Carbon on Steroids: The Untold Story of Methane, Climate, and Health

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Nobel Laureate 2007

At the 0.02% level

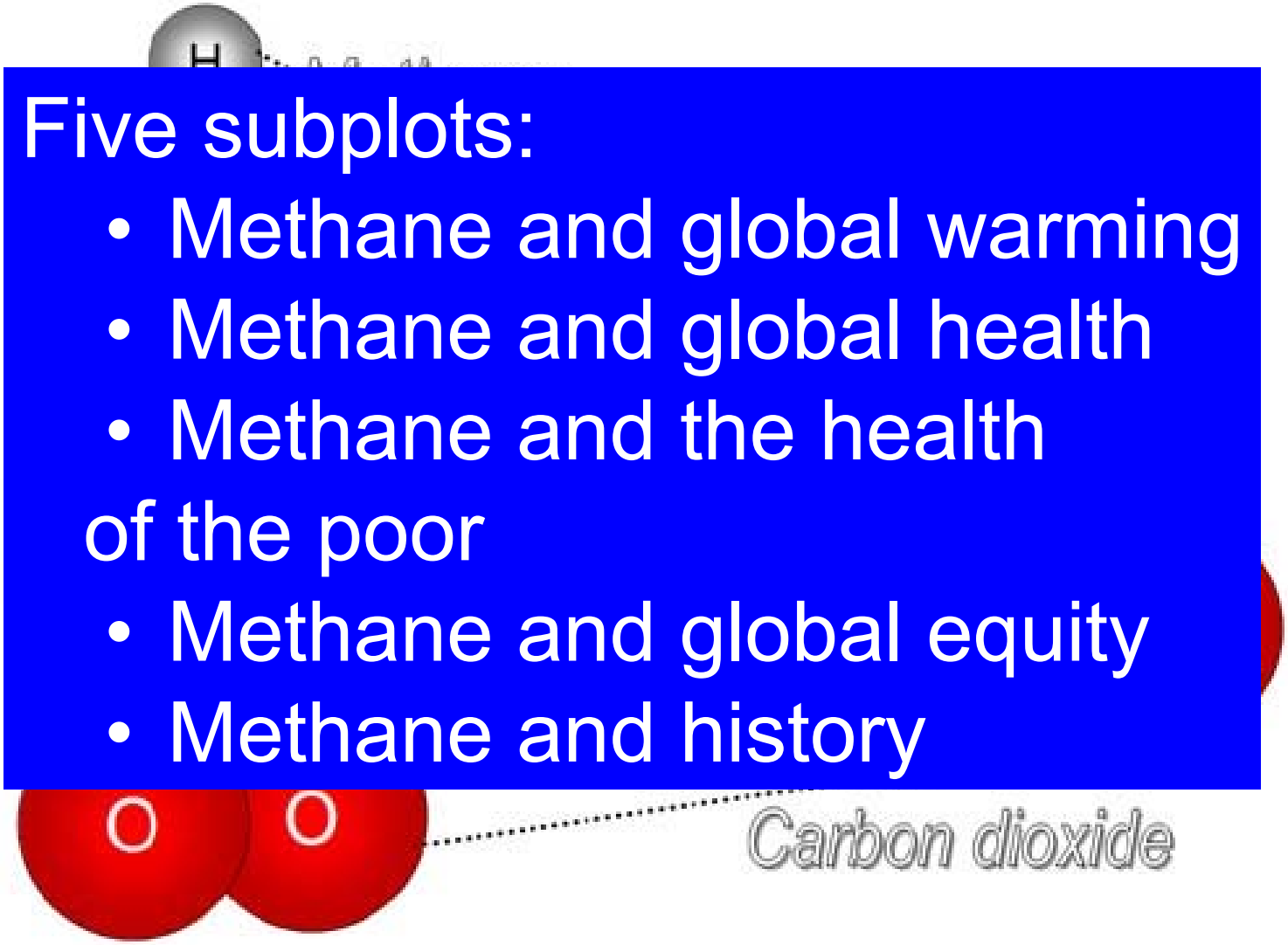
California Air Resources Board
Sacramento
November 10, 2008

See VIDEO of Smith's presentation at http://www.arb.ca.gov/research/seminars/player.php?flv=smith/kirksmith.flv

Carbon dioxide is important

Do not think otherwise

The Methane Story: CH_4



Five subplots:

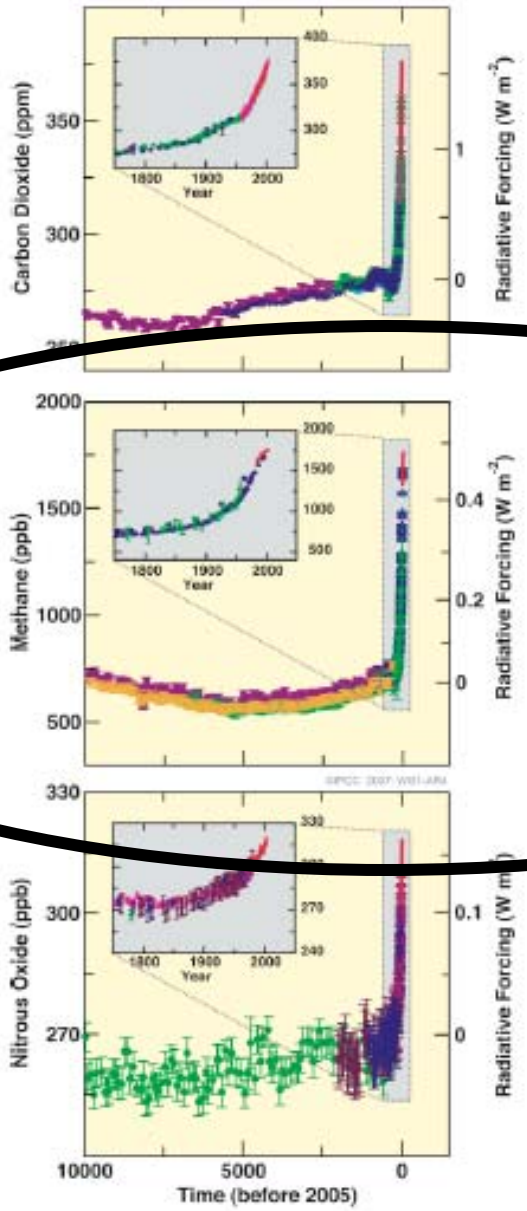
- Methane and global warming
- Methane and global health
- Methane and the health of the poor
- Methane and global equity
- Methane and history

What I am not speaking about

Particular methane reduction possibilities in California

Potential for runaway methane emissions as positive feedback in global warming

Atmospheric Greenhouse gas concentrations



Anthropogenic Sources

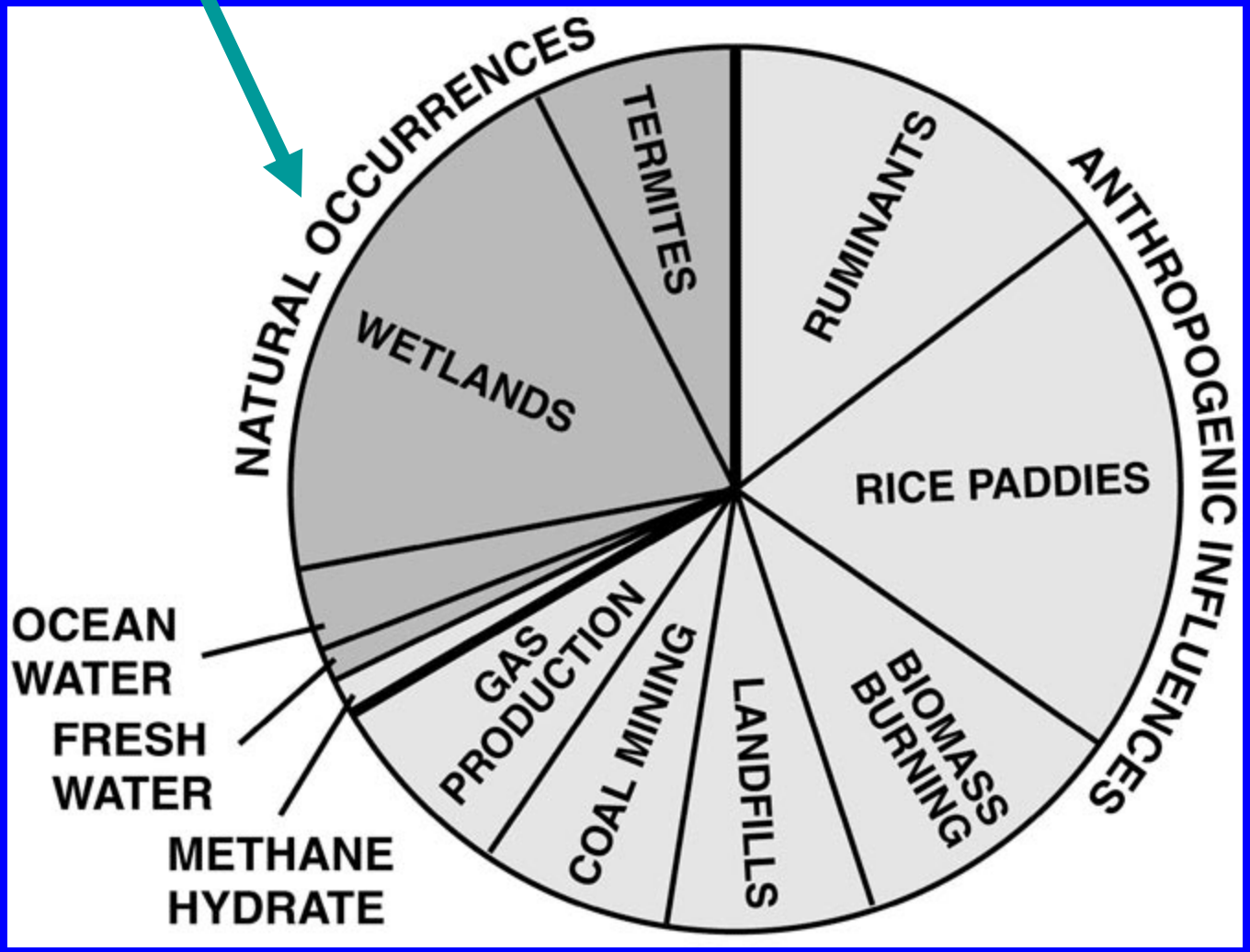
CO_2
Fossil fuels
Land use change
Cement manufacturing

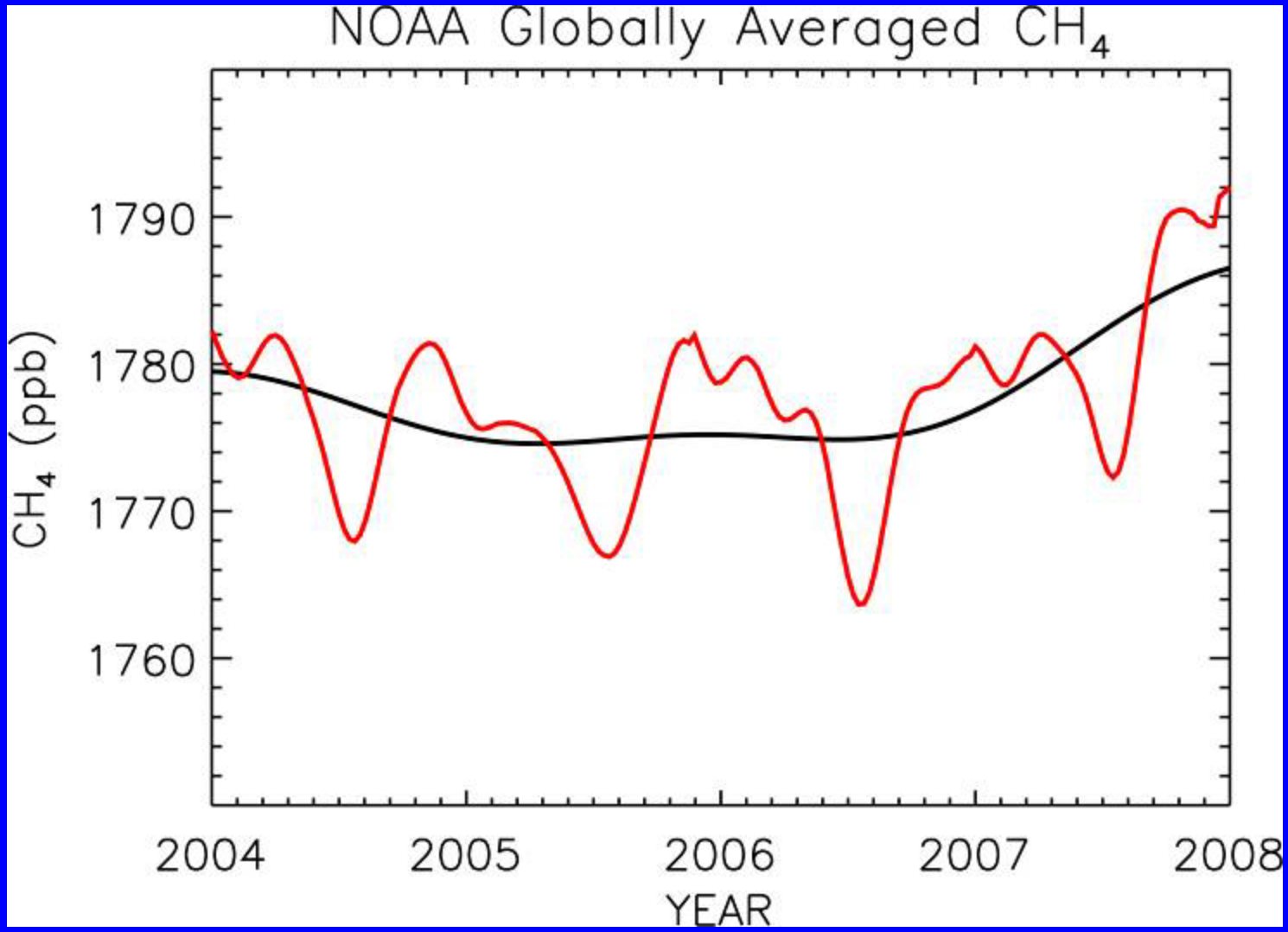
Methane
Landfills
Rice
Livestock
Waste management
Fossil recovery

N_2O
Fertilizer
Planted N-fixers
Combustion

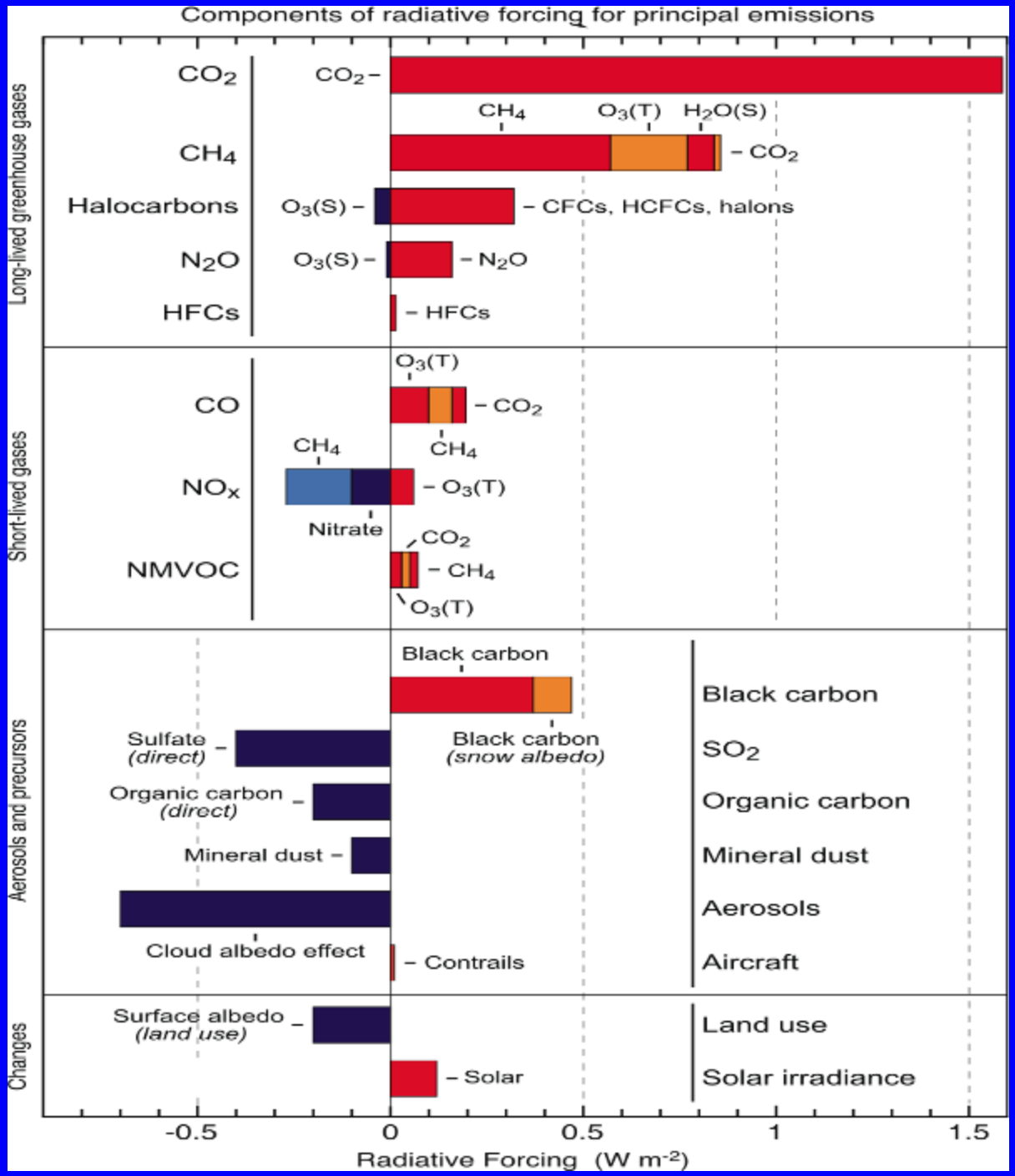
Figure SPM.1
IPCC 2007

Only one-third of emissions from natural sources





Emissions expected to grow at ~1.5% per year until 2030 – similar to CO2



Warming in 2005 from emissions since 1750

Methane more than half of total from CO_2

IPCC, 2007

1. Methane and Global Warming

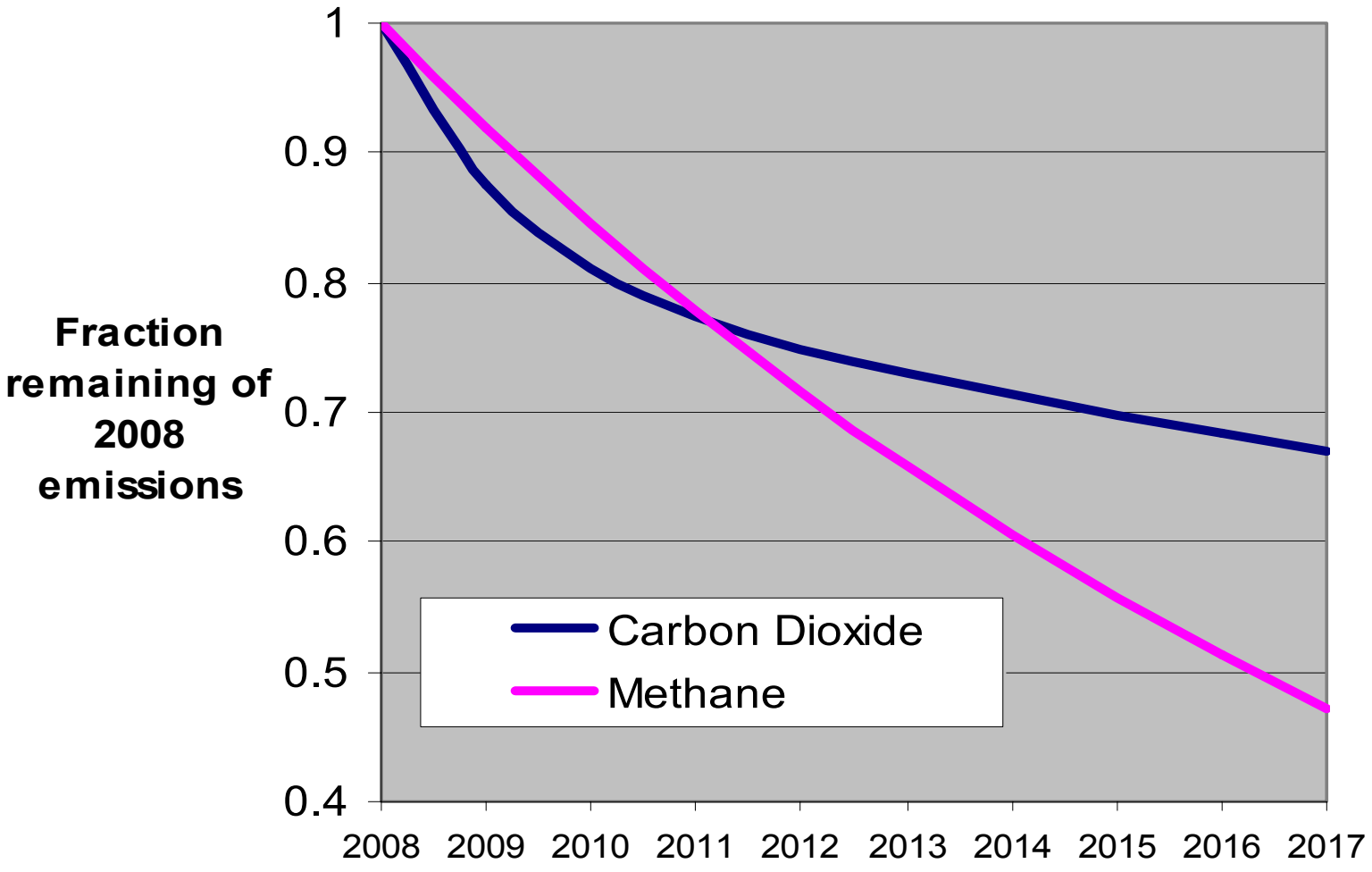
- A much more powerful greenhouse gas (GHG) than CO_2
- Partly due to its direct effect, but also because it creates ozone (O_3), another powerful GHG
- Nearly 100 times more per ton than CO_2 at any one time (73x from direct effects)
- Eventually turns to 2.75 times as much CO_2 by mass
- Methane has thus contributed a significant amount to global warming, more than half that of CO_2
- But has a much shorter atmospheric lifetime compared to CO_2

Math of GHG Decay (AR4)

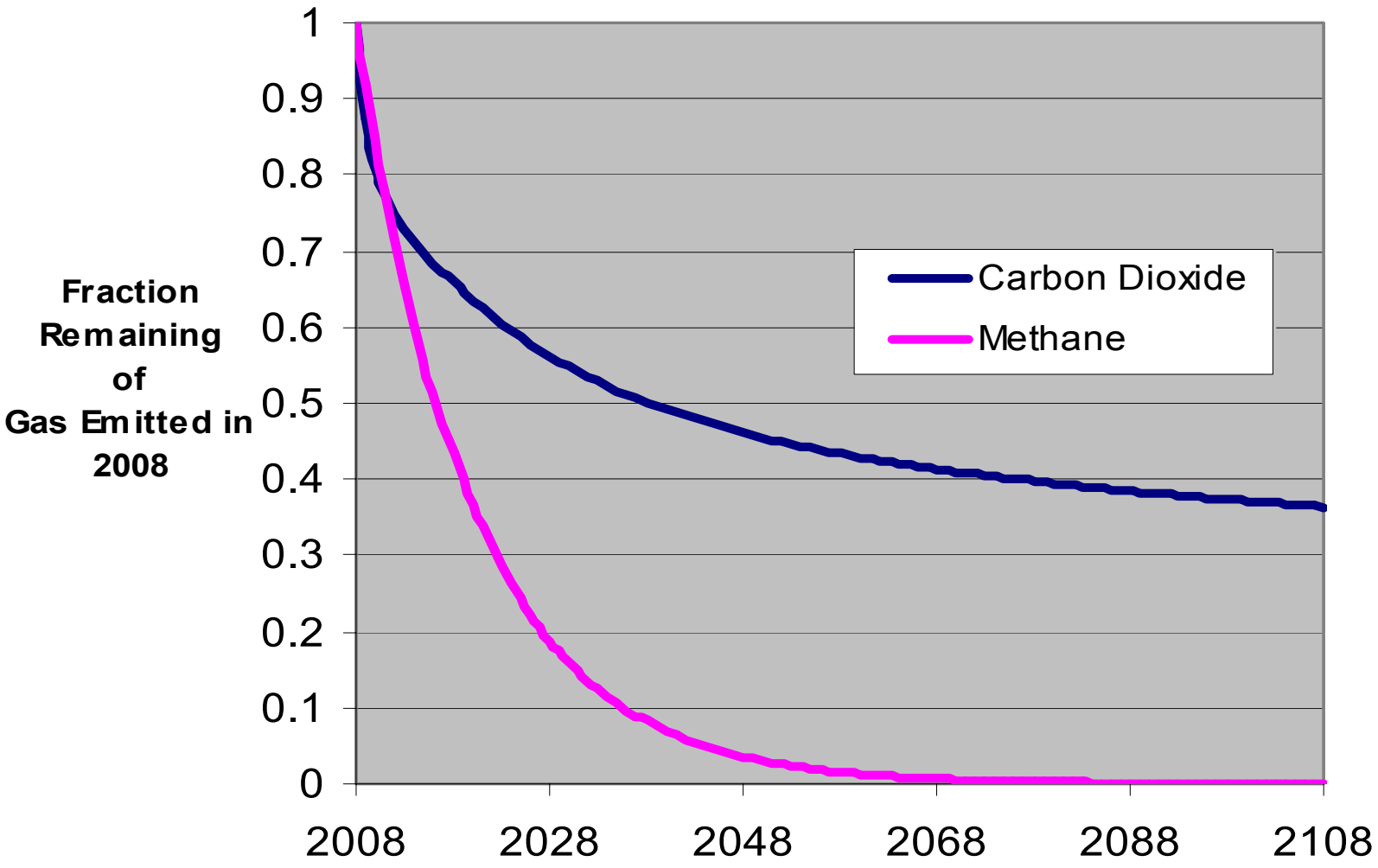
- CO_2 goes into four compartments:
  - 19% of total with a lifetime* of 1.2 years
  - 34% at 18.5 y
  - 26% at 173 y
  - 21% with a lifetime of “many thousand years”
- Methane has a 12 y lifetime,
  - but contributes to ozone, a GHG
  - and eventually oxidizes to CO_2

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

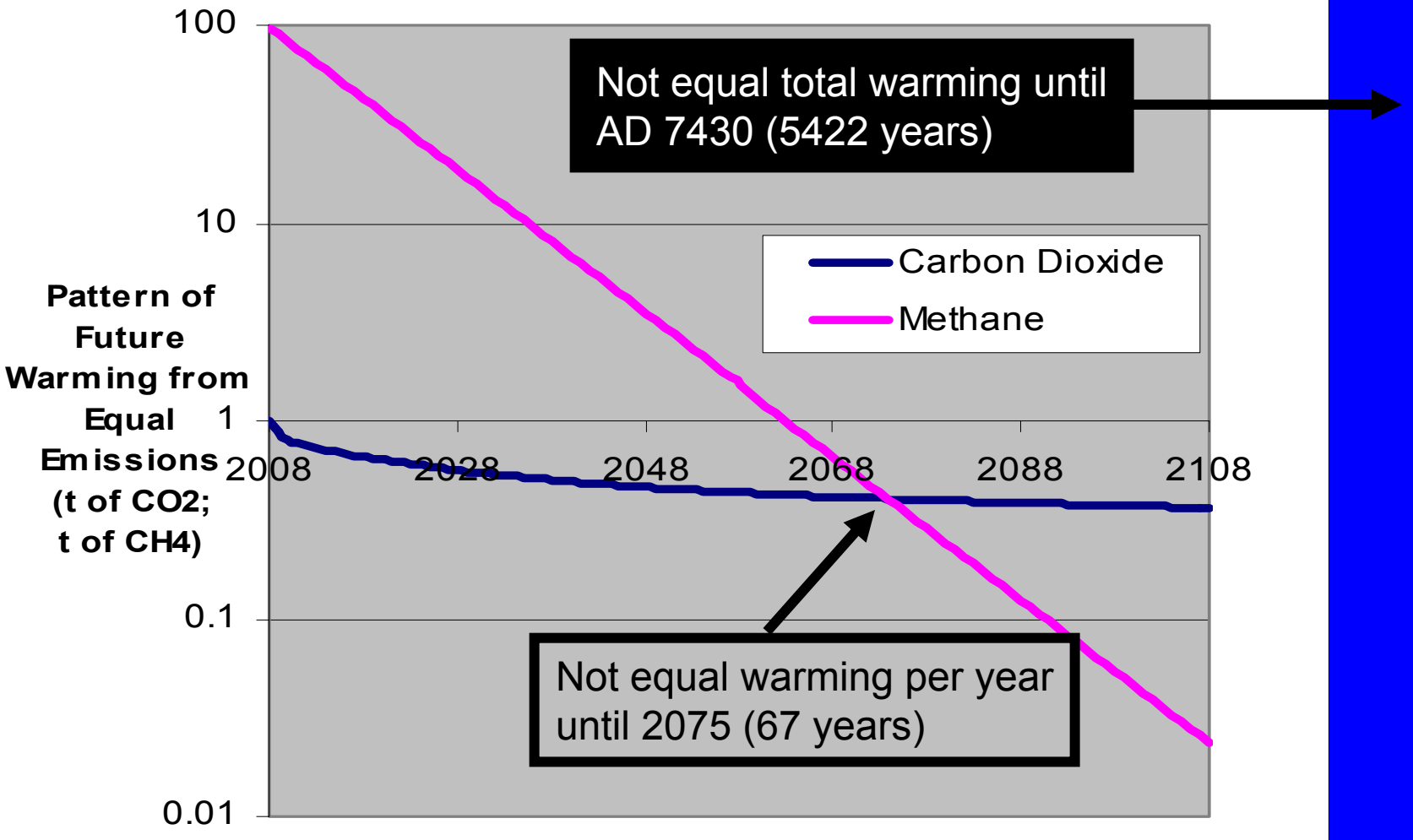
Natural CO2 and CH4 Depletion - first 10 years



Natural CO2 and CH4 Depeletion - 100 years



Relative Warming from CO2 and CH4 emitted in 2008

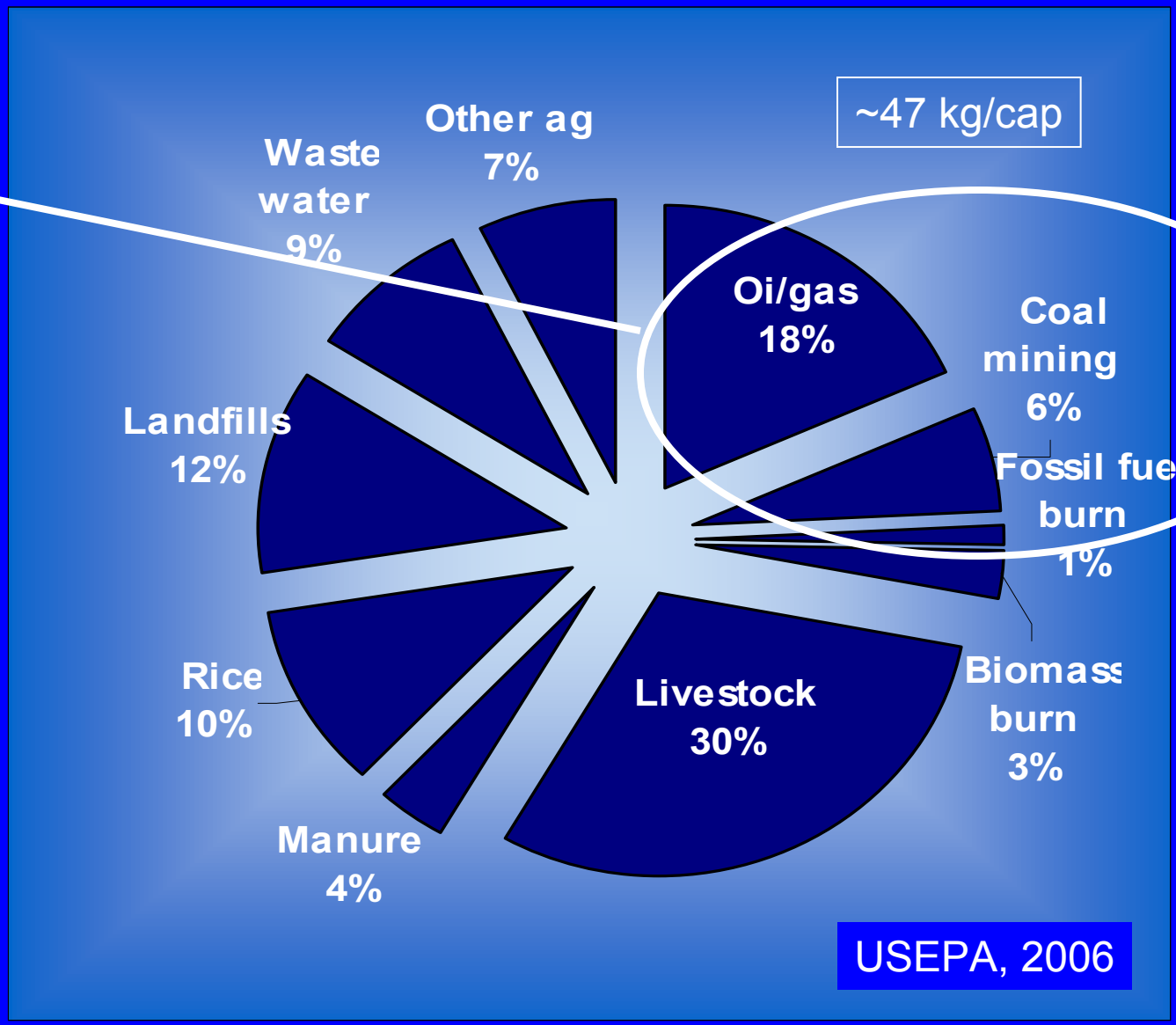


Actually two types of methane

- Biogenic methane (ruminants, biomass combustion, landfills, etc.) – the CO_2 it creates is renewable, i.e., does not add to atmospheric load of CO_2
- Fossil methane (natural gas, coal mines, fossil fuel combustion) – the CO_2 it creates does add to the load

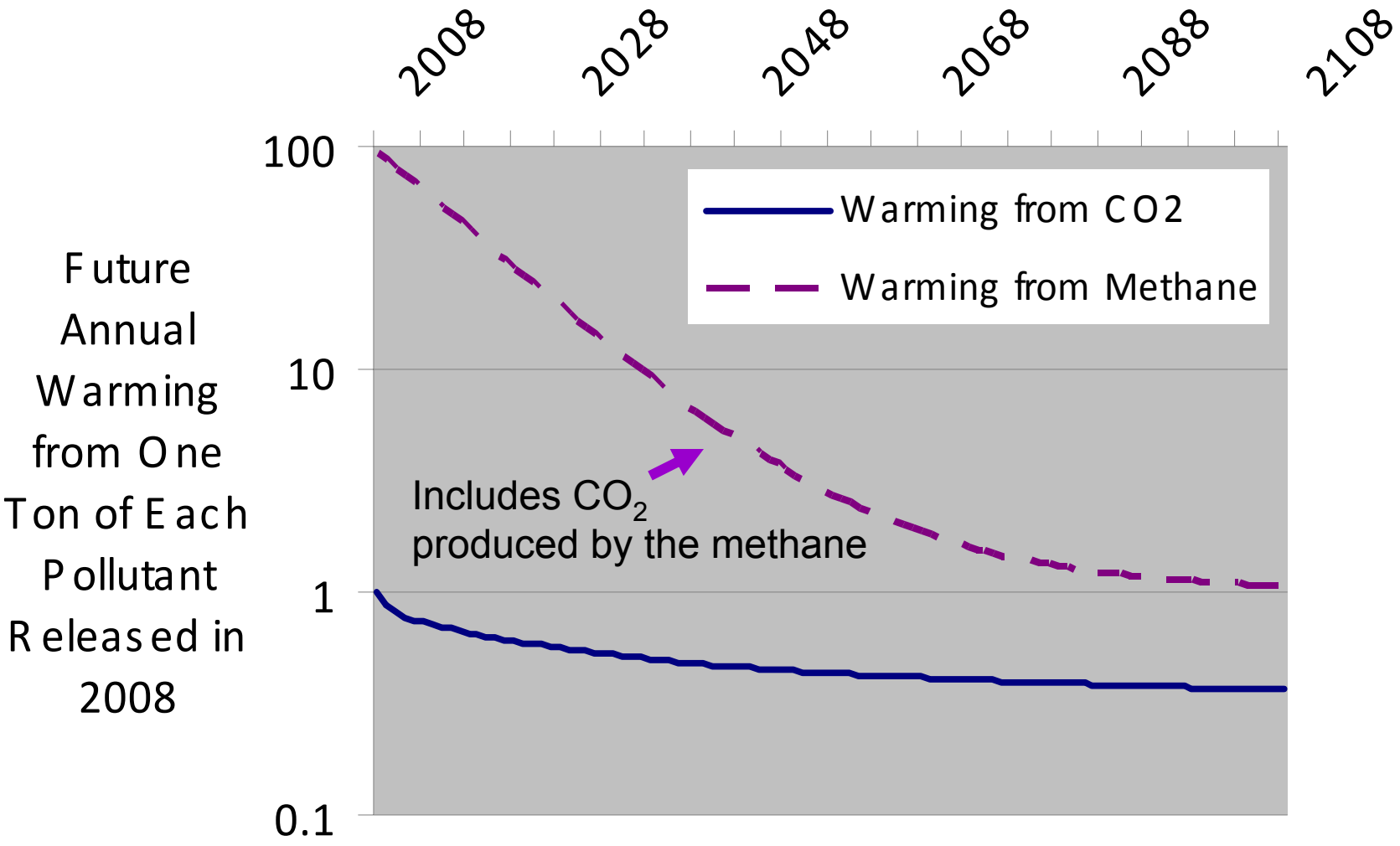
Global Anthropogenic Methane Emissions ~2005
Total ~ 305 million tons

Fossil methane ~25%

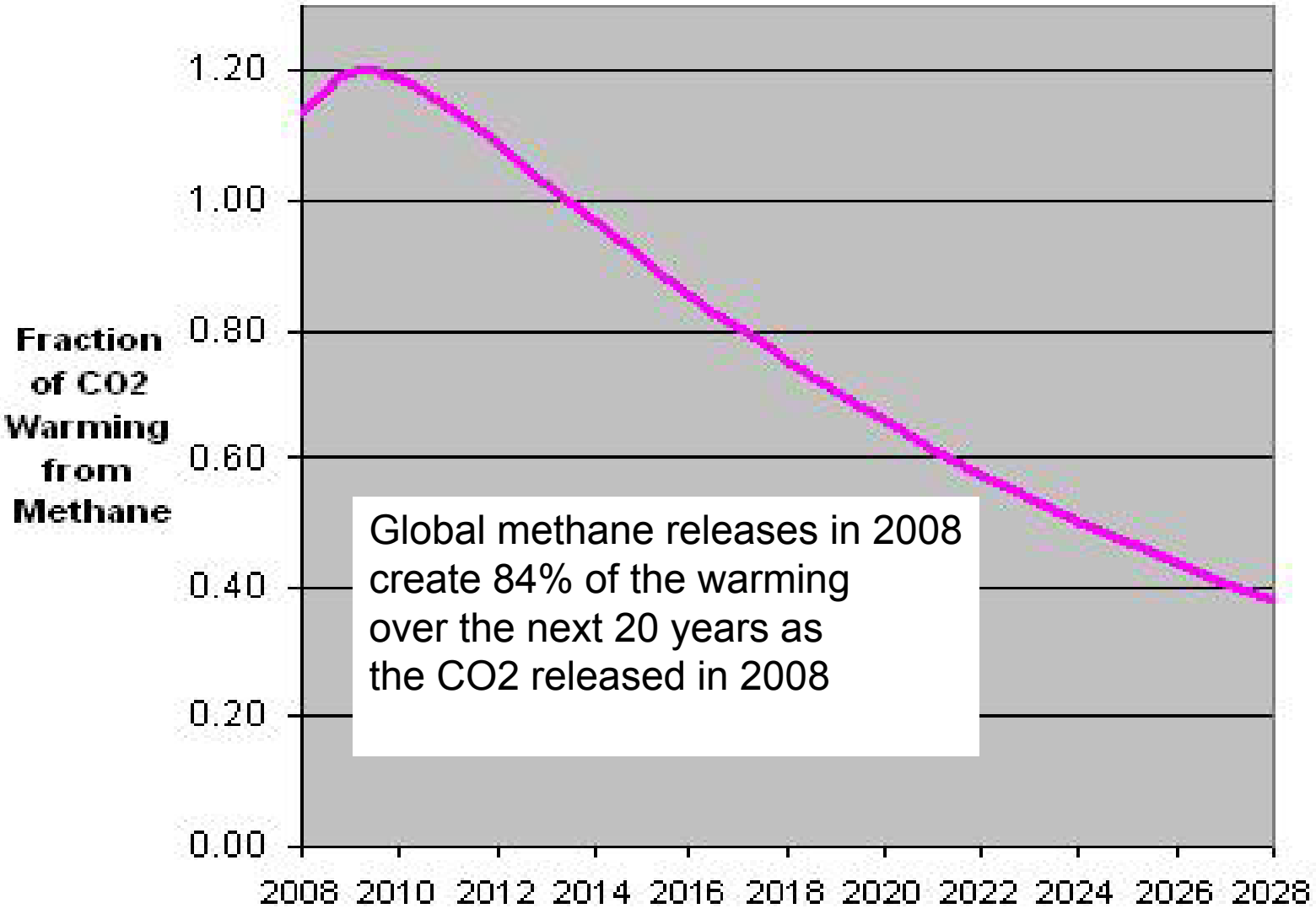


Expected to grow at ~1.5% per year

Future Warming of Fossil Methane and CO_2 from Equal Emissions in 2008



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

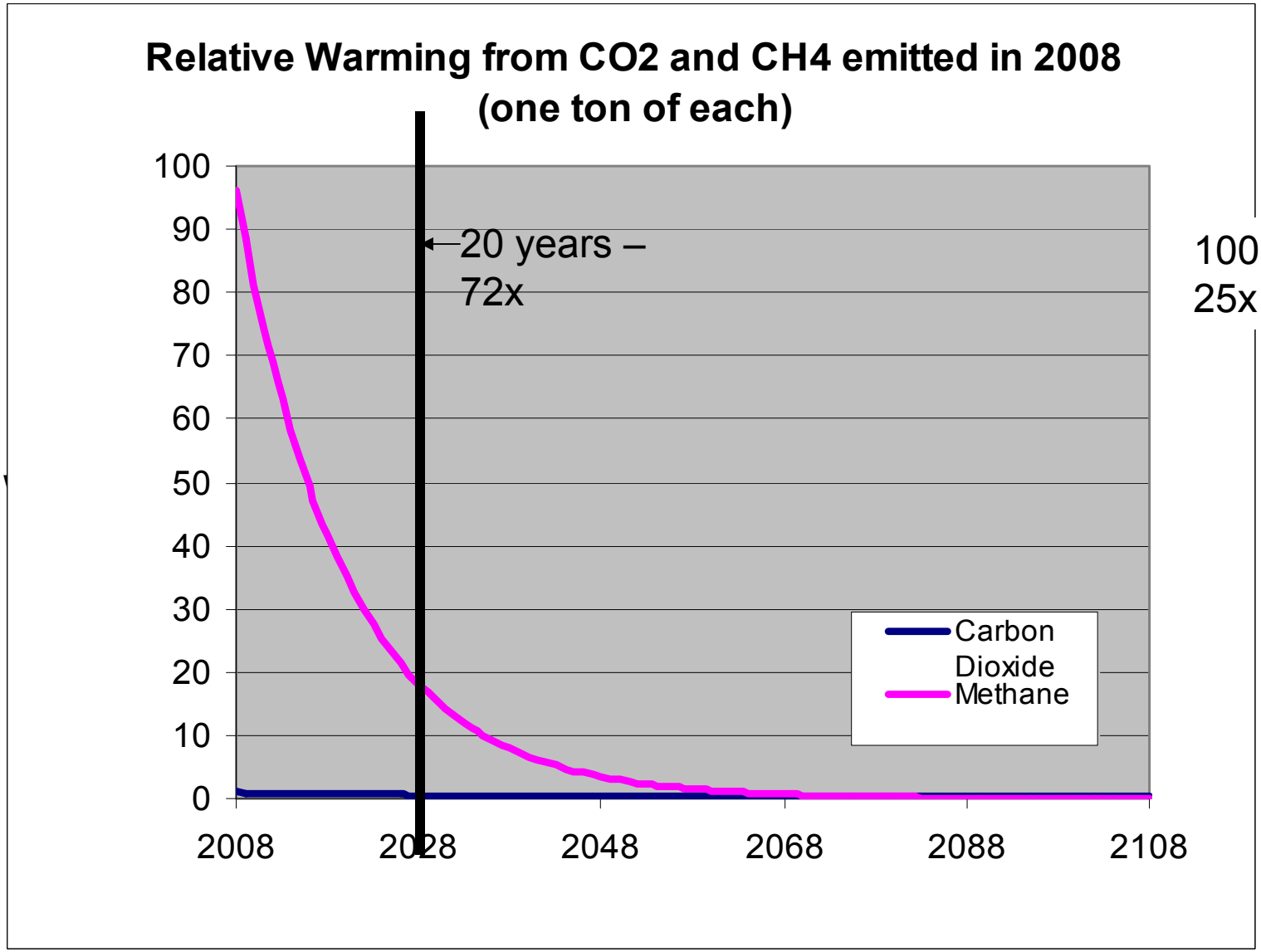


How can we compare projects to reduce different GHGs?

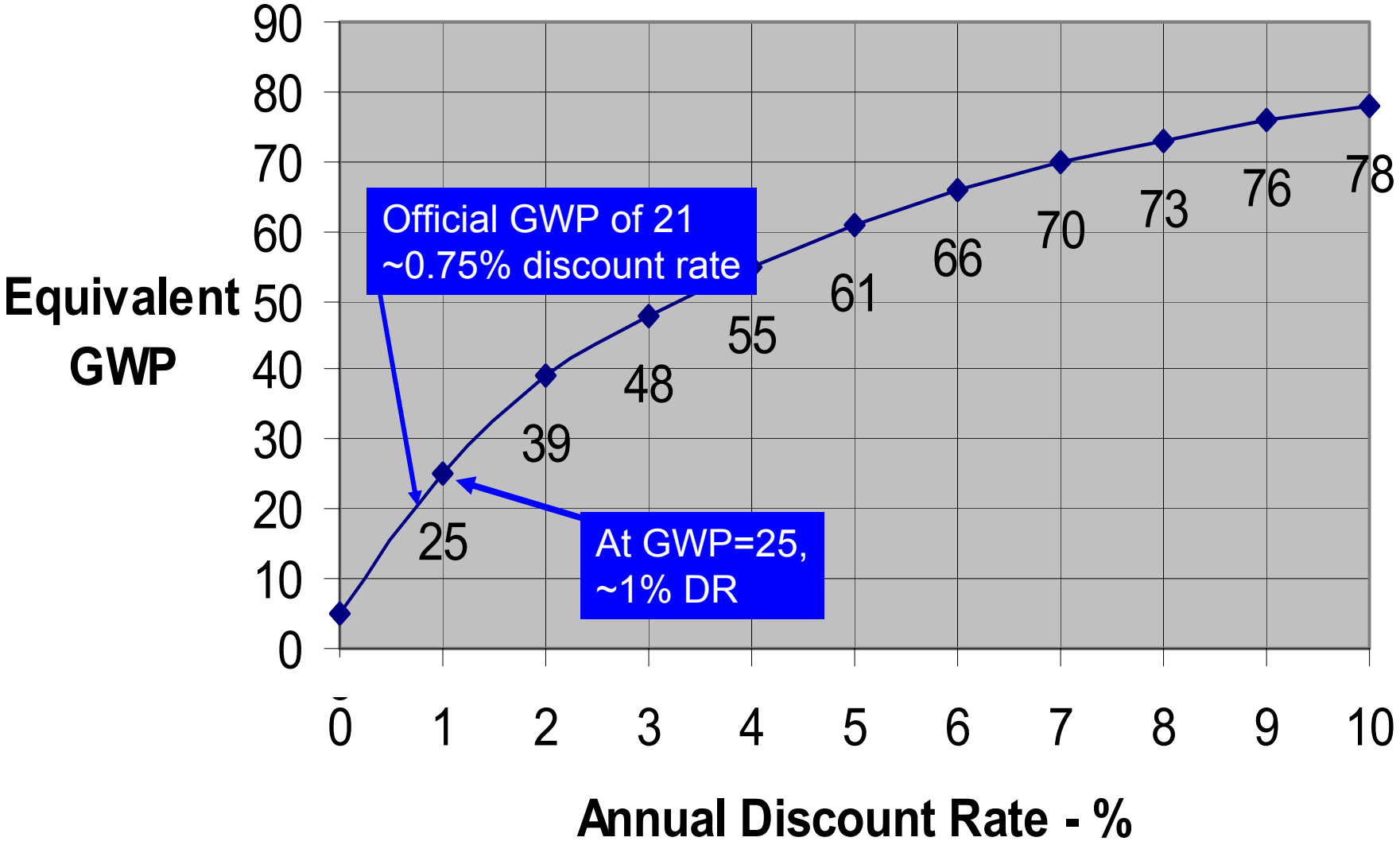
- Why not just take all future warming into account?
- This would mean that no effort would go into avoiding emissions of the shorter lived GHGs, such as methane, because CO_2 has such a long lifetime.
- It would result in spending most money to protect people thousands of years into the future and ignoring 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 those for California.

Methane and Time

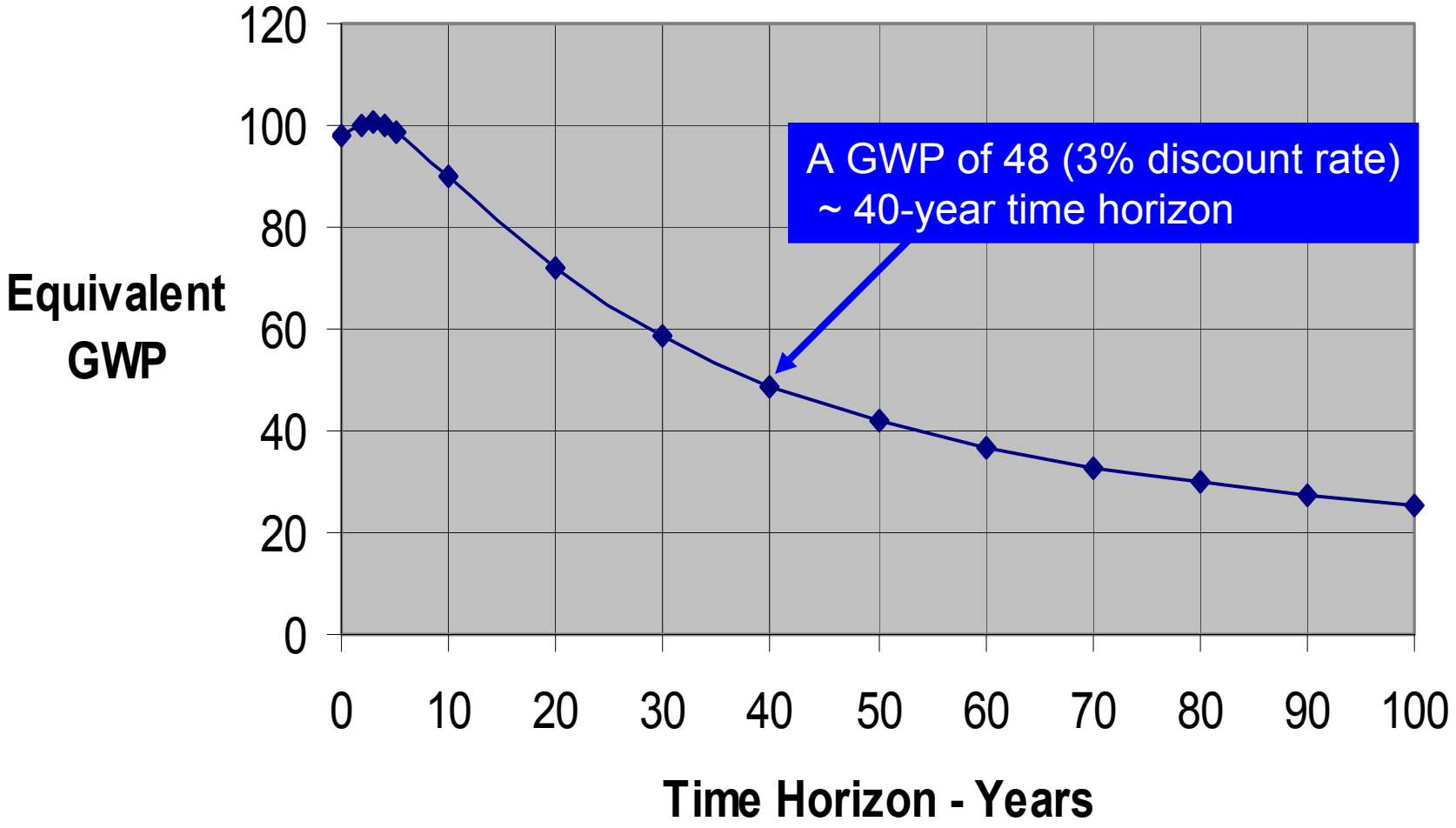
- The current official GWPs are based on 100-year time horizons
  - Methane is 21 x CO_2 by weight (25 in AR4)
  - Equivalent to ~0.75% discount rate
- For making decisions on how to spend resources when impacts are upon us, <1% is too low.
- The other GWP published by IPCC, has a 20-year time horizon
  - 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

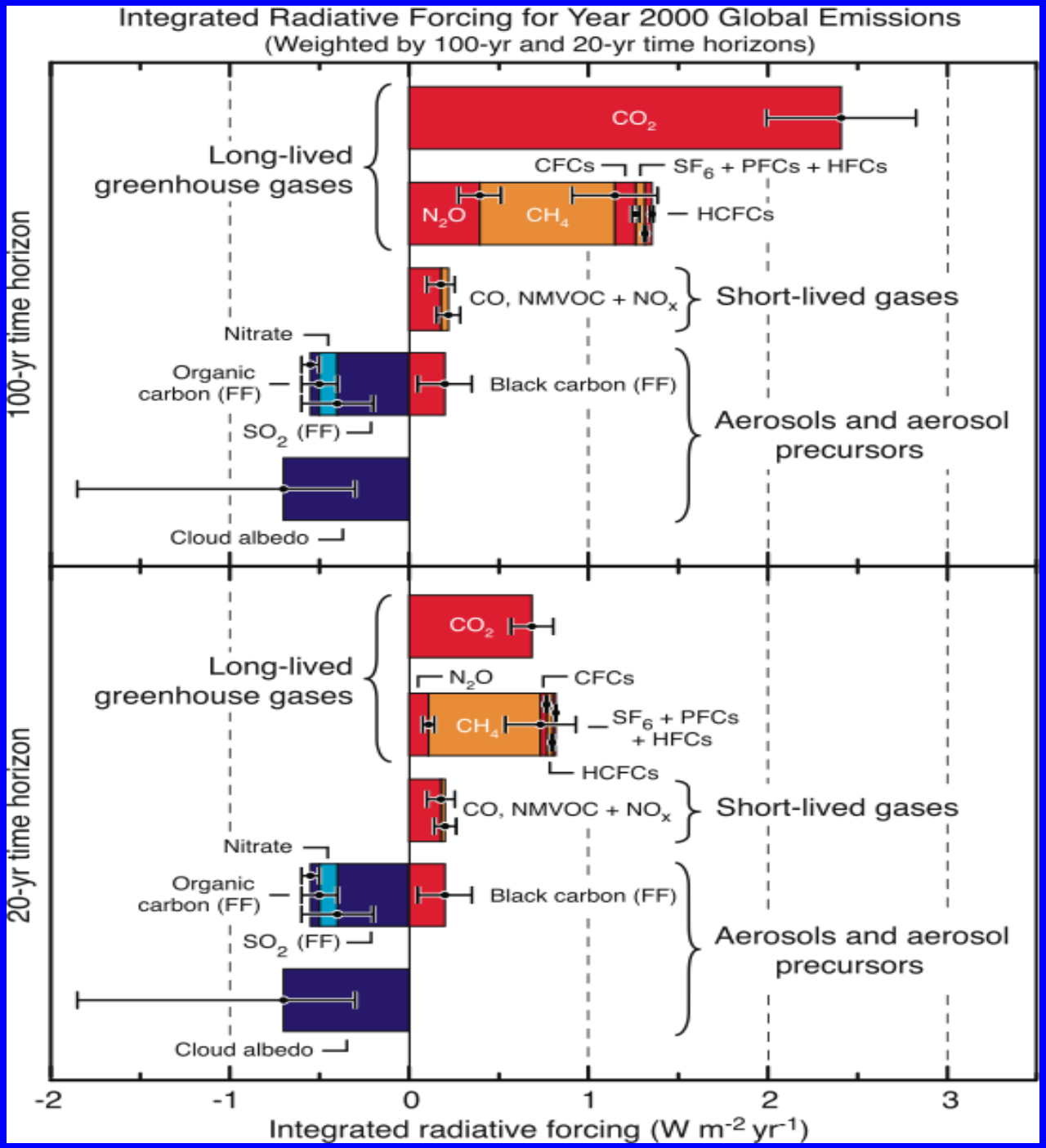

Relative Warming from CO2 and CH4 emitted in 2008
(one ton of each)
100
90
80
70
60
50
40
30
20
10
0
2008
2028
2048
2068
2088
2108
20 years –
72x
100 years –
25x
Carbon
Dioxide
Methane

Methane GWPs and Discount Rates



Methane GWPs and Time Horizons





100-y horizon

Time perspective makes a difference

20-y horizon

IPCC, 2007

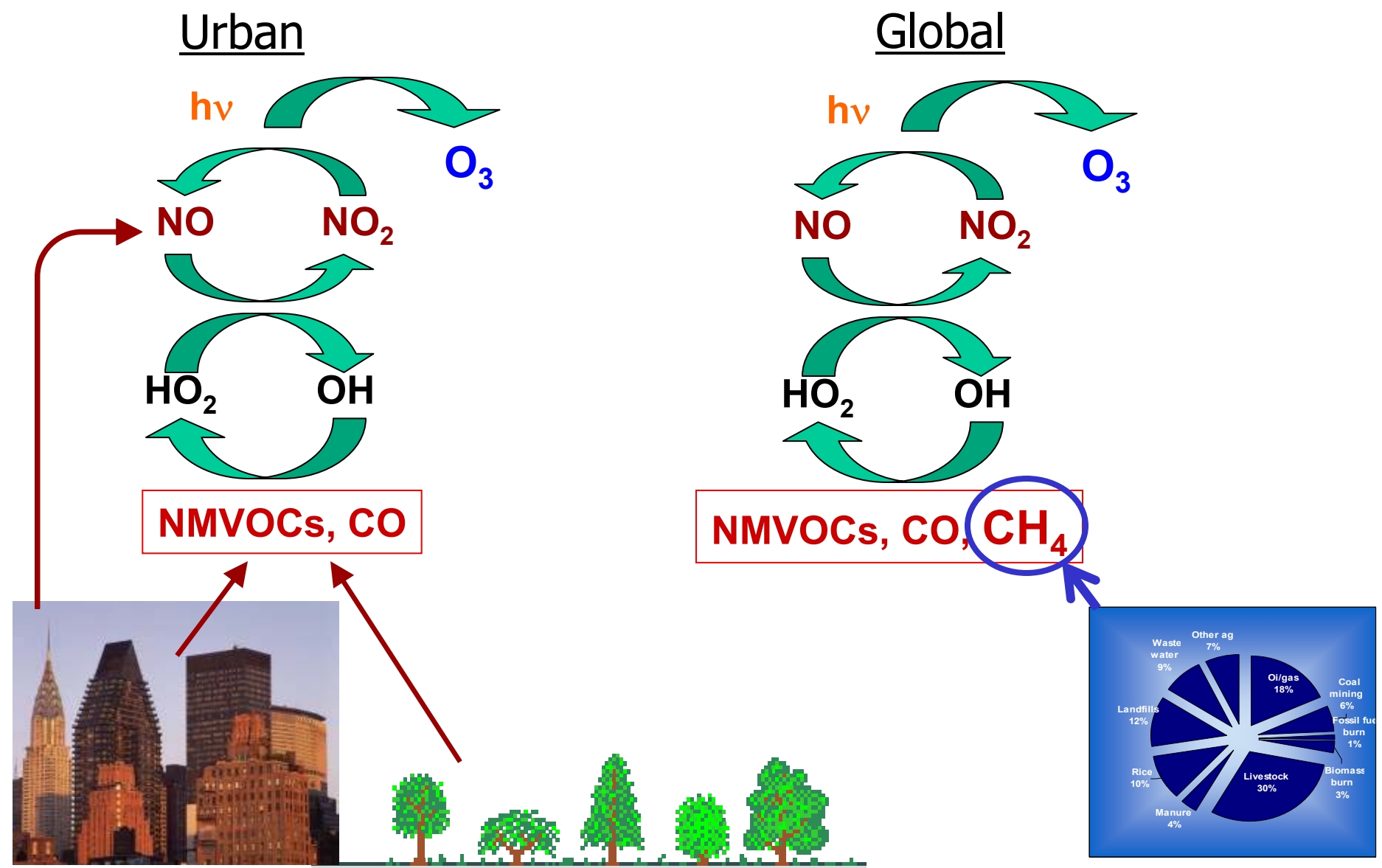
Methane #1: Summary

- 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
- Nearly 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 than changes in CO_2 emissions
- But there is also more variability in the system

2. Methane and Global Health

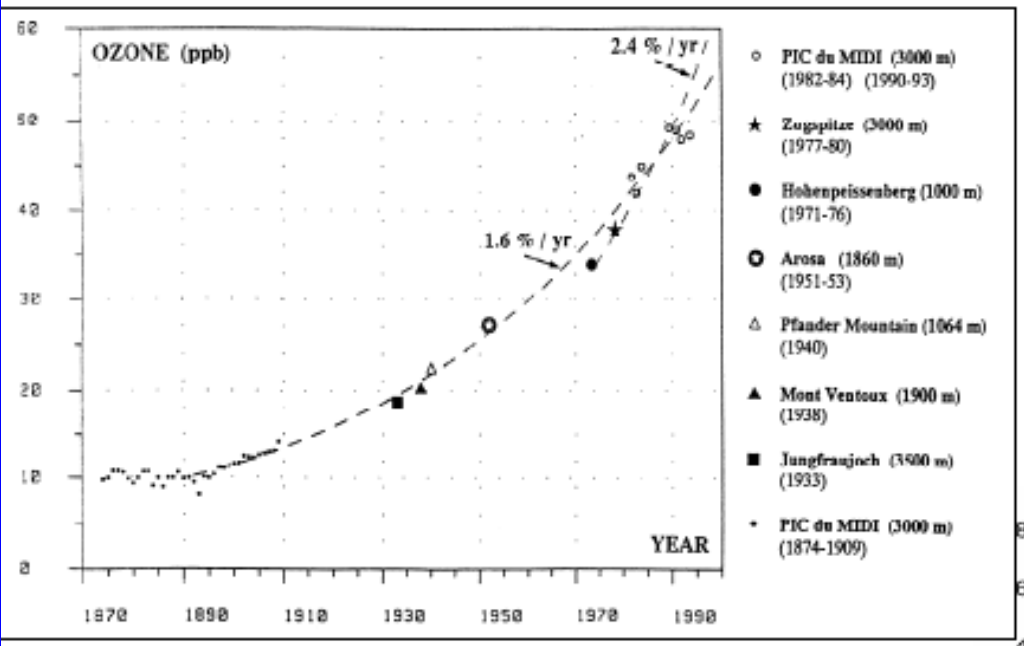
- Increases of wide-scale tropospheric (ground-level) ozone is becoming a major world problem
- A significant health-damaging pollutant
- Damaging to ecosystems and agriculture
- Methane emissions are the main cause
- Reduction of methane emissions, therefore, will help protect health worldwide immediately

Methane as a Global Ozone Precursor



Background Ozone is Growing …

… and Will Continue to Grow!

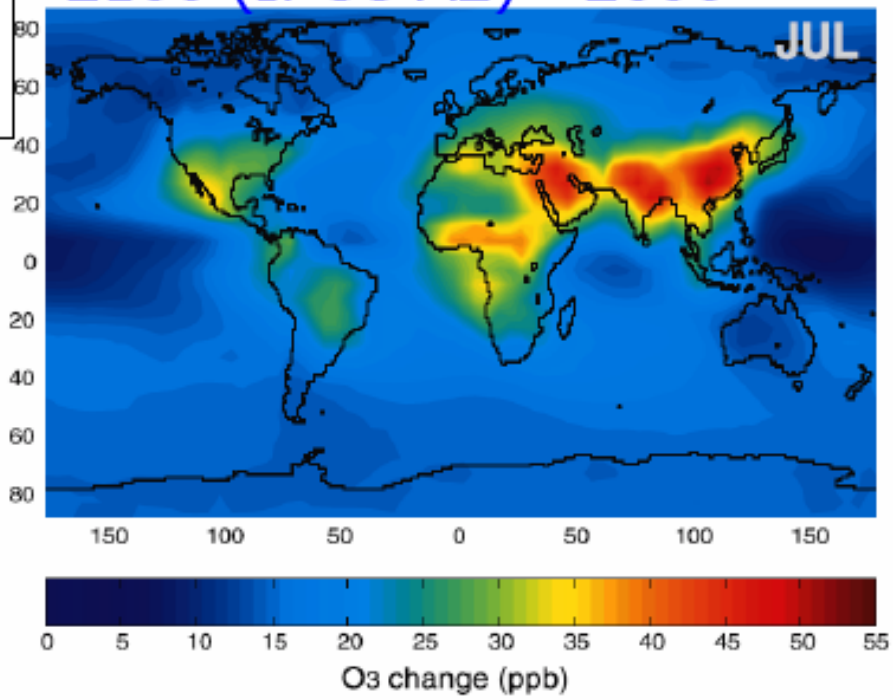


Ozone trend at European mountain sites, 1870-1990 (Marenco et al., 1994).

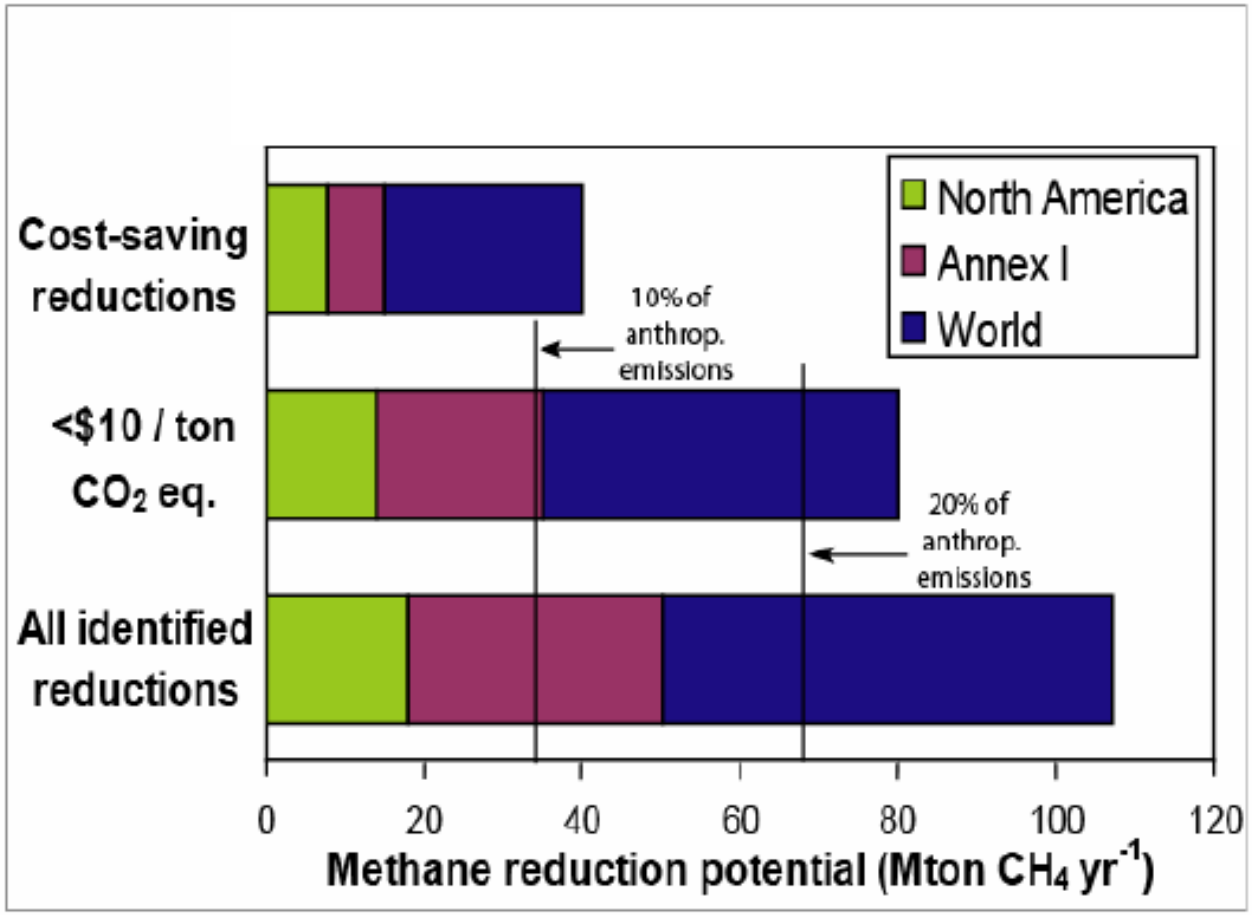
Mauzerall 2007

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

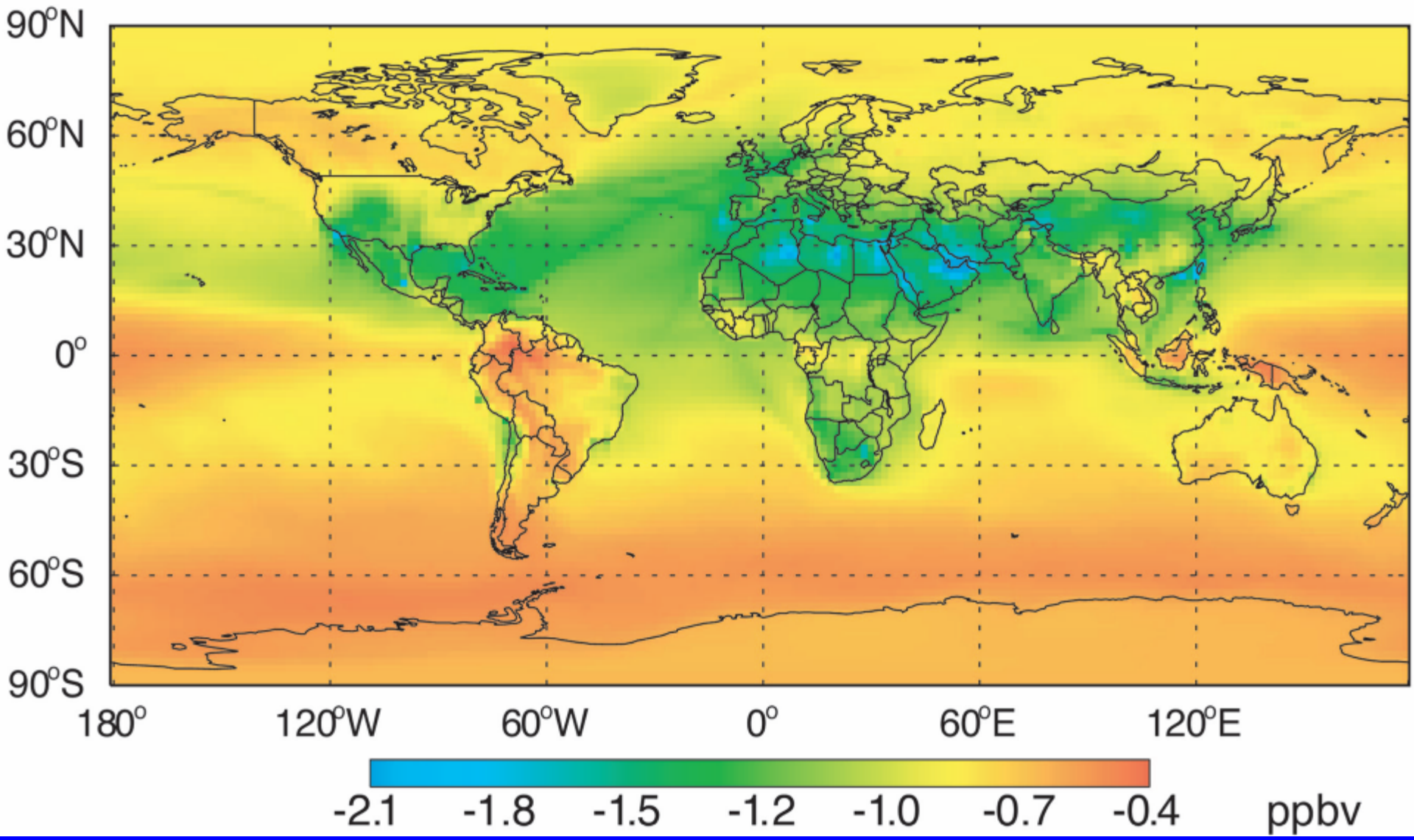


How Much Can Methane Be Reduced?



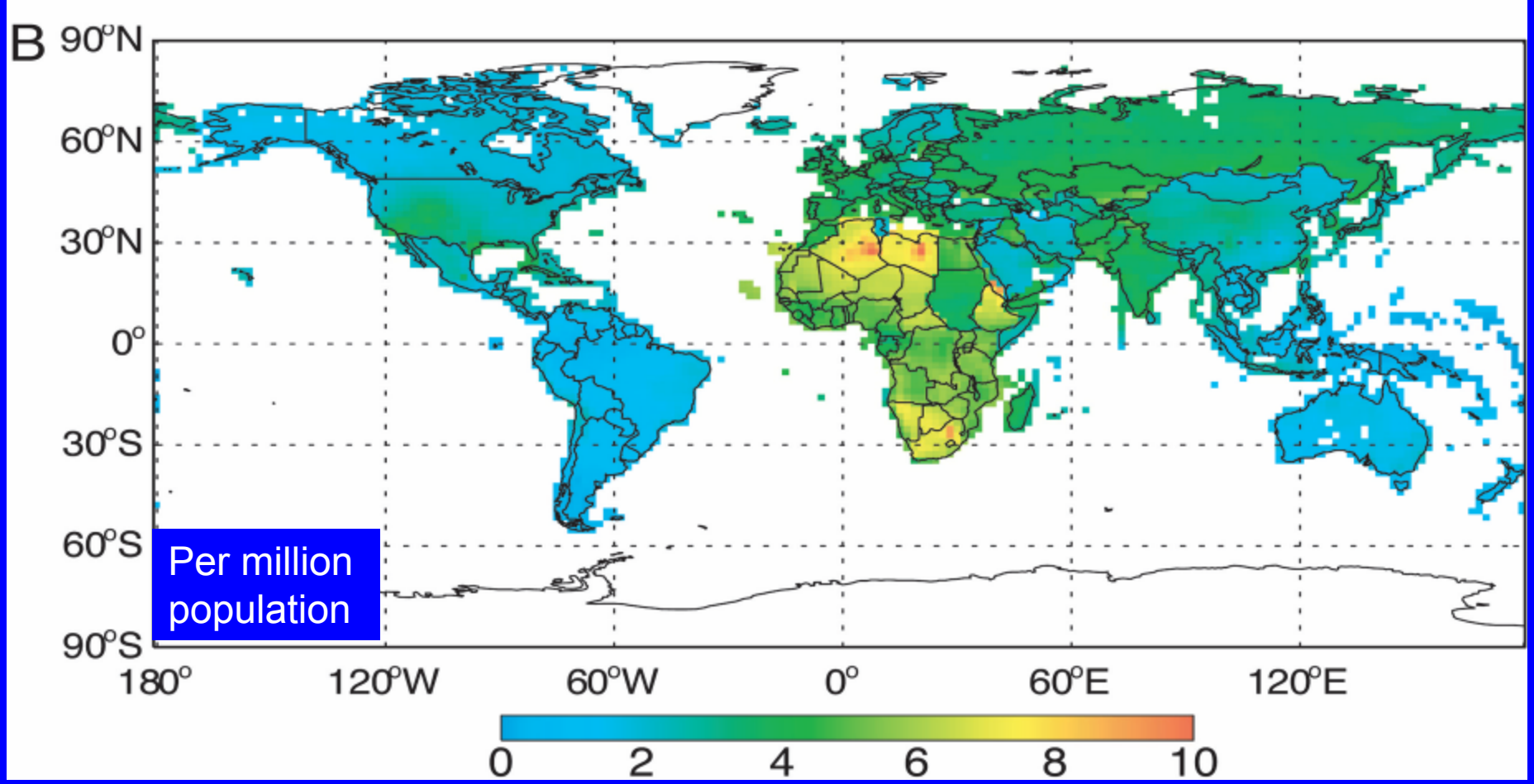
West & Fiore (2005)

Methane reduction potential from IEA (2003), for coal, oil and gas operations, wastewater, and landfills; maximum technically feasible in 2010.



Effect of a reduction of 20% (~61 MT)
in global methane emissions on tropospheric ozone

West et al., PNAS, 2006



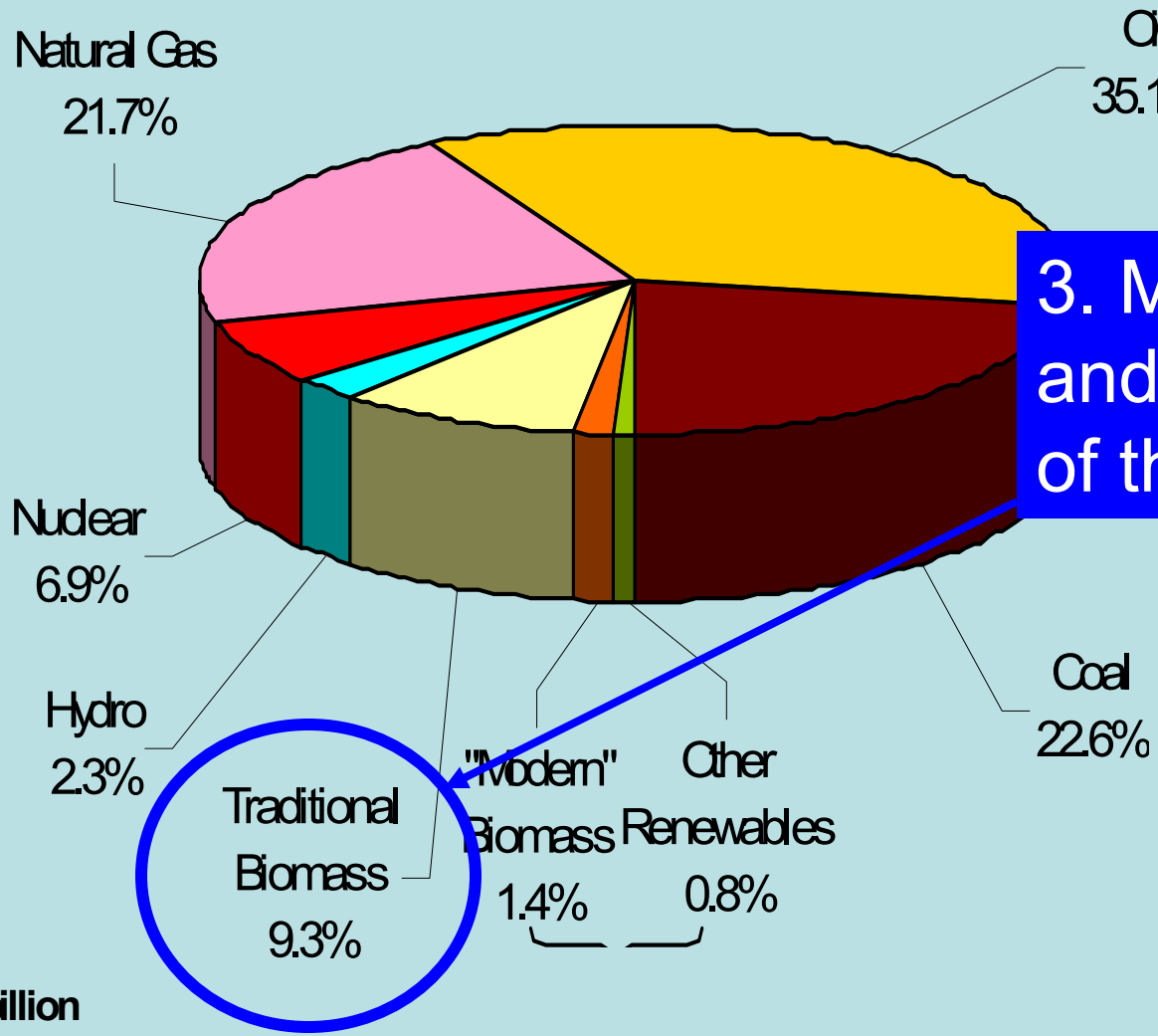
Reduction in ozone mortality from
20% reduction in methane emissions

West et al, PNAS, 2006

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

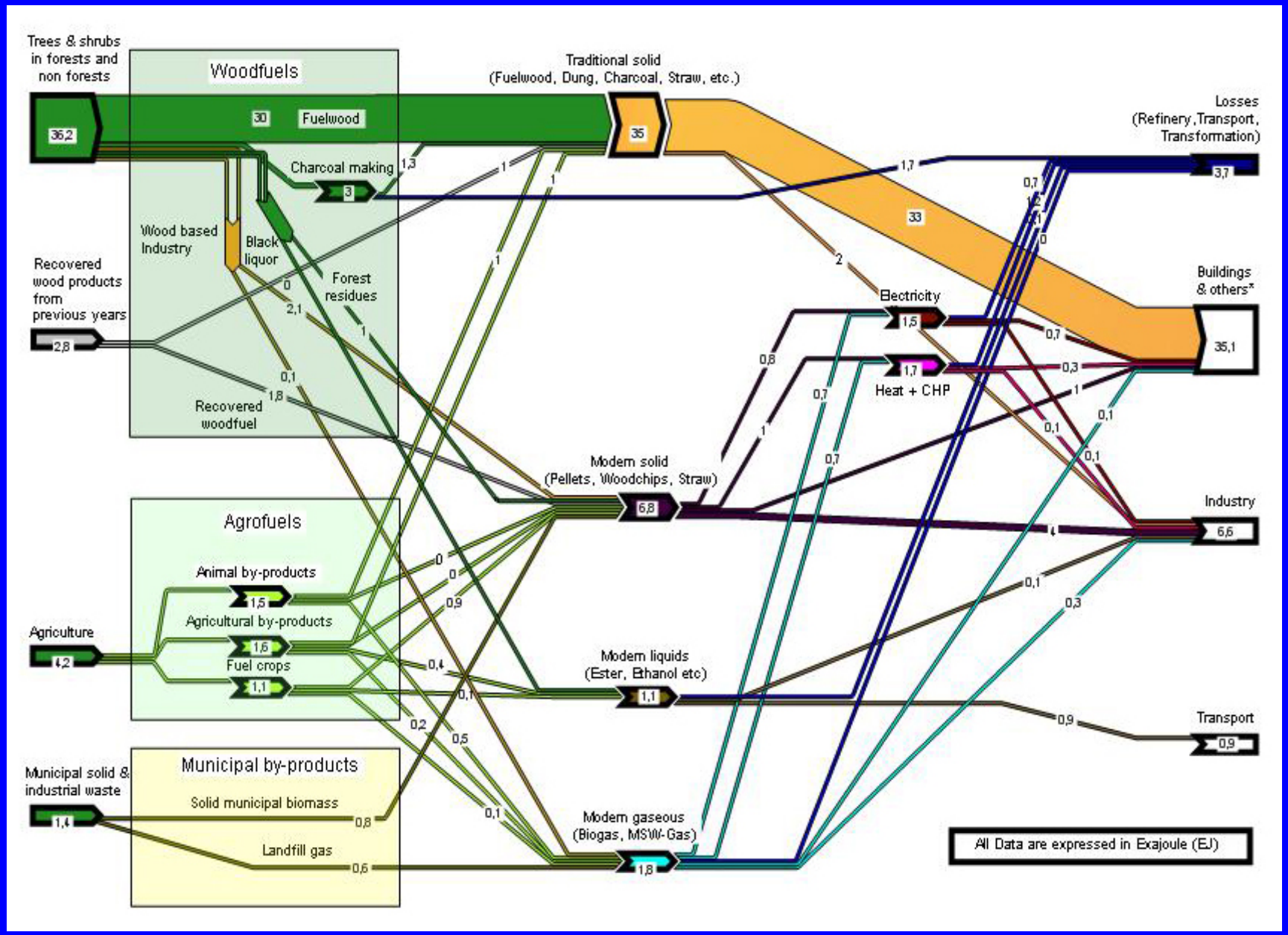
World Energy – 2001



3. Methane and the health of the poor

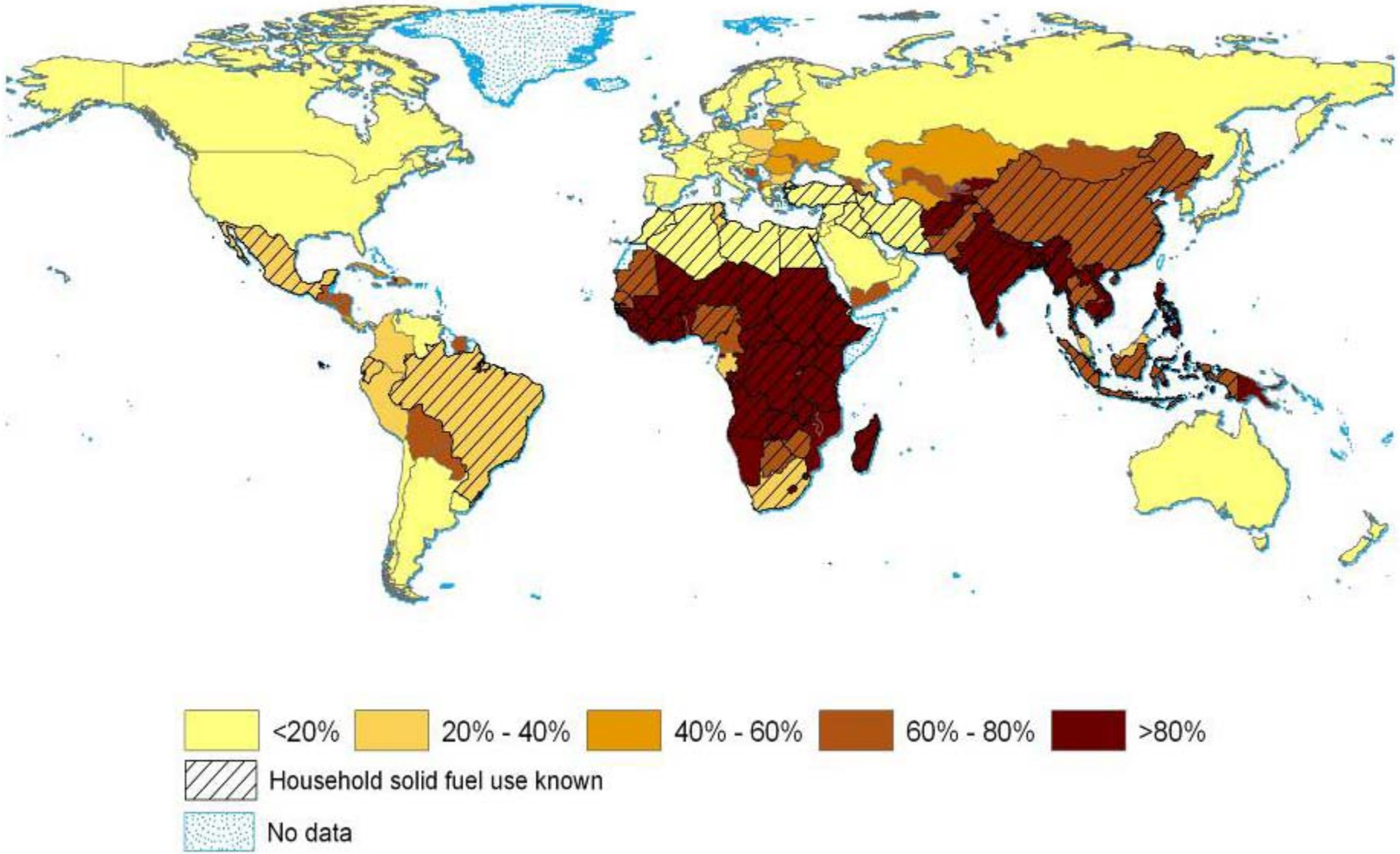
Population: 6.102 billion
Total energy use: 10.2 Gtoe
Per capita energy consumption: 1.67 toe

World Energy Assessment, 2004

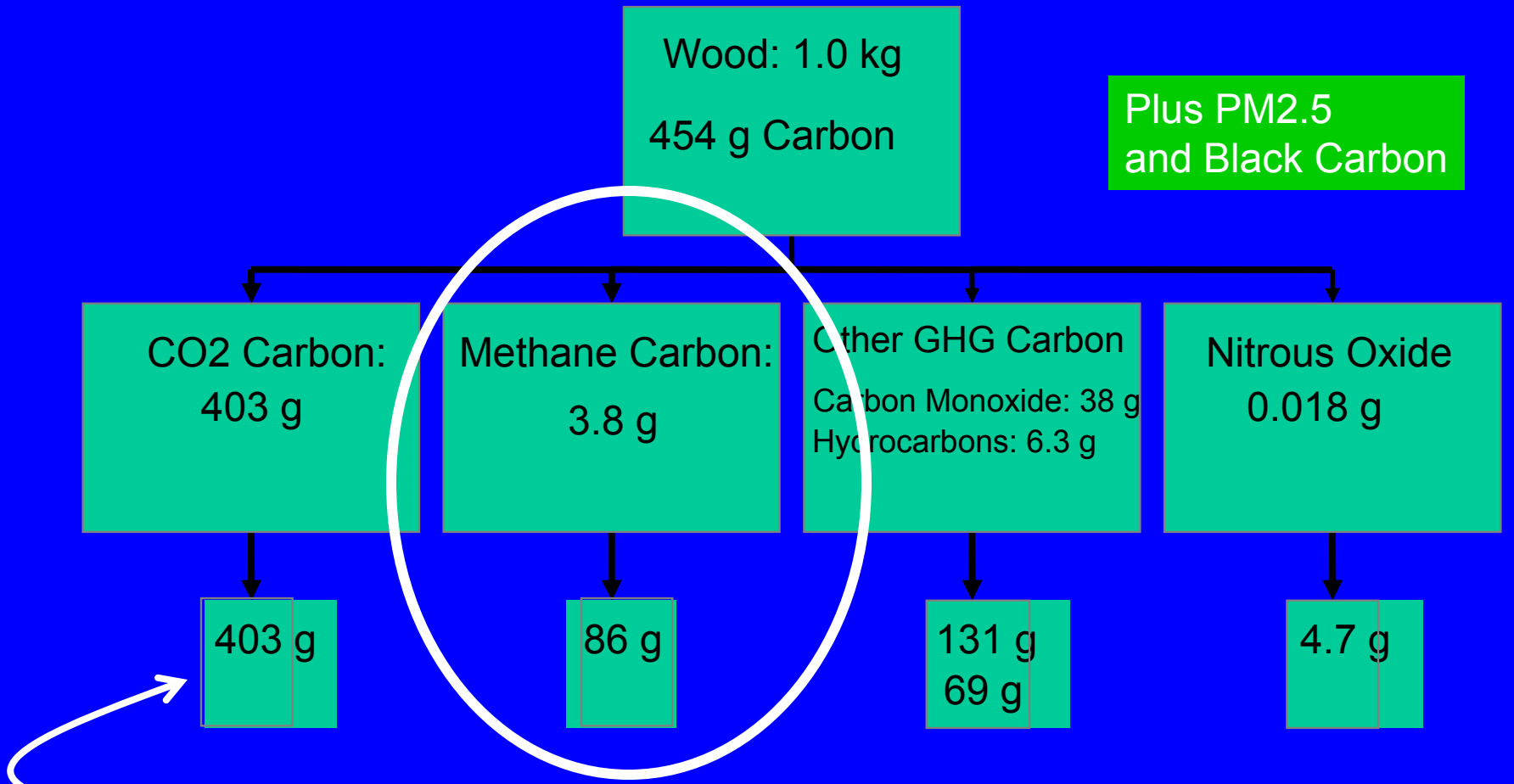


IPCC 2007, WGIII

National Household Solid Fuel Use, 2000

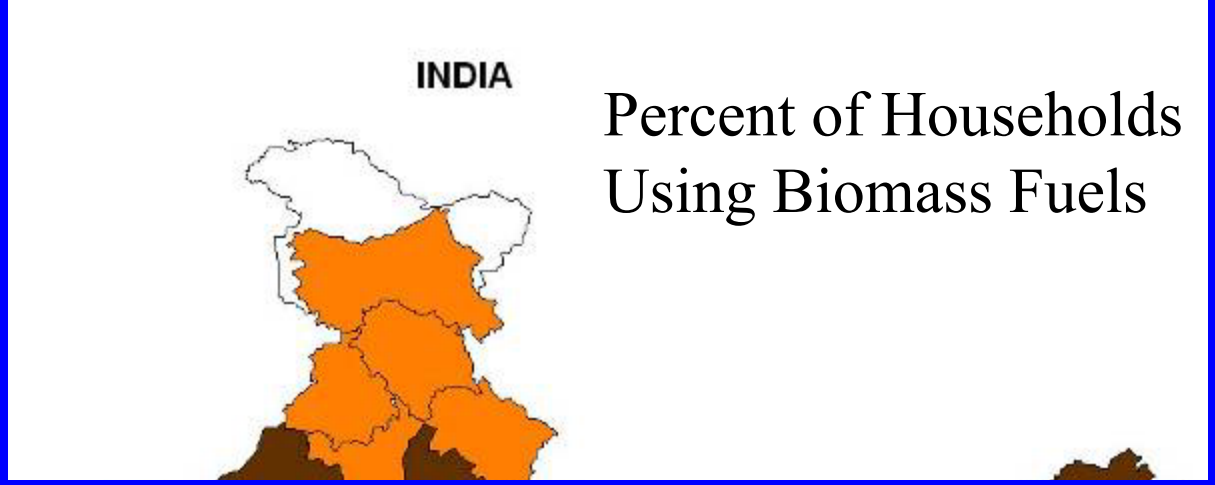


Greenhouse warming commitment per meal for typical wood-fired cookstove in China

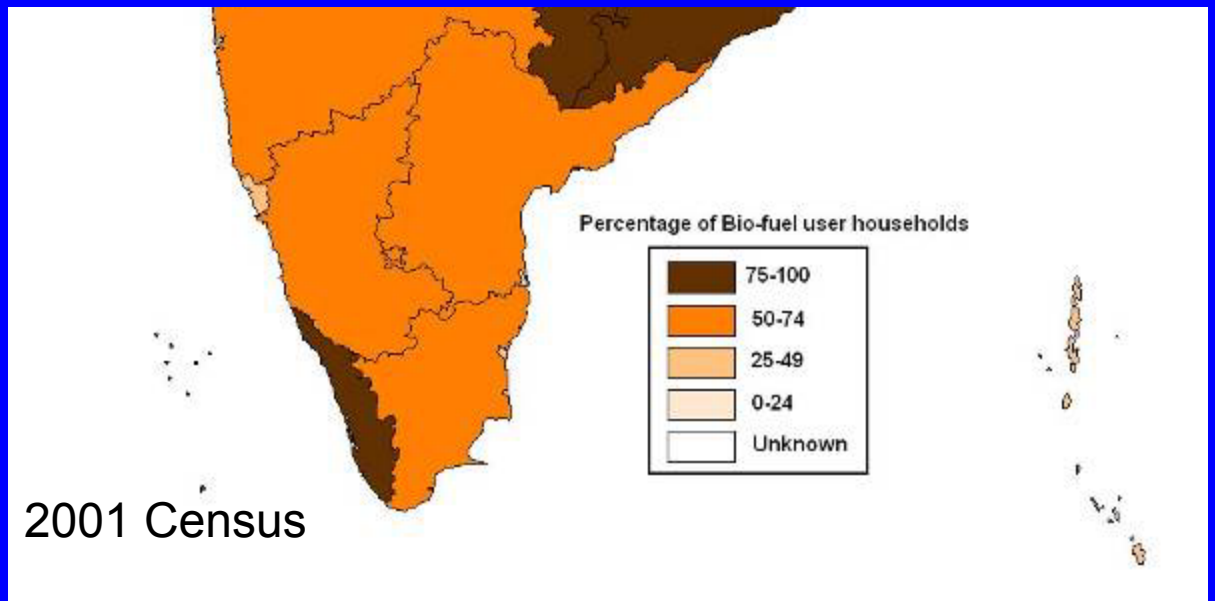


Global warming commitments of each of the gases as CO_2 equivalents

Zhang, et al., 2000

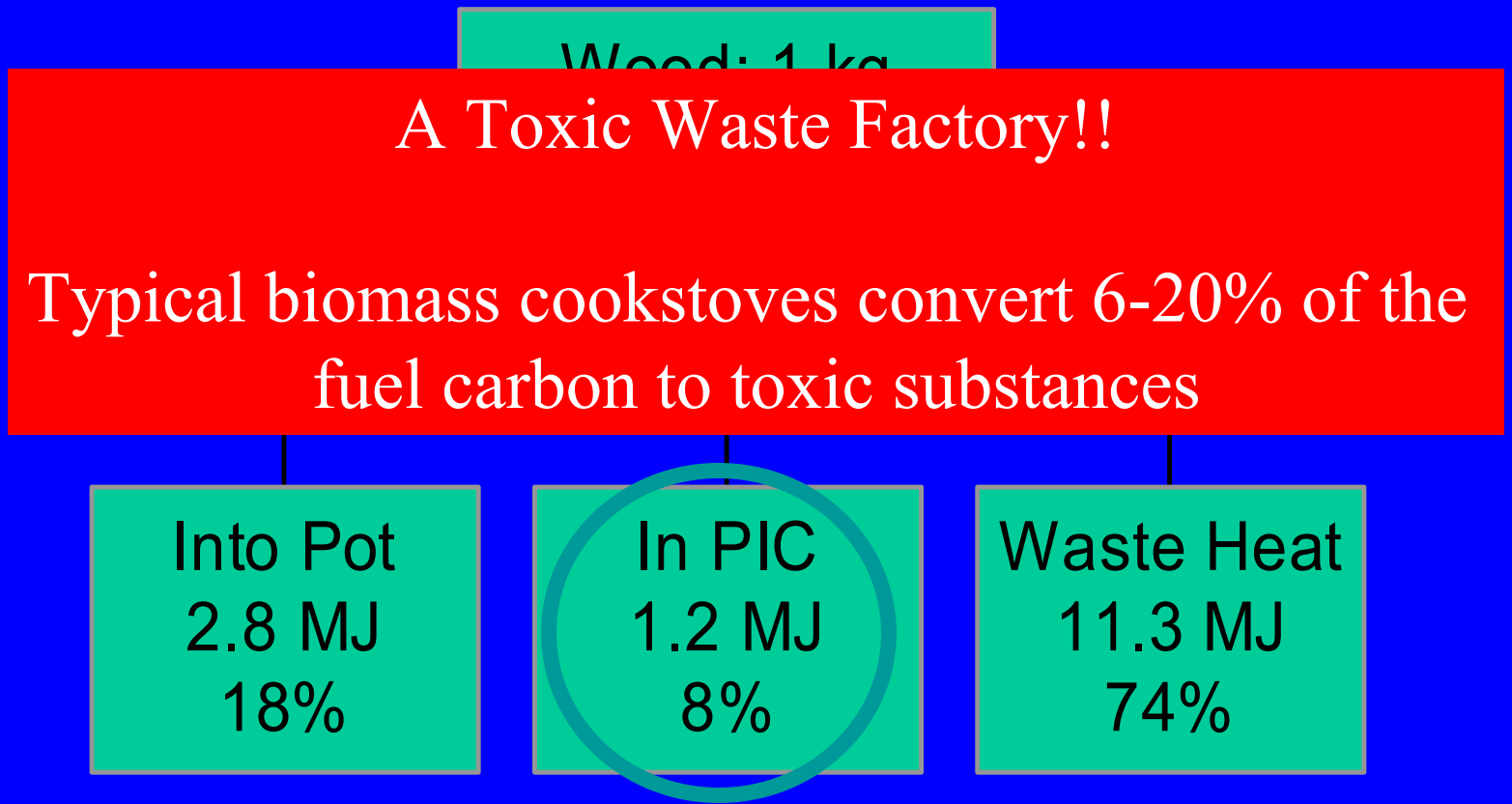


Nearly 2 million tons methane per year of the ~ 305 Mt total global human emissions



Smith, et al. 2000

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



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

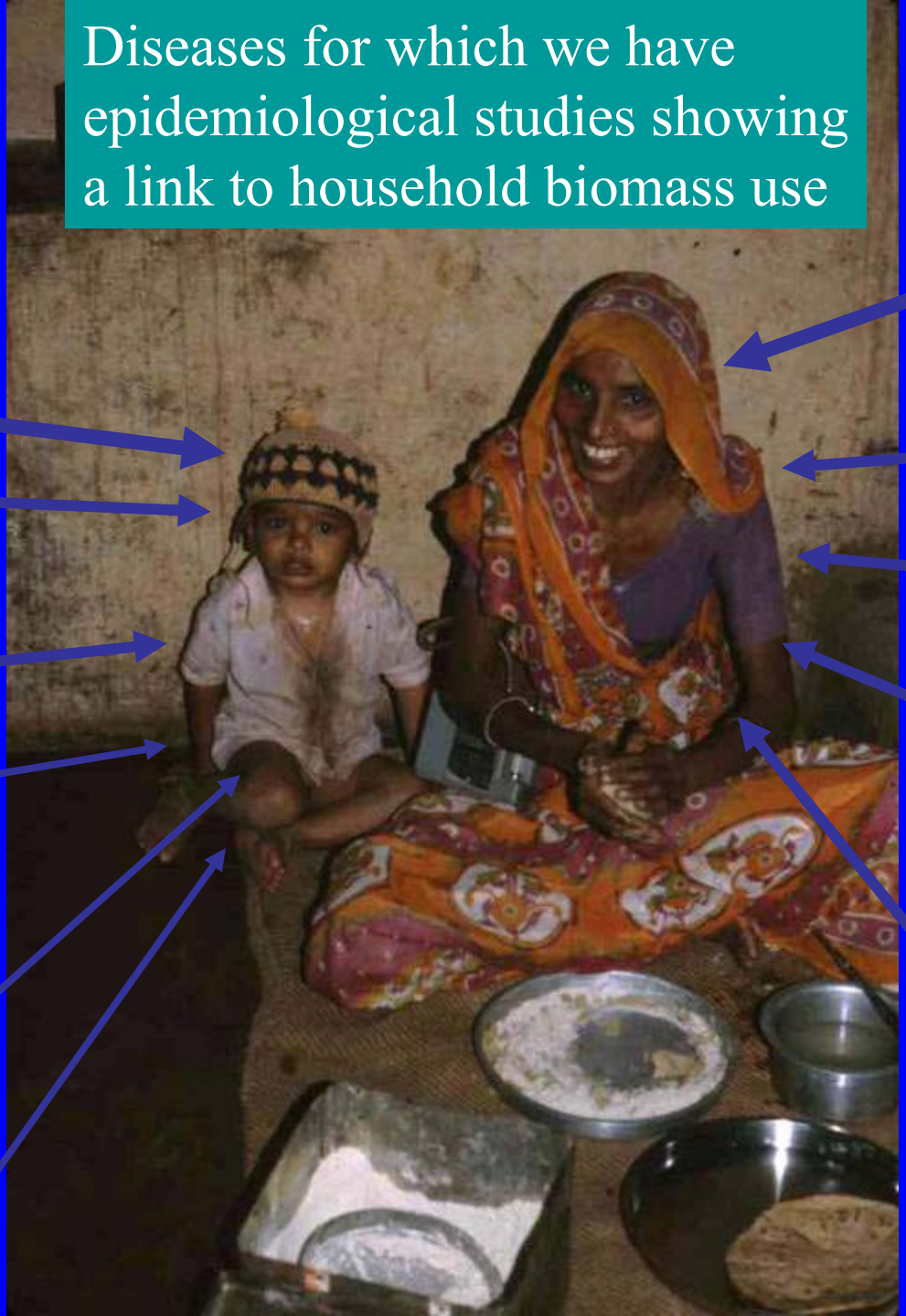
Source: Smith, et al., 2000

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

- Small particles, CO, NO_2 **Plus methane**
- 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*

Naeher, et al. 2007

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



ALRI/ Pneumonia (meningitis)

Low birth weight

Asthma?

Early infant death?

Birth defects?

Cognitive Impairment?

Chronic obstructive lung disease

Tuberculosis

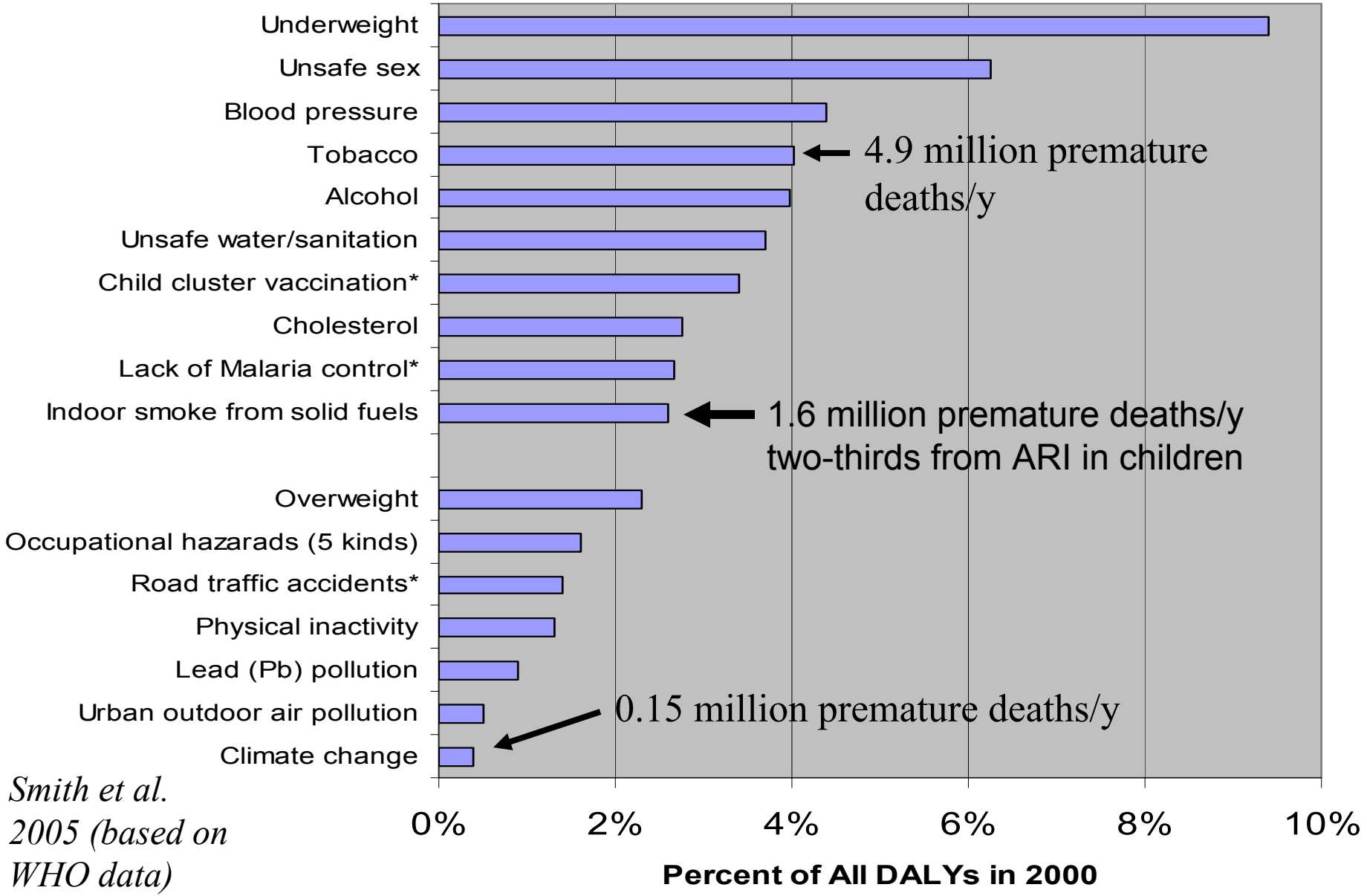
Blindness (cataracts, trachoma)

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

Heart disease?

Global Burden of Disease from Top 10 Risk Factors

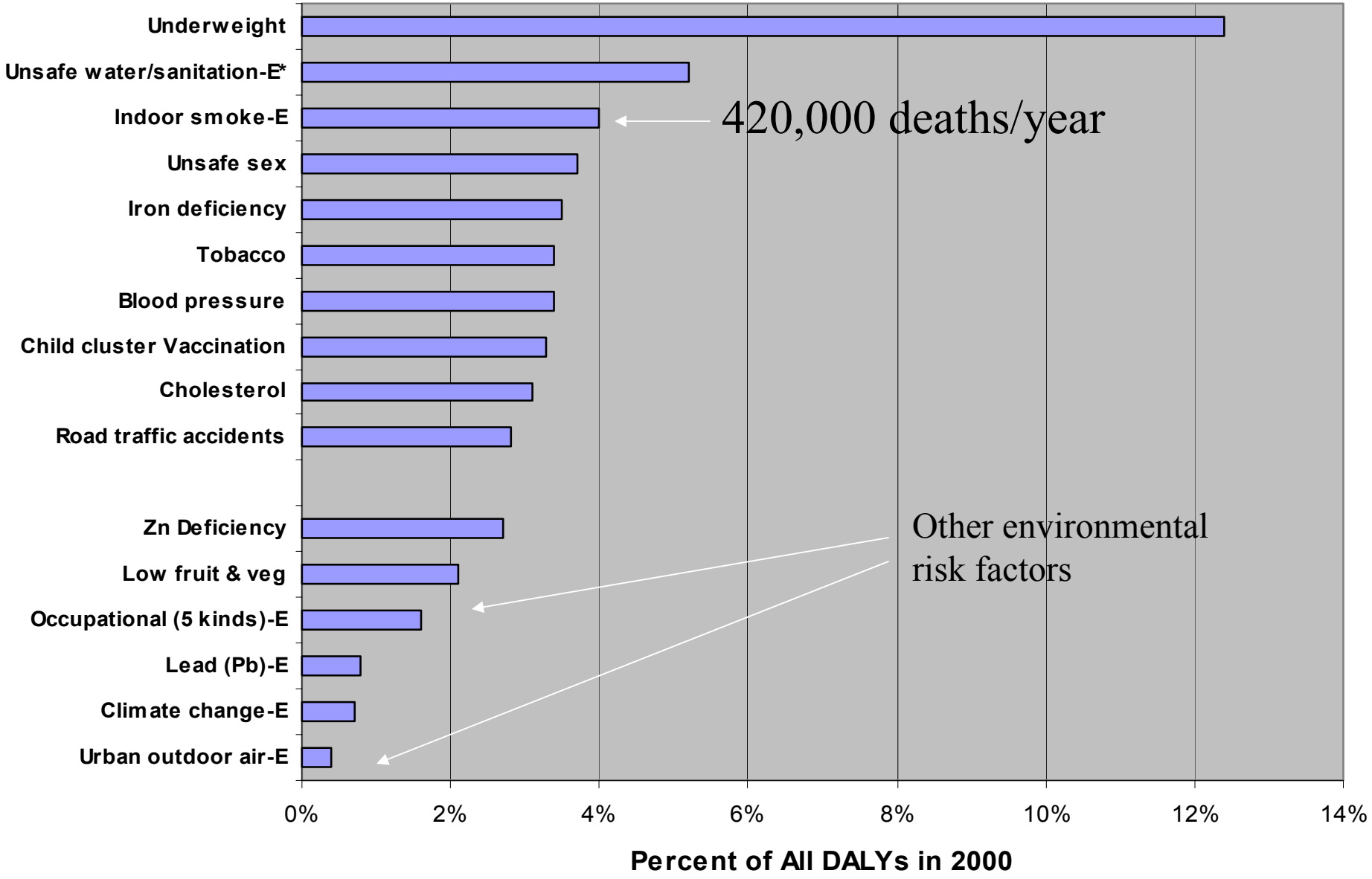
plus selected other risk factors



Smith et al. 2005 (based on WHO data)

Indian Burden of Disease from Top 10 Risk Factors

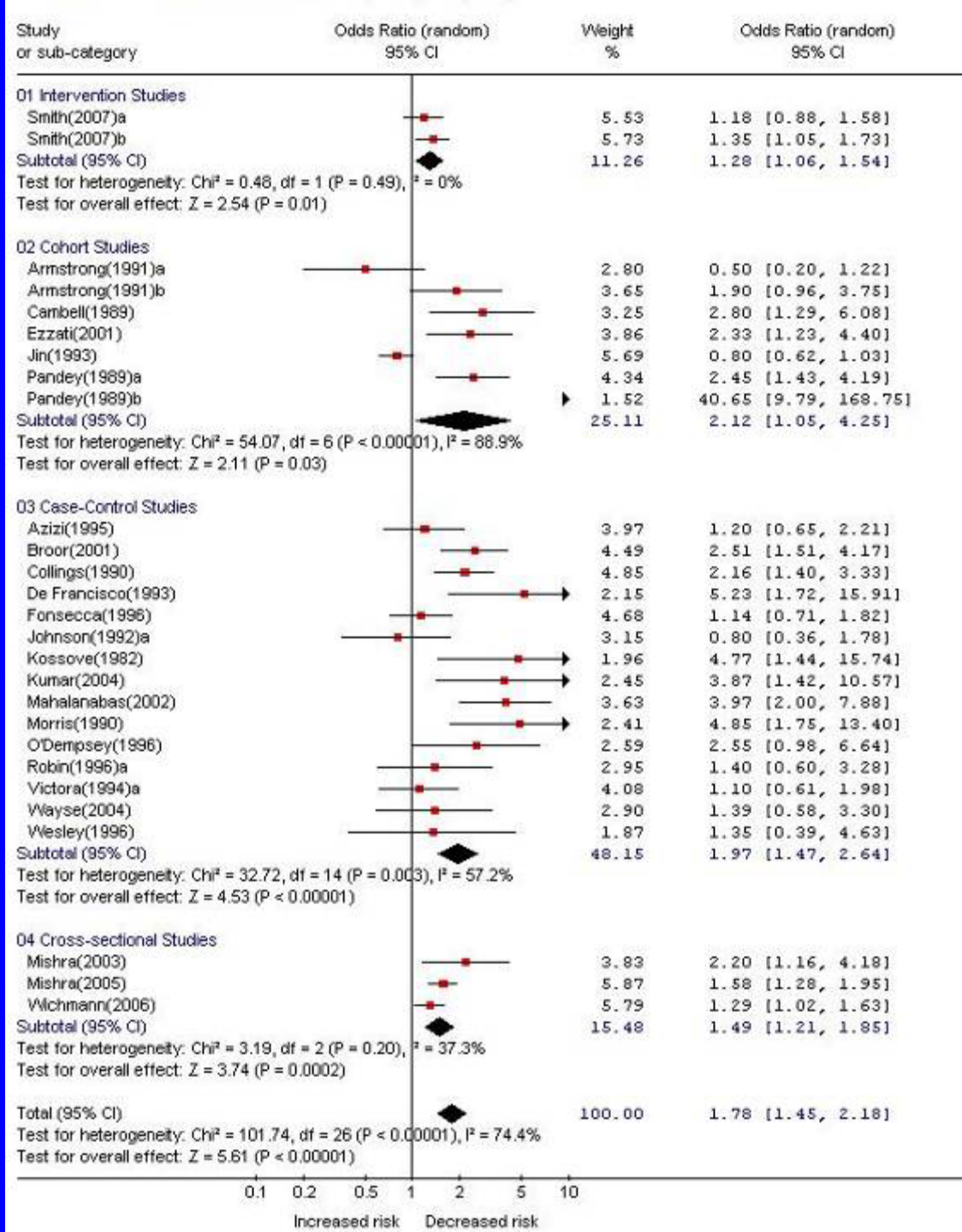
and Selected Other Risk Factors



Child Pneumonia - indoor air pollution

New Systematic Review and Meta-Analysis

Dherani et al.
Bull WHO, 2008



Chinese household rural energy:

A Chinese Hybrid Gasifier Stove
Winner of National Stove Contest

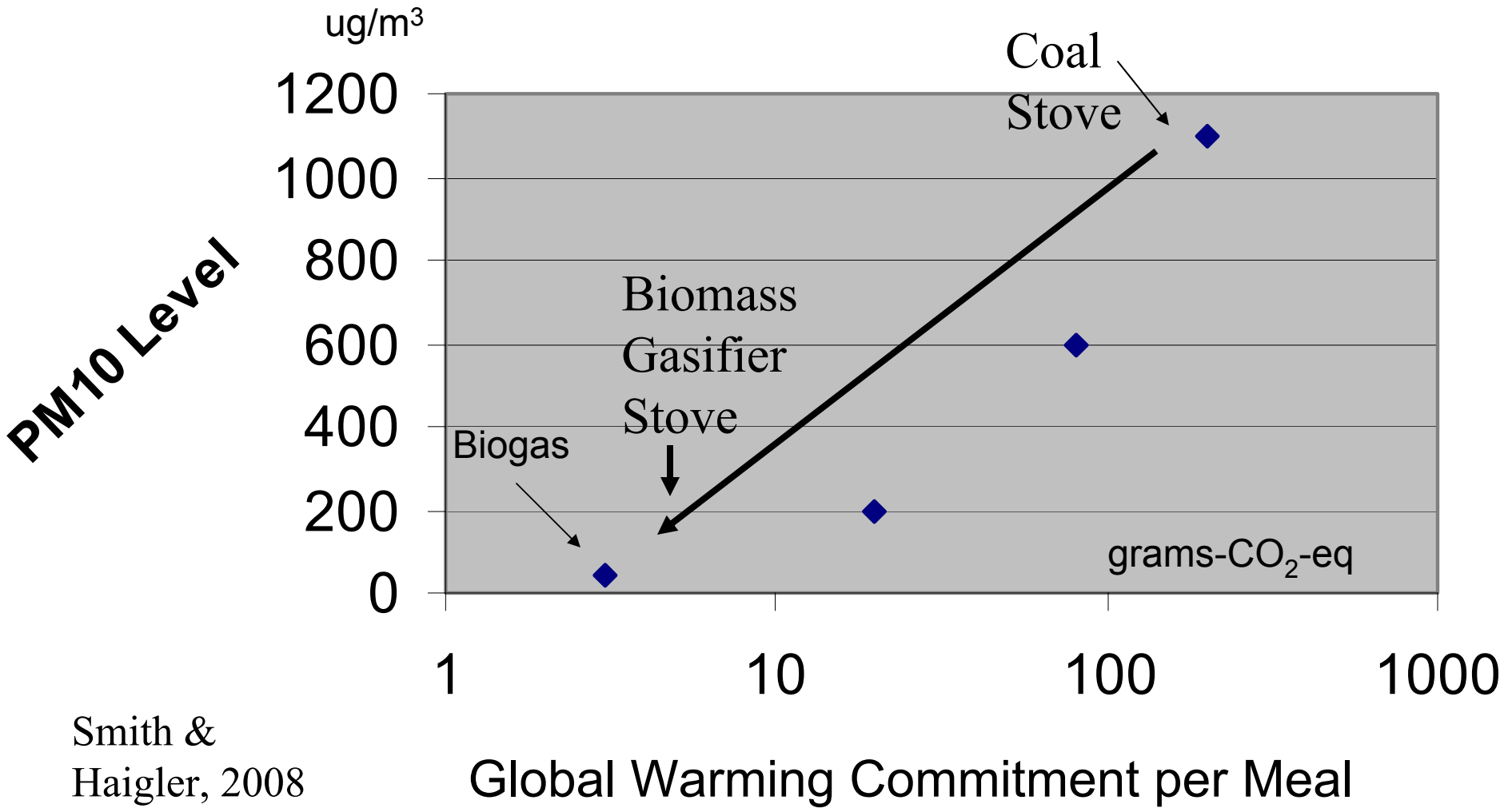
Efficiency 2x traditional stoves; Emissions 10-15x less:
Low health risk and essentially no greenhouse emissions

Compared to Coal Stove

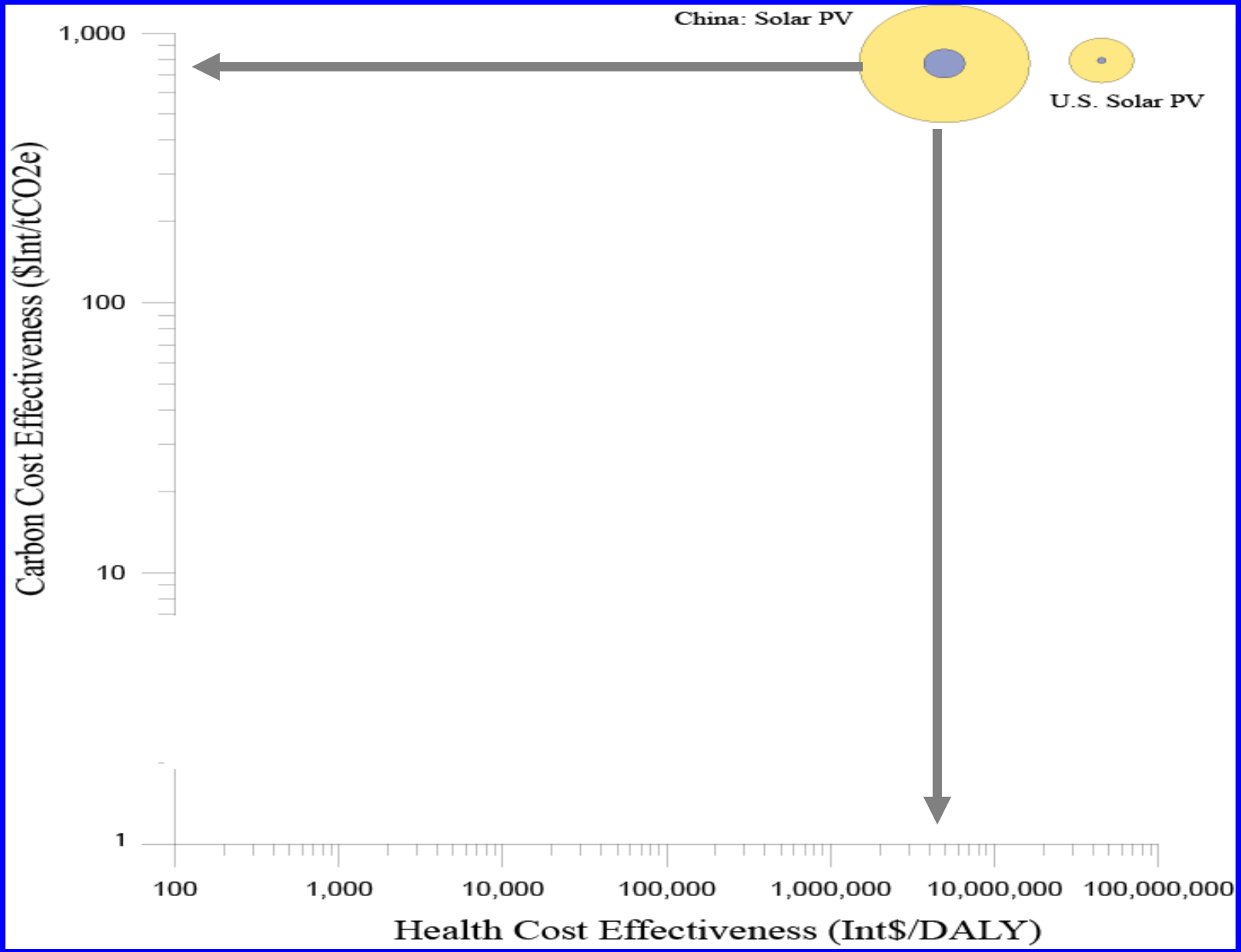
17% to 41% fuel efficiency
0.12 to 0.02 CO/CO2
1.6 to 0.26 g PM/kg fuel

18 W blower

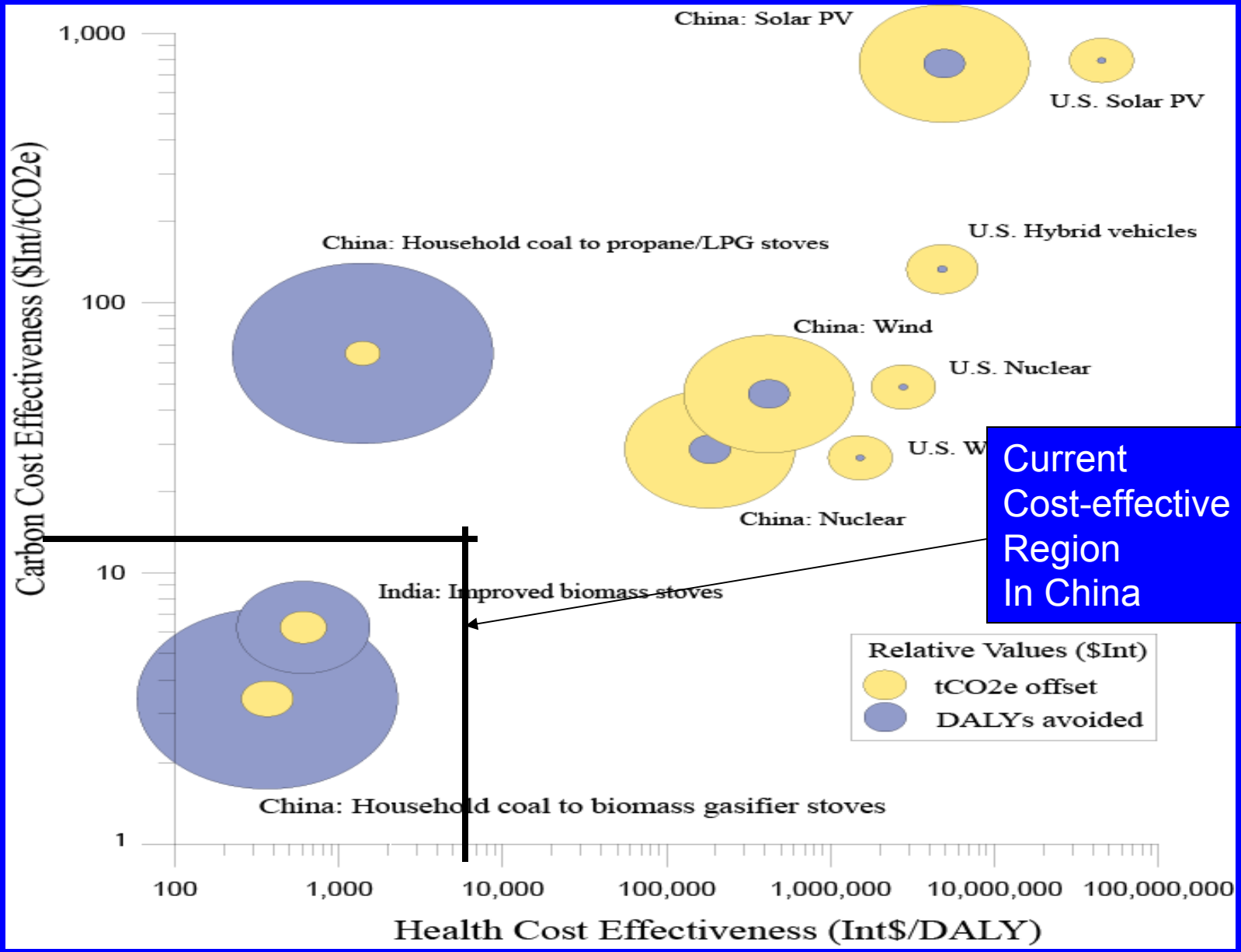
Health and Greenhouse Gas Benefits of Biomass Stove Options



Smith & Haigler, 2008

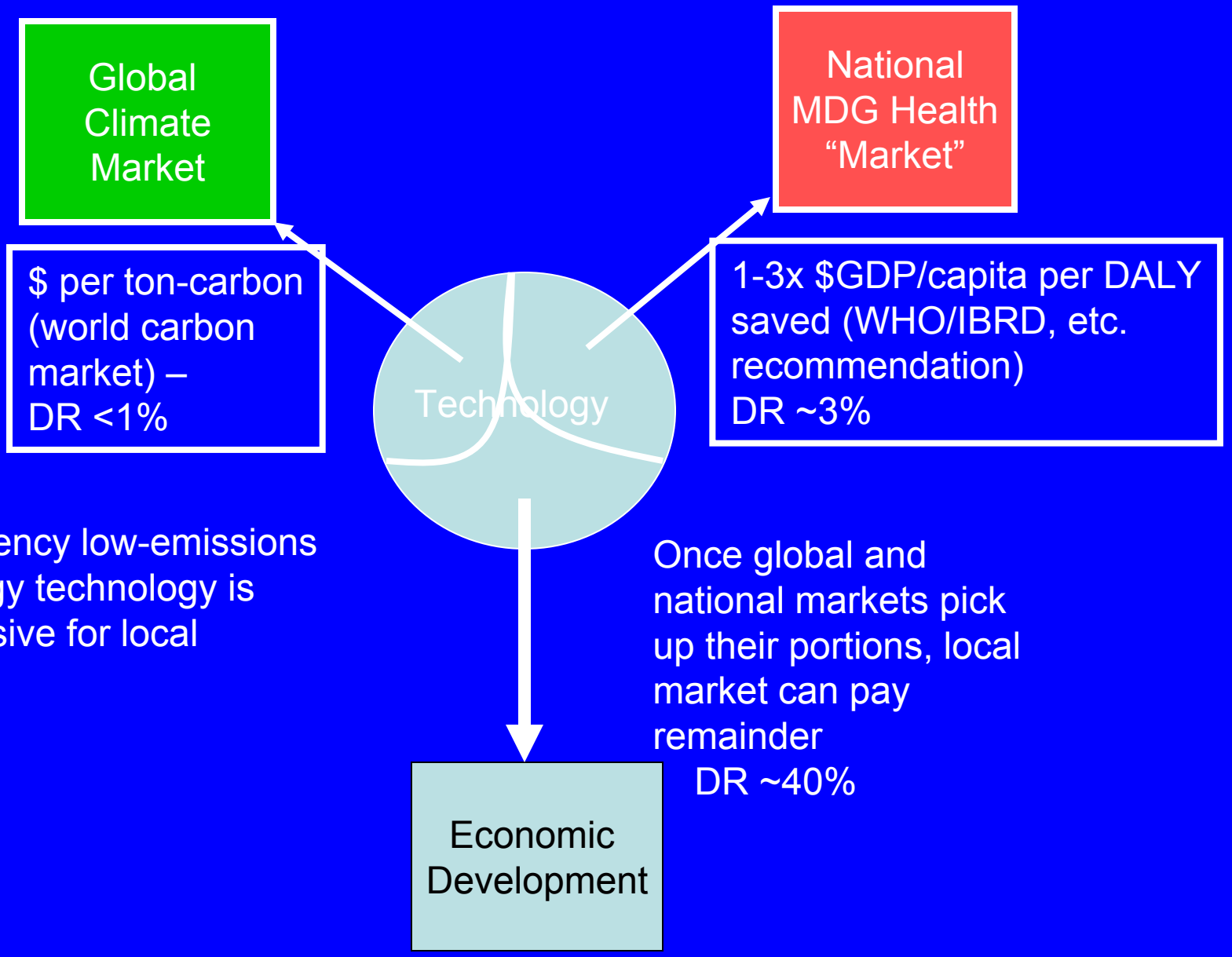


Smith & Haigler, 2008



Smith & Haigler, 2008

Paying for Rural Energy Development



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

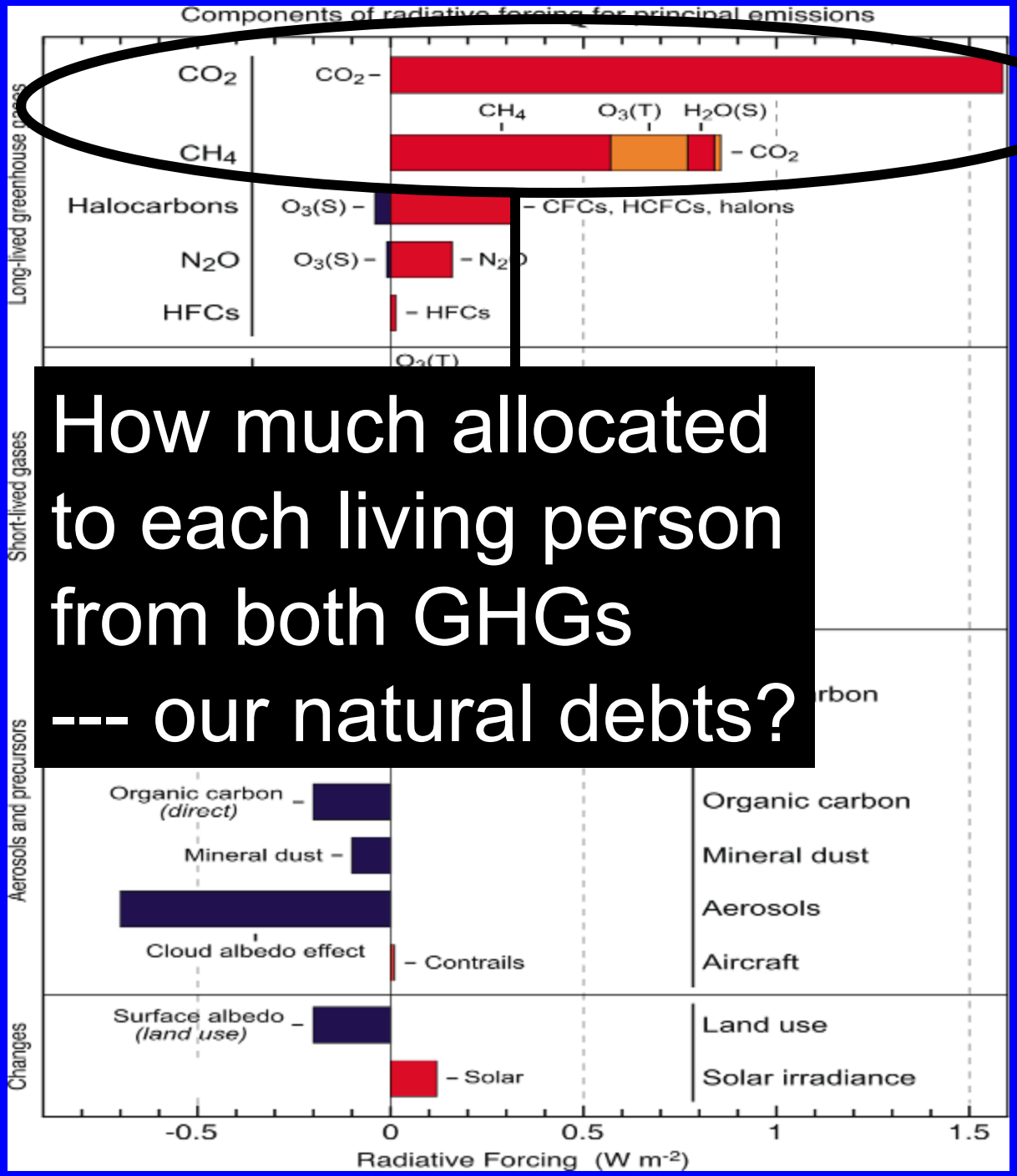
Once global and national markets pick up their portions, local market can pay remainder DR ~40%

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

4. Methane and Global 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?



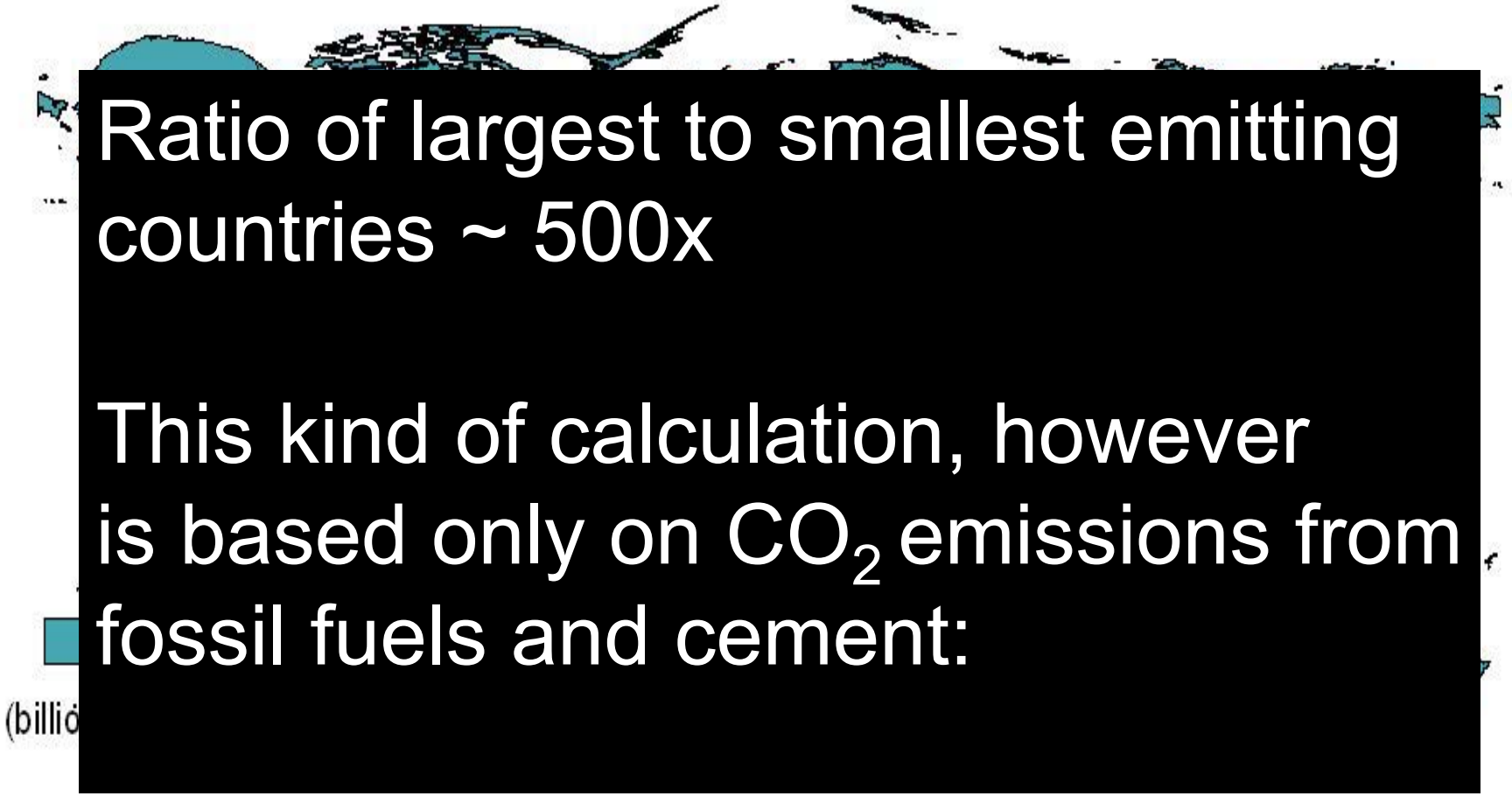
How much allocated to each living person from both GHGs --- our natural debts?

Warming in 2005 from emissions since 1750

More than half due to methane

IPCC, 2007

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

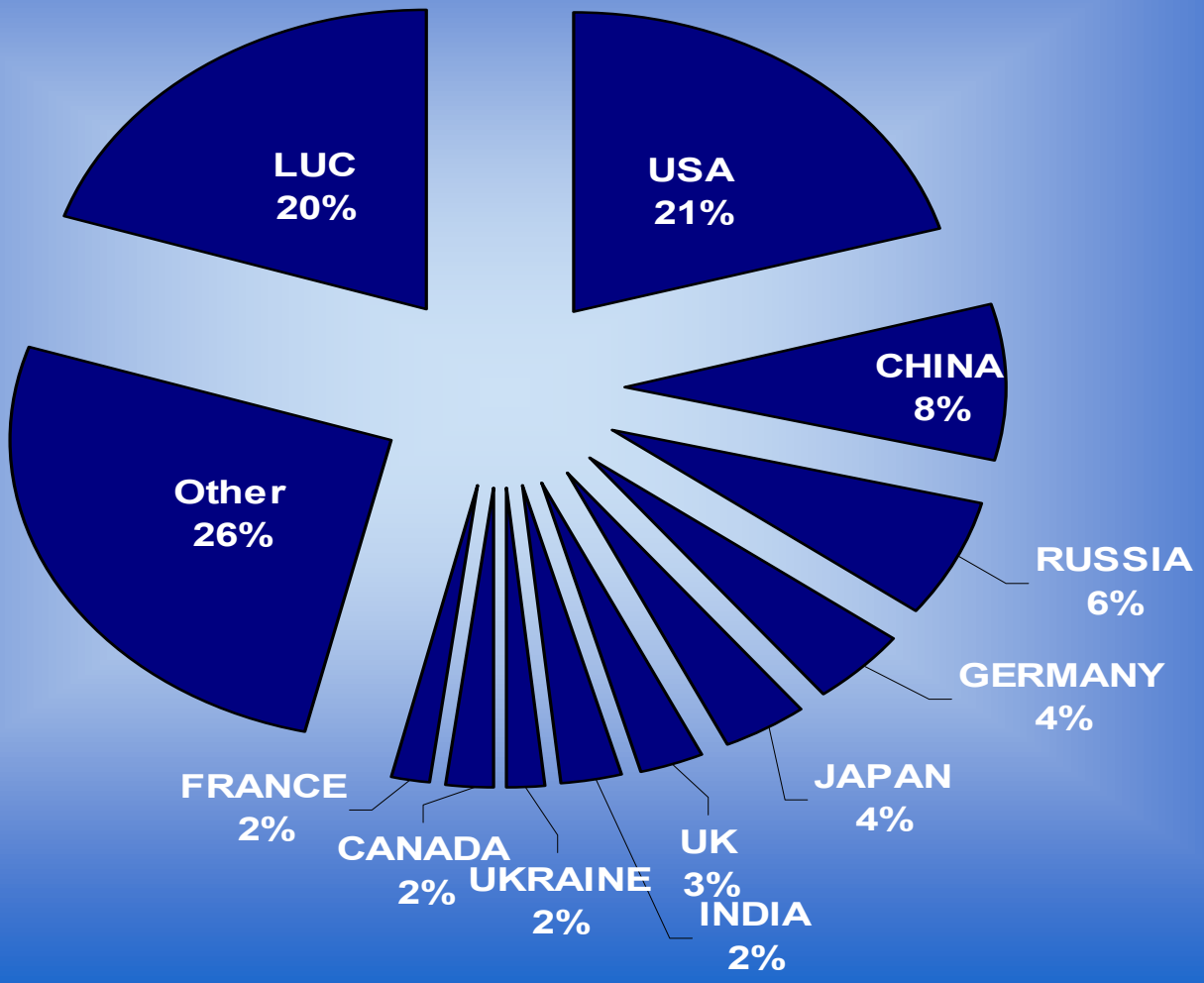


Ratio of largest to smallest emitting countries ~ 500x

This kind of calculation, however is based only on CO_2 emissions from fossil fuels and cement:

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 Global Natural Debt Among Top 10 Nations
CO_2 only in 2005

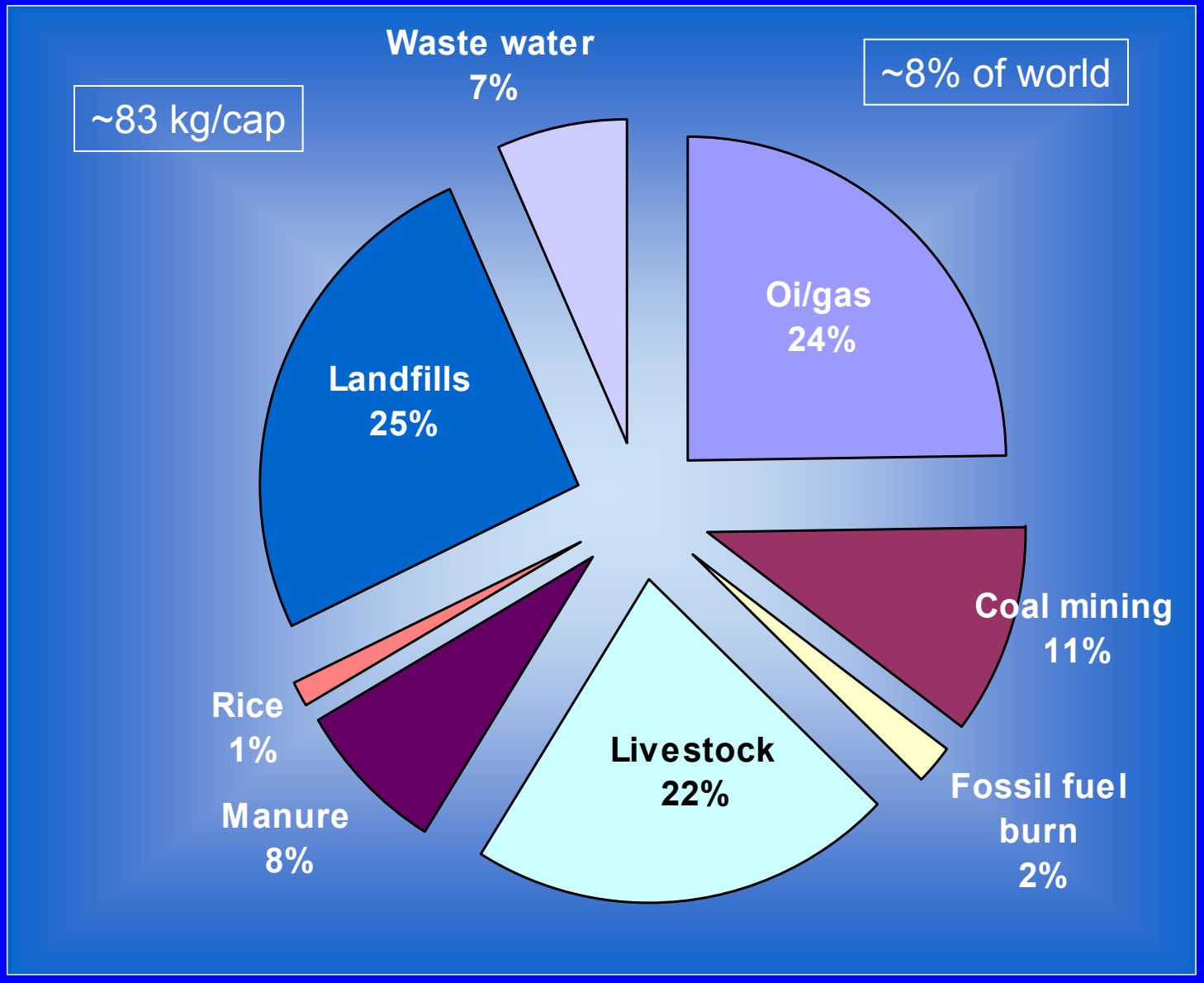


Brazil: 0.8%

Nb. Land-use change emissions not are parsed out by country

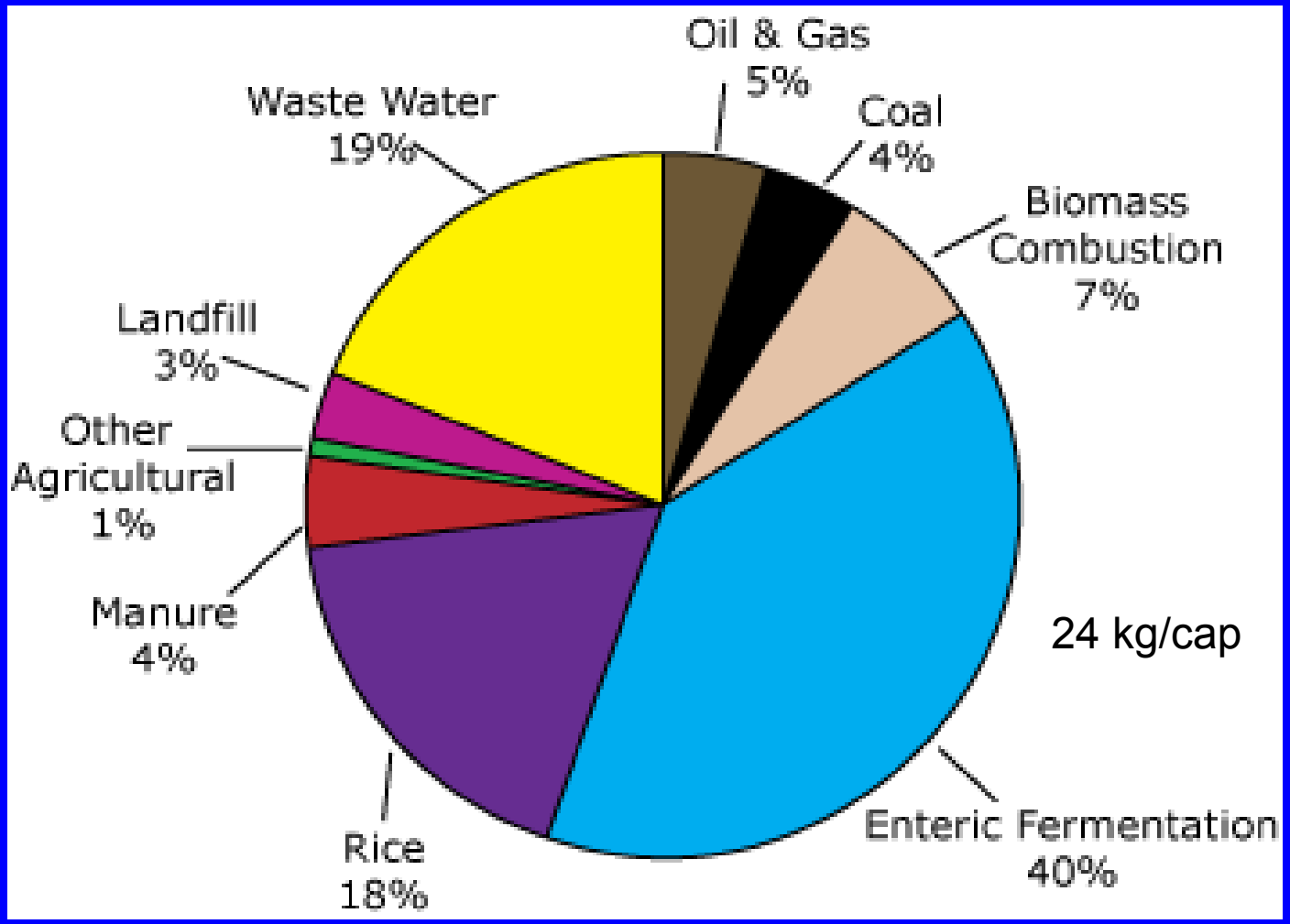
Smith and Rogers, in preparation

USA Anthropogenic Methane Emissions ~2005
Total ~ 25 million tons



USEPA
2006

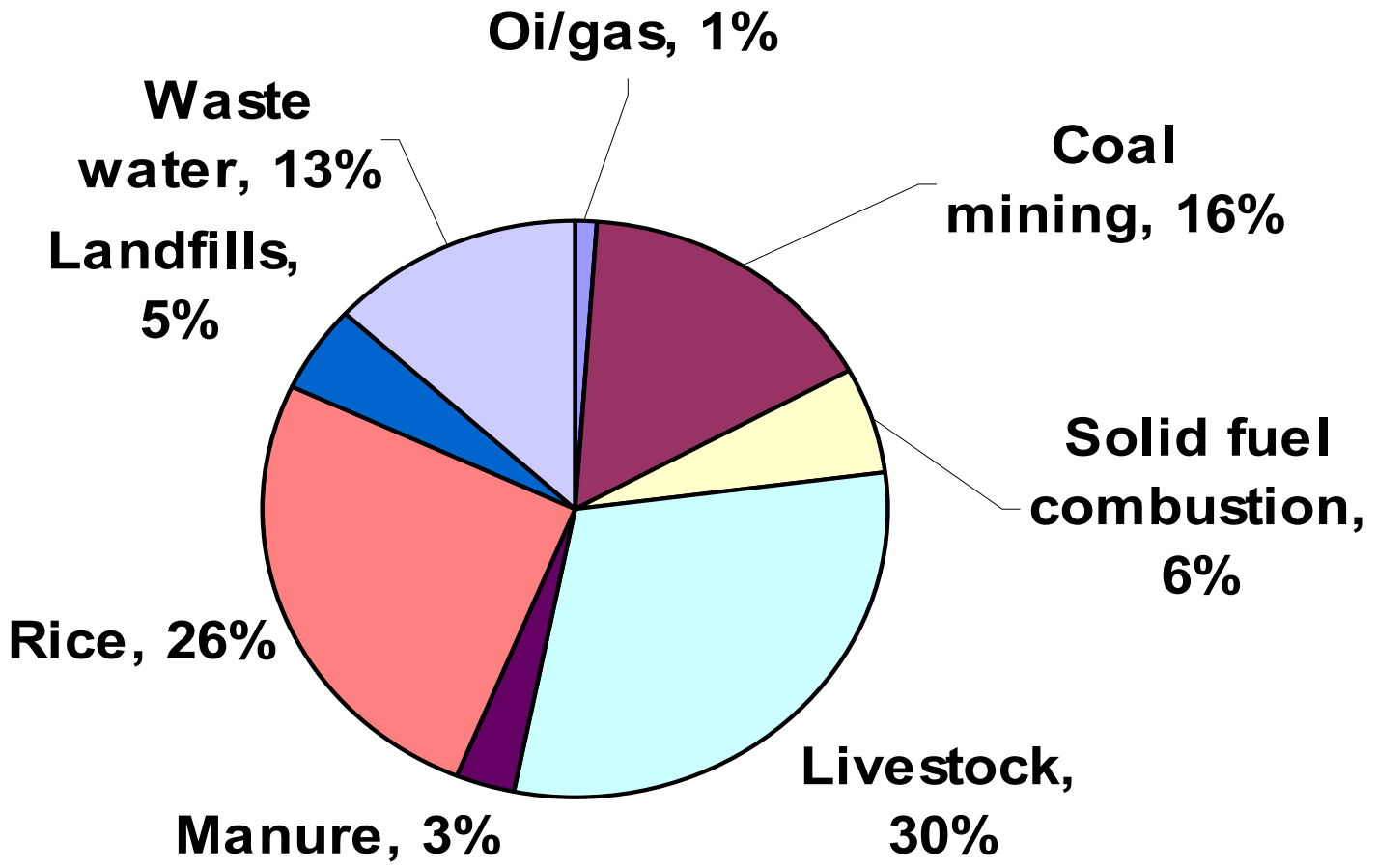
Methane Emissions from India in 2005
26.1 Mt (9% of world)



http://www.epa.gov/nonco2/econ-inv/international.html

Chinese Methane Emissions in 2005
41 MT = 13% of world

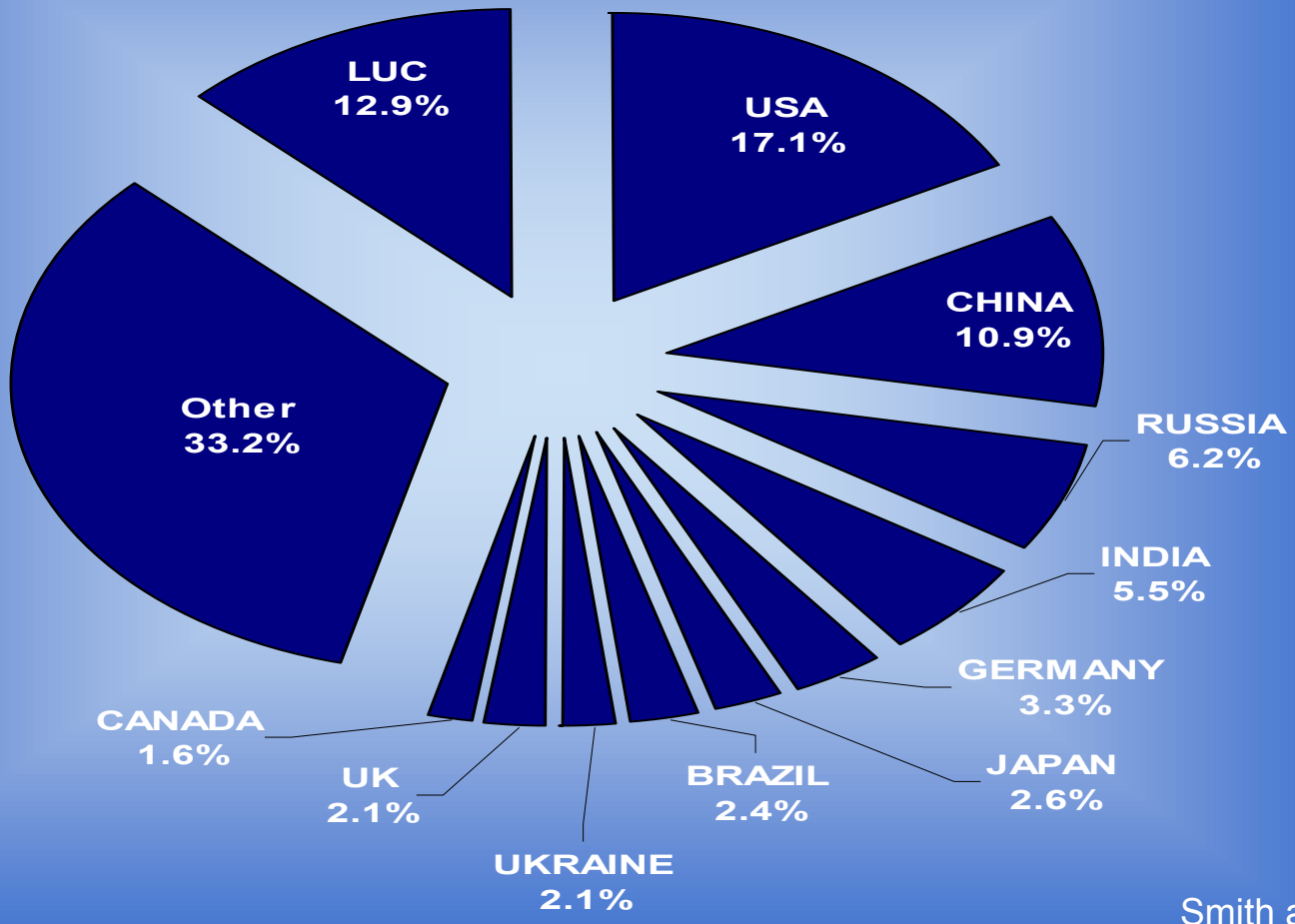
31 kg/capita



USEPA, 2006

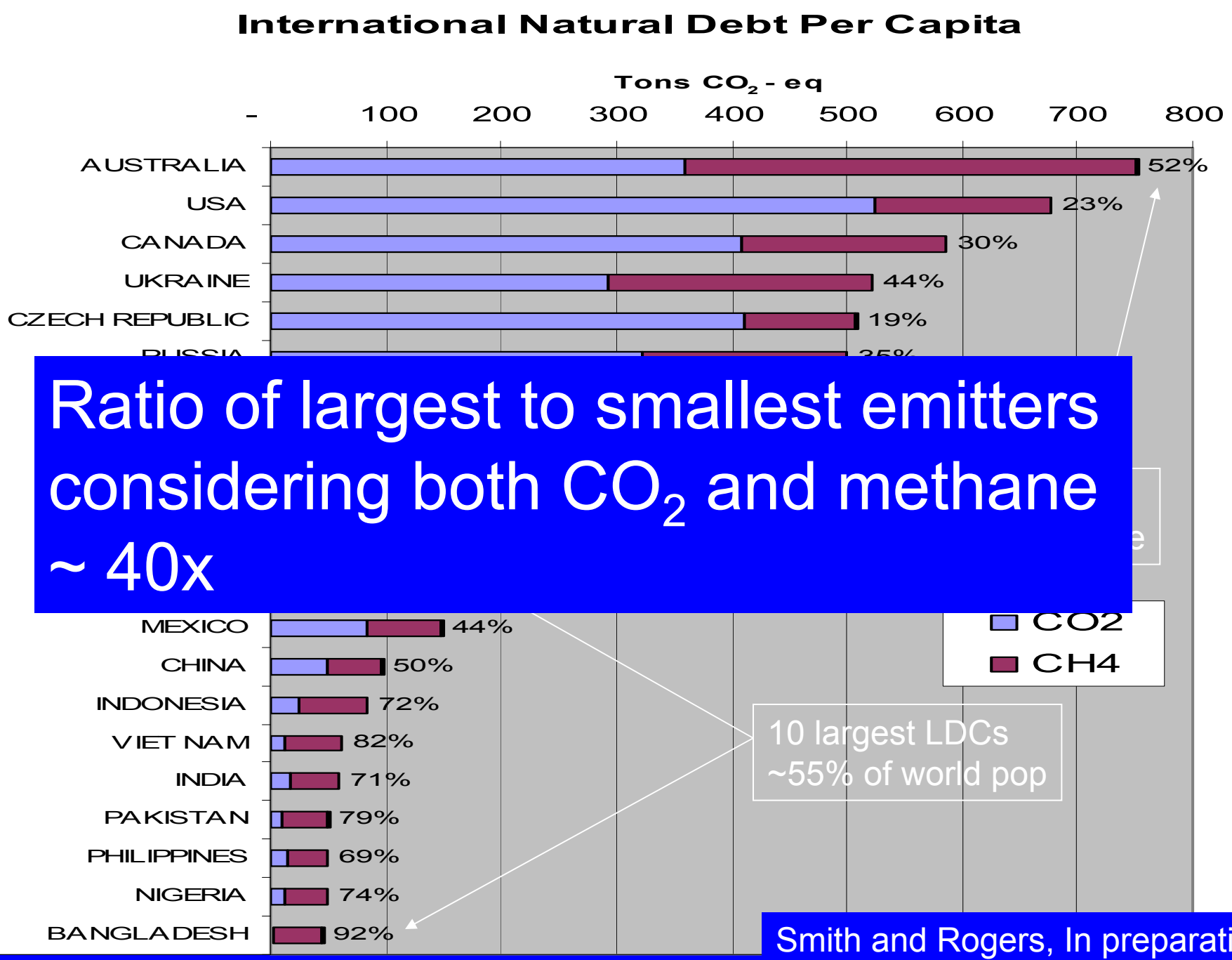
Distribution of Global Natural Debts in Top 10 Nations CH4 and CO2 in 2005

[compared to CO2 alone; note decrease for USA, increase for China, and large increases for India and Brazil]



Smith and Rogers, in preparation

Nb. National fossil fuel/cement emissions only for CO2, land-use change emissions are not parsed out by country


International Natural Debt Per Capita
Tons CO_2 - eq
- 100 200 300 400 500 600 700 800
AUSTRALIA 52%
USA 23%
CANADA 30%
UKRAINE 44%
CZECH REPUBLIC 19%
MEXICO 44%
CHINA 50%
INDONESIA 72%
VIET NAM 82%
INDIA 71%
PAKISTAN 79%
PHILIPPINES 69%
NIGERIA 74%
BANGLADESH 92%
CO2
CH4
10 largest LDCs
~55% of world pop
Ratio of largest to smallest emitters considering both CO_2 and methane ~ 40x
Smith and Rogers, In preparation

5. A Different Historical Framework

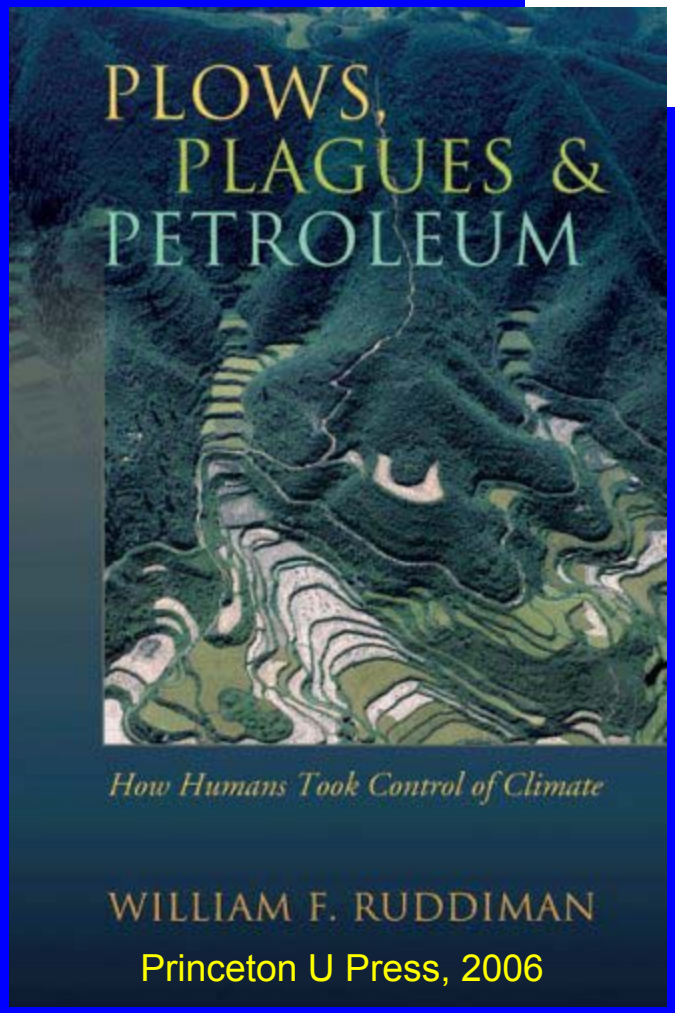
- Agrarian societies have been contributing to incipient climate change for several millennia.
- Reversing what would have been a natural decline in CO_2 and methane in this period
- Excess GHGs are not just a feature of industrialization, although the rate has risen dramatically after the industrial revolution

THE ANTHROPOGENIC GREENHOUSE ERA BEGAN THOUSANDS OF YEARS AGO

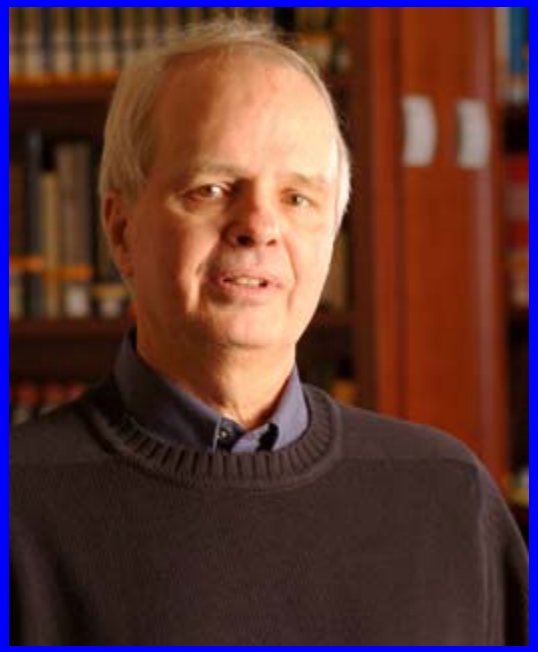
WILLIAM F. RUDDIMAN

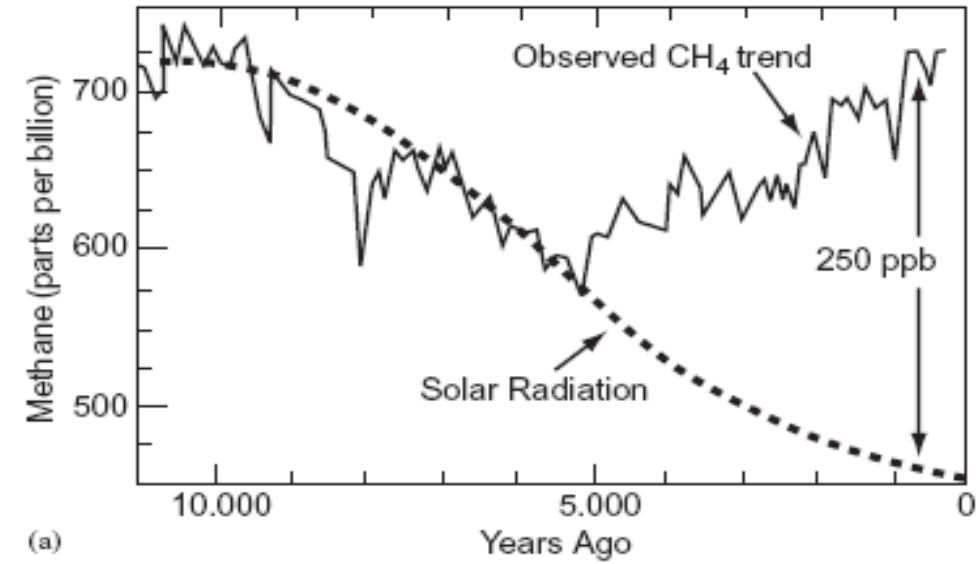
Department of Environmental Sciences, University of Virginia, Charlottesville, VA 22904, U.S.A.
E-mail: wfr5c@virginia.edu

Climatic Change **61**: 261–293, 2003.



Princeton U Press, 2006





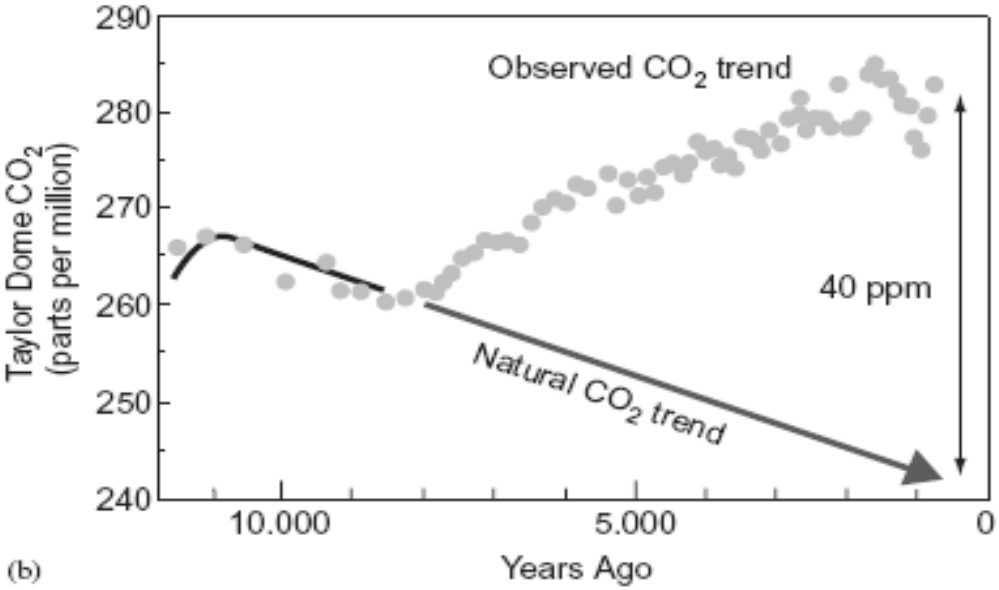


Fig. 1. Anthropogenic effects on (a) CH_4 and (b) CO_2 calculated as the difference between observed trends (Blunier et al., 1995; Indermuhle et al., 1999) and trends estimated from previous early interglacial intervals (Ruddiman, 2003).

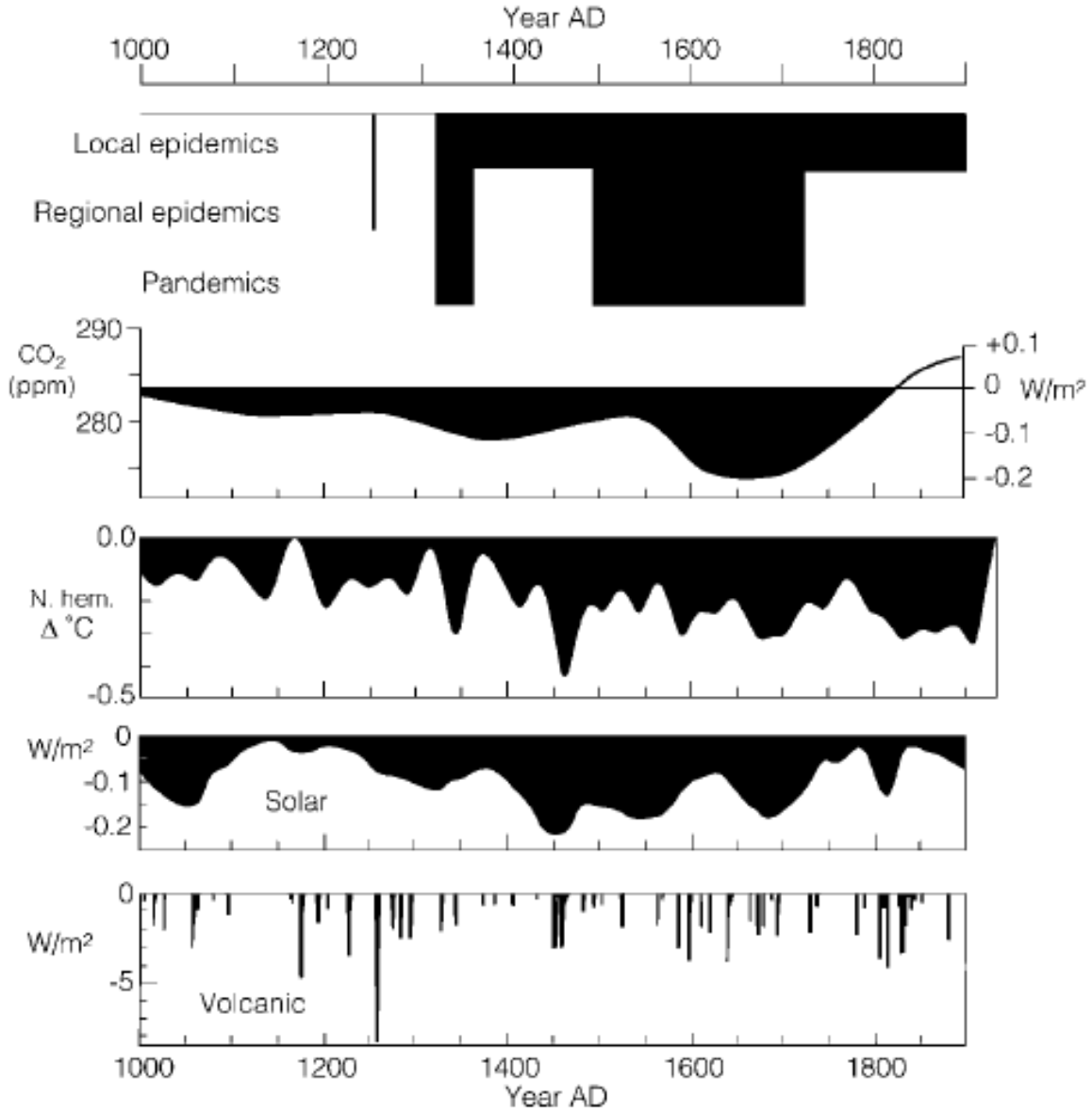
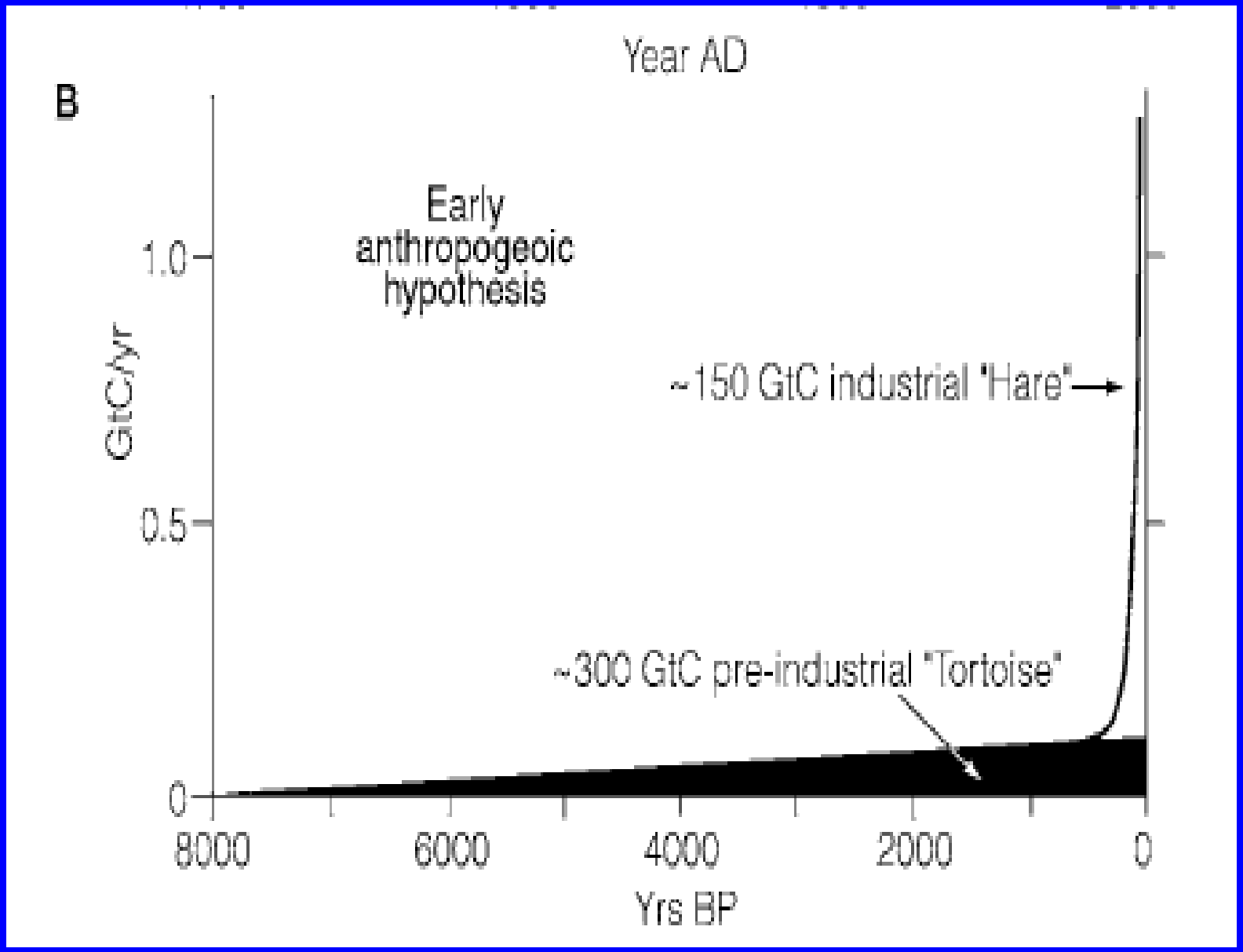


Figure 10. Estimated mean northern hemisphere temperature changes from 1000–1900 AD (Mann et al., 1999) compared to: plague epidemics and pandemics; ice-core CO_2 (average of changes at Taylor Dome and Law Dome shown in Figure 7); and solar and volcanic radiative forcing (from Bard et al., 2000; Crowley, 2000).

Ruddiman, 2003



Ruddiman 2003

Carbon dioxide is important

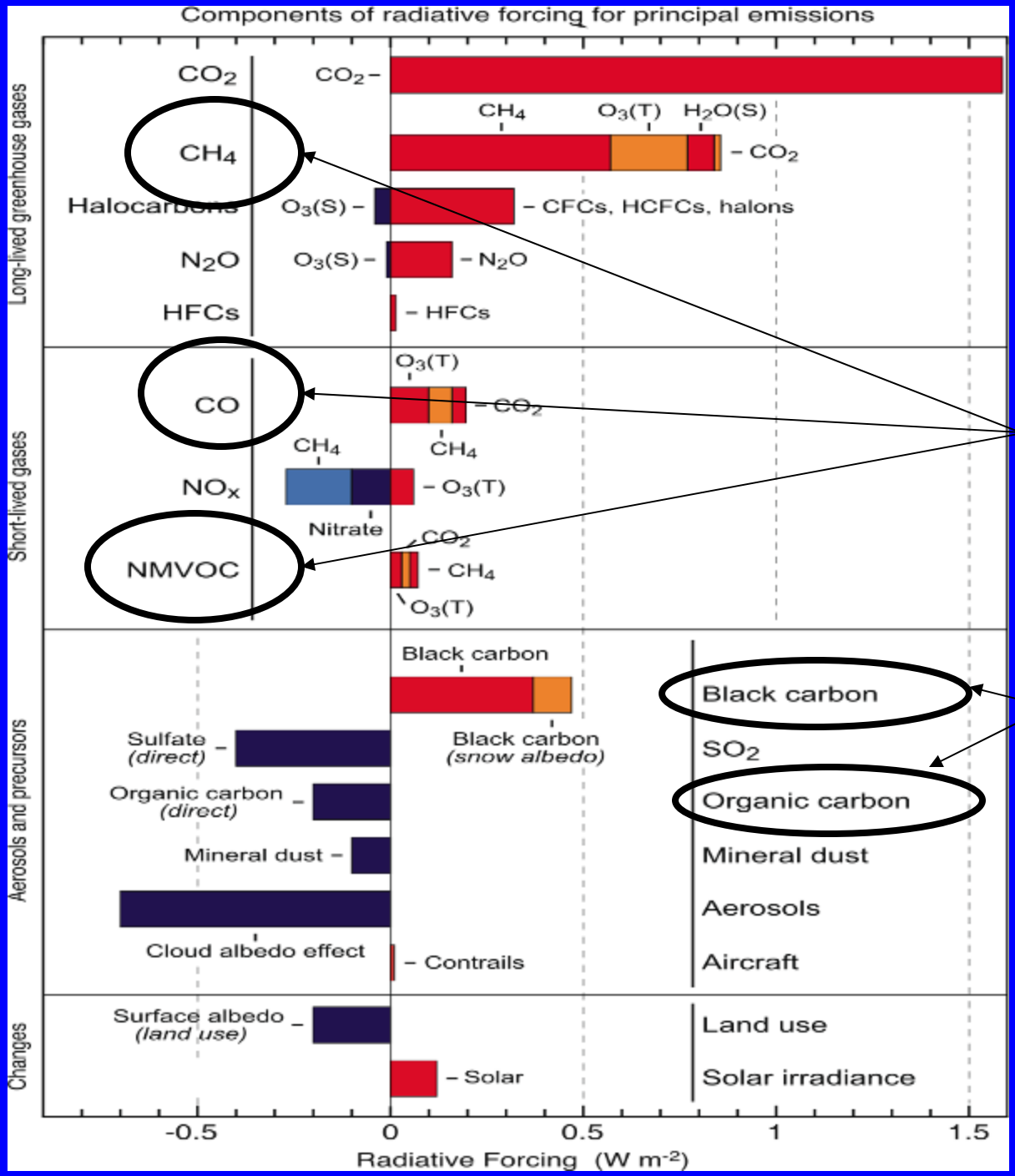
However, …

Laws of Carbon-thermodynamics

I. Keep all fossil and forest carbon out of the atmosphere

II. If you cannot do so, the least-damaging form to release is carbon dioxide because all other forms are worse for climate and health.

III. Even renewable (non-fossil) carbon is damaging for climate and health if not released as carbon dioxide.



Warming in 2005 from emissions since 1750

A large part from PIC: products of incomplete combustion

IPCC, 2007

Ranking of Carbon Emissions:
The Pharmaceutical Index

- Carbon dioxide is noxious if fossil or forest derived, but benign if from renewable sources
- Products of incomplete combustion (PIC) such as carbon monoxide and hydrocarbons are like CO_2 on caffeine – several times worse
- Methane from any source (fossil, biologic, or incomplete combustion) is like CO_2 on steroids – dozens of times worse.
- Black carbon in particles from incomplete combustion is like CO_2 on crack – hundreds of times worse.

Conclusion on Methane

- Methane emissions are more important than current official weighting factors indicate because of its large effect over the next generation
- May well 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
- Contributes directly to global tropospheric ozone levels
- 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 – bottom lines?

- 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
- For some impacts, the **rate** of warming is as important as the total amount
- Only way to slow the rate is to immediately reduce methane emissions (and other short-lived GH pollutants)
- While working to stop CO_2 in the long run

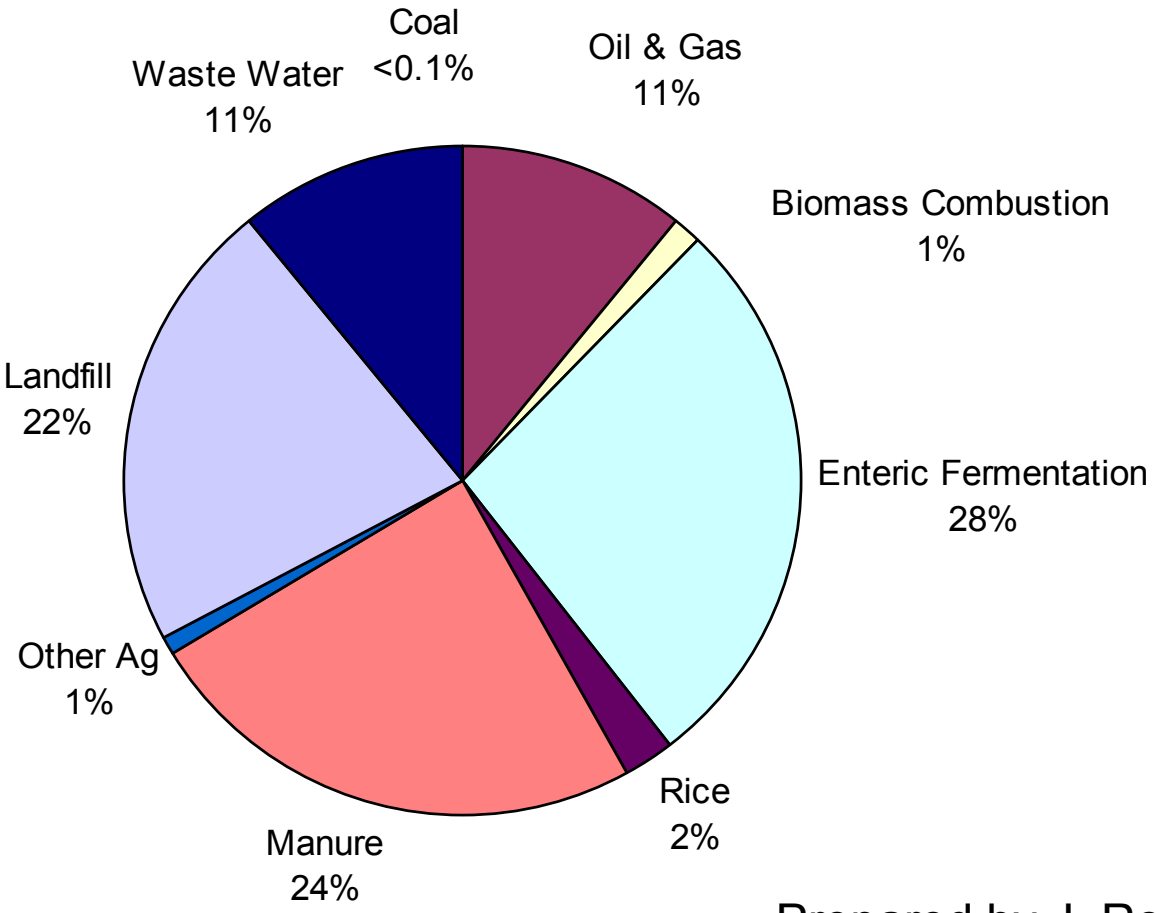
Carbon dioxide is still important

But, do you know your methane footprint?

California Methane Emissions 2004 – 1.2 MT

34.8 kg/capita

0.4% of world



Prepared by J. Rogers from CARB data

Publications and presentations available at

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

Thank you