Energy for Development Conference
ETH, Sept 10-11, 2009

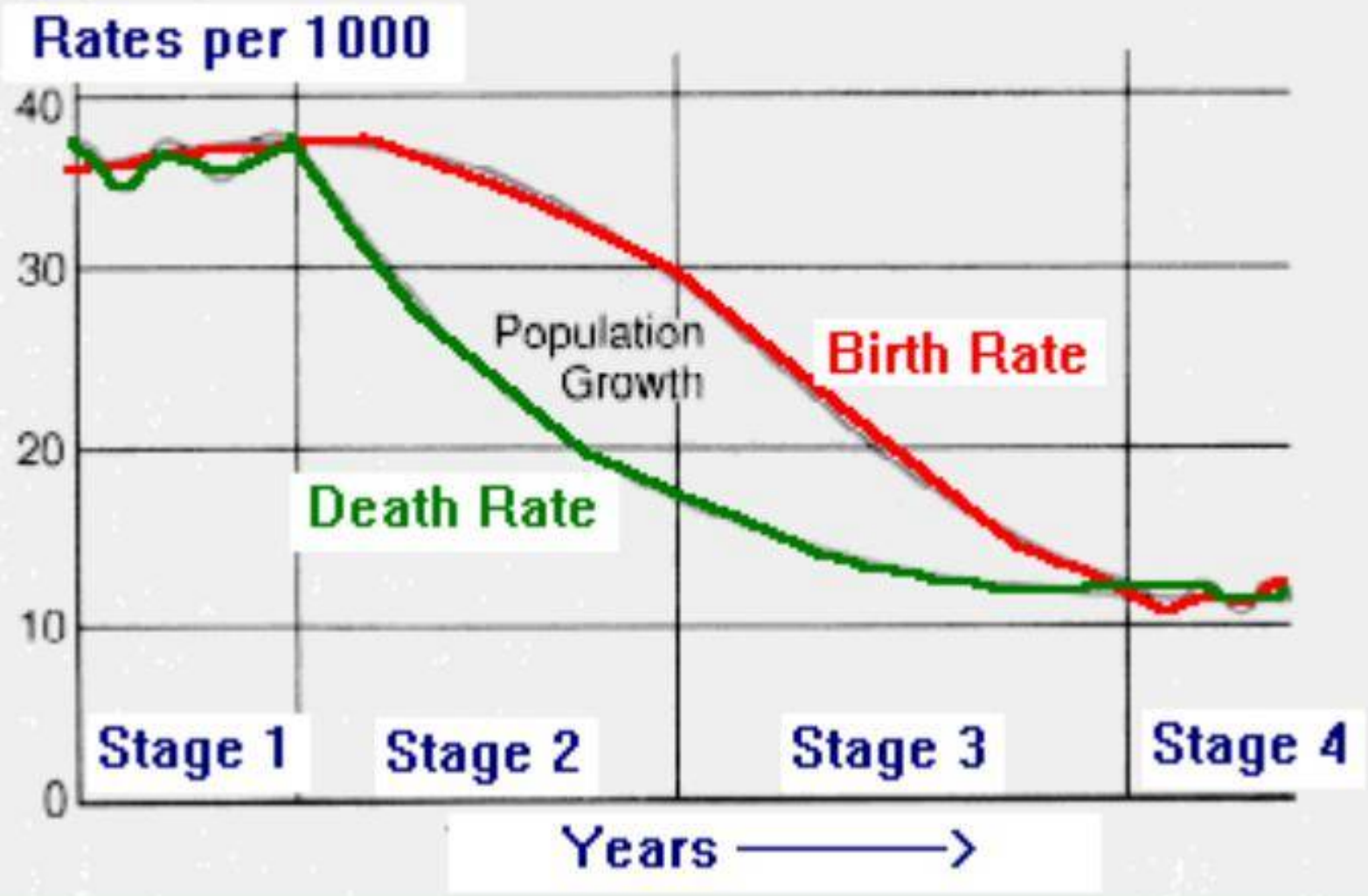
Combustion, Climate, Health, and the Environmental Risk Transition

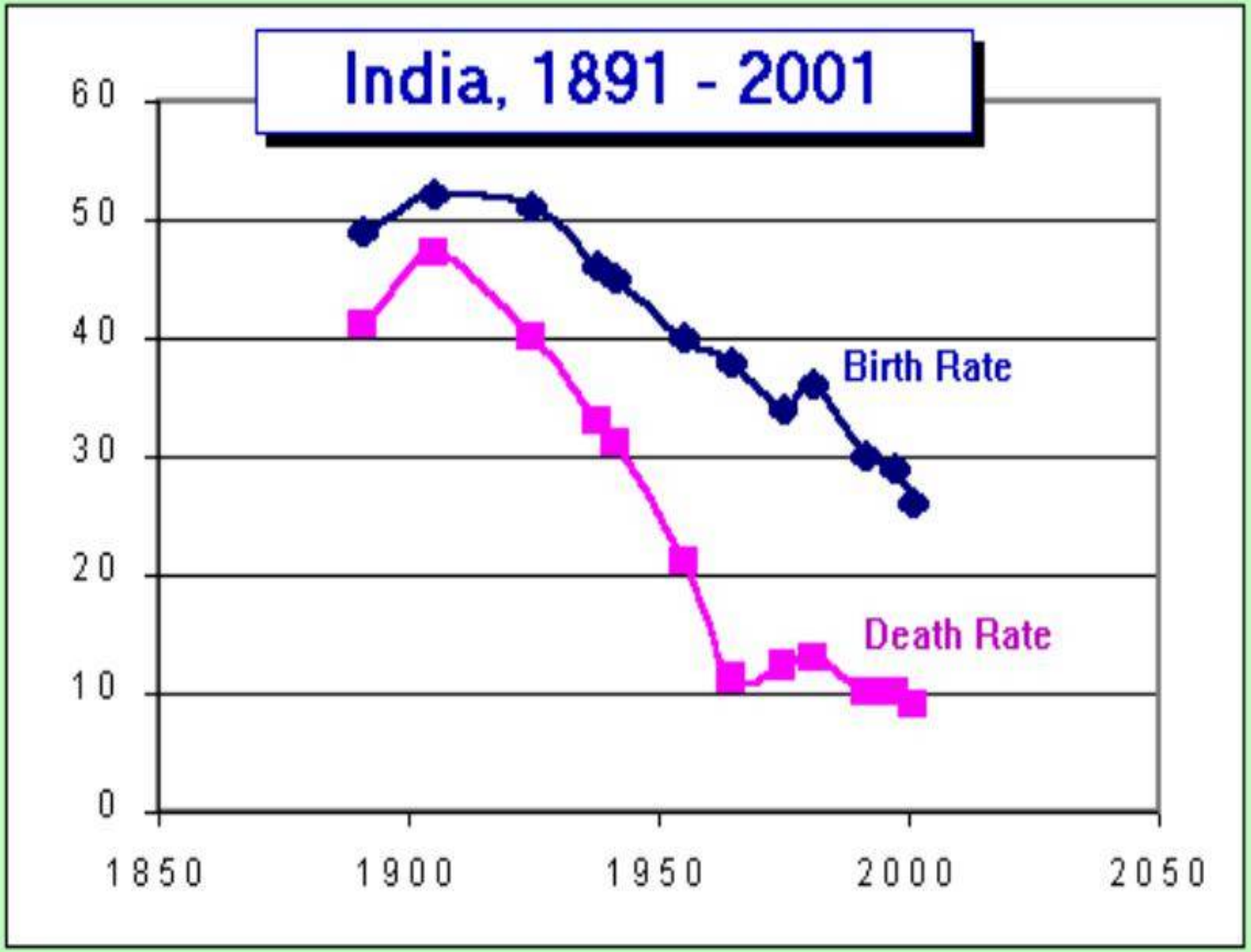
Kirk R. Smith
Professor of Global Environmental Health
University of California, Berkeley

Road Map

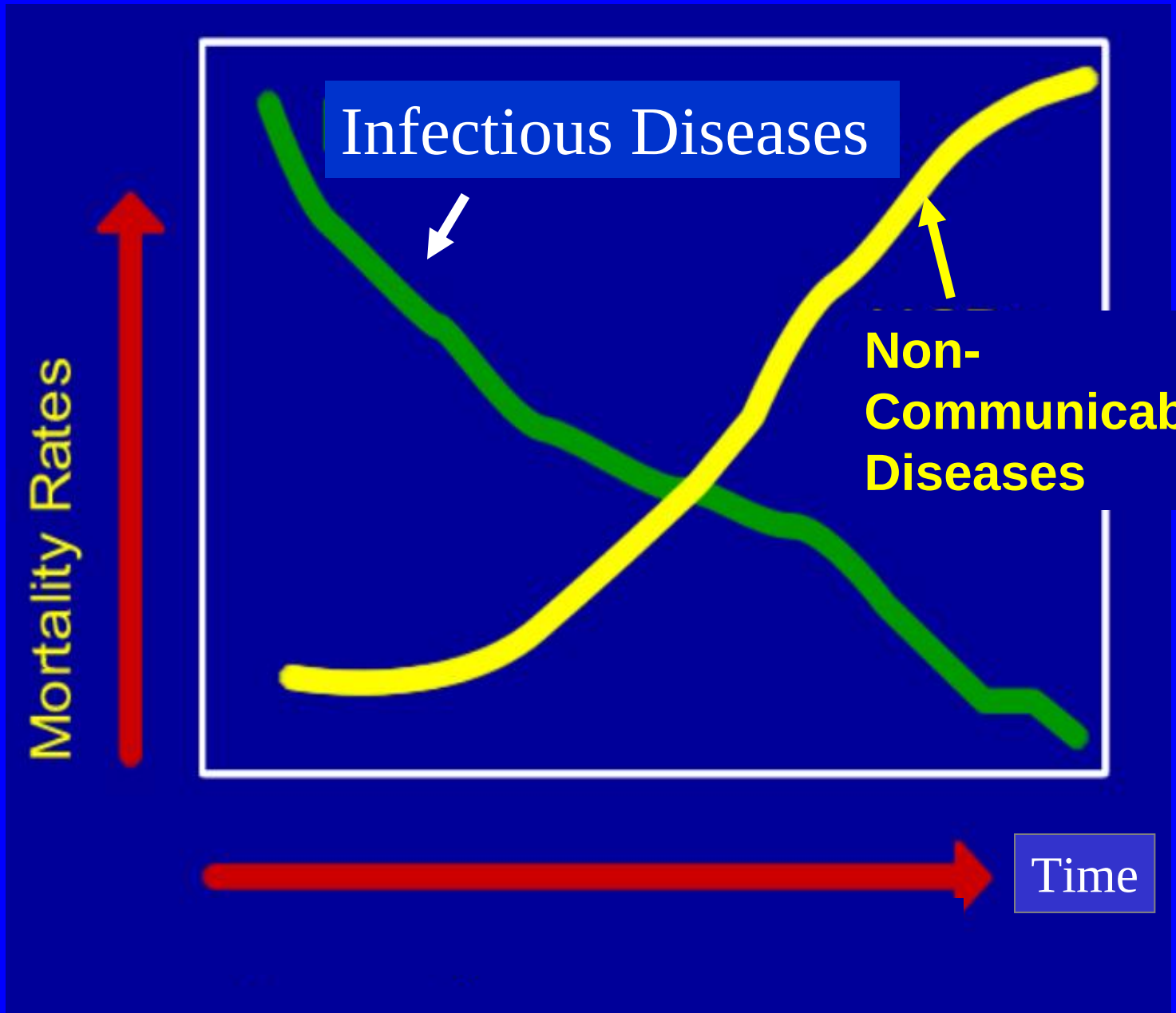
- A bit on transition frameworks and an intro to the environmental risk transition
- Why household fuel use causes ill health
- Global and Indian health impacts of household fuel use
- How household fuel use interacts with climate
- Potential for Co-benefits – health and climate
- Total impact of combustion mismanagement globally

The Demographic Transition

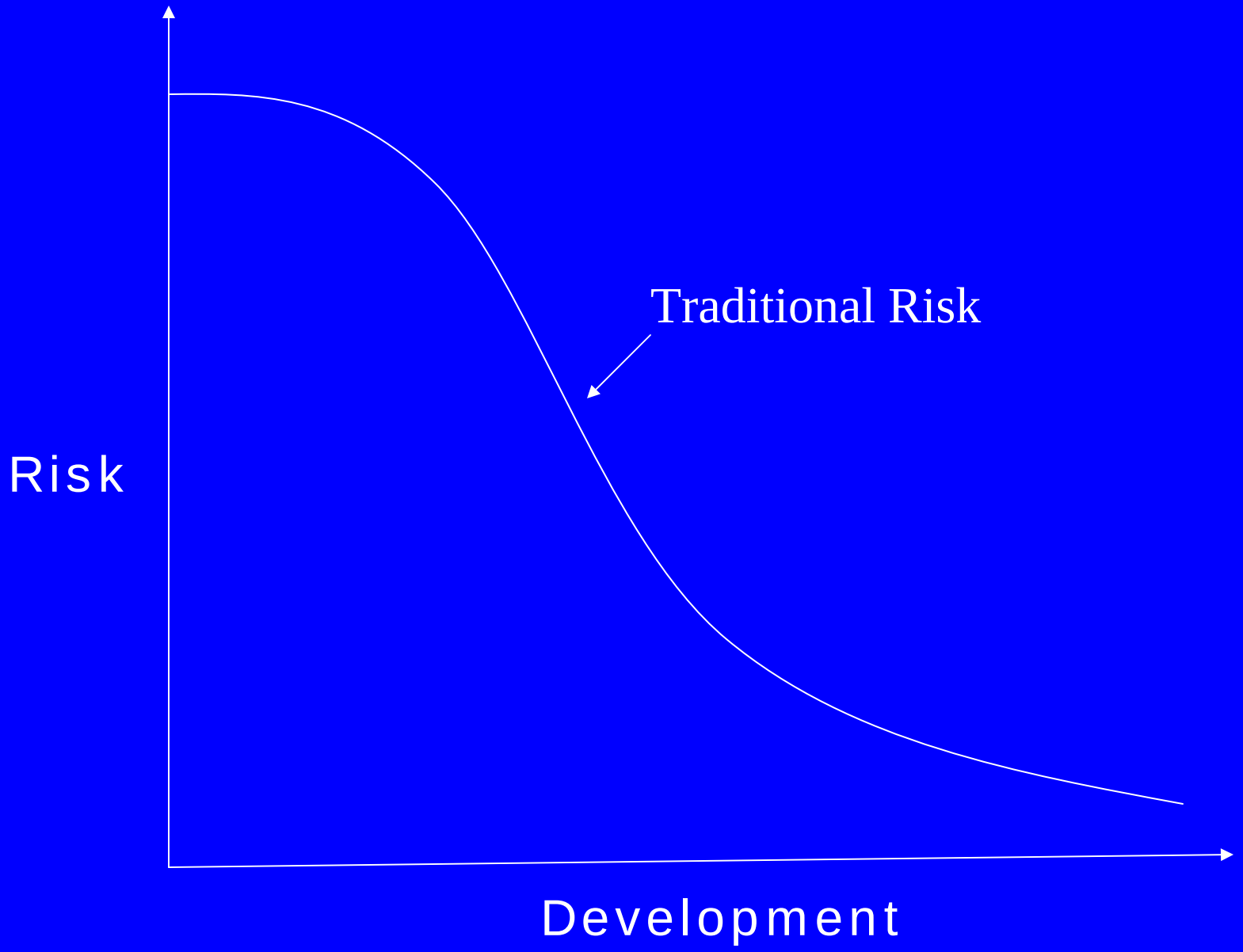



India, 1891 - 2001
60
50
40
30
20
10
0
1850
1900
1950
2000
2050
Birth Rate
Death Rate

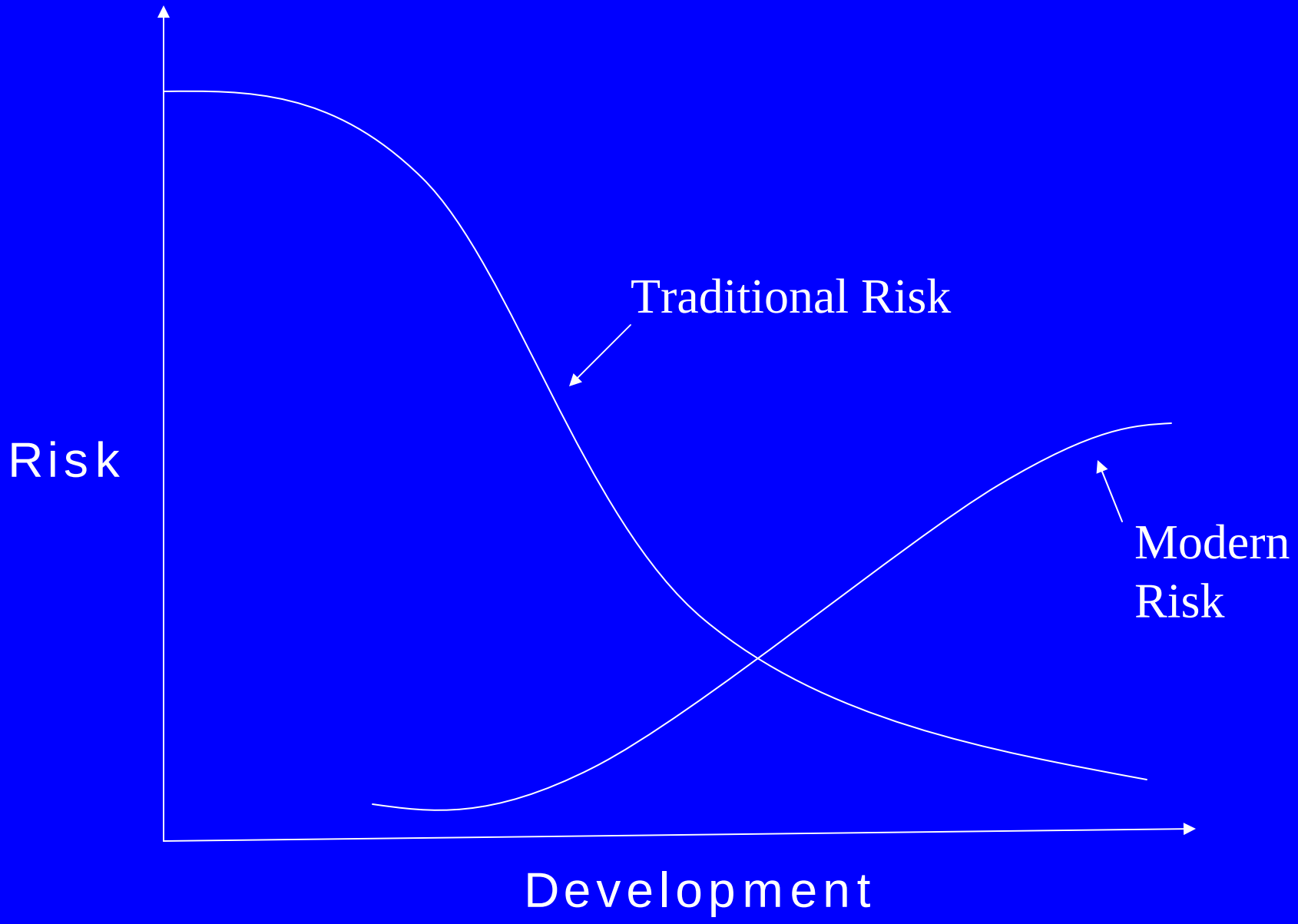
The Classic Epidemiological Transition



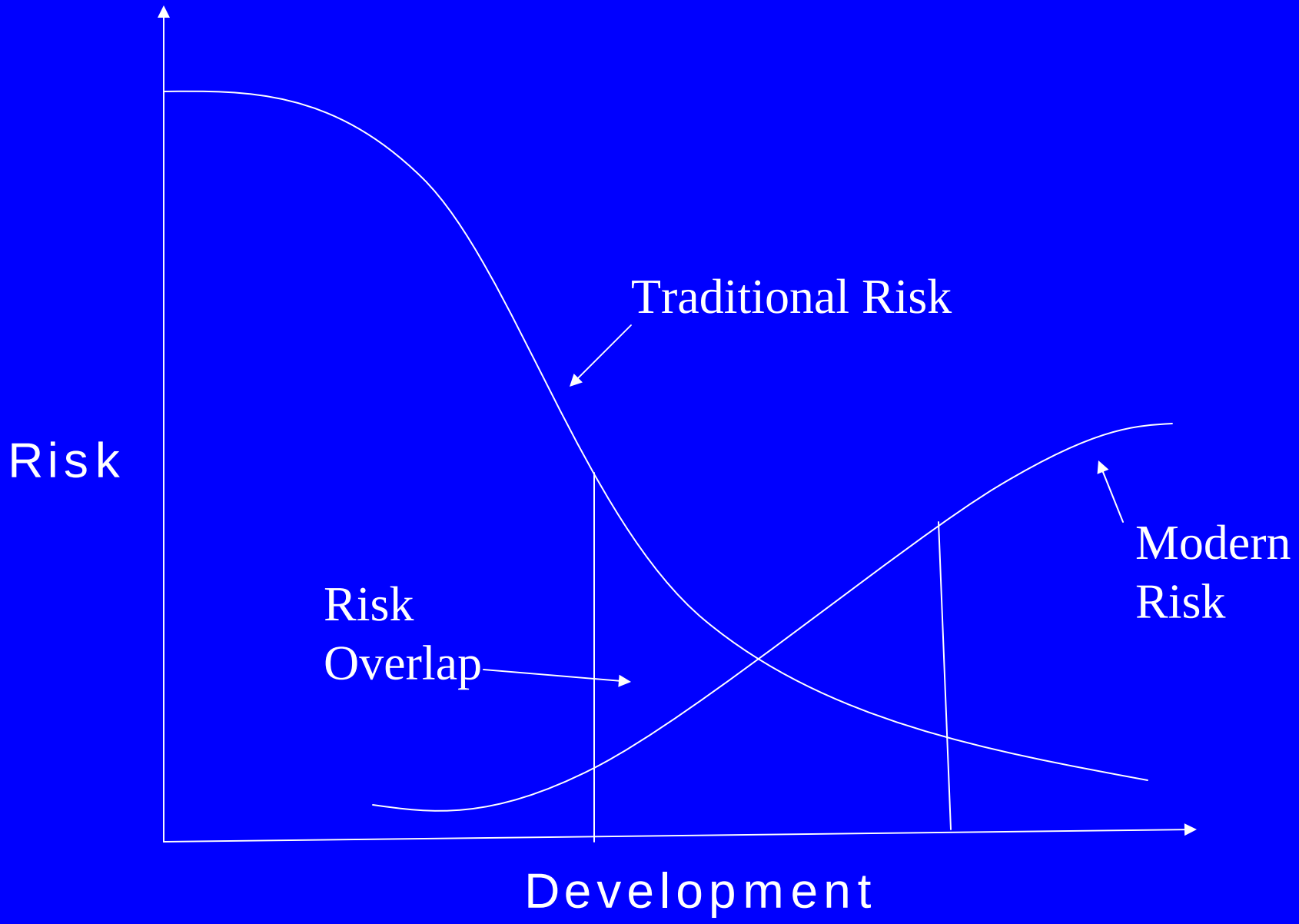
The Environmental Risk Transition



The Environmental Risk Transition



The Environmental Risk Transition



The Risk Overlap

- Risk Genesis: new types of risk created
- Risk Transfer: attempts to control one type can make other types worse
- Risk Synergism: risk of one type changes sensitivity to other risks

The Environmental Risk Transition

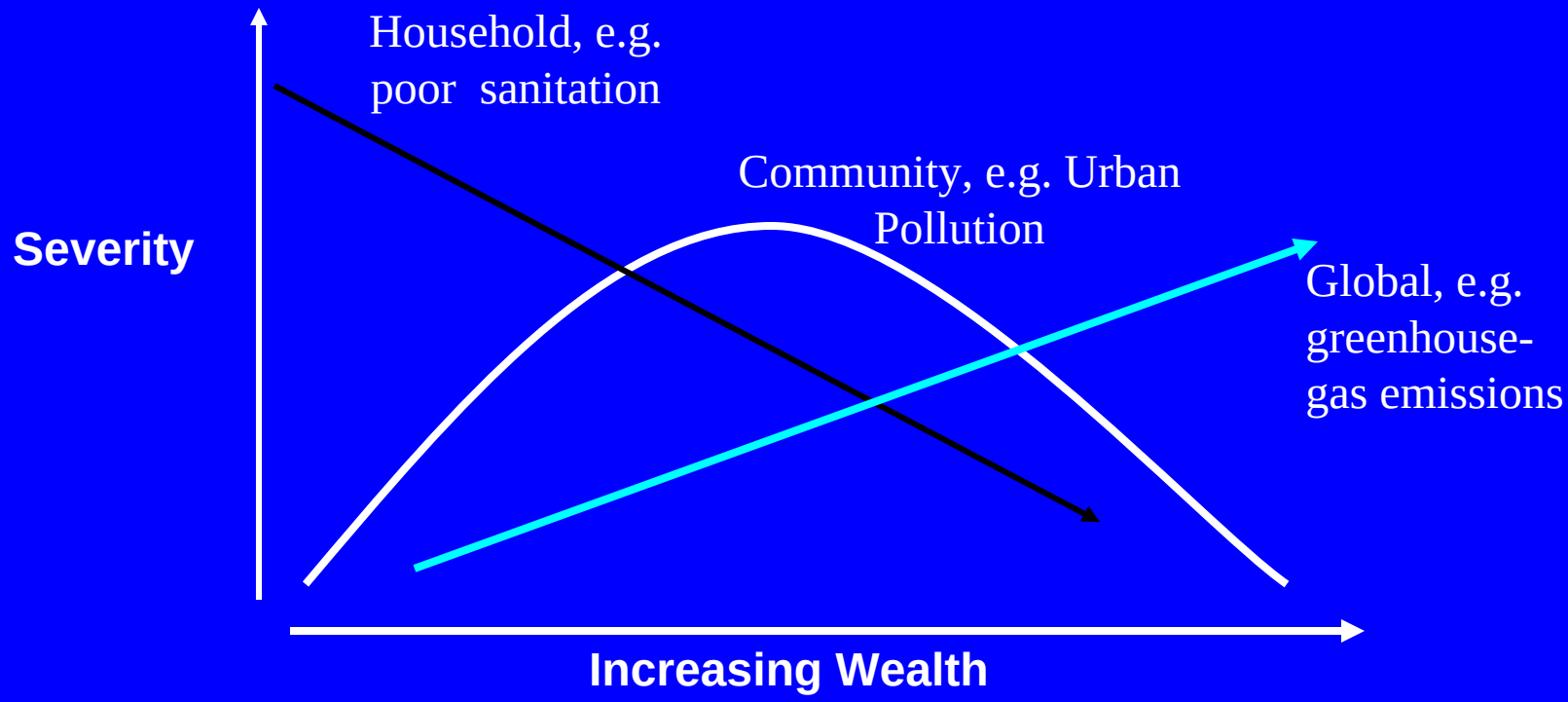
comes before

the **Epidemiologic Transition**

which comes before

the **Demographic Transition**

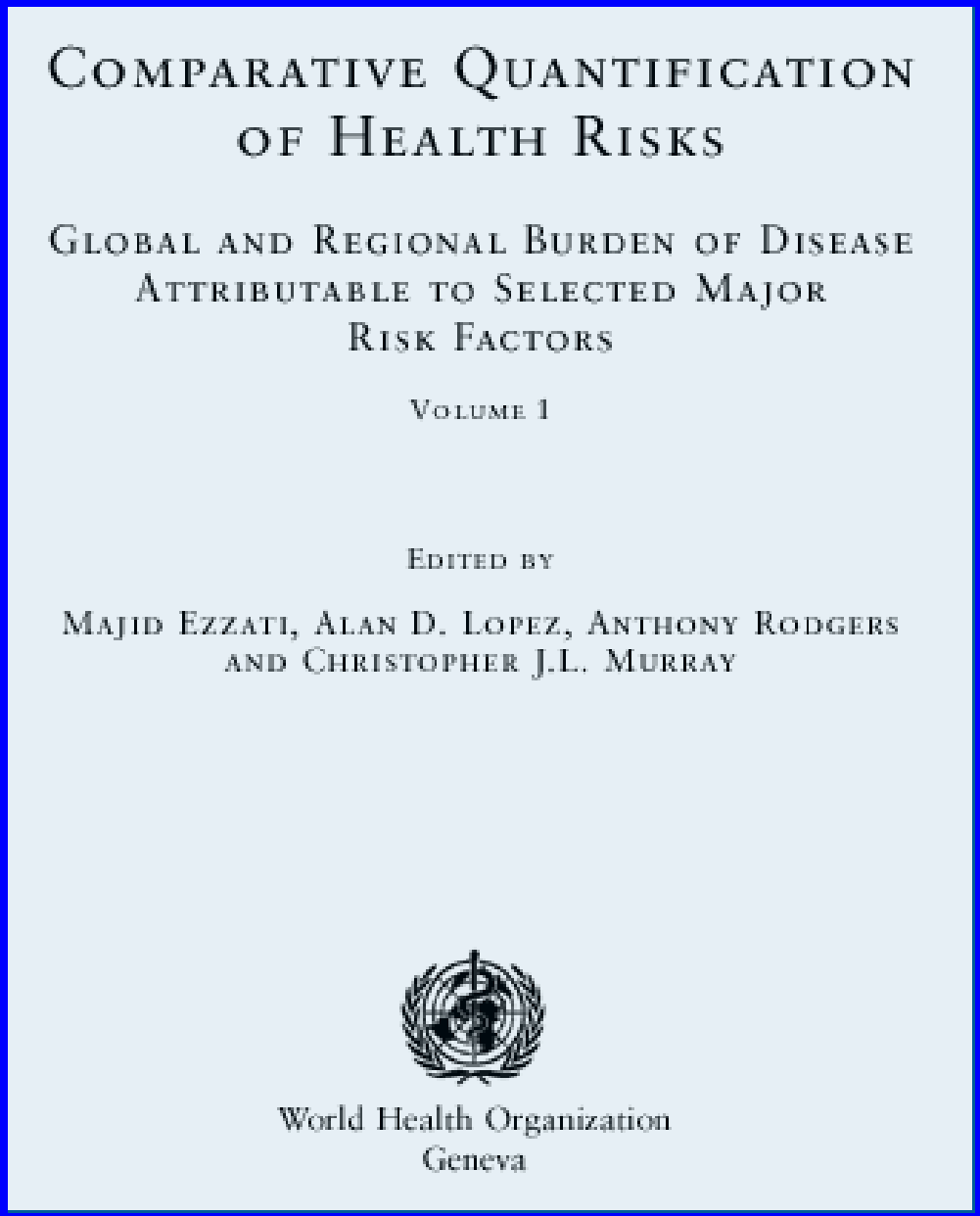
The Full Environmental Risk Transition



Shifting Environmental Burdens

Local → Global

Immediate → Delayed



Published in late 2004, 2 vols, ~2500 pp

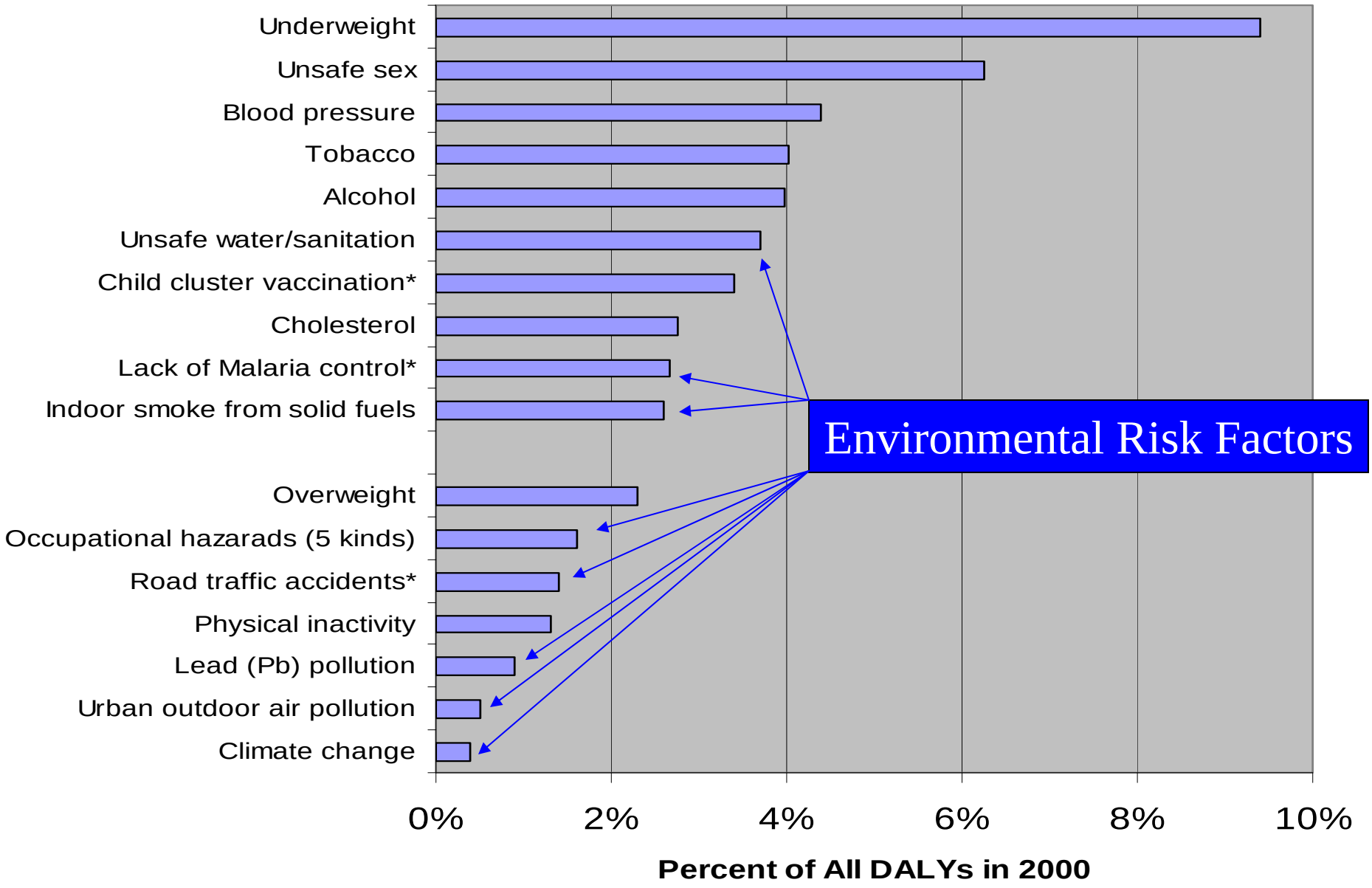
Available on World Health Organization website

Being completely revised Publication in 2010

http://www.who.int/publications/cra/en/

Global Burden of Disease from Top 10 Risk Factors

plus selected other risk factors



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

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

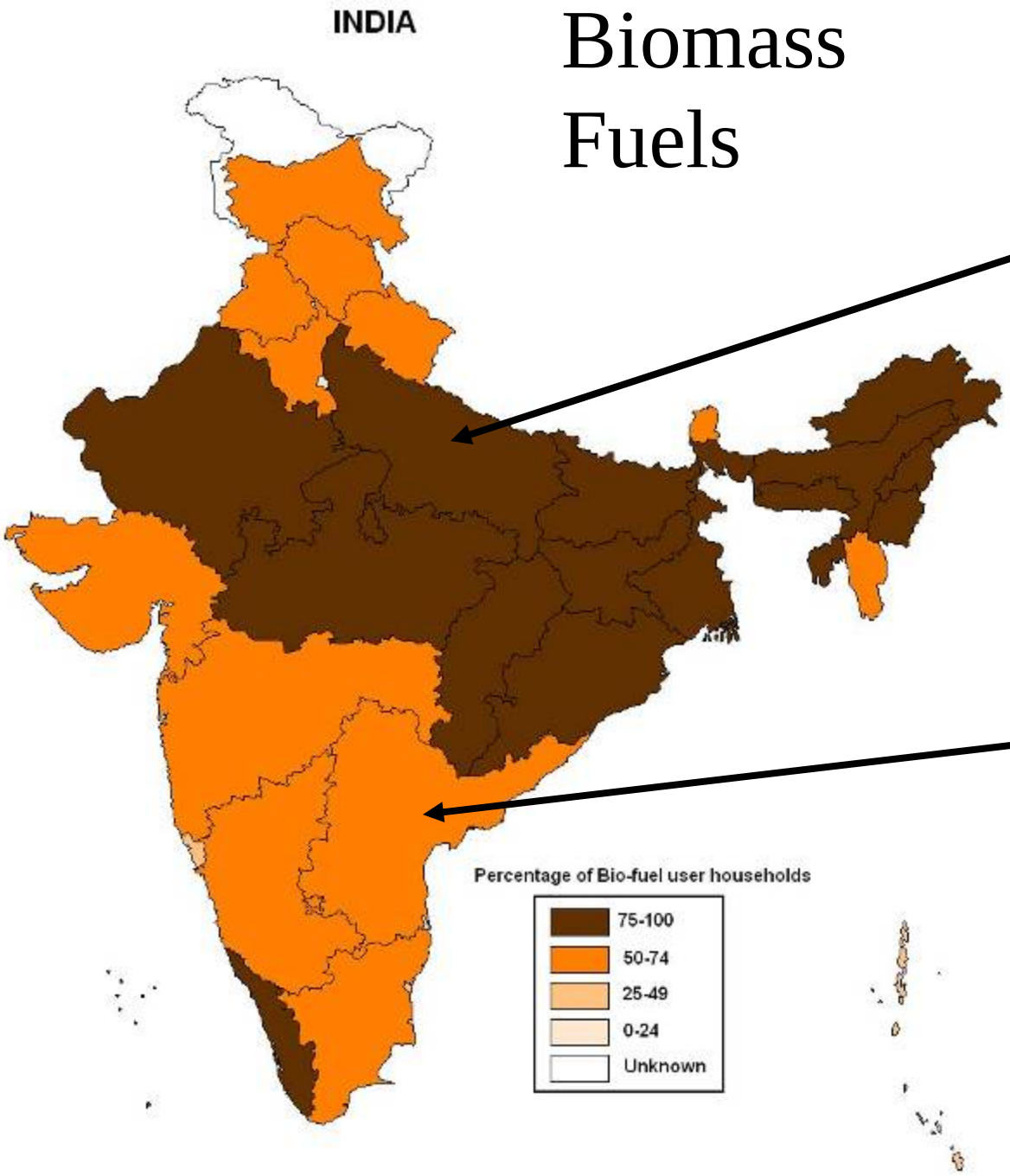
Source: Smith, et al., 2000

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

Biomass Fuels

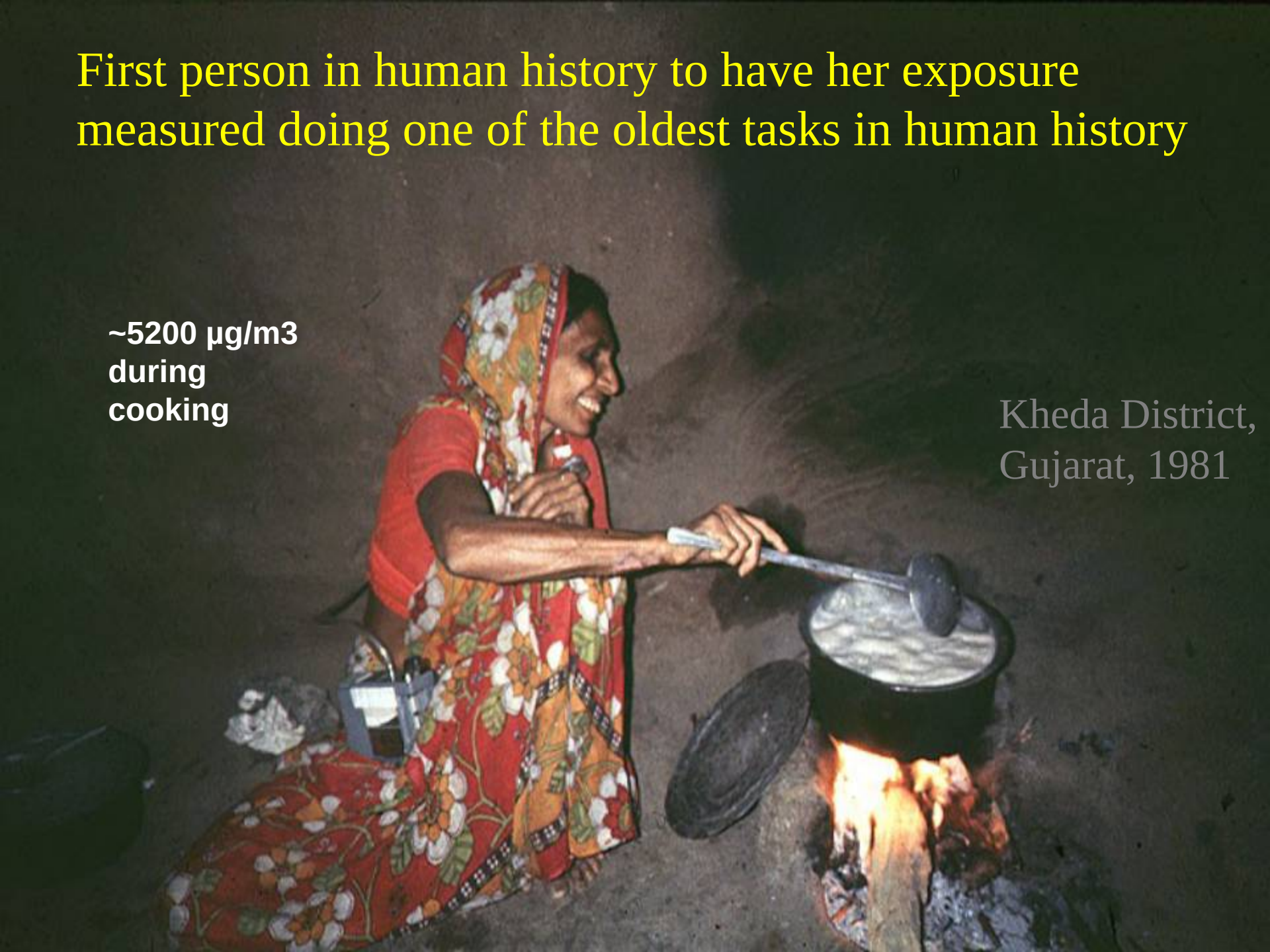


More than 75% of households

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



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

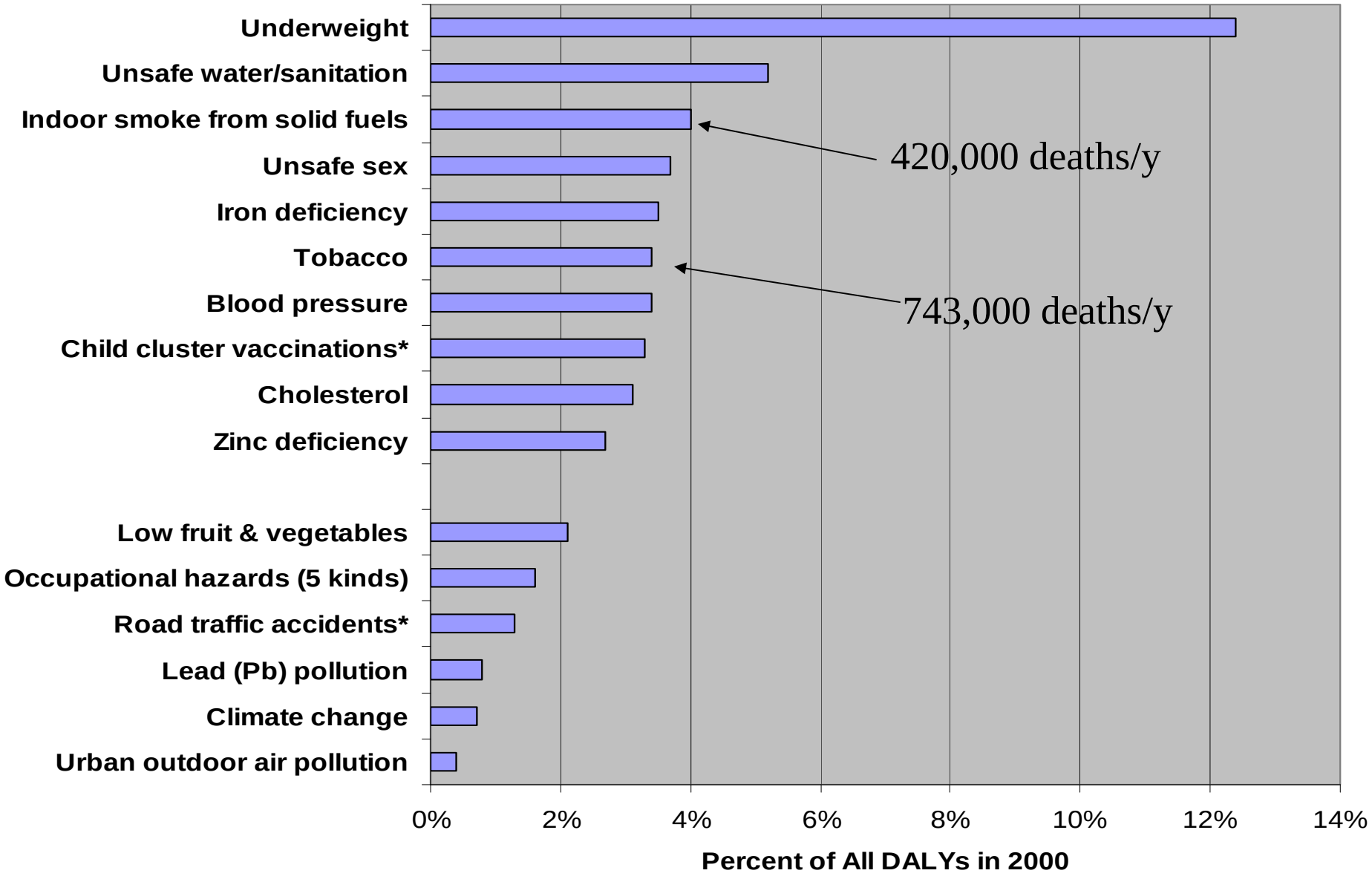
Absolutely no population even even poorest countries should be exposure to more than

70 µg/3

Data compliled by SRU, Chennai

Indian Burden of Disease from Top 10 Risk Factors

Plus Selected Other Risk Factors



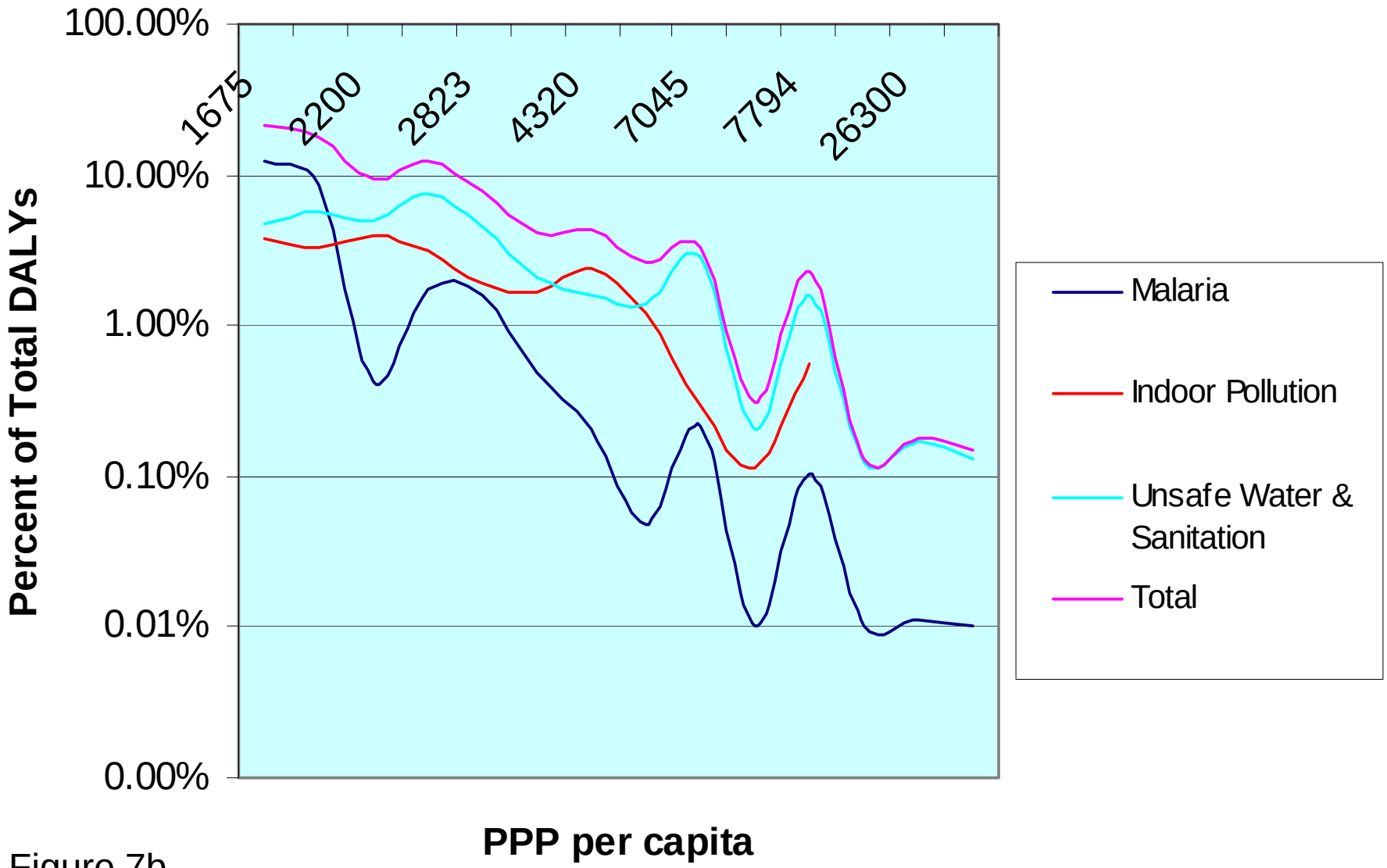

Household Risks-$PPP
100.00%
10.00%
1.00%
0.10%
0.01%
0.00%
1675
2200
2823
4320
7045
7794
26300
Percent of Total DALYs
PPP per capita
Malaria
Indoor Pollution
Unsafe Water & Sanitation
Total

Figure 7b

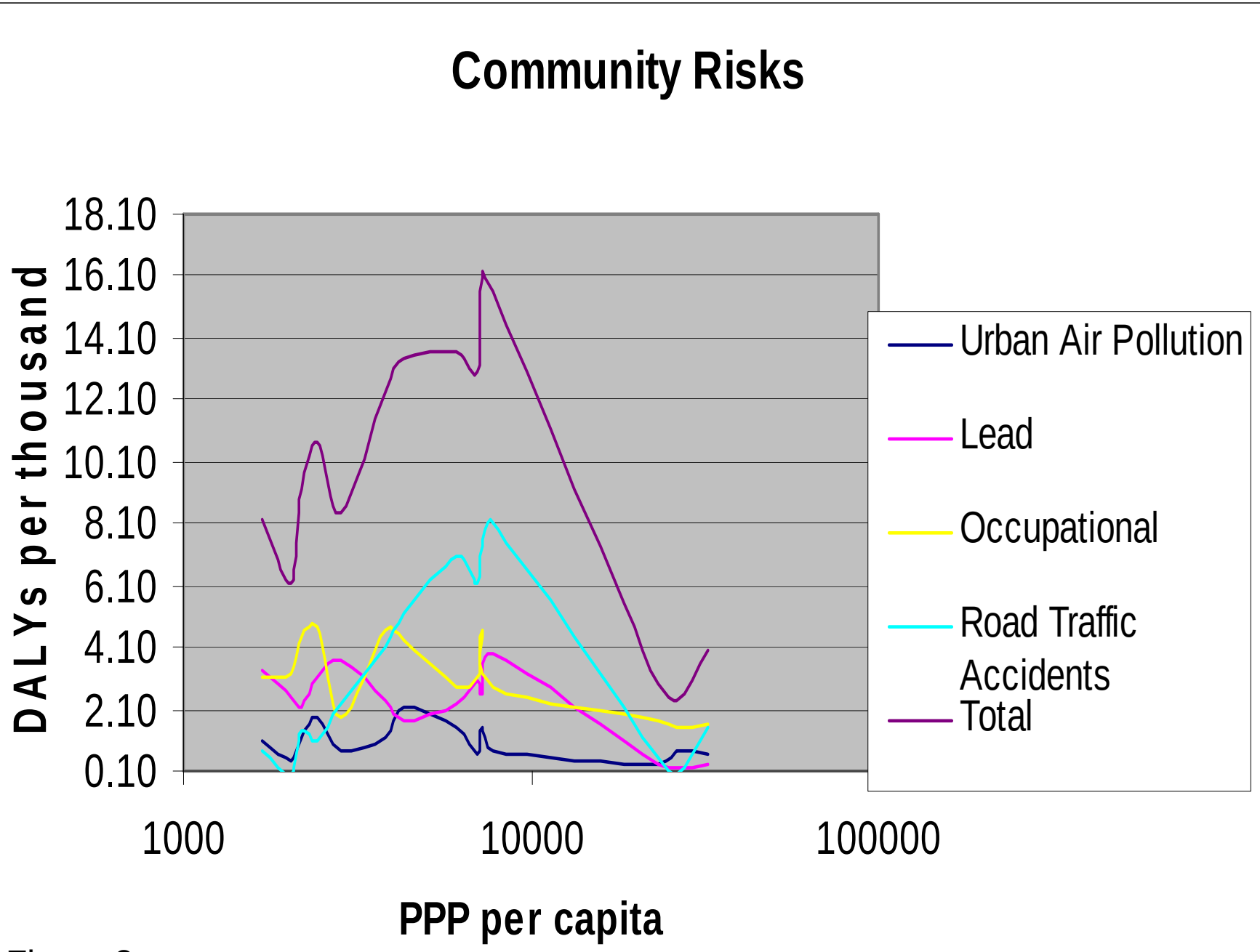
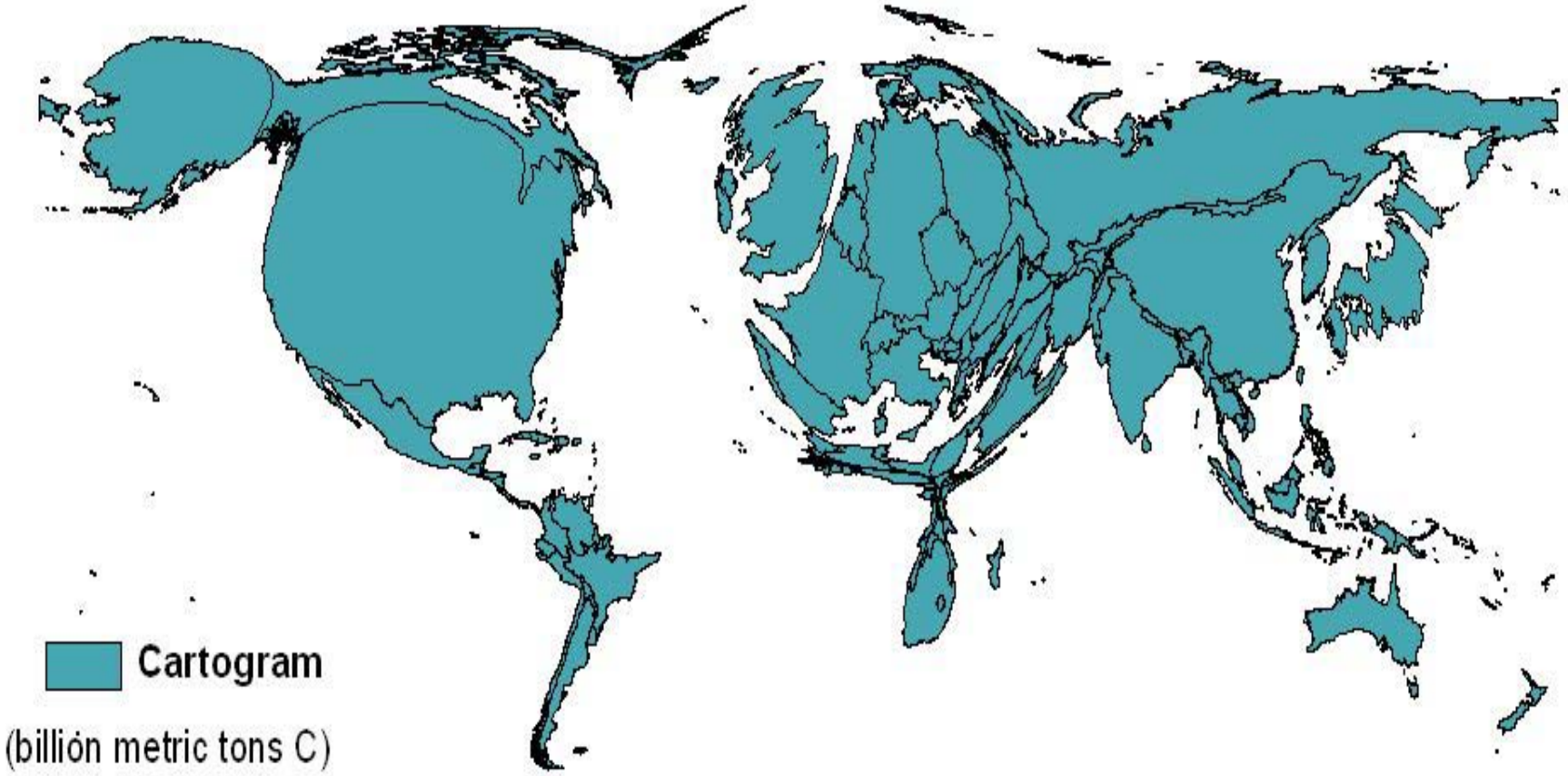

Community Risks
DALYs per thousand
18.10
16.10
14.10
12.10
10.10
8.10
6.10
4.10
2.10
0.10
1000
10000
100000
PPP per capita
Urban Air Pollution
Lead
Occupational
Road Traffic Accidents
Total

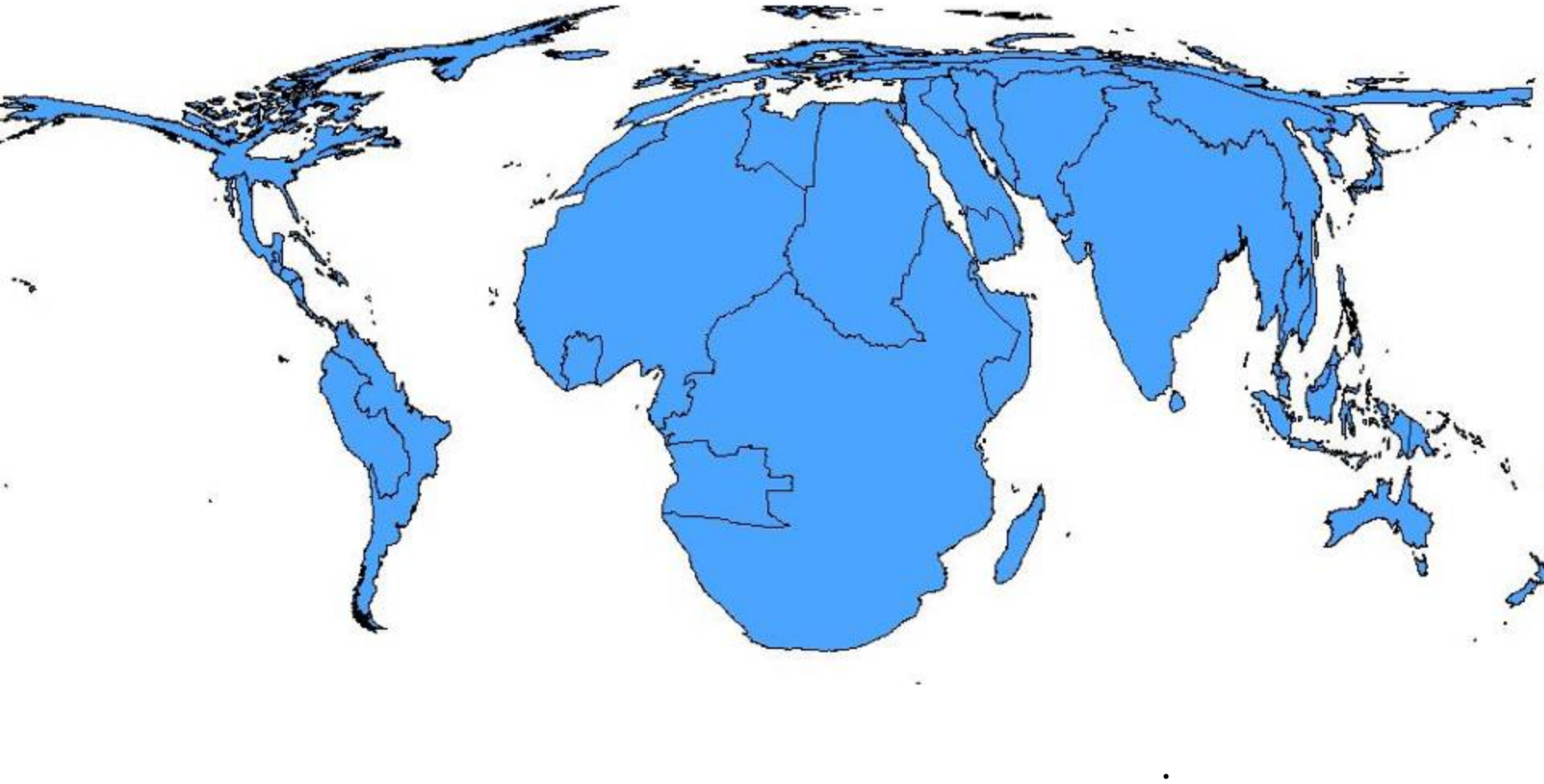
Figure 8a

Cumulative CO_2 emissions from fossil fuels (as depleted by natural processes)



Patz JA, Gibbs HK, Foley JA, Rogers JV, Smith KR, 2007, **Climate change and global health: Quantifying a growing ethical crisis**, EcoHealth 4(4): 397–405, 2007.

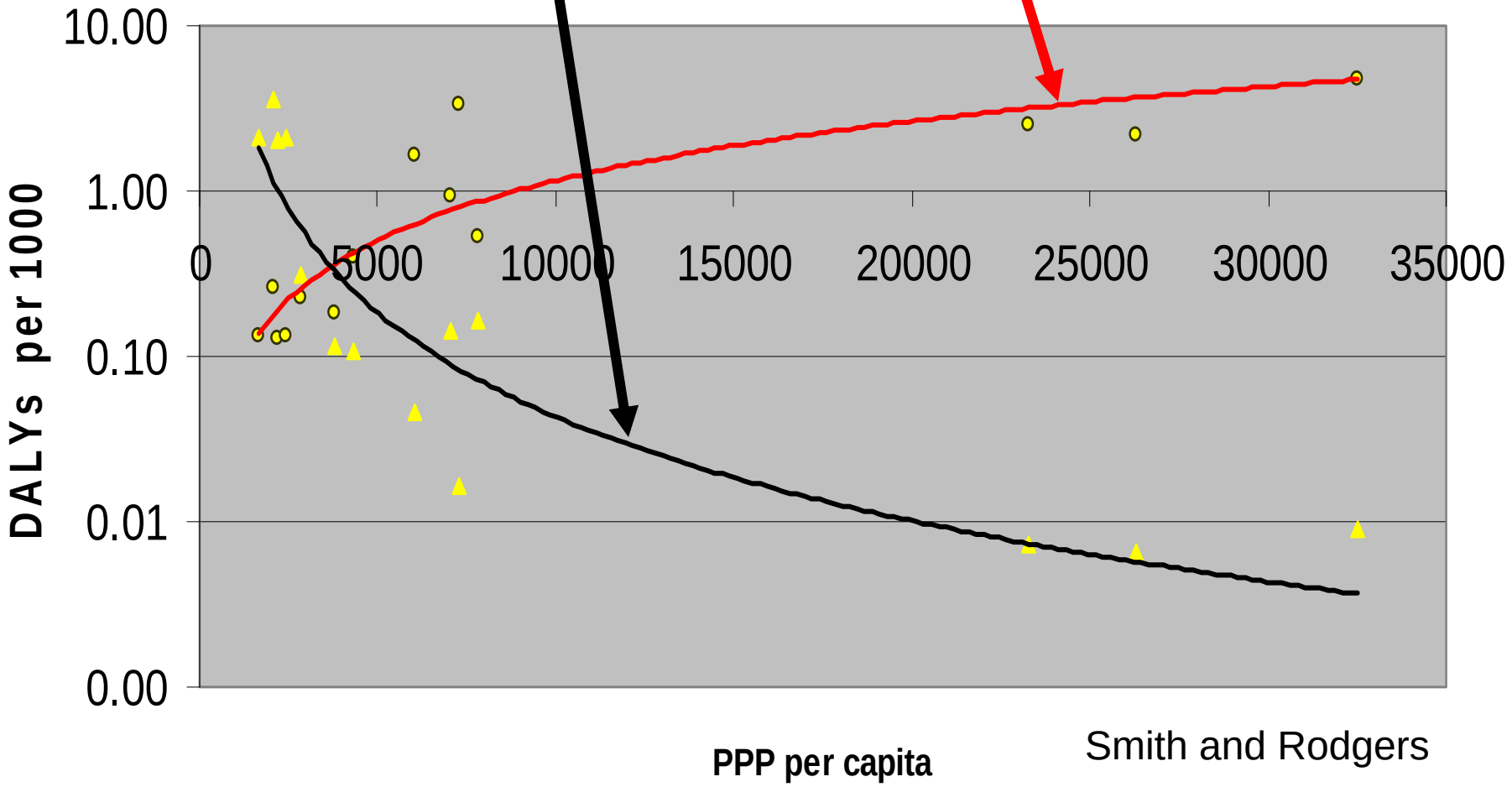
Cartogram of Climate-related Mortality (per million pop) yr. 2000



Patz JA, Gibbs HK, Foley JA, Rogers JV, Smith KR, 2007, **Climate change and global health: Quantifying a growing ethical crisis**, EcoHealth 4(4): 397–405, 2007.

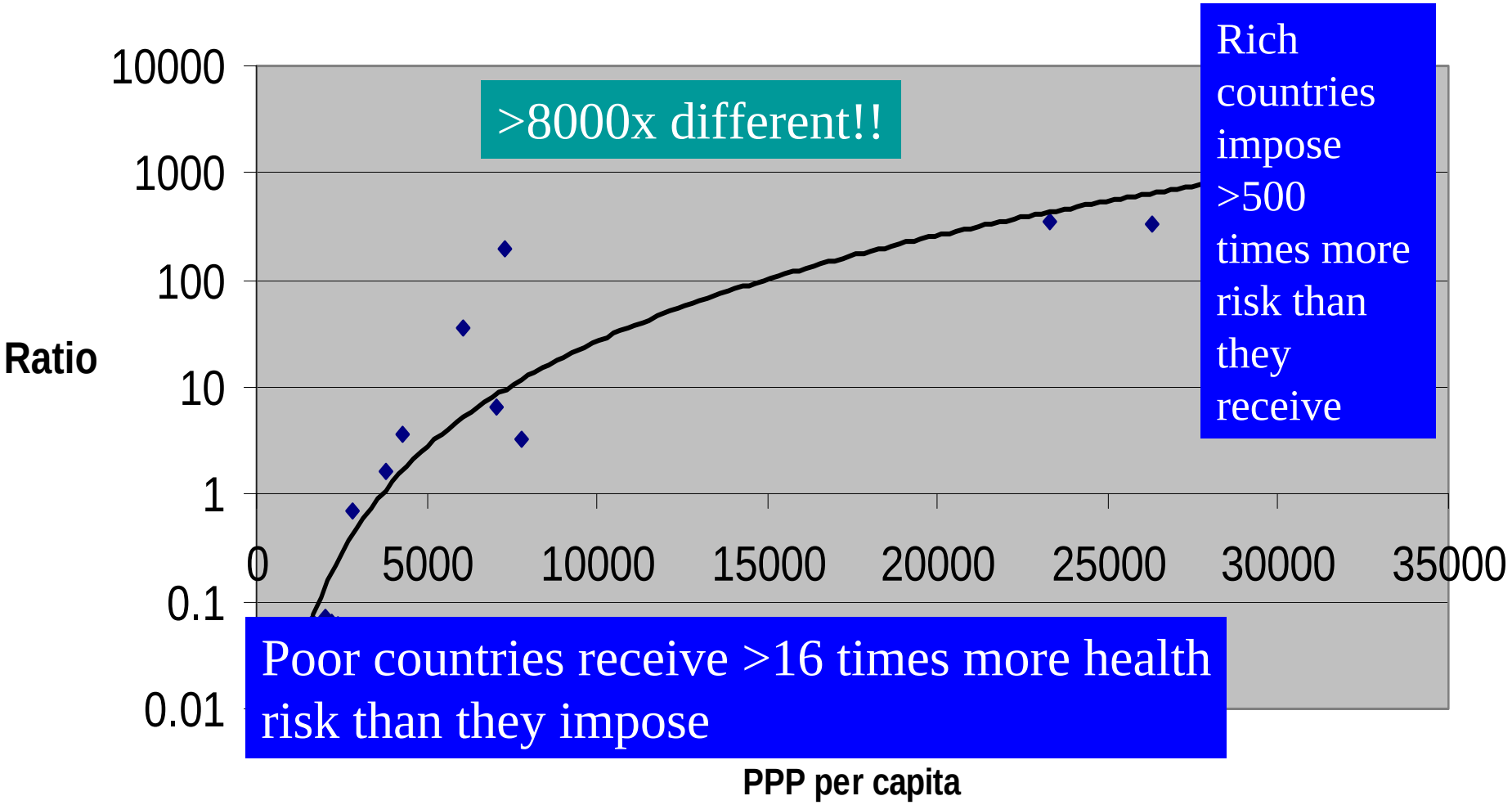
Distribution of Health Impacts from Climate Change

(Experiencing versus Imposing)



Smith and Rodgers

Distribution of Health Impacts from Climate Change (Ratio: Imposing/Experiencing)



Environmental Risk Transition
(Imposed Global Risk)

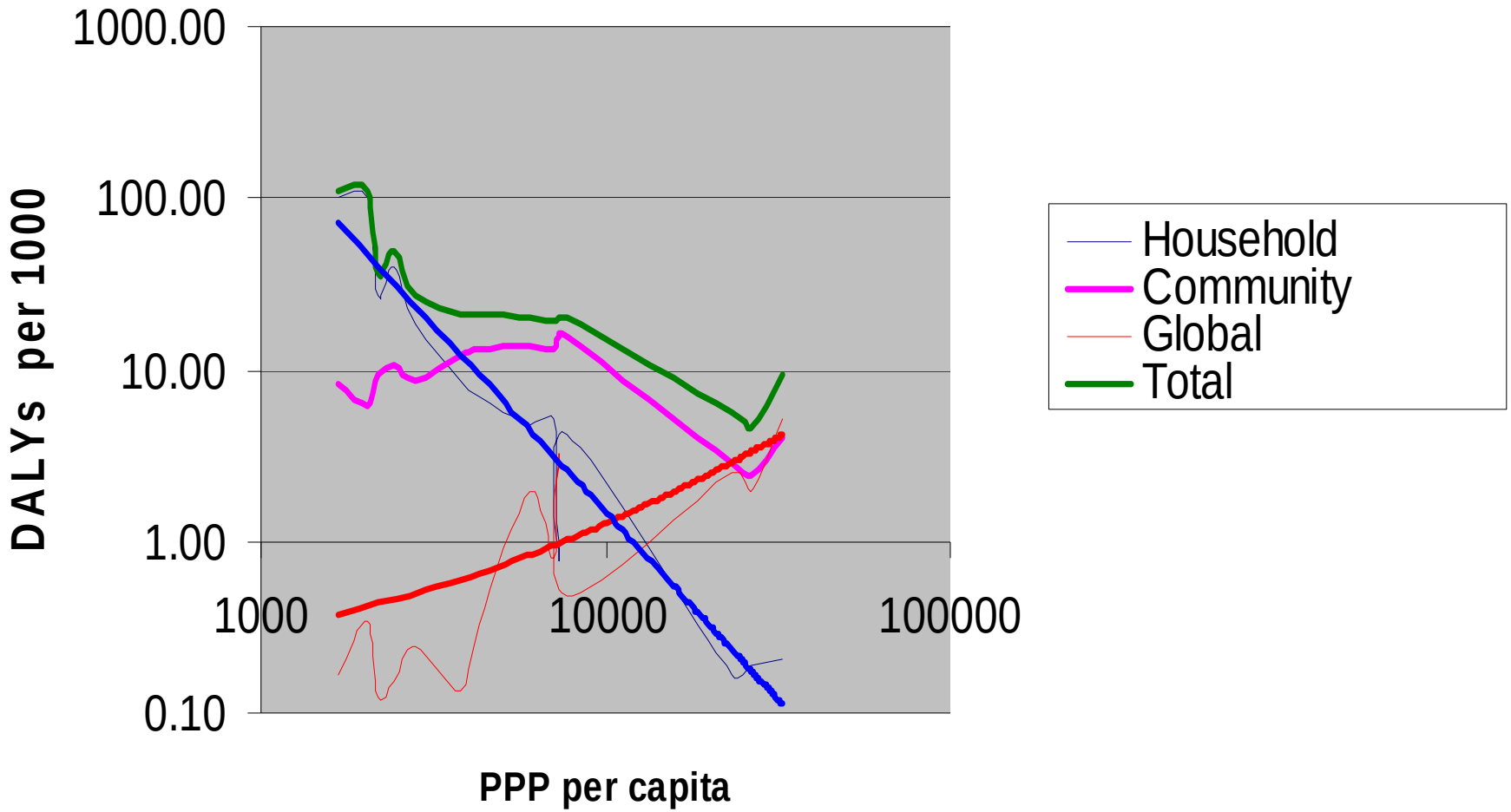
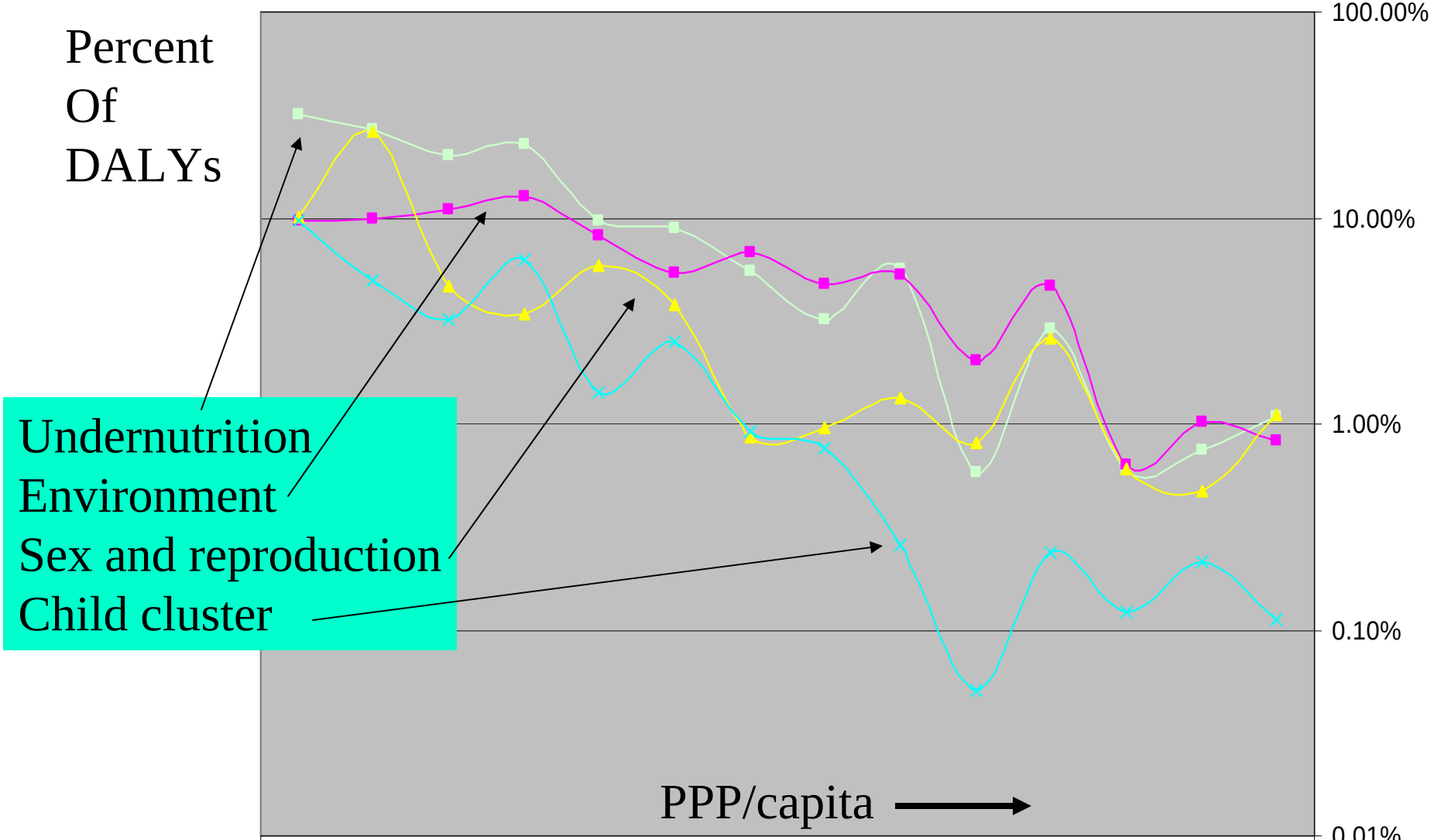
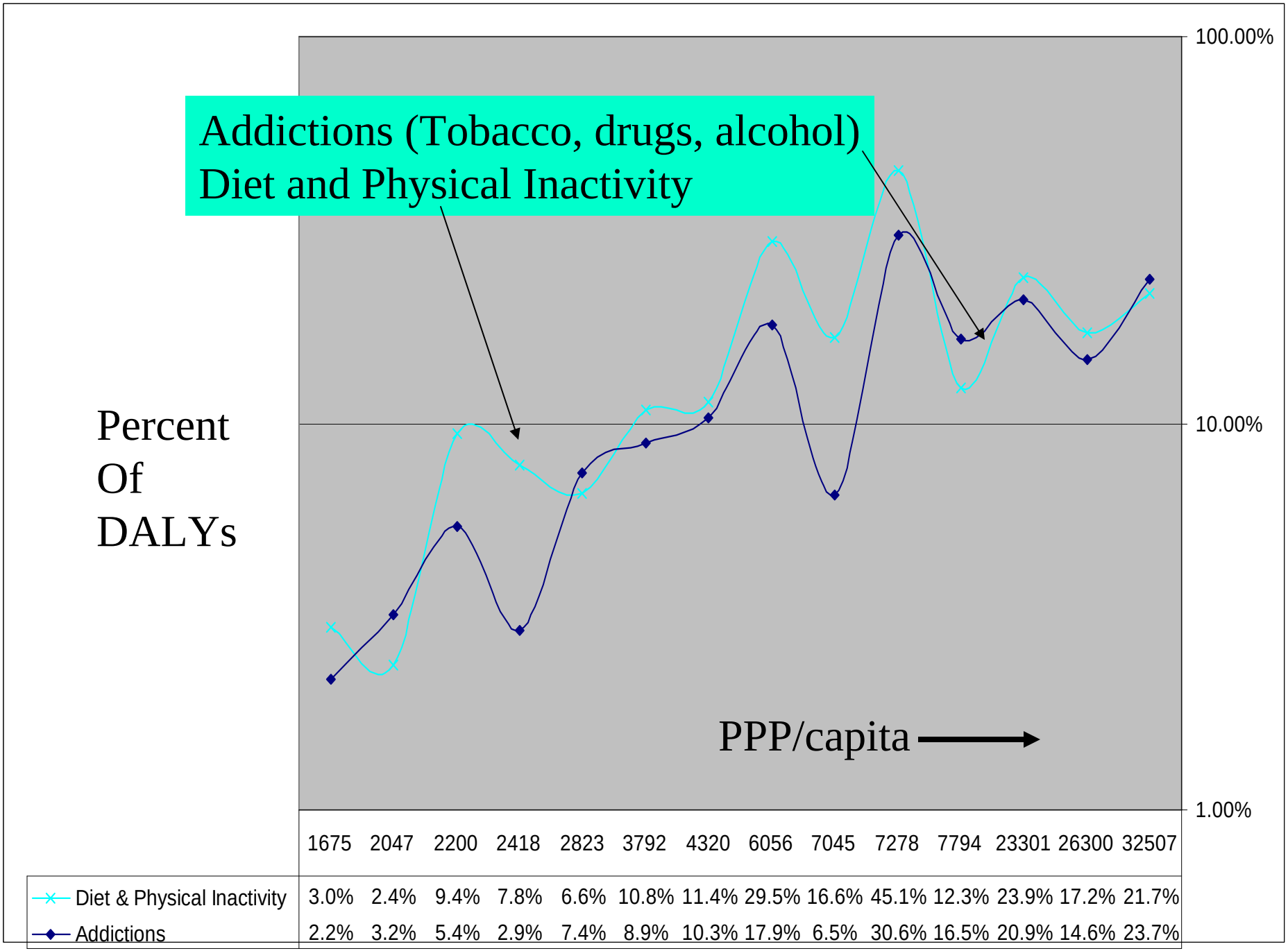
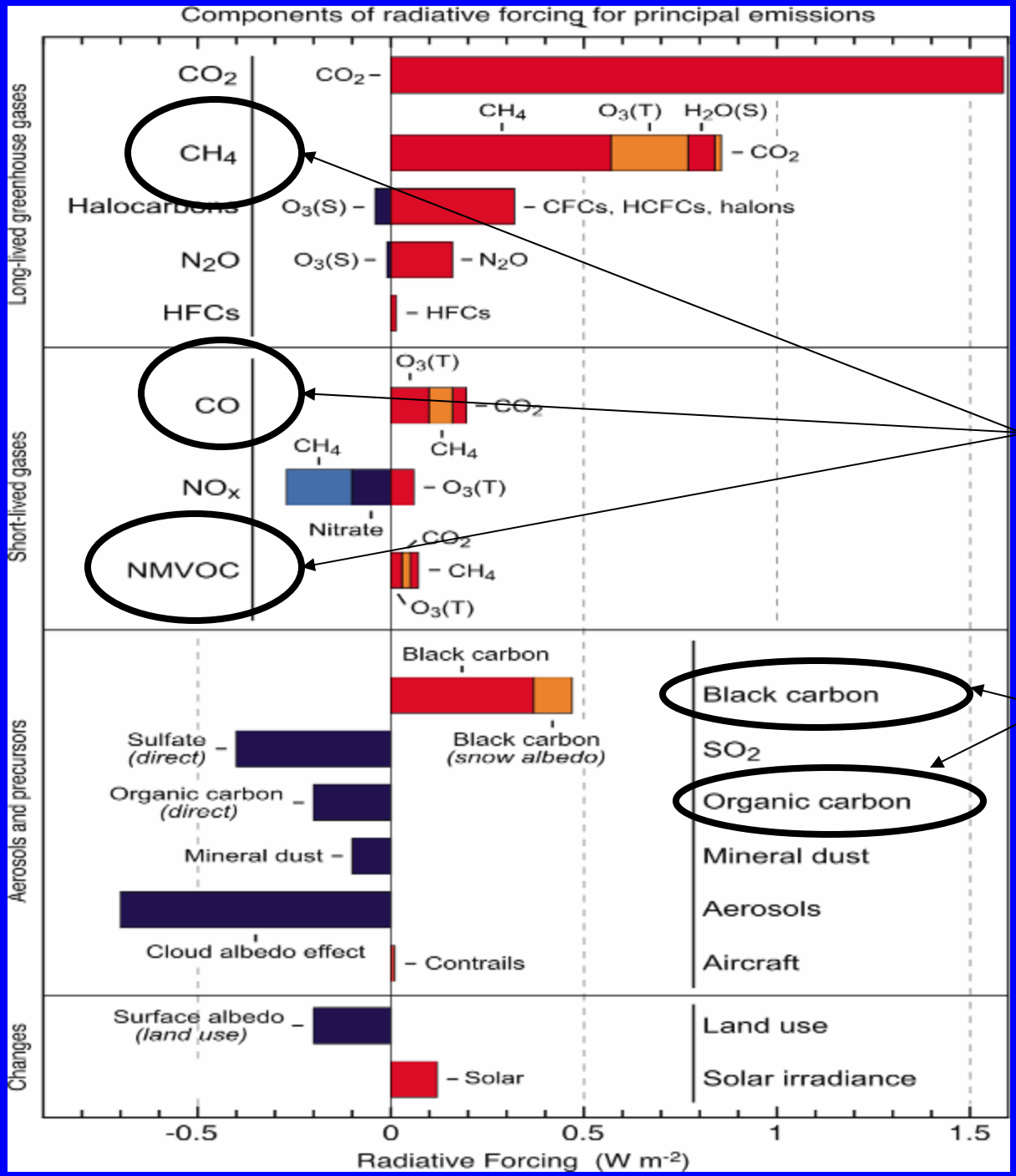


Figure 10



	1675	2047	2200	2418	2823	3792	4320	6056	7045	7278	7794	23301	26300	32507
Undernutrition	31.6%	26.8%	20.1%	22.8%	9.7%	9.0%	5.5%	3.2%	5.6%	0.6%	2.9%	0.6%	0.8%	1.1%
Environment	9.6%	10.0%	11.0%	12.6%	8.2%	5.4%	6.8%	4.8%	5.3%	2.0%	4.7%	0.6%	1.0%	0.8%
Sex and reproduct	10.1%	26.4%	4.7%	3.4%	5.9%	3.8%	0.9%	1.0%	1.4%	0.8%	2.6%	0.6%	0.5%	1.1%
Child Cluster	9.8%	5.0%	3.2%	6.3%	1.4%	2.5%	0.9%	0.8%	0.3%	0.1%	0.2%	0.1%	0.2%	0.1%

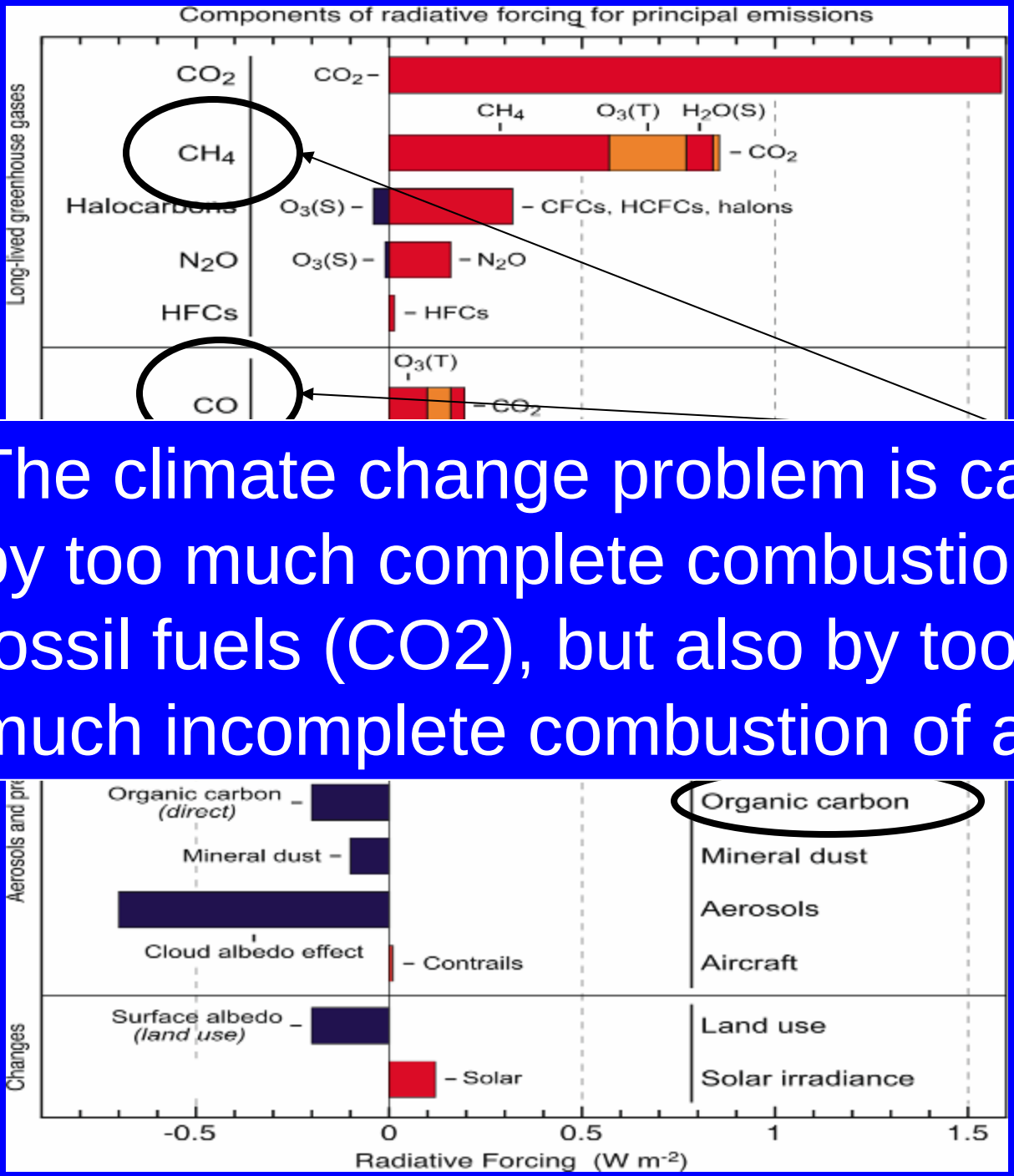

Addictions (Tobacco, drugs, alcohol)
Diet and Physical Inactivity
Percent
Of
DALYs
100.00%
10.00%
1.00%
PPP/capita
1675 2047 2200 2418 2823 3792 4320 6056 7045 7278 7794 23301 26300 32507
Diet & Physical Inactivity 3.0% 2.4% 9.4% 7.8% 6.6% 10.8% 11.4% 29.5% 16.6% 45.1% 12.3% 23.9% 17.2% 21.7%
Addictions 2.2% 3.2% 5.4% 2.9% 7.4% 8.9% 10.3% 17.9% 6.5% 30.6% 16.5% 20.9% 14.6% 23.7%



Warming in 2005 from emissions since 1750

A large part from PIC: products of incomplete combustion

IPCC, 2007



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)

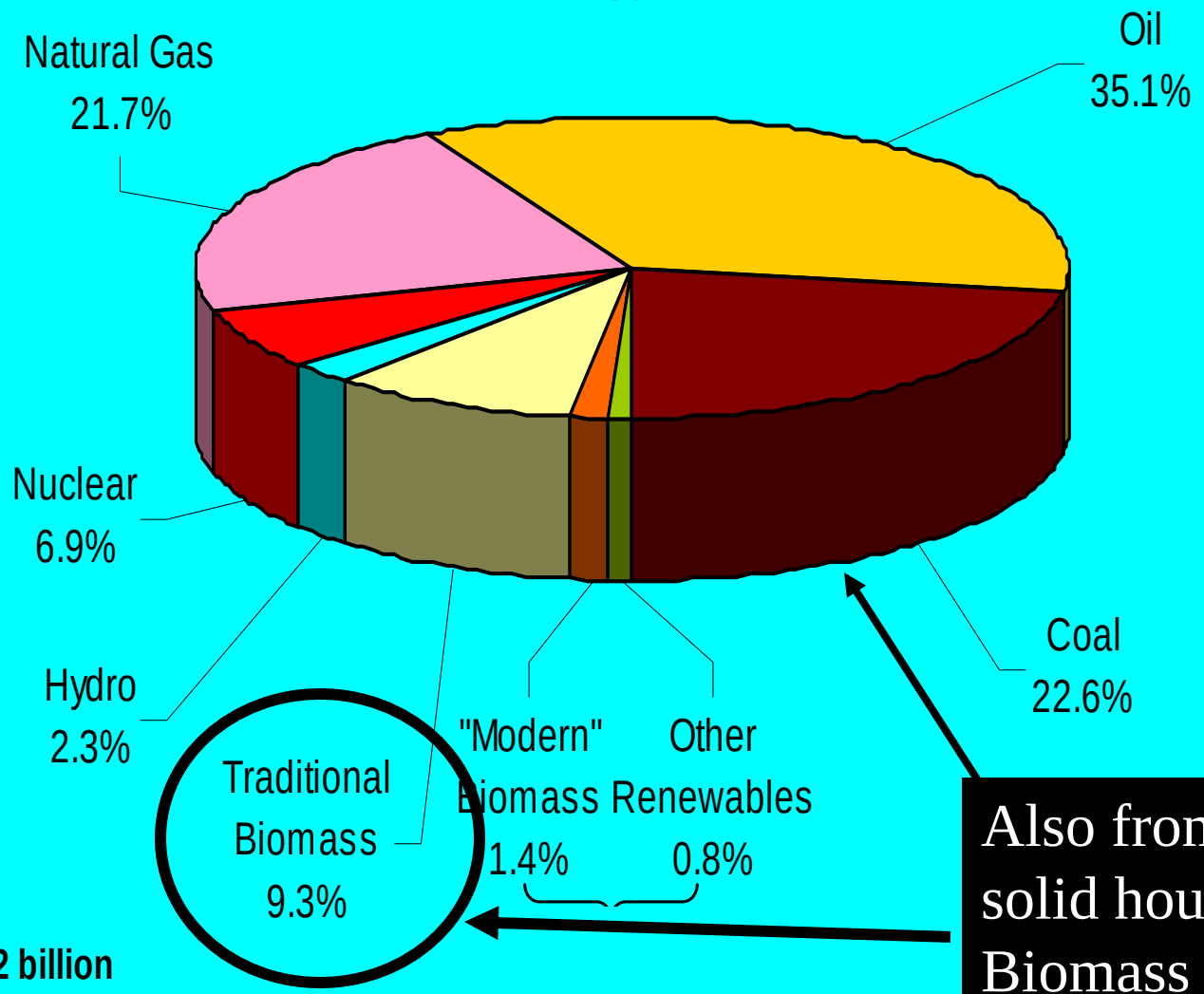
IPCC, 2007

Where do these PIC come from?

From forest and savannah fires – not directly human caused in general

Where else?

World Energy – 2001



Population: 6.102 billion

Total energy use: 10.2 Gtoe

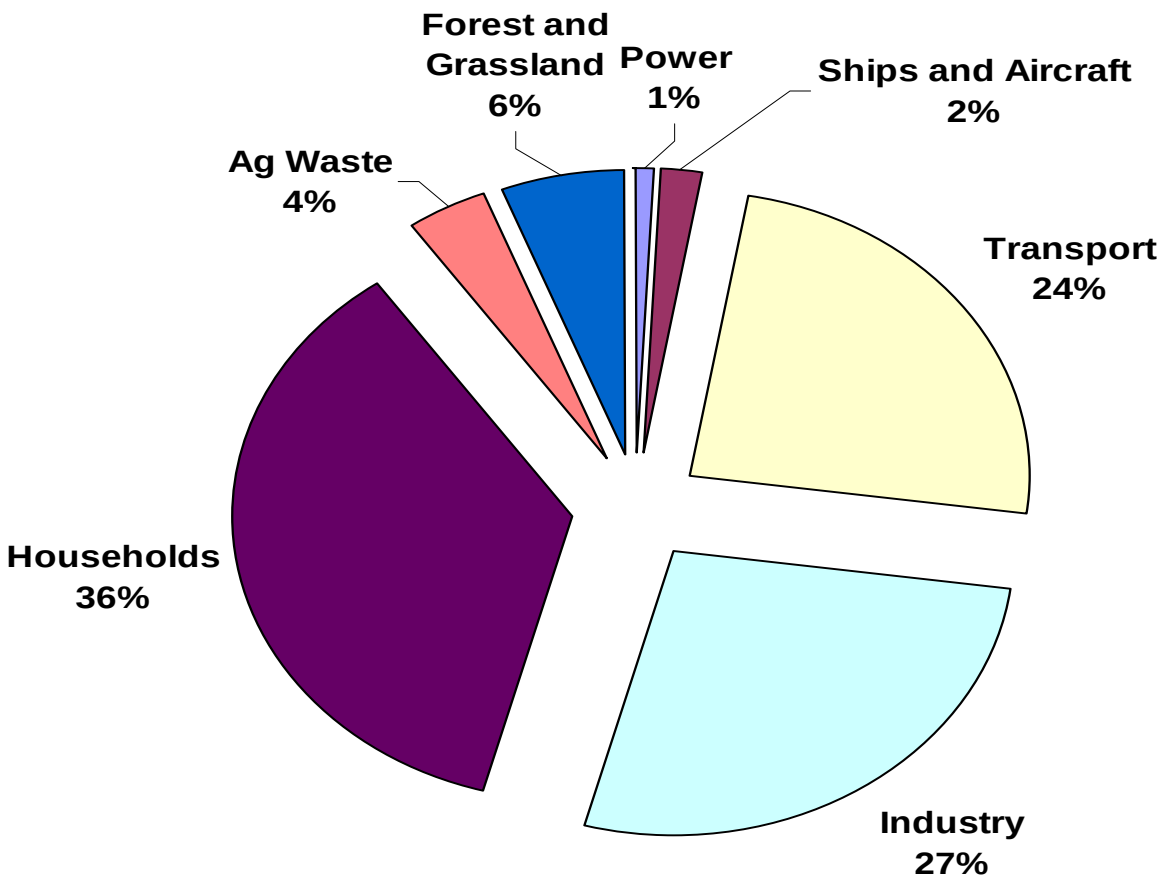
Per capita energy consumption: 1.67 toe

World Energy Assessment, 2004

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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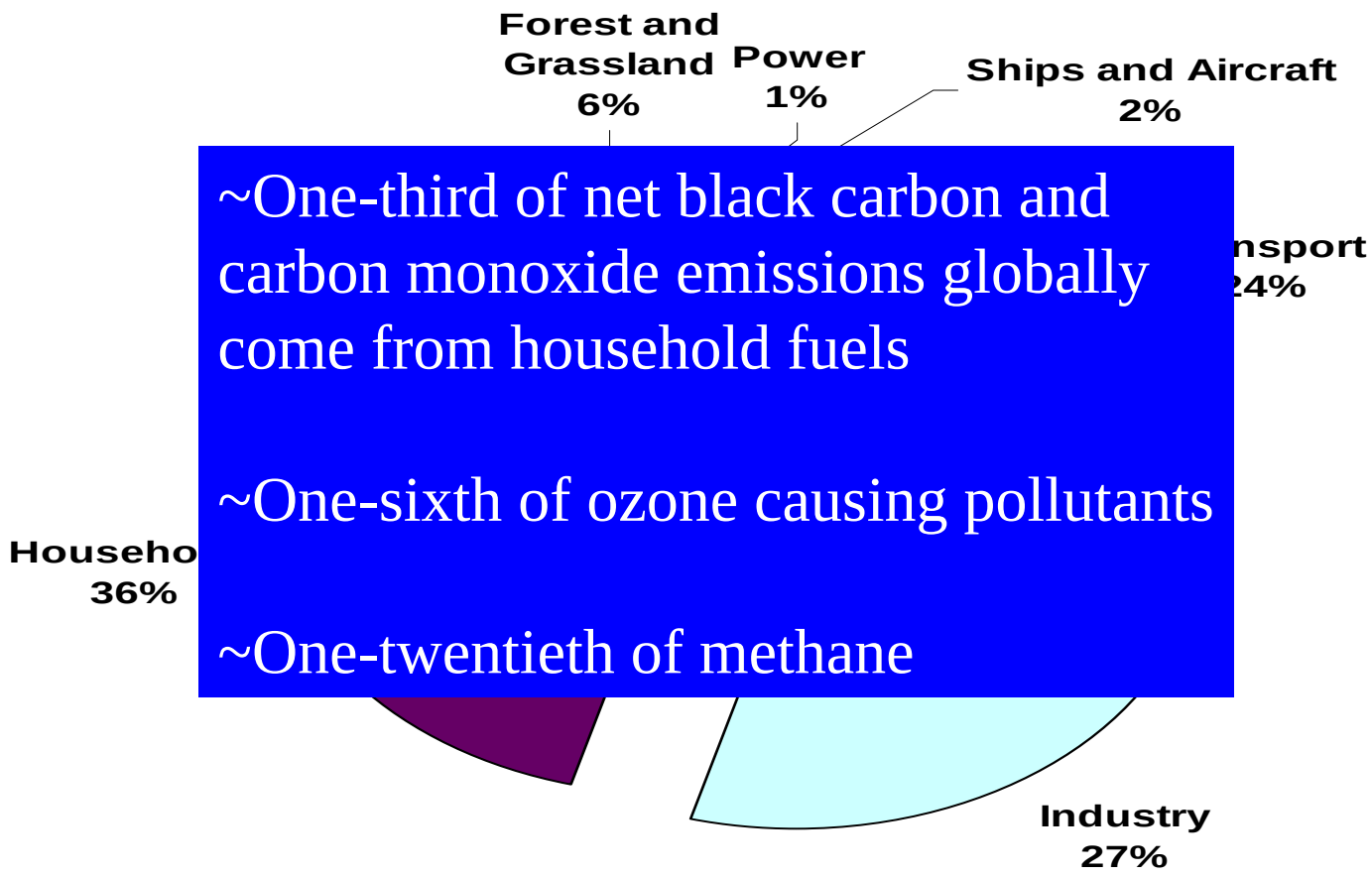
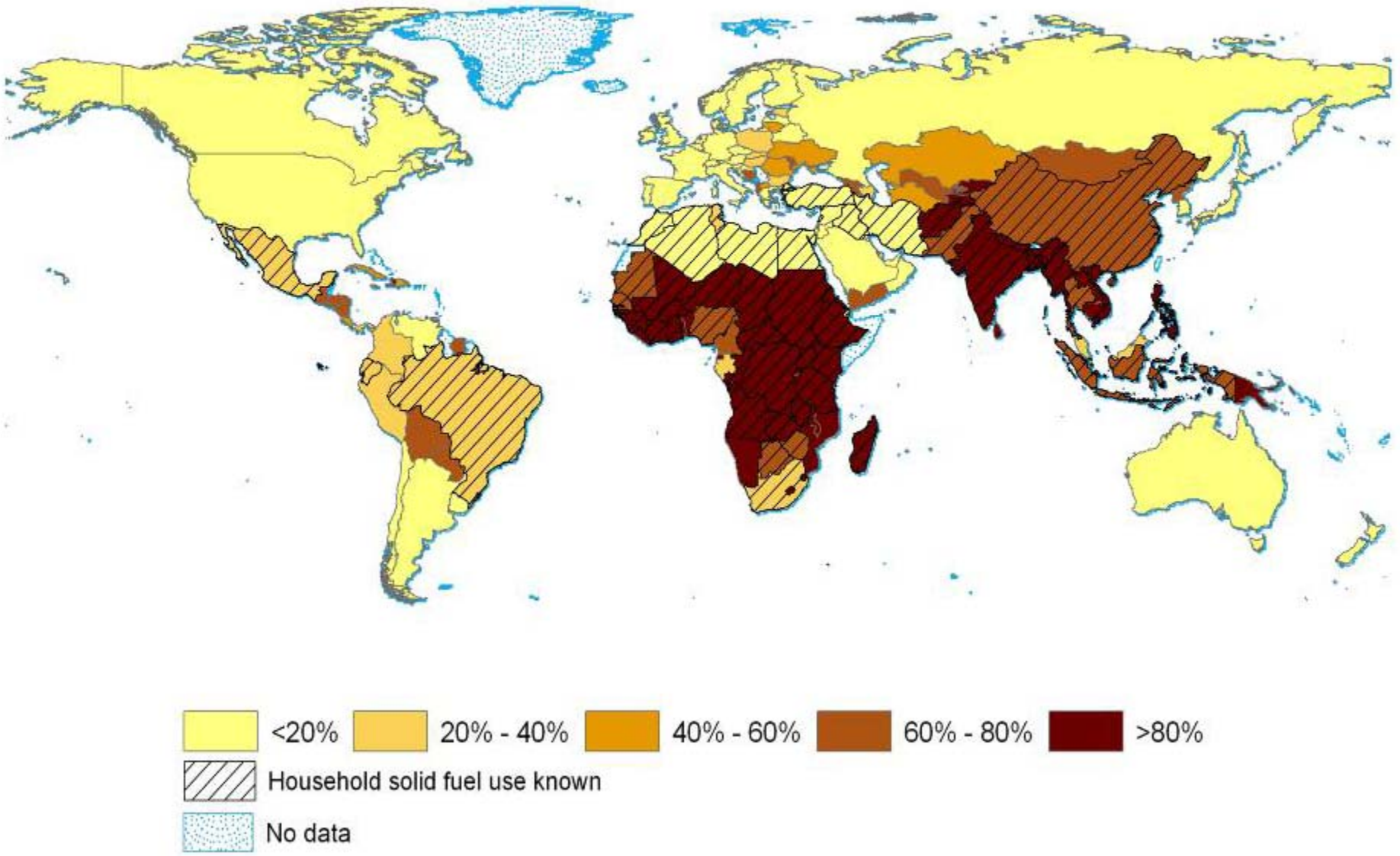


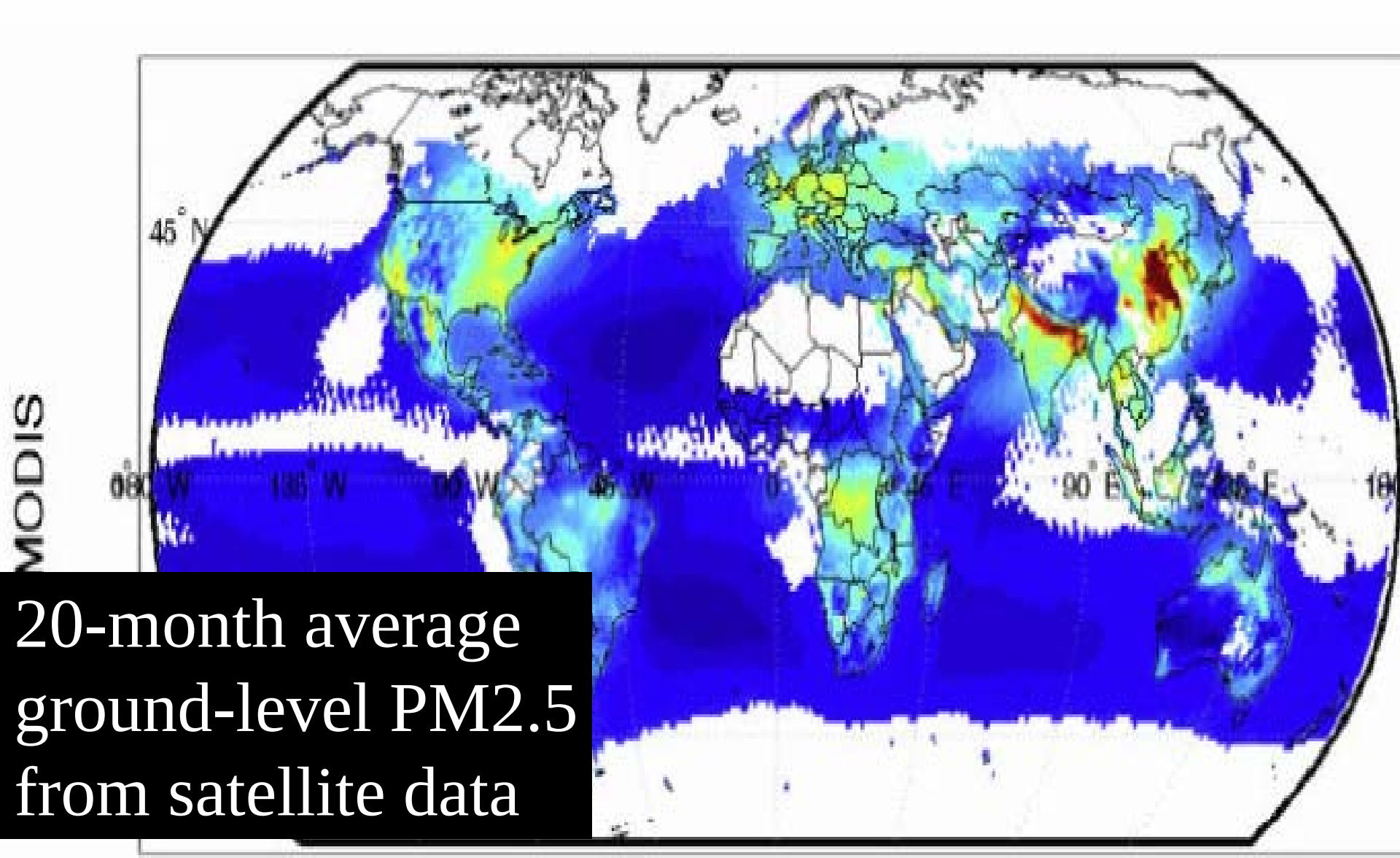
~One-third of net black carbon and carbon monoxide emissions globally come from household fuels

~One-sixth of ozone causing pollutants

~One-twentieth of methane

National Household Solid Fuel Use, 2000





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

A Biomass Gasifier Stove

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

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

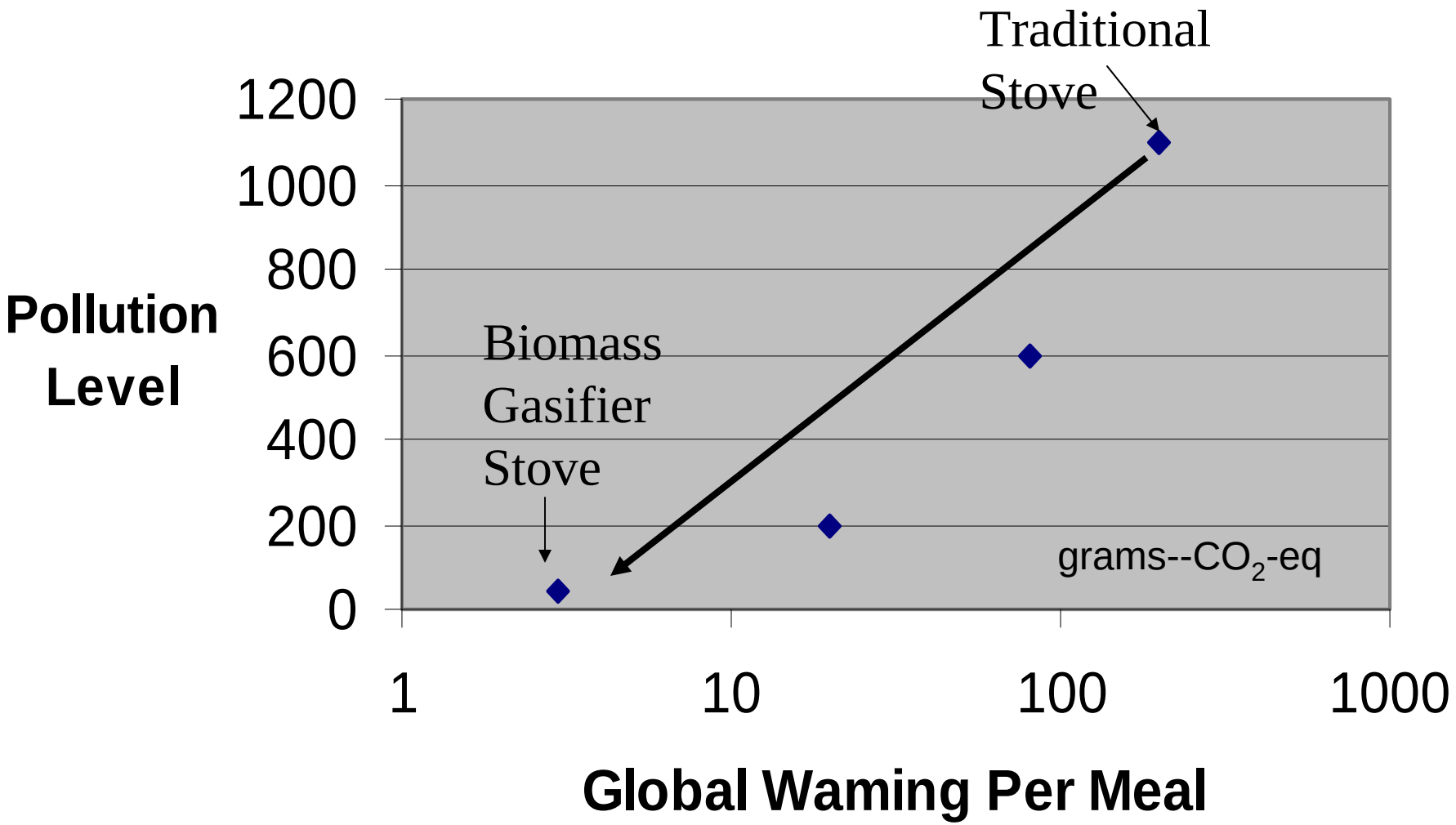
Compared to traditional biomass stove

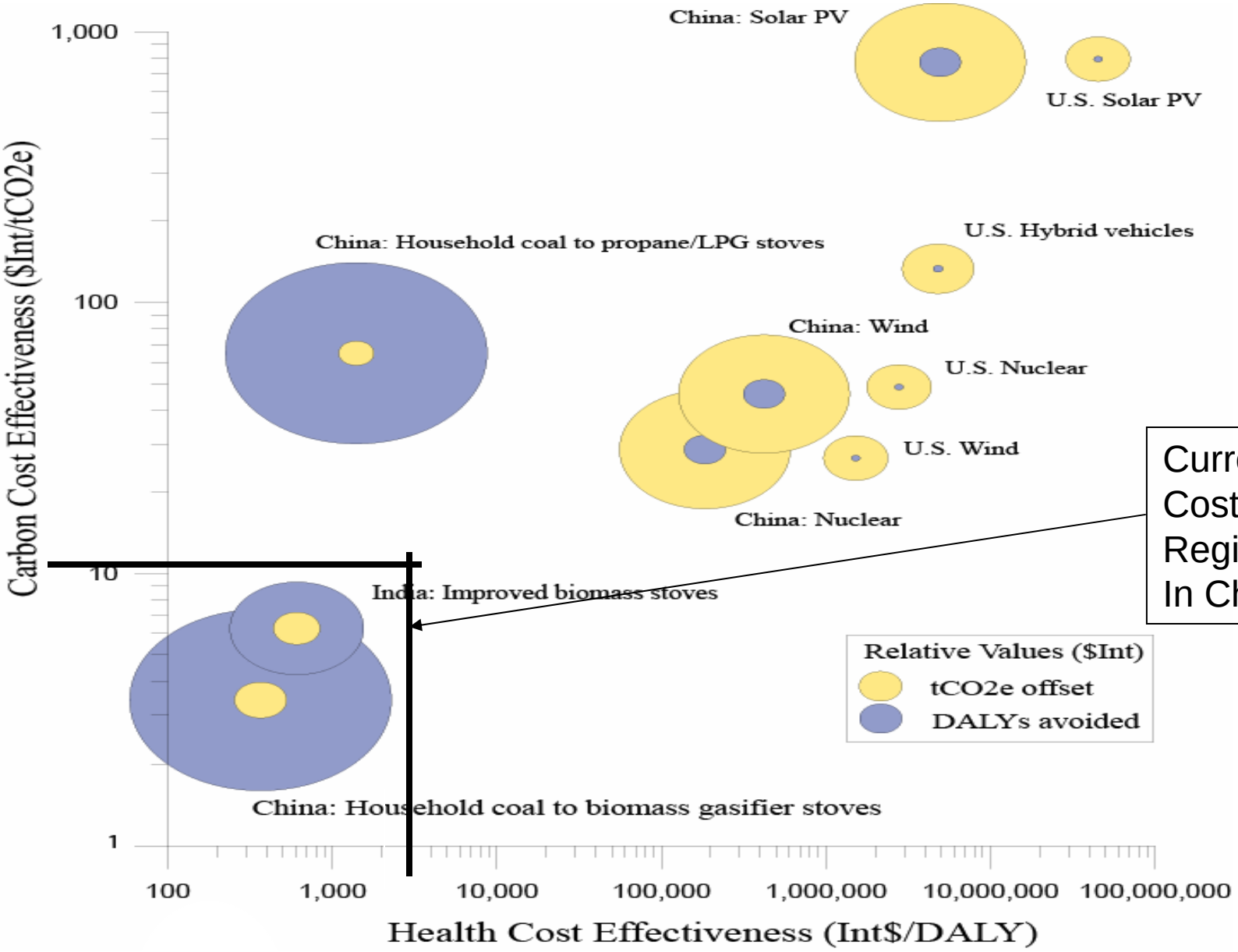
32-45 times less mass of small particles per meal

* Typical values ** Nominal combustion efficiency


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

Health and Greenhouse Gas Benefits of Biomass Stove Options

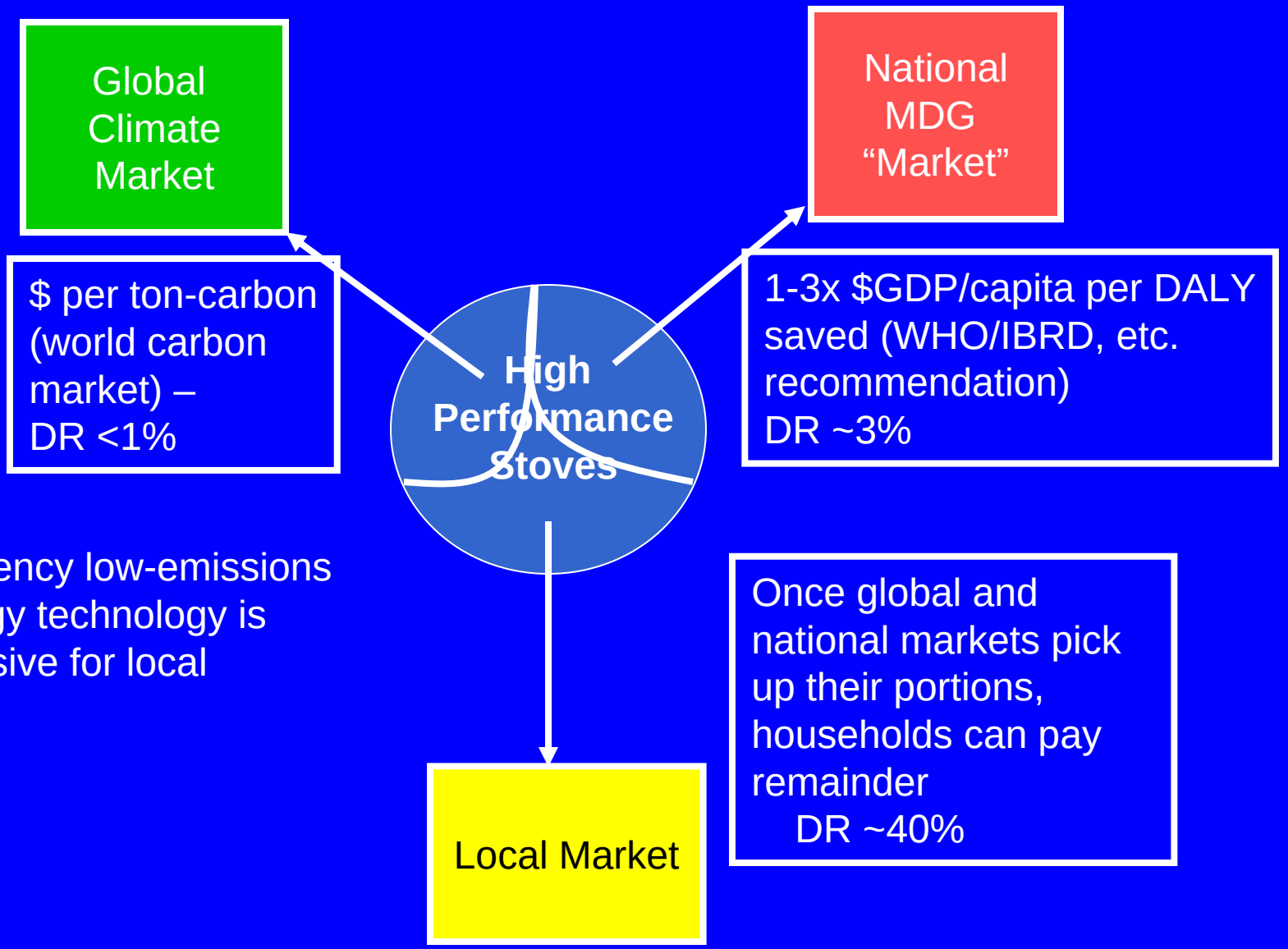




Current Cost-effective Region In China

Smith & Haigler, 2008

Paying for Rural Energy Development



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

PARACELSUS
1492-1541

Born in
Einsiedeln near Zurich

Paracelsus: "father of health science" - ?

- Praised "reason and experiment" as the true sources of knowledge:
  - **"The patients are your textbook, the sickbed is your study."**
  - **"Nothing so secret that it cannot be made apparent."**
- Proposed the prime directive of public health:
  - **"Privilege and lineage pale to nothingness, only distress has meaning."**

Paracelsus: "father of toxicology and environmental health"

- "Poison is in everything, and no thing is without poison. The dosage makes it either a poison or a remedy."

- Usually shortened to

"The Dose Makes the Poison"

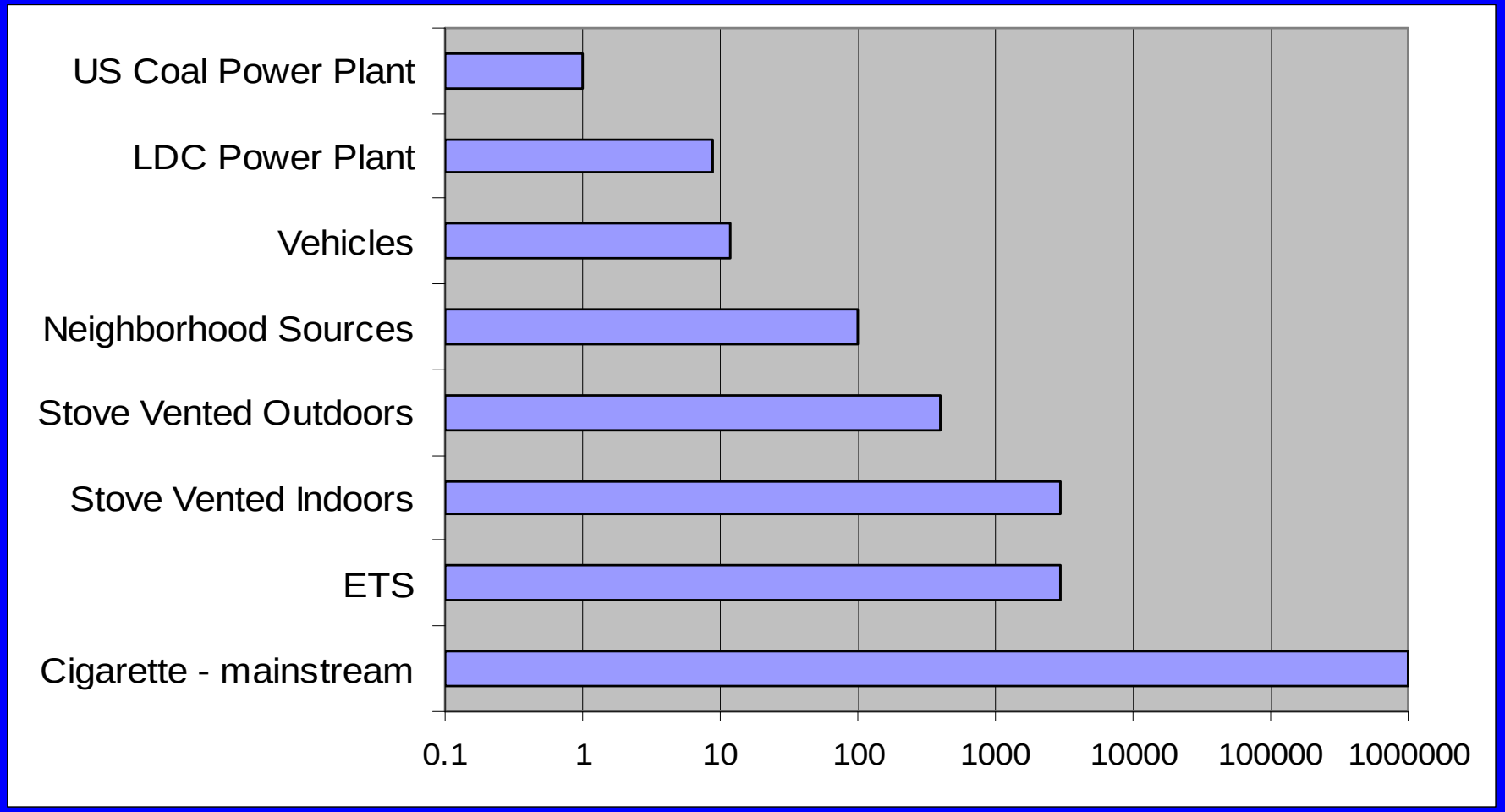
Intake Fraction (IF)

- For air pollution, *IF* is the fraction breathed in by the exposed population compared to amount emitted.

IF = 1.0

It matters where the burning is done

Intake Fraction Varies as Much as Toxicity (these are rough calculations for typical examples of sources in each class)



Smith, 1993

Grams Inhaled per Tonne Emitted

Combustion Mismanagement: Bad to put PIC in the wrong places

- Sticking burning stuff in your mouth
- In your home
- In your workplace
- In your community
- On your planet

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
Adjusted totals	**~ 8**	**~ 14%**	**~ 10%**

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

Thank you