# Cows, Coal, and Cooking: the Untold Story of Methane, Climate, and Health

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# Society has three basic options for responding to human-caused climate change

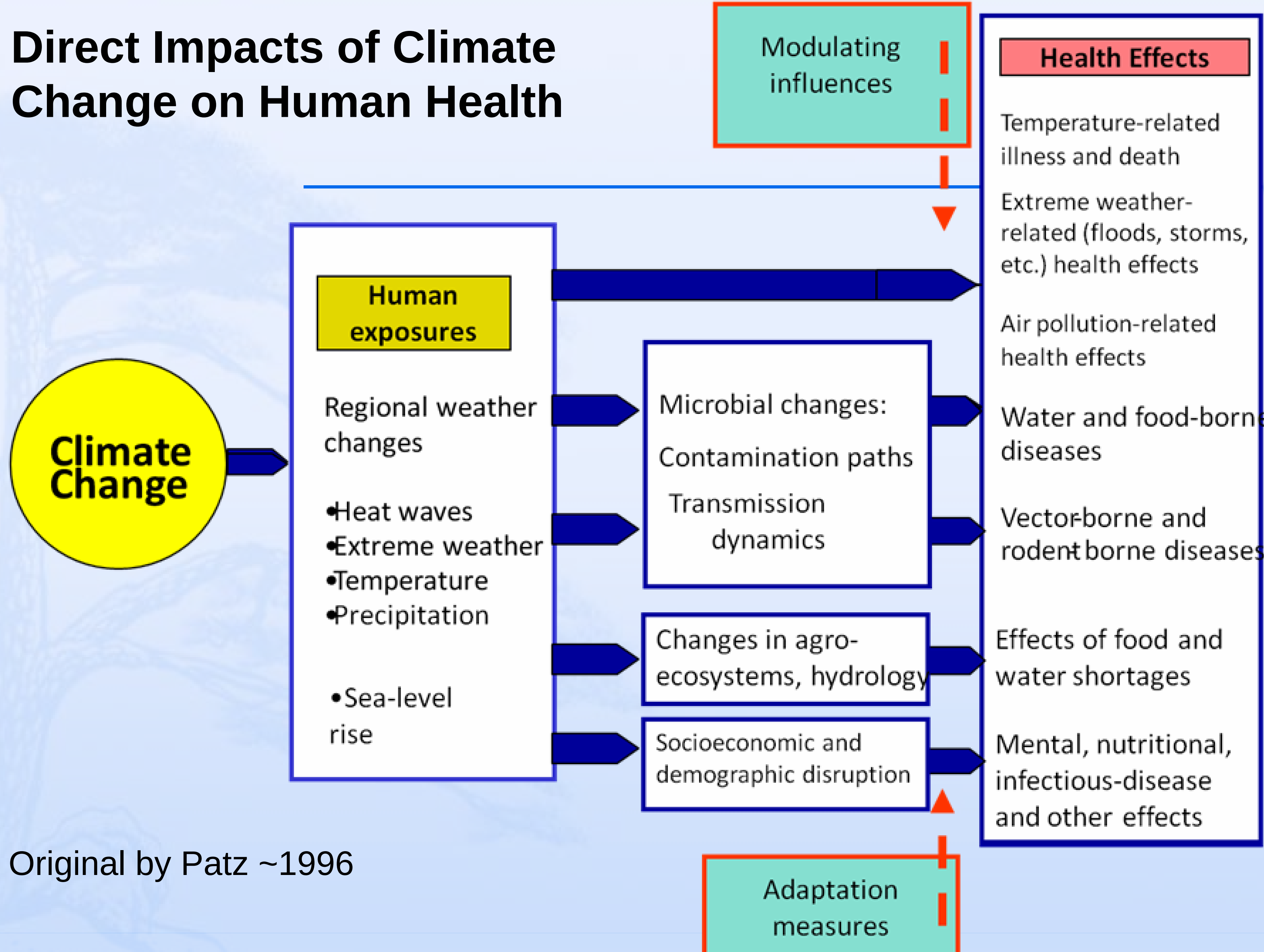
- <u>**Mitigate**</u> by working to reduce greenhouse gas (GHG) emissions from energy, agriculture, and land use or to capture them from the atmosphere in order to slow or, perhaps, reverse warming
- <u>**Adapt**</u> by reducing the negative effects of climate change through protecting coastlines, moving populations away from impacted areas, increasing efforts to control climate-related vectorborne diseases, insulating cities from heat stress, etc..
- <u>**Suffer**</u>**,** i.e., given that efforts in the first two arenas above are moving slowly, there is very likely to be suffering, perhaps considerable in poorer parts of the world, because of the climate change committed already.
- We will be doing all three, but can reduce the third if we put more effort into the first two.
- Some of the suffering will occur because climate change and the ways we deal with it interfere with our other long-term health goals, such as reduction of child death.

Framework from Holdren, 2006

# Two short briefings

- **How do the distributions of climate change emissions and health impacts compare?**
- **How does this change if the special characteristics of methane are included?**

# Direct Impacts of Climate Change on Human Health




Original by Patz ~1996

COMPARATIVE QUANTIFICATION OF HEALTH RISKS

GLOBAL AND REGIONAL BURDEN OF DISEASE ATTRIBUTABLE TO SELECTED MAJOR RISK FACTORS

VOLUME 1

EDITED BY

MAJID EZZATI, ALAN D. LOPEZ, ANTHONY RODGERS AND CHRISTOPHER J.L. MURRAY

Published in 2004, 2 vols, ~2500 pp (available on WHO CRA website)

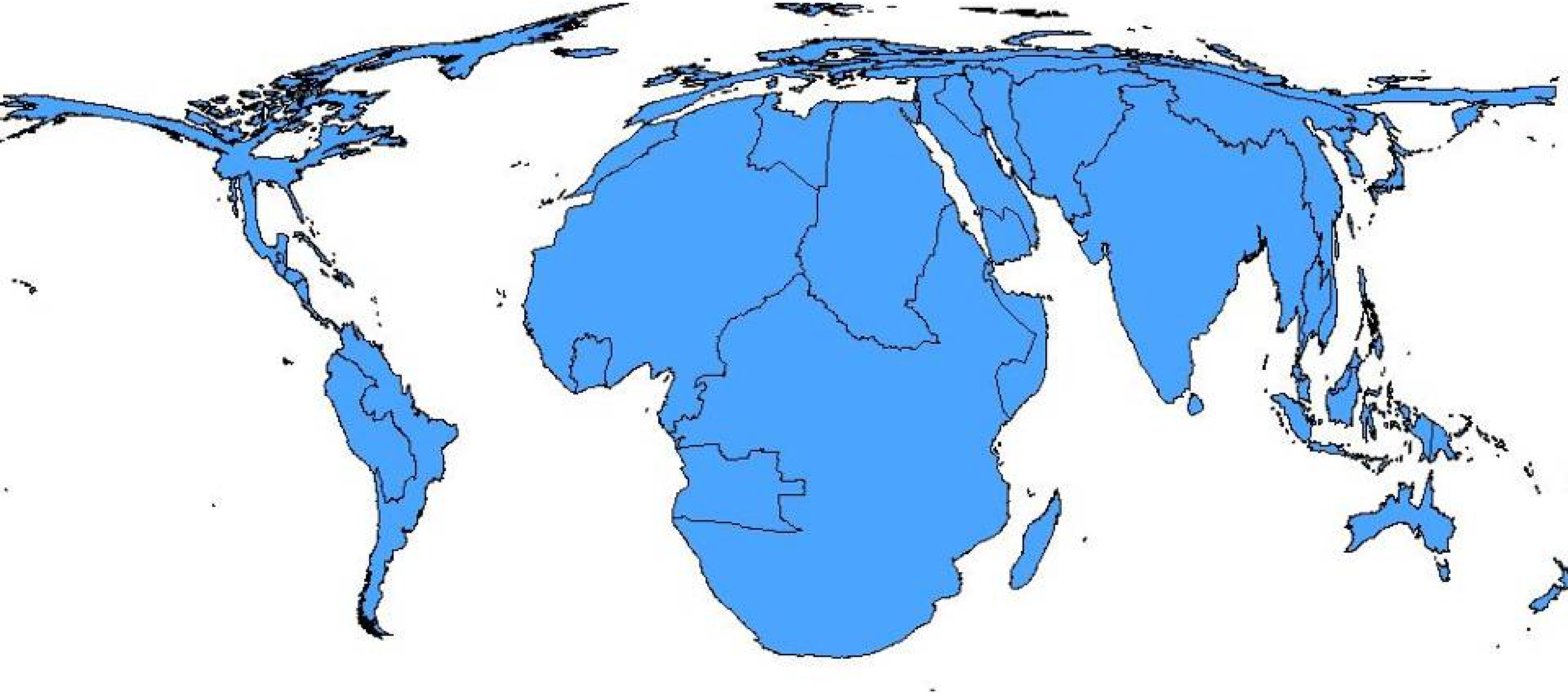
World Health Organization
Geneva

Global Warming Chapter: McMichael et al.,

# WHO Comparative Risk Assessment Climate Change Health Impacts as of 2000 (McMichael et al., 2004)

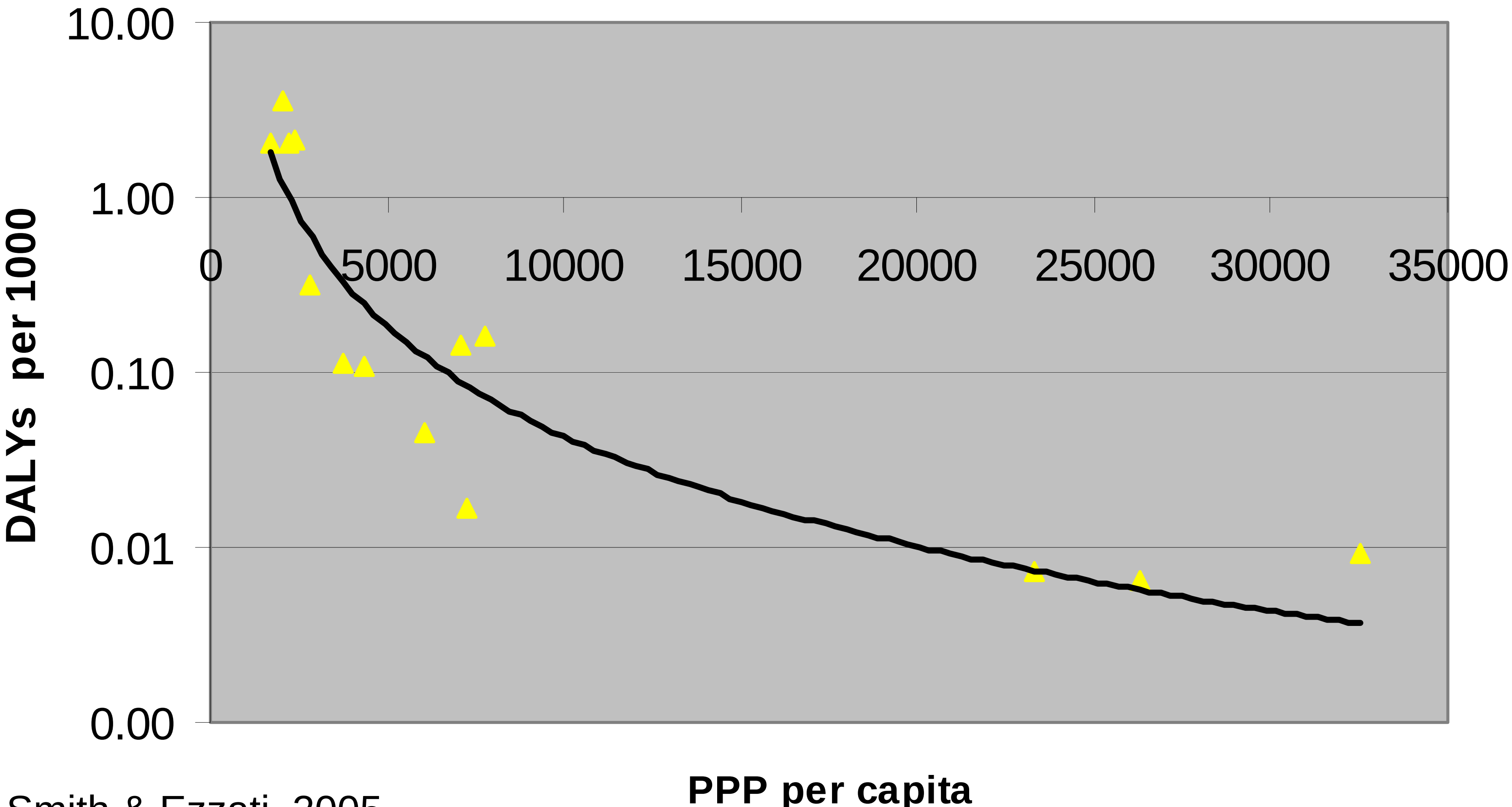
- Diarrhea – 2.4% of global burden
- Malaria – 2%; 6% in some regions
- 17% of protein-energy malnutrition
- 7% of dengue fever in some rich countries
- 150,000 deaths, 99% in poor countries (46% in South Asia)
- 0.4% of all DALYs (lost healthy life years)
- Most (88%) of impact in children under 5
- Not large today, but growing.

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



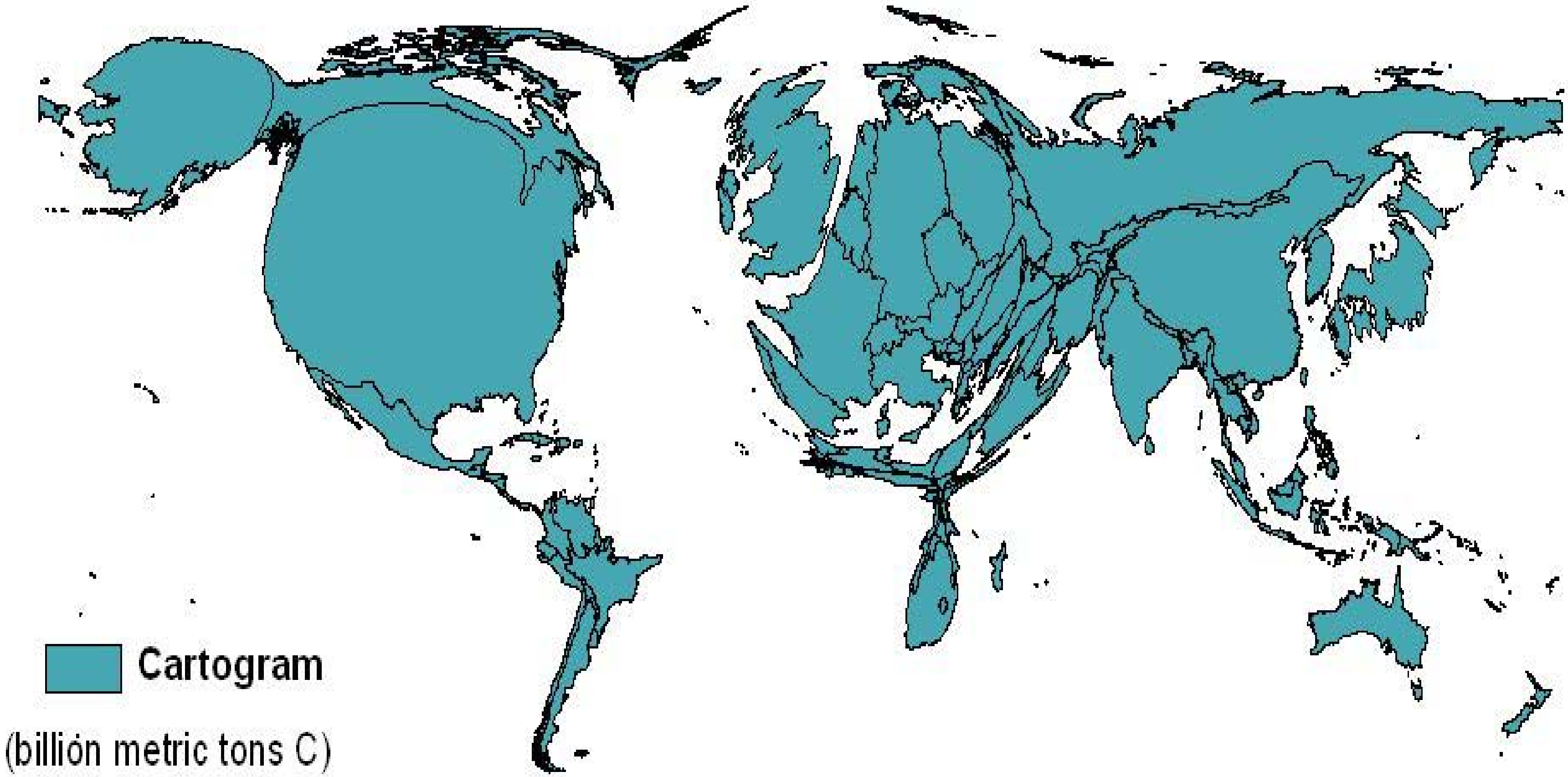
Patz JA, Gibbs HK, Foley JA, Rogers JV, Smith KR, 2007, **Climate change and global health: Quantifying a growing ethical crisis**, EcoHealth 4(4): 397–405, 2007.

# Health Impacts from Climate Change by Income Level across the World



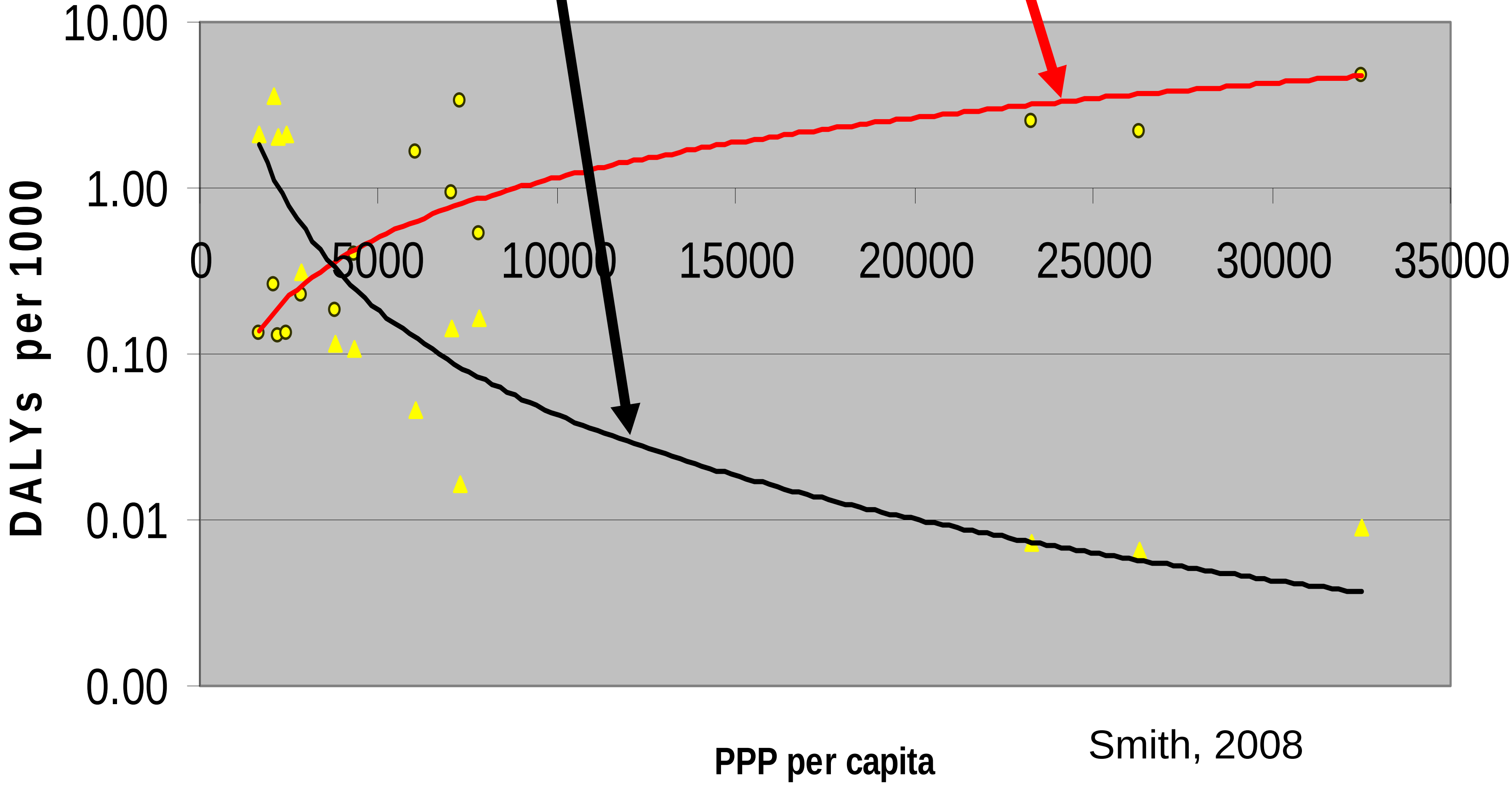

Smith & Ezzati, 2005

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



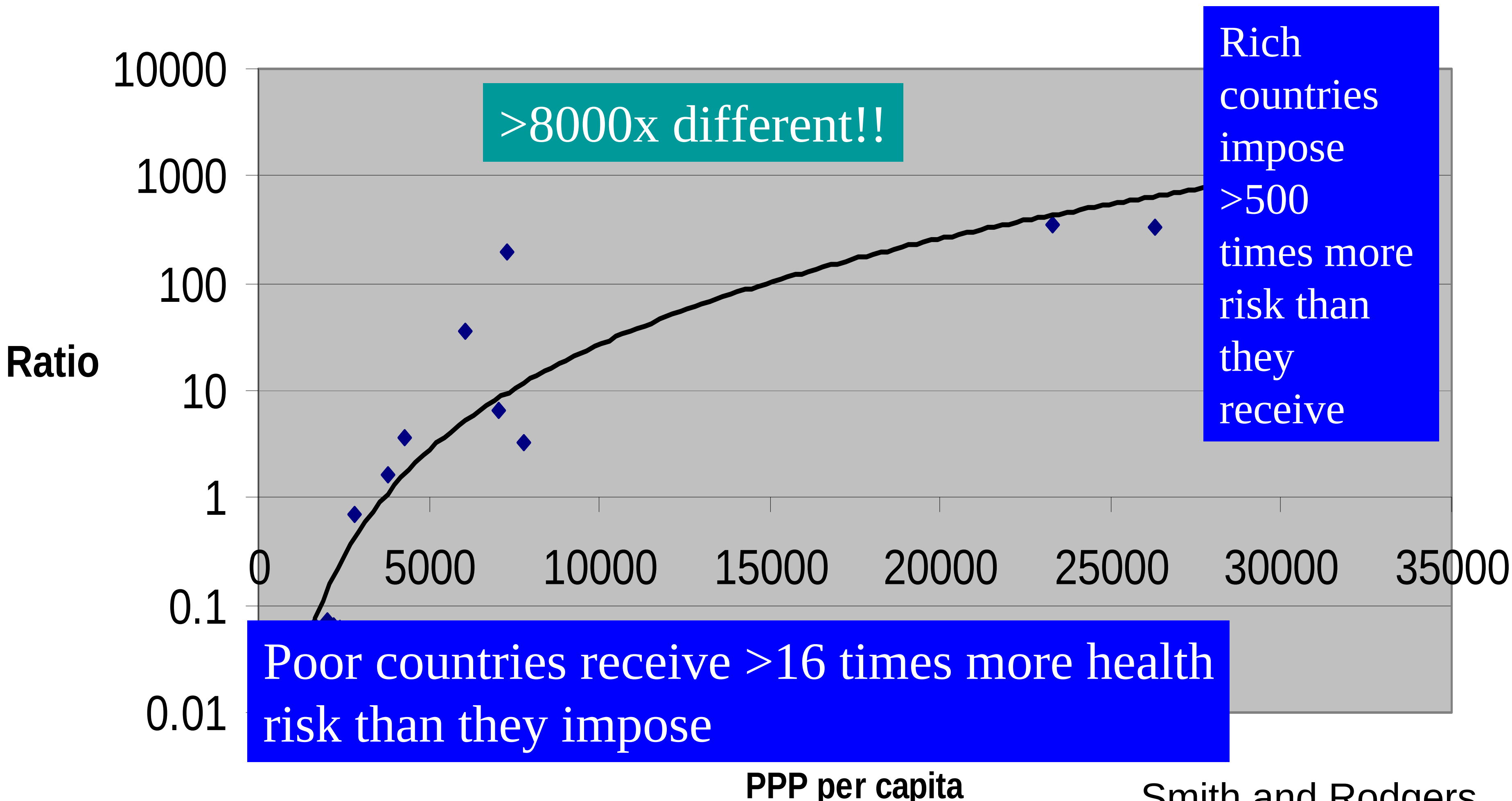

Patz JA, Gibbs HK, Foley JA, Rogers JV, Smith KR, 2007, **Climate change and global health: Quantifying a growing ethical crisis**, EcoHealth 4(4): 397–405, 2007.

# Distribution of Health Impacts from Climate Change (Experiencing versus Imposing)



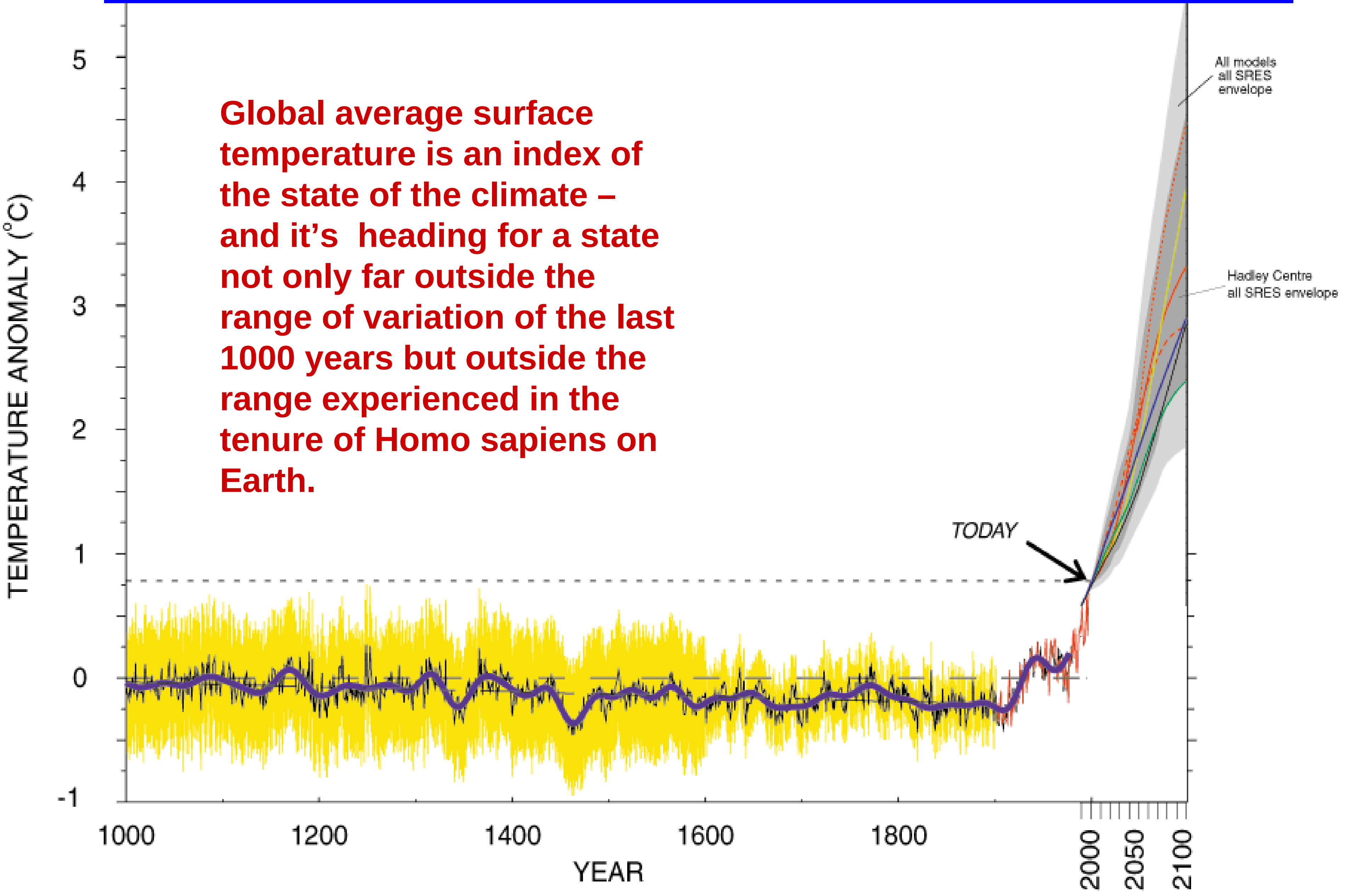

Smith, 2008

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

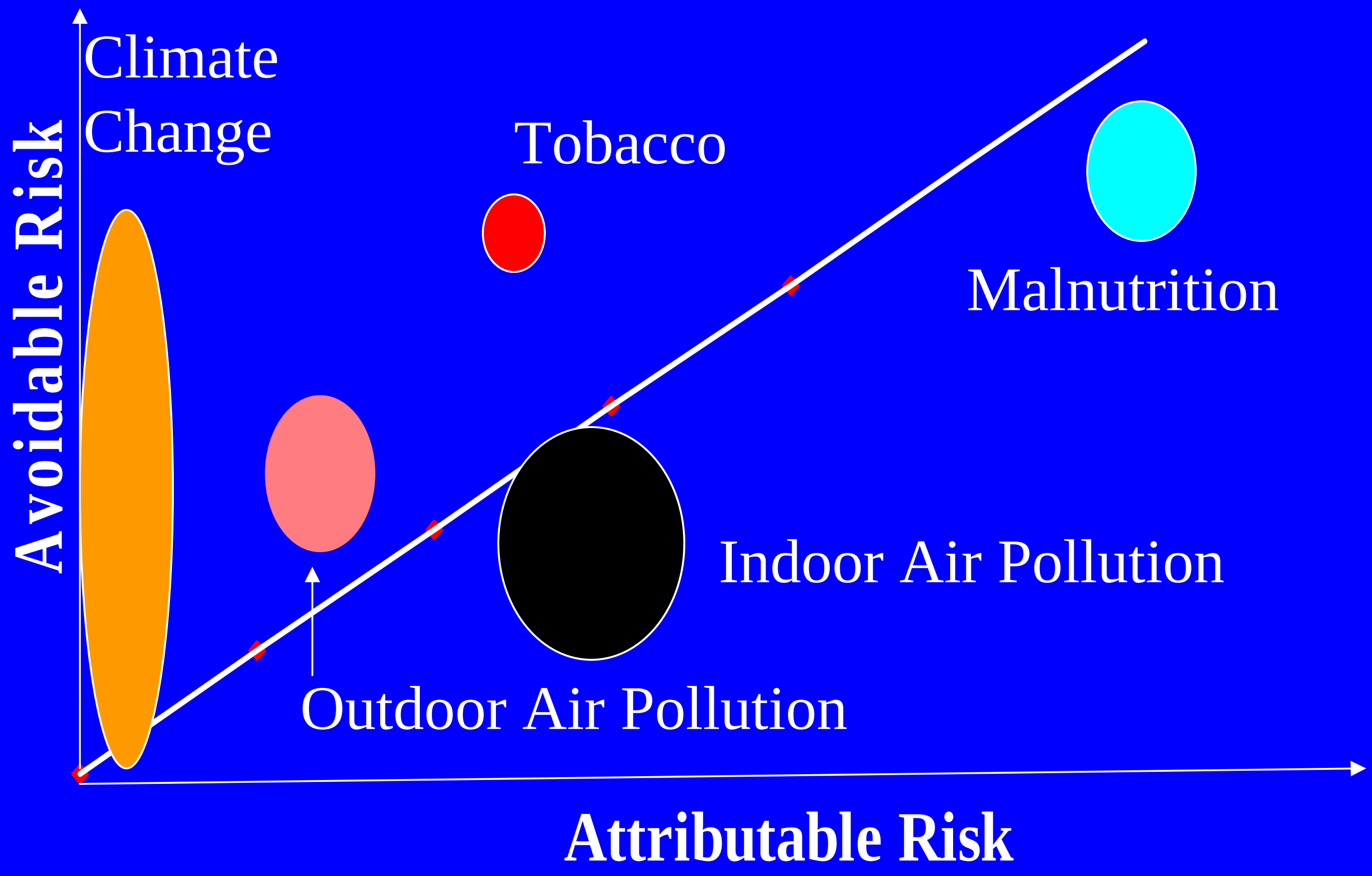



Smith and Rodgers

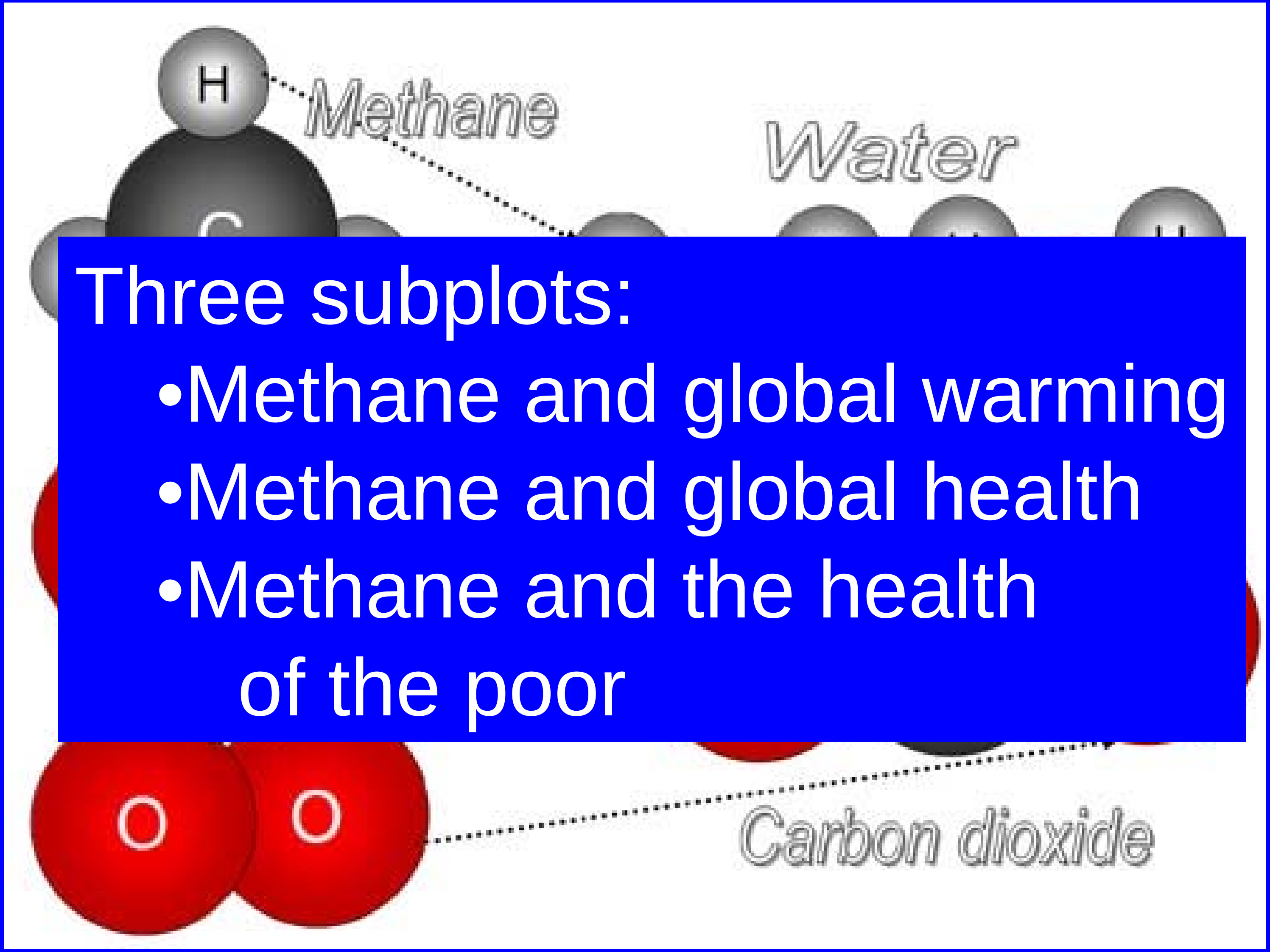
# 1000 years of Earth temperature history…and 100 years of projection



# Risk and Uncertainty



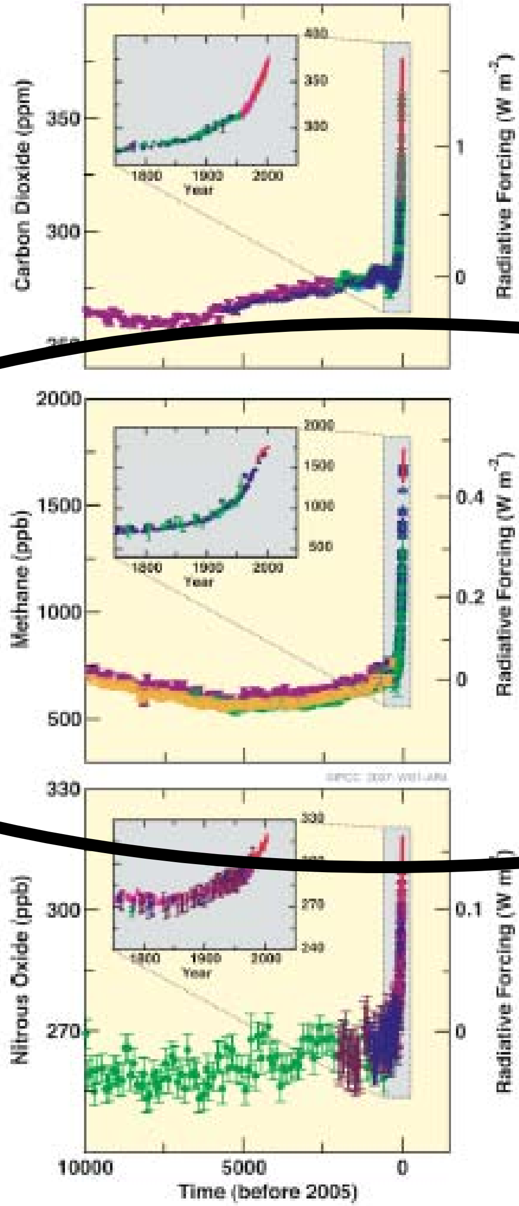
# The Methane Story: $CH_4$




Three subplots:

- Methane and global warming
- Methane and global health
- Methane and the health of the poor

Atmospheric Greenhouse gas concentrations




**Anthropogenic Sources**

**$CO_2$**

Fossil fuels

Land use change

Cement manufacturing

**Methane**

Landfills

Rice

Livestock

Waste management

Fossil recovery

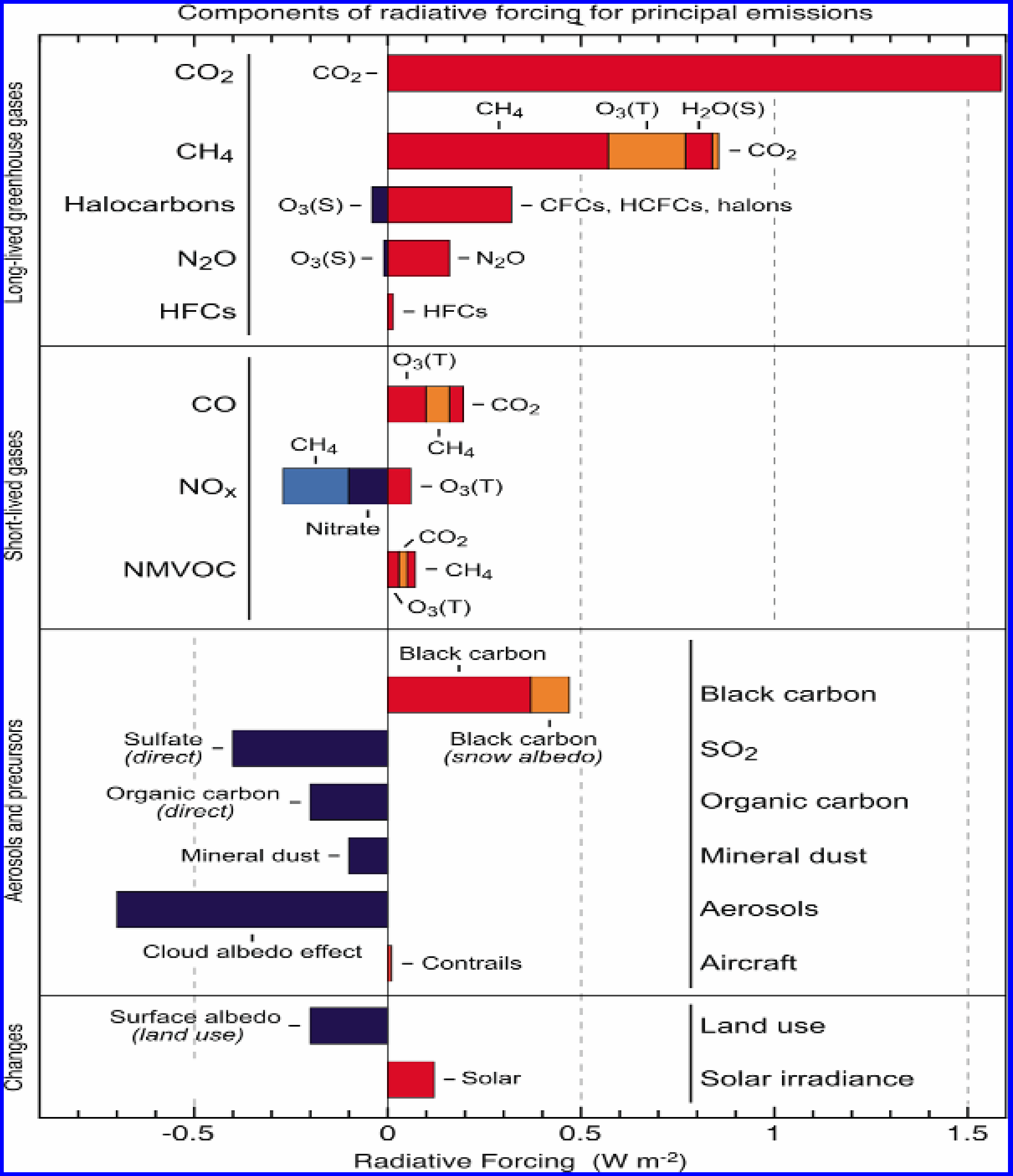
**$N_2O$**

Fertilizer

Planted N-fixers

Combustion

Figure SPM.1
IPCC 2007




Warming in 2005 from emissions since 1750

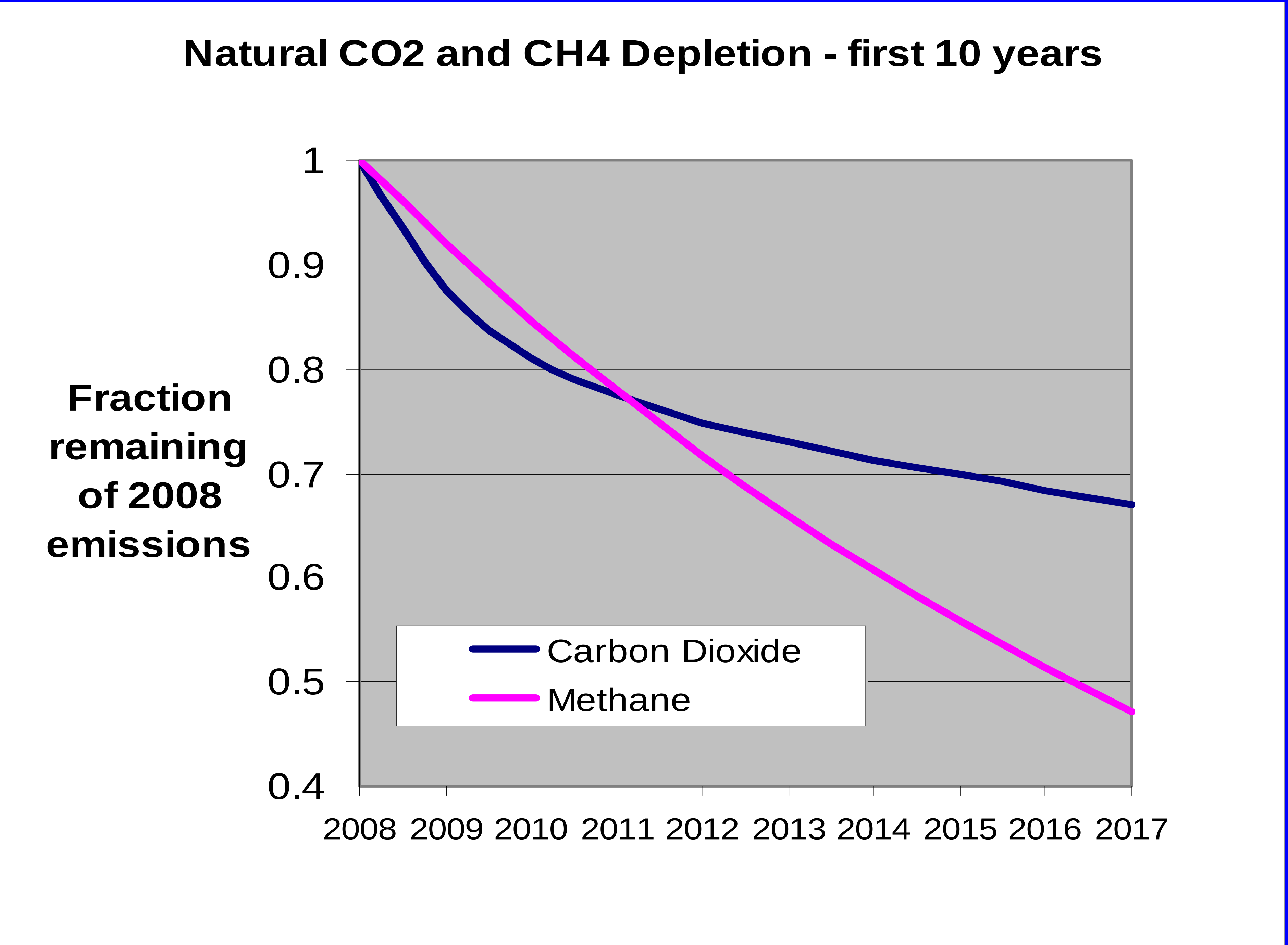
More than half due to methane

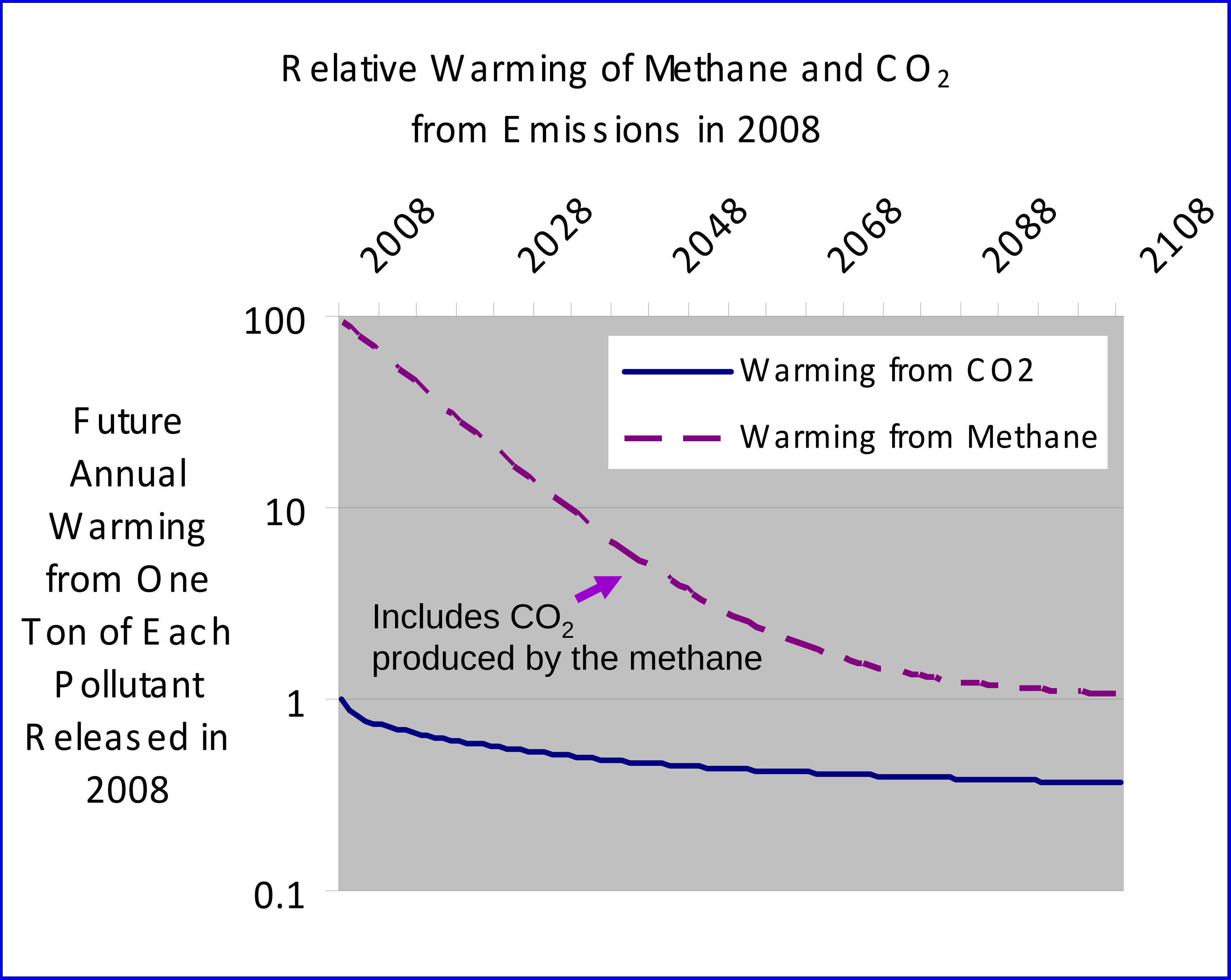
IPCC, 2007

# Math of GHG Decay (AR4)

- $CO_2$ goes into four compartments:
  - 19% of total with a lifetime* of 1.2 years
  - 34% at 18.5 y
  - 26% at 173 y
  - 21% with “infinite” lifetime
- Methane has a 12 y lifetime,
  - but contributes to ozone, a GHG
  - and eventually oxidizes to $CO_2$

*Lifetime refers to the time to reach 1/e (37%) of the original amount


Natural CO2 and CH4 Depletion - first 10 years
Fraction remaining of 2008 emissions
1
0.9
0.8
0.7
0.6
0.5
0.4
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
Carbon Dioxide
Methane

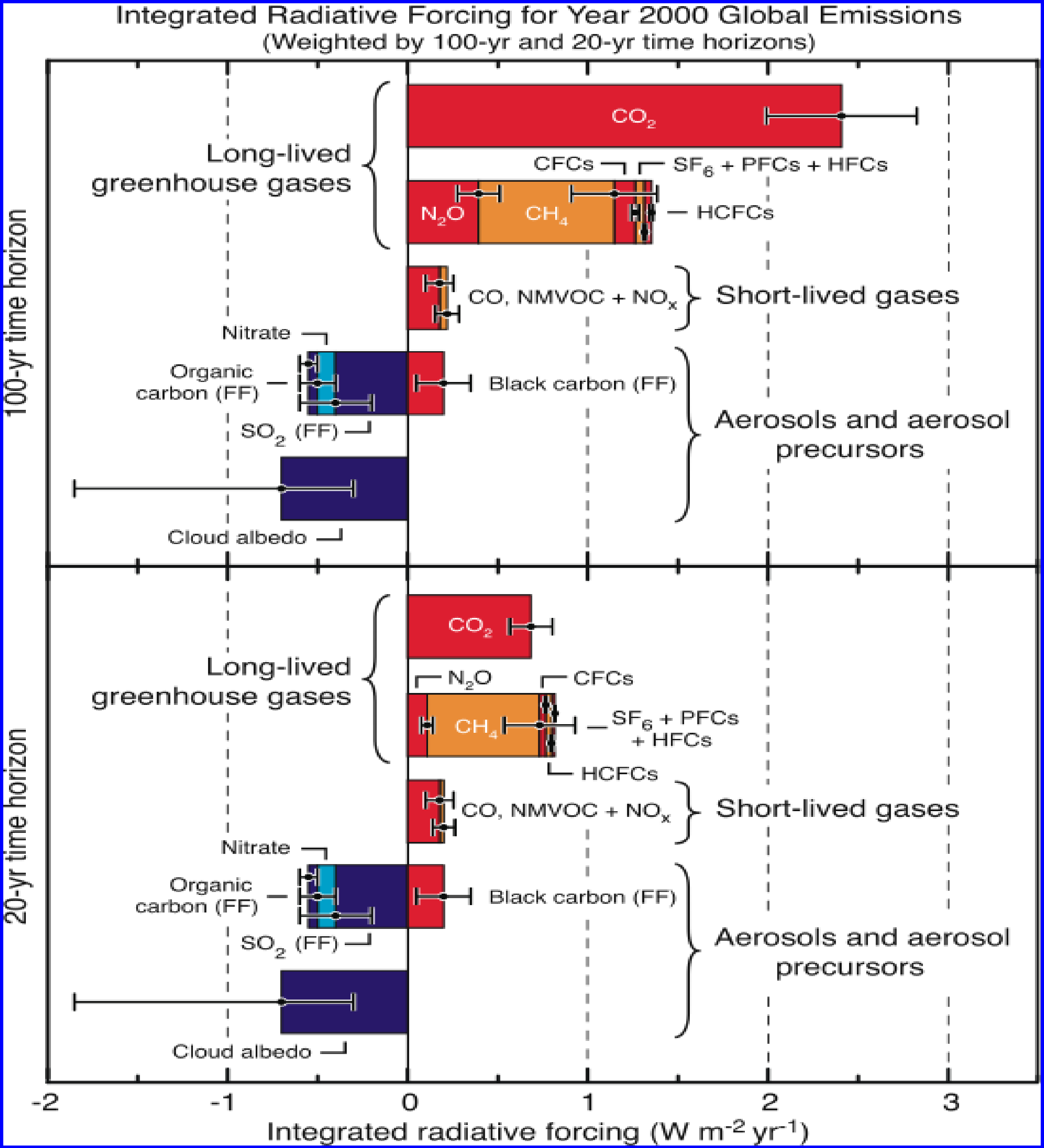

Relative Warming of Methane and CO2
from Emissions in 2008
2008
2028
2048
2068
2088
2108
100
10
1
0.1
Future Annual Warming from One Ton of Each Pollutant Released in 2008
Warming from CO2
Warming from Methane
Includes CO2
produced by the methane

# How can we compare projects to reduce different GHGs?

- Why not just take all future warming into account?
- This would mean that no effort would go into avoiding emissions of the shorter lived GHGs, such as methane, because $CO_2$ has such a long lifetime.
- It would result in spending most money to protect people thousands of years into the future and ignoring the needs of ourselves and our children.
- Thus, the IPCC established in 1996, official Global Warming Potentials (GWPs), which are weighting factors to compare the impact of different GHGs
- GWPs are built into the Kyoto Protocol, the Clean Development Mechanism, and nearly all national inventories and reduction plans, including Australia’s

# Methane and Time

- The current official GWPs are based on 100-year time horizons
  - Methane is 21 x $CO_2$ by weight
  - Equivalent to ~0.75% discount rate
- For making decisions on how to spend resources when impacts are upon us, <1% is too low.
- The other GWP published by IPCC, has a 20-year time horizon
  - Methane is 72 x $CO_2$ by weight
  - Equivalent to ~ 8% discount rate
  - More compatible with financial investments
- International health investments use a 3% discount rate, which would be a GWP of ~48



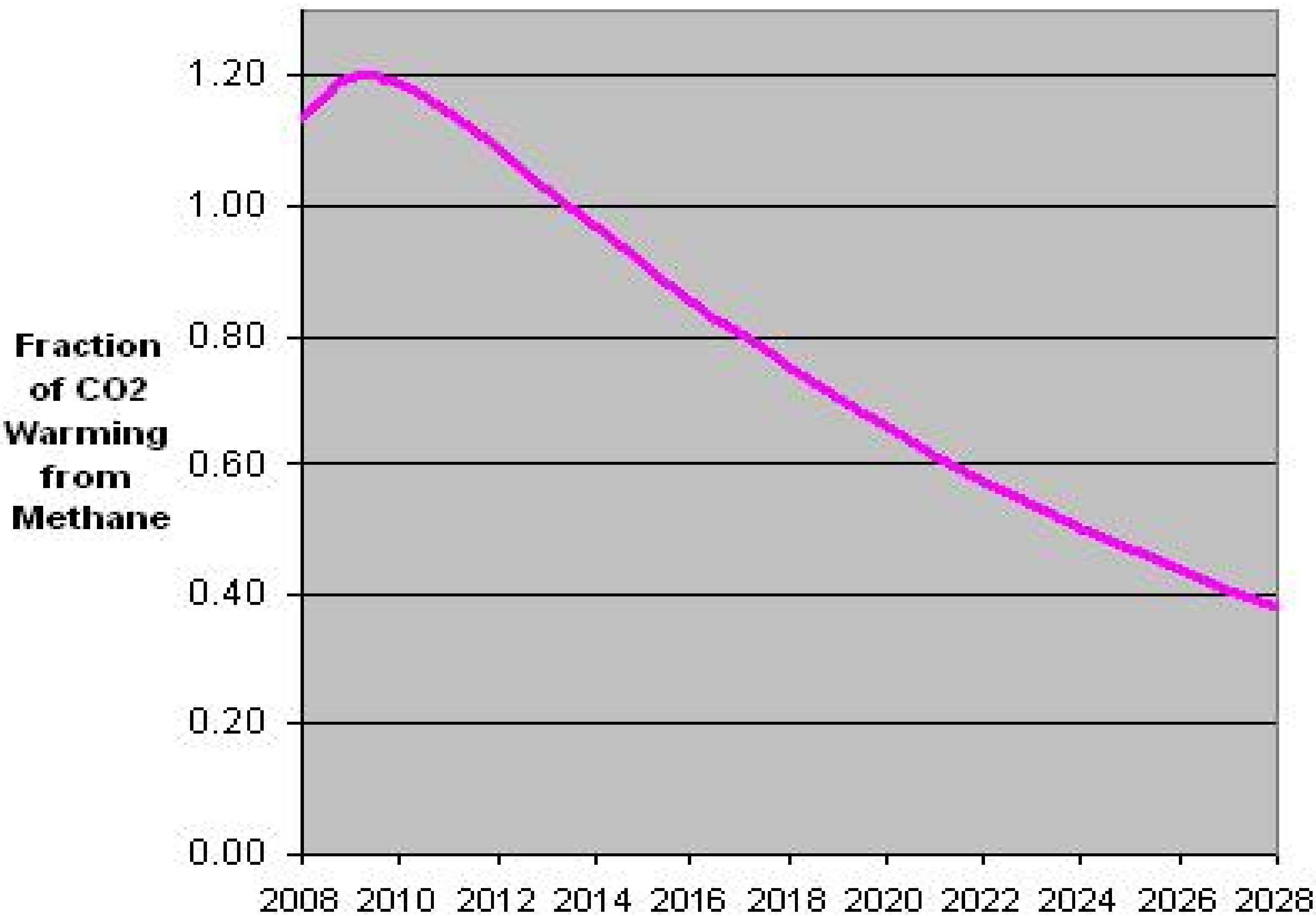

100-y horizon

Time perspective makes a difference

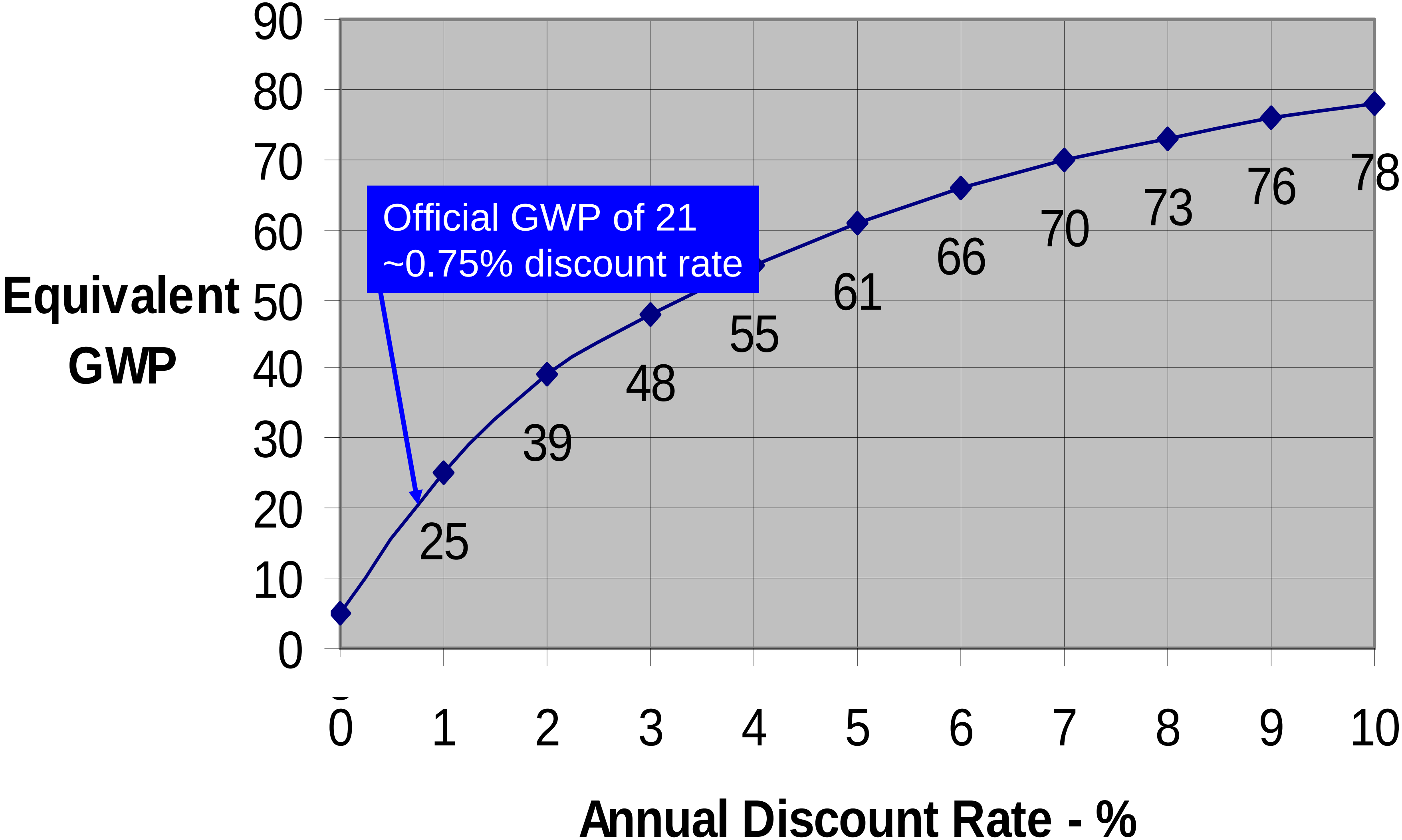
20-y horizon

IPCC, 2007

## Warming Contribution of Total ~2008 Emissions of Methane Compared to Total CO2 Emissions



# Methane GWPs and Discount Rates

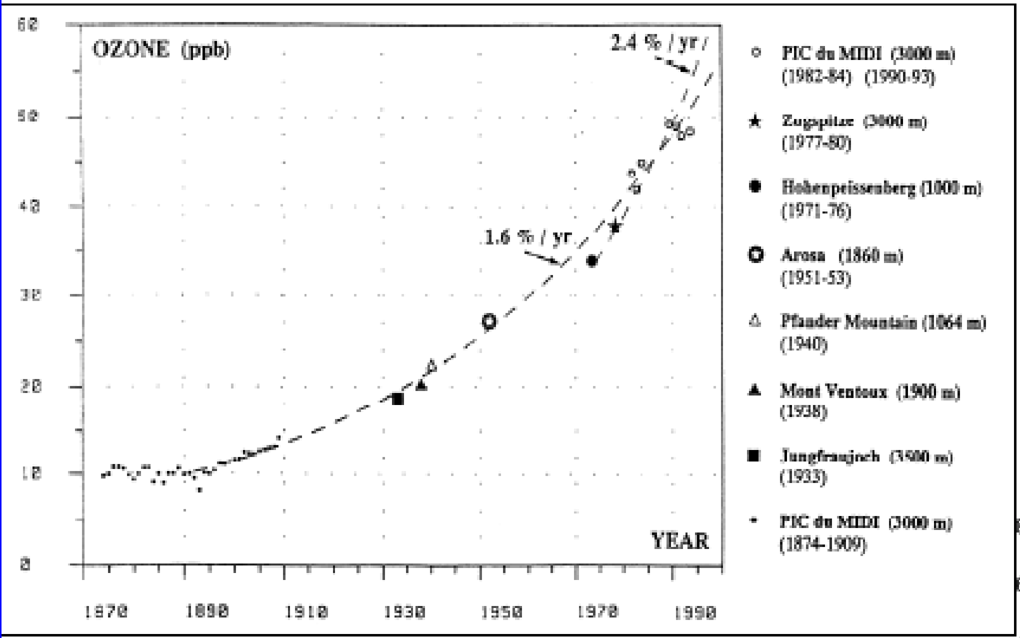


# Methane #1: Summary

- A much more powerful greenhouse gas (GHG) than $CO_2$
- Partly due to its direct effect, but also because it creates ozone ($O_3$), another powerful GHG
- About 100 times more per ton than $CO_2$ at any one time
- Eventually turns to 2.75 times as much $CO_2$ by mass
- Methane has thus contributed a significant amount to global warming,
- But has a much shorter atmospheric lifetime compared to $CO_2$
- Thus, changes in emission rates will have a much faster impact to lower warming

# Background Ozone is Growing …

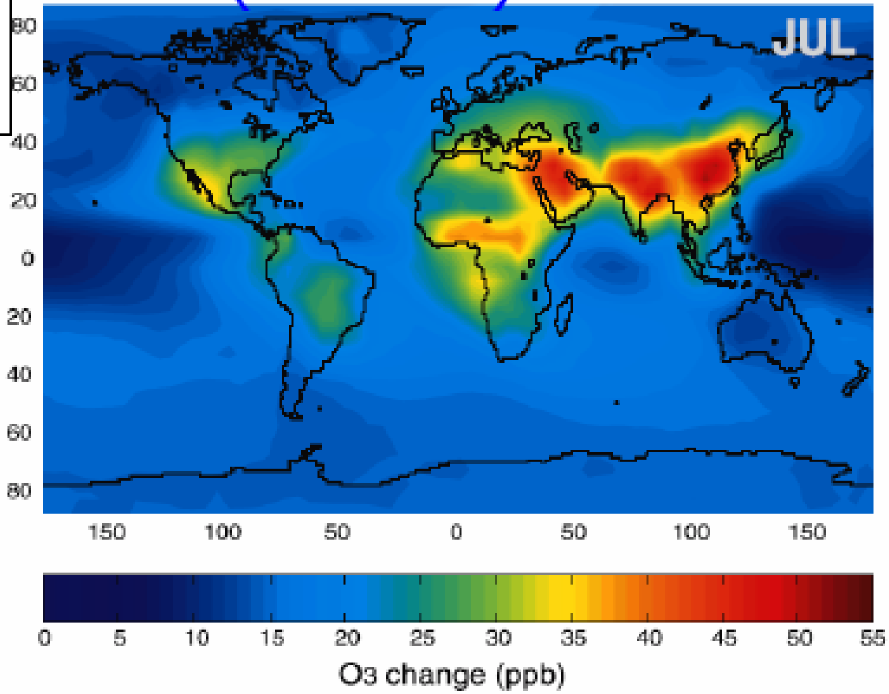
## … and Will Continue to Grow!




Ozone trend at European mountain sites, 1870-1990 (Marenco et al., 1994).

Historic and future increases in background ozone are due mainly to increased methane and $NO_X$ emissions (Wang *et al.*, 1998; Prather et al., 2003).

2100 (IPCC A2) - 2000



# Multiple Benefits of Reducing Methane

Reducing ~20% of anthropogenic methane emissions will:

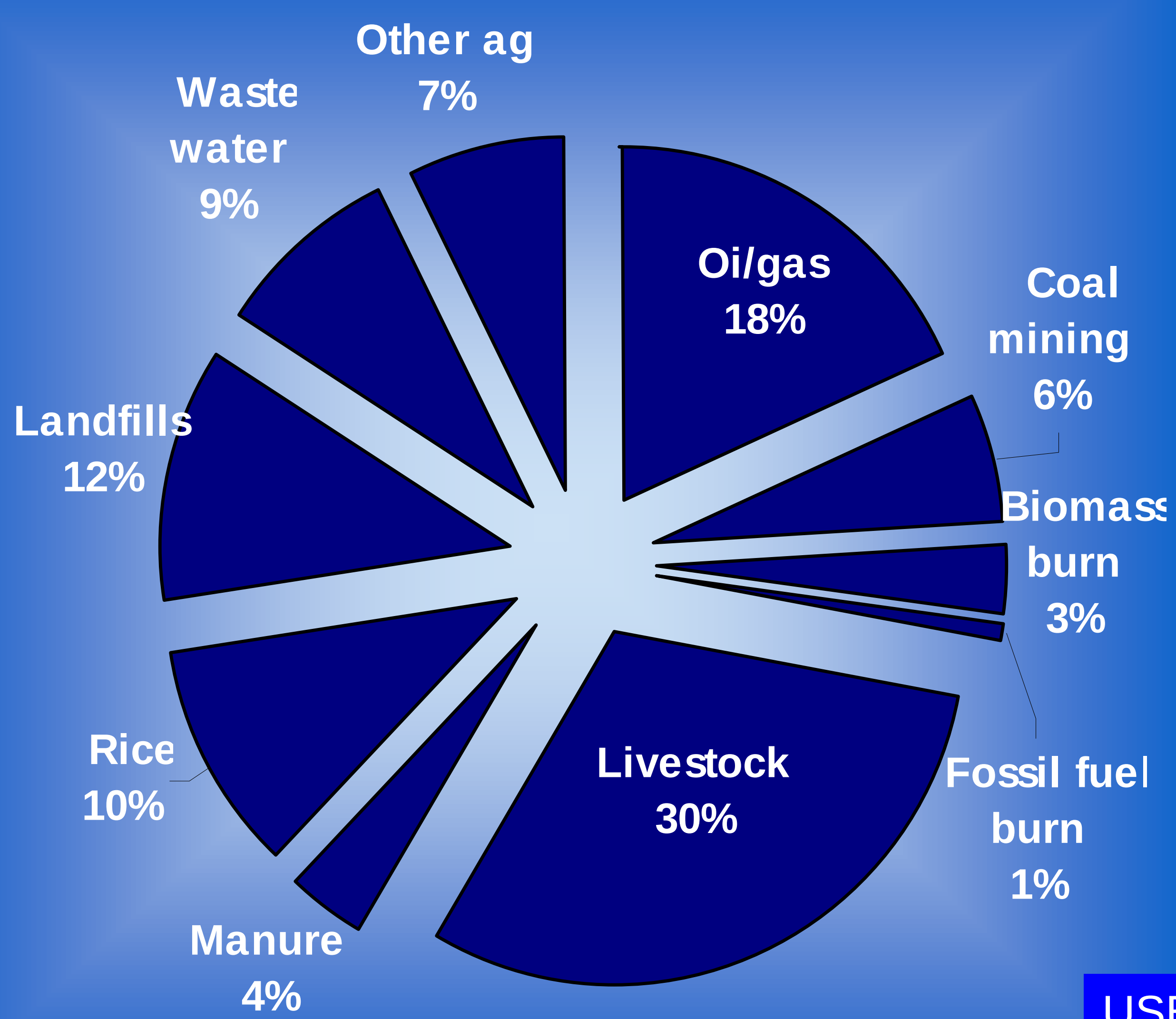
- Be possible at a net cost-savings.
- Reduce 8-hr. average ozone globally by ~1 ppb.
- Reduce global radiative forcing by ~0.14 W $m^{-2}$.
- Provide ~2% of global natural gas production.
- Prevent ~30,000 premature deaths globally in 2030, ~370,000 from 2010-2030.

Mauzerall, 2007

# Methane #2: Summary

- Methane is precursor to tropospheric (ground level) ozone
- Tropospheric ozone rising around the world
- Significant impact on natural ecosystems and agriculture
- WHO and other agencies lowering ozone standards/guidelines because of new evidence on mortality and continued evidence of morbidity
- Standards suggested by health protection are now at the top end of regional levels in some parts of the world, e.g., Europe
- Nowhere to hide

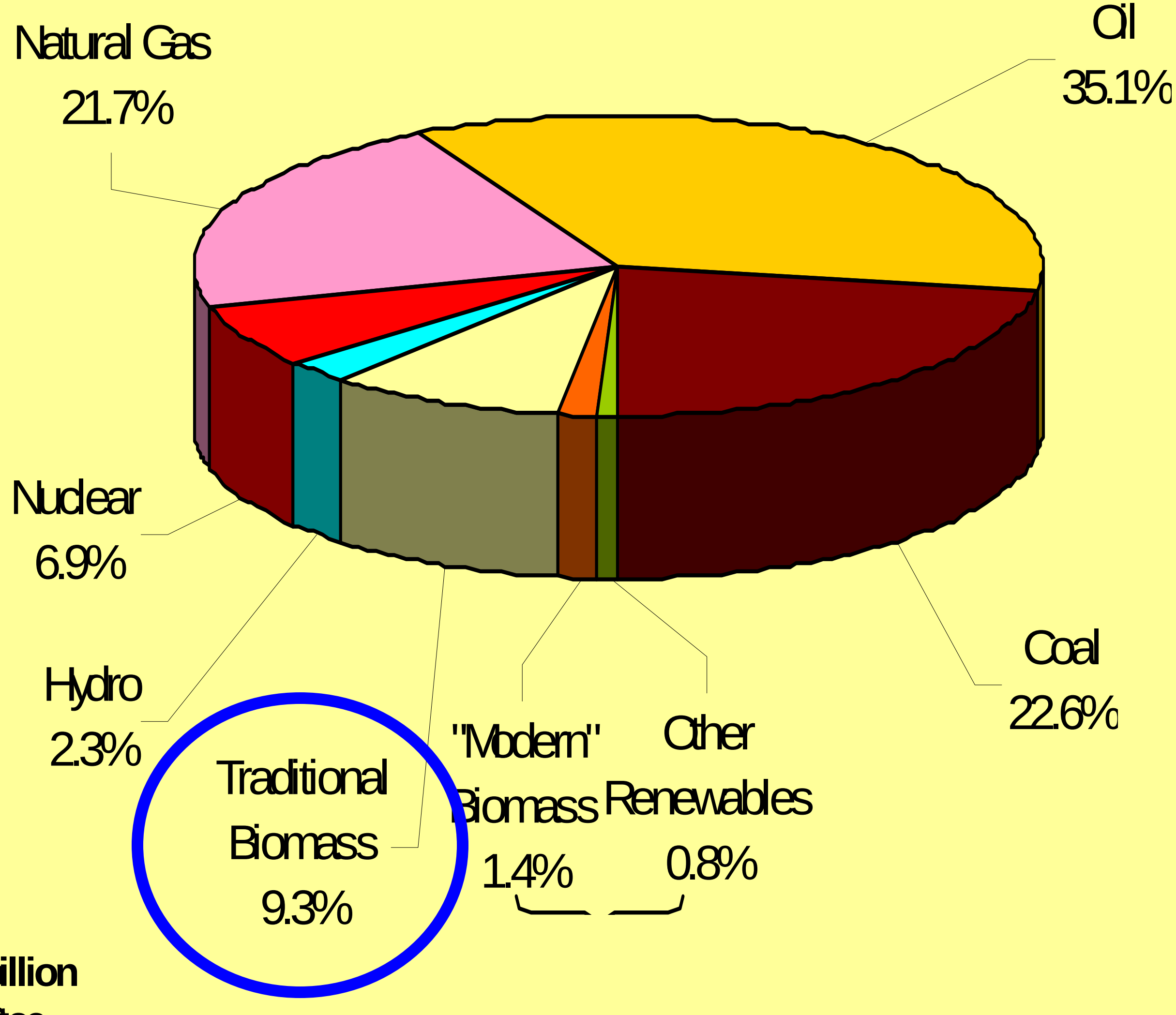
# Global Anthropogenic Methane Emissions ~2005
# Total ~ 305 million tons




Growing at
~1.5%
per year

USEPA, 2006

# World Energy – 2001




**Population: 6.102 billion**

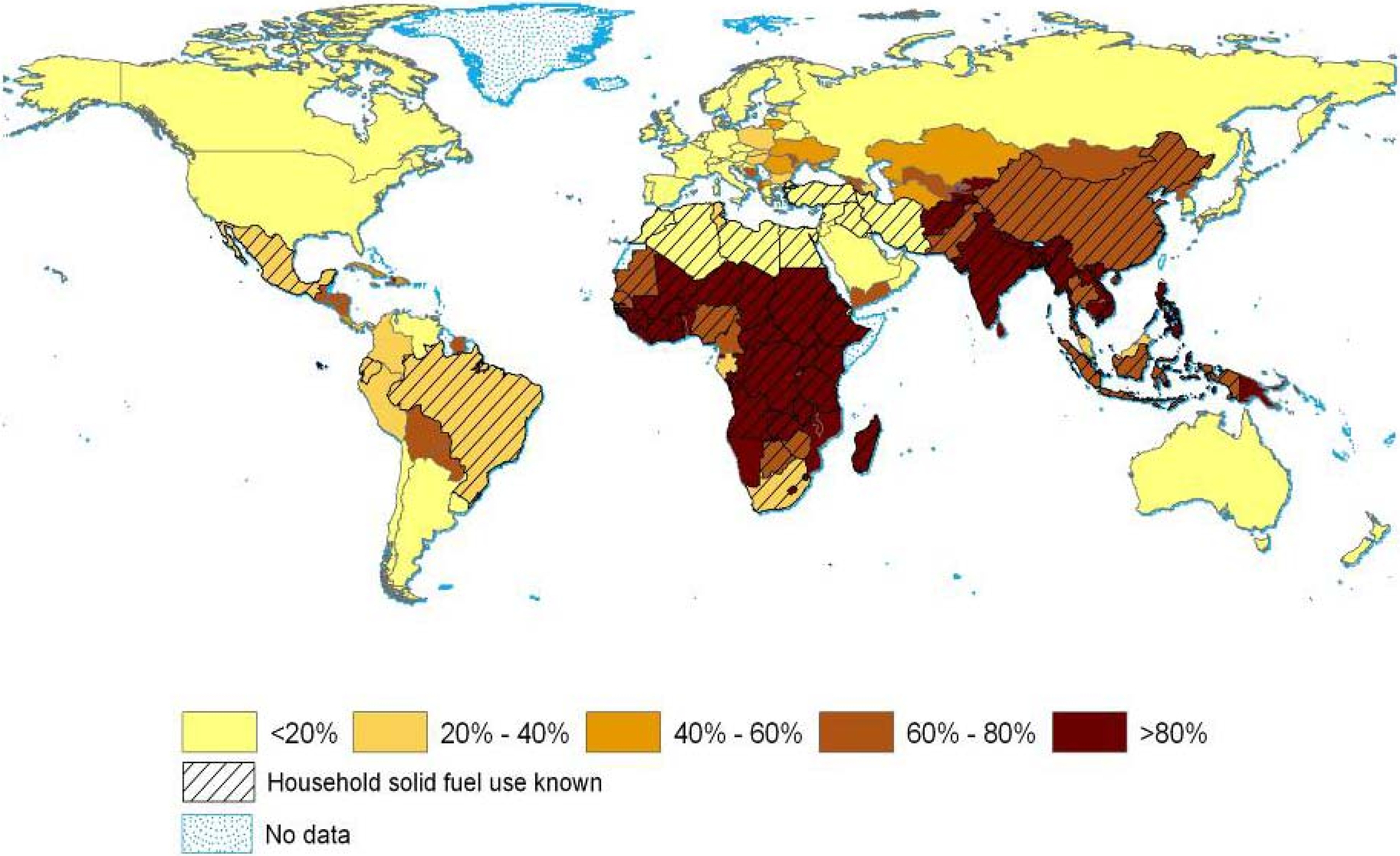
Total energy use: 10.2 Gtoe

Per capita energy consumption: 1.67 toe

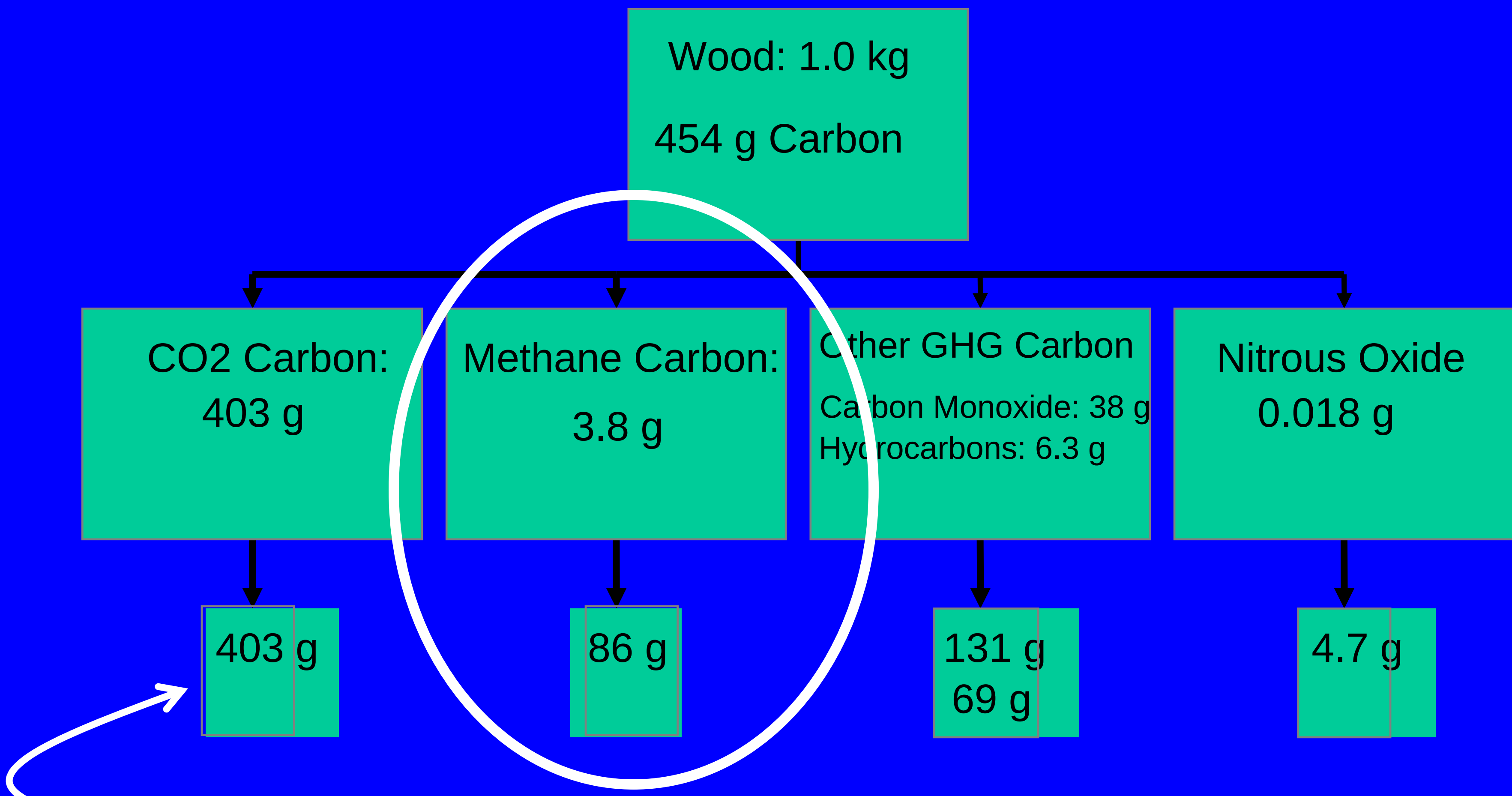
World Energy Assessment, 2004


Chinese household rural energy:

# National Household Solid Fuel Use, 2000



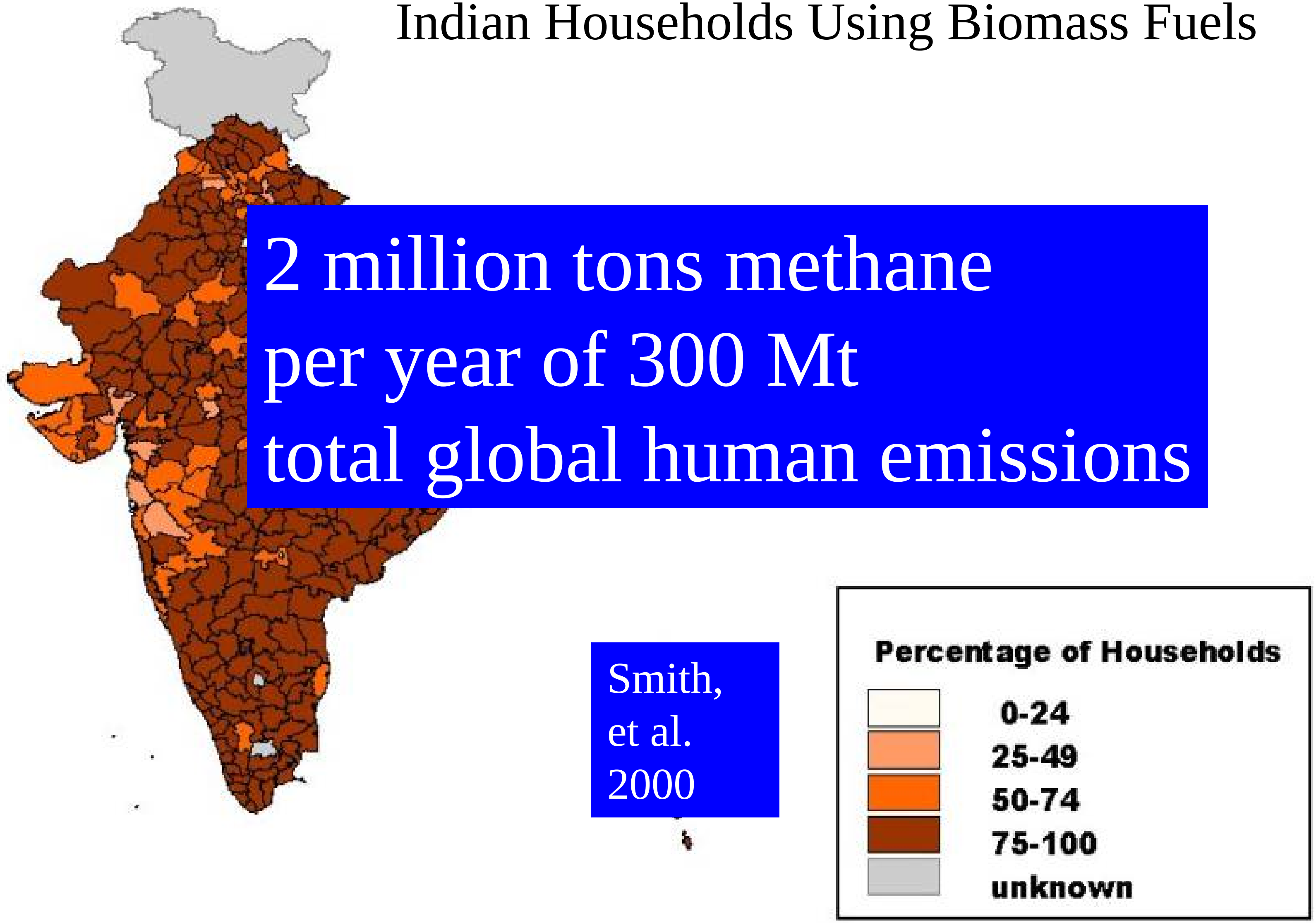
# Greenhouse warming commitment per meal for typical wood-fired cookstove in India




Global warming commitments of each of the gases as $CO_2$ equivalents

Source: Smith, et al., 2000

Indian Households Using Biomass Fuels




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

Smith,
et al.
2000

# Energy flows in a well-operating traditional wood-fired cookstove

**A Toxic Waste Factory!!**

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

Into Pot
2.8 MJ
18%

In PIC
1.2 MJ
8%

Waste Heat
11.3 MJ
74%

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

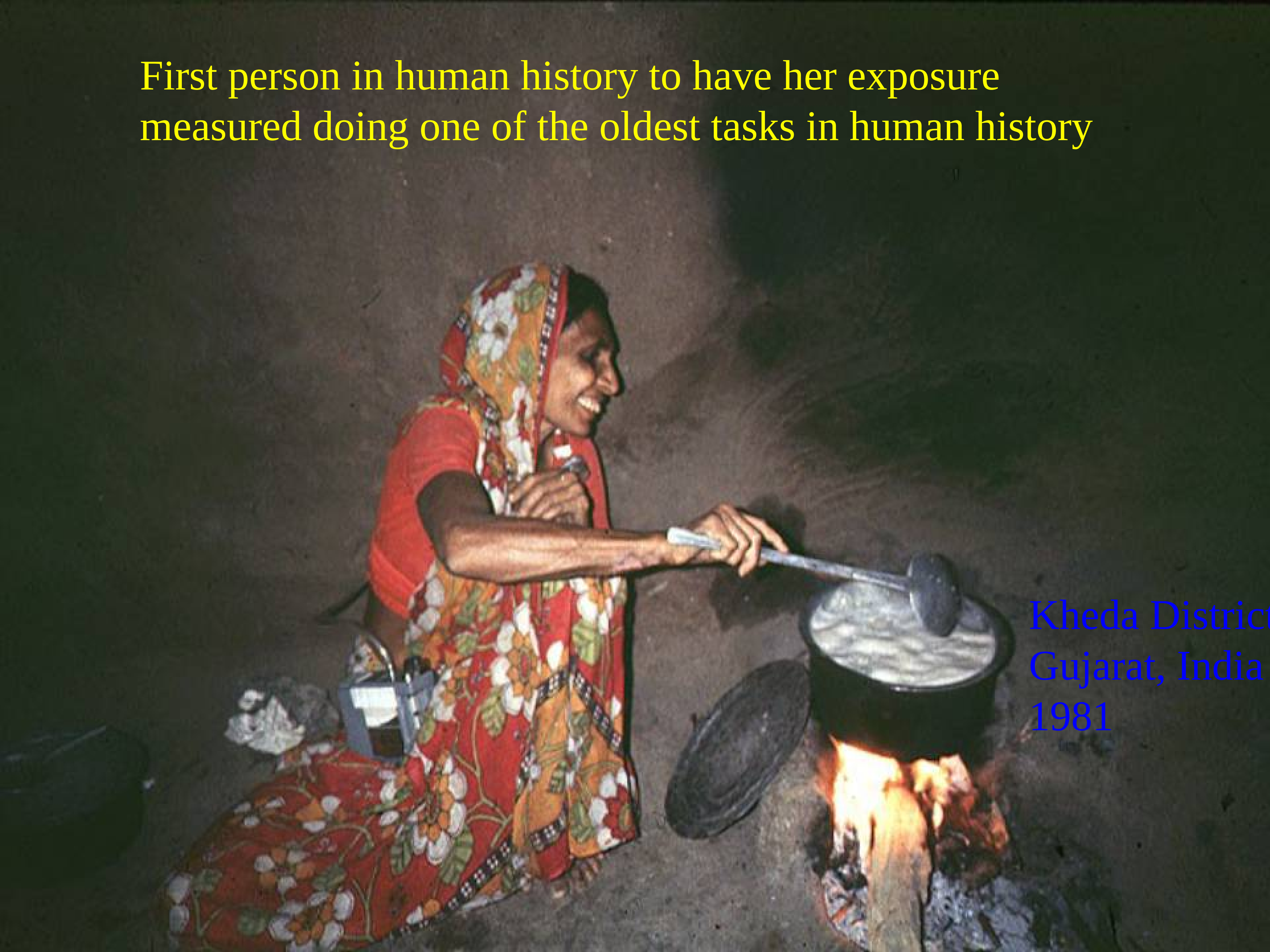
Source: Smith, et al., 2000

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

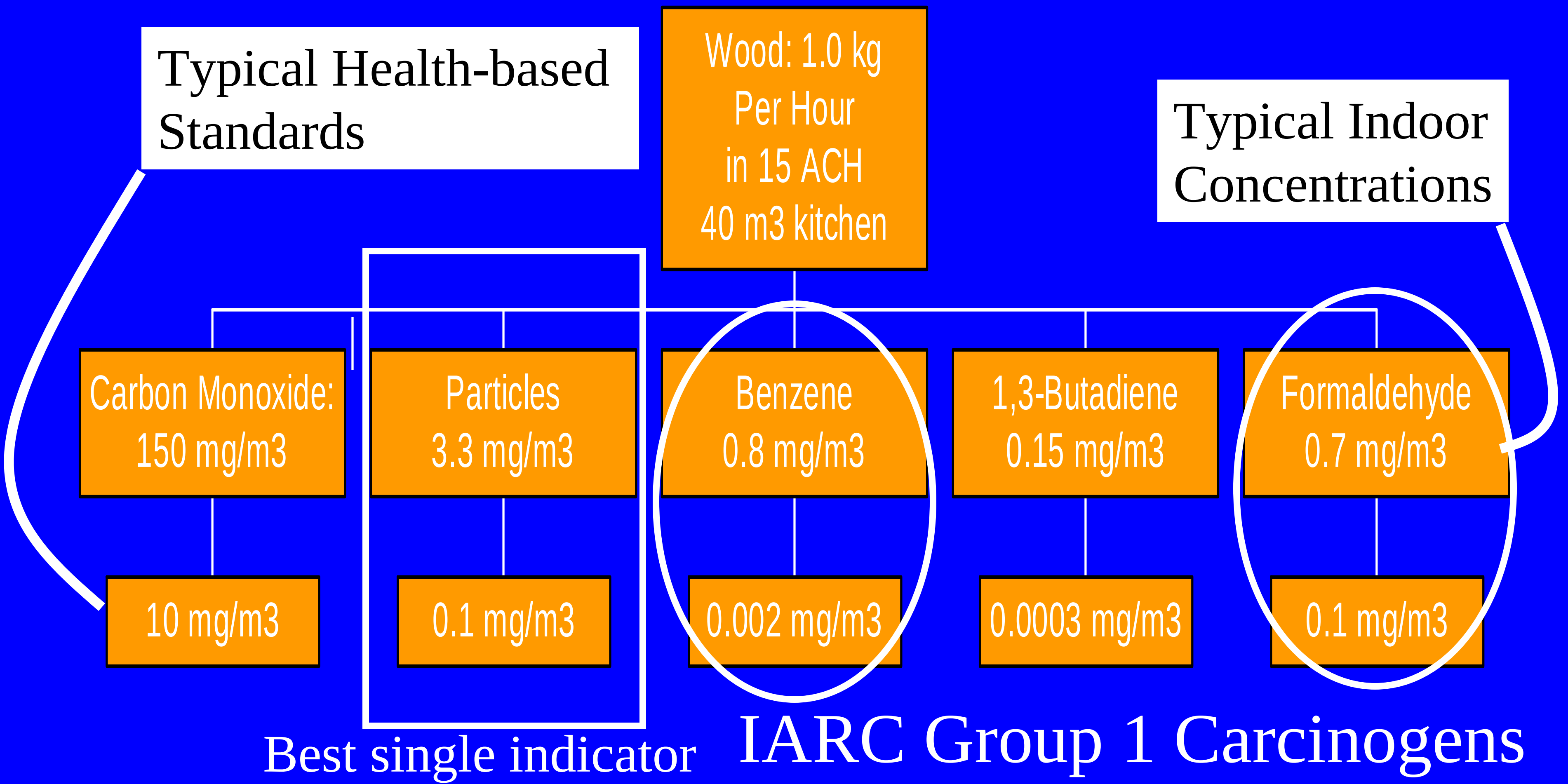
Plus methane

- 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($\alpha$)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*

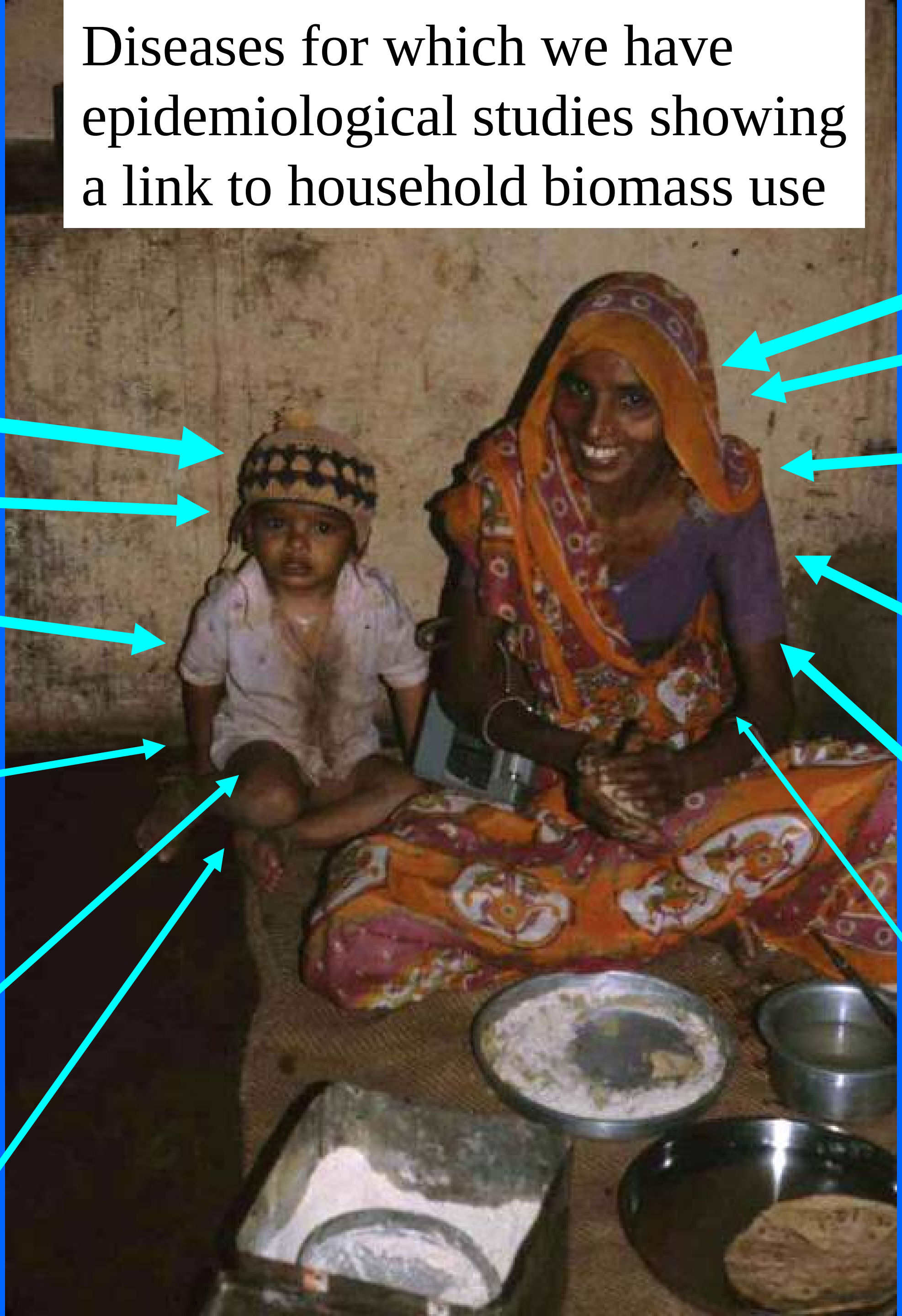
Naeher, et al. 2007


First person in human history to have her exposure
measured doing one of the oldest tasks in human history
Kheda Distric
Gujarat, India
1981

# Health-Damaging Air Pollutants From Typical Woodfired Cookstove in India.



Diseases for which we have epidemiological studies showing a link to household biomass use



ALRI/ Pneumonia (meningitis)

Asthma

Low birth weight

Early infant death?

Birth defects?

Cognitive Impairment?

Chronic obstructive lung disease

Interstitial lung disease

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

Blindness (cataracts, trachoma)

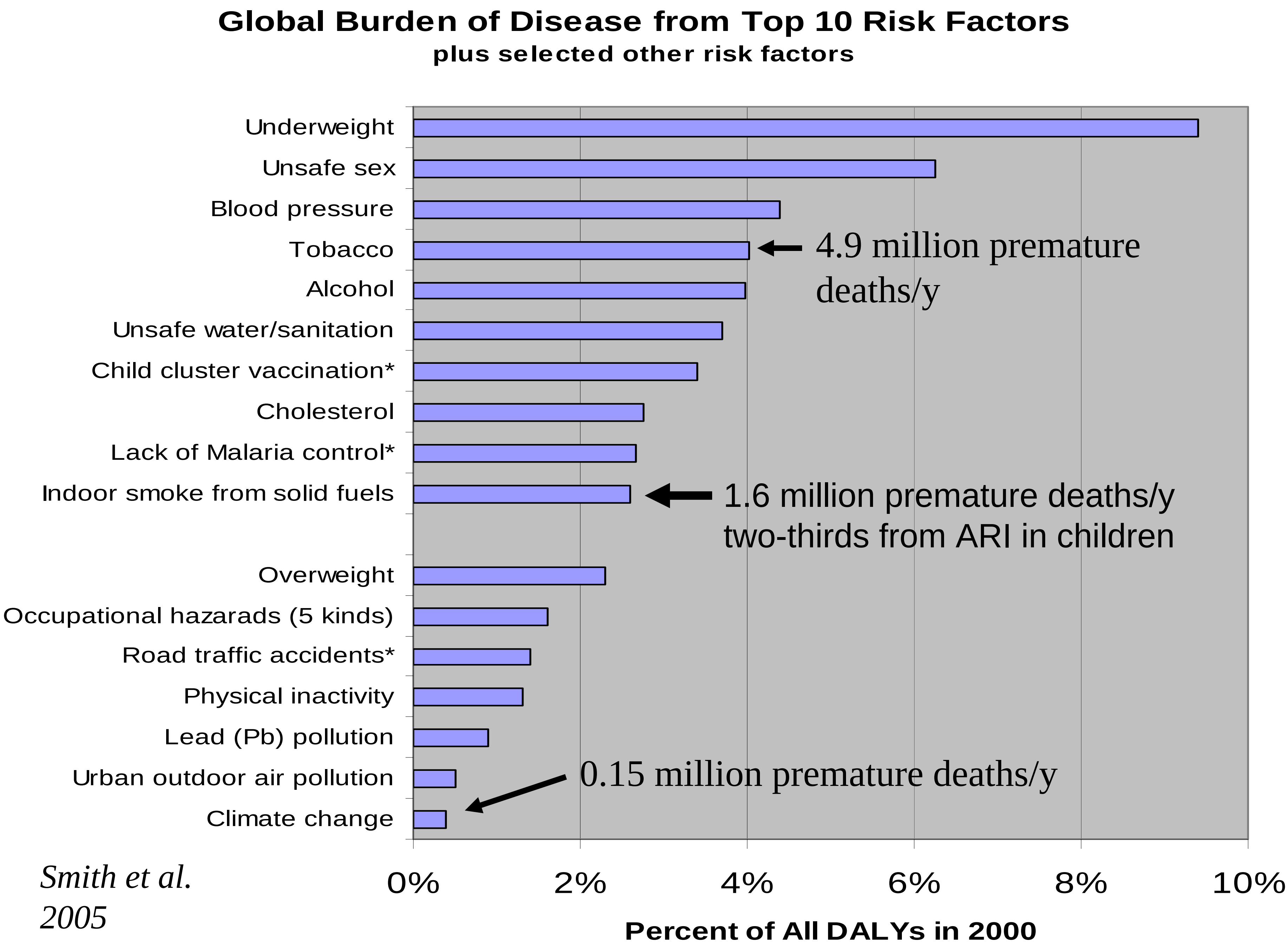
Tuberculosis

Heart disease?

# ALRI associated with use of solid fuels: analysis of ~12 observational studies

| Subgroup analyses | 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 cooking fire | 2.3 (1.8-2.9) |
| Studies adjusting for nutritional status | 3.1 (1.8-5.3) |
| Studies not adjusting for nutritonal 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) |

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

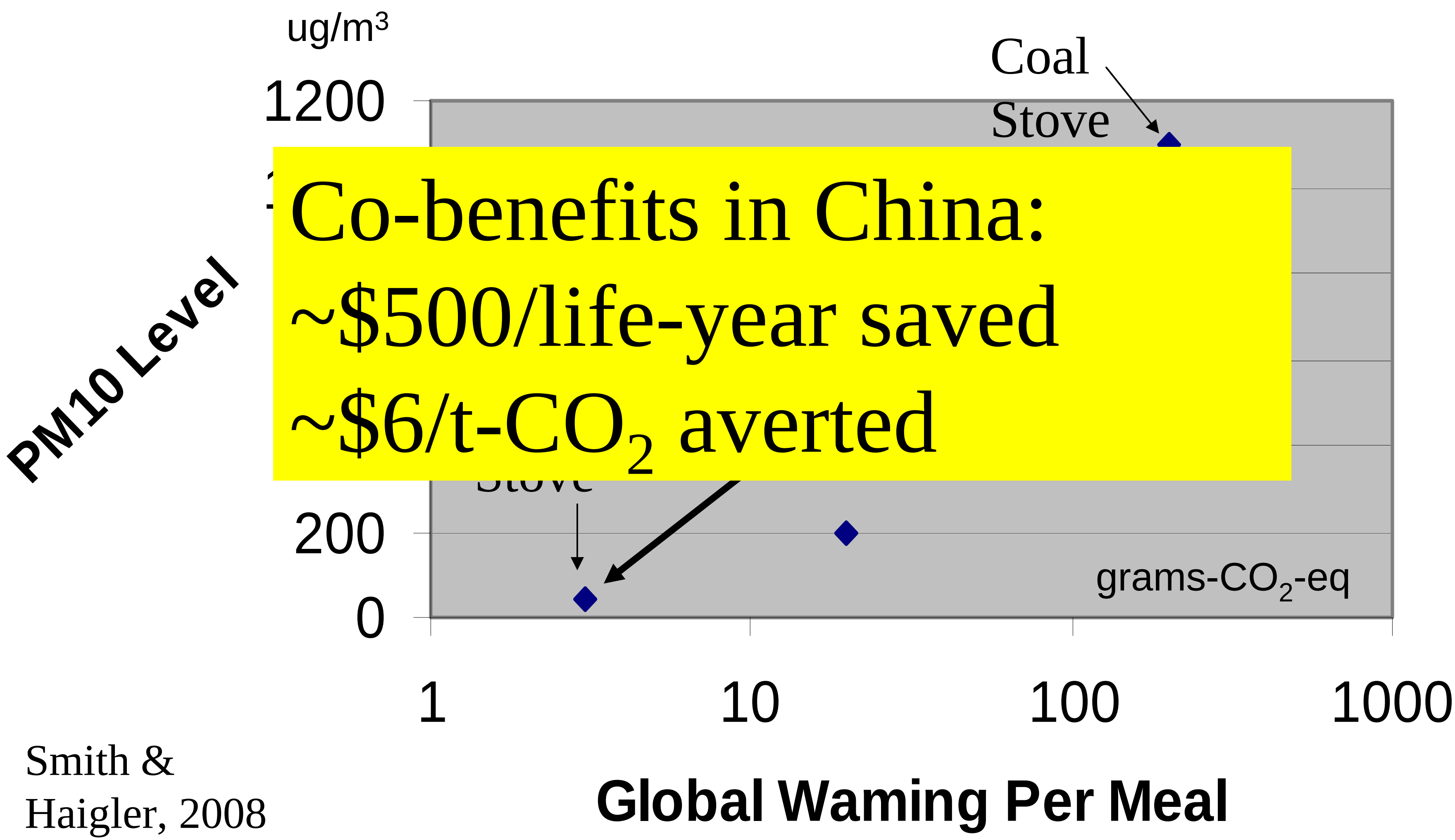



*Smith et al. 2005*

# A Chinese Biomass Gasifier Stove

Tests show emissions nearly at LPG levels:
Low health risk and essentially no greenhouse emissions

# Health and Greenhouse Gas Benefits of Biomass Stove Options

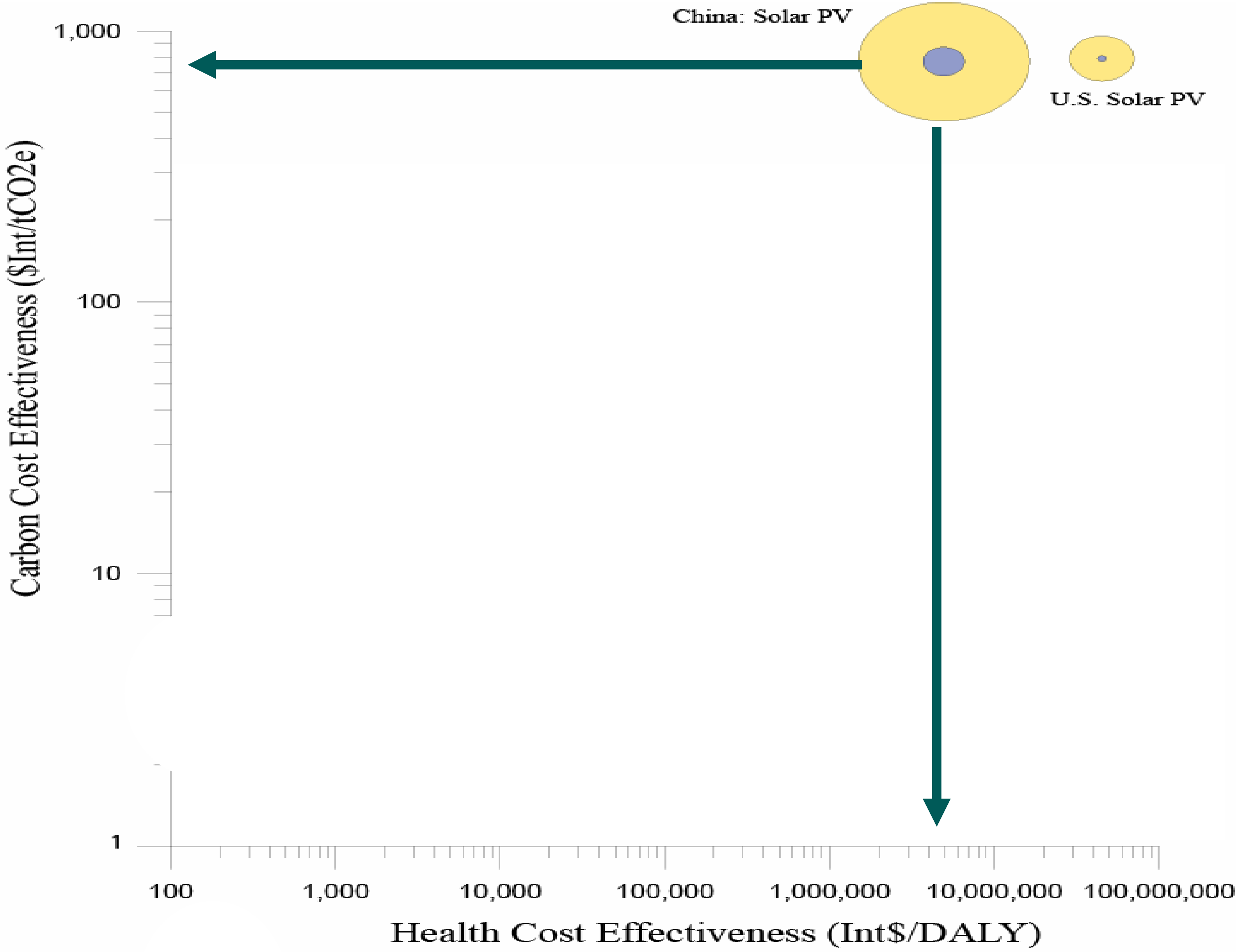



Co-benefits in China:

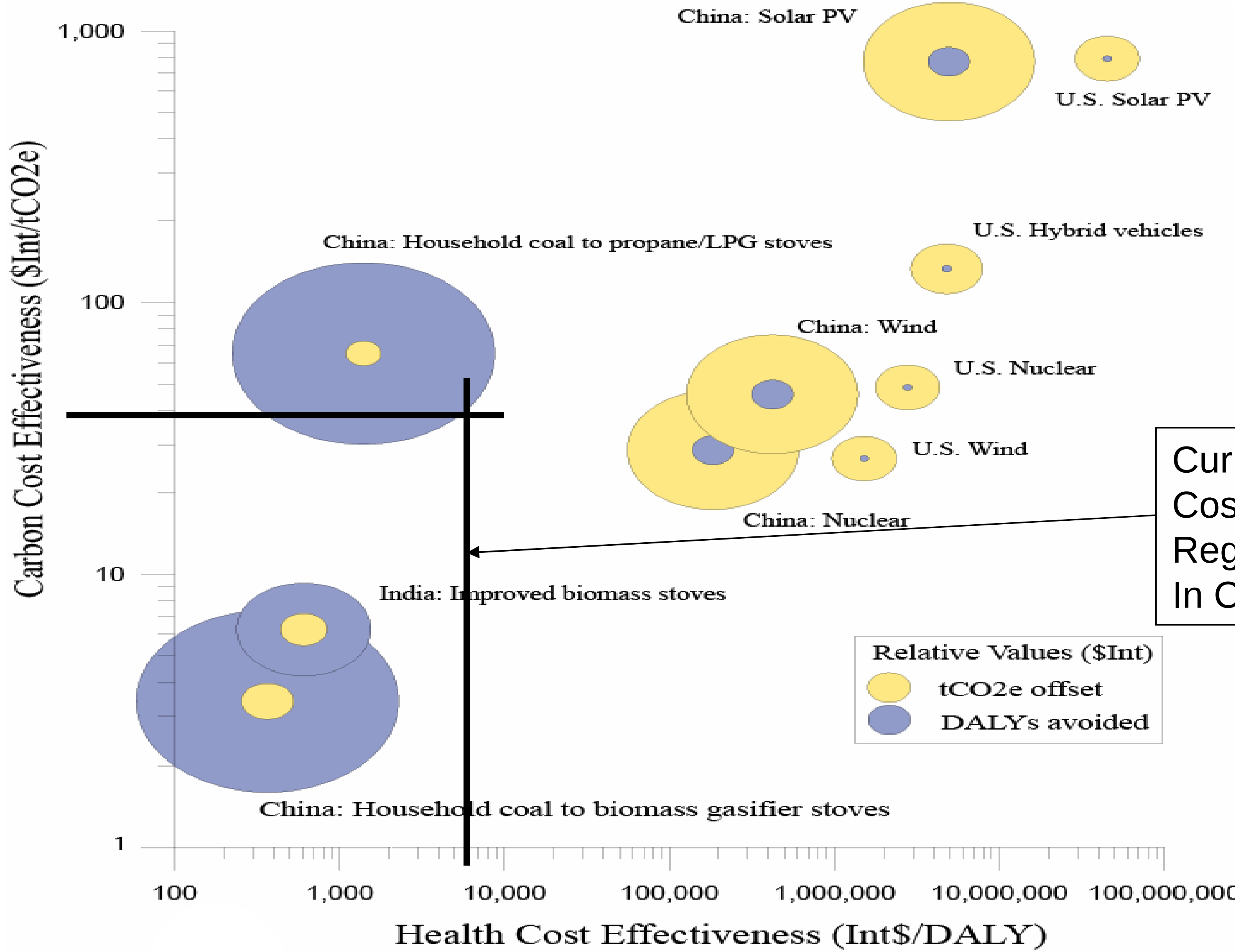
~$500/life-year saved

~$6/t-$CO_2$ averted

Smith & Haigler, 2008




Smith & Haigler, 2008




Current
Cost-effective
Region
In China

Smith & Haigler, 2008

# Paying for Rural Energy Development

Global Climate Market

$ per ton-carbon (world carbon market) –
DR <1%

National MDG Health "Market"

1-3x $GDP/capita per DALY saved (WHO/IBRD, etc. recommendation)
DR ~3%

Technology

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

Once global and national markets pick up their portions, local market can pay remainder
DR ~40%

Economic Development

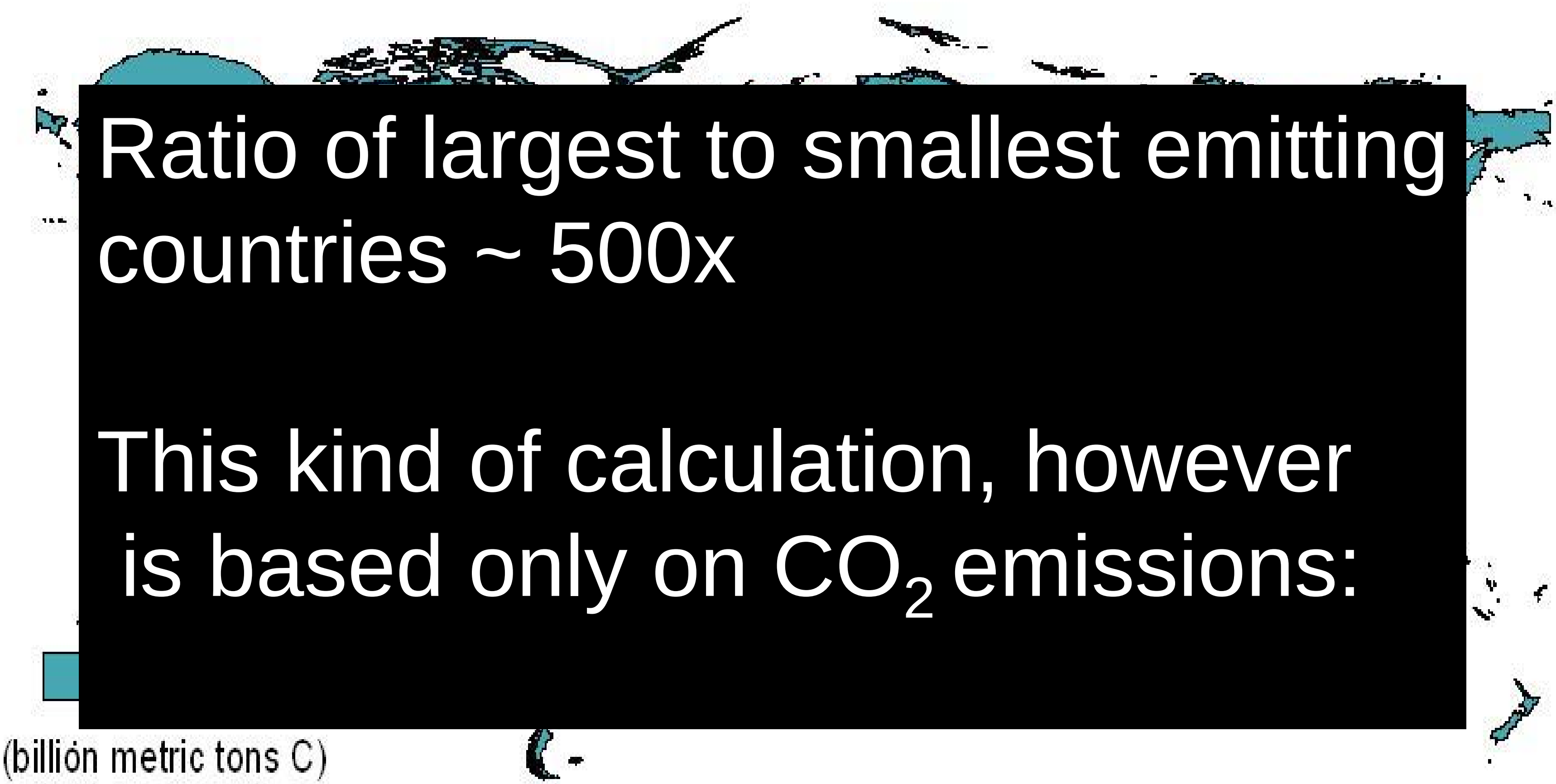
# Methane #3: Summary

- Methane is one of the constituents of products of incomplete combustion (PIC) from fuel combustion
- PIC are responsible for much burden of disease in the world's poorest populations
- Controlling this PIC has a double benefit: health and climate
- Can potentially be done economically – low hanging fruit for both

# Methane and equity

- We have seen how methane's health impacts, direct, indirect, and associated, mostly affect the poor
- What about methane emissions: how are they distributed?

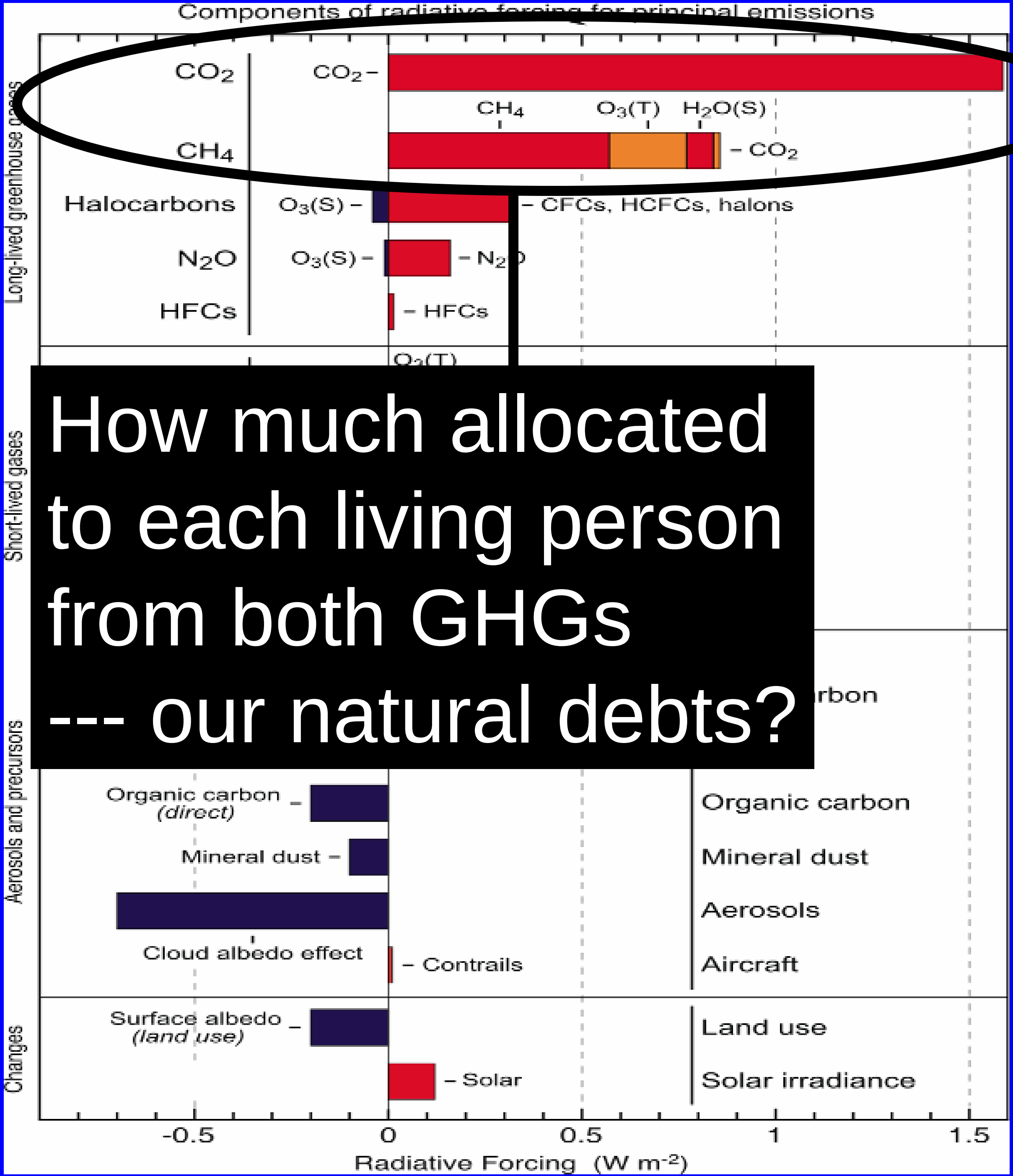
## National Natural Debts:
## Cumulative $CO_2$ emissions, depleted by natural processes




Ratio of largest to smallest emitting countries ~ 500x

This kind of calculation, however is based only on $CO_2$ emissions:

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.

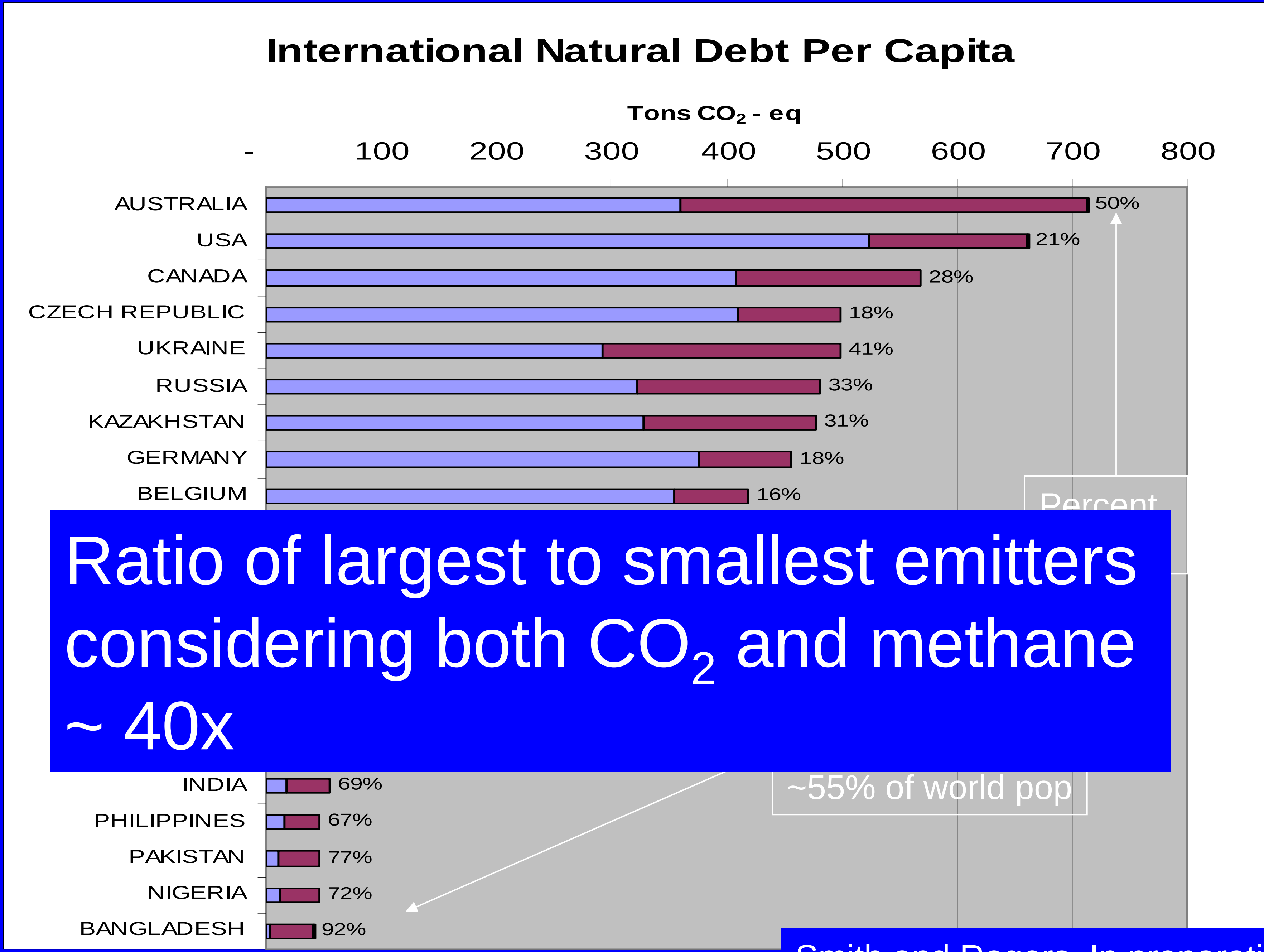



How much allocated to each living person from both GHGs --- our natural debts?

Warming in 2005 from emissions since 1750

More than half due to methane

IPCC, 2007

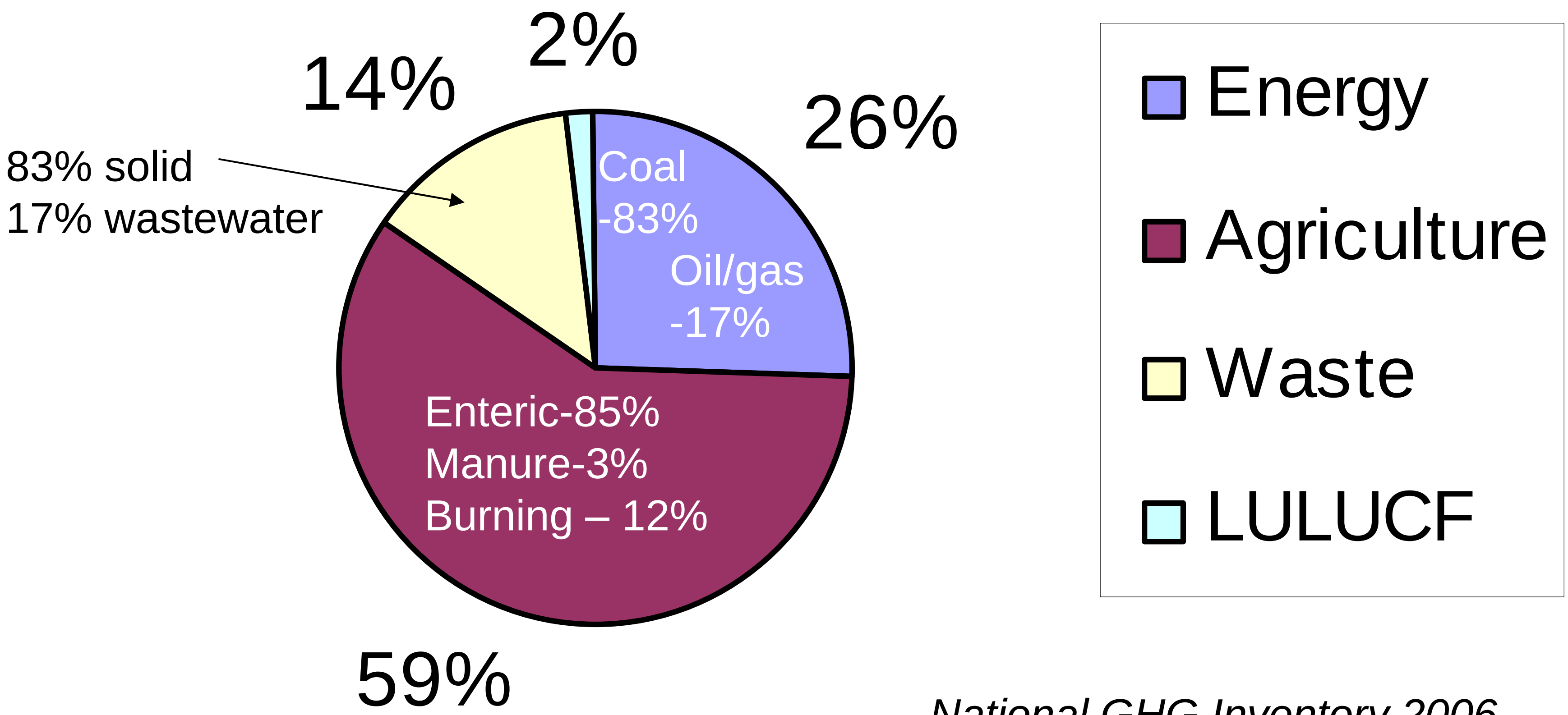



Ratio of largest to smallest emitters considering both $CO_2$ and methane ~ 40x

Smith and Rogers, In preparation

# Australian Methane Emissions - 2006

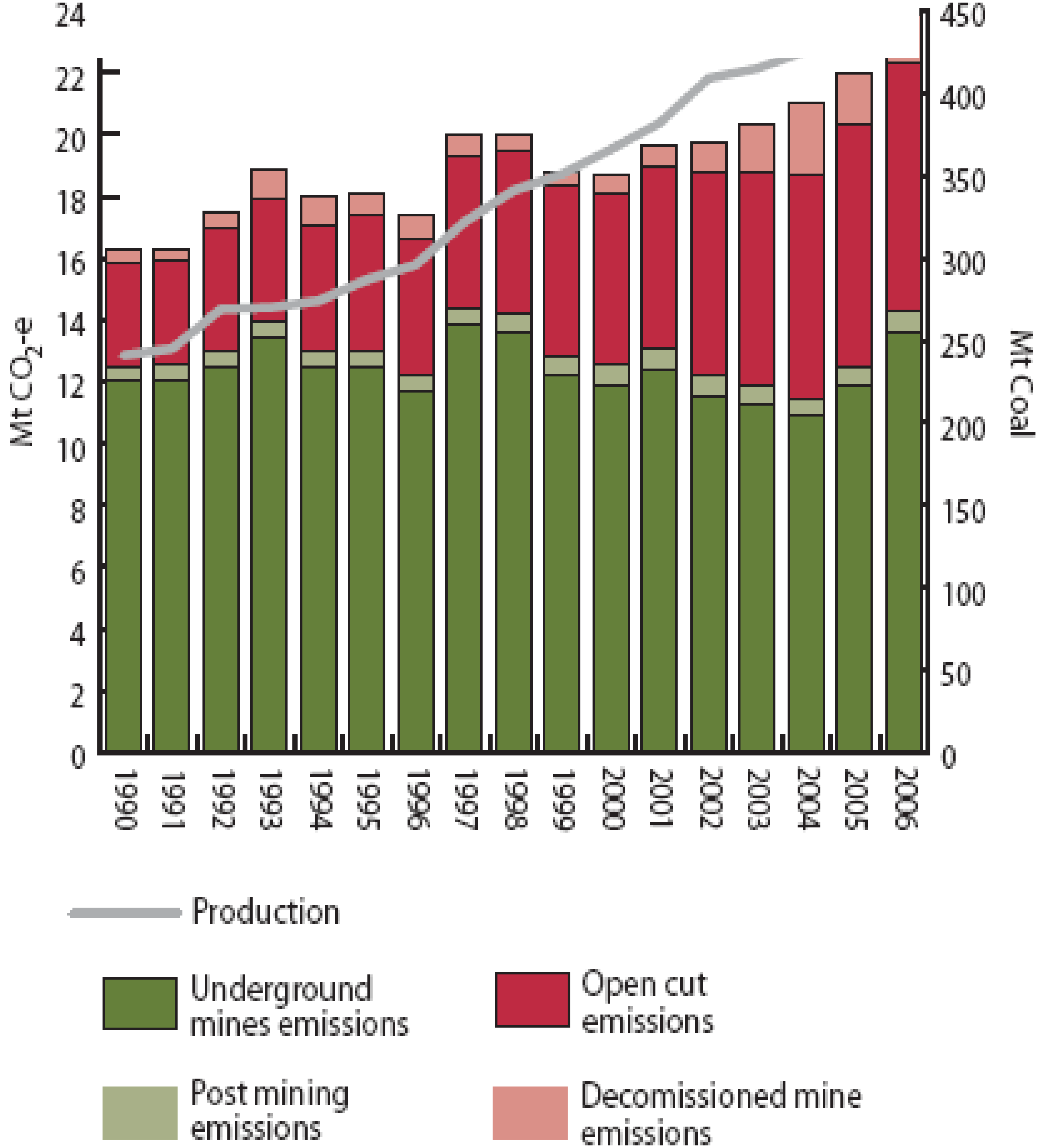
5.6 Mt ~2% of global total




*National GHG Inventory 2006*, Dept of Climate Change, 2008

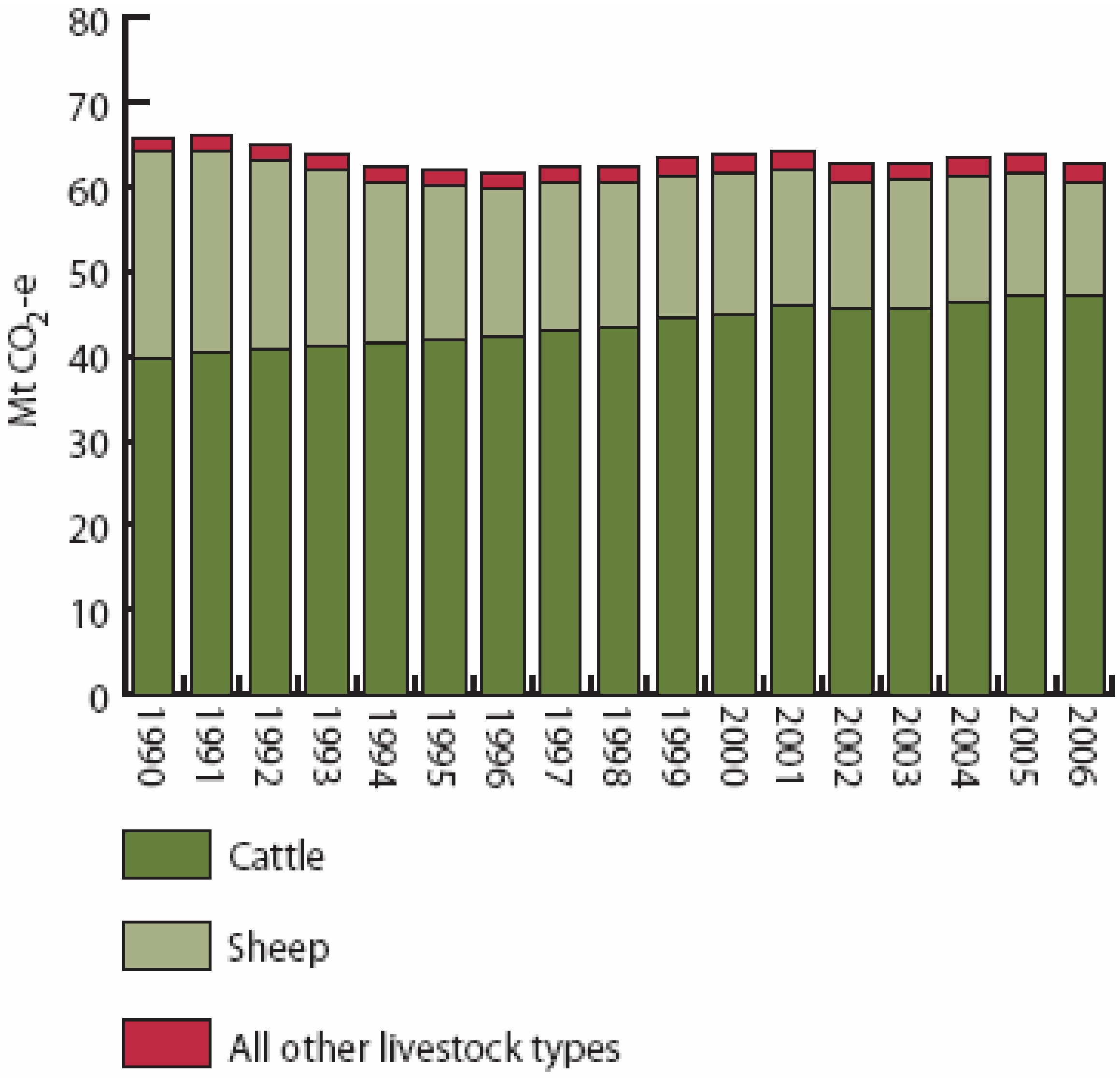
## Methane Emissions from Coal – trends

In Australia
83% of
fuel cycle
emissions are
due to
coal mining



In Australia 85% of agricultural emissions are due to enteric emissions from livestock

# Methane Emissions from Livestock – trends



# Conclusion on Methane

- Methane emissions are more important than current official weighting factors indicate because of its large effect over the next generation
- Likely to increase in “value”, perhaps during the post-Kyoto deliberations now starting
- Developing countries have a bigger role
- Methane is emitted as part of the poor combustion process of solid fuels, which also produce much health-damaging pollution
- Improving this combustion offers substantial GHG as well as health benefits in a cost-effective manner
- Ways to control are quite different from $CO_2$
- And may be easier in the short term

# Methane, cont.

- Increases of wide-scale ground-level ozone is becoming a major world problem
- A significant health-damaging pollutant
- Methane emissions are one of its causes
- Reduction of methane emissions, therefore, will help protect health worldwide in the short term

# Methane, cont.

- Way to reduce warming in the next generation is to put more attention on methane (and other shorter lived GHGs)
- Once the heat enters Earth's systems, it does not matter where it came from
- The **rate** of warming is as important as the total amount
- Way to slow the rate is to immediately reduce methane emissions
- While working to stop $CO_2$ in the long run

# Being Smart about Mitigation

- **Co-benefits**: Guide mitigation measures so they help achieve other societal goals, including health protection.
- **No-regrets:** providing a short-term more certain return (health) on a long-term more uncertain investment (climate protection)
- **Political bridge** over the international divide between developed and developing countries

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

If you are going to put carbon in the atmosphere,
the best form in terms of either climate
or health is carbon dioxide

Thank you