Household Energy, Black Carbon, Climate, and Health

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2009 International Workshop on
Black Carbon in Latin America

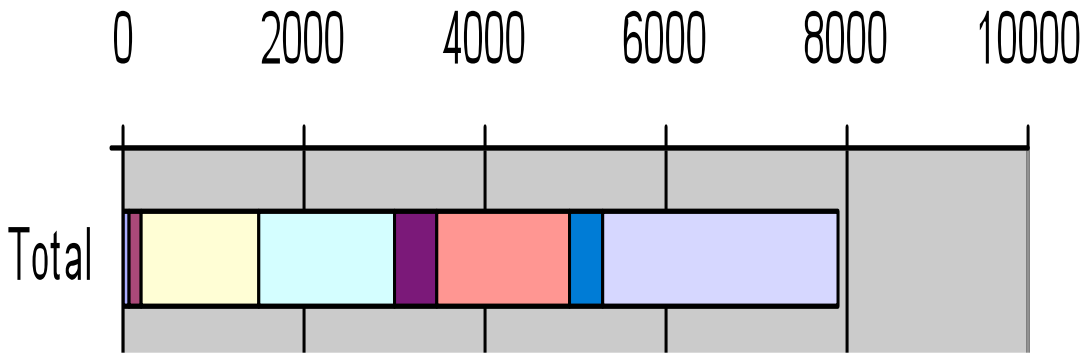
International Council on Clean Transportation, Instituto National de Ecologia, Centro Mario Molina

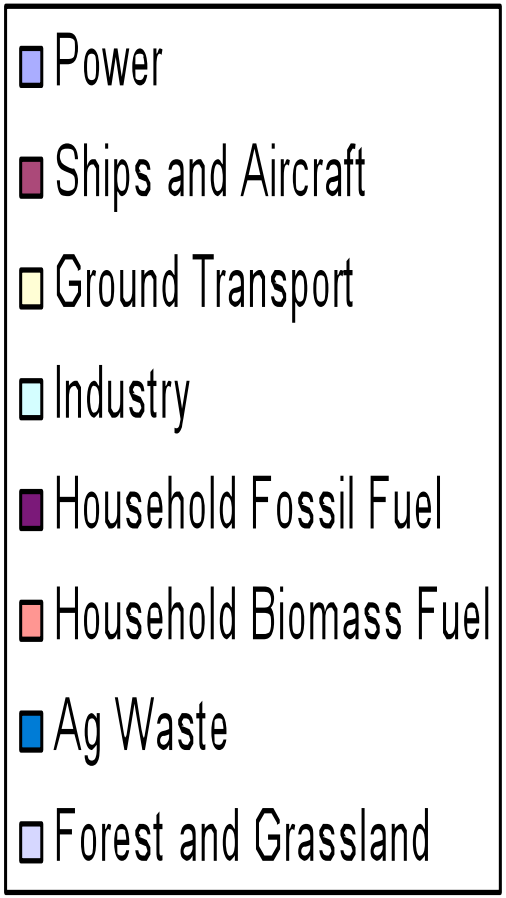
Mexico City, Oct 19, 2009

Road Map

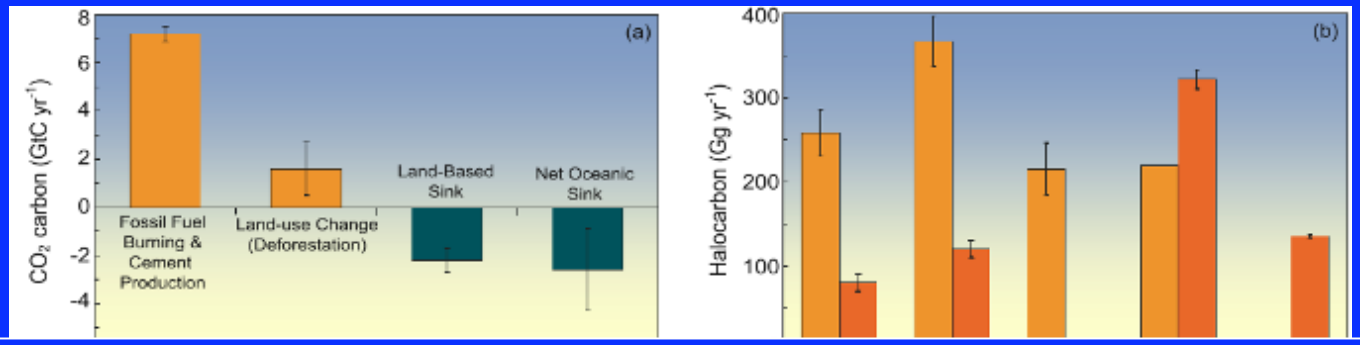
- BC inventories for household fuel: framing issues
- Household fuel's health impacts: pneumonia in children
- What interventions are needed for health and climate?

Black Carbon Emissions





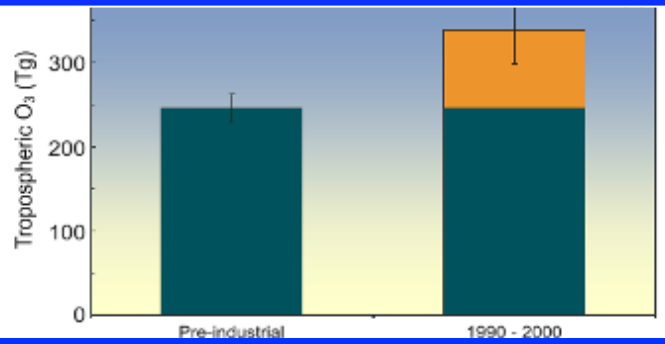
All BC and OC data from T. Bond's inventory
Feb 2009



Inventories for CO2, CH4, and N2O

Carefully parsed into “natural and “human-caused” as well as “pre-industrial and post-industrial”

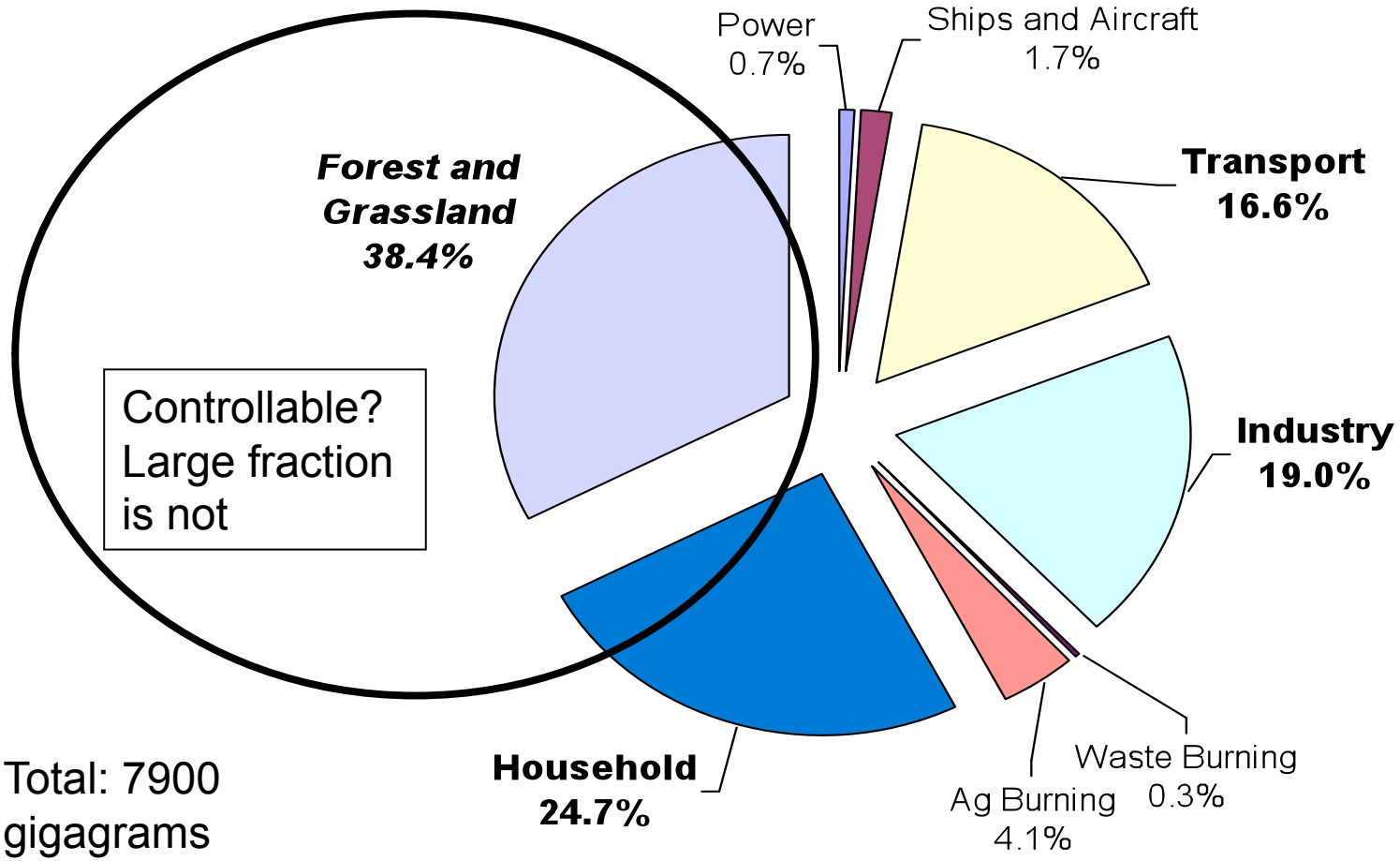
Not done yet for BC, OC, and Sulfate.



AR4 7.1, Figure 1

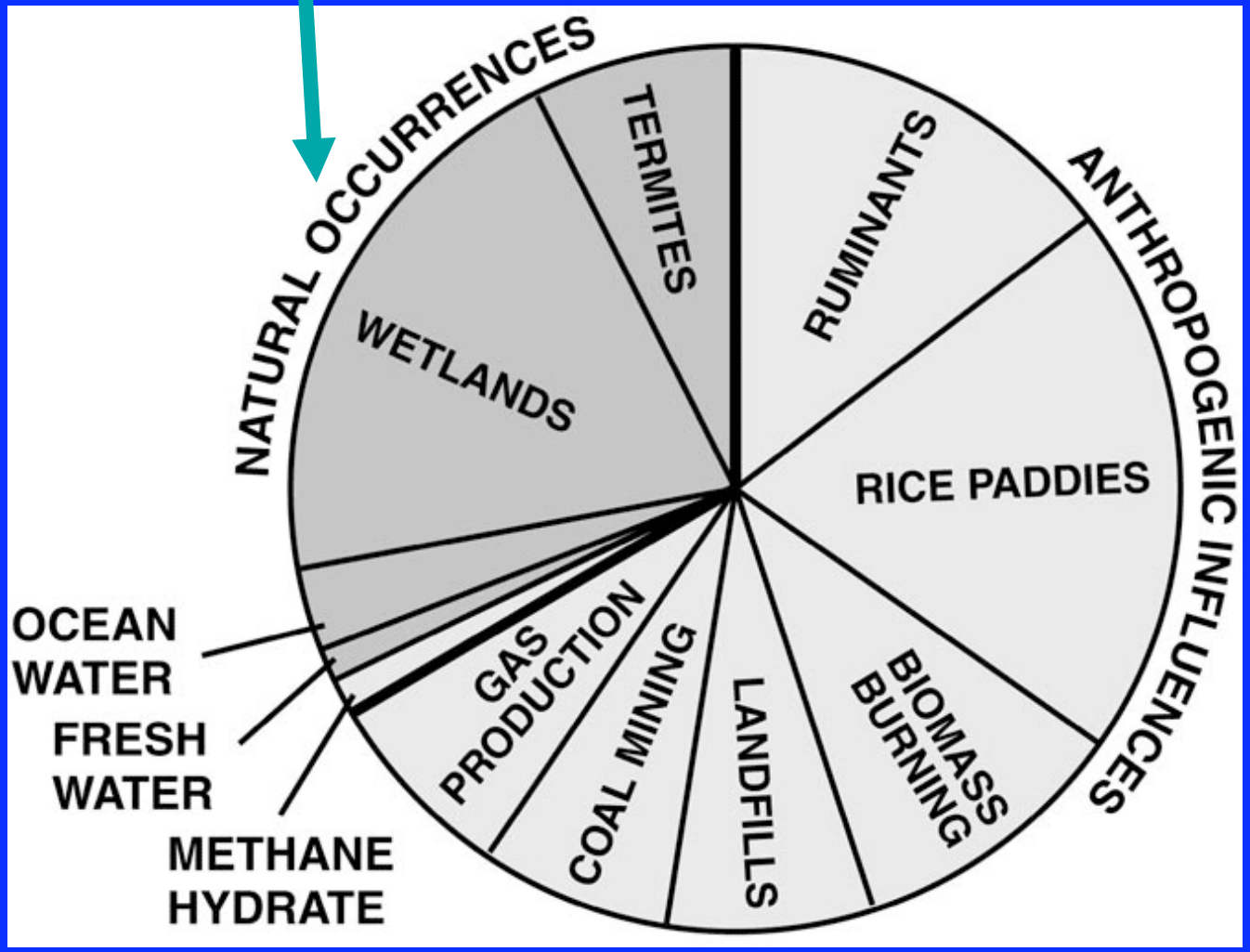
Total Black Carbon Emissions in 2000

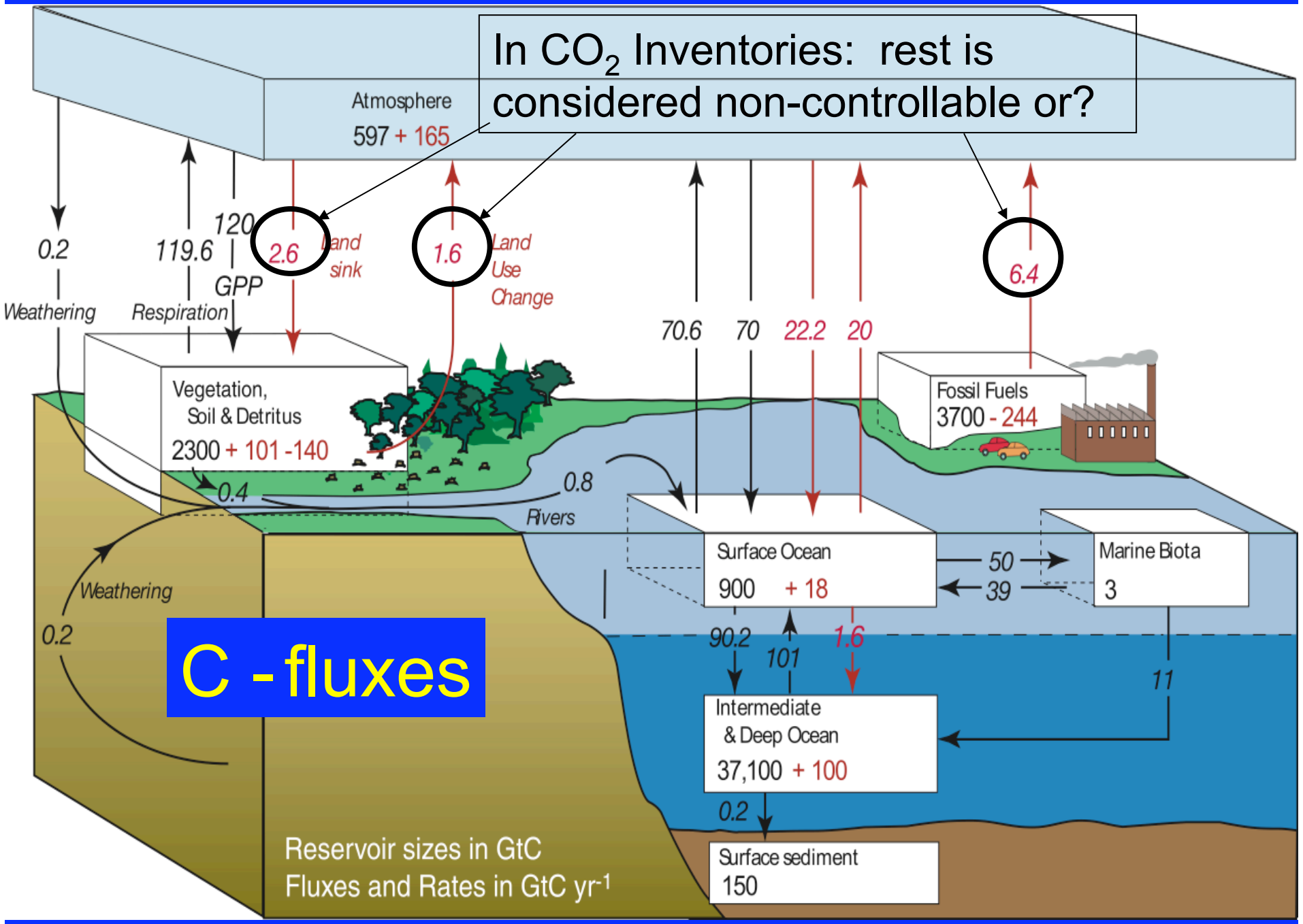
Source: T Bond Database, V 7.1.1 Feb 2009
Plus Bond et al., 2004



Total: 7900 gigagrams

One-third of methane emissions from natural sources – not put into anthropogenic group by IPCC

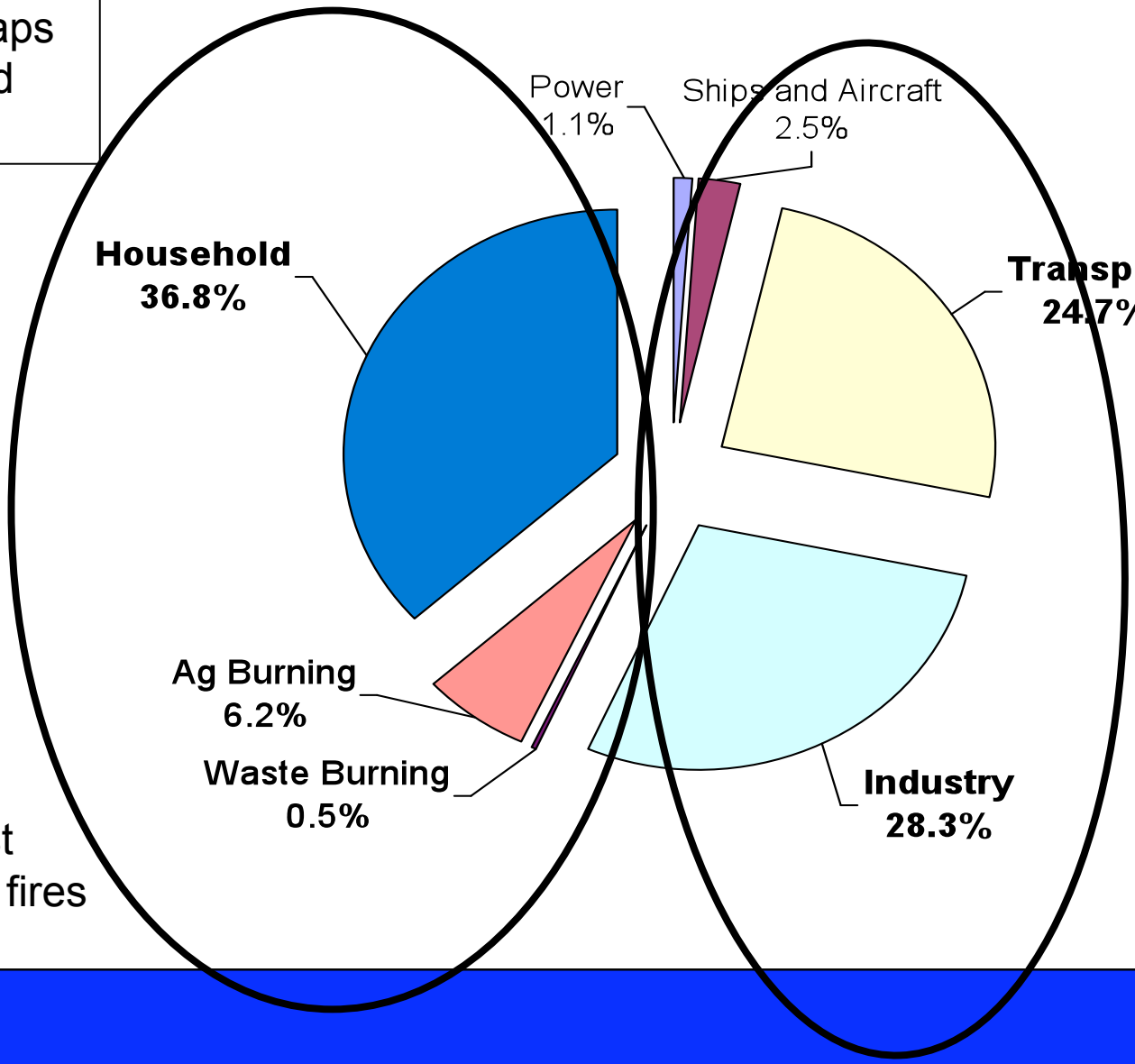



In CO_2 Inventories: rest is considered non-controllable or?
Atmosphere
597 + 165
0.2
Weathering
119.6
120
GPP
Respiration
2.6
Land sink
1.6
Land Use Change
6.4
70.6
70
22.2
20
Vegetation, Soil & Detritus
2300 + 101 -140
0.4
0.8
Rivers
Fossil Fuels
3700 - 244
Surface Ocean
900 + 18
50
39
Marine Biota
3
Weathering
0.2
C - fluxes
90.2
101
1.6
11
Intermediate & Deep Ocean
37,100 + 100
0.2
Surface sediment
150
Reservoir sizes in GtC
Fluxes and Rates in GtC yr-1

Controllable Black Carbon Emissions in 2000

Source: T Bond Database, V 7.1.1 Feb 2009

Pre-industrial but perhaps increased since



Total: 5300 gigagrams

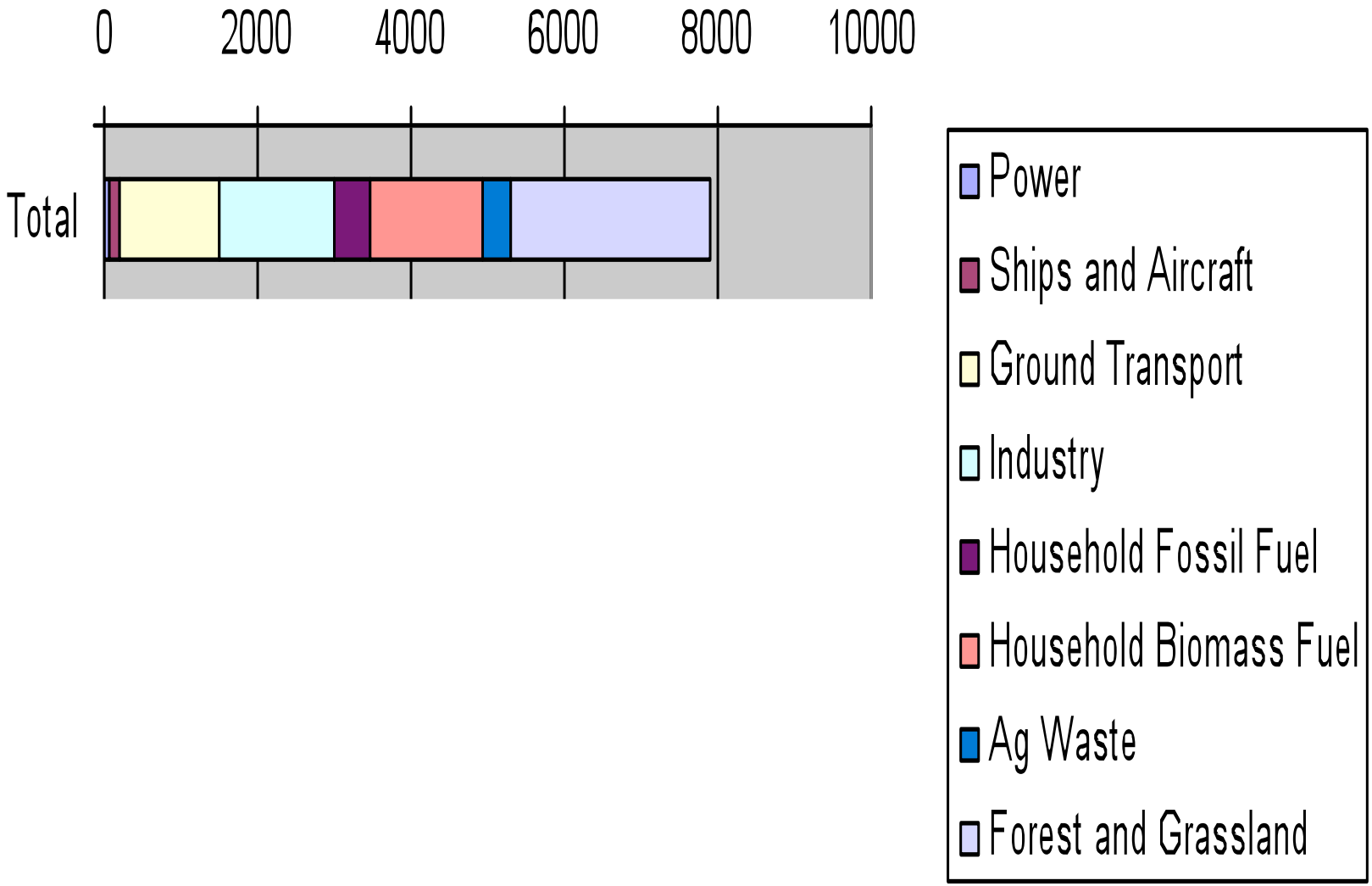
Unequivocably Post-1750

~36% of total BC

~57% of controllable

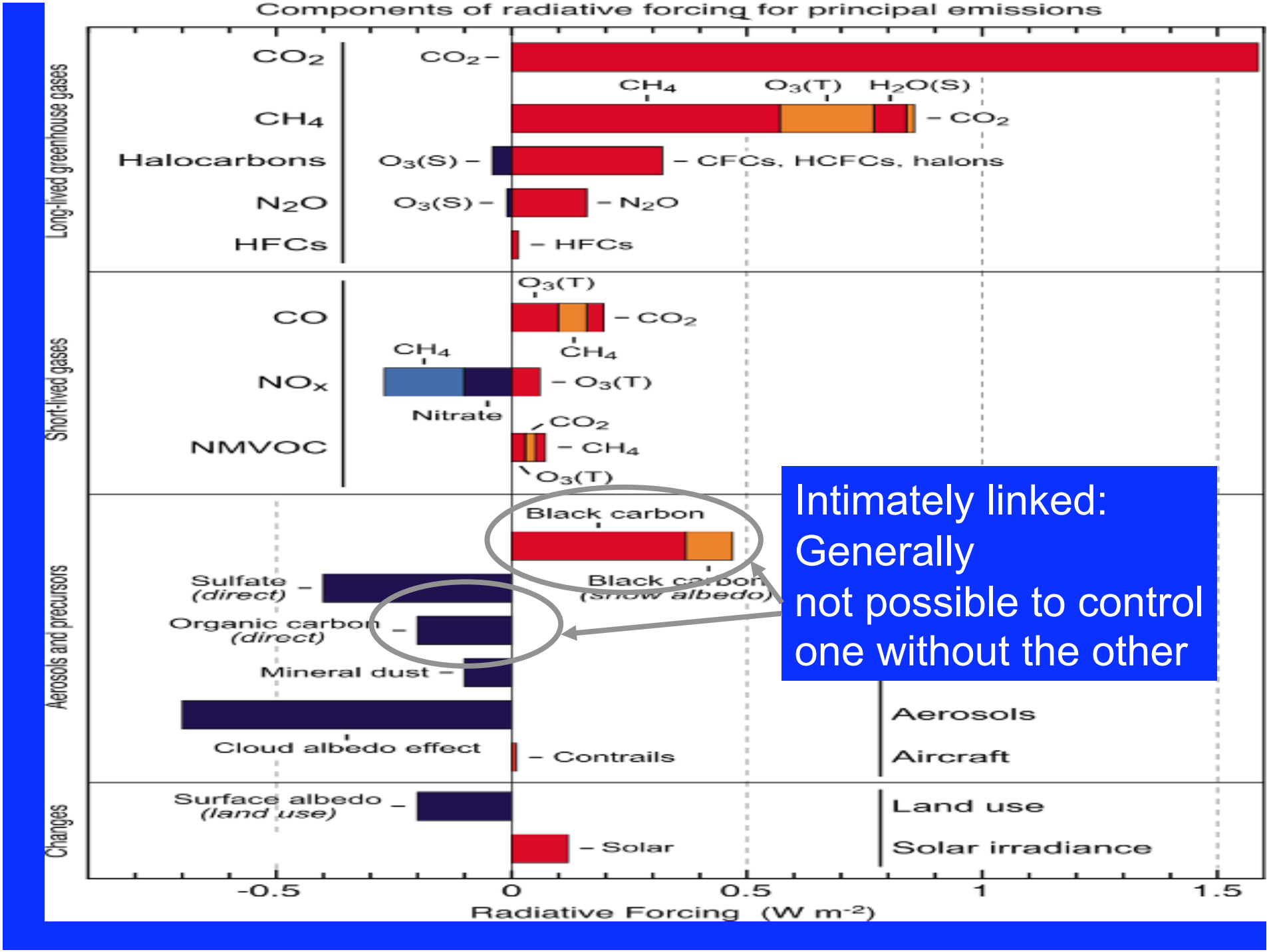
No forest or grass fires

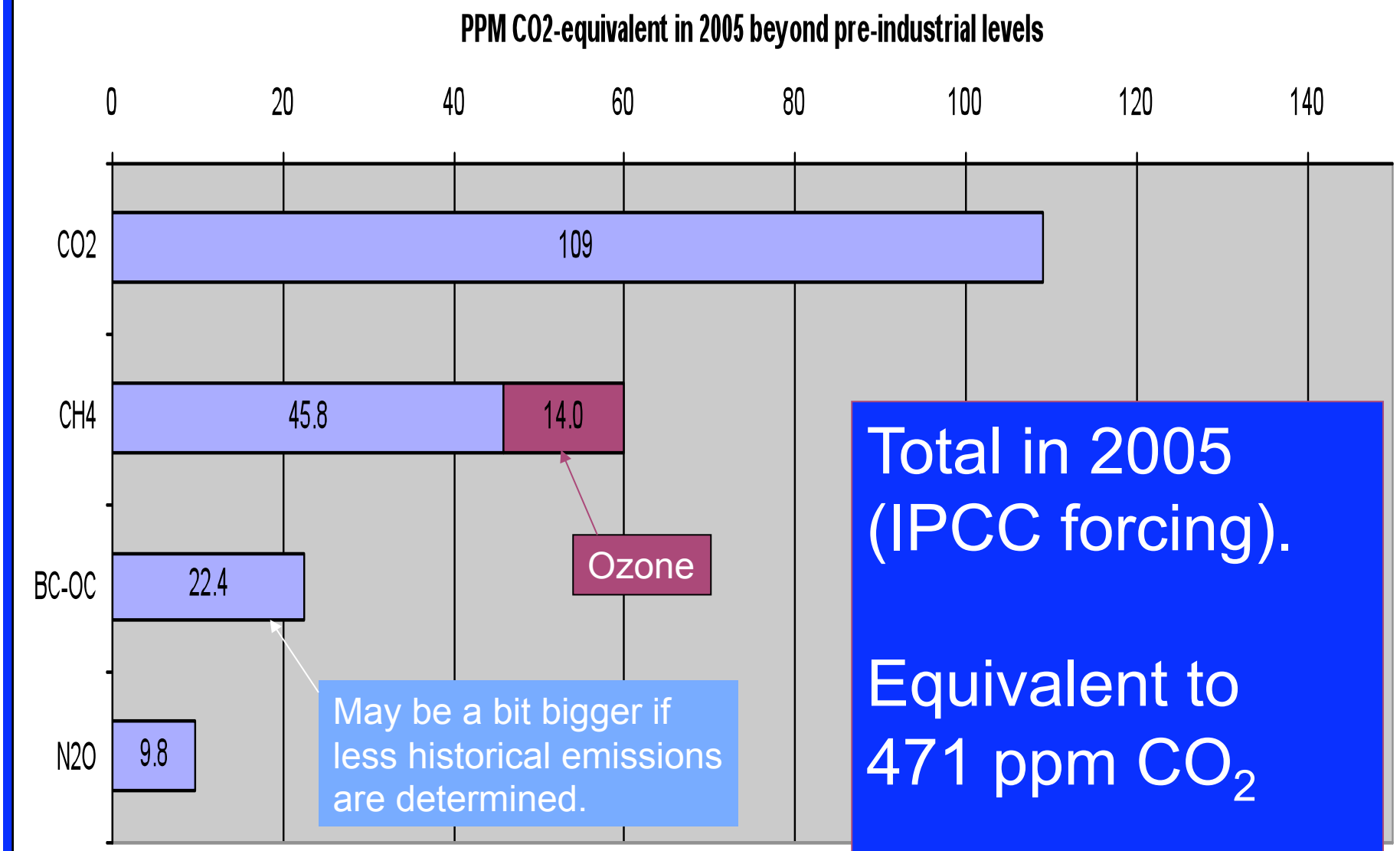
Black Carbon Emissions



Really four categories

- Natural – not amendable to human interventions (e.g., some wildfires)
- Pre-industrial but amendable to human interventions (e.g. household biomass fuel burning)
- Post-industrial (e.g., essentially all fossil fuel use)
- Net of the cooling from organic carbon particles


Components of radiative forcing for principal emissions
Long-lived greenhouse gases
Short-lived gases
Aerosols and precursors
Changes
CO2
CH4
Halocarbons
N2O
HFCs
CO
NOx
NMVOC
Black carbon
Sulfate (direct)
Organic carbon (direct)
Mineral dust
Cloud albedo effect
Surface albedo (land use)
Nitrate
Aerosols
Aircraft
Land use
Solar irradiance
Intimately linked:
Generally
not possible to control
one without the other
-0.5
0
0.5
1
1.5
Radiative Forcing (W m-2)



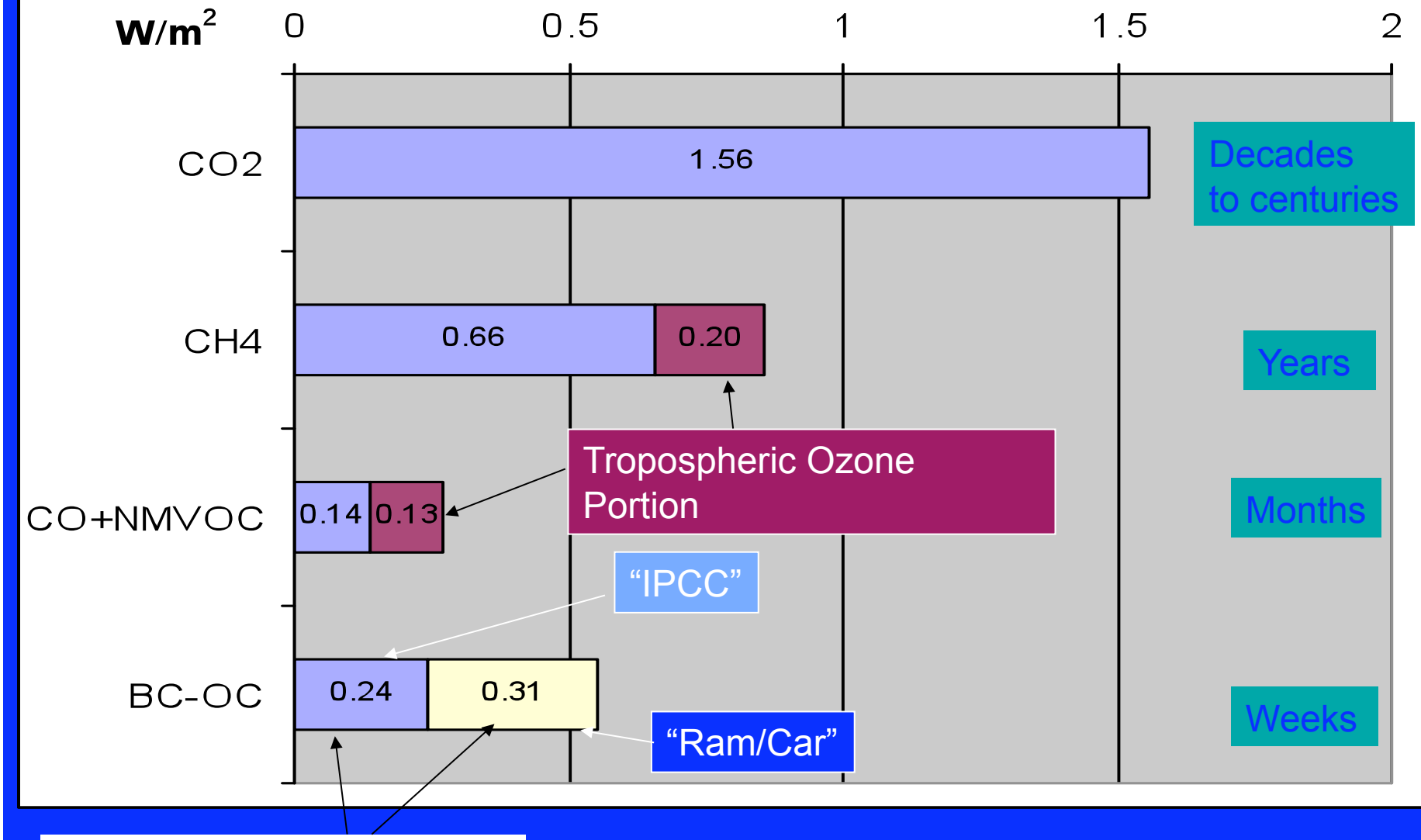
Total in 2005 (IPCC forcing).

Equivalent to 471 ppm CO_2

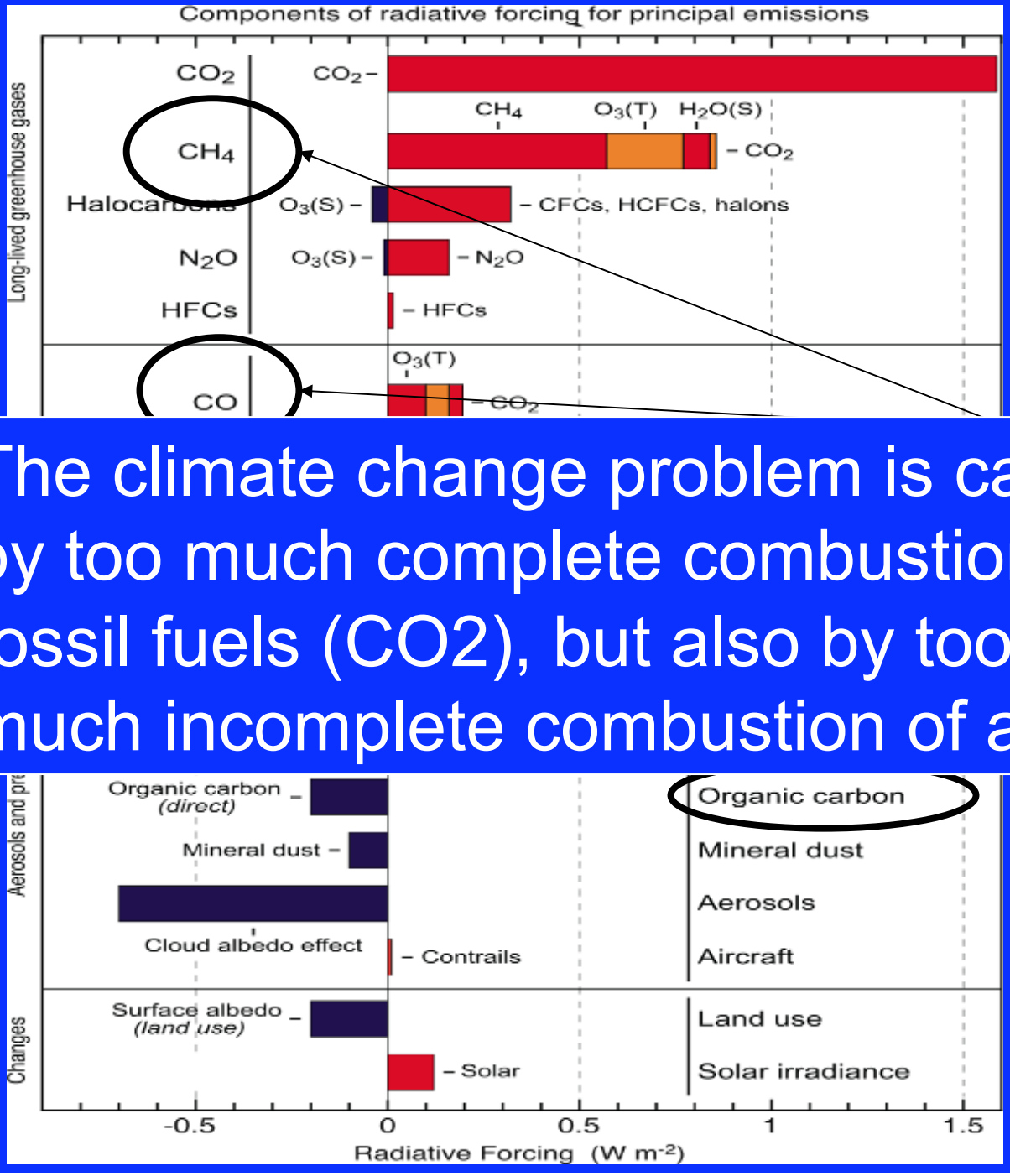
(on top of CO2 background ~270 ppm)

Recommended Accounting

Controllable PIC Emissions Plus CO_2 Radiation Forcing in 2005



Could be a bit bigger if more forest and grass fires are seen to be



Warming in 2005 from emissions since 1750

The climate change problem is caused not only by too much complete combustion of fossil fuels (CO2), but also by too much incomplete combustion of all fuels (PIC)

IPCC, 2007

Combustion Particles:
The Oldest Pollutant

- 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
  - First exposure response relationships for air pollutants

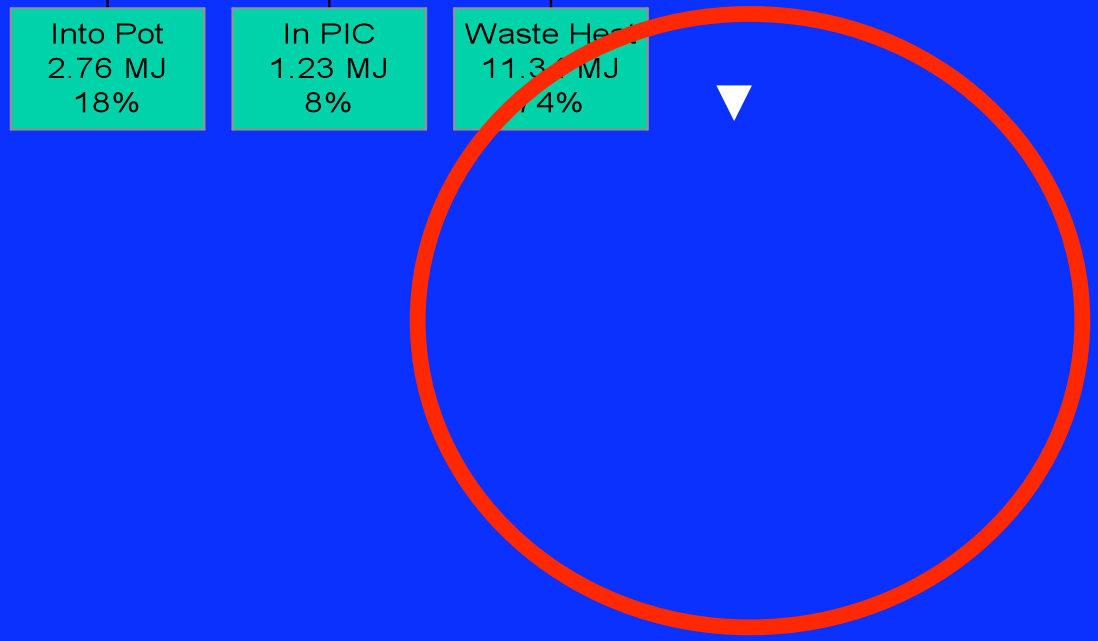
Combustion PM: The Newest Pollutant

- mechanisms of creation and impact are still not clear,
- effects of separate constituents, e.g., black carbon, still uncertain
- new health standards being implemented,
- 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

Energy flows in well-operating traditional woodfired cookstove

A Toxic Waste Factory!!

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



Smith et al., 2000

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

- Small particles. Includes 3-10% BC
- 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([¥])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*

Naeher et al. 2007, JIT

Size Distribution of Biomass Smoke Particles

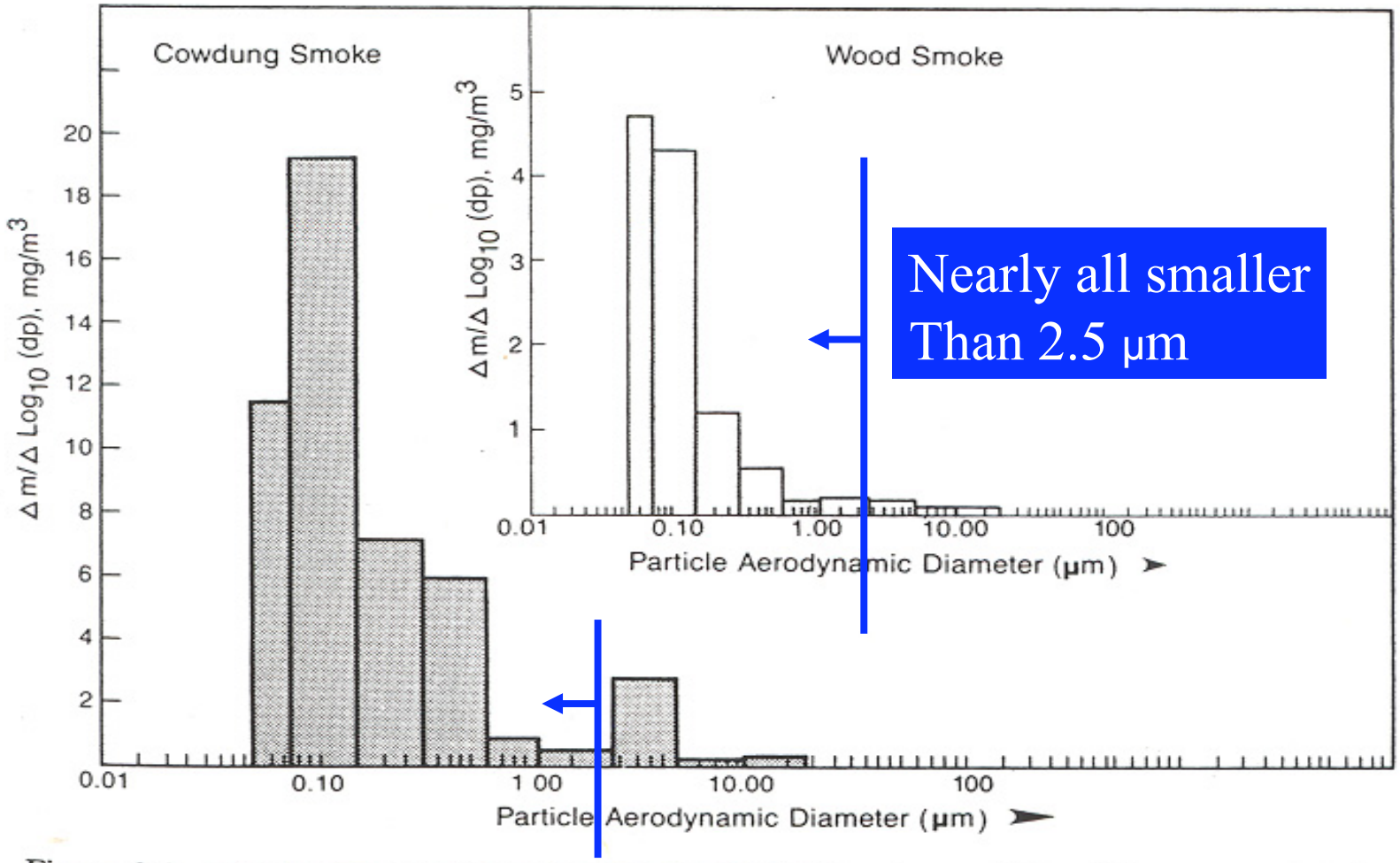
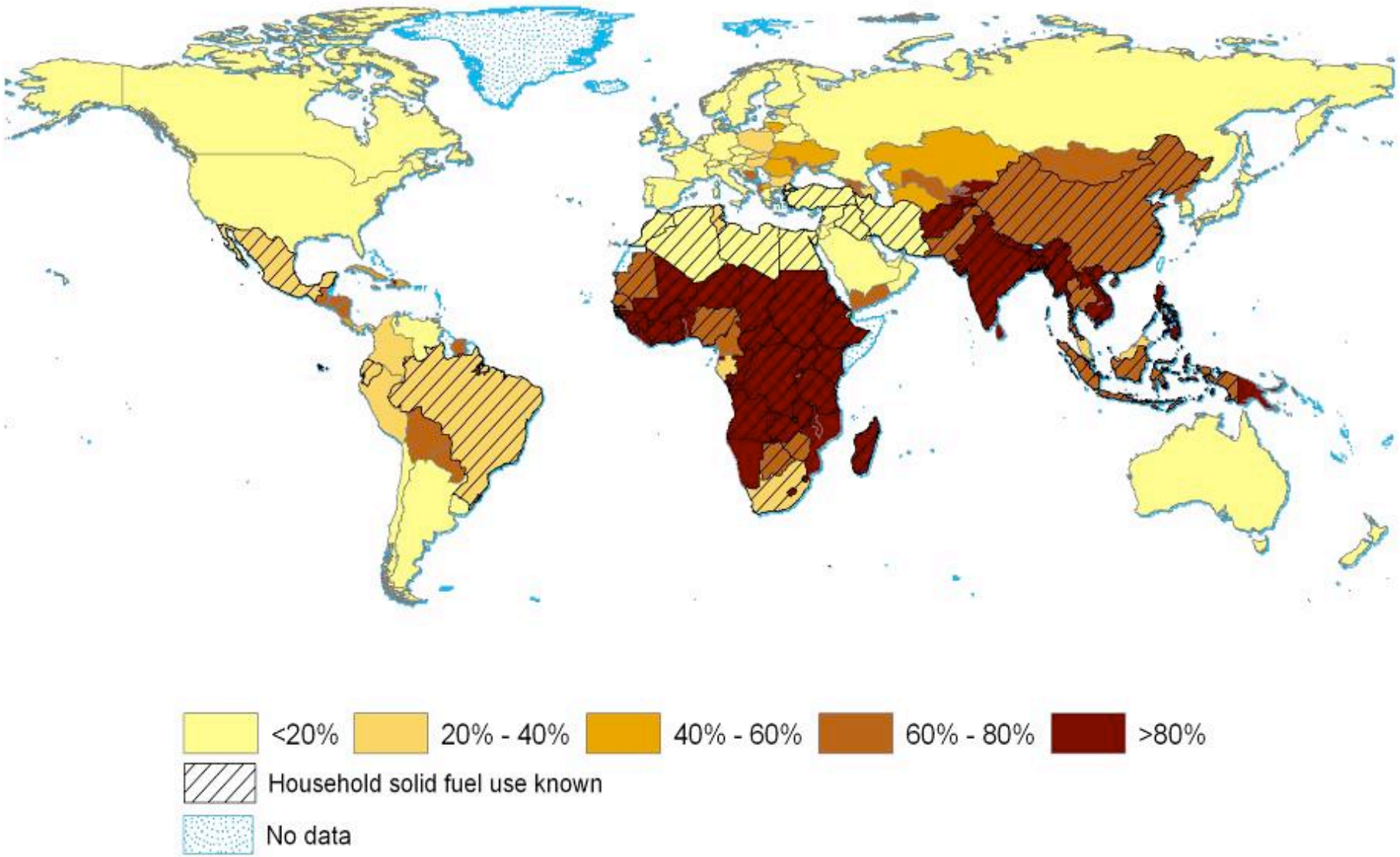
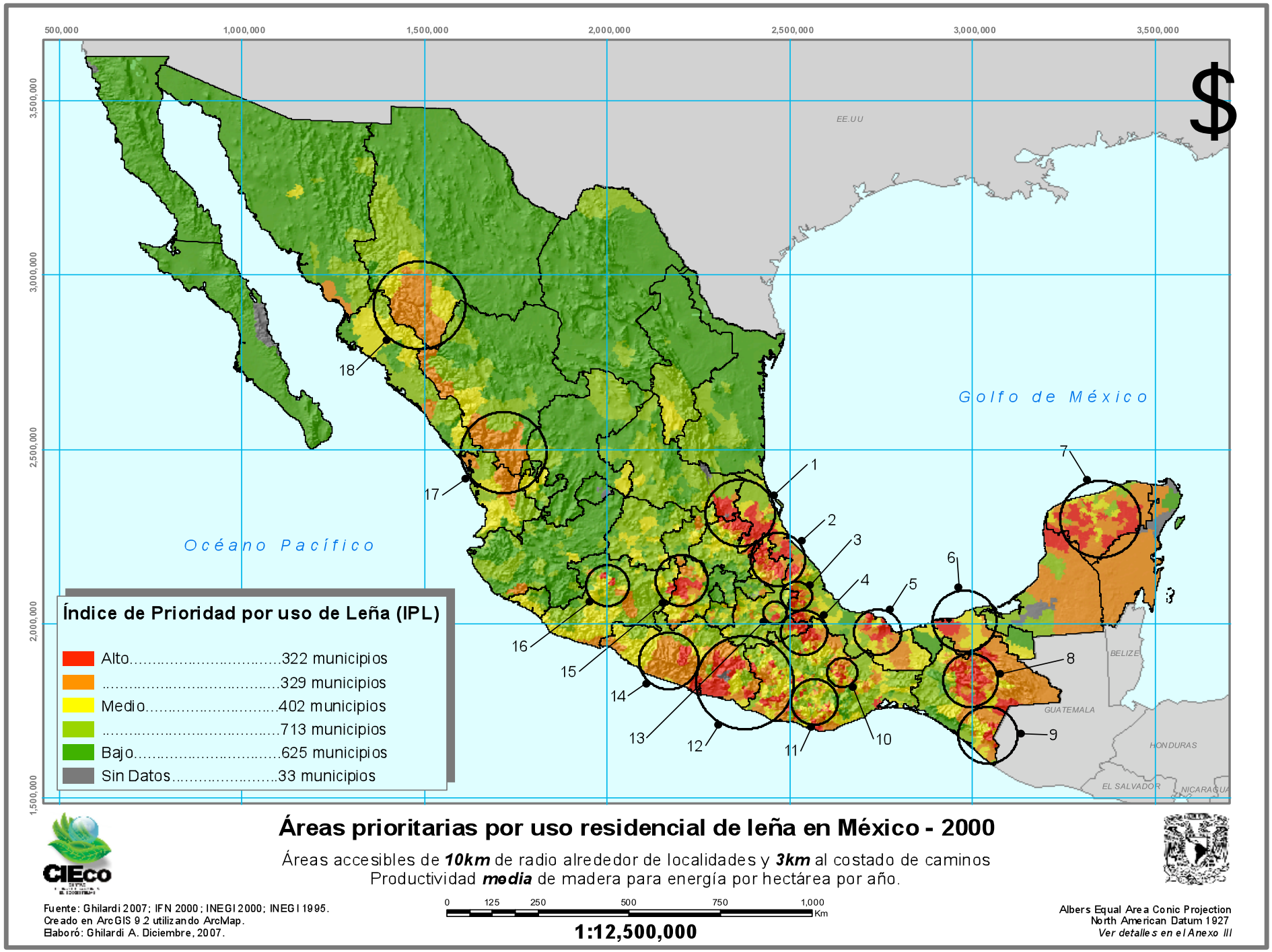


Figure 2.2. Size distribution of woodsmoke and dungsmoke particles. Measurements taken in the East–West Center simulated village house as reported in Smith *et al.* (1984b). (Figure prepared by Premlata Menon.)

Source: Smith, Apte et al. 1984

National Household Solid Fuel Use, 2000





Áreas prioritarias por uso residencial de leña en México - 2000

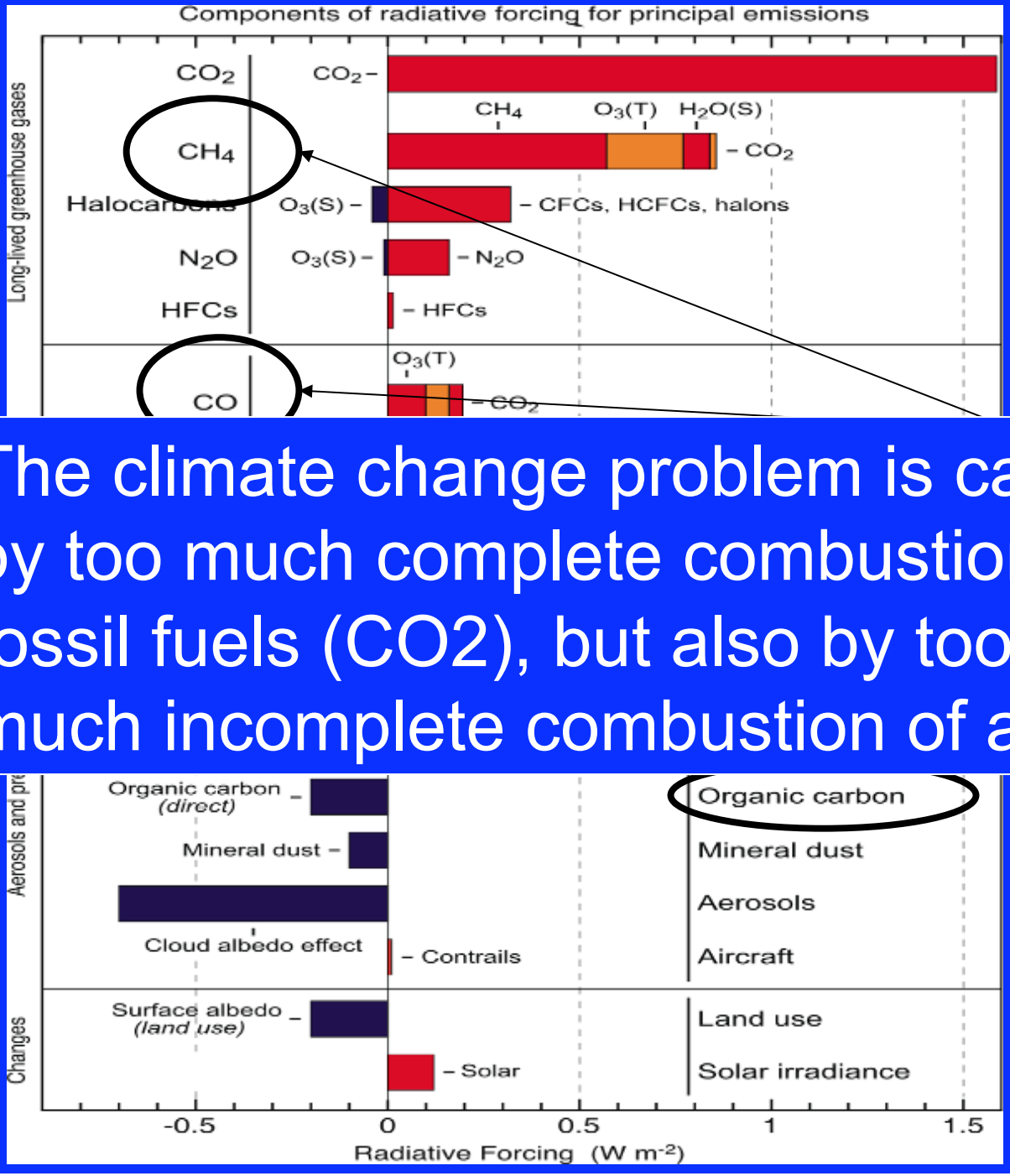
Áreas accesibles de ***10km*** de radio alrededor de localidades y ***3km*** al costado de caminos
Productividad ***media*** de madera para energía por hectárea por año.

Fuente: Ghilardi 2007; IFN 2000; INEGI 2000; INEGI 1995.
Creado en ArcGIS 9.2 utilizando ArcMap.
Elaboró: Ghilardi A. Diciembre, 2007.

0 125 250 500 750 1,000 Km

1:12,500,000

Albers Equal Area Conic Projection
North American Datum 1927
Ver detalles en el Anexo III



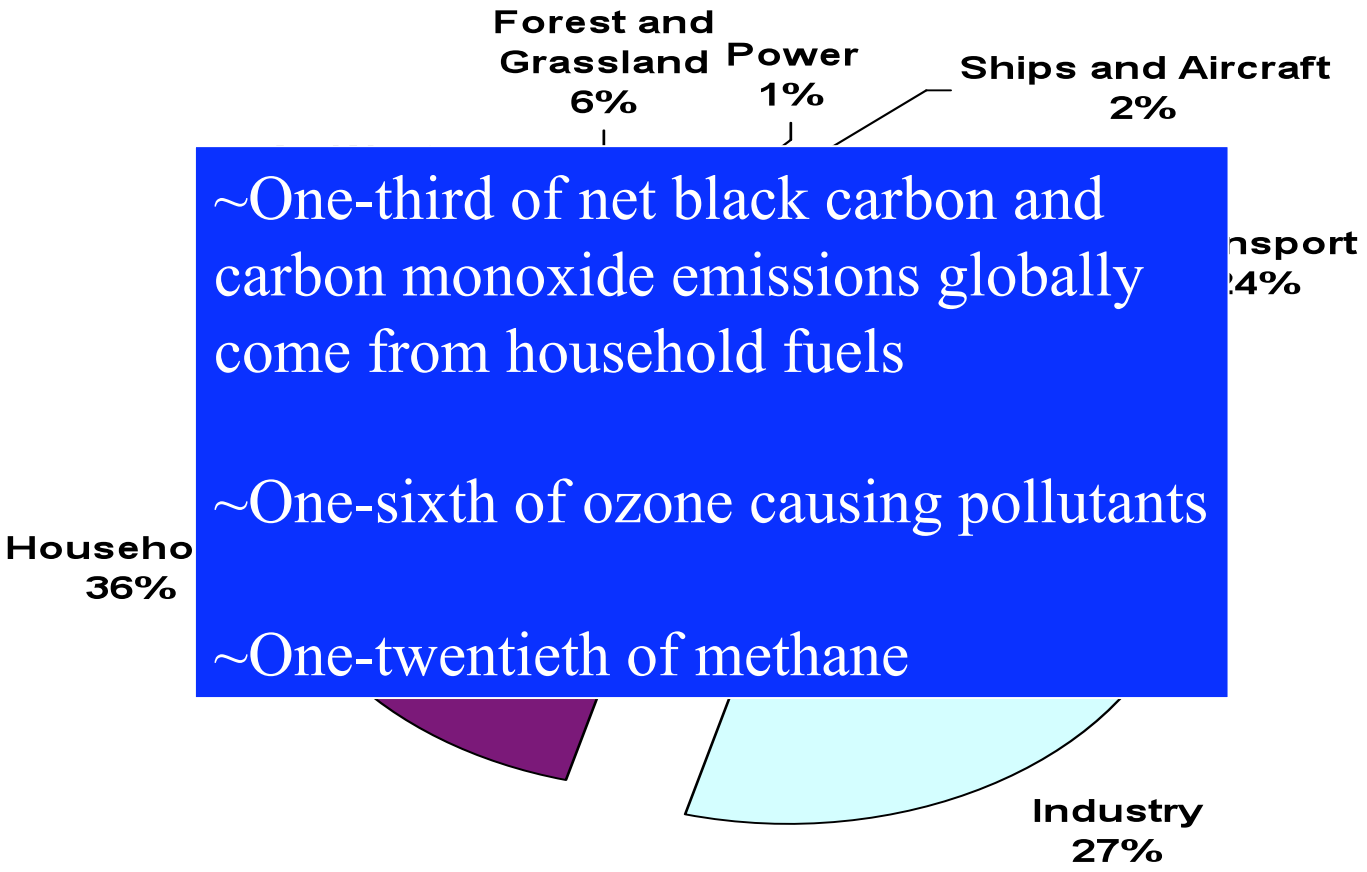
Warming in 2005 from emissions since 1750

The climate change problem is caused not only by too much complete combustion of fossil fuels (CO2), but also by too much incomplete combustion of all fuels (PIC)

IPCC, 2007

Controllable Global Warming from Black Carbon Emissions

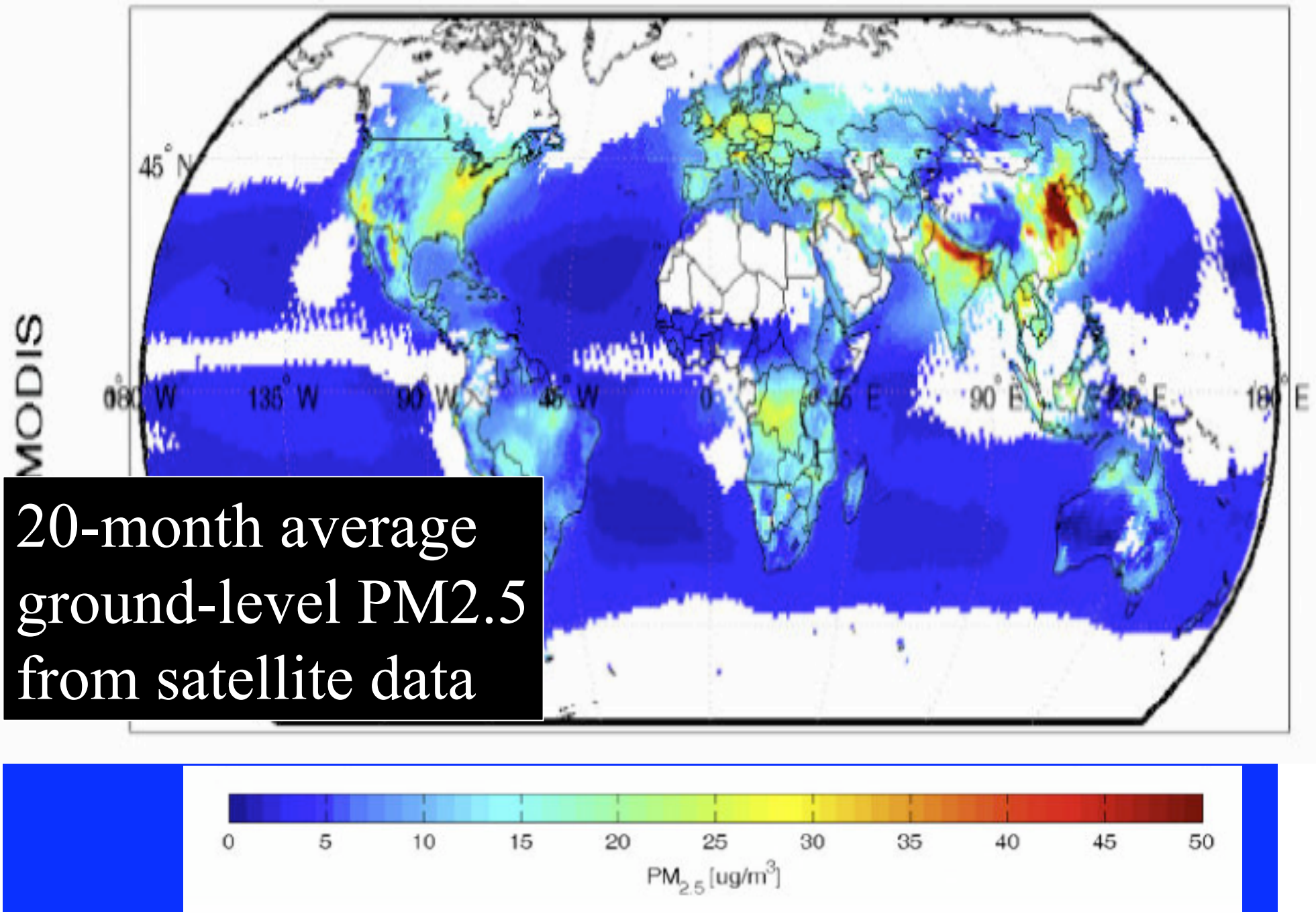
Net of OC, Forcings from IPCC, 2007: 0.25 W/m^2
Inventory from T Bond Database, V 7.1.1 Feb 2009



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

~One-sixth of ozone causing pollutants

~One-twentieth of methane

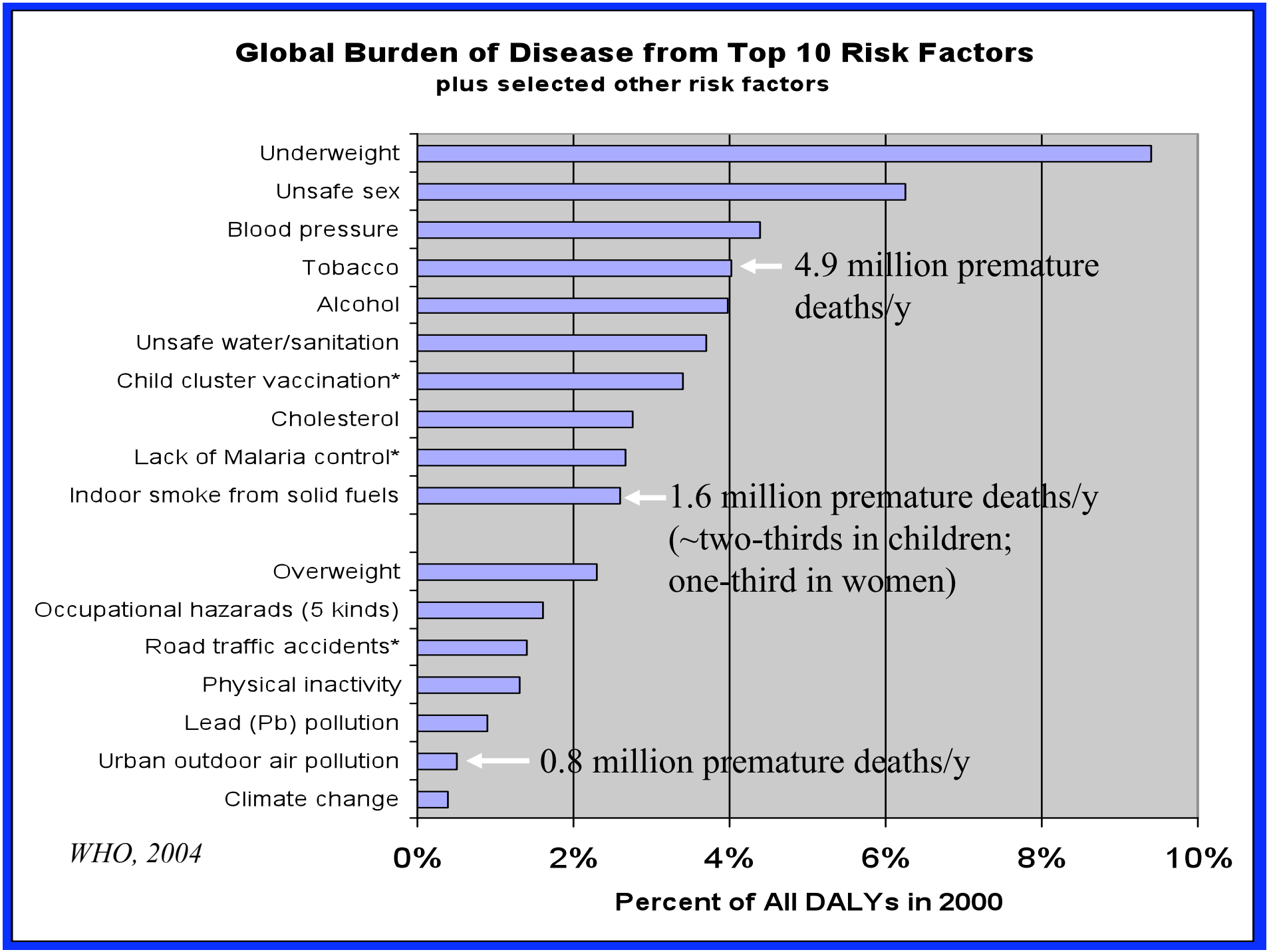


20-month average ground-level PM2.5 from satellite data

Oldest Pollution Source in Human History
By definition

How Big the Health Impact Globally?

Highland Guatemala


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 premature deaths/y
1.6 million premature deaths/y (~two-thirds in children; one-third in women)
0.8 million premature deaths/y
WHO, 2004
0%
2%
4%
6%
8%
10%
Percent of All DALYs in 2000

Diseases for which we have some epidemiological studies

ALRI/ Pneumonia (meningitis)

Asthma

Low birth weight

Early infant death

Cognitive Effects?

Chronic obstructive lung disease

Interstitial lung disease

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

Blindness (cataract trachoma)

Tuberculosis

Heart disease

Pneumonia from acute lower respiratory infections (ALRI)

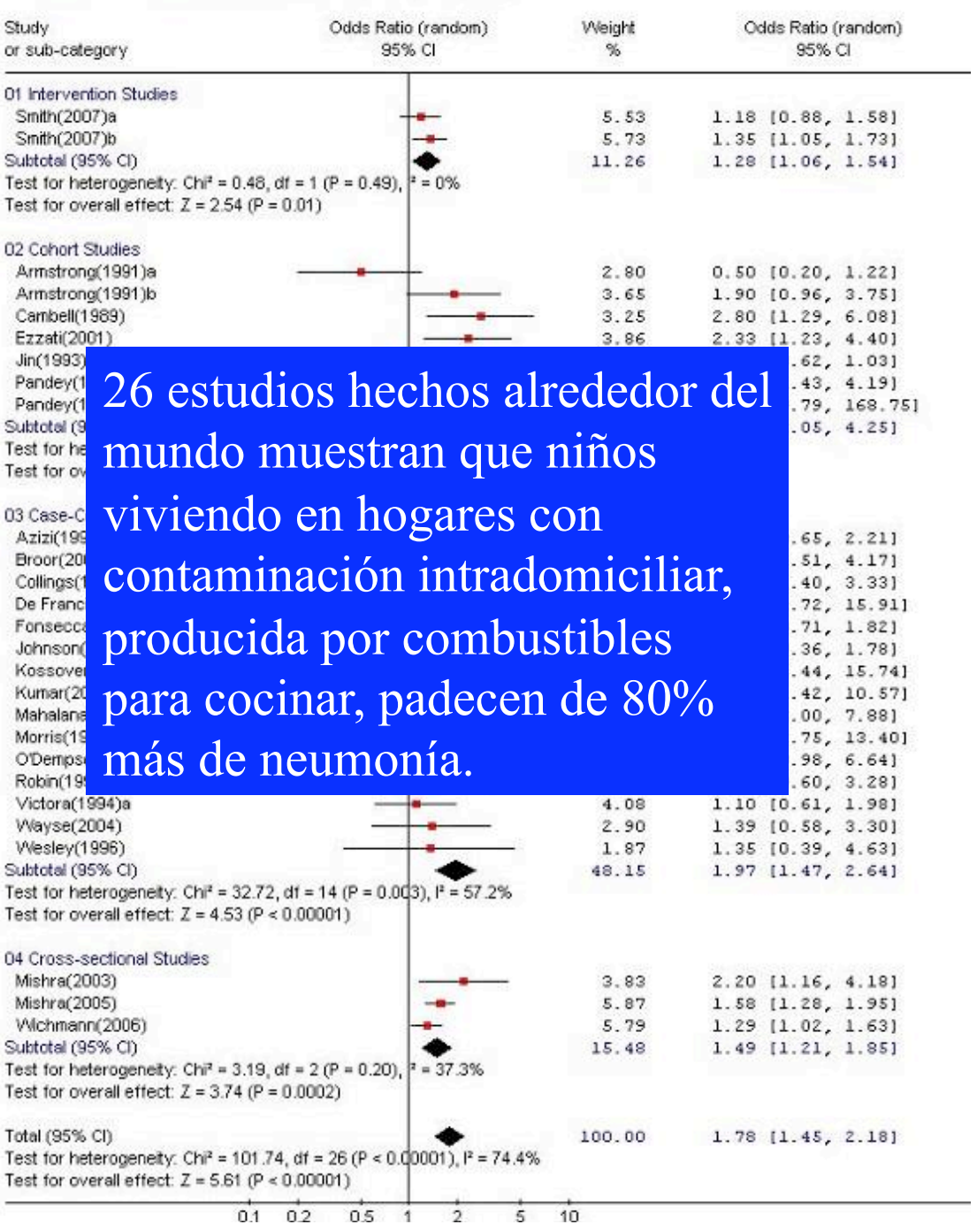
Chief cause of death among the world's children (~2 million per year). Thus, it is the chief global cause of lost healthy life years.

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

Tip de Estudio	N*	OR	95% IC
Intervención	2	1.28	1.06, 1.54
Cohorte	7	2.12	1.06, 4.25
Caso-control	15	1.97	1.47, 2.64
Transversal	3	1.49	1.21, 1.85
Todos	26	1.78	1.45, 2.18

*Numero de estimaciones disponibles

Dherani et al., 2008
Bull WHO

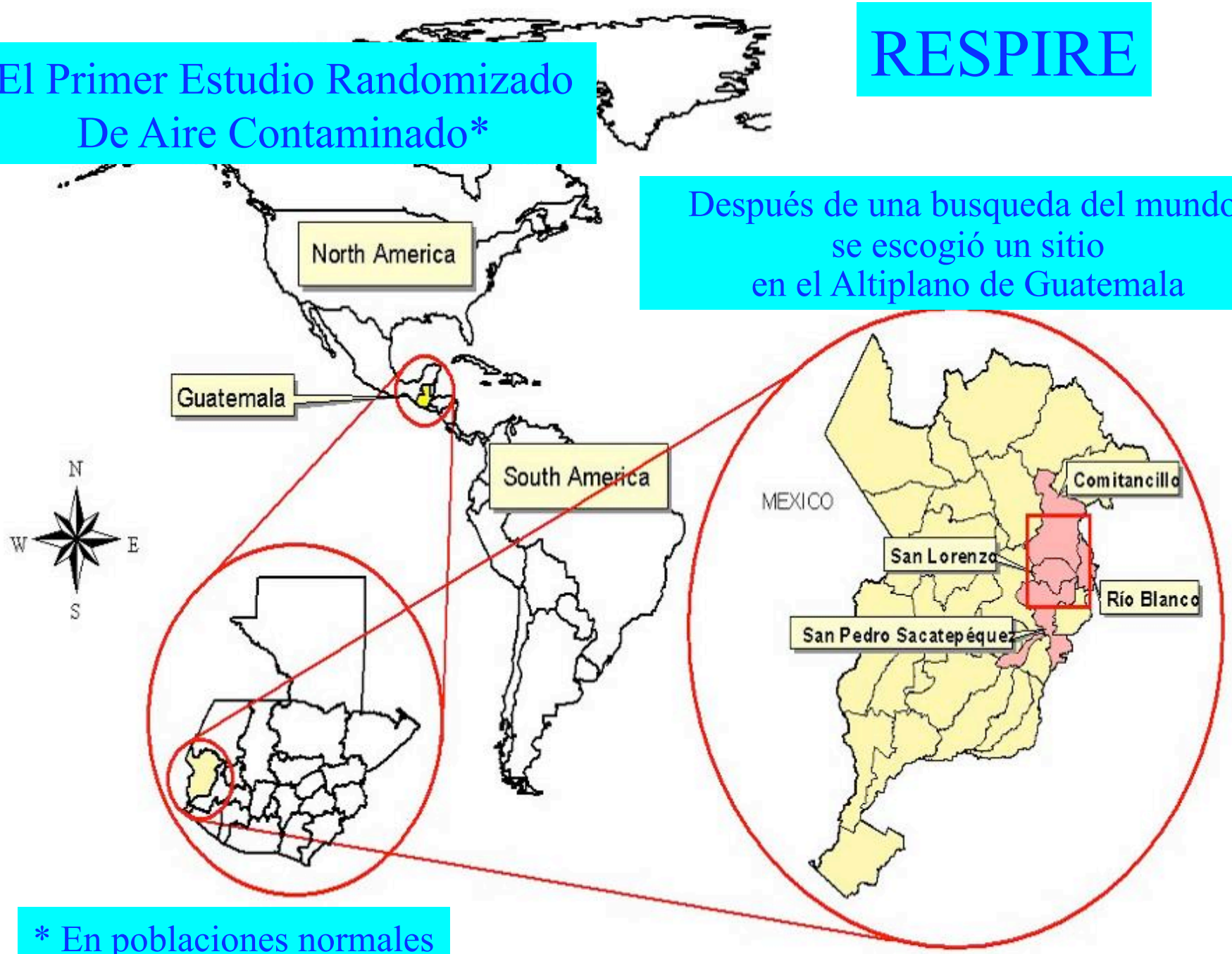


26 estudios hechos alrededor del mundo muestran que niños viviendo en hogares con contaminación intradomiciliar, producida por combustibles para cocinar, padecen de 80% más de neumonía.

RESPIRE

El Primer Estudio Randomizado De Aire Contaminado*

Después de una busqueda del mundo,
se escogió un sitio
en el Altiplano de Guatemala

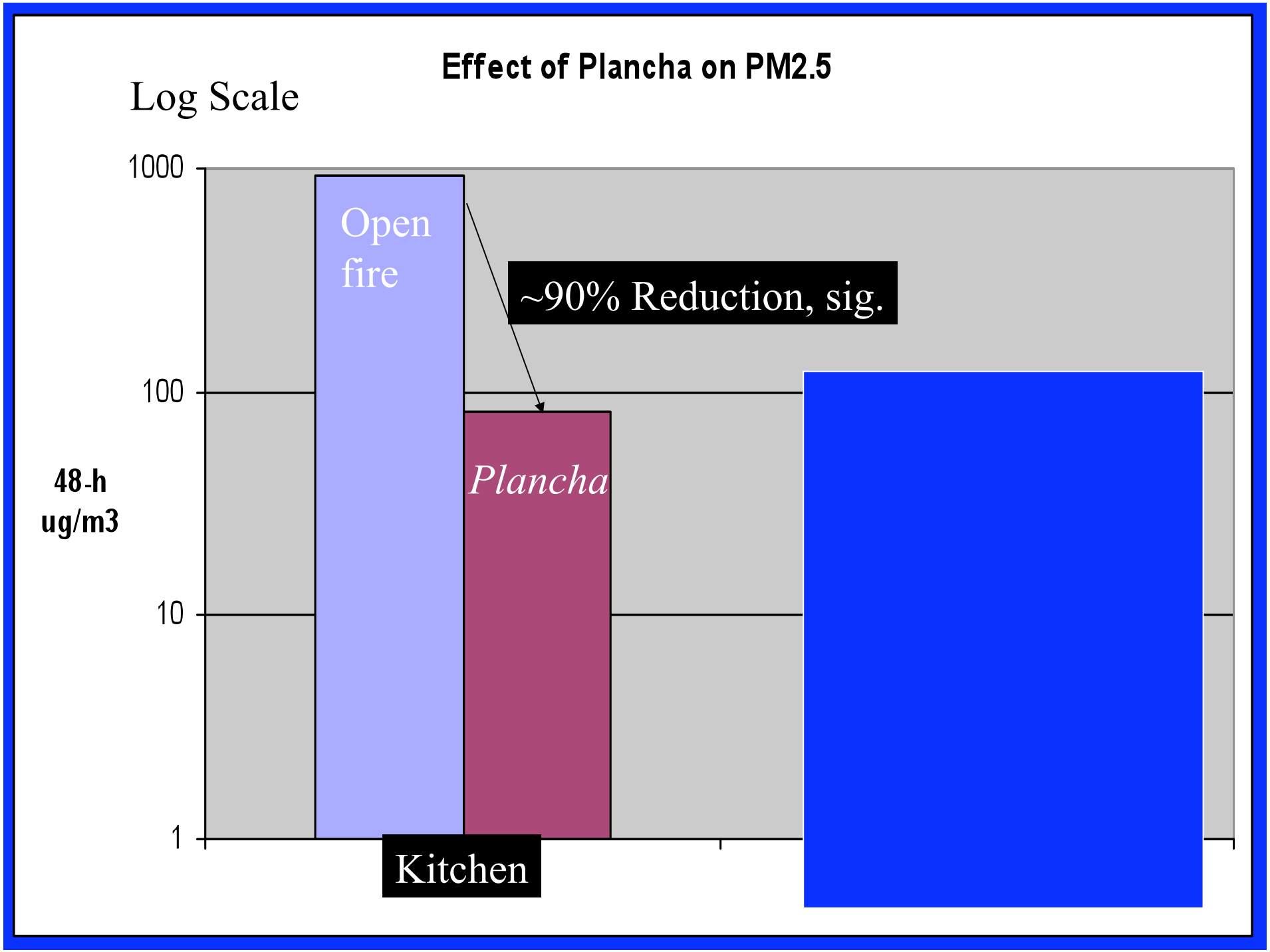


* En poblaciones normales

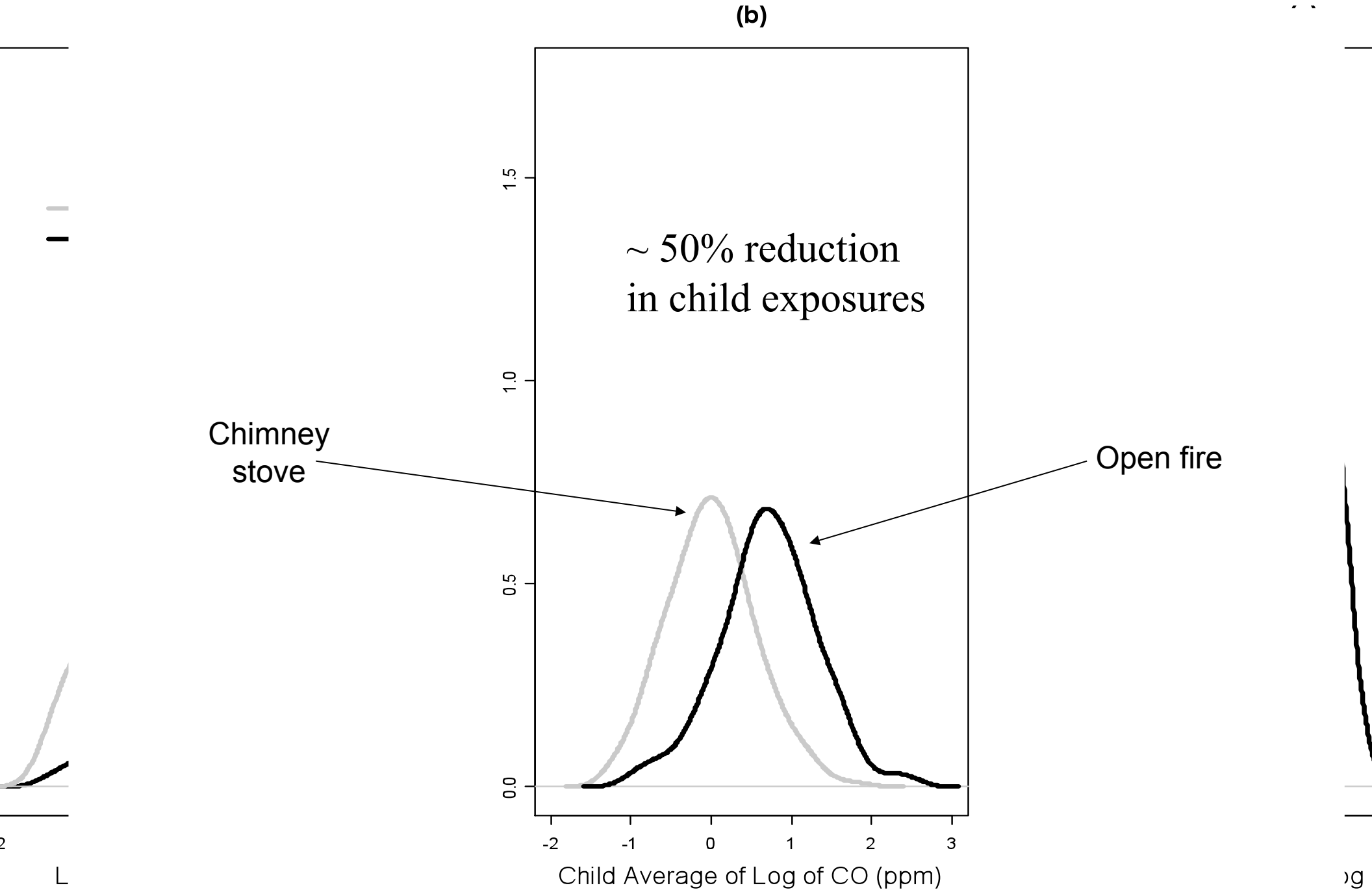
RESPIRE: (Randomized Exposure Study of Pollution Indoors and Respiratory Effects)

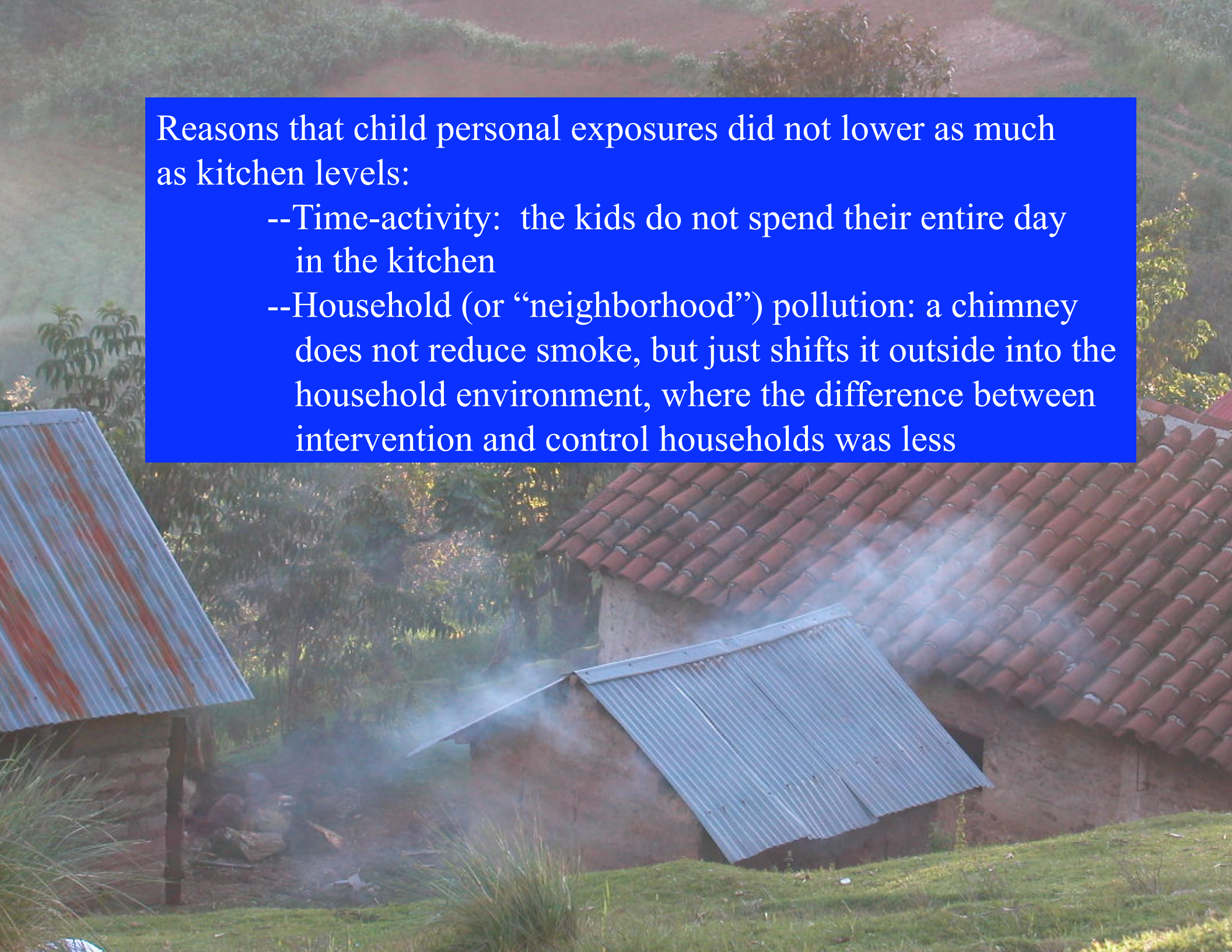
Traditional 3-stone open fire

Plancha chimney wood stove


Effect of Plancha on PM2.5
Log Scale
1000
100
10
1
48-h
ug/m3
Open
fire
~90% Reduction, sig.
Plancha
Kitchen

Tubito
Tubito

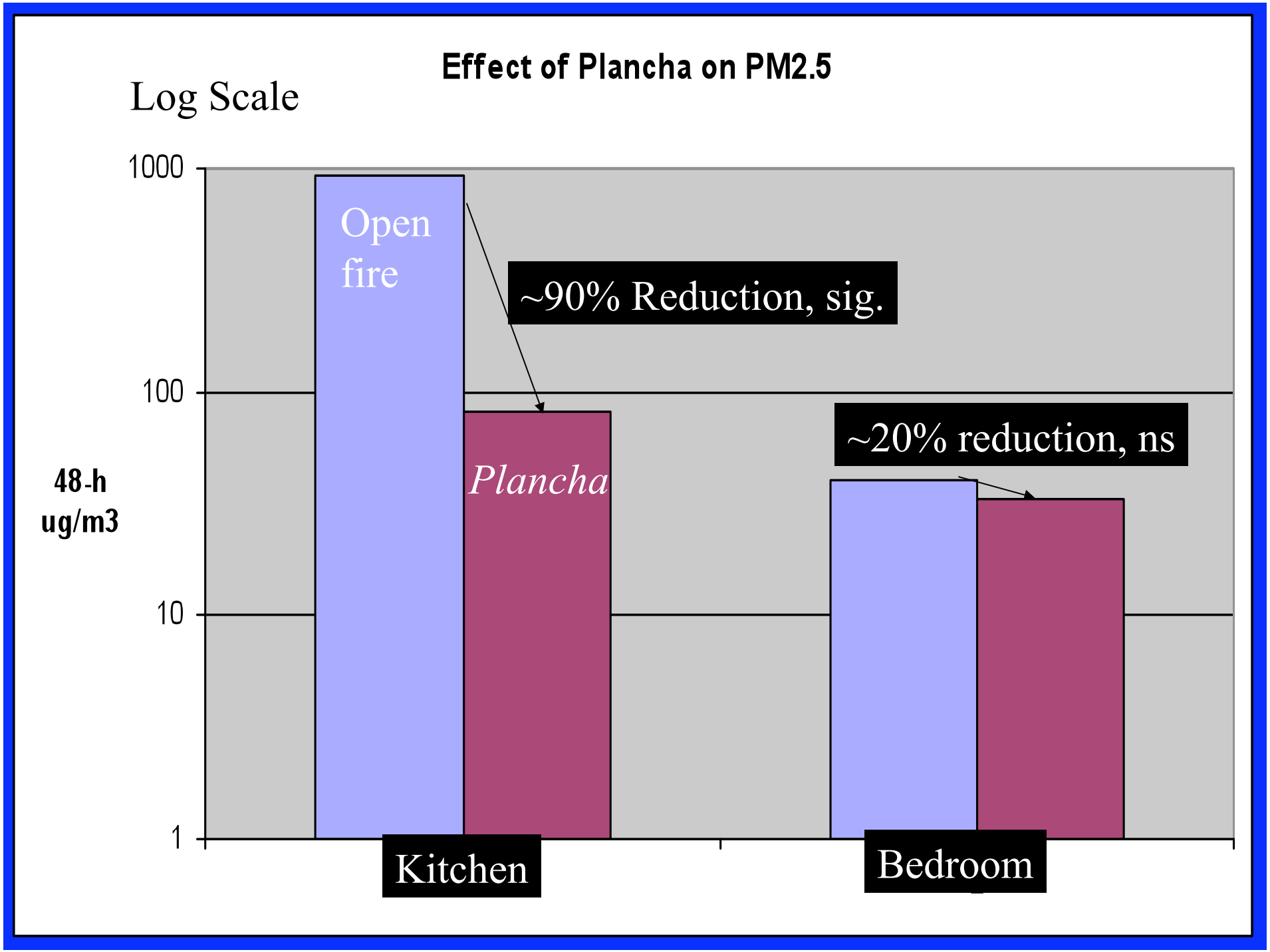

(b)
~ 50% reduction
in child exposures
Chimney
stove
Open fire
0.0
0.5
1.0
1.5
-2
-1
0
1
2
3
Child Average of Log of CO (ppm)



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

--Time-activity: the kids do not spend their entire day in the kitchen

--Household (or "neighborhood") pollution: a chimney does not reduce smoke, but just shifts it outside into the household environment, where the difference between intervention and control households was less

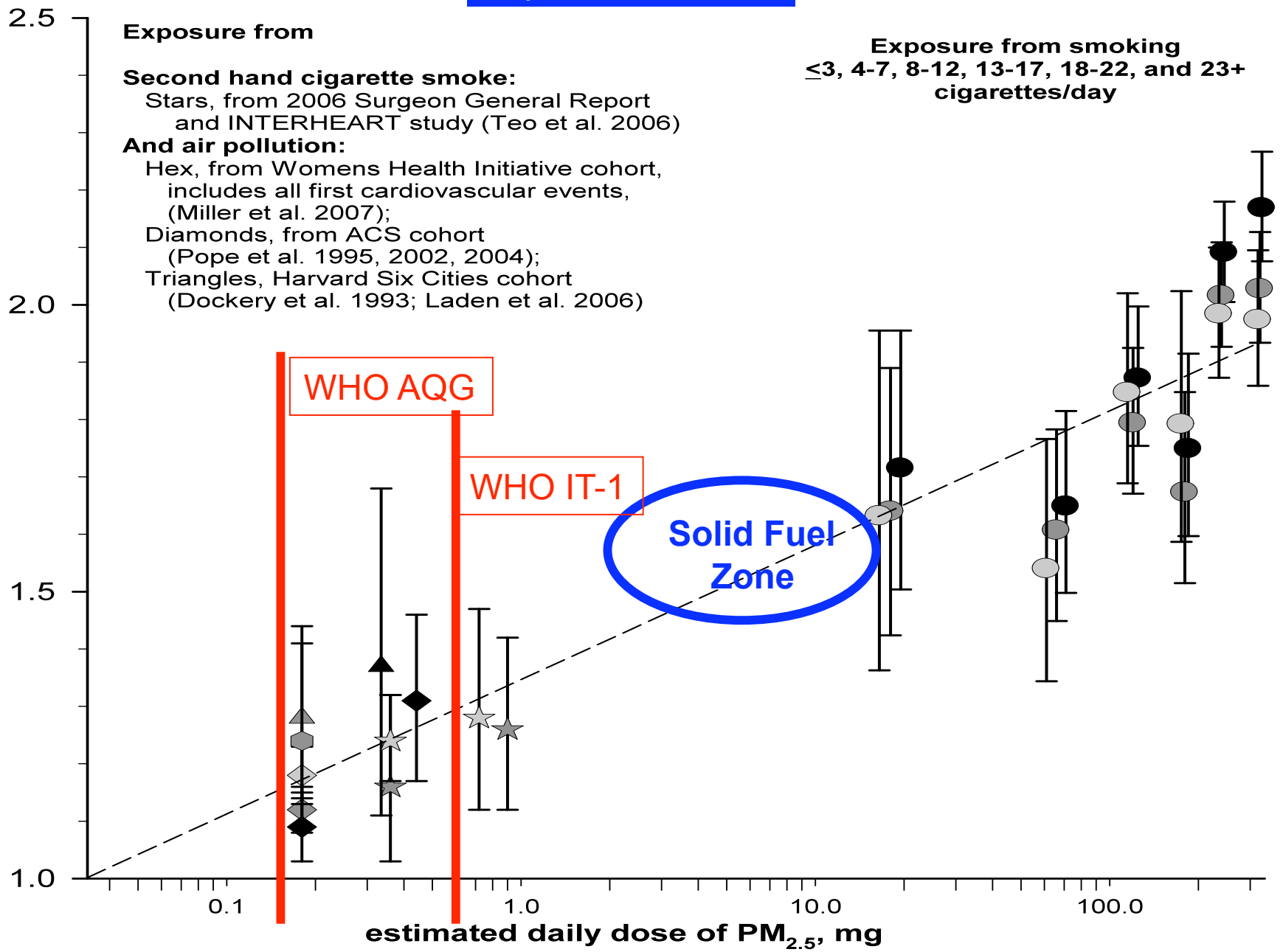

Effect of Plancha on PM2.5
Log Scale
1000
100
10
1
48-h
ug/m3
Open
fire
Plancha
~90% Reduction, sig.
~20% reduction, ns
Kitchen
Bedroom

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



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

Chinese National Stove Contest - 2007

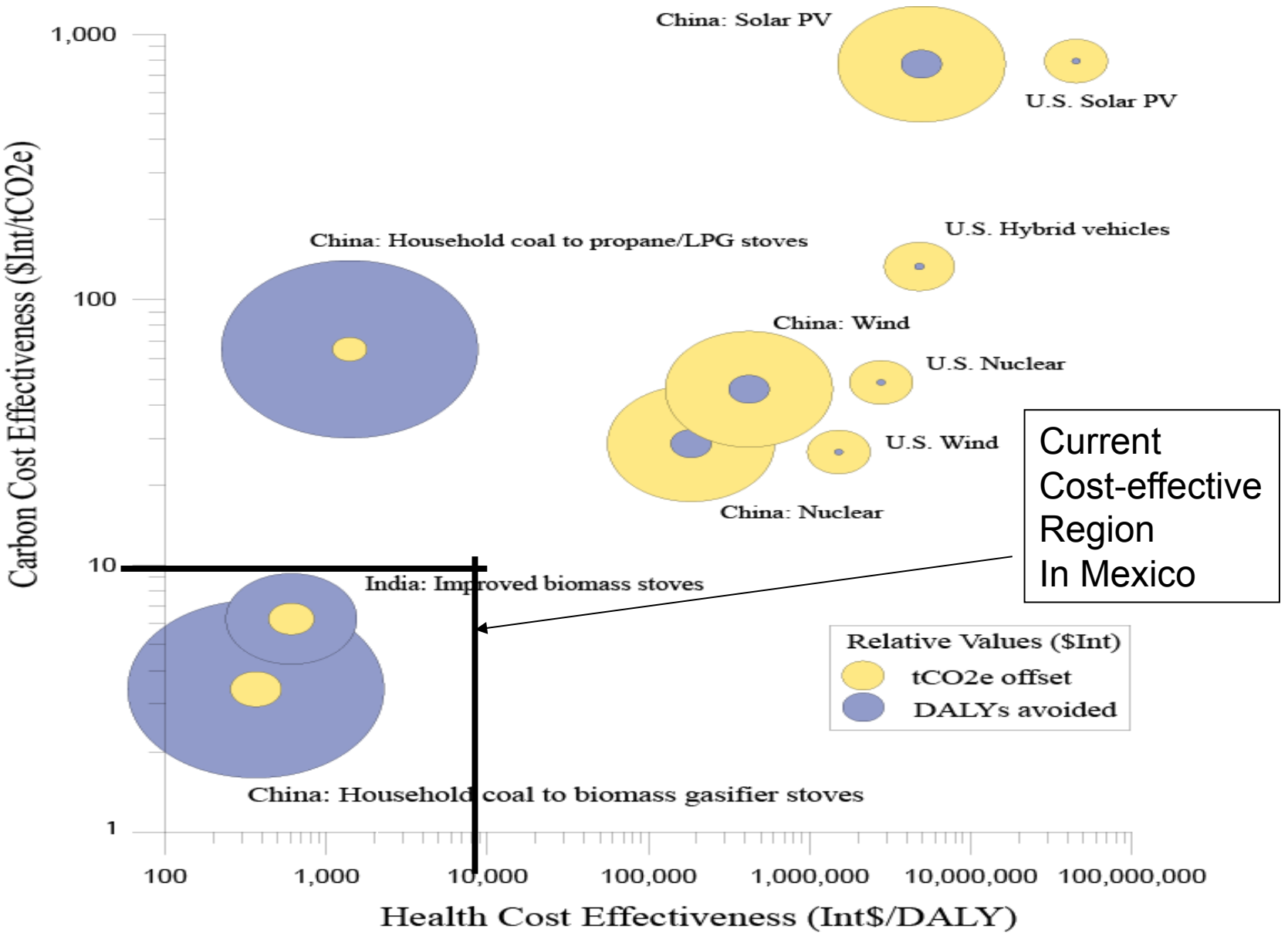
	CO/CO2	NCE**	Eff %	CO g/kg	PM g/ kg	Relative PM/ meal	Less PM/ meal
Traditional Coal*	0.12	89.3%	25	166	1.6	23%	4.3x
Traditional Biomass*							1
Biomass Stov							
Linhong							45x
Luoyang							42x
Zhenghong							37x
Daxu							32x

* Typical

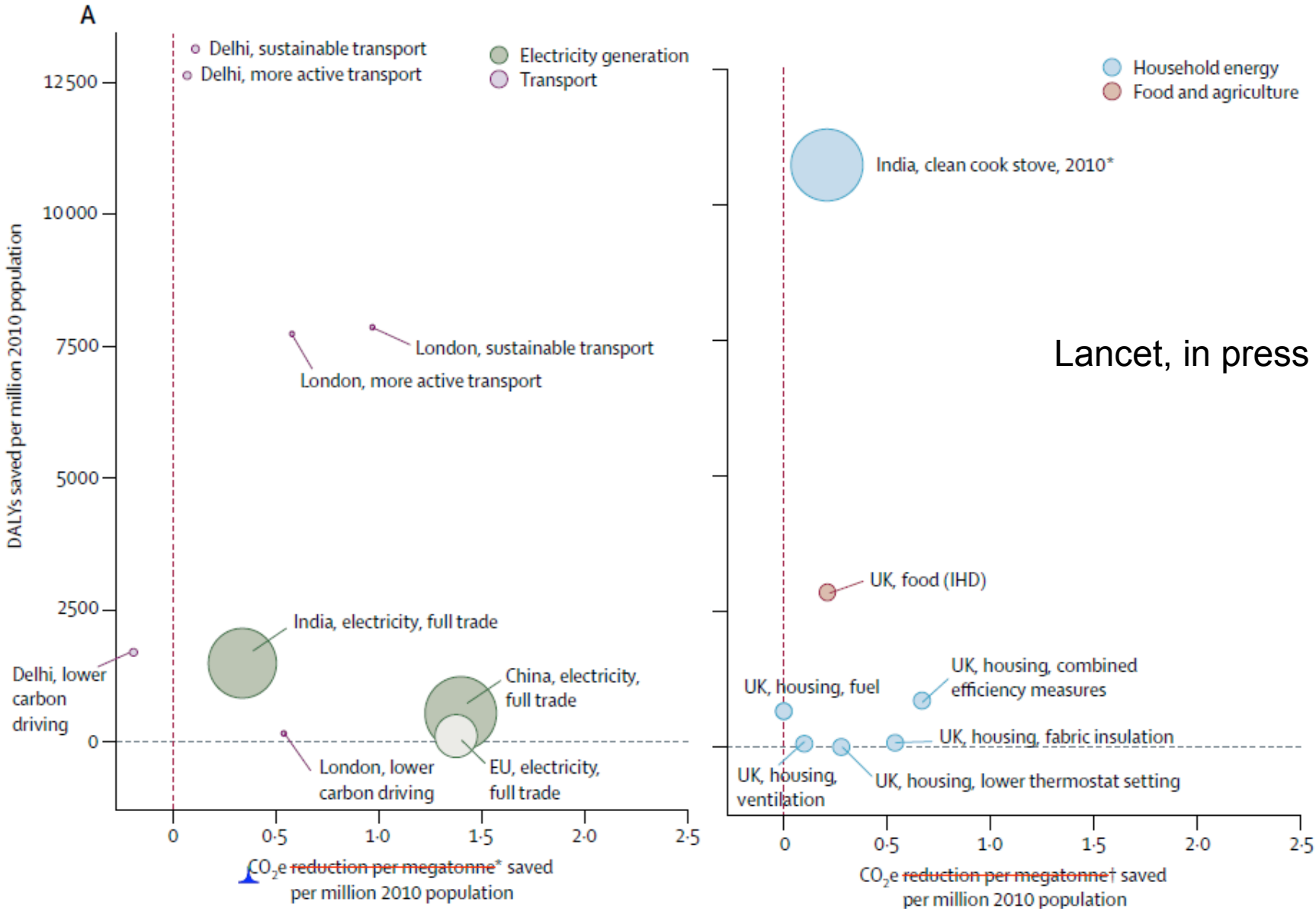
Compared to traditional biomass stove

32-45 times less mass of small particles per meal in lab

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



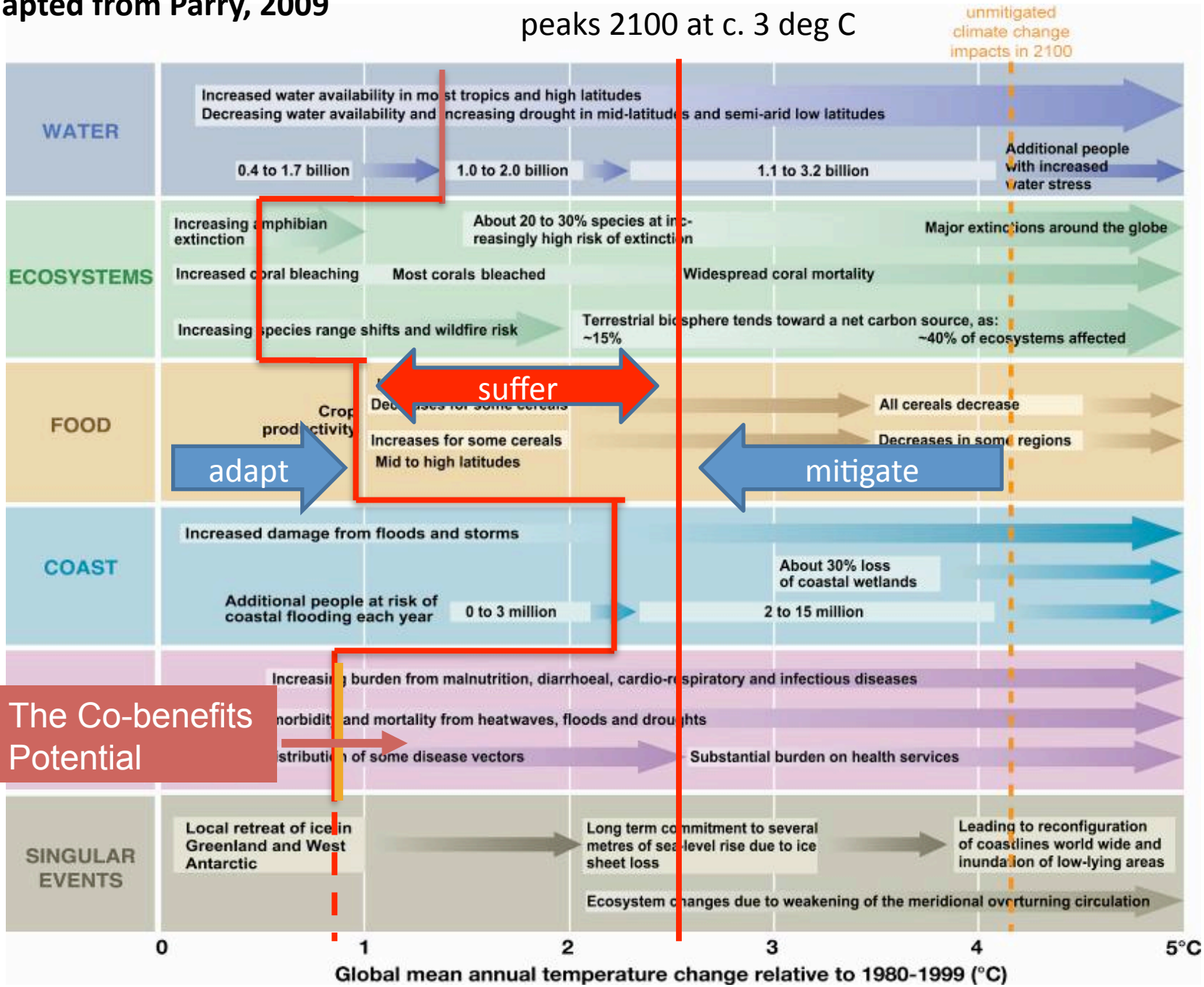
Smith & Haigler, 2008



Lancet, in press

Adapted from Parry, 2009

Emission peak 2035; T peaks 2100 at c. 3 deg C



The Co-benefits Potential

“Wood is the fuel that heats you twice” - ?

- Actually four times
- Chopping
- Burning
- Fever from pneumonia
- Global warming
- Bottom line: combustion particles of all types have major impacts on health

“The Health Implications of the Shorter-lived Greenhouse Pollutants: Black Carbon, Sulfate, and Ozone”

Includes first published long-term cohort study of BC health effects – 66 US cities over 18 years

Smith KR, Jerrett M, Anderson R. et al. (Series on the impact on public health of strategies to reduce GHGs)

the Lancet (in press 2009). To be released Nov 25.

Thank you

All presentations and pubs available at http://ehs.sph.berkeley.edu/krsmith