Stoves, Health, and Climate
Where are we now?

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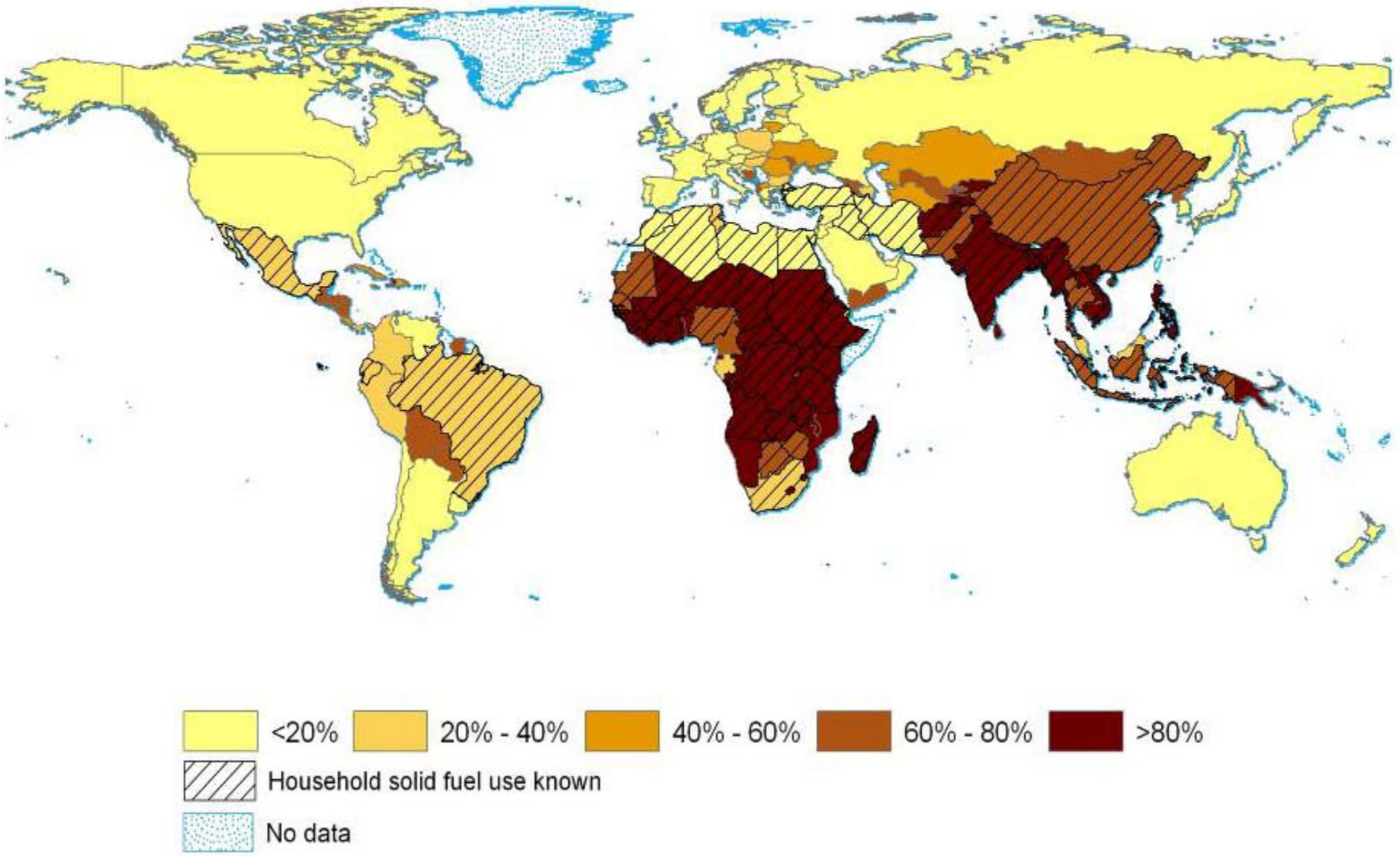
USAID, US Embassy
New Delhi, September 16, 2009

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



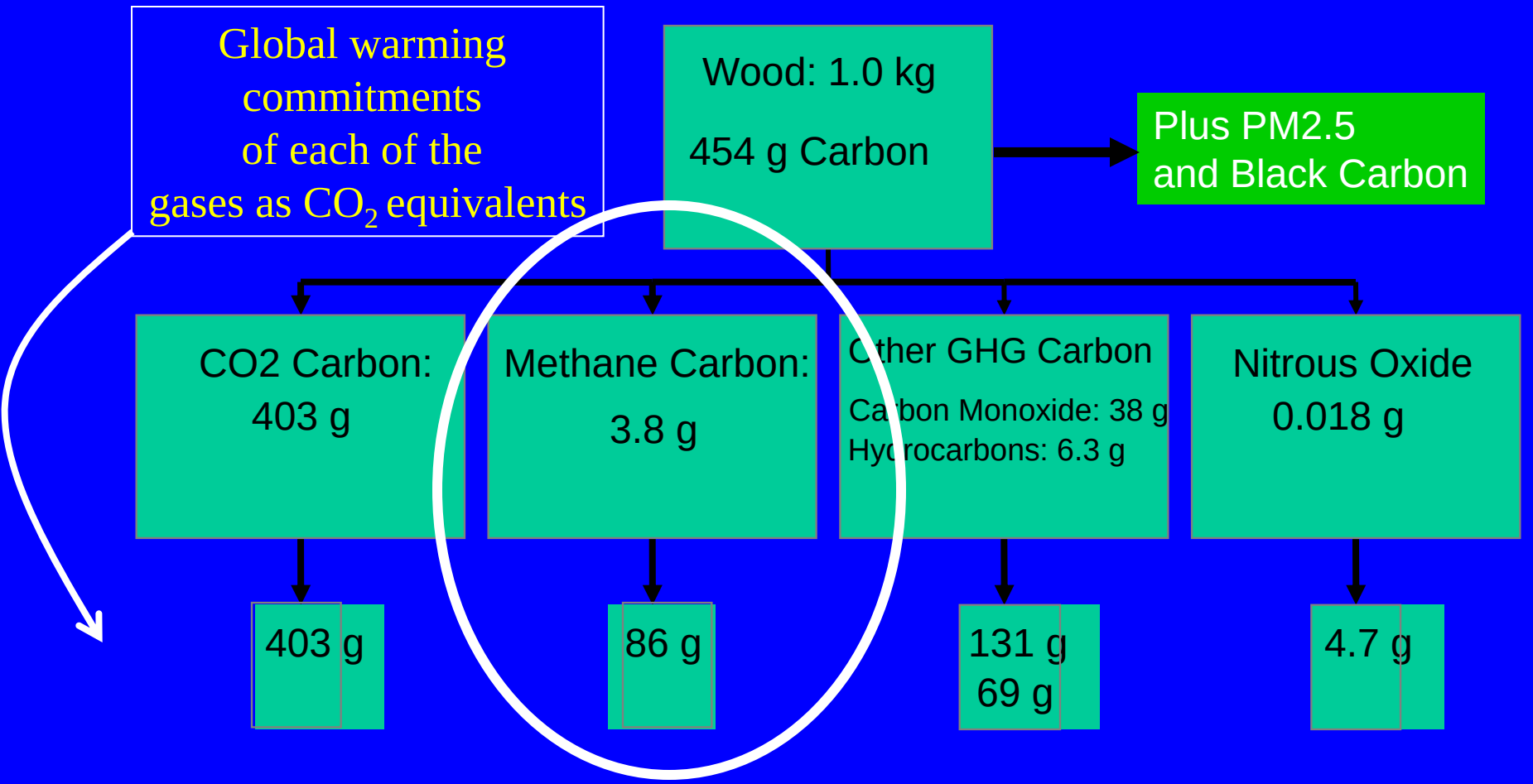
Fuel Combustion

- 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



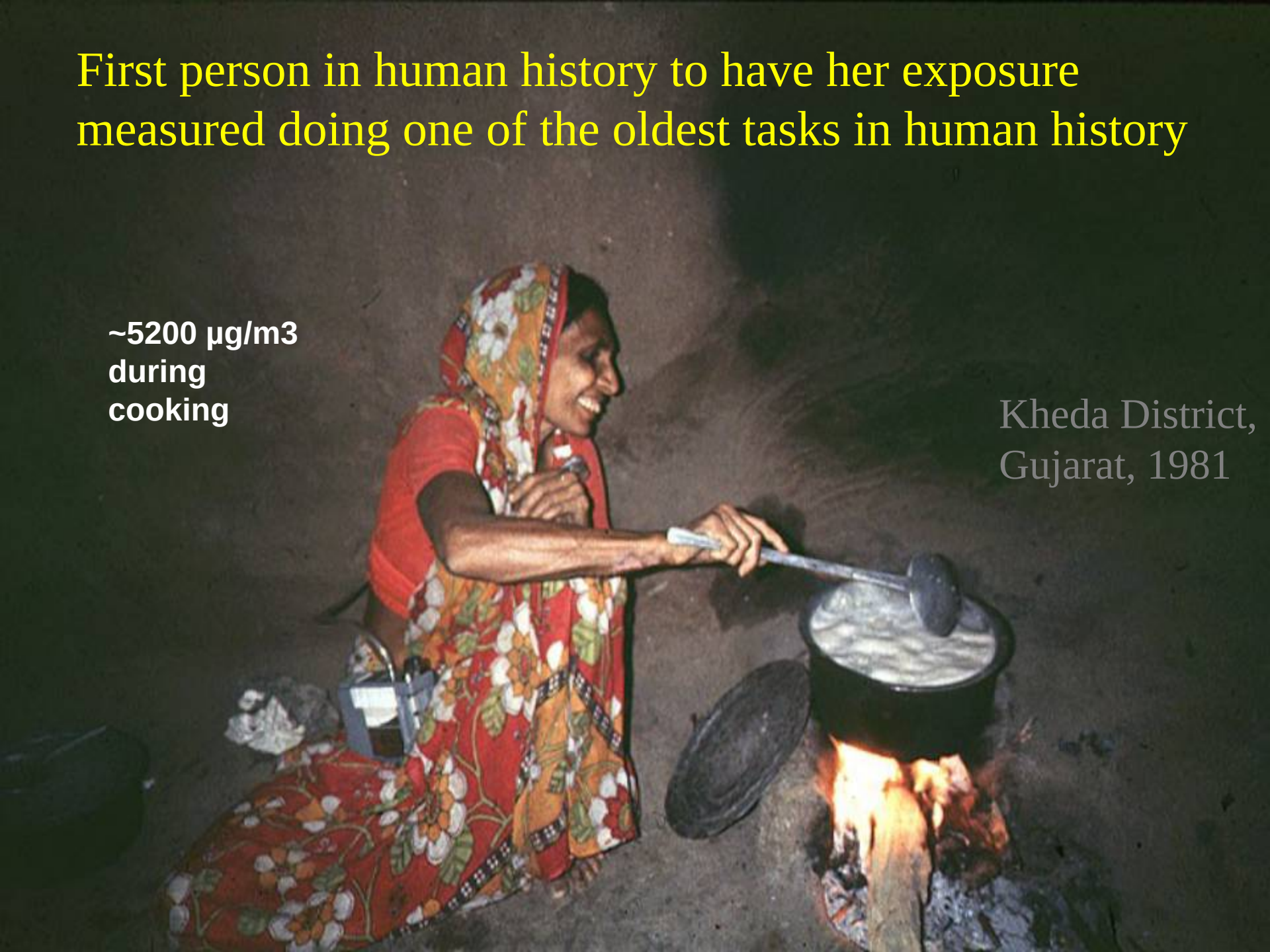
Smith, et al., 2000

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

First person in human history to have her exposure measured doing one of the oldest tasks in human history



Location	Region	Number of households	Range (24 hour average of PM 10)	Mean (µg/m3) (24 hr average of Kitchen & Living Concentrations of PM10)	Other Determinants
Tamil Nadu	Southµ	4		223	Fuel/ Kitchen/Stove
Andhra Pradesh	South	3		485	Fuel/ Kitchen
Karnataka	South	3		898	Fuel/ Stove
Madhya Pradesh	West/Central	7		690	Fuel/ Kitchen
Gujarat	West	6		780	Fuel/ Kitchen
Goa	West	1		635	Fuel/ Kitchen
West Bengal	East/North East	9		795	Fuel/ Kitchen
Haryana	North	1		850	Fuel/ Kitchen
Uttaranchal	North/Mountain	76	270-2240	620	Fuel/ Kitchen

WHO Global Air Quality Guideline for Indoor/Outdoor particle Levels

20 µg/m3

Absolutely no population even even poorest countries should be exposure to more than

70 µg/3

Data compliled by SRU, Chennai

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

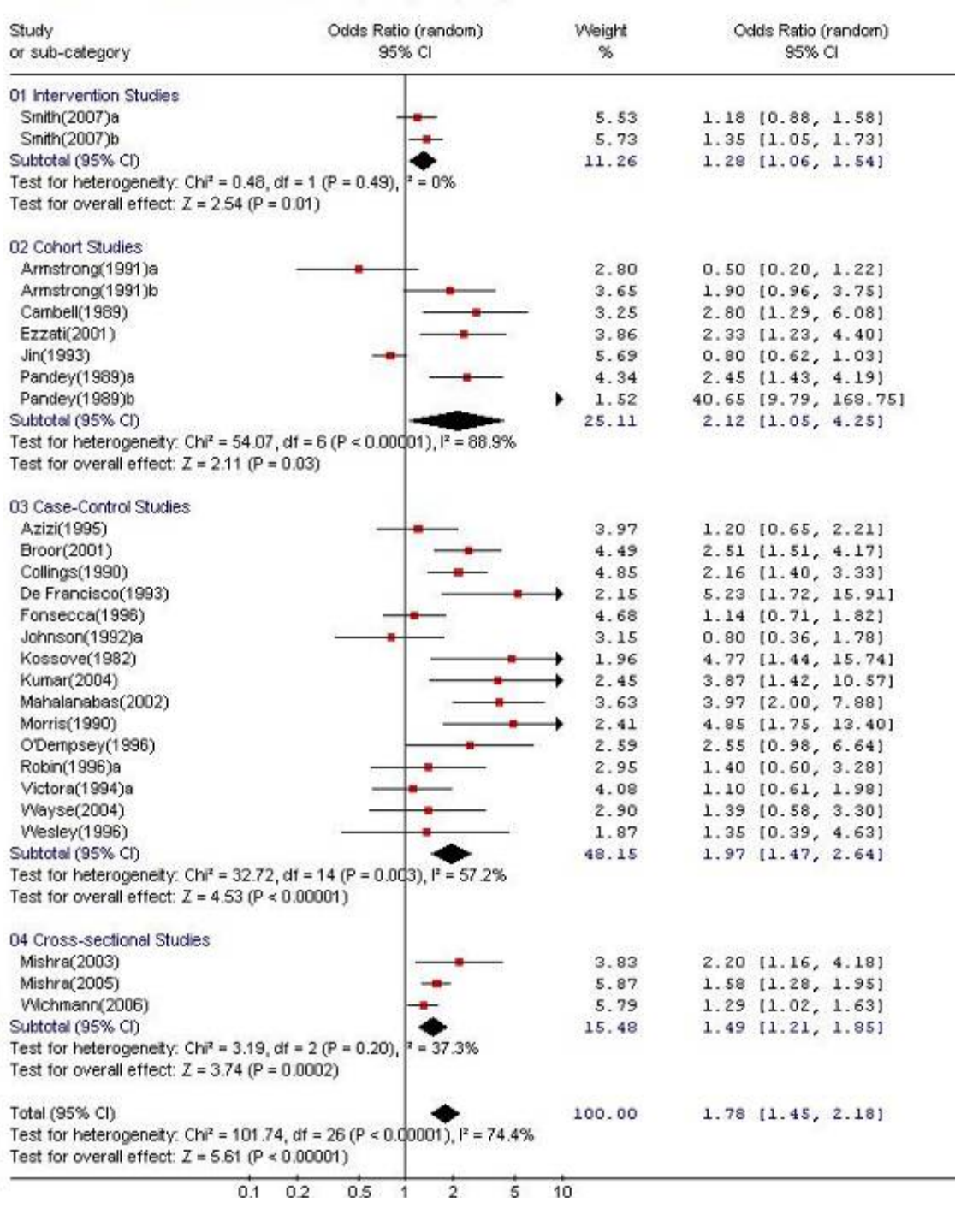
- Dozens of studies have shown consistent relationships between household solid fuel use (SFU) and
  - Pneumonia (ALRI) in young children
  - Chronic obstructive lung disease (COPD) in women
- A few studies have shown (for each endpoint)
  - TB, lung cancer, low birthweight, stillbirth, cataracts, asthma
- 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

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	1.97	1.47, 2.64
Cross-sectional	3	1.49	1.21, 1.85
All	26	1.78	1.45, 2.18

*Number of estimates available

Dherani et al., 2008
Bull WHO

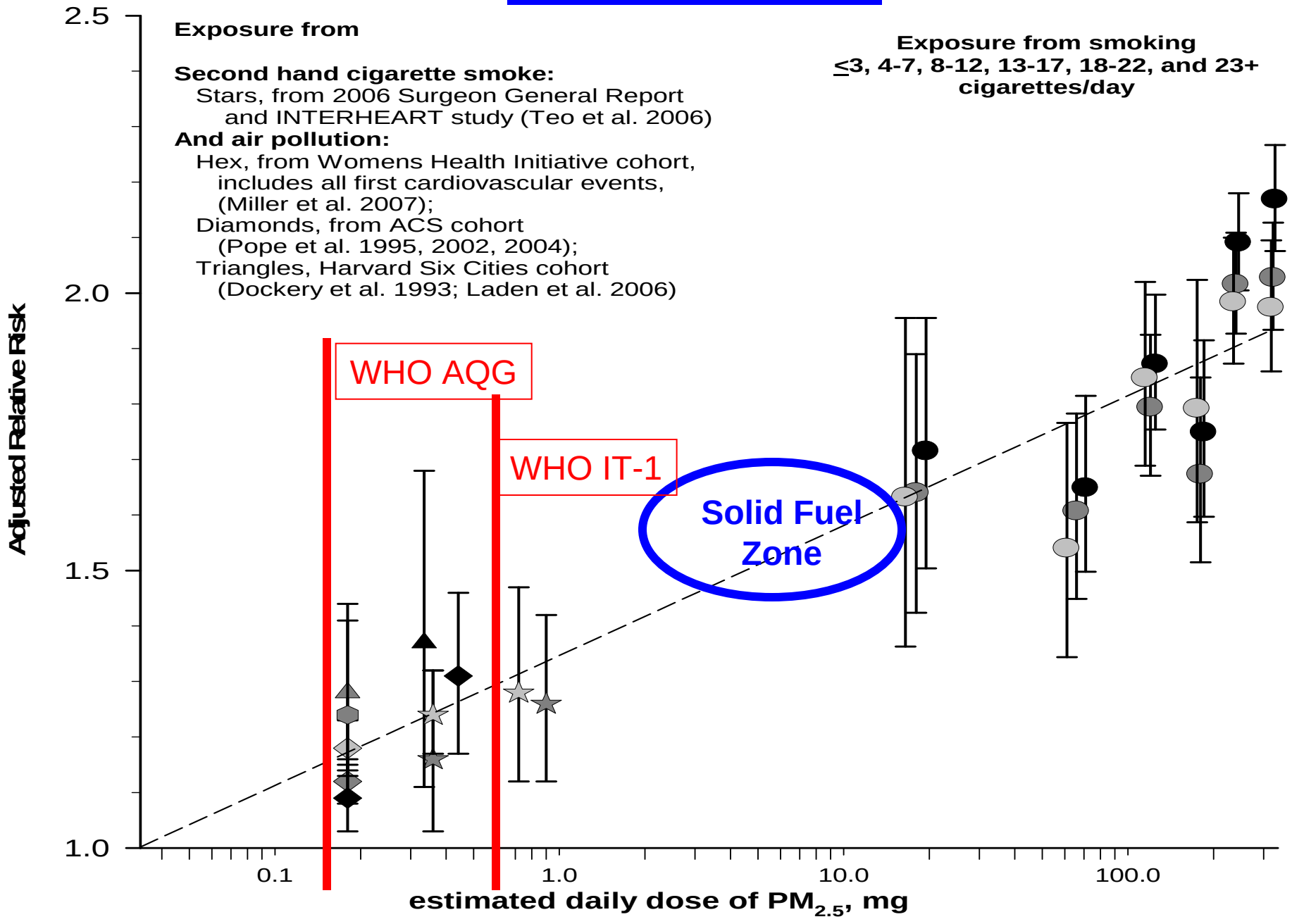
Kirk



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

Heart Disease Risk
Pope et al, forthcoming

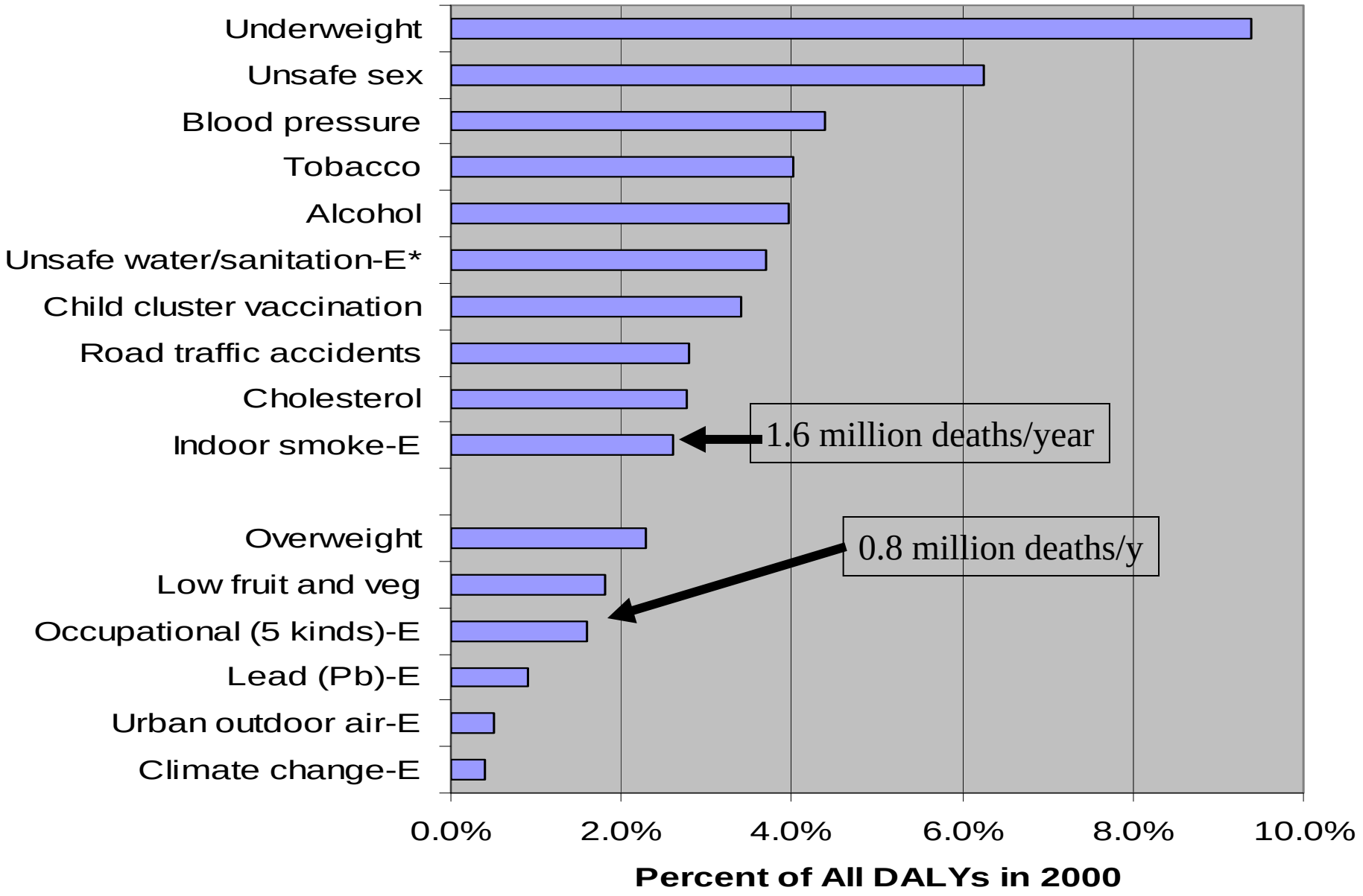


Burden of Disease

- 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

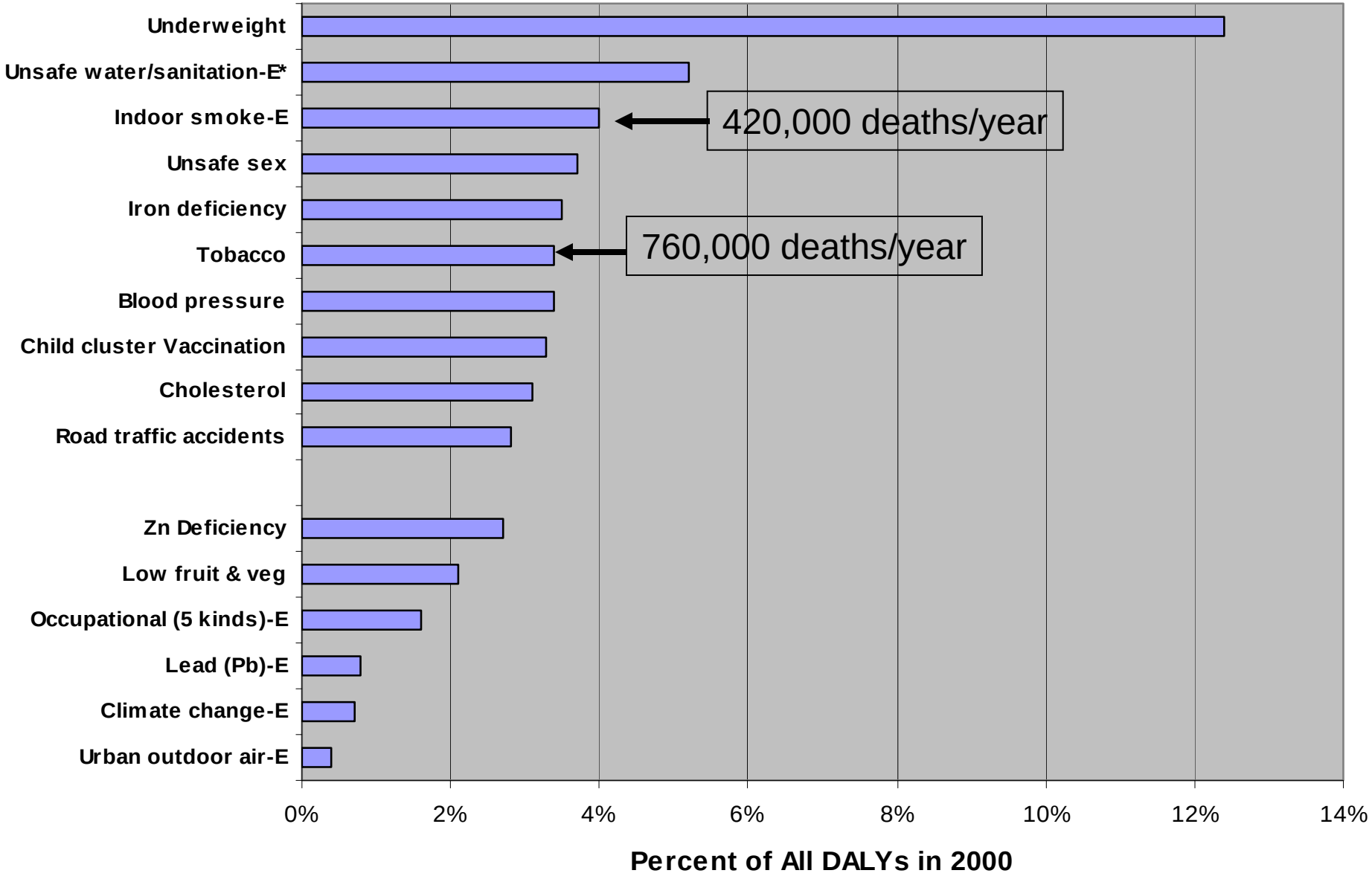
Global Burden of Disease from Top 10 Risk Factors

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 some other diseases will be sufficiently improved to include them
- Overall effect on total still unclear

Strategic Health Research:

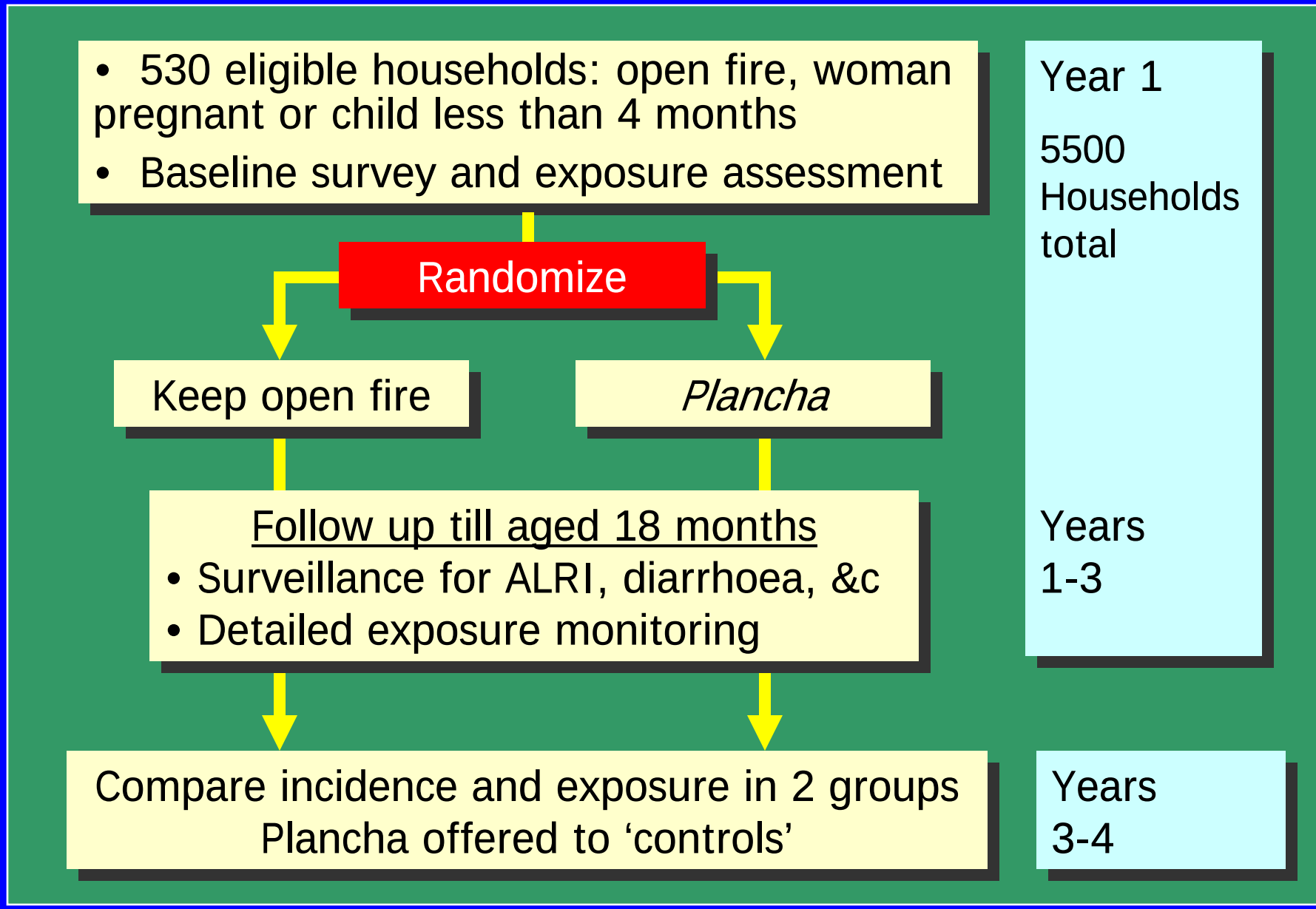
- One good lung cancer study would probably tip cancer into the top evidence category
- TB effect nearly demonstrated, but one or two more positive studies would do so.
- Showing birth defects and child cognitive function would have public relations impact
- Need heart disease studies, since it is so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

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

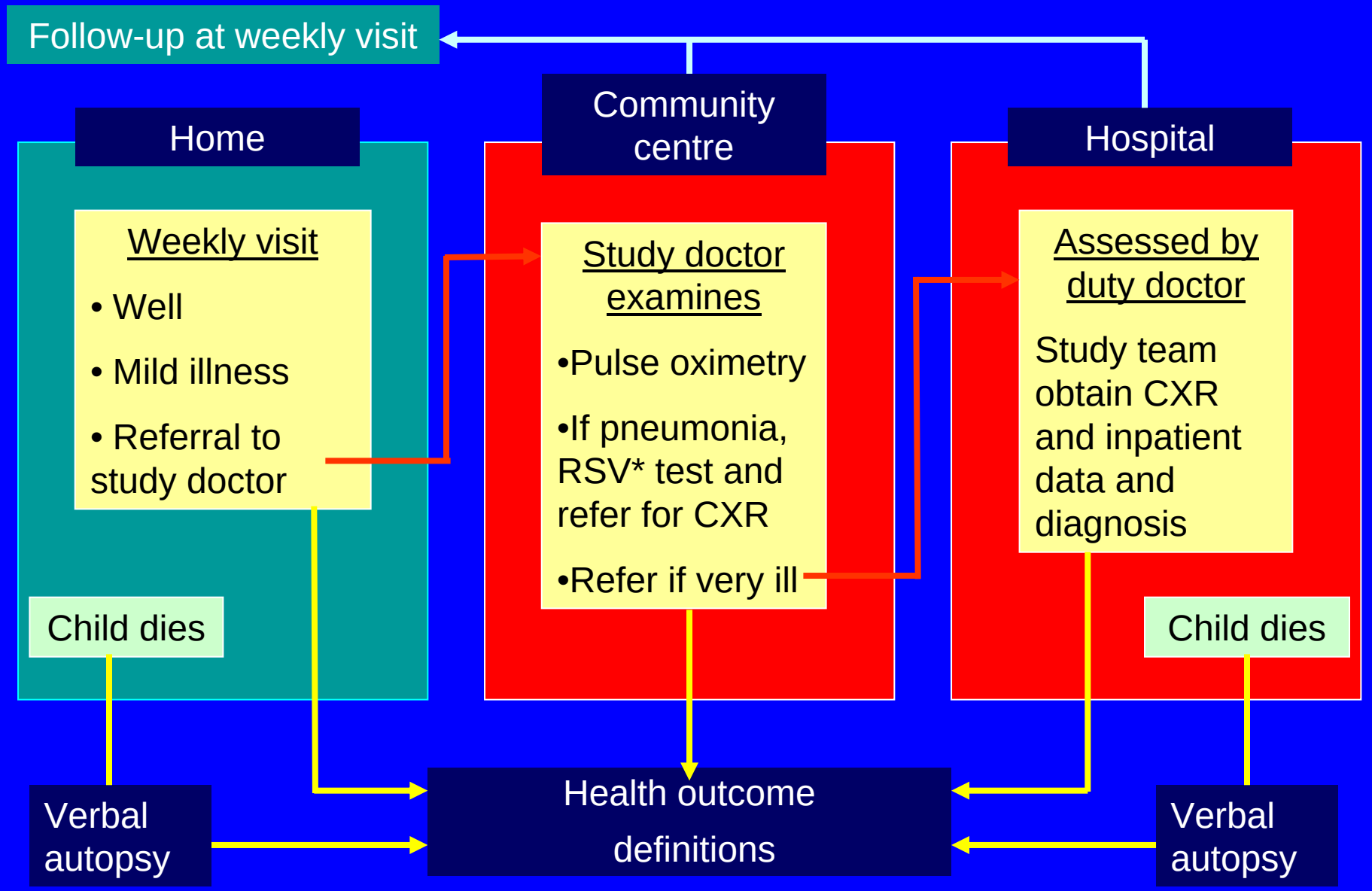
Traditional 3-stone open fire

Plancha chimney wood stove

Overview of RESPIRE study design



Overview of child health outcomes assessment



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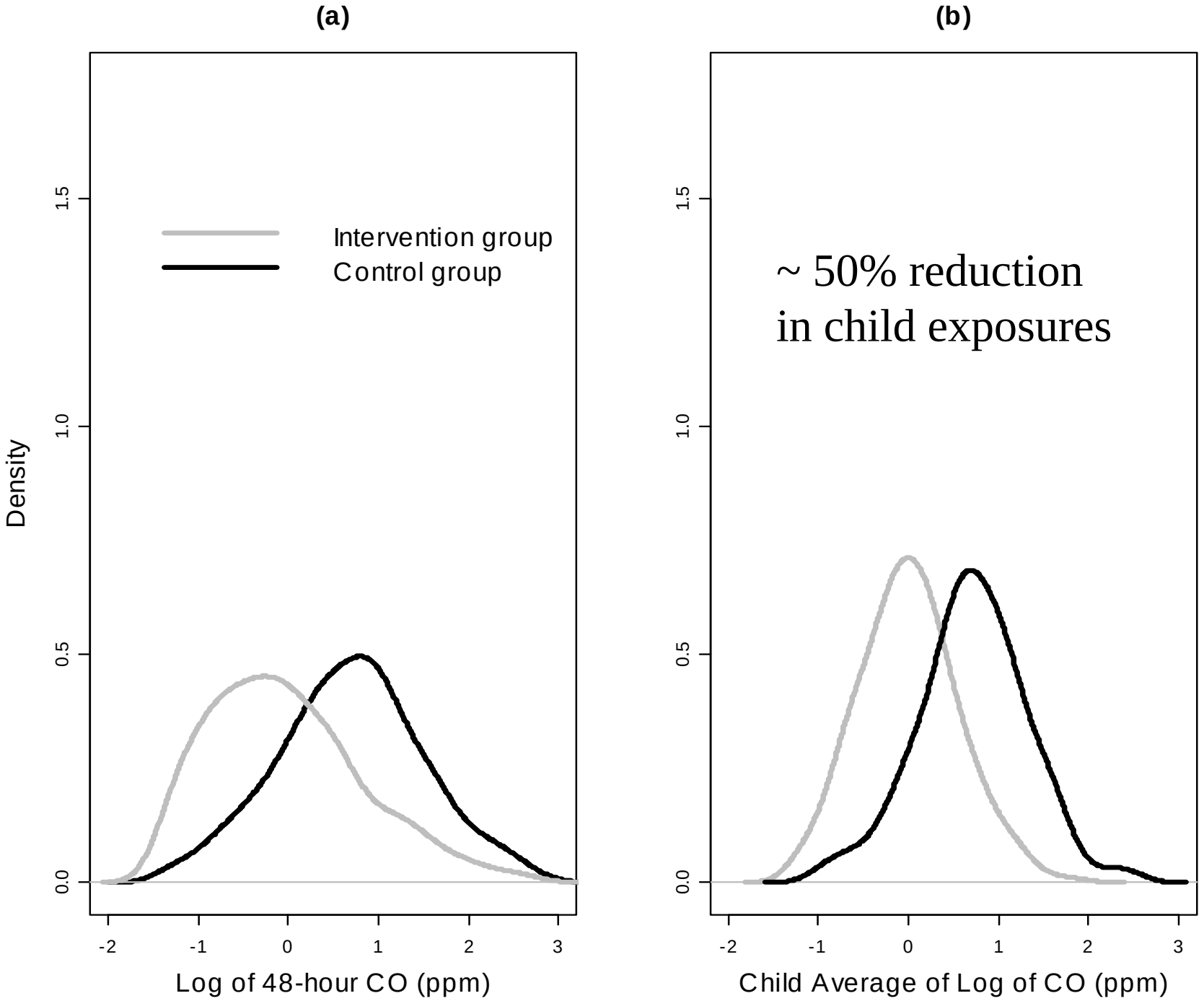
* Respiratory syncitial virus


Tubito
Tubito


(a)
(b)
Density
1.5
1.0
0.5
0.0
Intervention group
Control group
~ 50% reduction
in child exposures
-2
-1
0
1
2
3
Log of 48-hour CO (ppm)
Child Average of Log of CO (ppm)

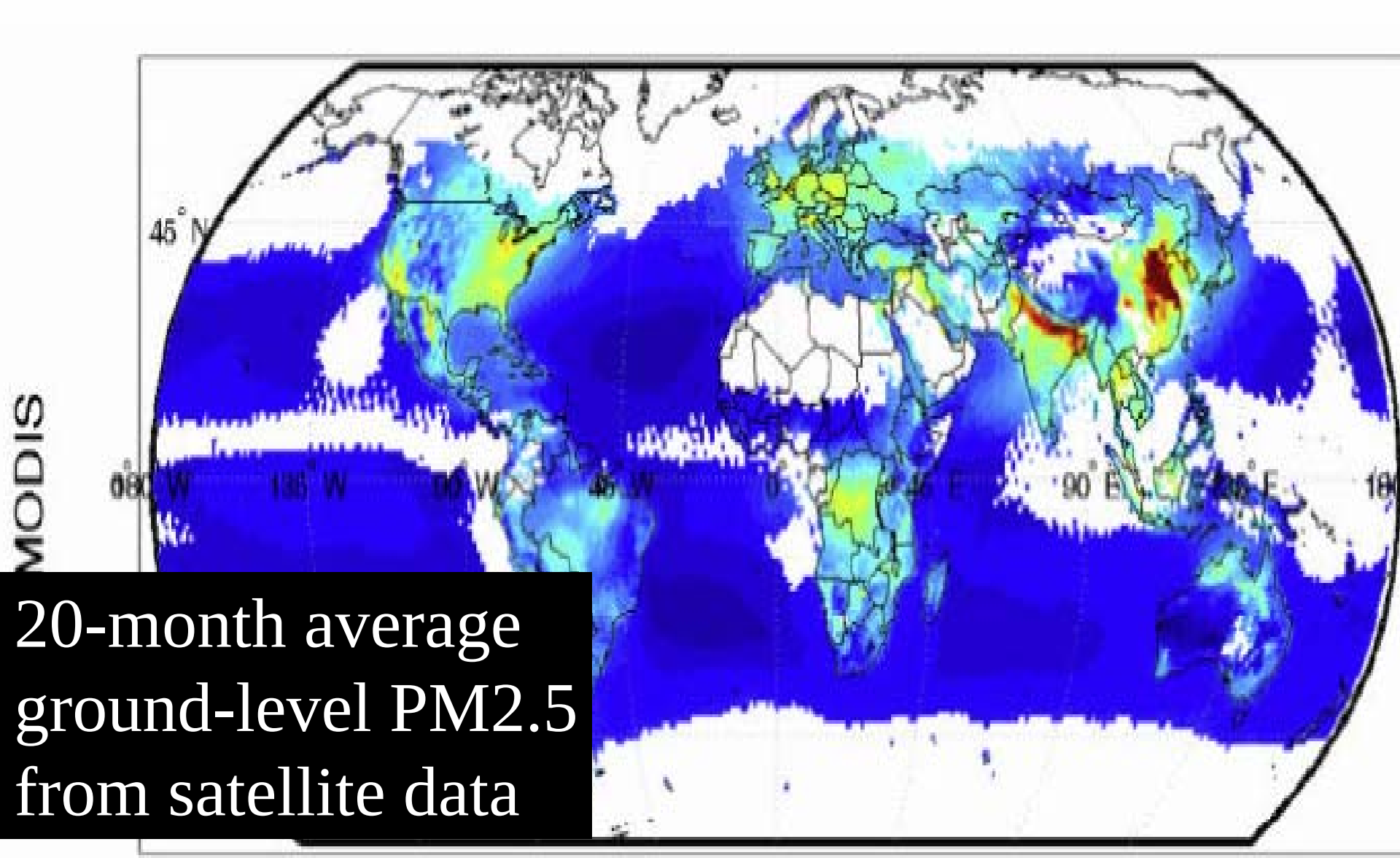
Unpublished results from RESPIRE have been removed

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

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

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



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

Chinese National Stove Contest - 2007

	CO/CO2	NCE**	Eff %	CO g/kg	PM g/kg	Relative PM/ meal	Less PM/ meal
Traditional Coal*	0.12	89.3%	25	166	1.6	23%	4.3x
Traditional Biomass*	0.15	87.0%	18	92	5.0	100%	1
Biomass Stove Winners							
Linhong	0.011	98.9%	35.9	2.2	0.22	2.2%	45x
Luoyang	0.019	98.1%	35.9	4.4	0.24	2.4%	42x
Zhenghong	0.019	98.1%	32.6	5.1	0.24	2.7%	37x
Daxu	0.020	98.1%	32.6	5.8	0.28	3.1%	32x

* Typical values ** Nominal combustion efficiency

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Traditional Coal*	0.12	89.3%	25	166	1.6	23%	4.3x
Traditional Biomass*							1
Biomass Stov							
Linhong							45x
Luoyang							42x
Zhenghong							37x
Daxu							32x

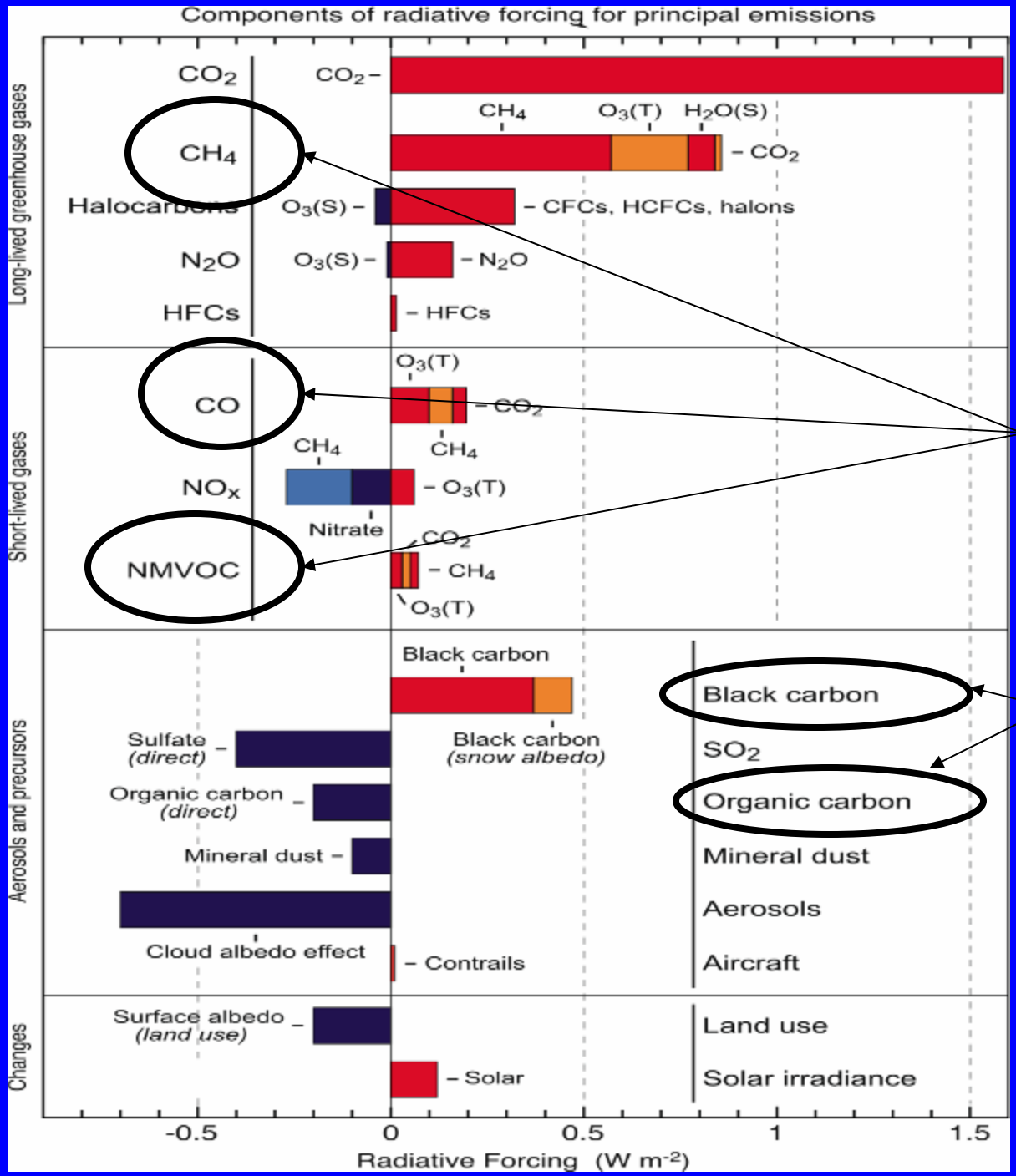
Compared to traditional biomass stove

32-45 times less mass of small particles per meal

* Typical values ** Nominal combustion efficiency

Climate connection

- SF PIC contain important greenhouse pollutants (GHPs) including
  - Methane – second most important GHP after CO2
  - Black carbon – extremely powerful GHP – 3rd most important after CO2
- 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 >35% of global black carbon
- Major opportunities for co-benefits, i.e., tap international carbon market to pay for stove/fuel improvements

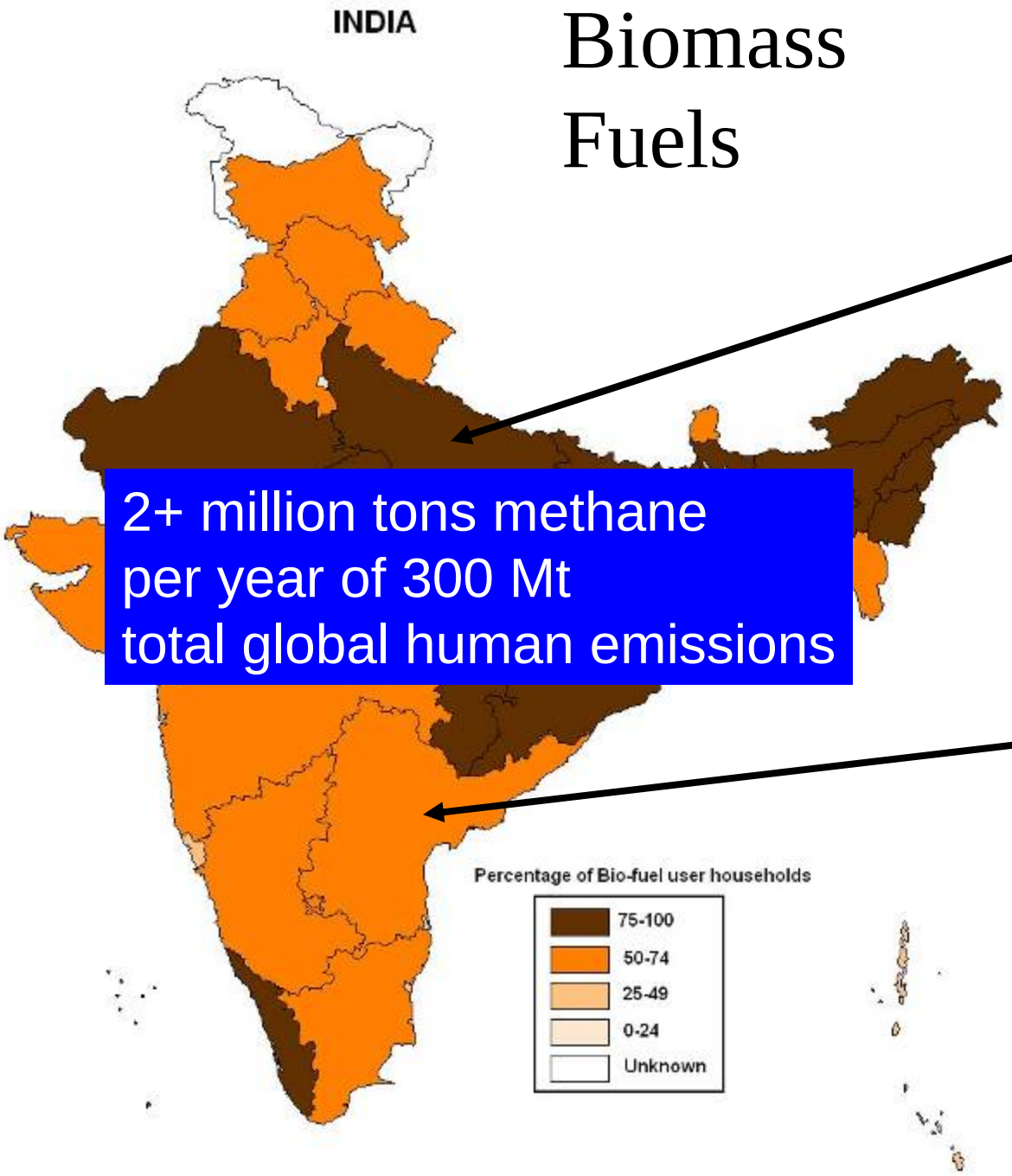


Warming in 2005 from emissions since 1750

A large part from PIC: products of incomplete combustion

IPCC, 2007

Biomass Fuels



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

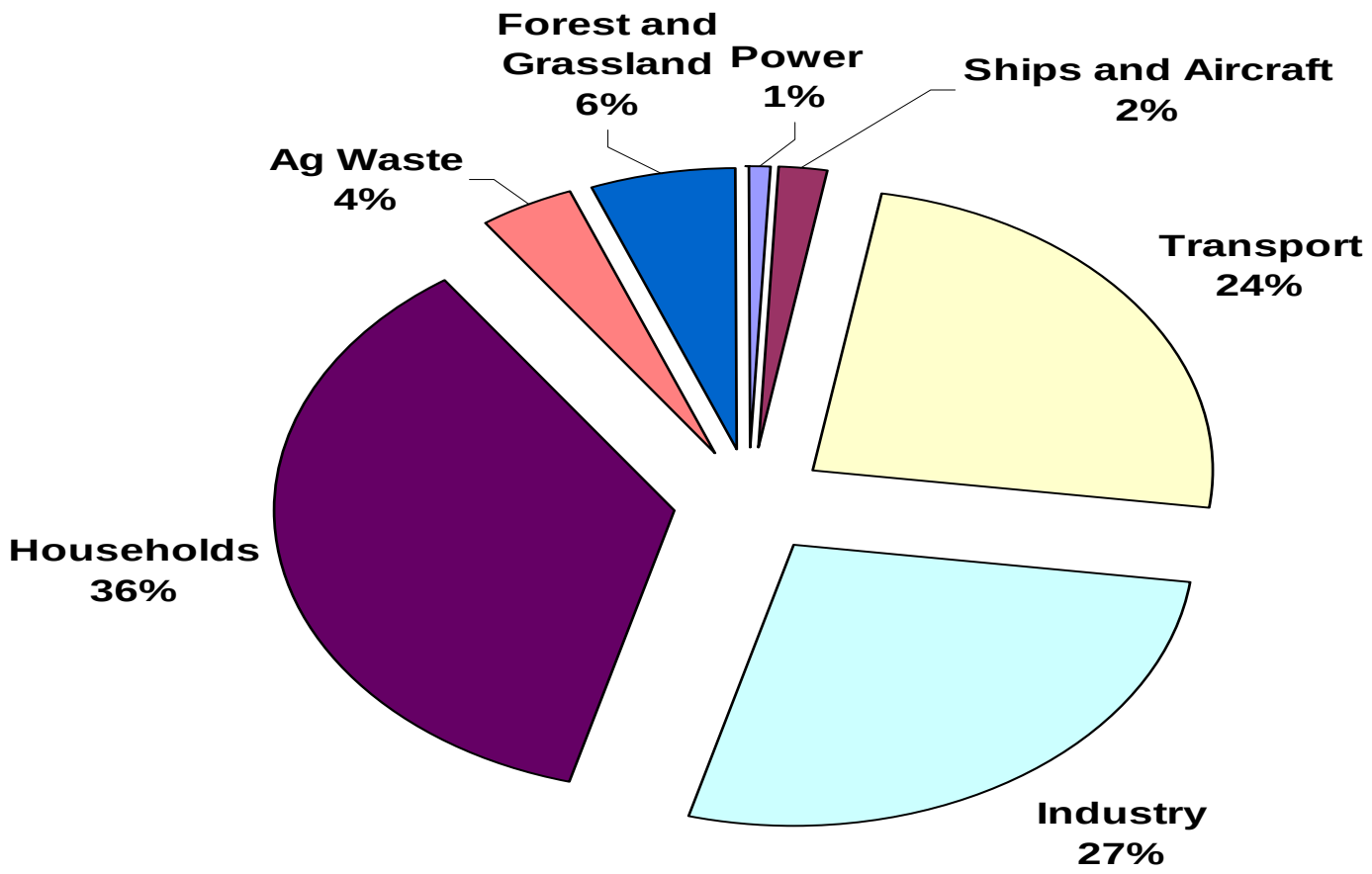
More than 75% of households

50-74% of households

2000 Census

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



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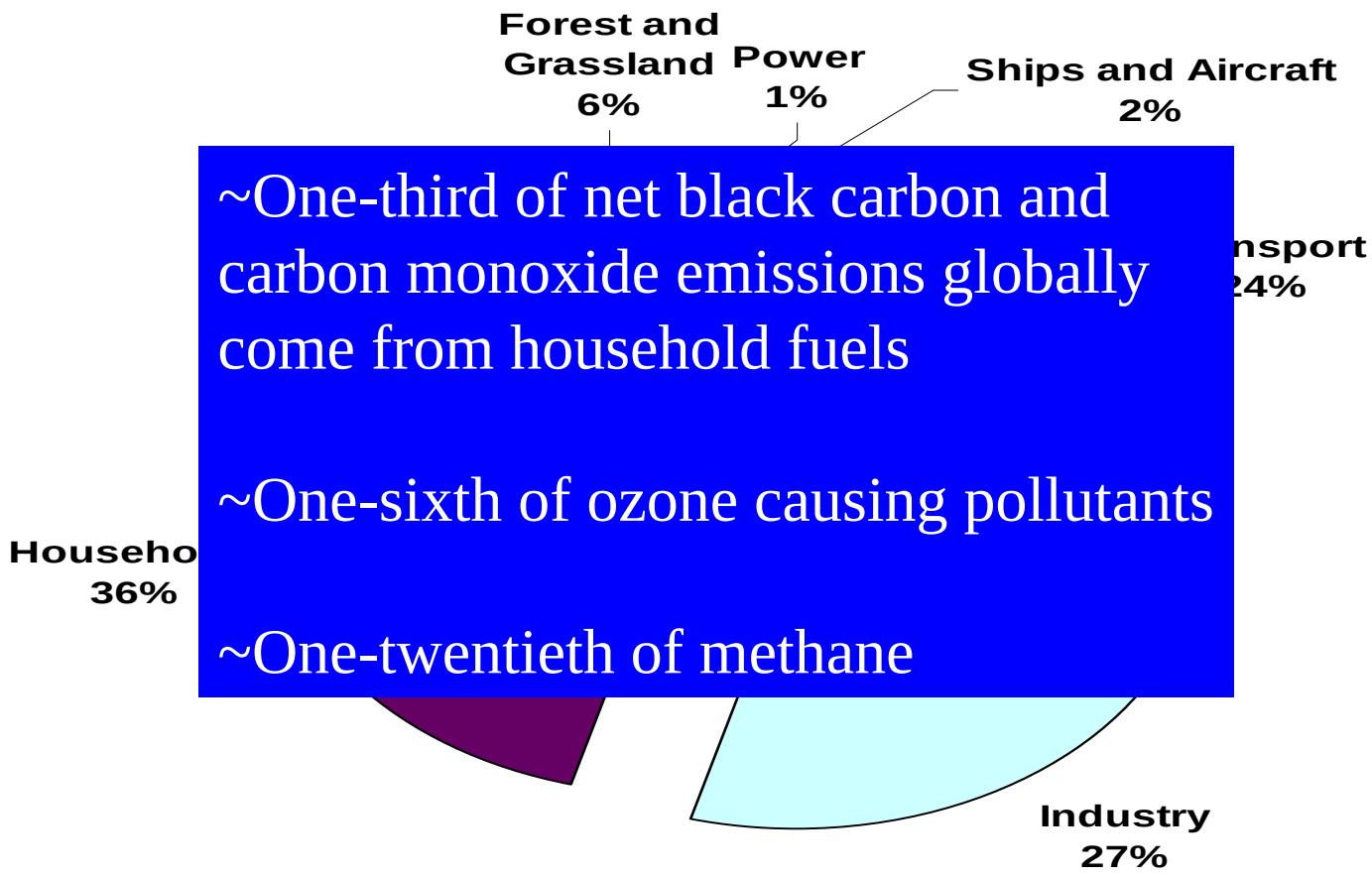


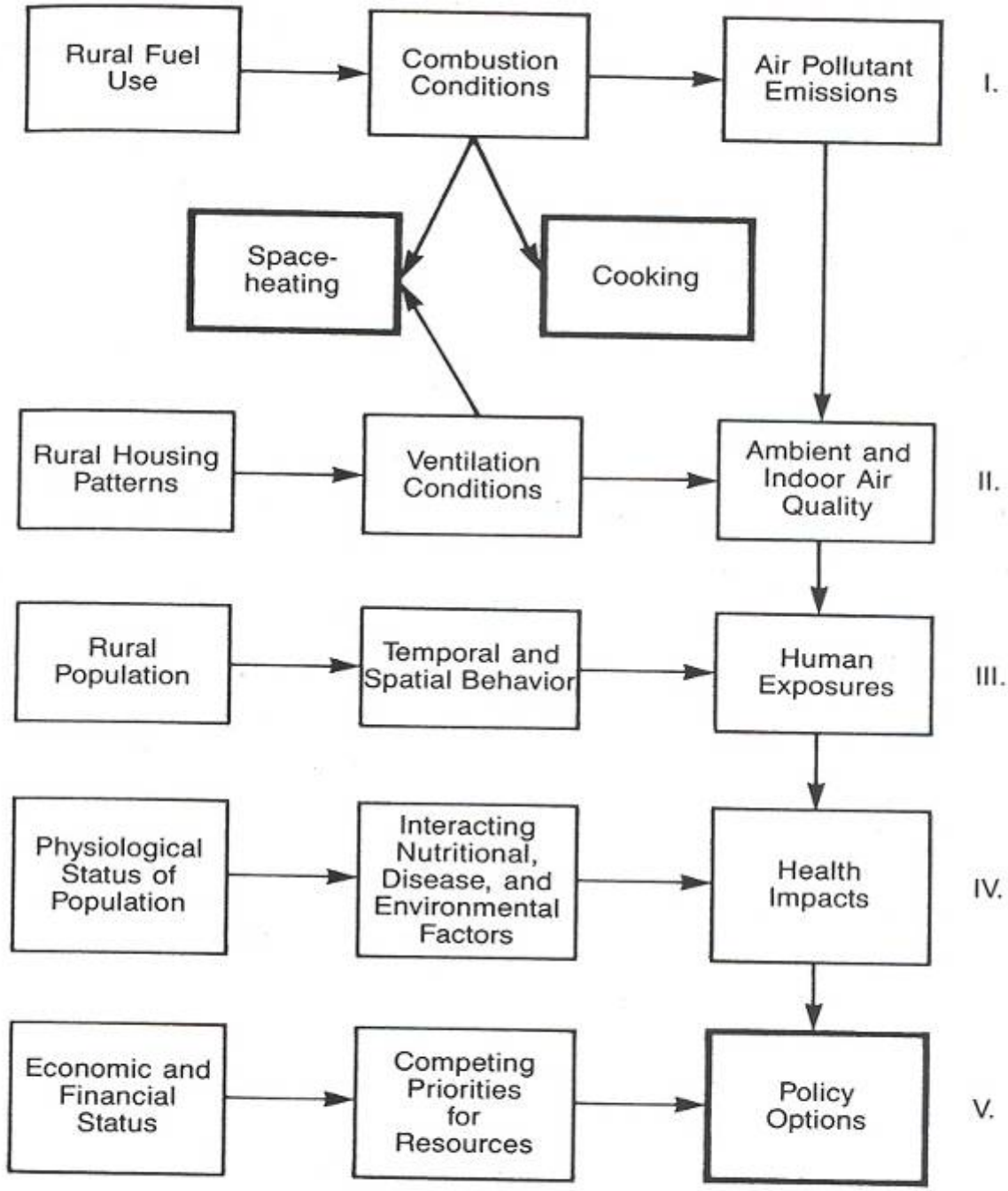
~One-third of net black carbon and carbon monoxide emissions globally come from household fuels

~One-sixth of ozone causing pollutants

~One-twentieth of methane

What Can be Done?

Smith, 1983



Engineering Interventions to Reduce Health Burden from Household Solid Fuel Use

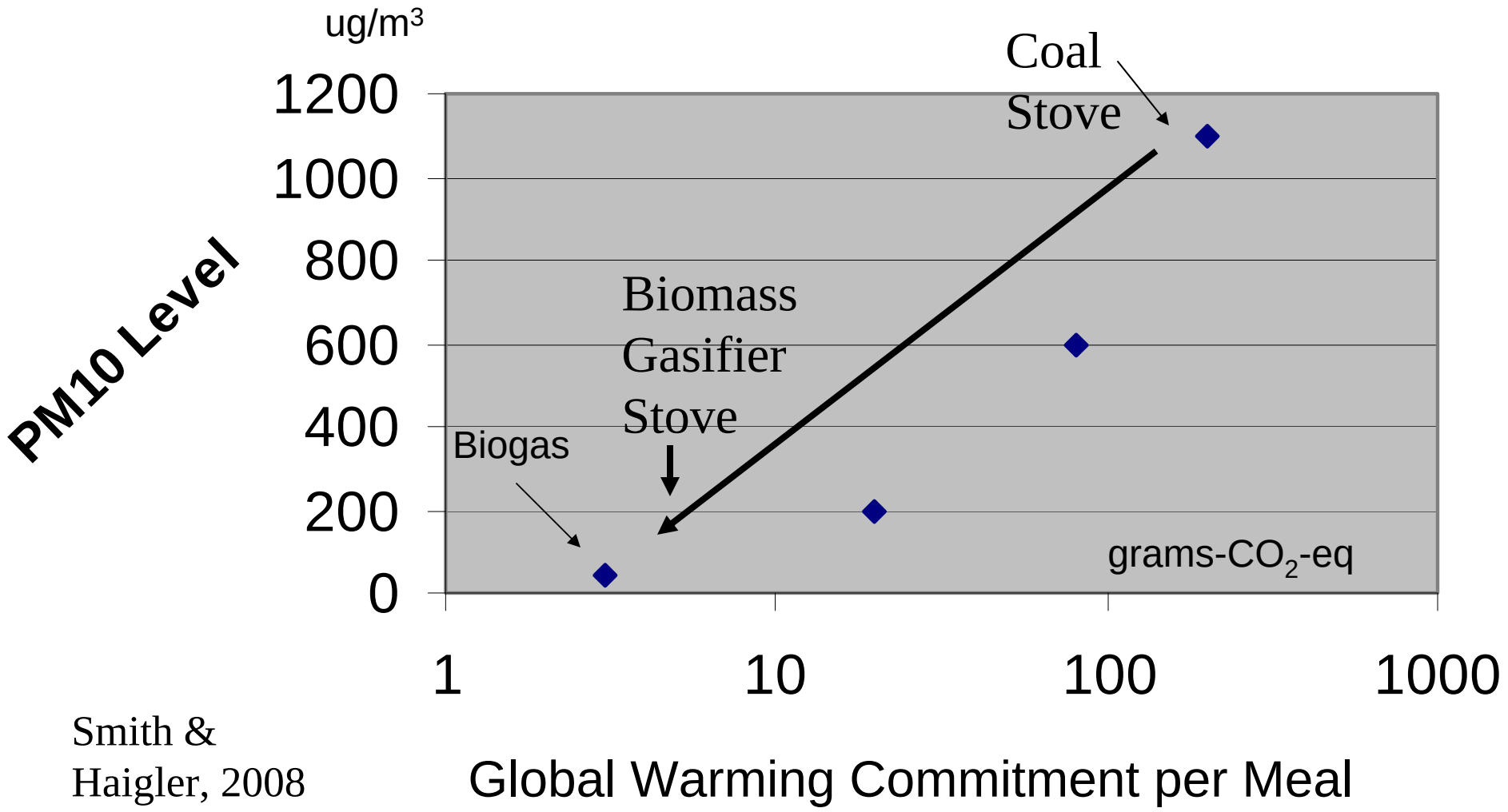
- Ventilation changes (put smoke outside)
  - More windows/openings
  - Chimneys on stoves
- Stoves with better combustion (low emissions)
  - Using existing biomass fuels, e.g., “gasifier” stoves
  - Using processed biomass, e.g., pellet stoves
  - Better energy efficiency alone may not help
- Liquid/gaseous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

A Biomass Gasifier Stove

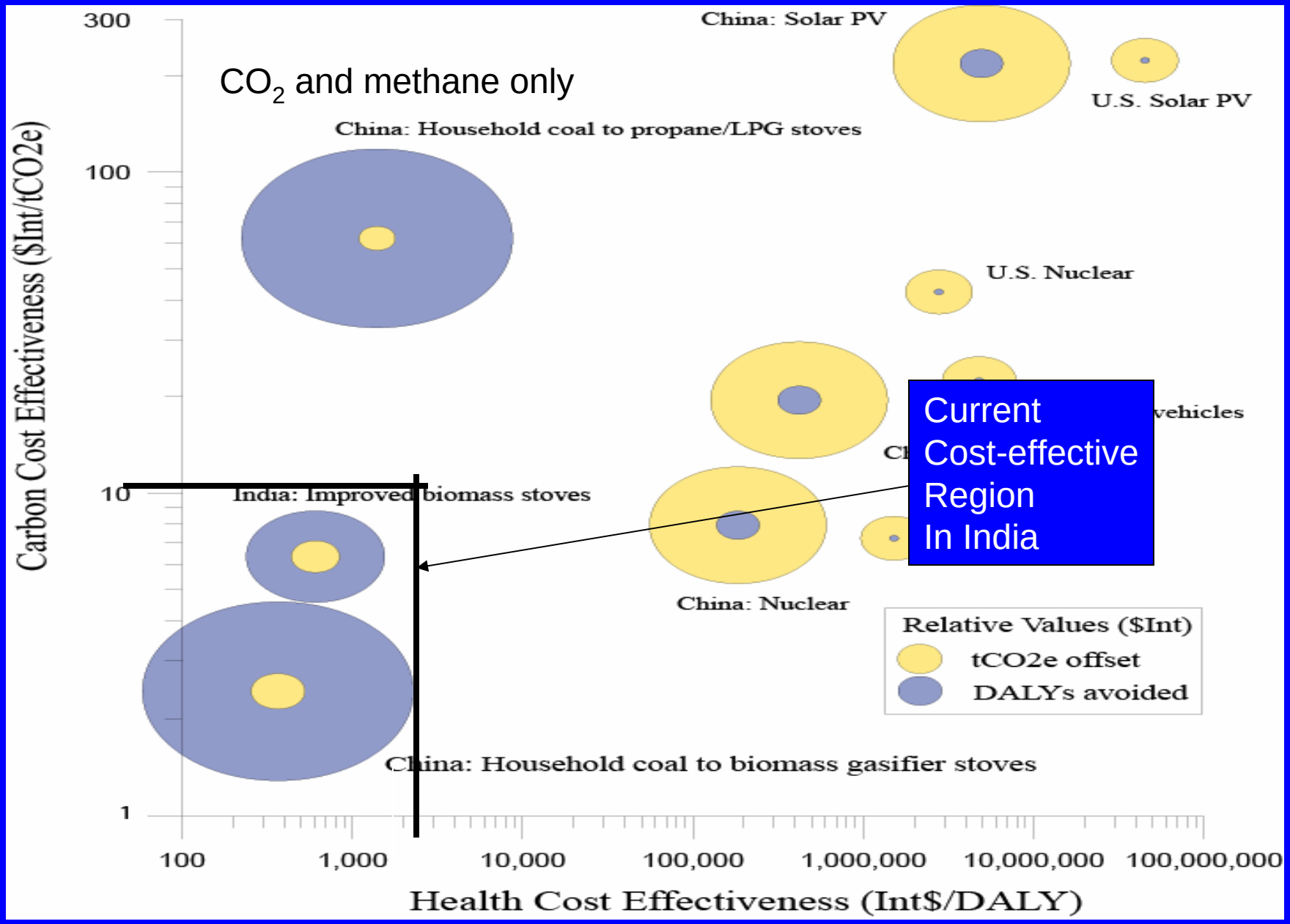
Tests show emissions nearly at levels of gas stoves:
Low health risk and essentially no greenhouse emissions


Retail cost
~$80
CO2-eq
Savings
~$60/y
Hot water
Blower
08.11.2008

Health and Greenhouse Gas Benefits of Biomass Stove Options



Smith & Haigler, 2008



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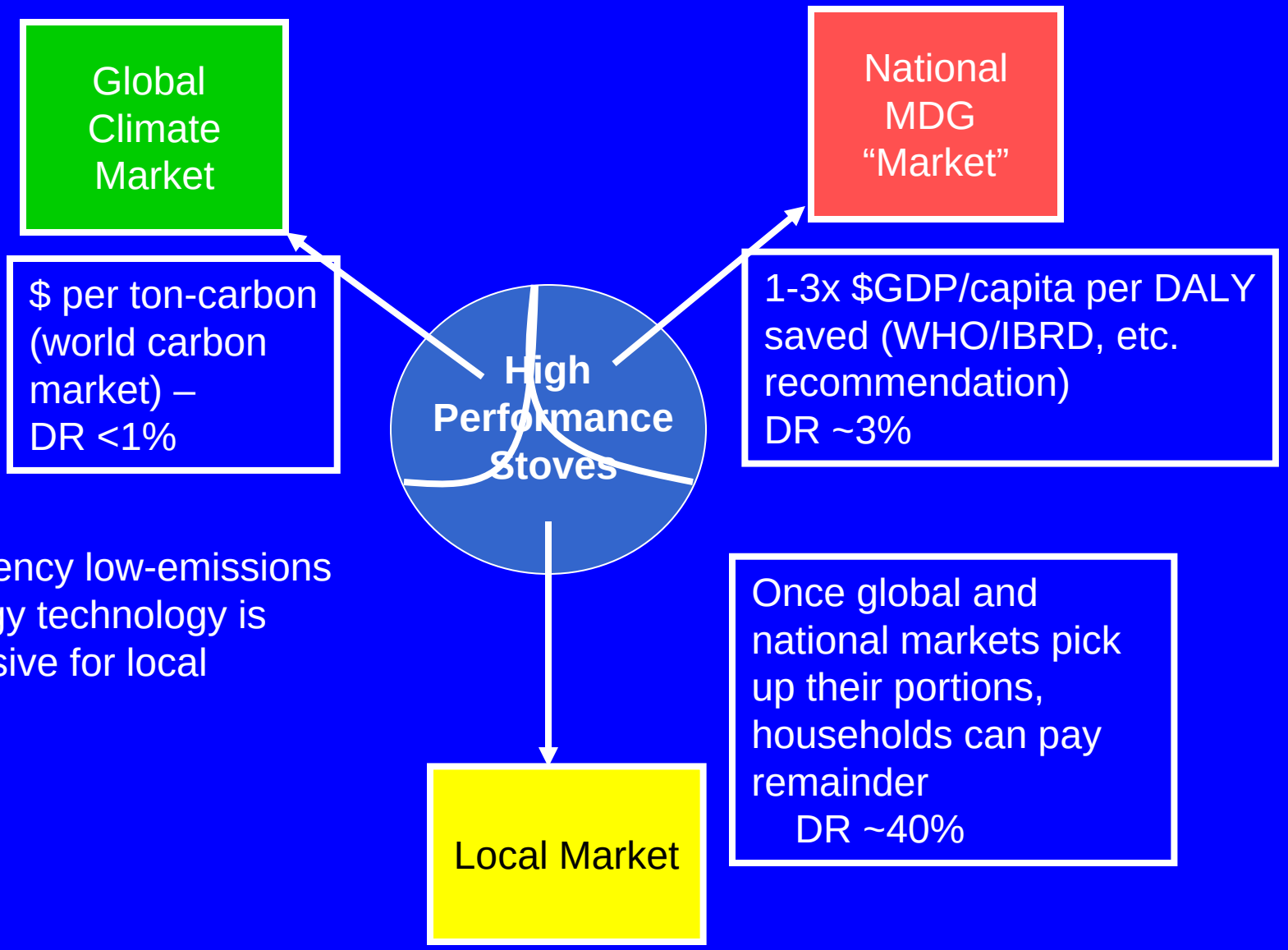
Smith & Haigler, 2008

Paying for Rural Energy Development



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

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Dissemination Lessons

- Need to start in places/populations where success is easier and quicker
- Need to create a modest range of models for different fuels, foods, and incomes – perhaps designed to be phased (model for bride, for the first child, etc)
- Need to have sophisticated supply chains to assure quality and availability
- Need to consider innovative financing approaches to lower perceived cost to households (micro-finance, smart subsidies, etc.)
- Need to consider dissemination in conjunction with other widespread programs, e.g., pre-natal care
- Need to create incentives for purchase and proper use: marketing and service contracts

Technical Lessons

- Extremely low emissions are possible with good designs, particularly “semi-gasifier” stoves
- Better to have low emissions than rely on chimney, but reliability of low emissions an issue particularly with fuel variability
- Best to have both: chimneys will last longer with lower emissions
- Hybrid designs (with electric blowers) may have sufficiently reliable low emissions to be promoted without chimneys
- Need to have robust devices that require as little operator thinking as possible
- Need to move to manufactured units made with ceramic and/or metal to maintain performance

Joint Lessons

- Need to incorporate both lab and field-based M&E for determining impact and providing mid-course corrections
- Need to have government certification/ benchmarking as with other household appliances
- Protection of IPR will be important at some stage
- Only government and private business probably have sufficient capabilities for the sustained effort to deal with the ~15 crore stoves needed in India
- As a purely market-based approach will probably not be able to disseminate technology of sufficient performance, a hybrid approach is needed until rural incomes grow.

Publications and presentations available at

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

Thank you