

How to Trick the Belgians into Paying for Improved Stoves:

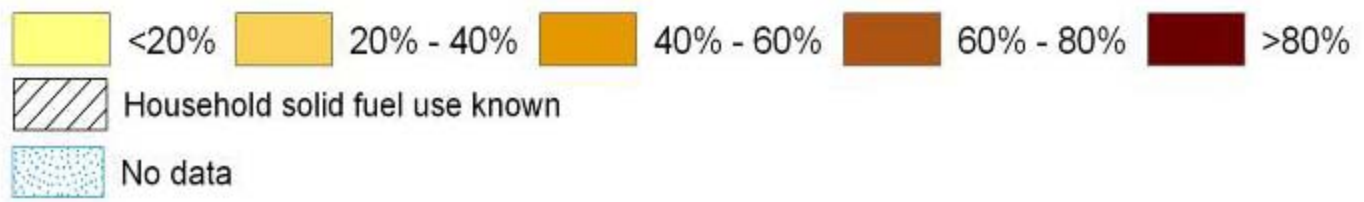
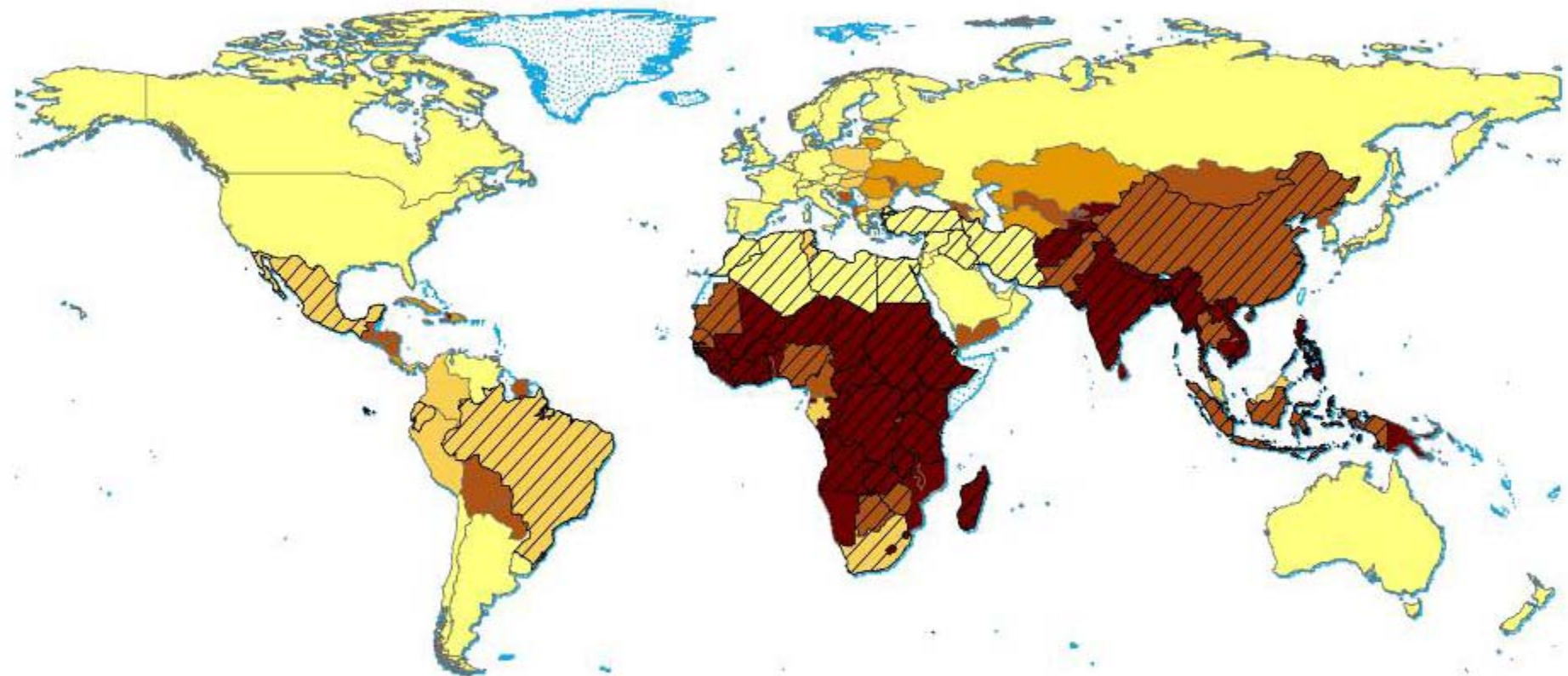
Health, Climate, and Household Solid Fuel Use

Kirk R. Smith

Professor of Global Environmental Health
University of California, Berkeley

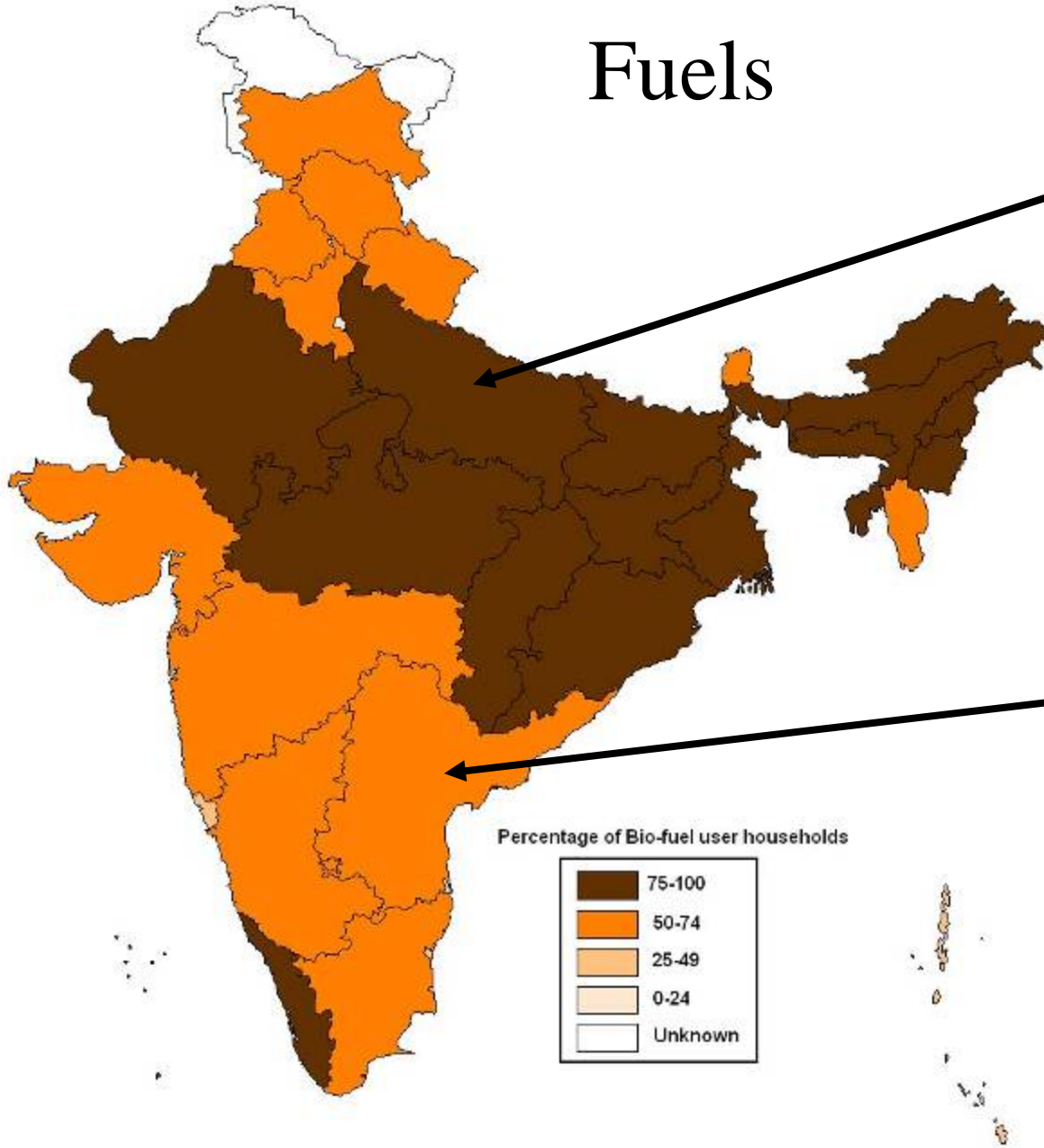
USEPA Workshop on Short-lived Climate Forcers,
University of North Carolina, Chapel Hill,
March 3, 2010

National Household Solid Fuel Use, 2000



INDIA

Biomass Fuels



More than
75% of
households

50-74% of
households

2000 Census

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



Kheda District
Gujarat, India
1981

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%

How much of what pollutants are produced?

- Only one old database of systematic measurements available for answering this question.
- ~30 fuel/stove combinations each in India and China
- Emission factors for ~55 pollutants both health- and climate-damaging, along with efficiency
- Developed under EPA grant in early 1990s
- Published over the late 1990s – still used by IPCC and other atmospheric science modelers
- Not done since in a systematic way with better measurement technology and more complete set of fuel/stove combinations including modern advanced stoves
- Jim Jetter at EPA and others doing great job on an ad hoc basis, but much more systematic work needed, particularly in field settings as we know now that lab tests do not well duplicate field results.
- Should be in EPA Emissions Database: CHIEF
- Serious problems require serious responses.

**GREENHOUSE GASES FROM BIOMASS AND FOSSIL FUEL STOVES
IN DEVELOPING COUNTRIES: A MANILA PILOT STUDY**

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Health, energy, and greenhouse-gas impacts of biomass combustion in household stoves

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Poor biomass combustion in stoves entails three major environmental liabilities due in significant part to emissions of products of incomplete combustion (PICs). First, poor combustion contributes directly to low energy efficiency, with its attendant problems of onerous human labor requirements and pressure on biomass resources from harvesting. Second, some PICs are hazardous to health when breathed in the concentrations commonly found in homes using unvented biomass stoves. Third, a different set of PICs are strong direct or indirect greenhouse gases, potentially contributing to global warming. To evaluate the impacts in these three areas, it is valuable to construct carbon balances of alternative stove/fuel systems in what can be called “triple carbon balance” analysis (TCBA). Here TCBA is applied to traditional and improved woodstoves in developing countries and to one of the chief alternatives, kerosene. The tentative, counterintuitive result is that a switch to fossil fuels can sometimes be justified on all three environmental grounds.

Energy

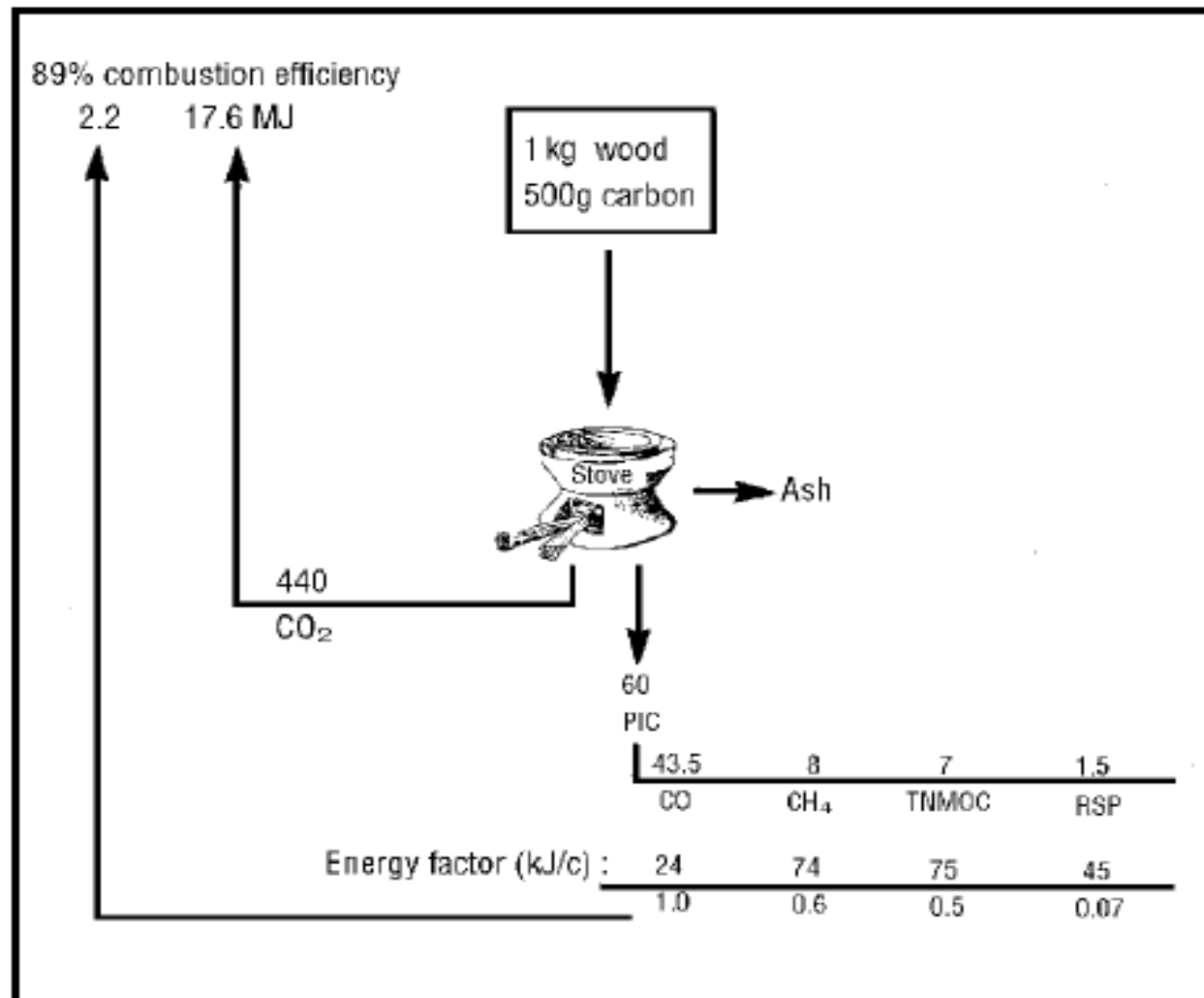
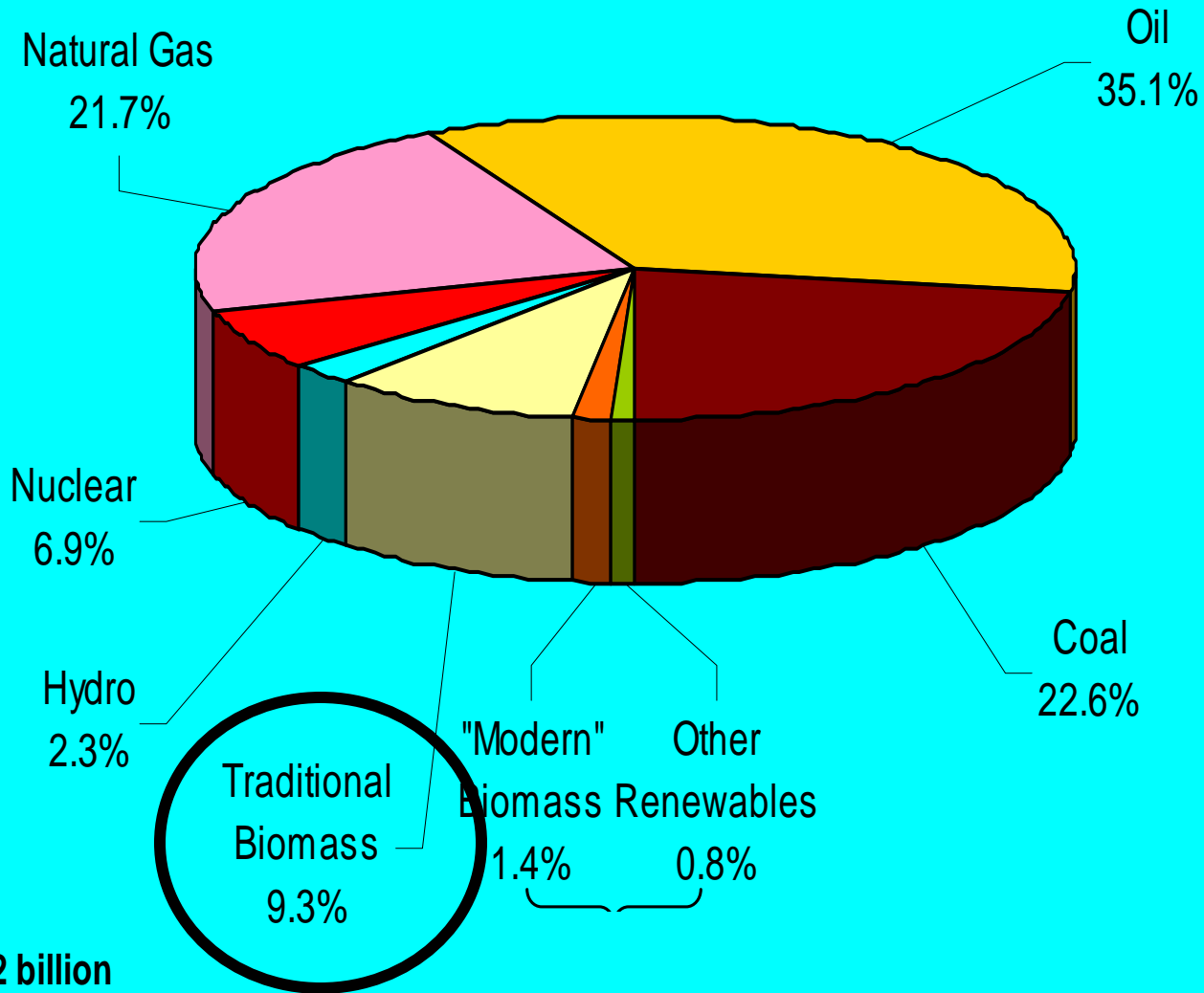


Fig. 1. Movement of fuel carbon through a traditional wood-fired cookstove as measured in the Philippines [Smith et al., 1992; Smith, Khalil, et al., 1993]. Sixty grams of carbon was not combusted completely (i.e., was released as PICs). Based on the available carbon energy in each PIC, if it had all been combusted completely, another 2.2 MJ would have been released as heat. The stove, therefore, has a combustion efficiency of about 89%. All the numbers refer to grams of carbon alone; i.e., the full mass of CO would be 28/12 (2.33) times larger.

Smith,
1994

World Energy – 2001

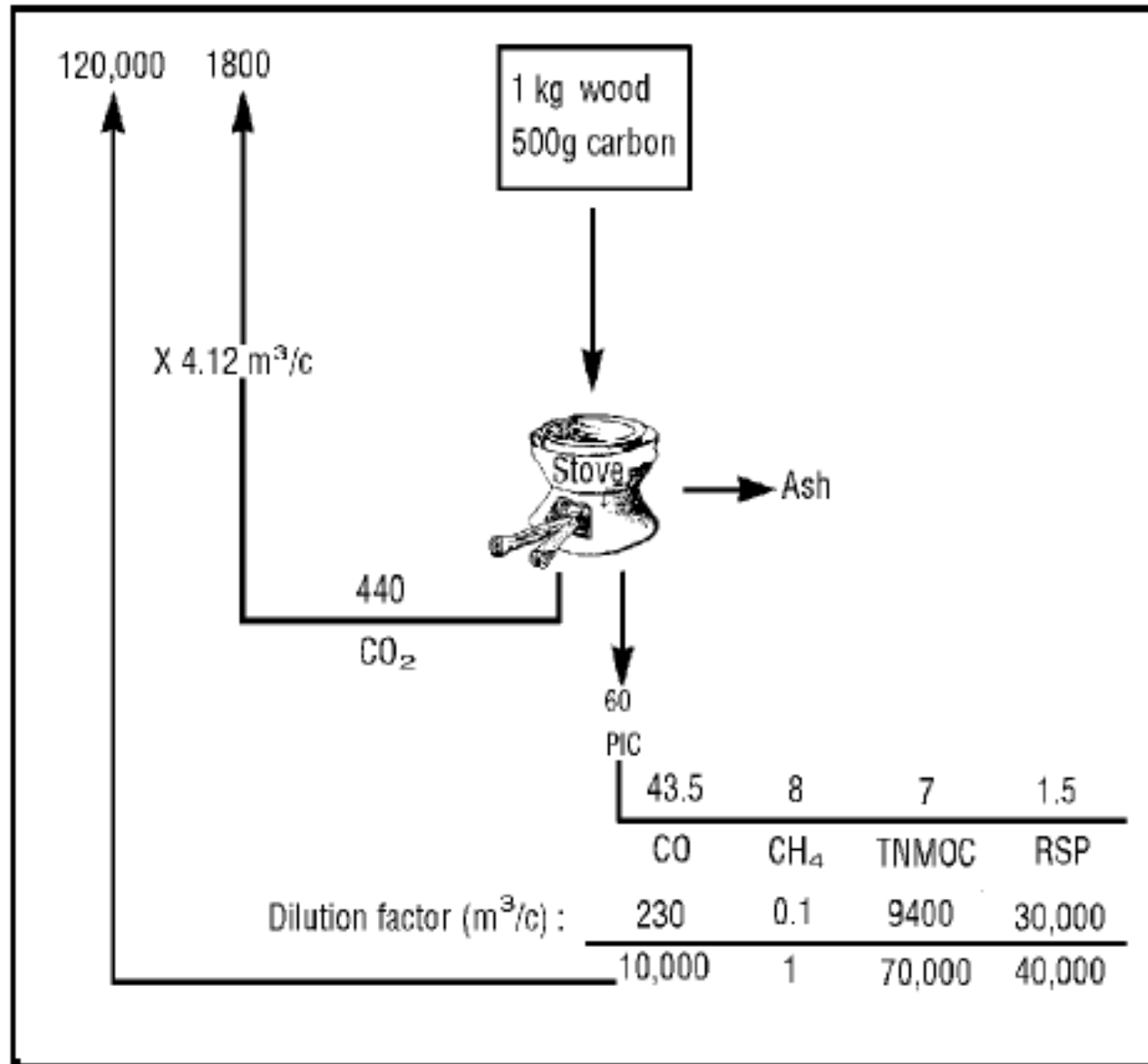


Population: 6.102 billion

Total energy use: 10.2 Gtoe

Per capita energy consumption: 1.67 toe

Health

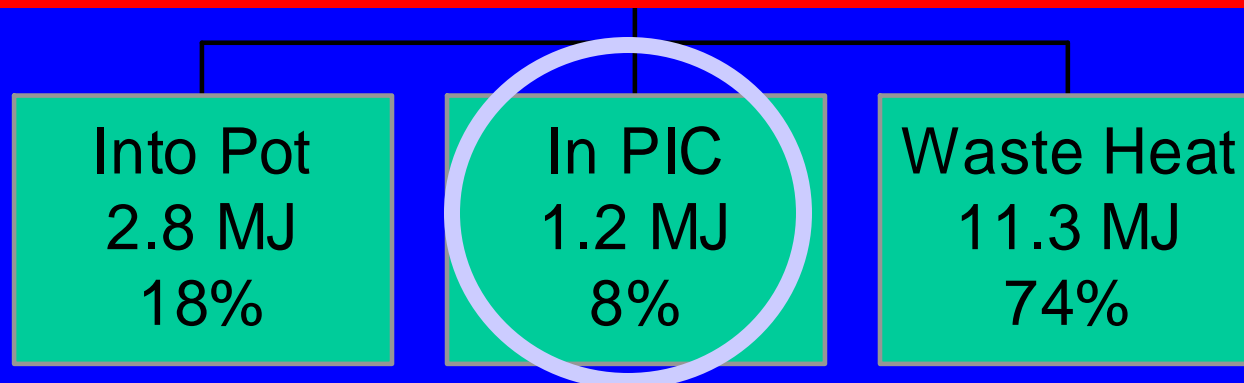


Smith,
1994

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

- Small particles, CO, SO₂, NO₂ (also CH₄ & N₂O)
- 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

Perfect Storm for Health Impacts

- Highly polluting activity
- Half of world households
- Several times a day
- Just when people are present
- Most vulnerable (women and young children) most likely to be there

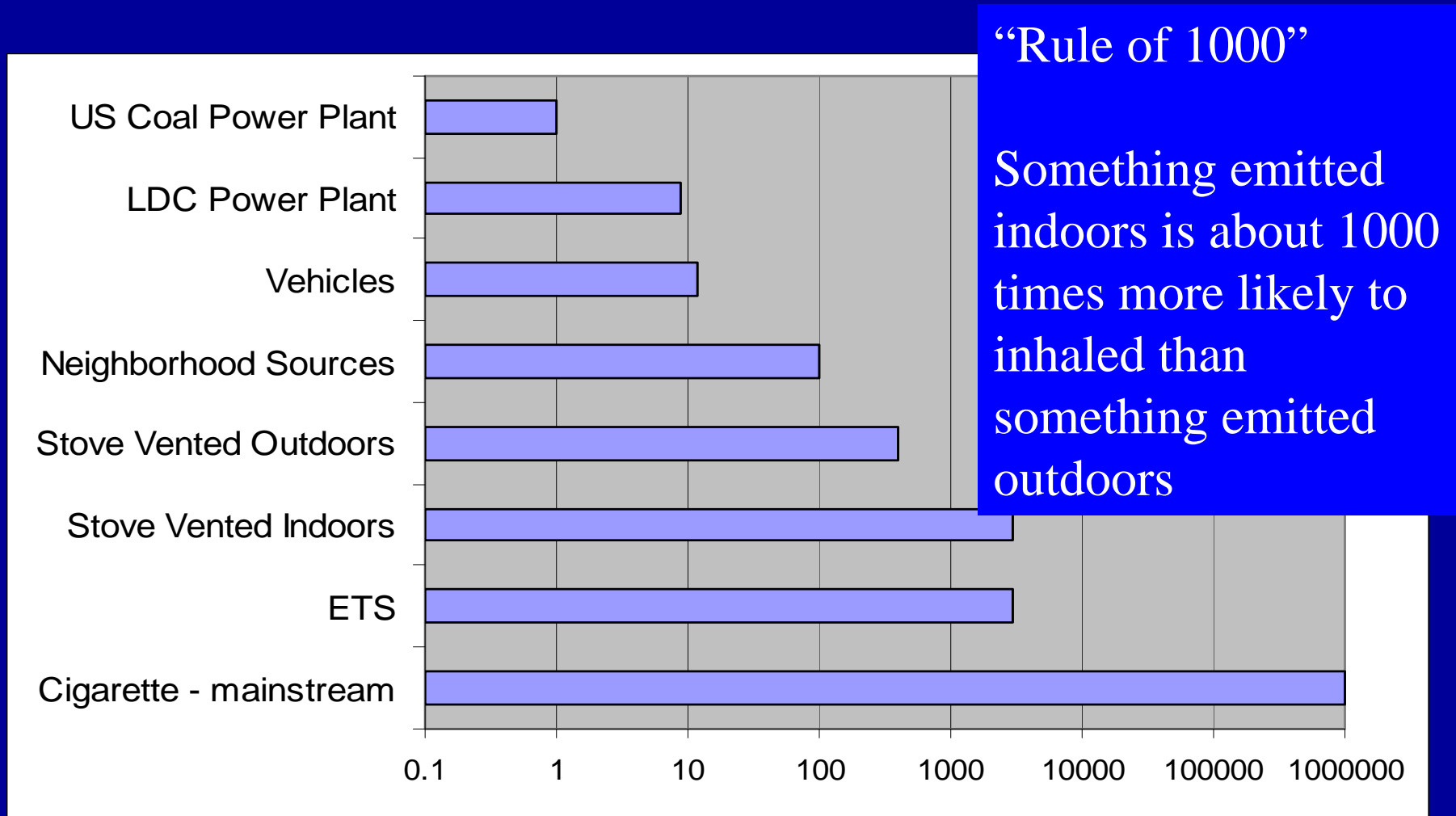
In other words, the Intake Fraction
is extremely large

IF is the fraction of material emitted
that is actually breathed in by someone



IF = 1.0

Intake Fractions : these are rough calculations for typical examples of sources in each class

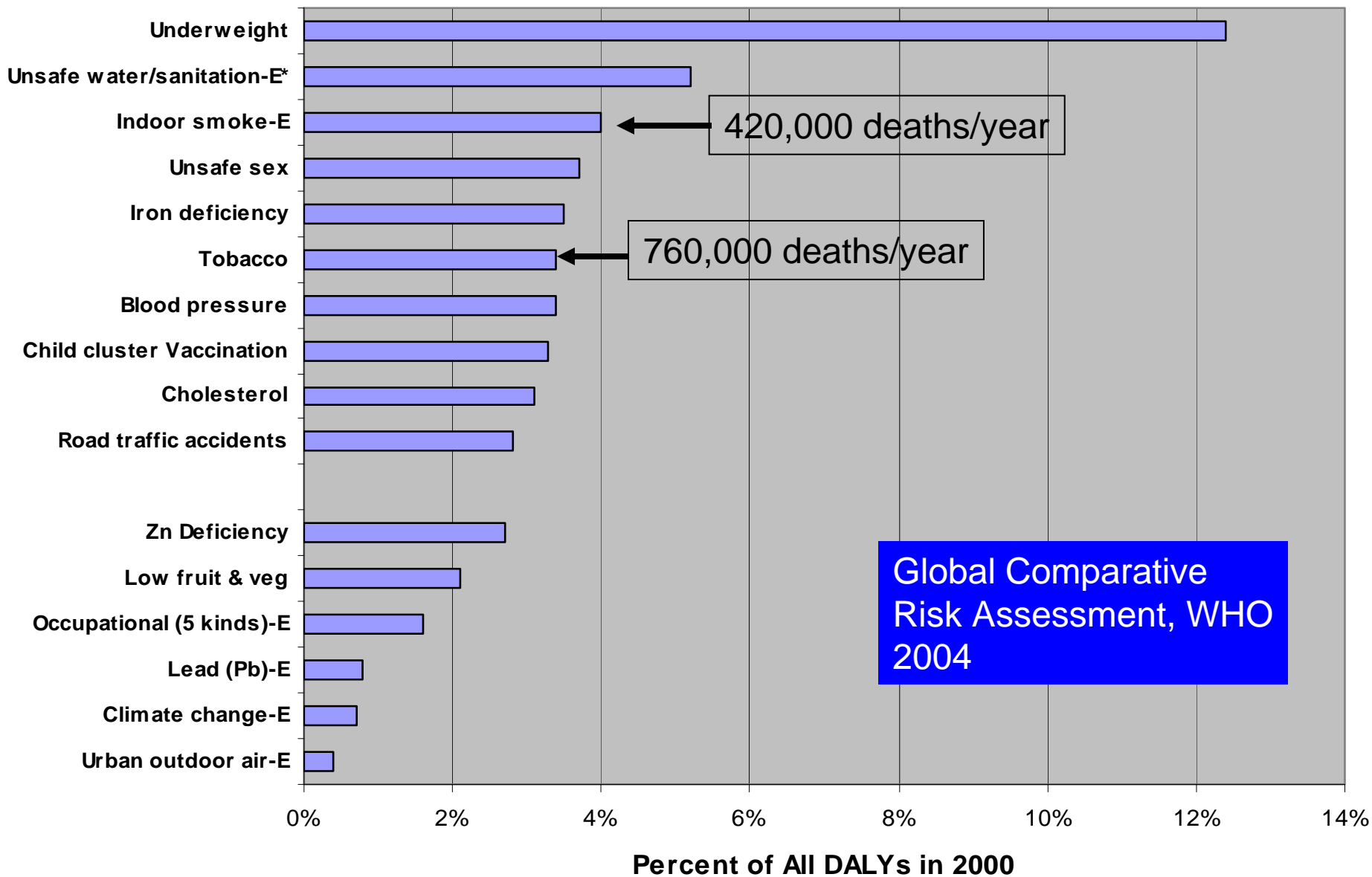


Smith, 1993

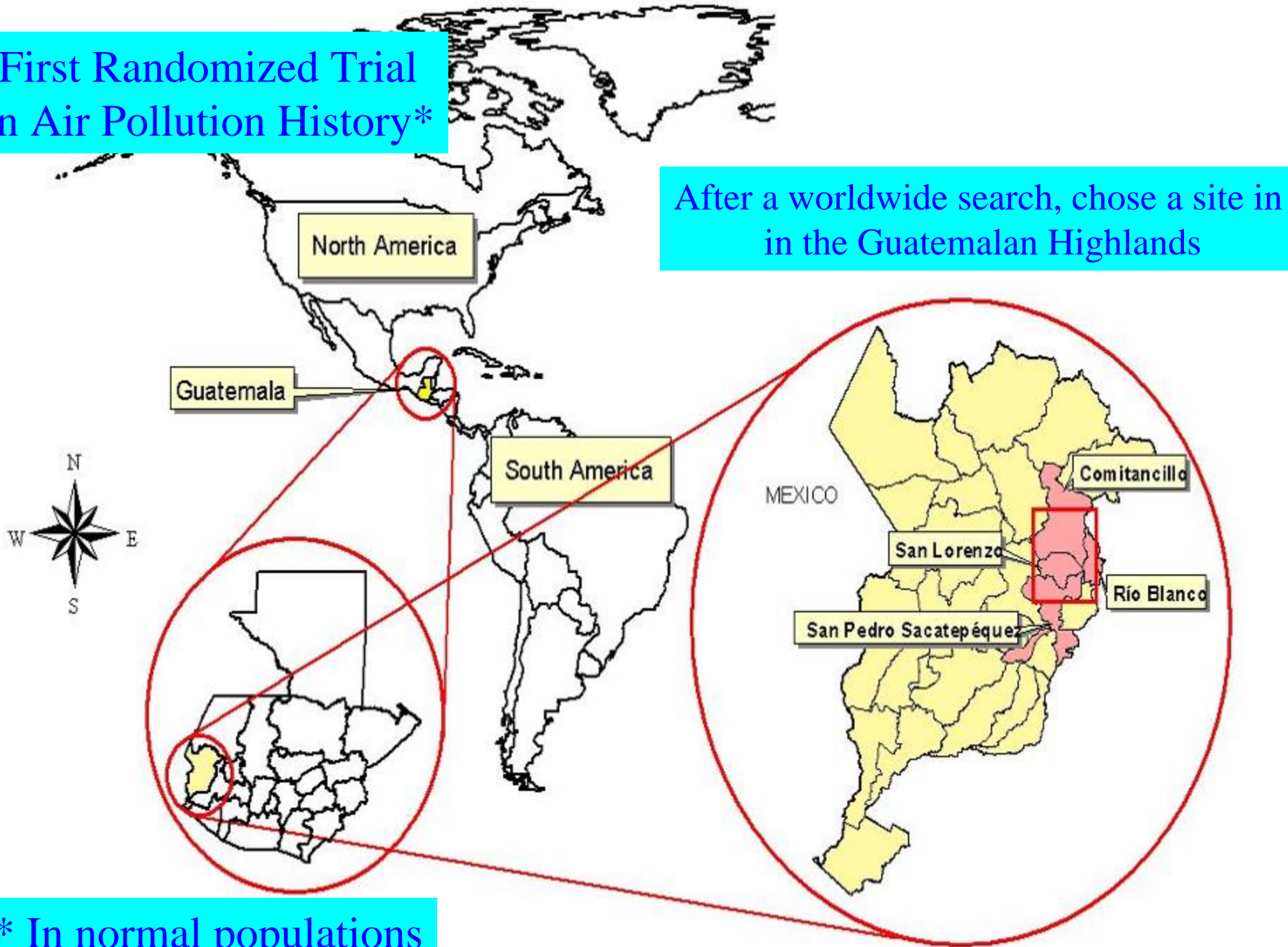
Grams Inhaled per Ton Emitted

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	South	4	WHO Global Air Quality Guideline for Indoor/Outdoor particle Levels 20 µg/m3 Absolutely no population even even poorest countries should be exposed to more than 70 µg/3	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

Indian Burden of Disease from Top 10 Risk Factors and Selected Other Risk Factors



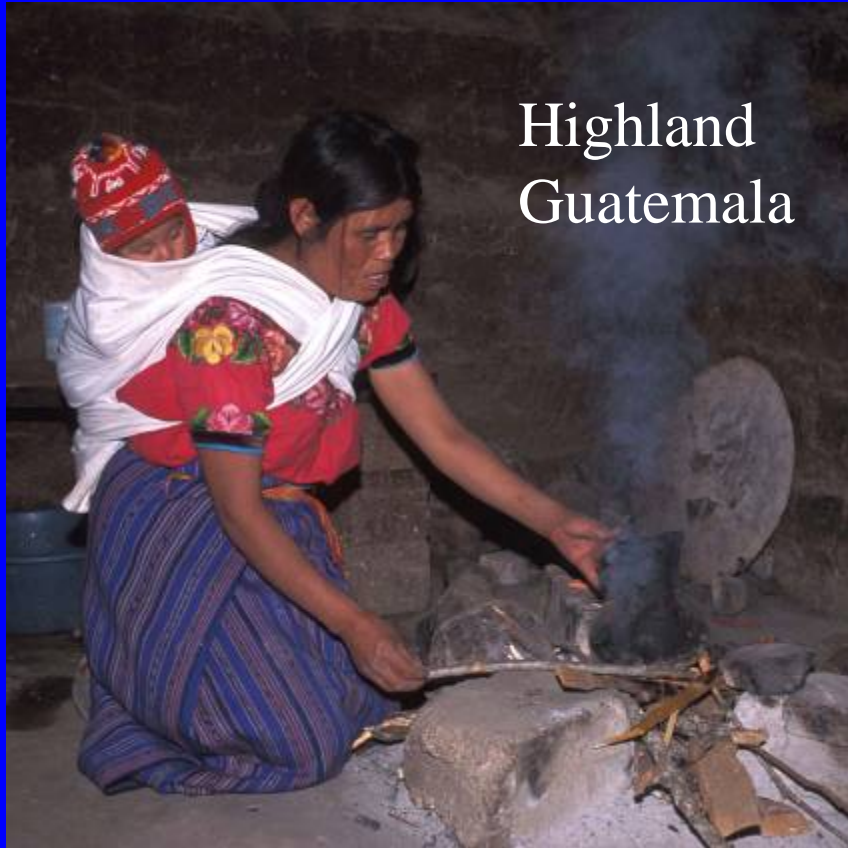
First Randomized Trial In Air Pollution History*



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)



Highland
Guatemala

Traditional 3-stone open fire



Chimney woodstove

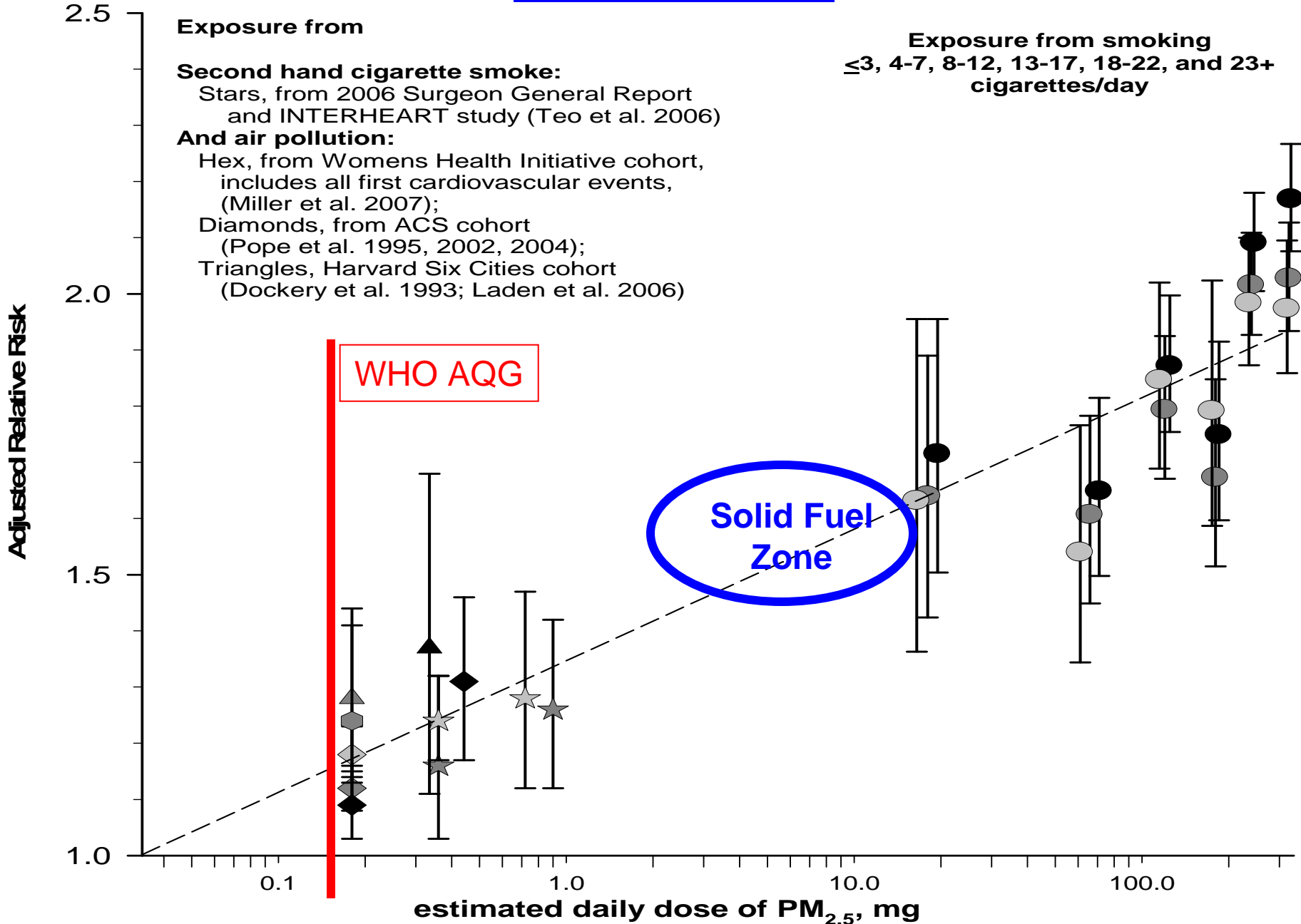
Unpublished results from
RESPIRE
have been removed

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

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

Heart Disease Risk

Pope et al, 2009



Climate

CO₂ equivalent

470

440

1 kg wood
500g carbon



Ash

440
CO₂

60
PIC

20 years

43.5	8	7	1.5
CO	CH ₄	NMHC	RSP

GWP (CO₂ equivalent/c) :

4.5	22	12	1
196	184	84	1.5

100 years

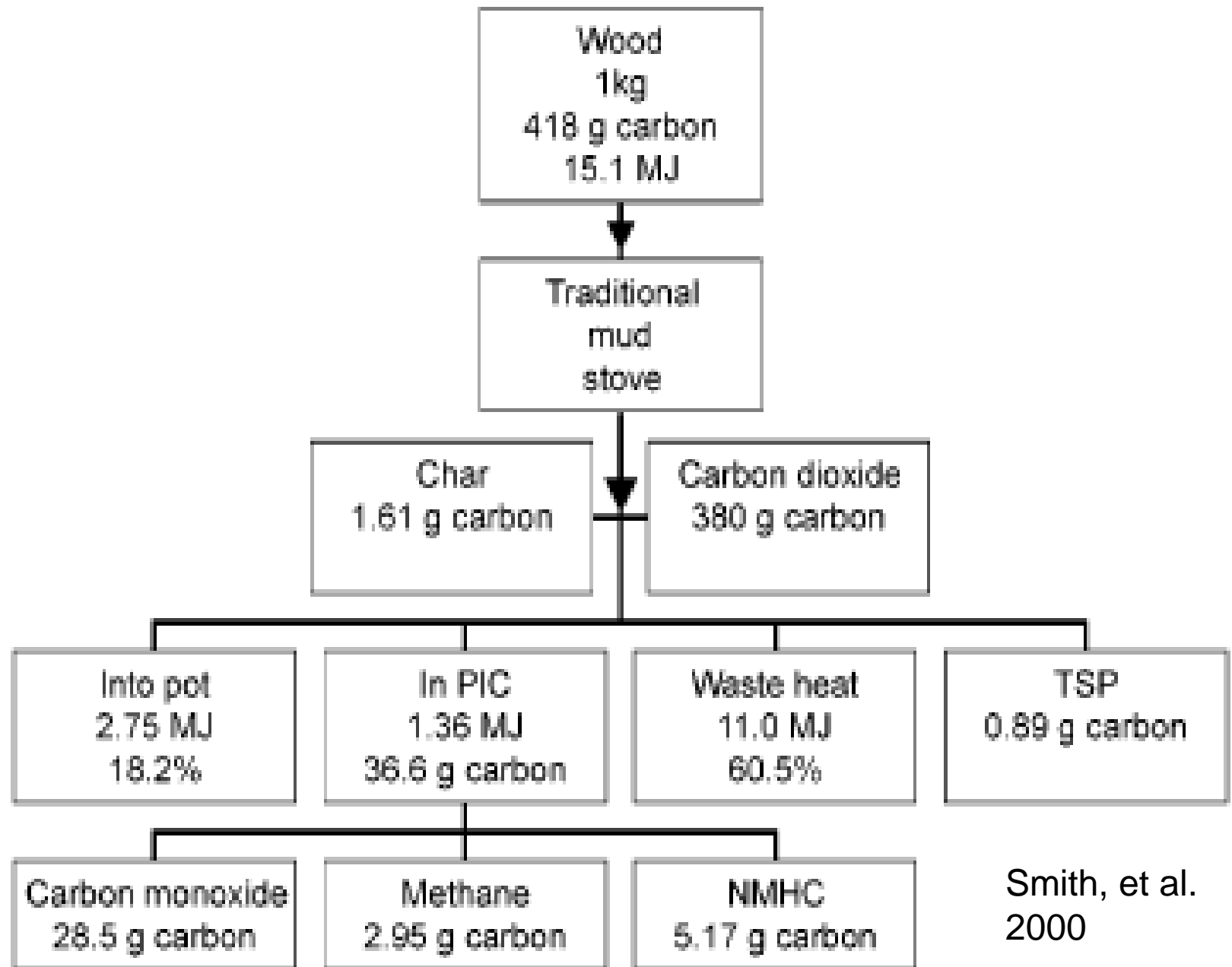
170

GWP (CO₂ equivalent/c) :

1.9	7.5	4.1	1
83	61	29	1.5

Smith,
1994

(a)





PERGAMON



Atmospheric Environment 34 (2000) 4537–4549

**ATMOSPHERIC
ENVIRONMENT**

www.elsevier.com/locate/atmosenv

Greenhouse gases and other airborne pollutants from household stoves in China: a database for emission factors

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Received 1 August 1999; received in revised form 25 September 1999; accepted 28 September 1999

GREENHOUSE IMPLICATIONS OF HOUSEHOLD STOVES: An Analysis for India

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Junfeng Zhang,³ V. Joshi,⁴ and M.A.K. Khalil⁵

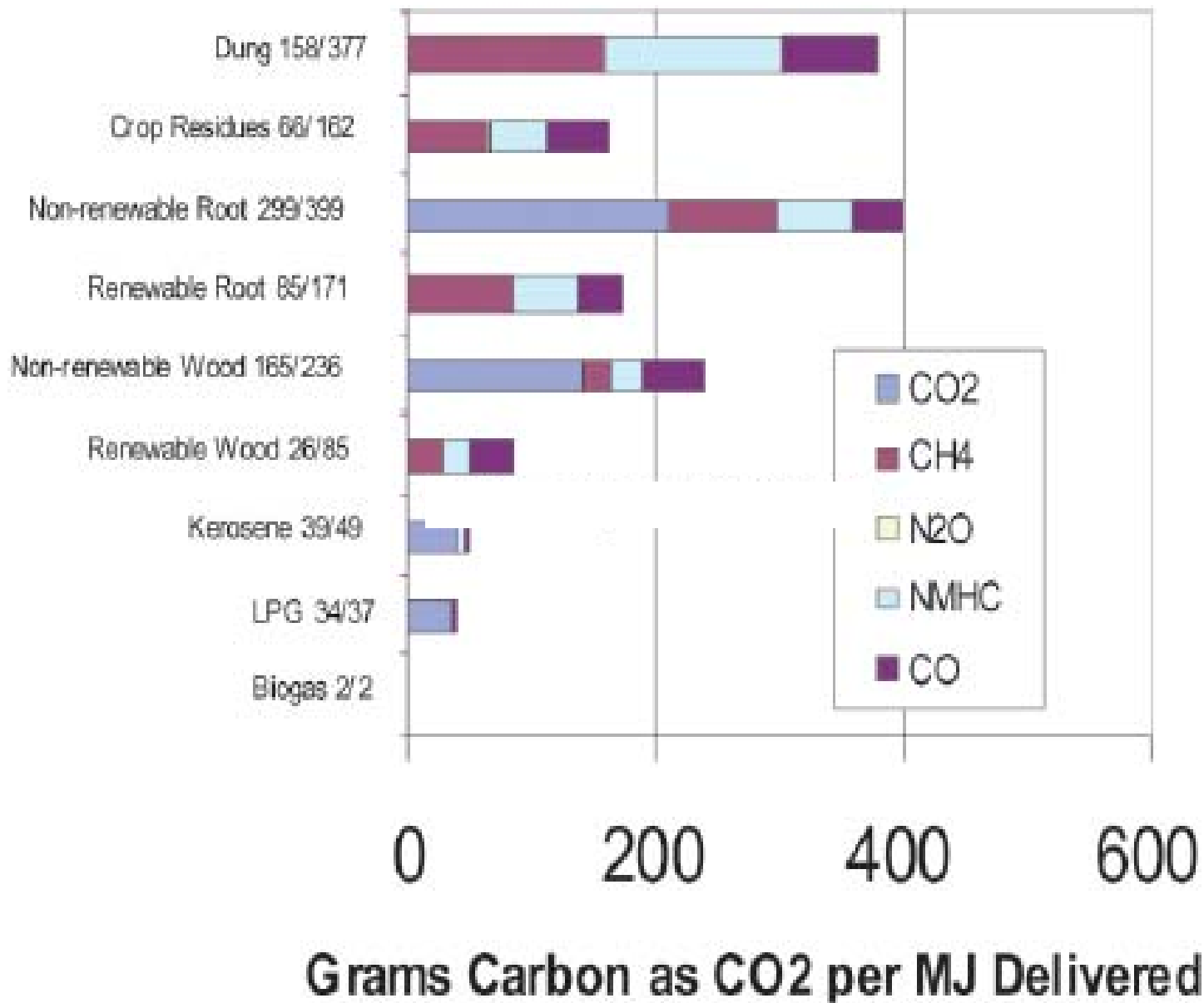
¹*Environmental Health Sciences, University of California, Berkeley, California 94720
and Environment Program, East-West Center, Honolulu, Hawaii*

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³*Environmental and Occupational Health Sciences Institute Piscataway,
New Jersey 08854*

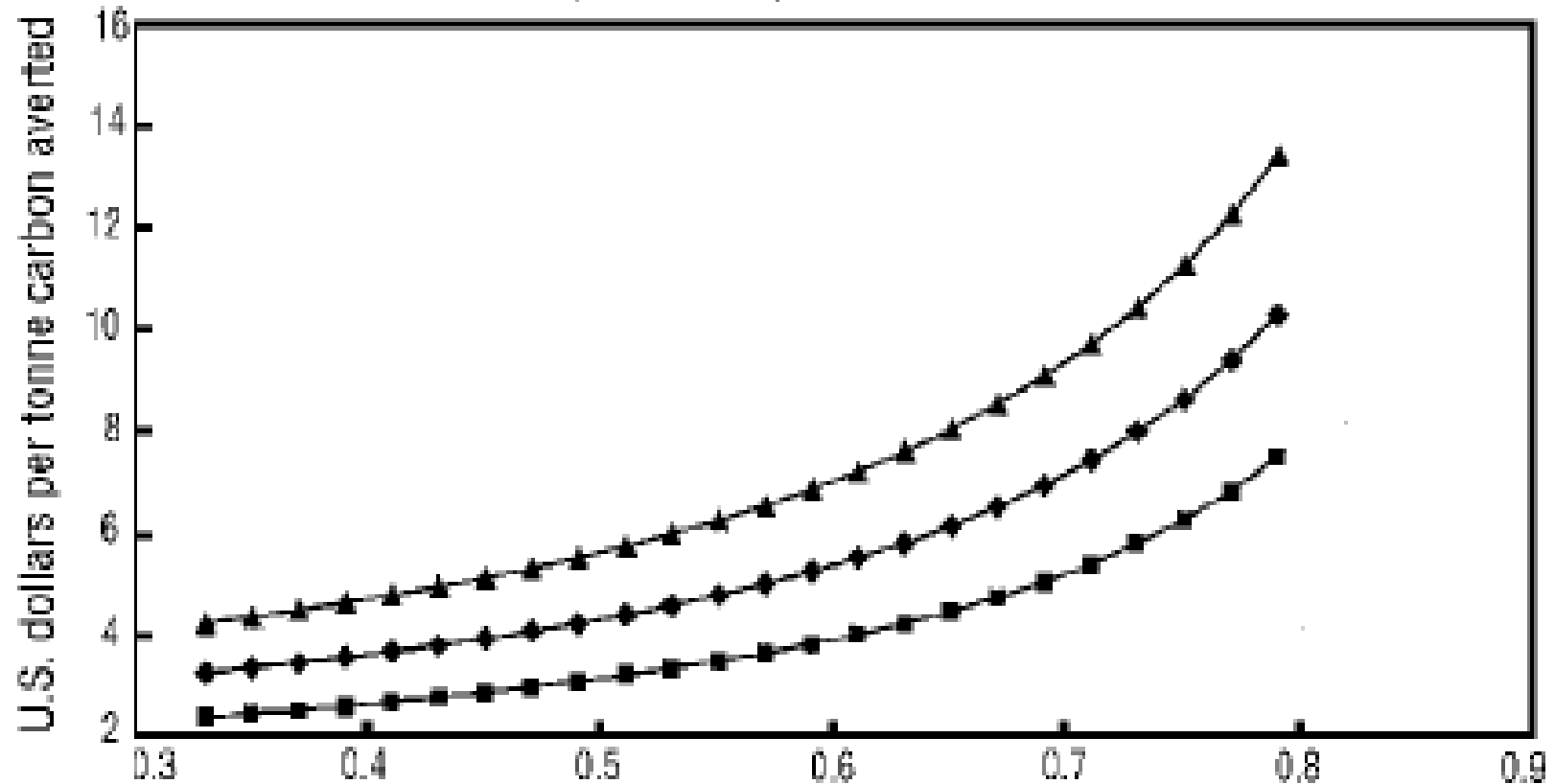
⁴*Swiss Agency for Development and Cooperation, New Delhi, 110021*

⁵*Physics Department, Portland State University, Portland, Oregon 97207*



Smith, et al.
2000

At \$50 per stove; 10-year life; 5-15% discount rate



Fuel use compared to traditional open stove

■ 5% discount rate

◆ 10% discount rate

▲ 15% discount rate

No credit taken for lowered fuel and health costs

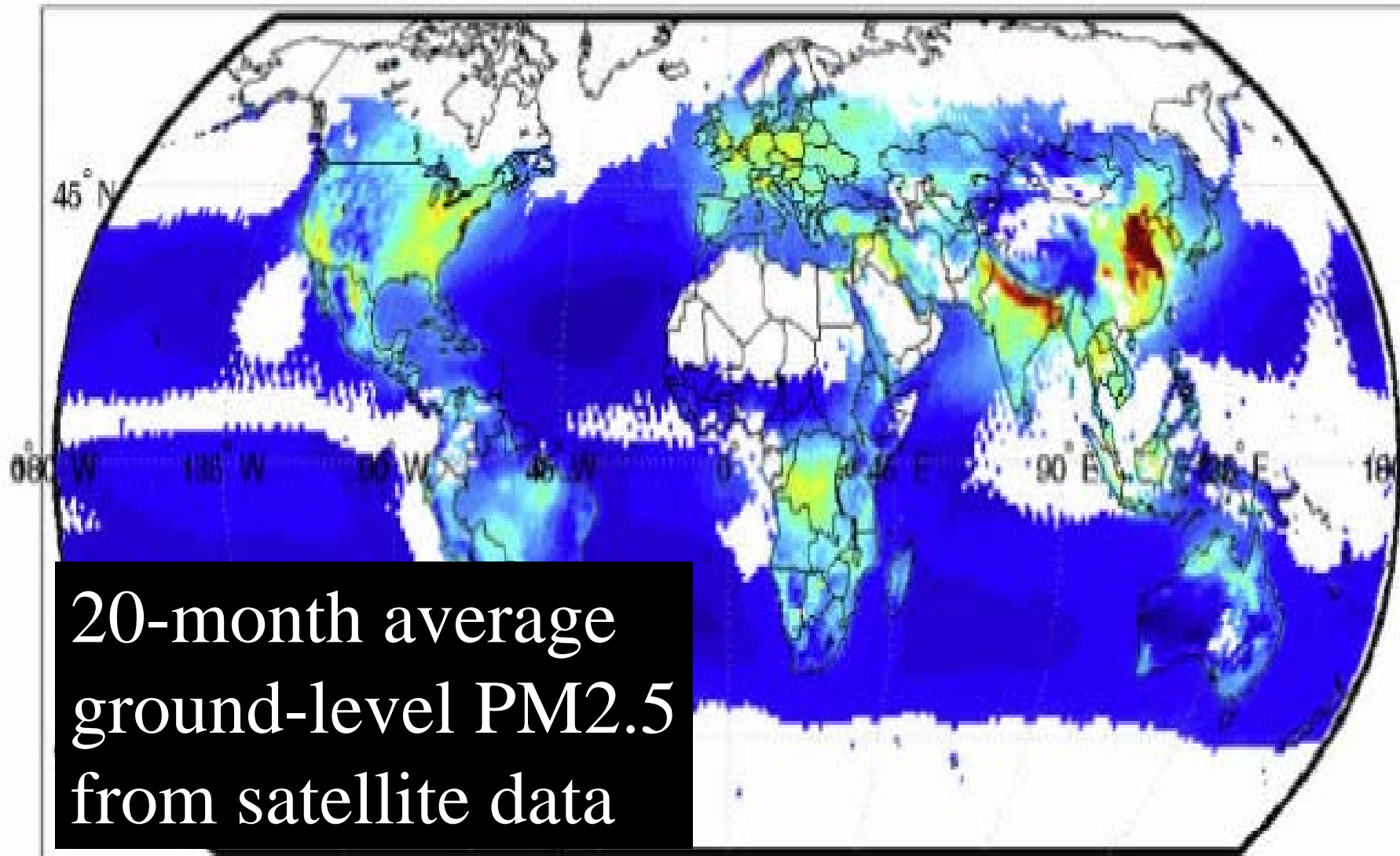
Traditional stove using six tonnes wood per year

Smith, 1994

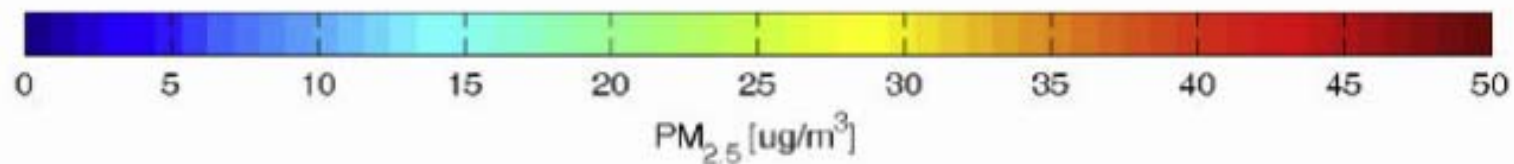
Other current issues

- About one-sixth of human-generated ozone precursors in the world come from household combustion
- About one-third of human-caused carbon monoxide
- About one-third of human-caused black carbon
- A large amount of other combustion-related particles
- Thus, regional outdoor air pollution is heavily affected by household combustion in some areas with consequent impacts on health, agriculture, and ecosystems.
- For example, in large Asian river basins with dense rural populations, such as the Yangtze and Ganges.

MODIS



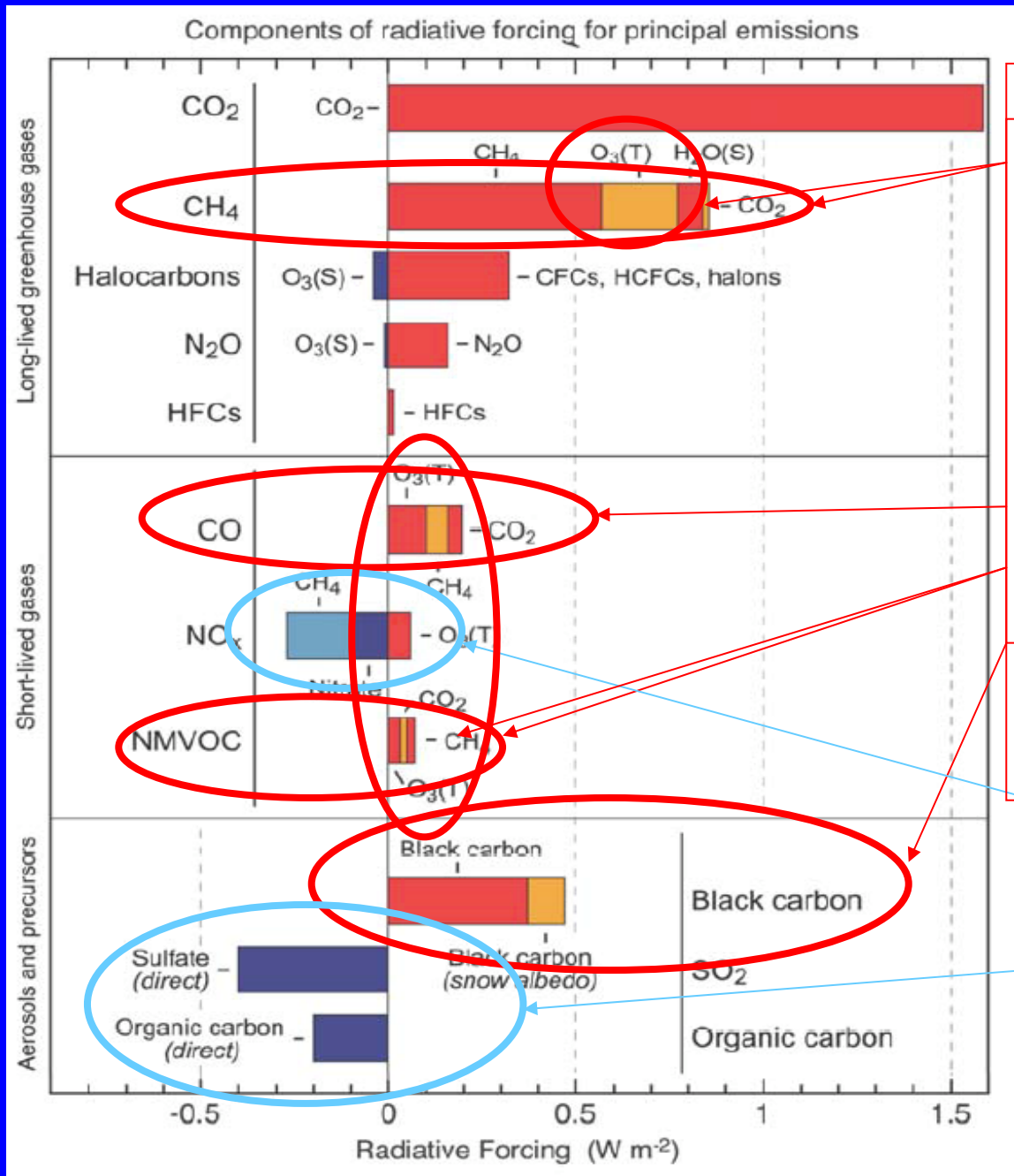
20-month average
ground-level PM_{2.5}
from satellite data



Emissions attributable to household solid fuels in India

Place	Year	PM2.5	CH4	CO2	SO2	NOx	N2O
Andhra Pradesh	1990	15	4	7	11	9	2
	2005	40	4	2	4	5	2
Tamil Nadu	1990	15	5	0	1	4	2
	2005	24	4	0	0	1	1

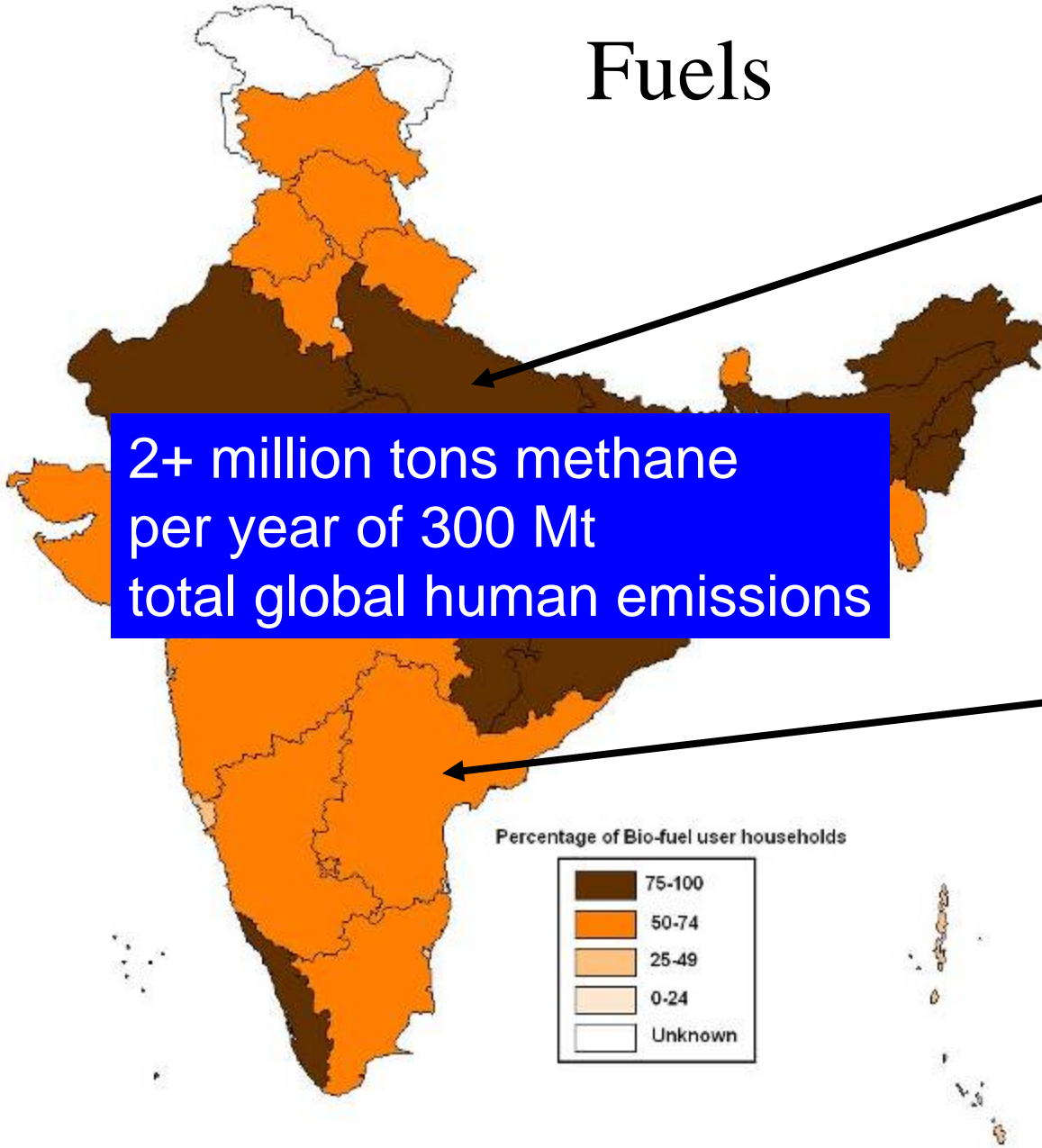
Global warming in 2005 due to all human emissions since 1750



CO₂ is important for climate, Several of the non-CO₂, but so are many other greenhouse gases create pollutants, including the ones a good proportion of both circled that, unlike CO₂, also their climate forcing and have significant health as health damage through well as climate impacts the secondary pollutant, tropospheric ozone, and organic carbon particles however, have cooling impacts on climate but are still health damaging

INDIA

Biomass Fuels



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

More than 75% of households

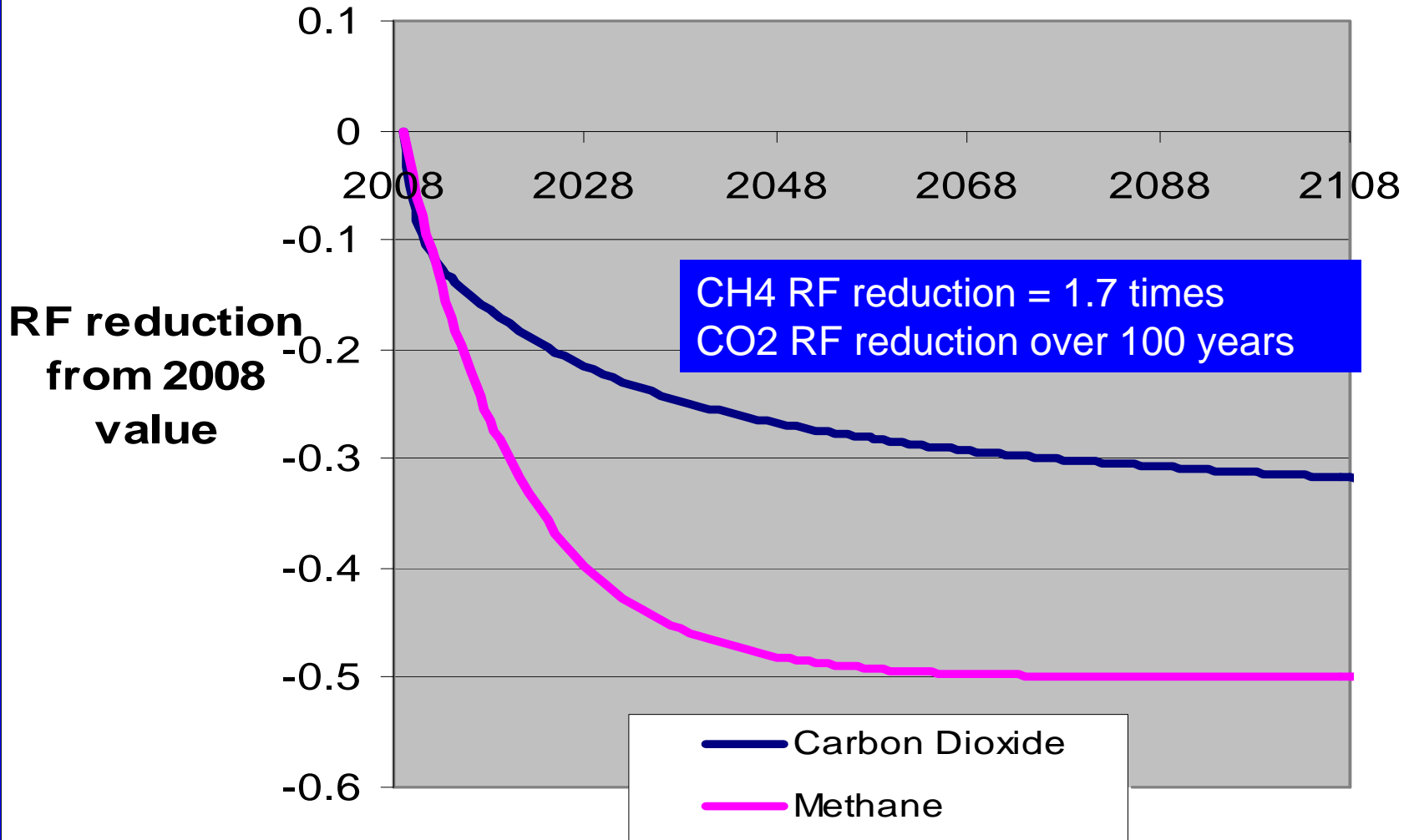
50-74% of households

2000 Census

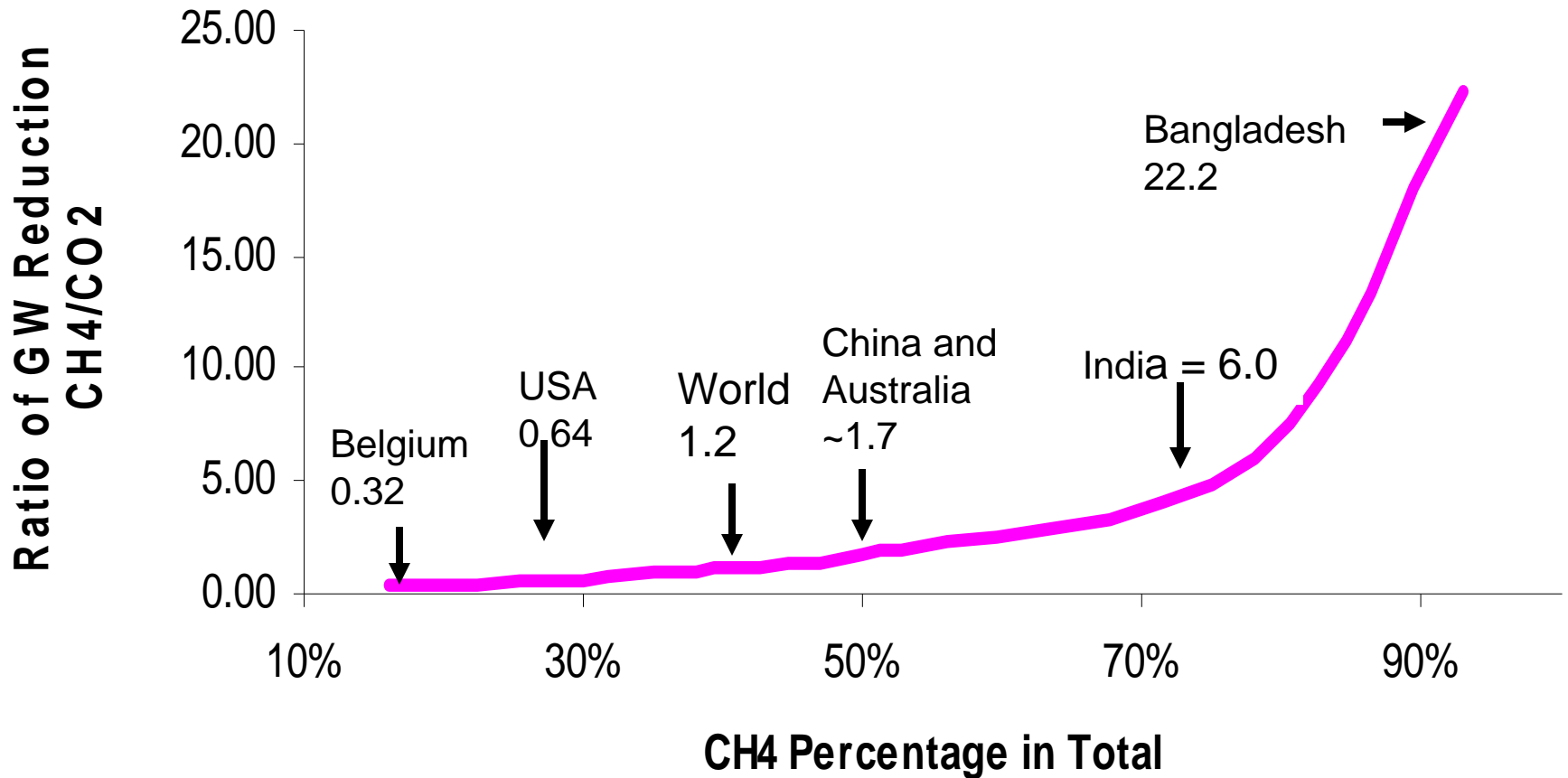
Hypothetical Choice of Interventions

1. Stop emitting CH₄ today for rest of century
 2. Stop emitting CO₂ today for rest of century
- Which will produce the biggest drop in integrated radiative forcing over a century based on direct forcing values in IPCC AR4?

Interventions for China and Australia Where CH₄=CO₂ in 2005

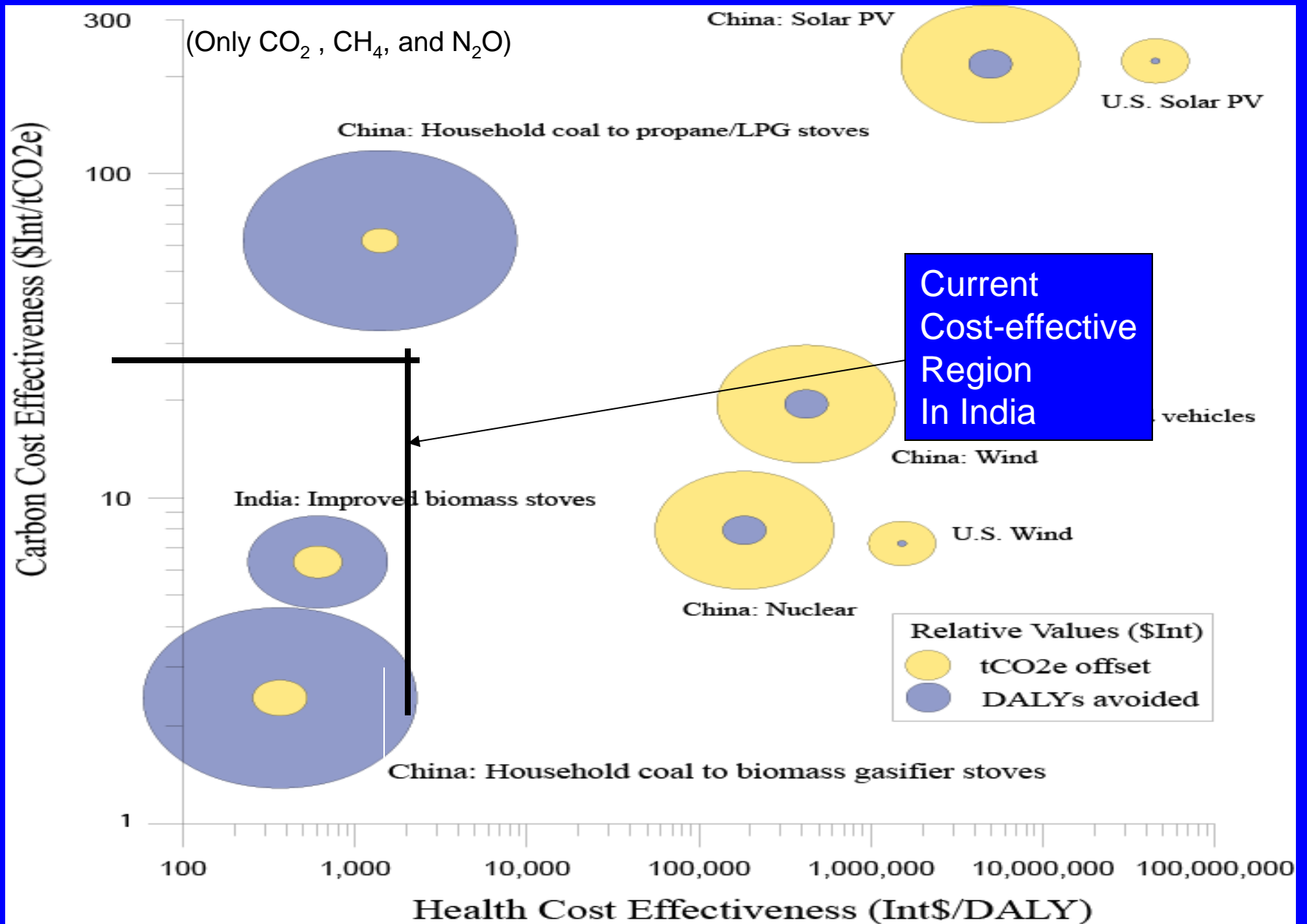


Amount of Warming Reduction in 100 Years: Comparison of CH4 and CO2

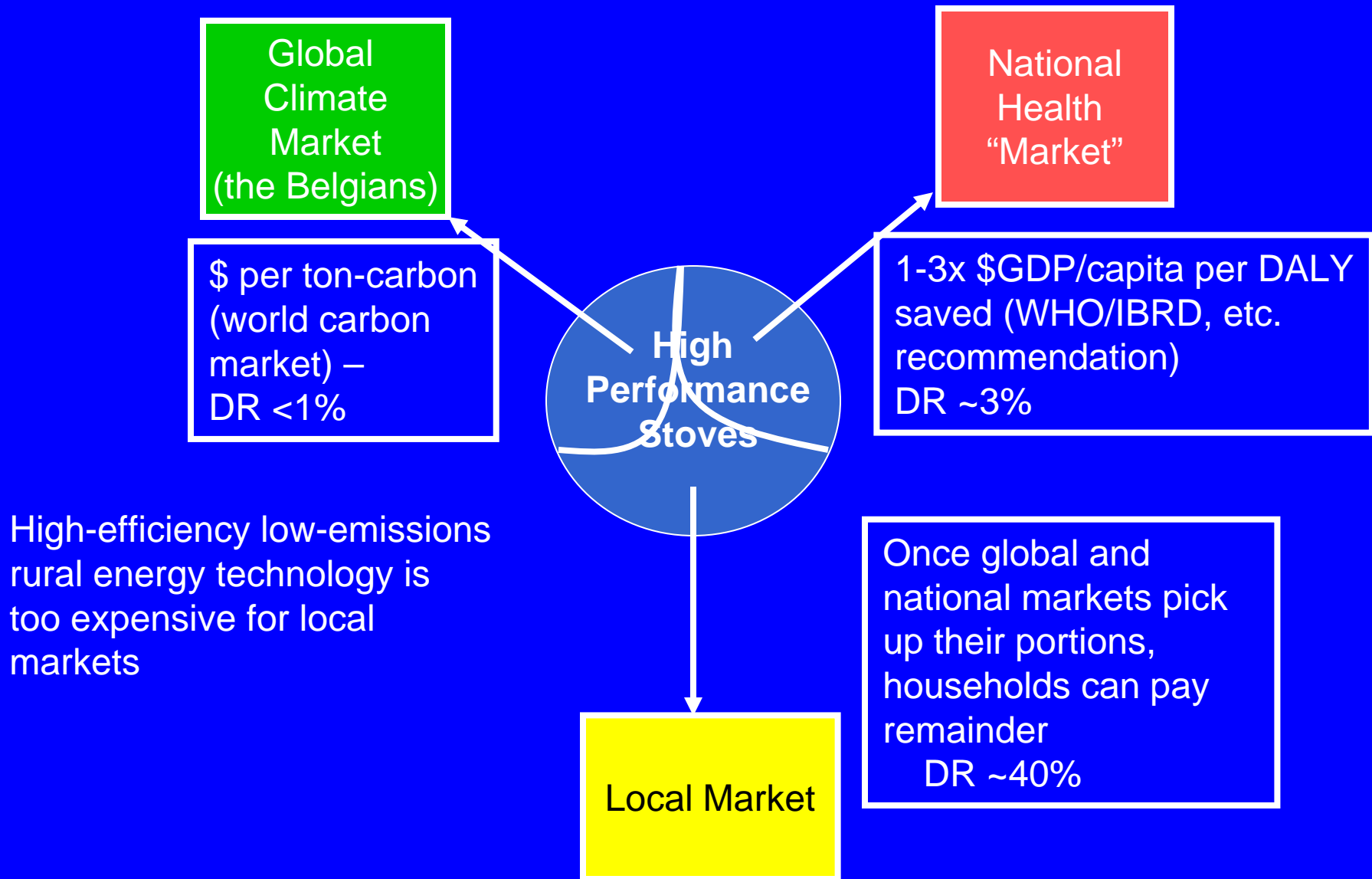


Selling it to the Belgians

From Smith & Haigler, 2008



Paying for Rural Energy Development



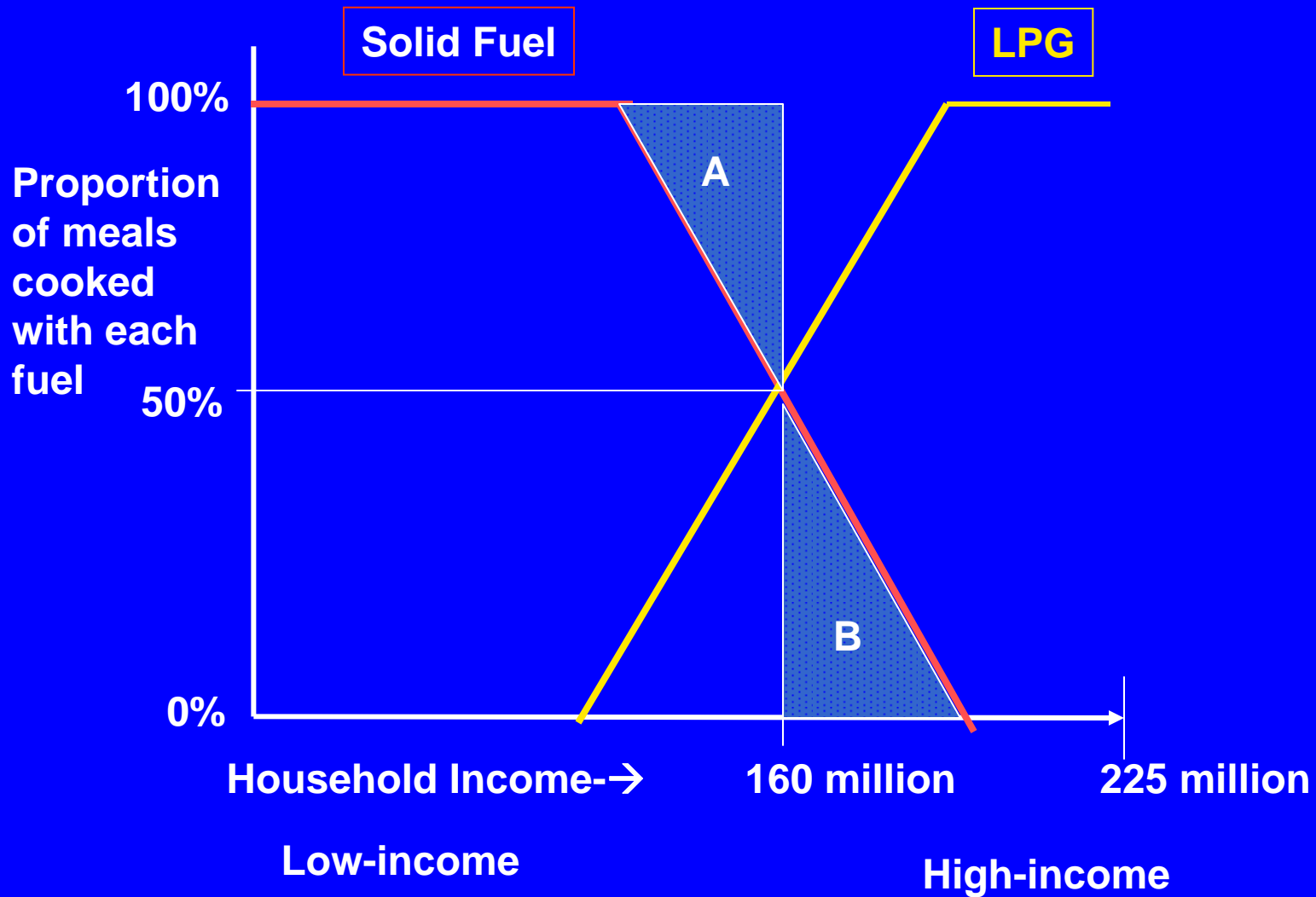
Bottom Lines

- Improved household combustion will bring great health benefits to the most vulnerable populations in the world
- Considering only the official (“Kyoto”) GHGs, it would bring reasonable climate benefits as well
- Reduction in aerosol and ozone-precursor emissions will have significant benefits for regional air quality of concern for health, agriculture, and ecosystem protection
- Assessing climate forcing from reduction in aerosol emissions is much more complex, but if newer assessments are accepted, will bring additional substantial benefits in the form of less global warming.

Indian National Cookstove Initiative

- **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.”**
- Major innovations to be encouraged in technology, dissemination modes, and M&E – innovation prizes and guaranteed sales
- Multiple approaches to each must be piloted and assessed
- Role for purely private sector
- Role for private-public partnerships
- Role for public sector for reaching vulnerable groups
- All require government backup in terms of standards, benchmarks, smart subsidies, etc.

Proportion of Indian Household Meals Cooked by Fuel Type in 2005



Wood is the fuel that heats you twice

(Old English Proverb)

- Actually four times
- Chopping (~20 kJ/kg)
- Burning (~20 MJ/kg)
- Fever from pneumonia
- Global warming (~20 GJ/kg)
- But better combustion can get rid of the last two

THE LANCET 374: Nov/Dec 2009 (six articles)

Health and Climate Change 1

Includes co-benefits calculation of a 150-million stove intervention in India

Public health benefits of strategies to reduce greenhouse-gas emissions: household energy

Paul Wilkinson, Kirk R Smith, Michael Davies, Heather Adair, Ben G Armstrong, Mark Barrett, Nigel Bruce, Andy Haines, Ian Hamilton, Tadj Oreszczyn, Ian Ridley, Cathryn Tonne, Zaid Chalabi

Health and Climate Change 5

Includes study of long-term health impacts of black carbon

Public health benefits of strategies to reduce greenhouse-gas emissions: health implications of short-lived greenhouse pollutants

Kirk R Smith, Michael Jerrett, H Ross Anderson, Richard T Burnett, Vicki Stone, Richard Derwent, Richard W Atkinson, Aaron Cohen, Seth B Shonkoff, Daniel Krewski, C Arden Pope III, Michael J Thun, George Thurston

In this report we review the health effects of three short-lived greenhouse pollutants—**black carbon, ozone, and sulphates**. We undertook new meta-analyses of existing time-series studies and an analysis of a cohort of 352 000 people in 66 US cities during 18 years of follow-up. This cohort study provides estimates of mortality effects from long-term exposure to elemental carbon, an indicator of black carbon mass, and evidence that ozone exerts an independent risk of mortality. Associations among these pollutants make drawing conclusions about their individual health effects difficult at present, but sulphate seems to have the most robust effects in multiple-pollutant models. Generally, the

All presentations and publications available at
<http://ehs.sph.berkeley.edu/krsmith>

Or just google “Kirk R. Smith”

Thank you