	109215	11943	127	11546	22947	37012	13420
U009	**3. HIV/AIDS**	84457784	6215039	1923486	11002792	18824803	4373213	299351	23497	420	42662599	5985984	1878957	17299389	13746555	2624463	230670
U010	**4. Diarrhoeal diseases**	61966183	29217337	800330	791539	721612	446922	197262	122248	55269	32352519	26863437	754533	652616	545936	373258	201900
U011	**5. Childhood-cluster diseases**	41479543	19033686	1422740	174377	55101	19437	4748	1821	613	20712522	19065281	1447659	172987	53966	19174	4837
U012	a. Pertussis	12594810	6231695	50837	44	0	0	0	0	0	6282575	6261471	50717	34	0	13	0
U013	b. Poliomyelitis	150660	15348	9021	29583	17300	3733	643	460	123	76211	15357	8675	28237	16931	3822	615
U014	c. Diphtheria	184710	83919	8085	1348	1346	1207	206	21	11	96143	67627	19365	523	386	572	29
U015	d. Measles	21475463	9387297	1255475	84251	83	20	23	0	0	10727148	9394304	1269212	84741	29	30	0
U016	e. Tetanus	7073899	3315427	99323	59152	36372	14477	3876	1340	479	3530446	3326522	99690	59452	36620	14737	4192
U017	**6. Meningitis***	6191790	1504271	596798	445433	257091	184063	53527	33371	6998	3081551	1676034	734345	341757	167759	110215	48775
U018	**7. Hepatitis B**	2170326	105358	137204	275807	430017	397164	82713	26027	4975	1459264	188406	62506	173729	115391	110437	36630
U019	**Hepatitis C**	1003682	35920	56182	100610	192346	210317	48794	20514	3442	668127	72373	24200	67867	53705	61307	30322
U020	**8. Malaria**	46485868	20191868	607710	620617	438228	247611	87288	40647	9444	22243414	22056596	601958	689661	453207	280704	99111
U021	**9. Tropical-cluster diseases**	12245452	311034	2512134	3070382	1576828	643186	115534	37265	6156	8272521	266359	1203242	1297027	593336	496341	75537
U022	a. Trypanosomiasis	1525287	75814	412367	236703	148103	84732	6426	1970	54	966168	41943	237244	149181	79329	46509	3694
U023	b. Chagas disease	666764	65	50	182129	71755	58490	21730	6937	1754	342910	137	193	198737	51644	48058	15987
U024	c. Schistosomiasis	1701795	8779	325555	322328	193817	110544	41702	15248	2506	1020479	5691	221149	232053	128589	58850	17056
U025	d. Leishmaniasis	2089888	83685	477545	410956	200263	60230	13331	3321	135	1249465	115737	367279	246063	67203	30097	11647
U026	e. lymphatic filariasis	5777436	133357	1268387	1866390	878568	248993	13583	3489	415	4413181	94654	349733	425651	206680	266630	15772
U027	f. Onchocerciasis	484282	9335	28230	51876	84323	80198	18762	6301	1293	280317	8197	27645	45343	59892	46198	11380
U028	**10. Leprosy**	198778	7694	25203	20293	25074	25666	7702	4506	516	116652	10370	23264	16689	15828	9135	4389
U029	**11. Dengue**	615529	67552	177902	15445	9070	5409	2019	1034	440	278872	76029	215987	23174	10408	6396	2644
U030	**12. Japanese encephalitis**	709219	100148	92418	61558	70268	9948	2292	1205	279	338116	160556	131203	41495	26926	7282	2513
U031	**13. Trachoma**	2328780	1861	2594	32532	183952	201068	111206	53718	10162	597093	1973	7118	68754	517423	559520	344796
U032	**14. Intestinal nematode infections**	2951341	257716	1196068	14526	7512	8174	4301	1450	492	1490238	273831	1158847	12068	5192	5921	3469
U033	a. Ascariasis	1816942	157488	751279	695	270	222	11	15	40	910021	171105	735150	311	161	21	111
U034	b. Trichuriasis	1006248	82408	432805	1371	908	699	367	108	27	518693	74437	411117	823	388	433	238
U035	c. Hookworm disease	58617	339	3937	11312	5396	5924	3091	1074	262	31336	0	4583	9796	4212	4859	2723
U036	Other intestinal infections	69534	17481	8047	1148	937	1329	831	252	163	30188	28290	7997	1138	432	607	397
U037	Other infectious diseases	41445320	8567237	2450753	2311612	2584703	2021325	757612	461907	118307	19273457	10586539	4372108	2370886	1795391	1650048	667703
U038	**B. Respiratory infections**	94603349	32429989	6247258	2411409	1749936	1847020	1735082	1261667	494366	48176727	30184256	6903318	2987156	1481589	1357246	1460806
U039	1. Lower respiratory infections	91373521	31836027	5573644	2310964	1655193	1773743	1682121	1232996	482877	46547564	29539590	6167276	2918287	1434738	1329549	1425397
U040	2. Upper respiratory infections	1795292	458484	84253	86969	82518	70655	51526	28370	11405	874181	513743	201270	59304	45228	26339	34405
U041	3. Otitis media	1434536	135477	589362	13476	12225	2623	1435	300	84	754982	130923	534772	9565	1622	1358	1004
U042	**C. Maternal conditions**	33631593	0	0	0	0	0	0									
U043	1. Maternal haemorrhage	4437585	0	0	0	0	0	0									
U044	2. Maternal sepsis	6903085	0	0	0	0	0	0									
U045	3. Hypertensive disorders*	2162701	0	0	0	0	0	0									
U046	4. Obstructed labour	3048291	0	0	0	0	0	0									
U047	5. Abortion	4652171	0	0	0	0	0	0									
U048	Other maternal conditions	12427759	0	0	0	0	0	0									
U049	**D. Perinatal conditions***	97335086	53209265	1343	1031	347	89	12									
U050	1. Low birth weight	46334234	25061999	52	13	20	0	9									
U051	2. Birth asphyxia and birth trauma	34445758	19353003	790	302	73	33	3									
U052	Other perinatal conditions	16555094	8794262	502	716	253	56	0									
U053	**E. Nutritional deficiencies**	34416632	10258276	1921013	1793247	1025783	698252	230984									
U054	1. Protein-energy malnutrition	16910328	7556012	560106	156056	69278	103279	71114									
U055	2. Iodine deficiency	3519322	1283895	471857	528	748	1215	641									
U056	3. Vitamin A deficiency	792562	257306	84825	3330	6358	7864	3519									

Global Burden of Disease Database
World Health Organization

Being completely updated 2007-2009



The major disease targets for public health interventions in the world today
ARI
Perinatal
HIV
Child Cluster
Malnutrition
Stroke
Road Traffic
Malaria
TB
Maternal
COPD
Congenital
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
Percent of Total
Almost all Women & Children
World Lost DALYs

We have a means to answer the first, but what about the second?

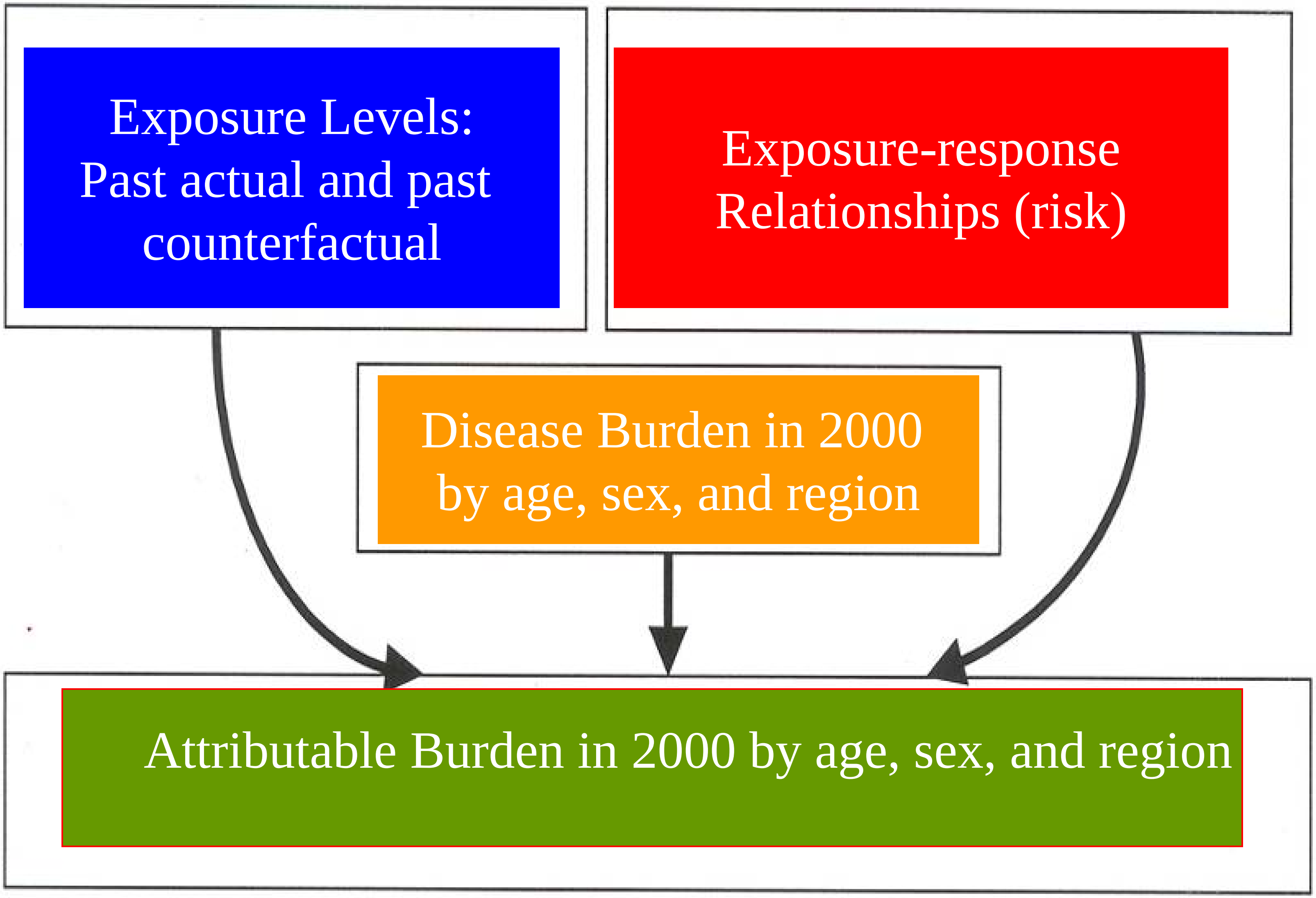
- What is the total impact of disease and injury in the population? -- the overall target for public health interventions?
  - Which diseases are most important for which groups?
  - Are things getting better or worse?
- How do we compare the impacts of different risk factors and potential interventions that affect different populations?
  - For example, what is the burden of disease from environmental factors?
  - How does the impact of tobacco smoking compare to that from air pollution?

Comparative Risk Assessment (CRA) 2-year 30-institution project organized by the World Health Organizaton

Disease, injury, and death due to 26 major risk factors calculated by age, sex, and 14 global regions.

Fully published in late 2004 in two volumes by WHO

Comparative Risk Assessment Method



Outdoor Exposure - pollutant for exposure assessment

Criteria

- Index of combustion processes
- Compelling evidence of health effect
- Widely available measure

- Inhalable particles (PM_{10}) and fine particles ($PM_{2.5}$)

Two sources of epidemiological evidence

- Chronic exposure studies

  geographical comparisons

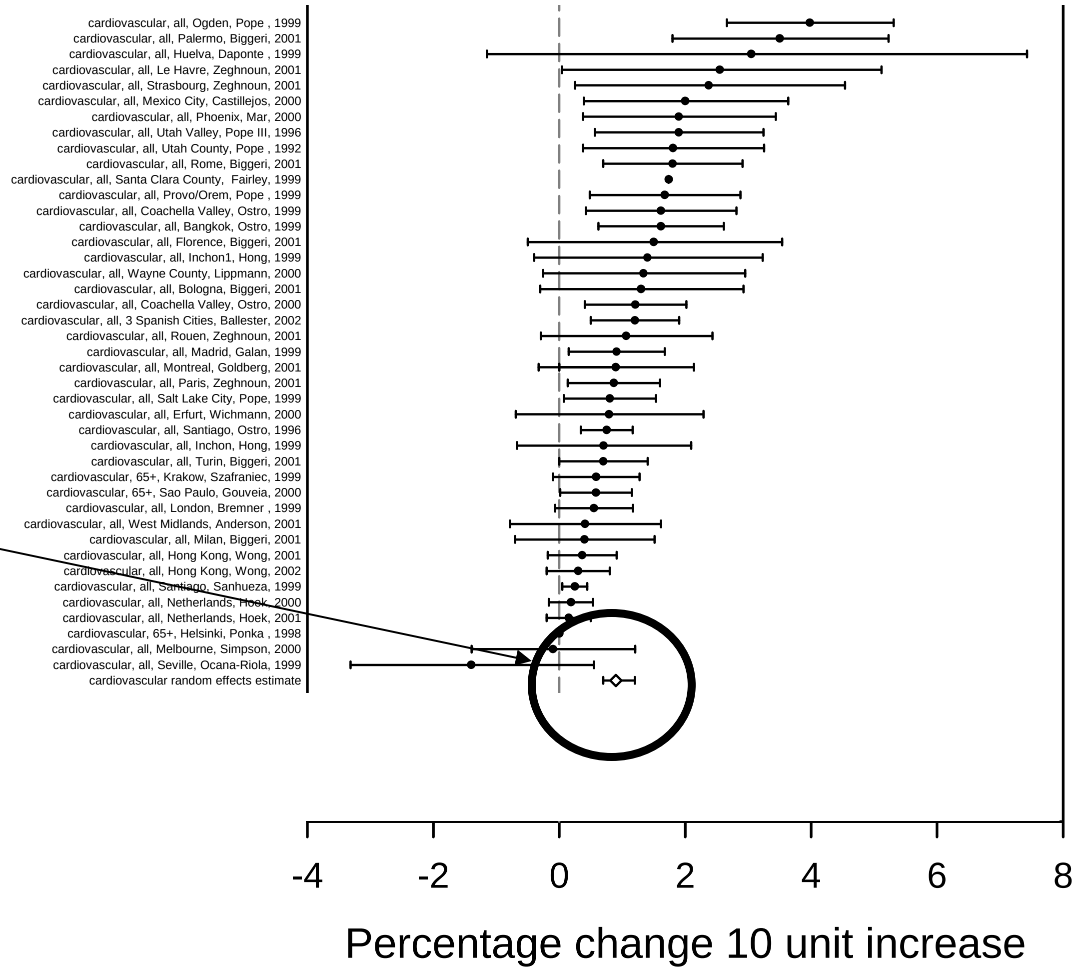
- Short-term exposure studies

  daily time series analyses

How generalizable is the existing evidence, which is mostly from Western Europe and North America?

Example of Meta-analysis Cardiovascular mortality and PM10

Combined Estimate

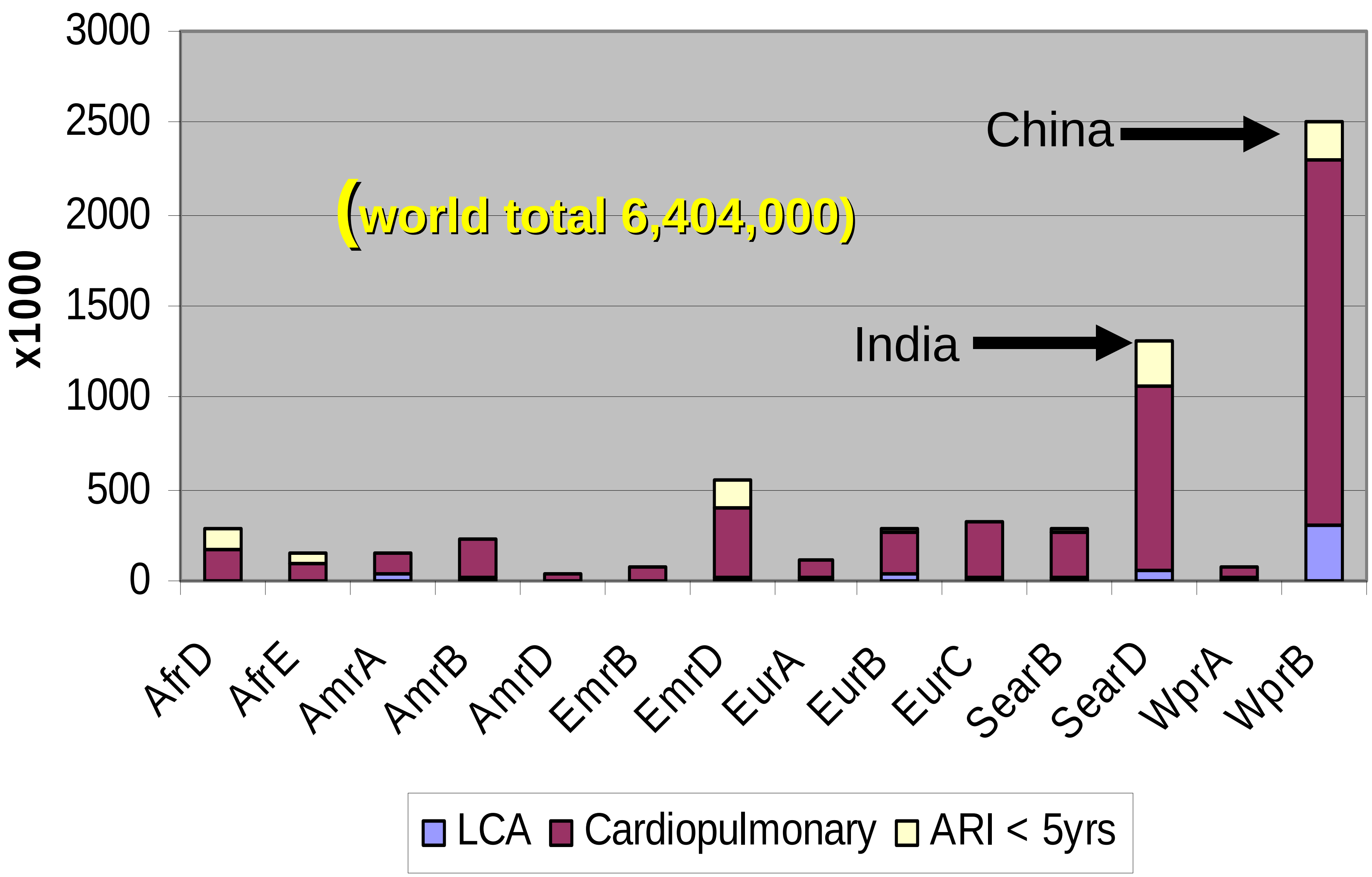


ACS cohort (Pope et al JAMA 2002) 500 000 adults followed 1982 - 1998

RR (adj) per 10μg/m^3 $PM_{2.5}$ 1979-83		
	RR	95% CI
Cardiopulmonary	1.06	1.02-1.10
Lung Cancer	1.08	1.01-1.16

Random effects Cox proportional hazards model controlling for age, sex, race, smoking, education, marital status, body mass, alcohol, occupational exposure and diet.

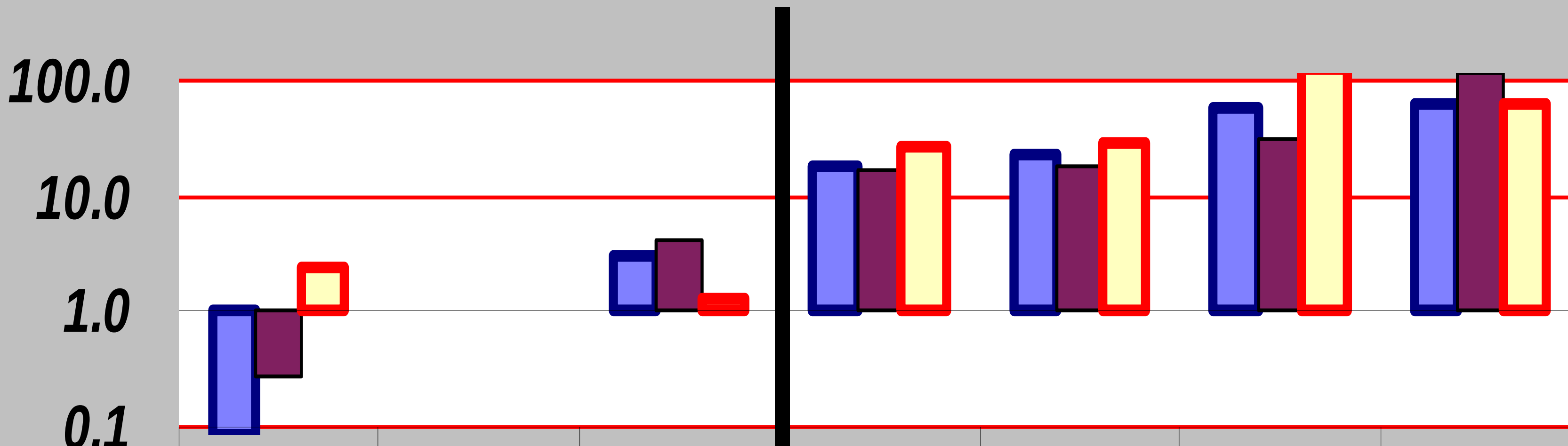
Lost healthy life years (DALYs)



IAQ Exposure Measure for CRA

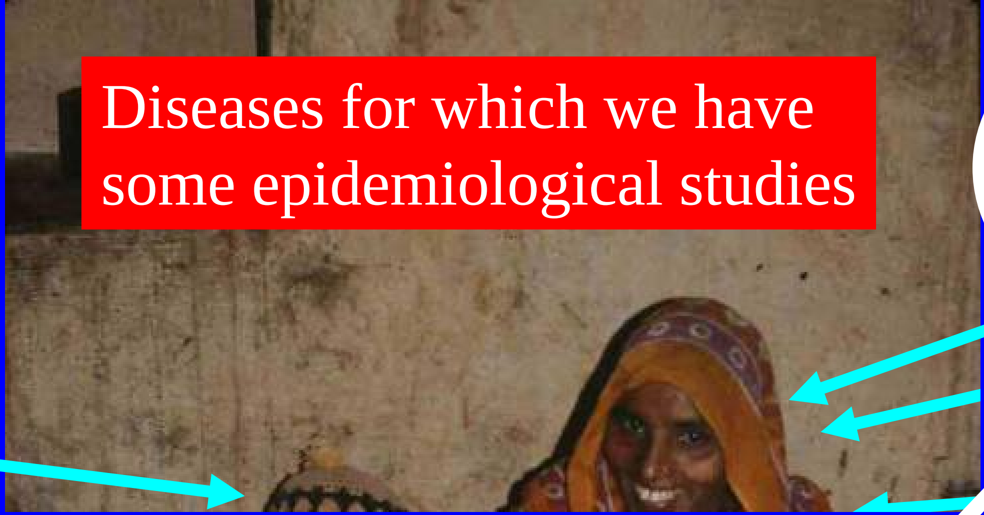
- Insufficient measurements of indoor exposures worldwide to use concentration
- Binary metric is possible: use or no use of solid fuels for household cooking and heating: biomass (wood, crop residues, dung) and coal
- Household survey data available for ~100 nations
- Model developed to estimate levels in other ~80 countries.

The Energy Ladder: Relative Pollutant Emissions Per Meal



	Biogas	LPG	Kerosene	Wood	Roots	Crop Residues	Dung
CO	0.1	1.0	3	19	22	60	64
Hydrocarbons	0.3	1.0	4.2	17	18	32	115
PM	2.5	1.0	1.3	26	30	124	63

Smith, et al., 2005



Diseases for which we have some epidemiological studies

ALRI/
Pneumonia
(meningitis)

Chronic obstructive lung disease

Only two qualified with sufficient evidence to be included in the CRA

Acute lower respiratory infections (ALRI)

Chief cause of death among the world's children (~2 million per year). Thus, it is the chief global cause of lost healthy life years.

Child mortality occurs almost entirely in developing countries, and as pneumonia.

Well-accepted risk factors (malnutrition, micro-nutrient deficiencies, other diseases, crowding, chilling) do not account for its scale.

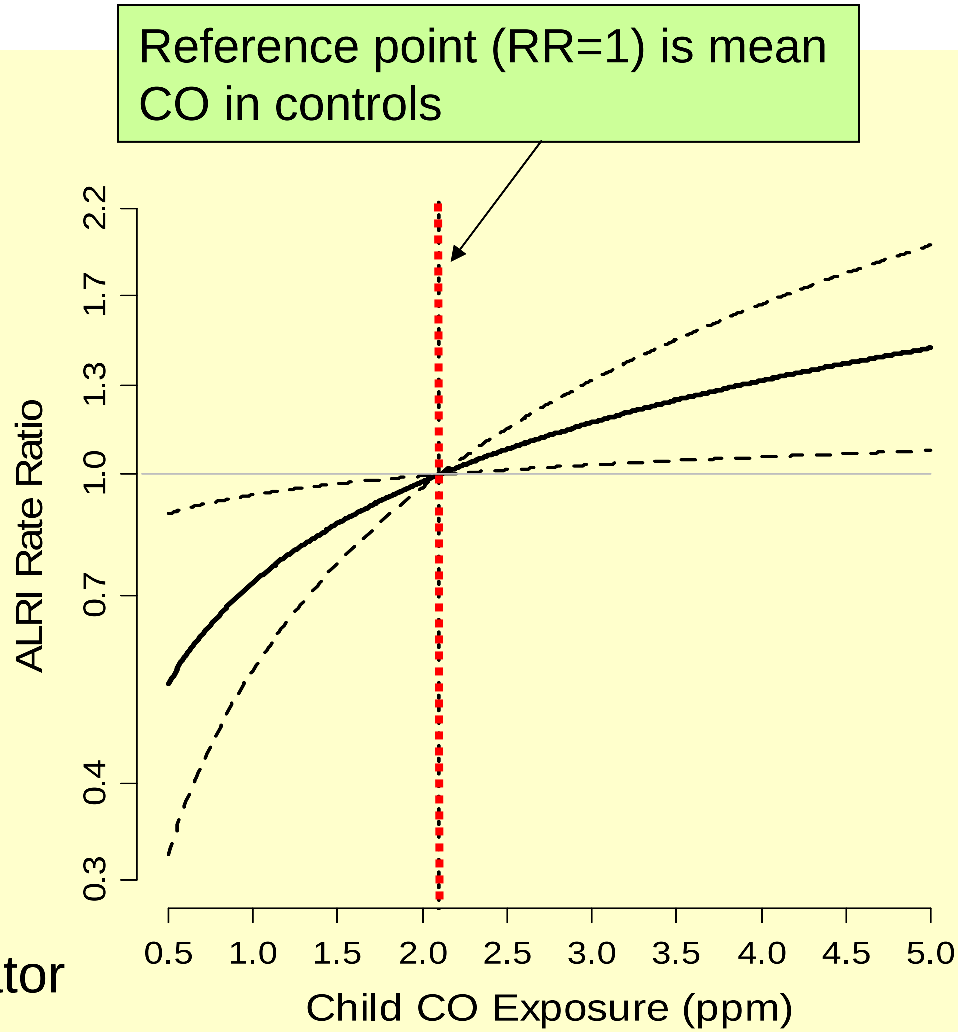
Meta-analysis of studies of ALRI and solid fuels, in children aged <5 years

Subgroup analyses of ~14 studies	Odds ratio (95% CI)
All studies	2.3 (1.9-2.7)
Use of solid fuel	2.0 (1.4-2.8)
Duration of time child spent near the [illegible]	2.3 (1.8-2.9)
[illegible]	[illegible]3)
Studies not adjusting for nutritional status	2.2 (2.0-3.0)
Children aged <2 years old	2.5 (2.0-3.0)
Children aged <5 years old	1.8 (1.3-2.5)

Children in households using solid fuels have twice the rate of serious ALRI

Smith et al in WHO, Comparative quantification of health risks, 2004

Exposure-response relationship
Results from the First Randomized Trial



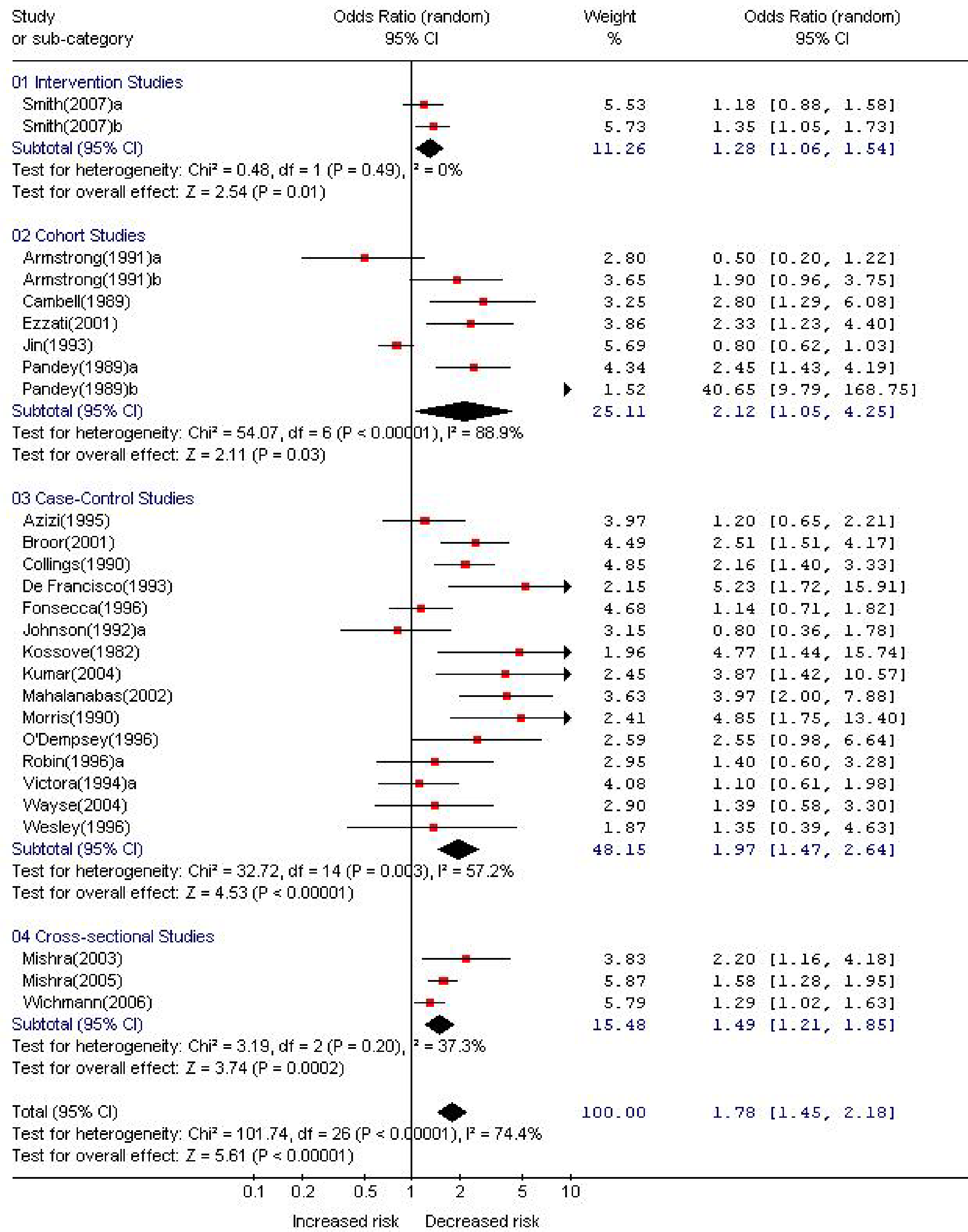
Guatemala

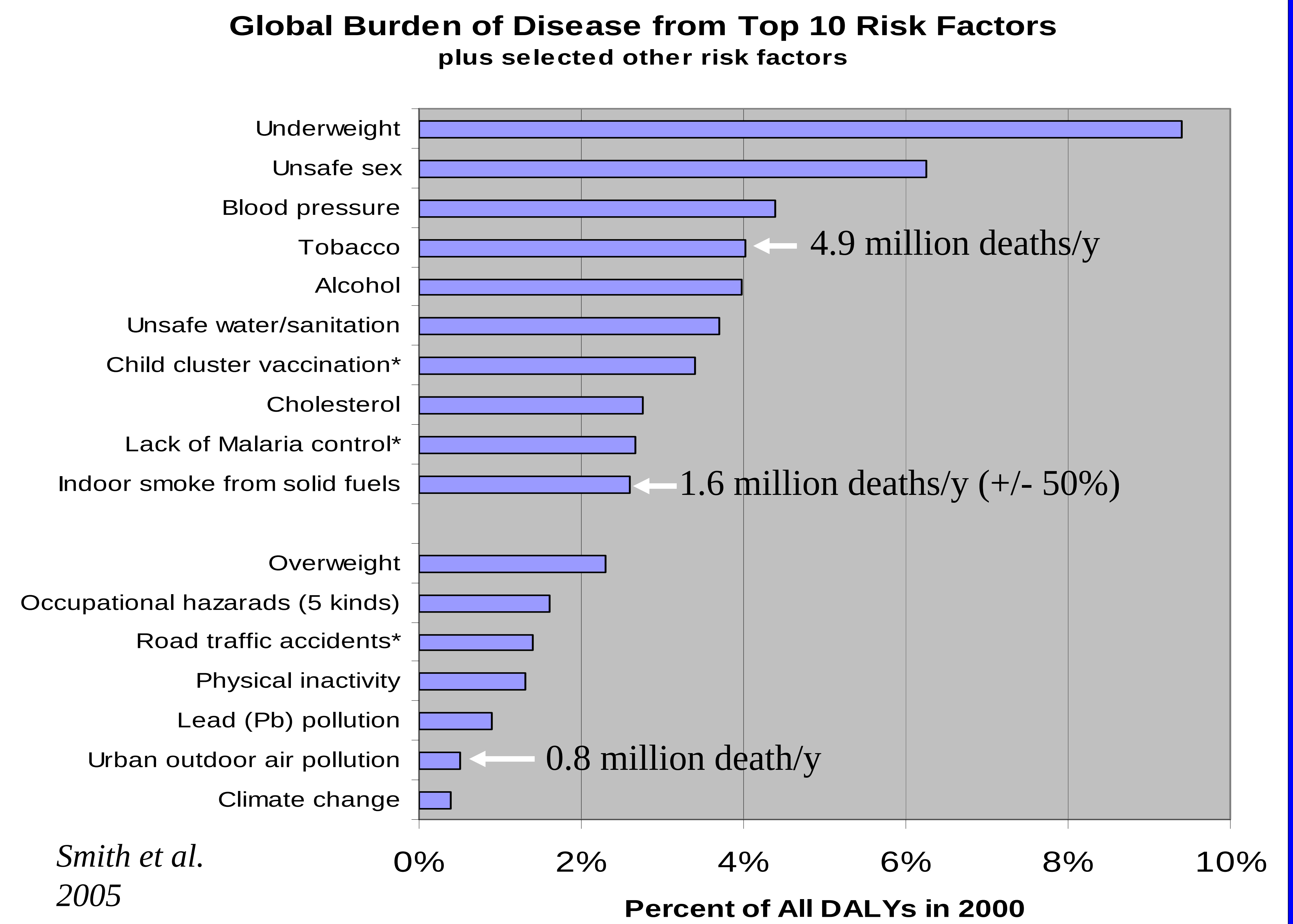
CO as indicator of PM

Log linear function provided the best fit

ALRI-IAP Systematic Review and Meta-Analysis

Dherani et al.
Bull WHO, 2008

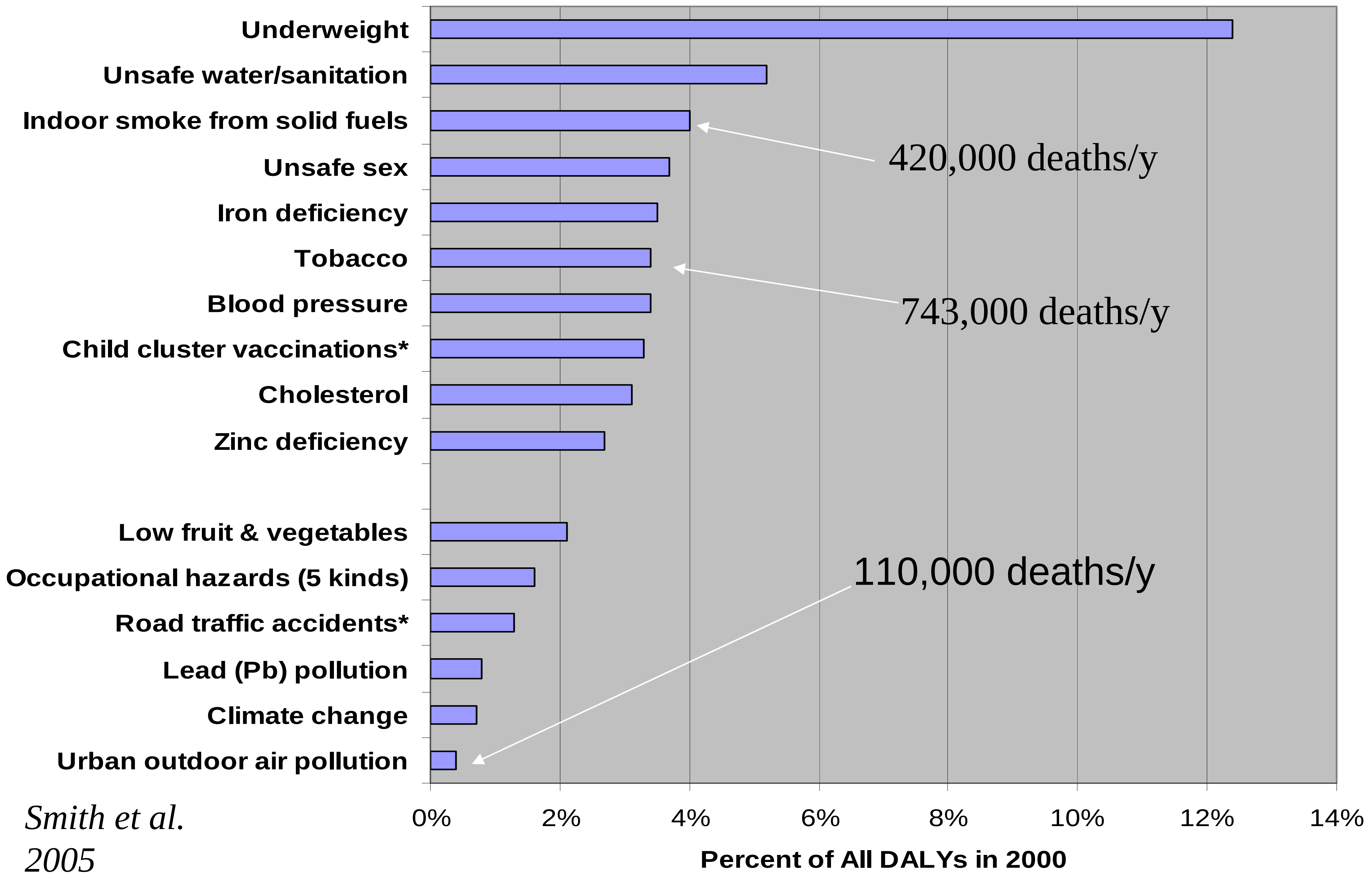




Global Burden of Disease from Top 10 Risk Factors
plus selected other risk factors
Underweight
Unsafe sex
Blood pressure
Tobacco
Alcohol
Unsafe water/sanitation
Child cluster vaccination*
Cholesterol
Lack of Malaria control*
Indoor smoke from solid fuels
Overweight
Occupational hazarads (5 kinds)
Road traffic accidents*
Physical inactivity
Lead (Pb) pollution
Urban outdoor air pollution
Climate change
4.9 million deaths/y
1.6 million deaths/y (+/- 50%)
0.8 million death/y
0%
2%
4%
6%
8%
10%
Percent of All DALYs in 2000
Smith et al. 2005

Indian Burden of Disease from Top 10 Risk Factors

Plus Selected Other Risk Factors

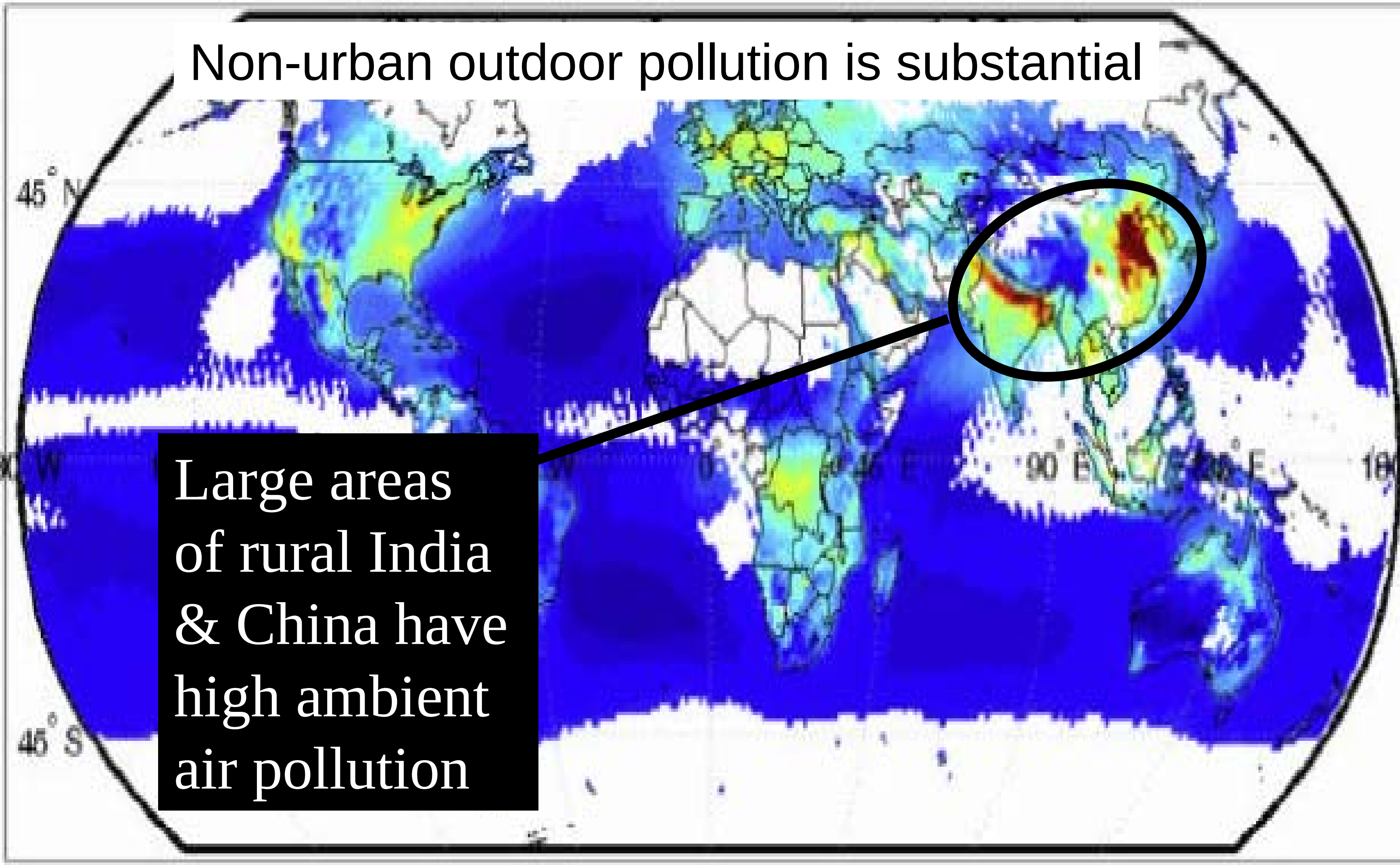


Smith et al. 2005

Global Health Effects of Combustion Particles: Premature Deaths Per Year

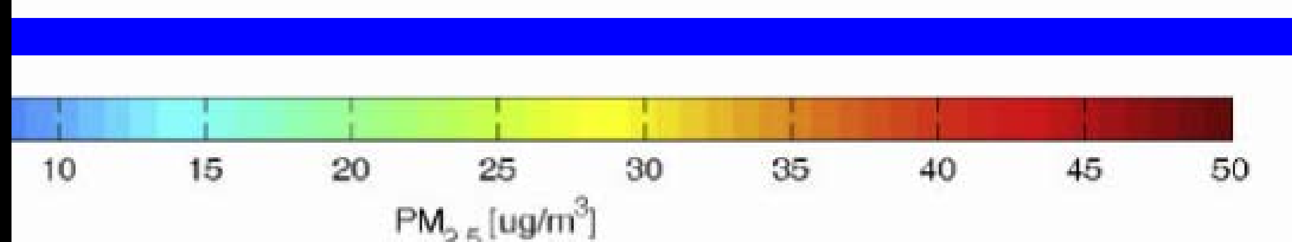
- Urban outdoor air pollution: ~800,000
- Household use of solid fuels: ~1,600,000
- Environmental tobacco smoke: ~300,000
- Occupational exposures: ~250,000
- Total ~ 3 million per year
  - With active smoking: ~8 million
- Compare with global totals for
  - Dirty water: 2 million
  - HIV: 3 million
  - All cancer: 7 million
  - Malnutrition: 4 million

Non-urban outdoor pollution is substantial



Large areas of rural India & China have high ambient air pollution

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



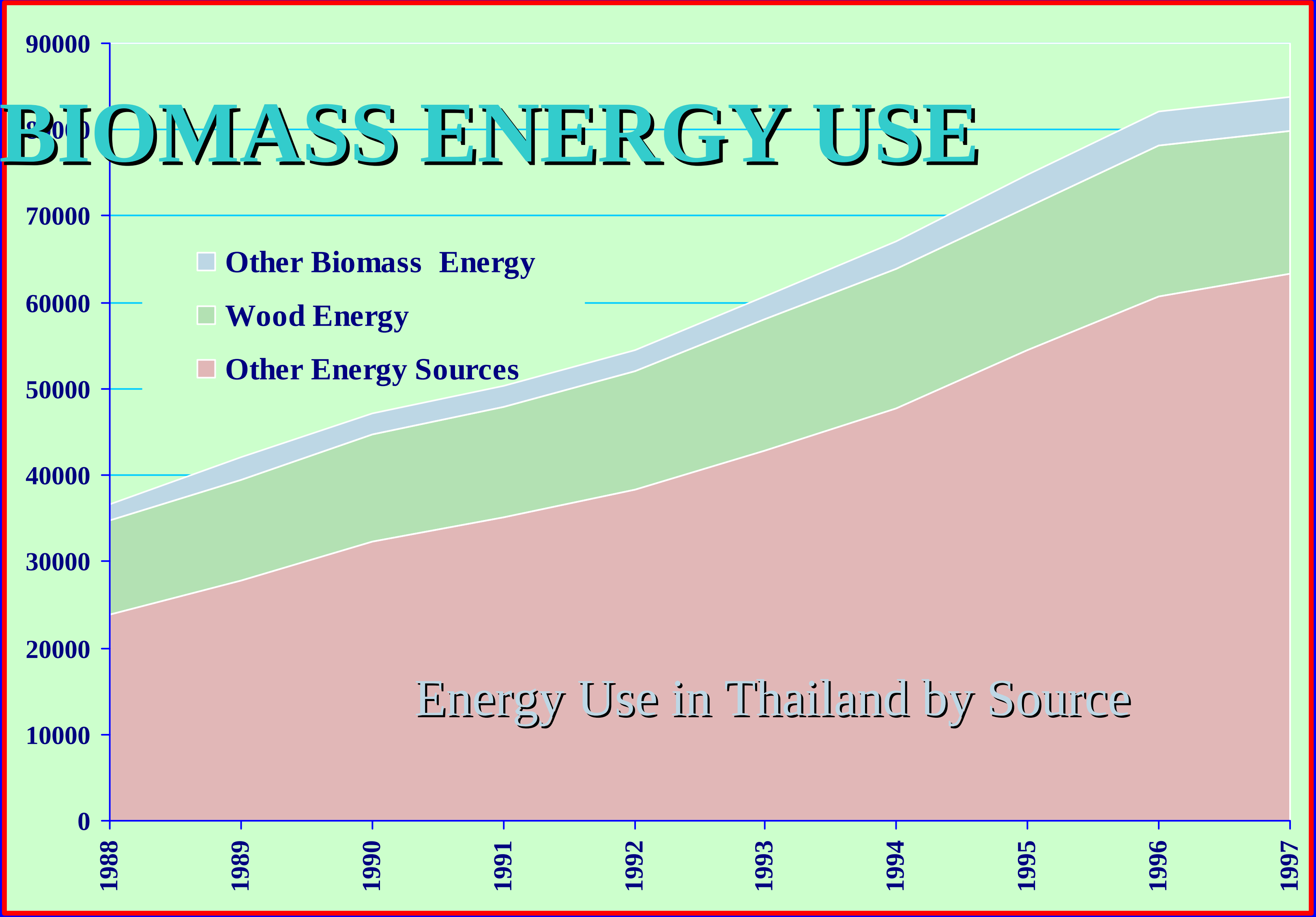
Solid-fuel Using Households: Large Global Exposures to some surprising pollutants – perhaps largest

- Ultrafine particles – fresh and combustion-generated
- Formaldehyde
- Benzene
- PAH
- Dioxin
- Etc.

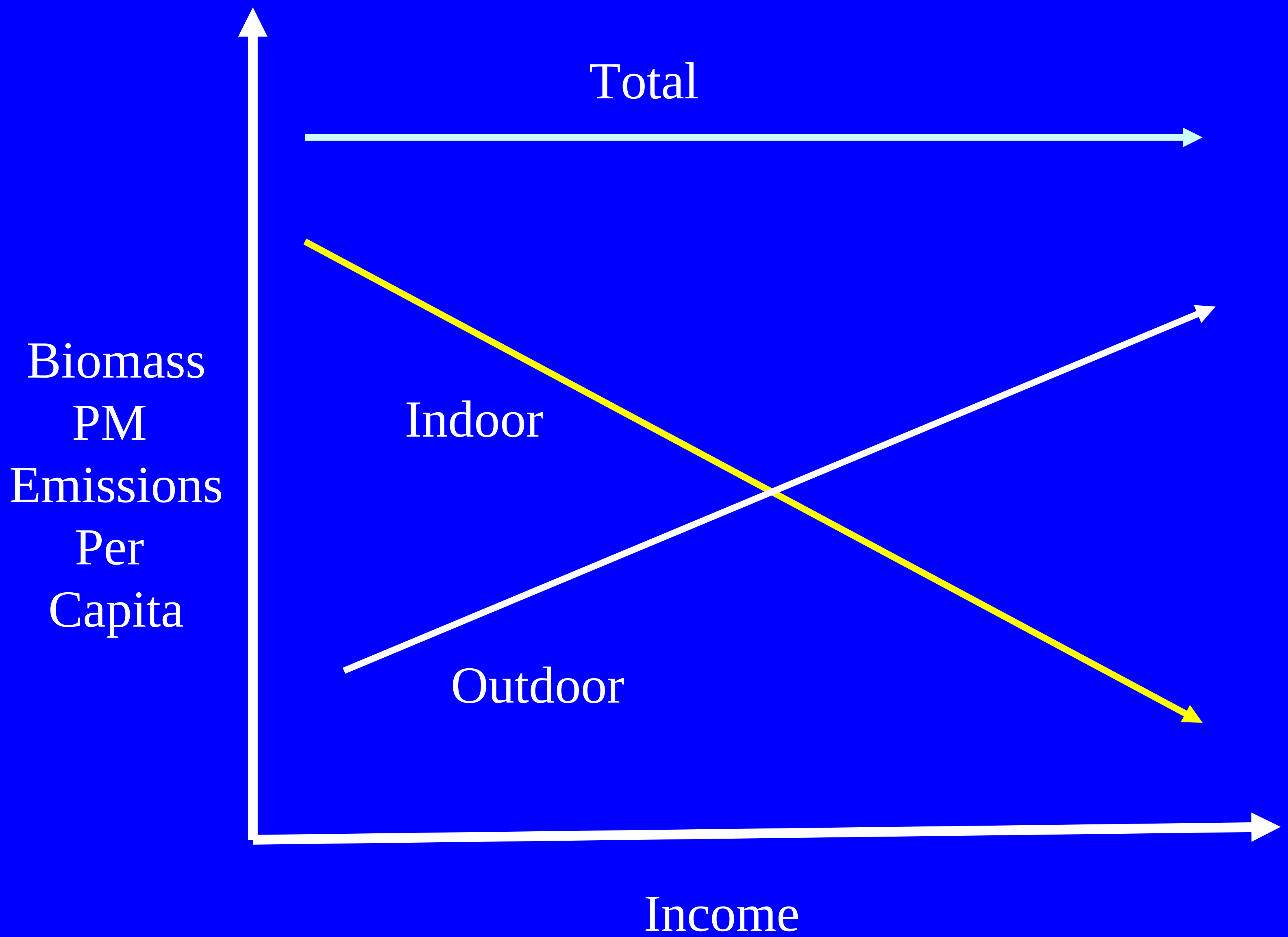
Biomass smoke – a global concern

- A significant contribution to PM2.5 emissions around the world – more than half in many developed countries (Canada, Denmark, much of USA, etc.)
  - Ag burning a function of ag production, not income - California
  - Wood heating and fireplace use common in many developed countries – Silicon Valley
- Growing because of energy prices
- And climate change
- Not clear whether effects across all major health outcomes are the same as those found in urban studies of PM
  - Chronic and Acute Respiratory
  - Cardiovascular
  - Cancer
- Households in LDCs perhaps only widespread exposure to nearly pure biomass smoke

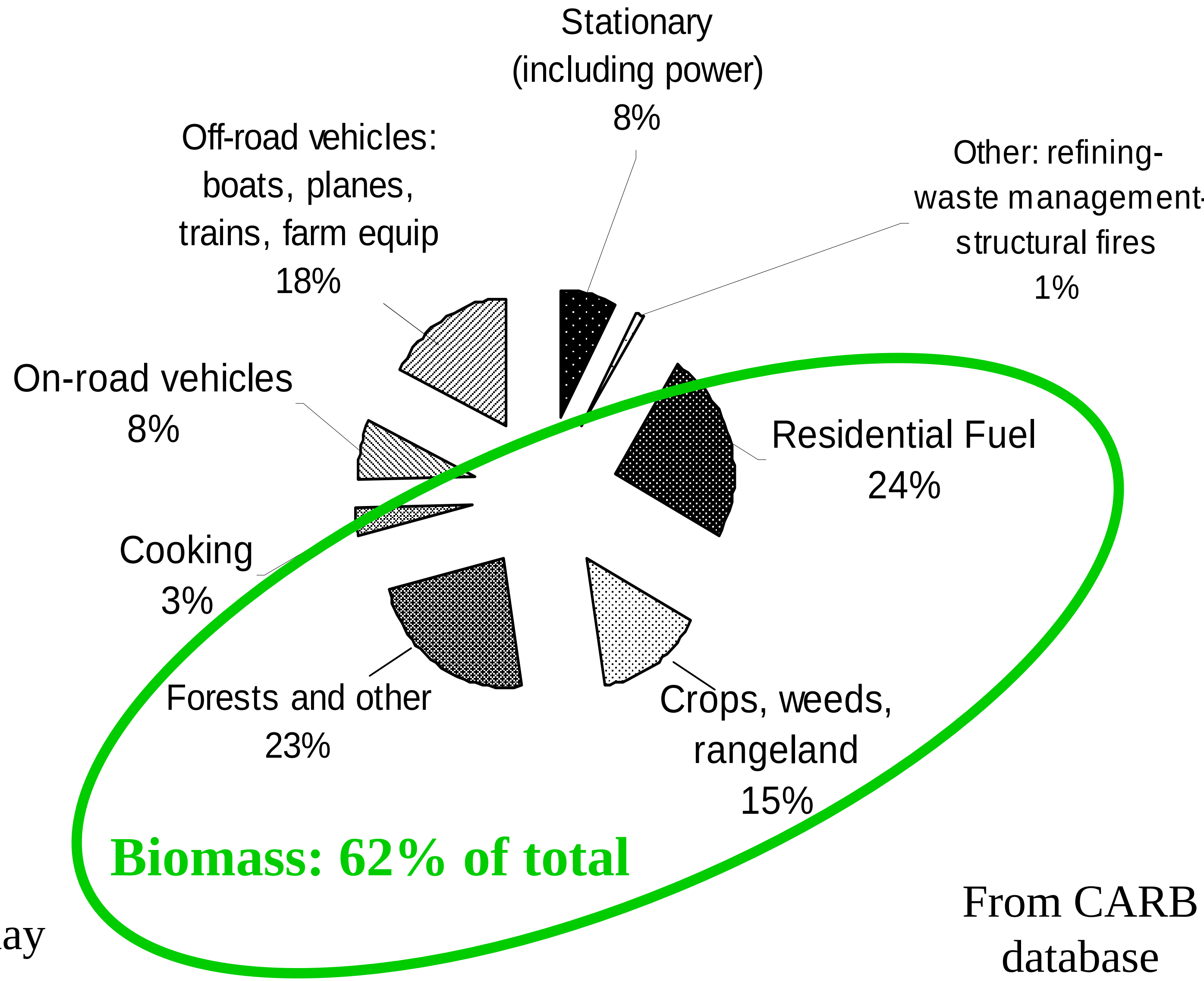
BIOMASS ENERGY USE



Source: RWEDP

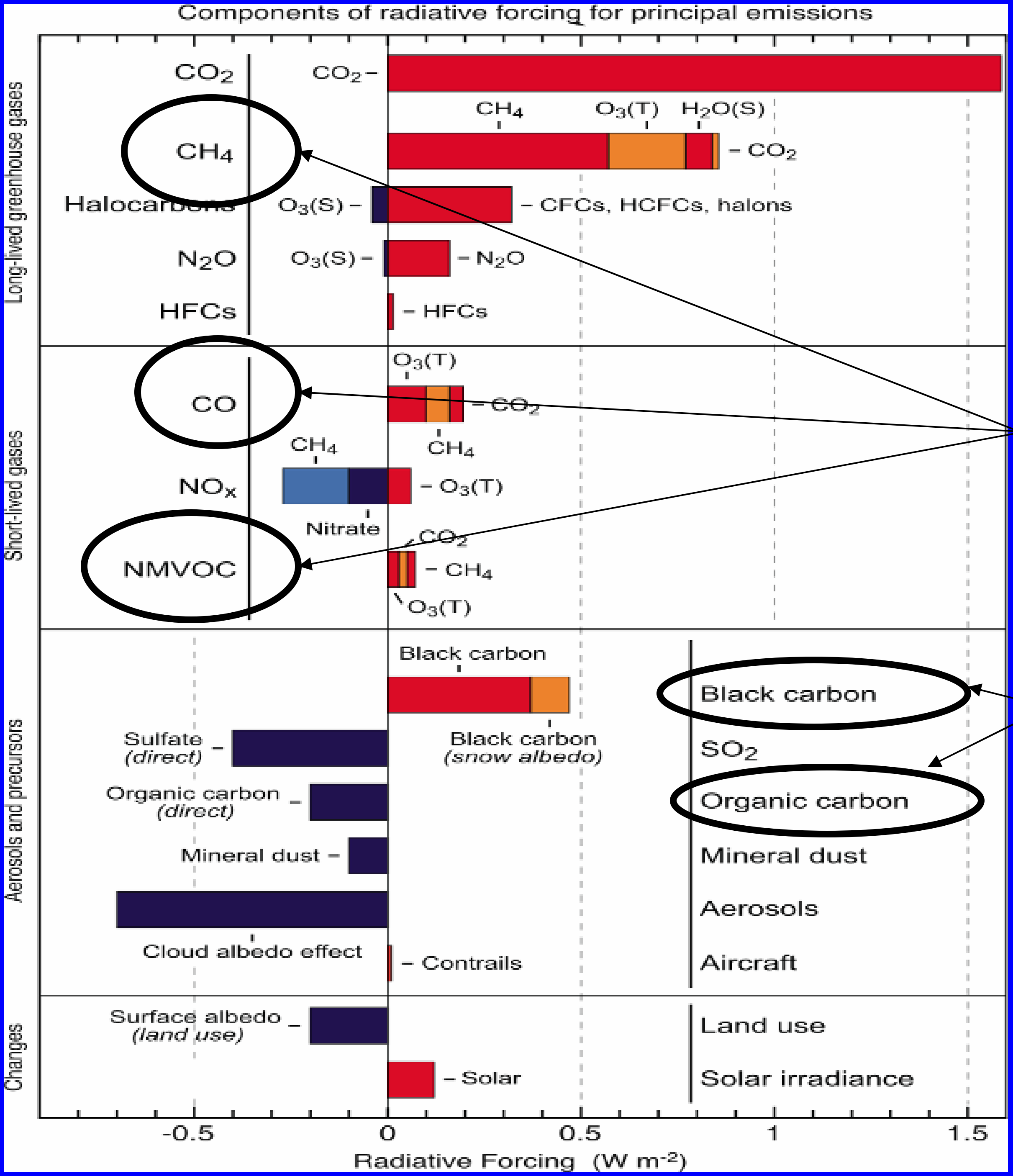

Total
Biomass
PM
Emissions
Per
Capita
Indoor
Outdoor
Income

California's 2005 Combustion $PM_{2.5}$ Emissions



~450 t/day

From CARB
database

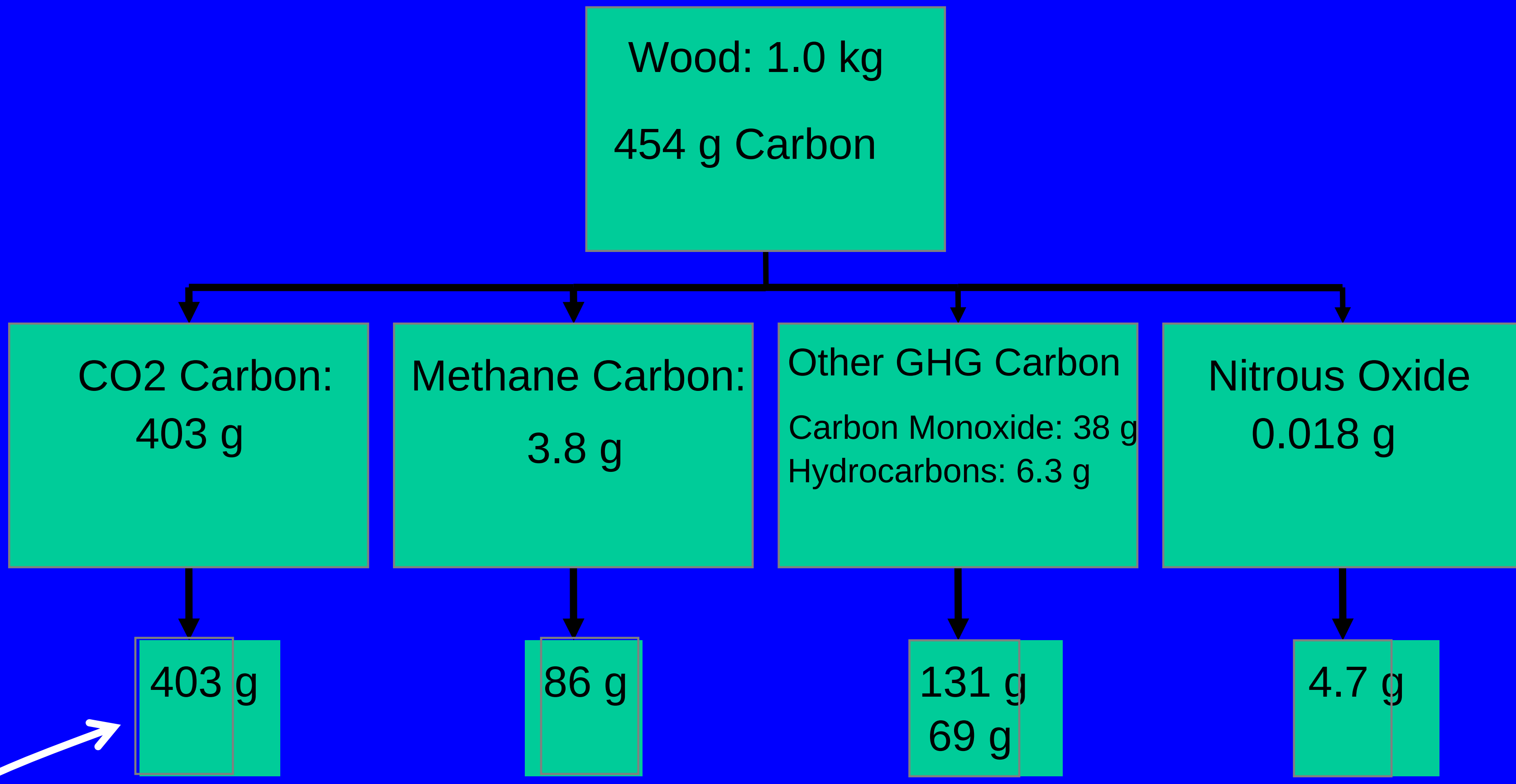


Warming in 2005 from emissions since 1750

A large part from PIC: products of incomplete combustion

IPCC, 2007

Greenhouse warming commitment per meal for typical Indian wood-fired cookstove



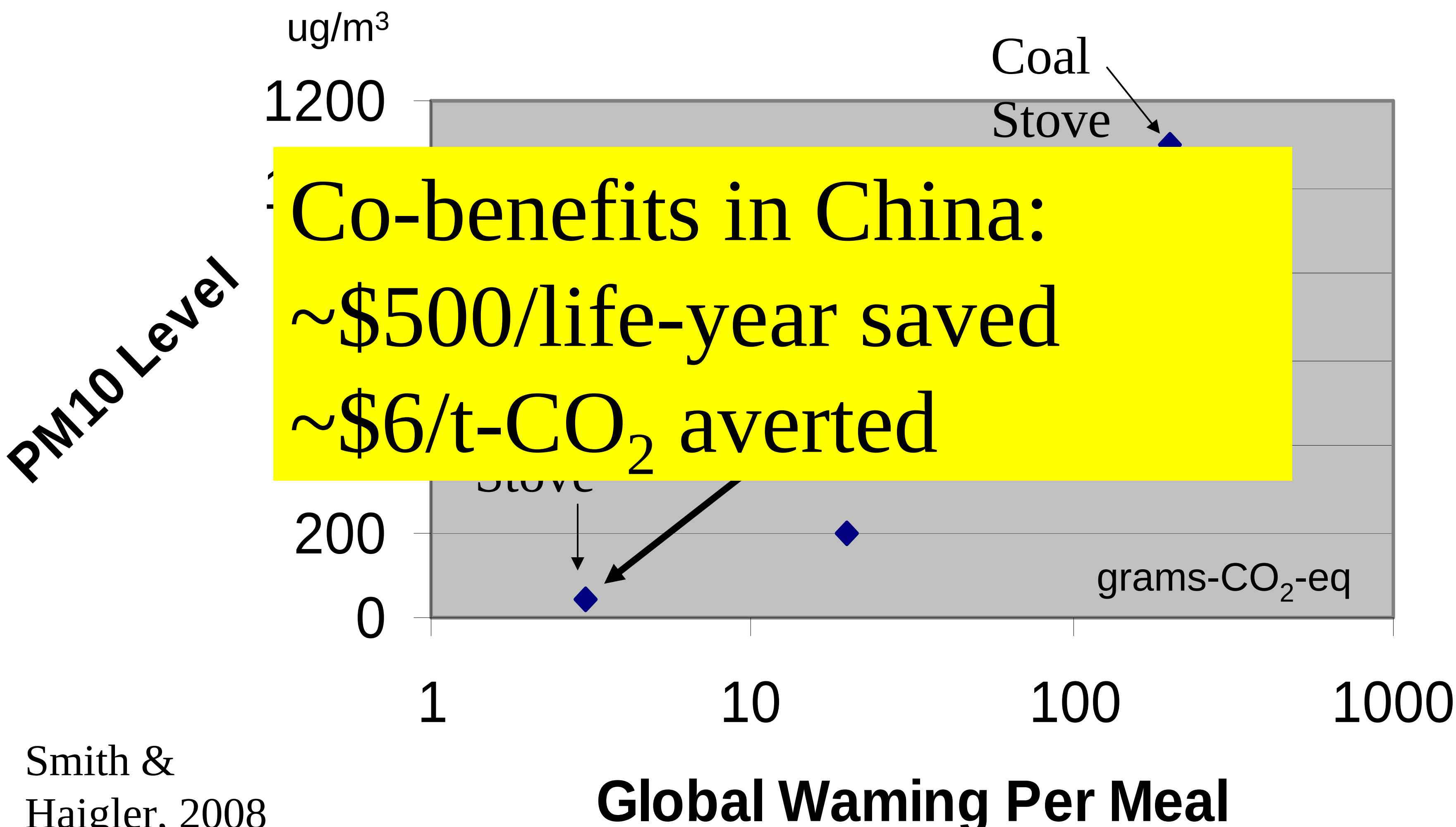
Global warming commitments of each of the gases as CO_2 equivalents

Source: Smith, et al., 2000

- The semi-gasifier stove customers do not need to buy fuel at present. They only need simply processed fuel. The gasification efficiency can be as high as 60%, and thermal efficiency more than 45%. The most significant character is it doesn't emit dark smoke, and is friendly to the environment and the farmers' health.

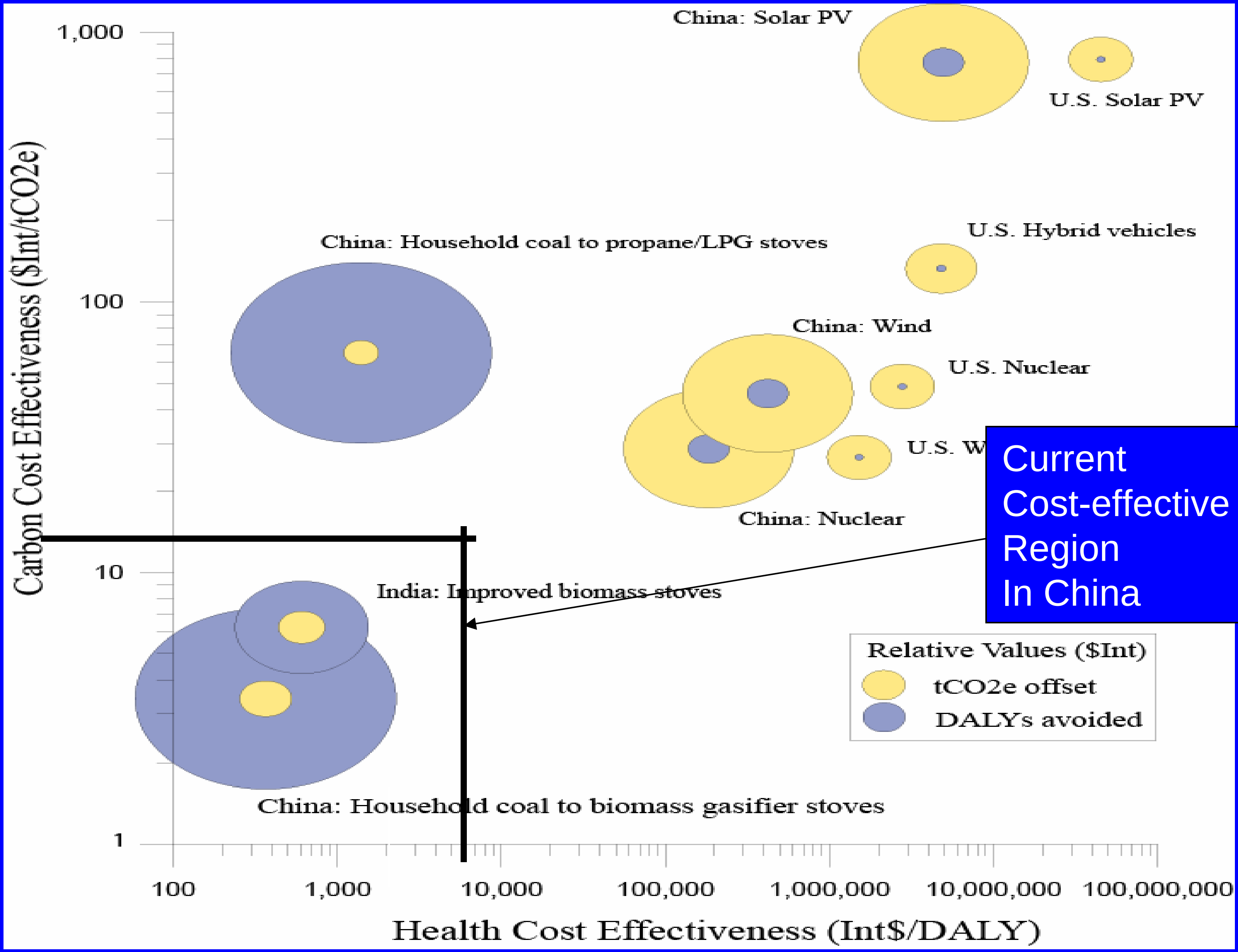
Lab tests show PIC levels nearly at LPG levels. But can it be reliably achieved in the field?

Health and Greenhouse Gas Benefits of Biomass Stove Options



Co-benefits in China:
~$500/life-year saved
~$6/t-$CO_2$ averted

Smith & Haigler, 2008



Smith & Haigler, 2008

Conclusions

- It is difficult to burn unprocessed solid fuels completely in simple household-scale devices.
- Consequently, a large fraction of the fuel C is diverted to PIC
- Leading to inefficient use of the primary resource
- And, because of the proximity to population, the PIC seem to be responsible for much ill-health in developing countries.

Conclusions (cont.)

- Because the average Global Warming Potential of PIC carbon is greater than CO_2, there is significant global warming commitment per unit energy use for household devices, even when the biomass is harvested renewably.
- To be greenhouse-gas neutral, therefore, a biomass fuel cycle must not only be based on renewable harvesting, but it also must have good combustion efficiency, i.e., produce little PIC

Conclusions (cont.)

- Careful improvements/reductions in solid household fuel use offer multiple benefits in energy, health, and global warming.
- Probably requires coordinated improvement of fuel and stove
- Cost-effectiveness compares well with other interventions:
- Significant engineering challenge to reliably produce high combustion and overall efficiencies cheaply with simple solid fuels

Summary: The Hazards of Combustion Mismanagement

- Sticking burning stuff in your mouth
- In your home
- In your workplace
- In your community
- On your planet
- Letting it burn down your house

•

Combustion Risk Factor	**Million Deaths**	**Percent of Global Deaths**	**Percent of Disease Burden**
Tobacco	4.9	8.7%	4.1%
Indoor smoke from household solid fuel	1.6	2.9	2.6
ETS and Workplace	0.5	0.6	1.5
Urban outdoor air pollution	0.80	1.4	0.8
Climate change	0.15	0.3	0.4
Fires	0.24	0.4	0.7
Adjusted totals	**~ 8**	**~ 14%**	**~ 10%**

Combustion Mismanagement

An ancient but still large source of death and disease around the world

One out of seven deaths each year occurs prematurely because of combustion mismanagement, mostly from small particles.

And growing!

Laws of Carbon-thermodynamics

I. Keep all fossil and forest carbon out of the atmosphere

II. If you cannot do so, the least-damaging form to release is carbon dioxide because all other forms are worse for climate and health.

III. Even renewable (non-fossil) carbon is damaging for climate and health if not released as carbon dioxide.

Laws of Particle Health

- Don’t release combustion particles into the air – they are all bad for health
- If you must, do so far from people
- If you cannot avoid doing so, do it outside not inside
- Whatever you do, don’t stick burning stuff in your mouth

Need for fast, cheap, and easy PM monitoring techniques: something the aerosol community can help with

Aerosol Science and Technology, 38:1054–1062, 2004

ISSN: 0278-6826 print / 1521-7388 online
DOI: 10.1080/027868290883333

Combined Optical and Ionization Measurement Techniques for Inexpensive Characterization of Micrometer and Submicrometer Aerosols

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ISSN 1047-3289 *J. Air &*

An Inexpensive Dual-Chamber Particle Monitor: Laboratory Characterization

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ABSTRACT
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ARTICLE | Journal of Environmental Monitoring]

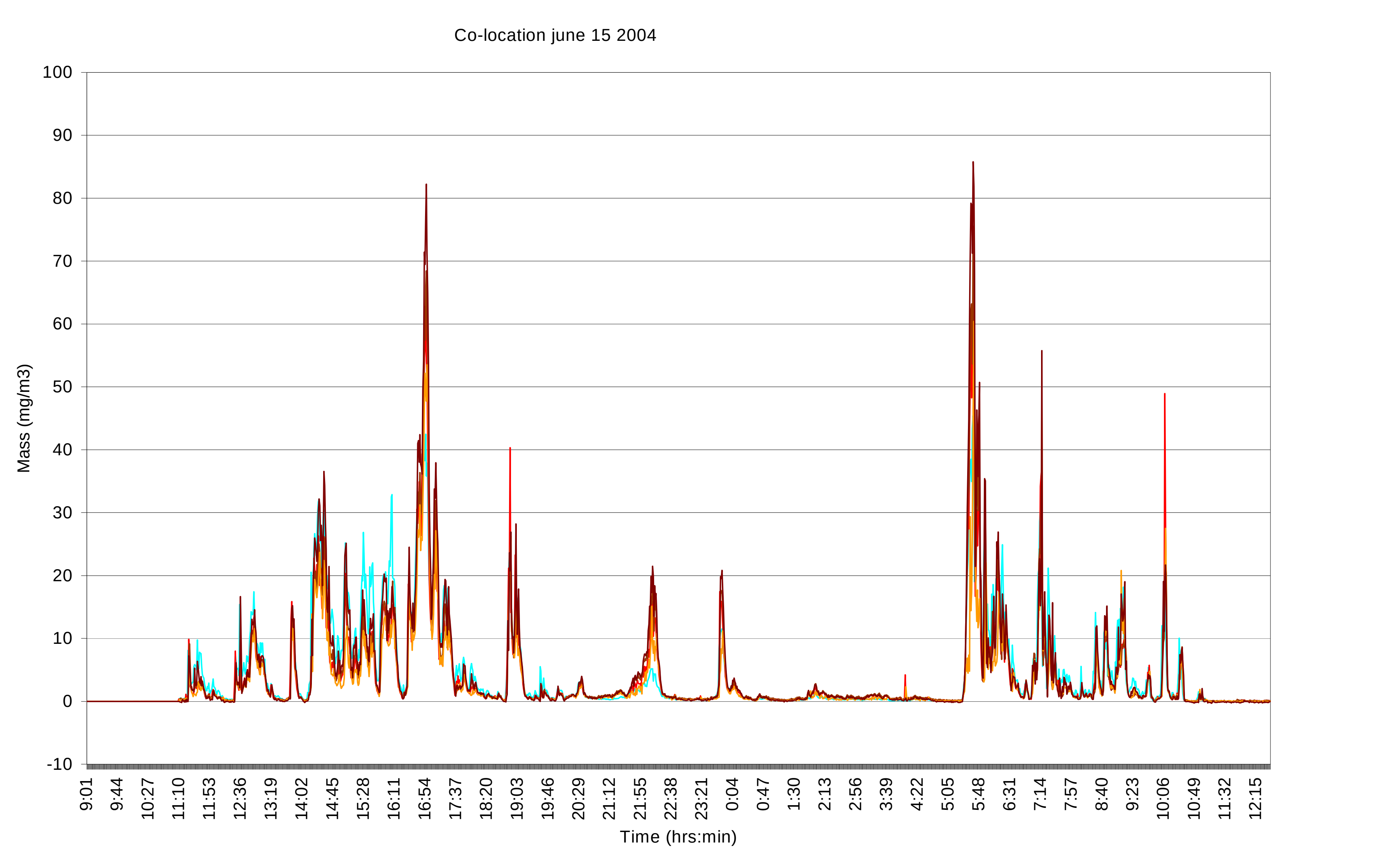
An inexpensive light-scattering particle monitor: field validation

Zohir Chowdhury,[*a] Rufus Edwards,[b] Michael Johnson,[c] Kyra Naumoff Shields,[a] Tracy Allen,[d] Eduardo Canuz[a] and Kirk R. Smith[a]

Receipt/Acceptance Data: Forthcoming 2007
Publication data
DOI: 10.1039/b000000x

We have developed a small, light, passive, inexpensive, datalogging particle monitor called the "UCB" (University of California Berkeley Particle Monitor). Following previously published laboratory assessments, we present here results of tests of its performance in field settings. We demonstrate the mass sensitivity of the UCB in relation to gravimetric filter-based $PM_{2.5}$ mass estimates as well as commercial light-scattering instruments co-located in field chamber tests and in kitchens of wood-burning households. Although requiring adjustment for differences in sensitivity, Inter-monitor performance was consistently high ($r^2>0.99$). Moreover, the UCB can consistently estimate $PM_{2.5}$ mass concentrations in wood-burning kitchens (Pearson $r^2= 0.885$; N=99), with good agreement between duplicate measures (Pearson $r^2= 0.940$; N=88). In addition, with appropriate cleaning of the sensing chamber, UCB mass sensitivity does not decrease with time when used intensively in open woodfire kitchens, demonstrating the significant potential of this monitor.

Guatemala house with open fire DustTrak vs UCB particle monitor



Most the papers and other publications from which these data were taken are available at http://ehs.sph.berkeley.edu/krsmith

Thank you