Co-benefits from Air Pollution Control for Health and Climate in China

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Why Worry about Co-benefits?

- Helps share the cost of greenhouse pollutant mitigation with achievement of other societal goals, such as providing acceptable levels of health protection
- Potentially reduces political gap between developed and developing countries in international climate negotiations – early achievement of more certain benefits that directly relate to development needs (“no regrets investments”)

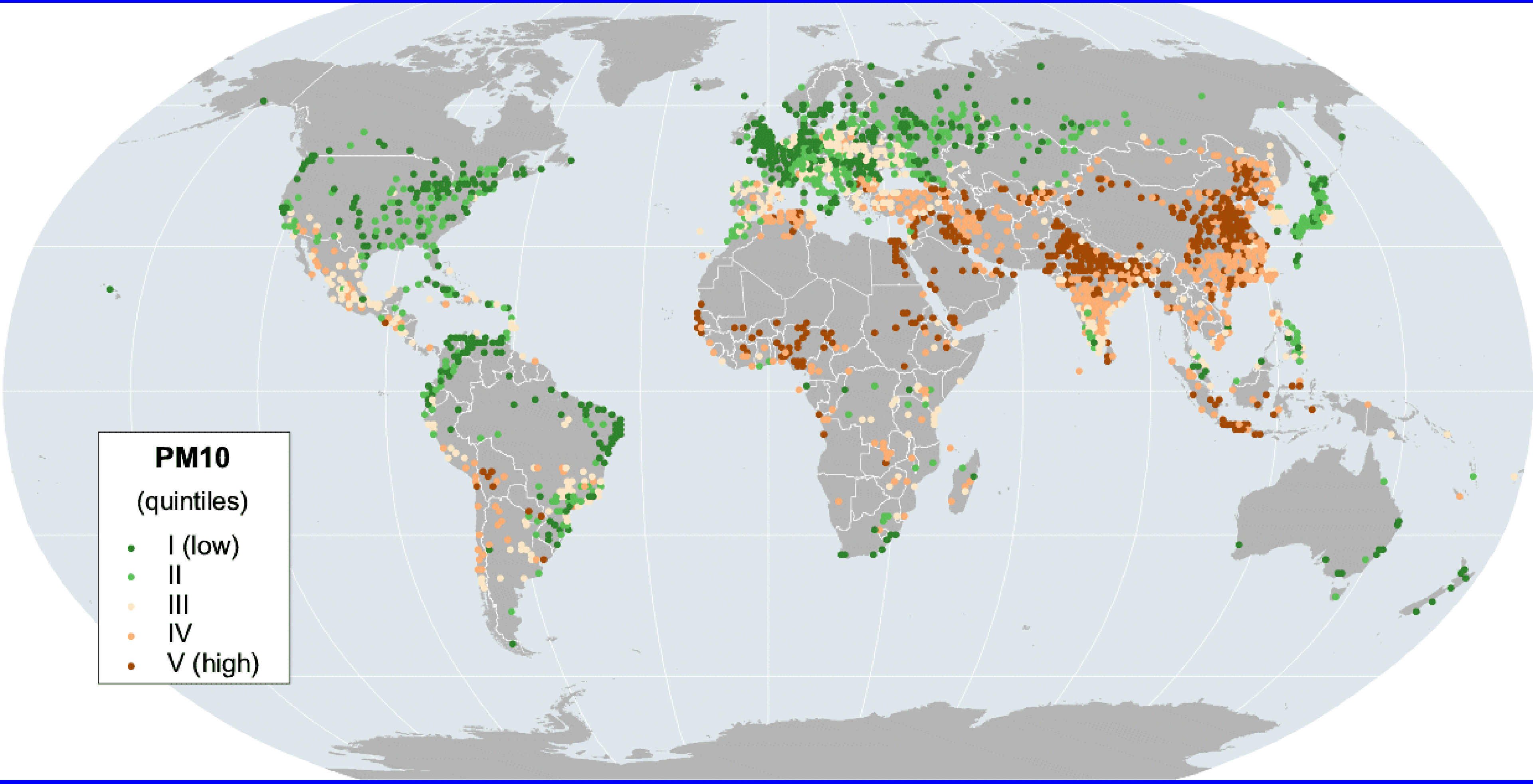
Roadmap

- Many types of co-benefits (e.g., changing built environment)
- Energy related air pollution probably has strongest links
- Two categories discussed here
  - Methane: under-appreciated greenhouse and health-related pollutant
  - Household Fuels in China

Air Pollution from Energy Use

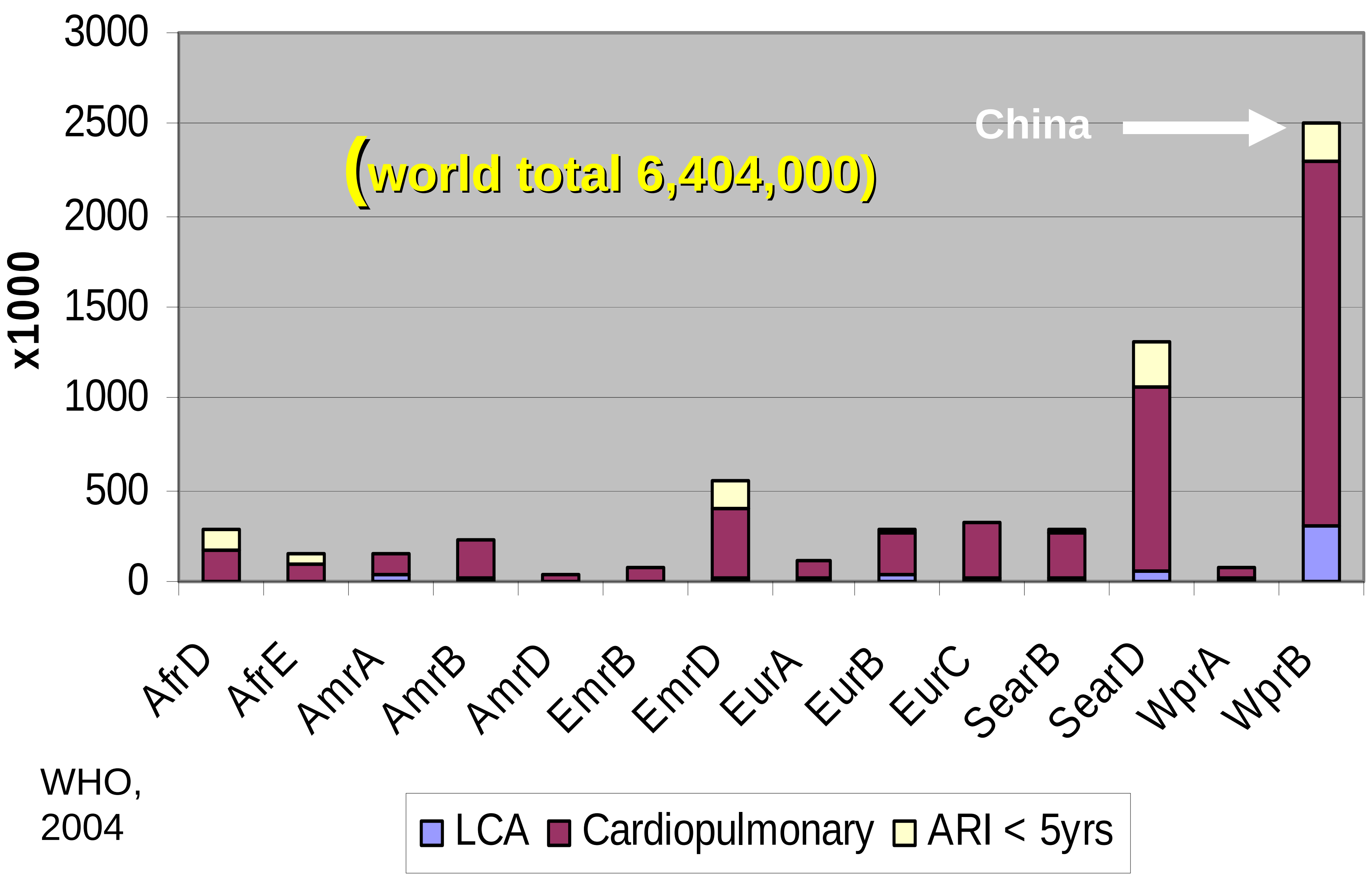
- Household solid fuels
  - Large source of ill-health worldwide in poorest populations – 1.6 million premature deaths
  - Non-renewable biomass and coal carbon emissions
  - Poor combustion leads to non-CO_2 GH-related emissions
- Outdoor emissions from energy systems
  - 0.8 million premature deaths
  - Most well documented benefits, climate and health
- Special advantage to eliminating black carbon, but difficult to ascertain relative climate impacts of different aerosols.
- China has the largest global impacts for both these categories of air pollution

Estimated PM10 Concentration in World Cities (pop=100,000+)

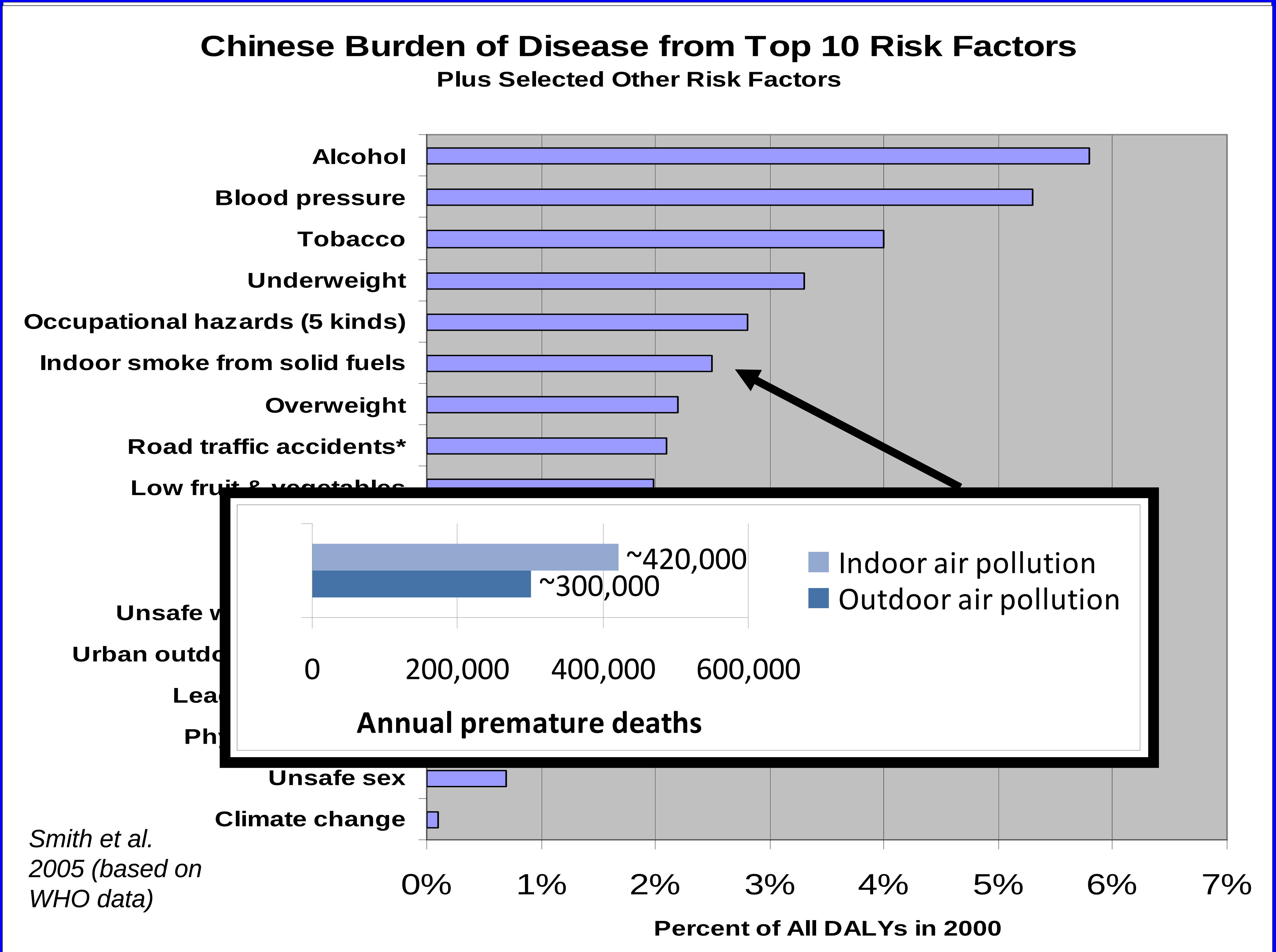


WHO, 2004

DALYs Attributable Globally to Urban Outdoor Air Pollution

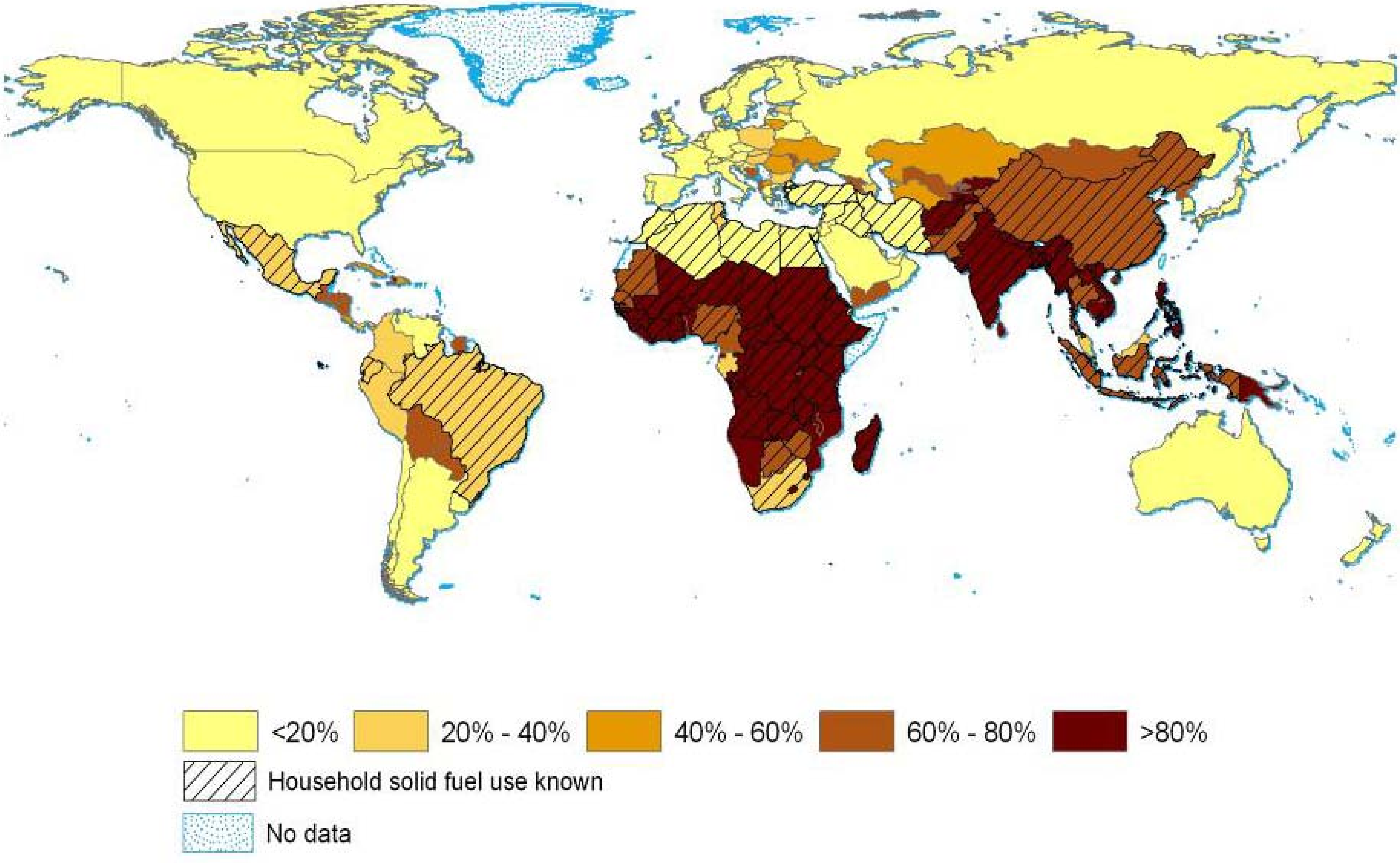


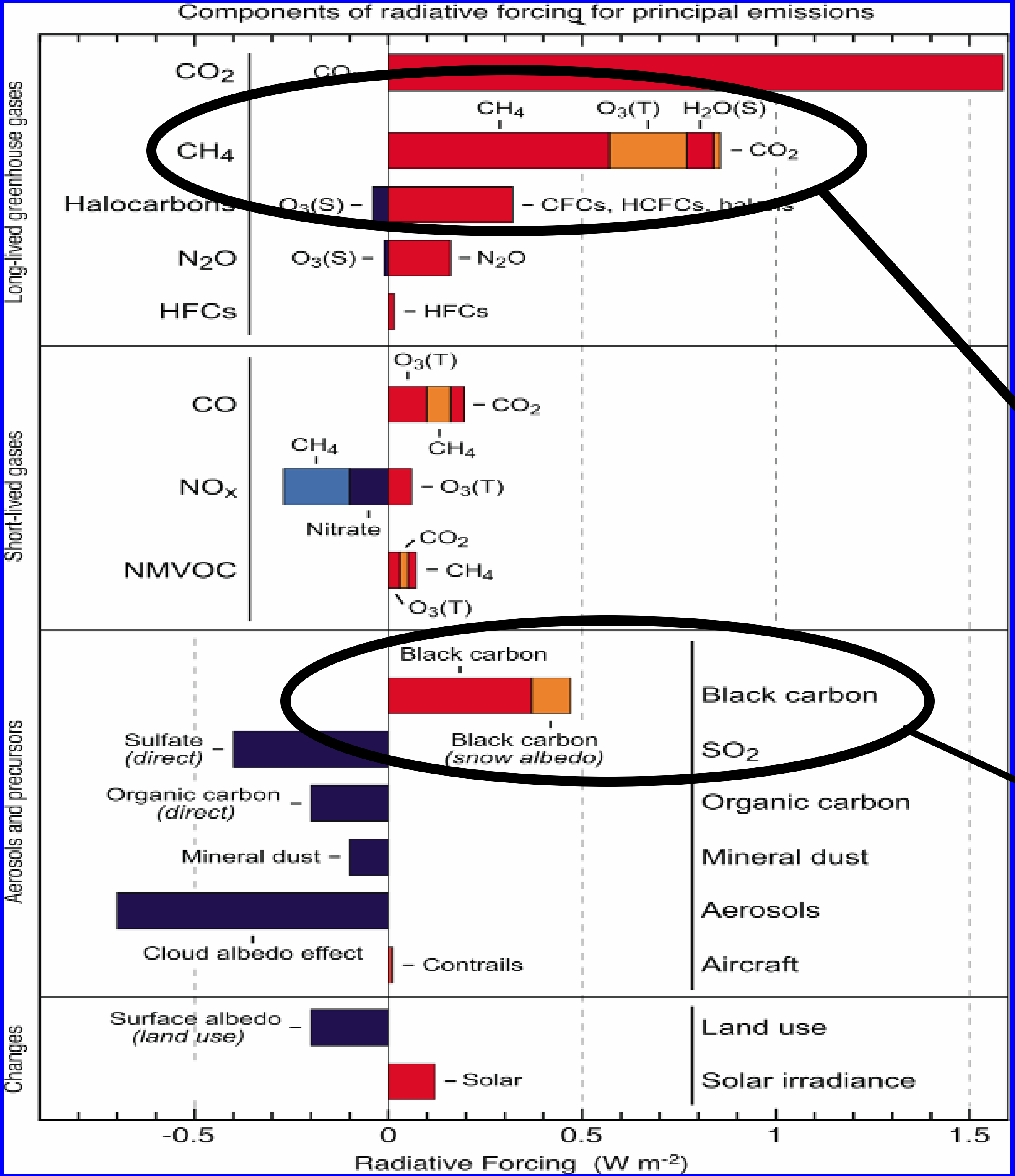
WHO, 2004



Chinese Burden of Disease from Top 10 Risk Factors
Plus Selected Other Risk Factors
Alcohol
Blood pressure
Tobacco
Underweight
Occupational hazards (5 kinds)
Indoor smoke from solid fuels
Overweight
Road traffic accidents*
Unsafe sex
Climate change
~420,000
~300,000
Indoor air pollution
Outdoor air pollution
0
200,000
400,000
600,000
Annual premature deaths
0%
1%
2%
3%
4%
5%
6%
7%
Percent of All DALYs in 2000
Smith et al. 2005 (based on WHO data)

National Household Solid Fuel Use, 2000



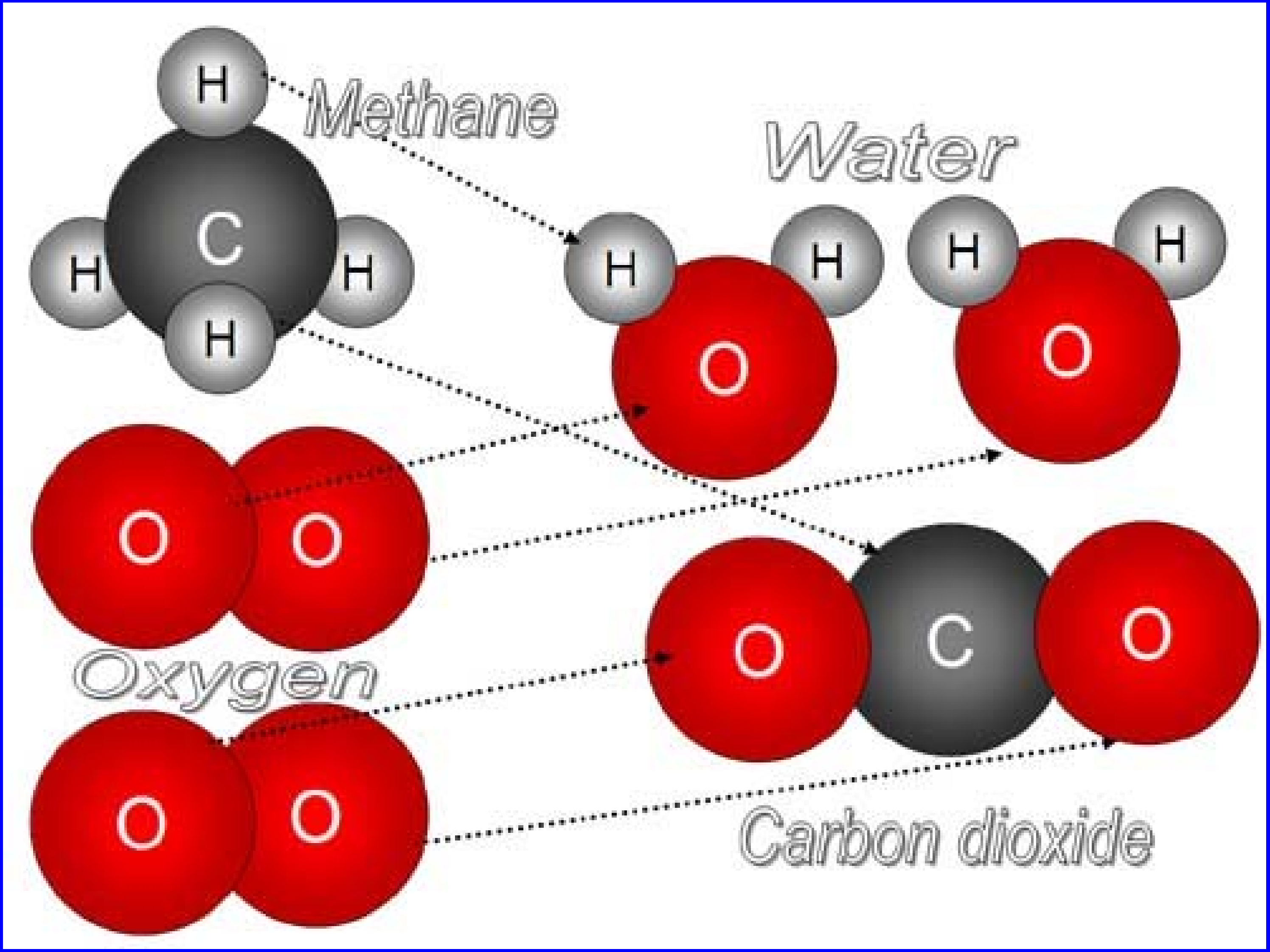


Warming in 2005 from emissions since 1750

Note importance of methane and black carbon

IPCC, 2007

The Methane Story: CH_4



Atmospheric Greenhouse gas concentrations

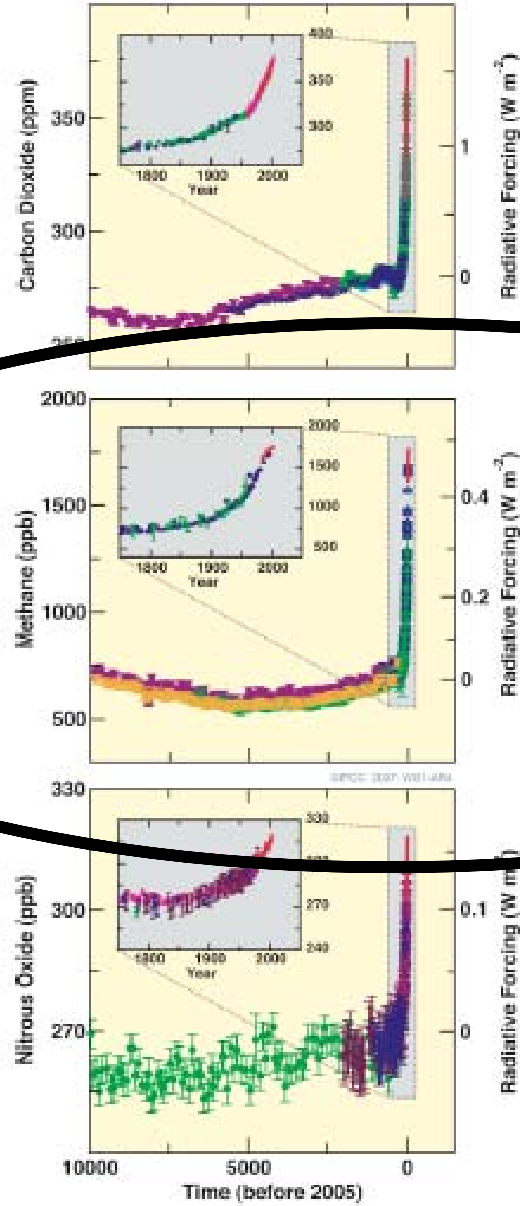


Figure SPM.1
IPCC 2007

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

Methane and Global Warming

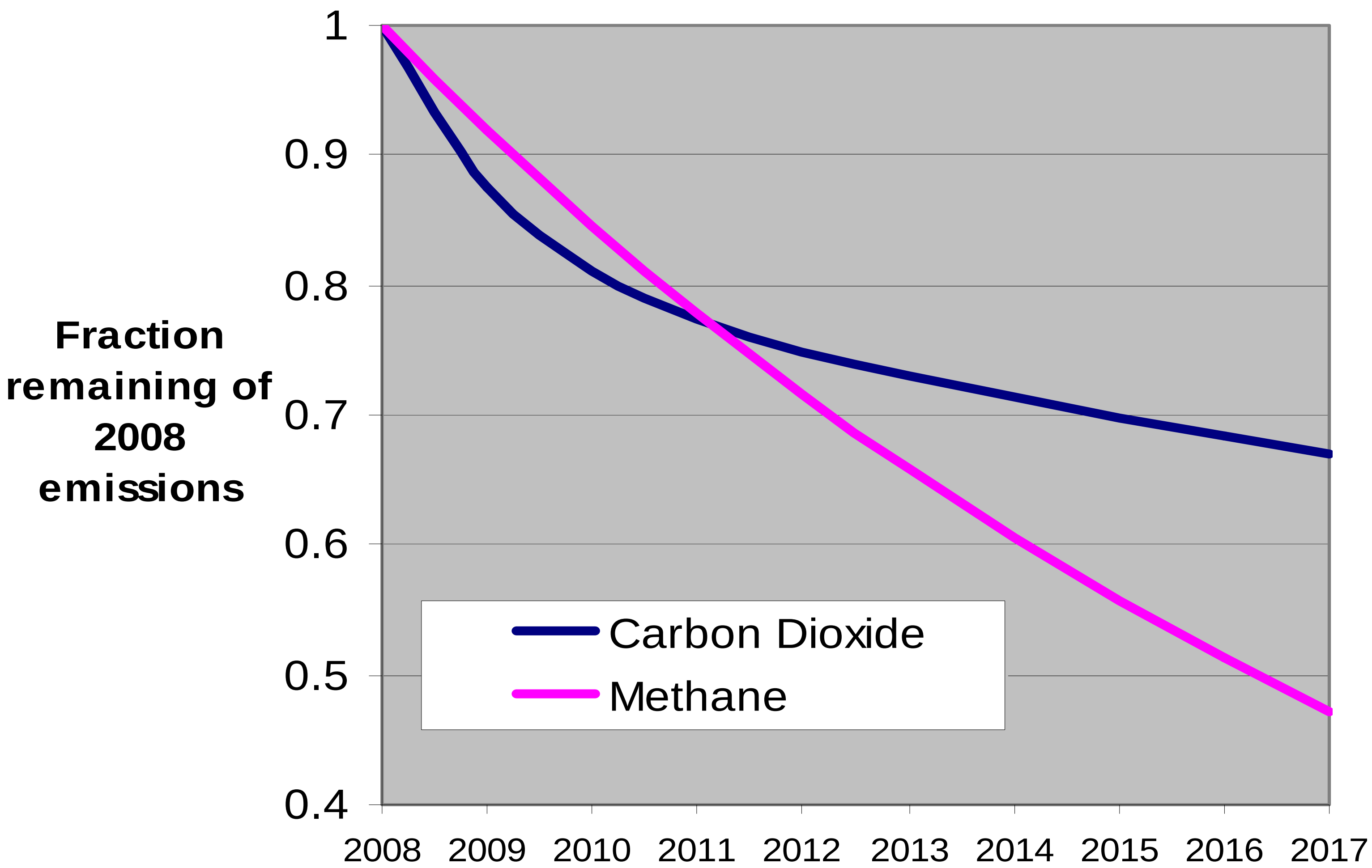
- A much more powerful greenhouse gas (GHG) than CO_2
- Partly due to its direct effect, but also because it creates ozone (O_3), another powerful GHG
- Nearly 100 times more per ton than CO_2 at any one time (73x from direct effects)
- Eventually turns to 2.75 times as much CO_2 by mass
- Methane has 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

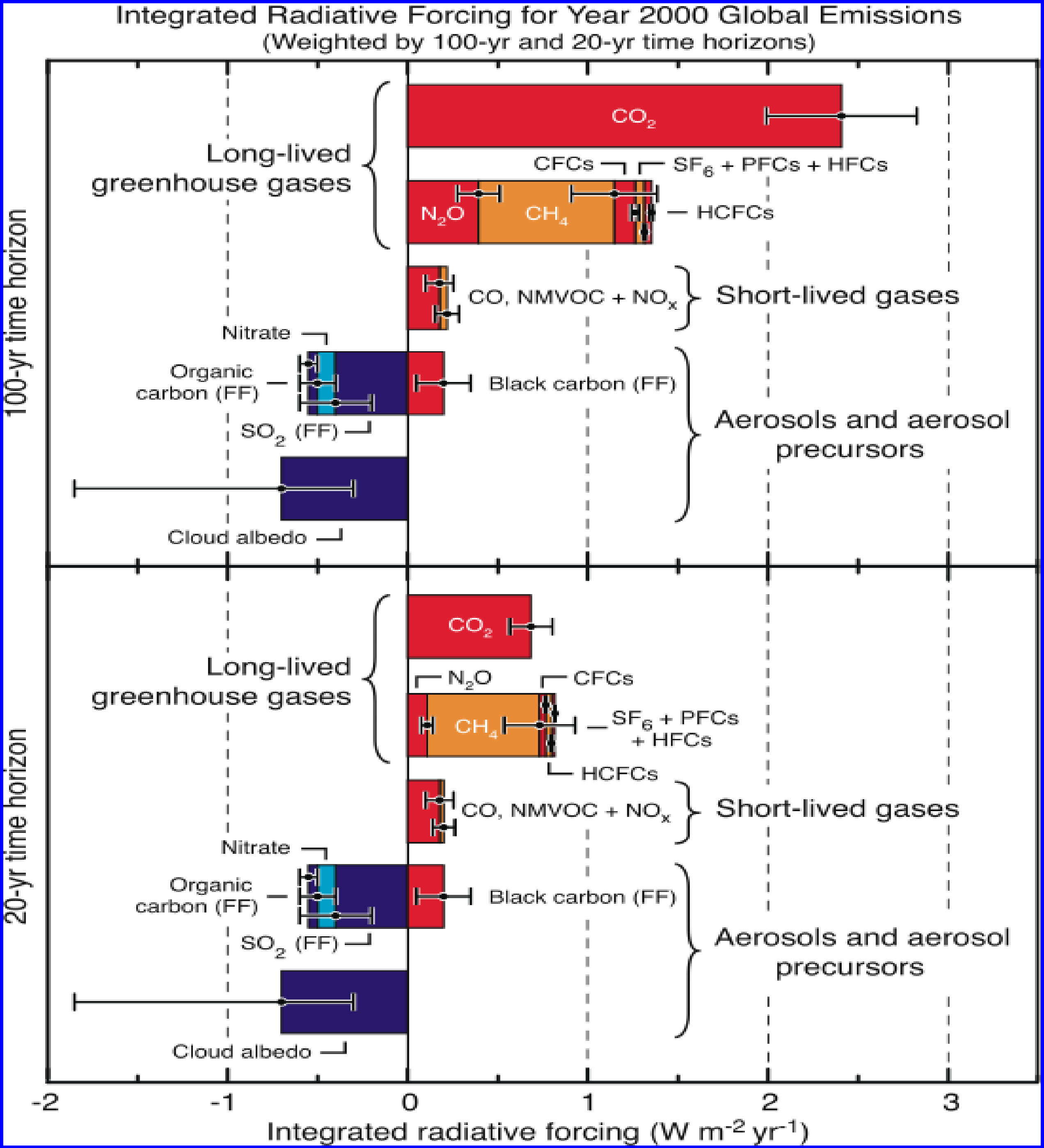
Math of GHG Decay (AR4)

- 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





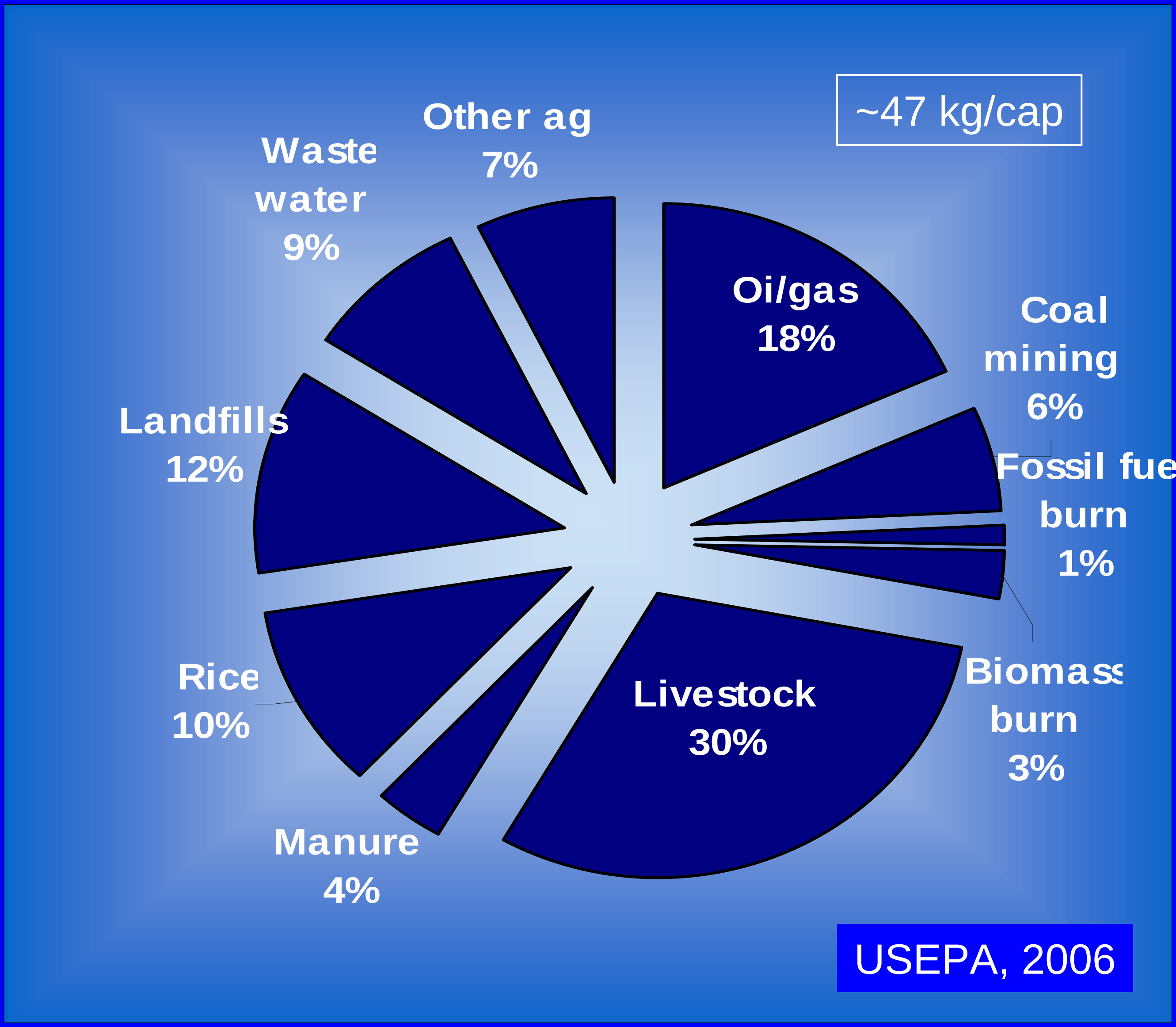
100-y horizon

Time perspective makes a difference

20-y horizon

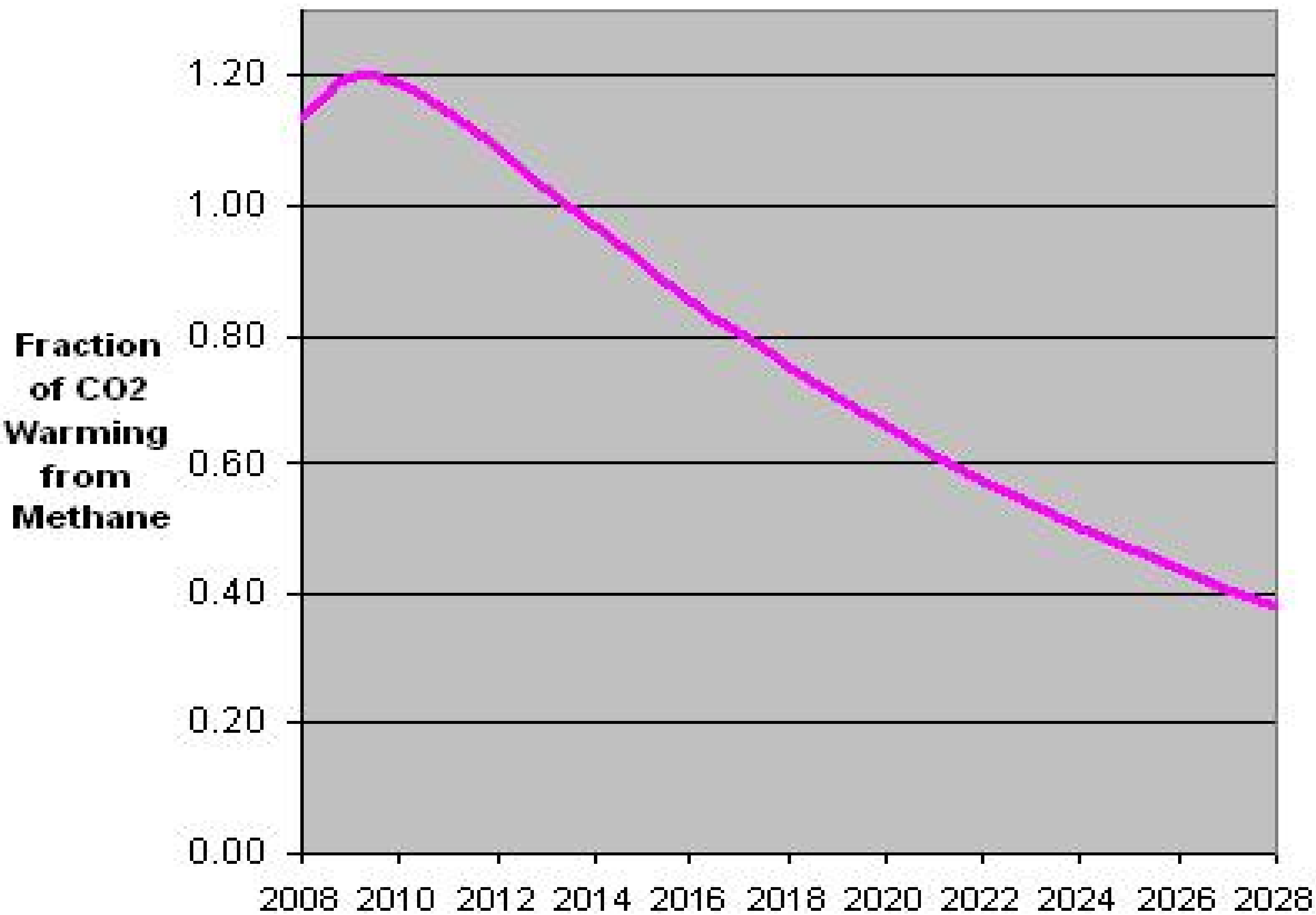
IPCC, 2007

Global Anthropogenic Methane Emissions ~2005
Total ~ 305 million tons



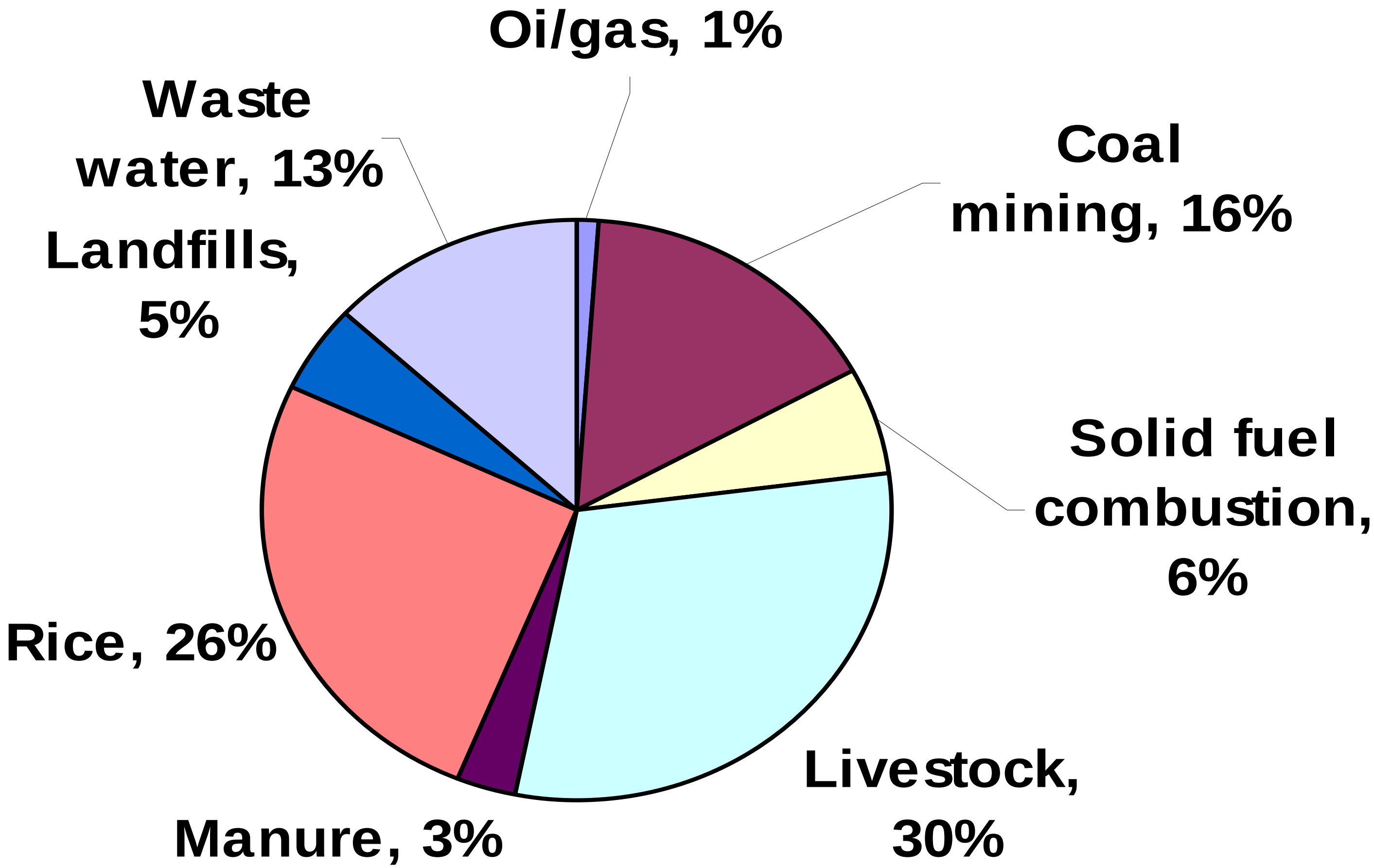
Expected to grow at ~1.5% per year

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

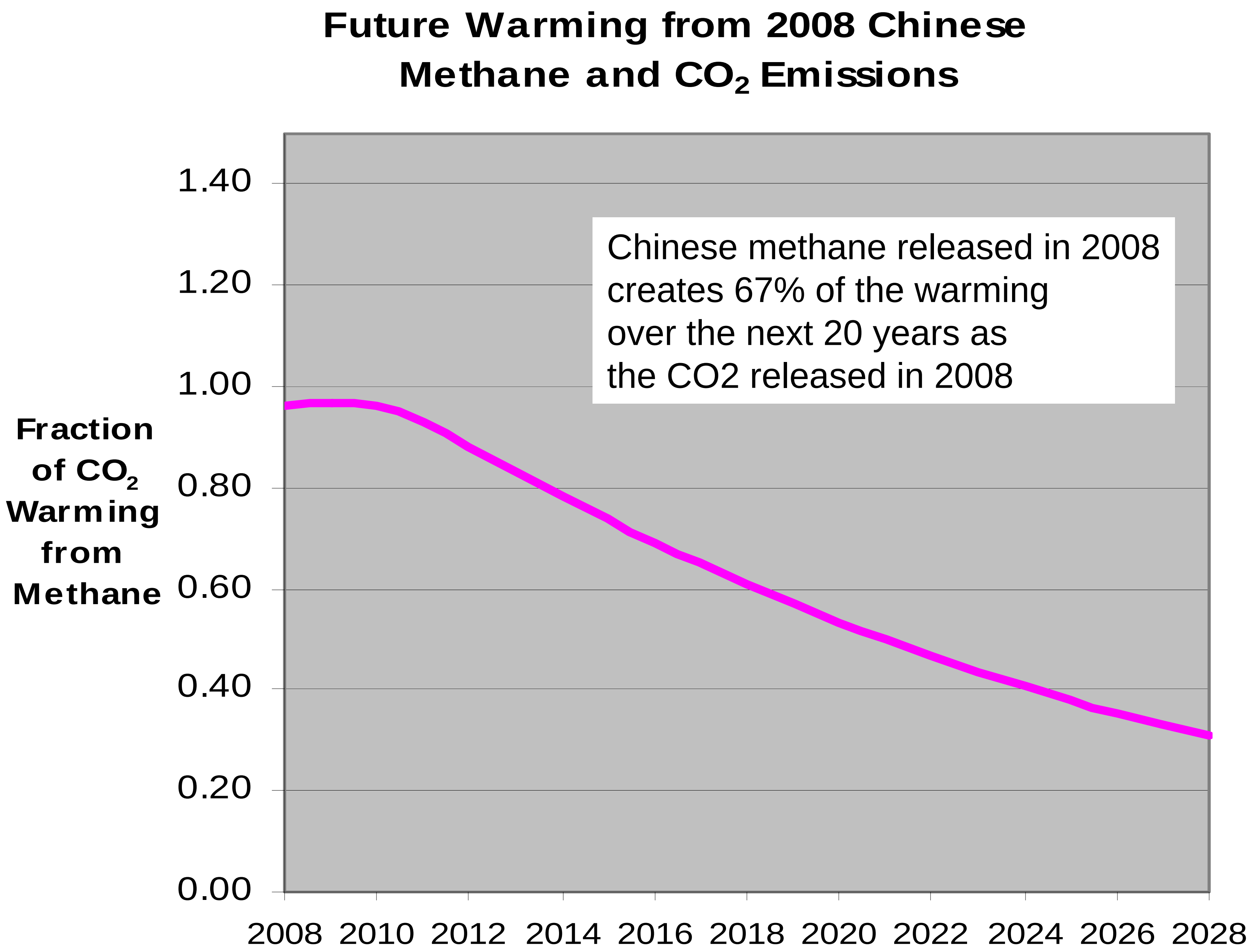


Chinese Methane Emissions in 2005
41 MT = 13% of world

31 kg/capita

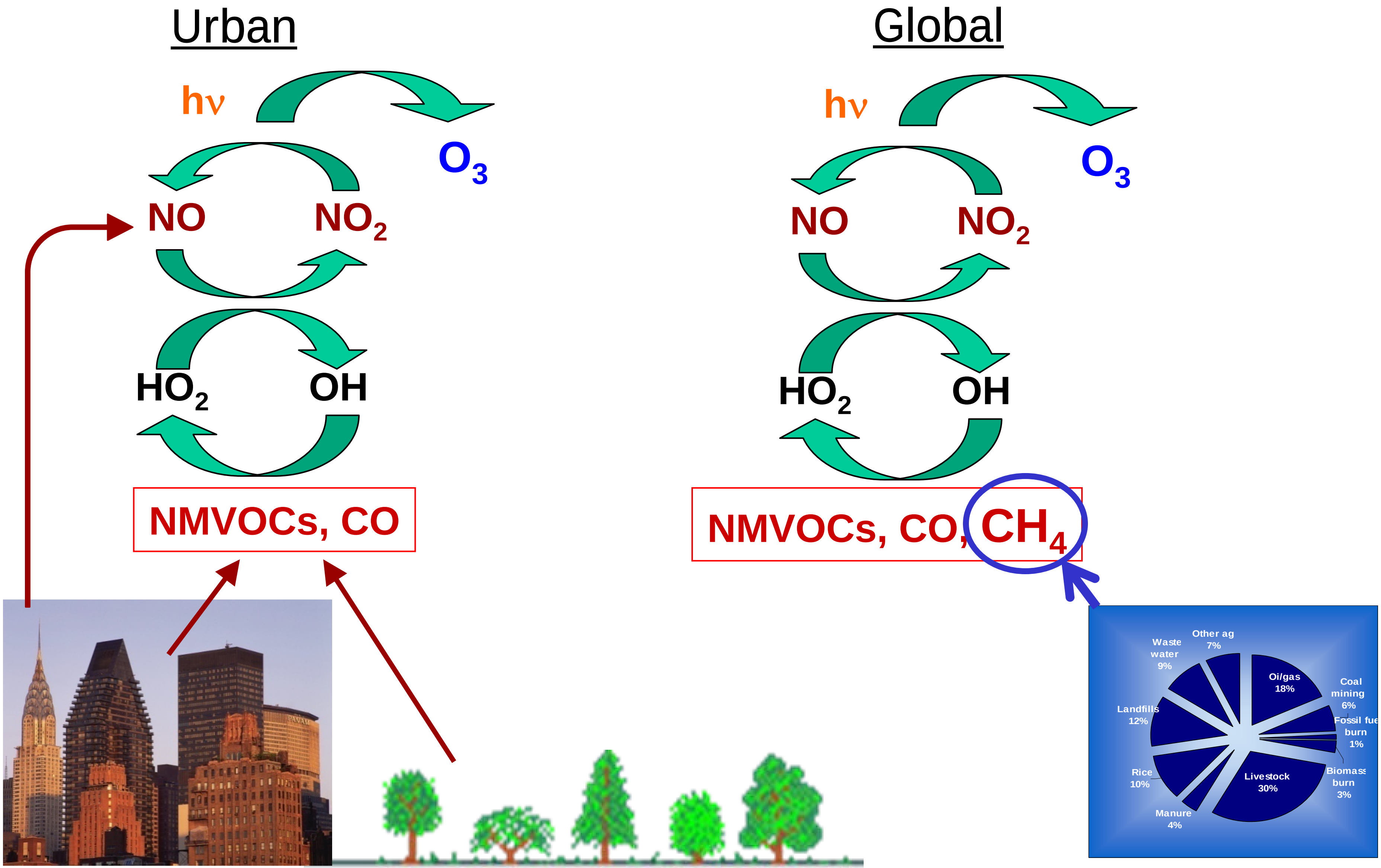


USEPA, 2006



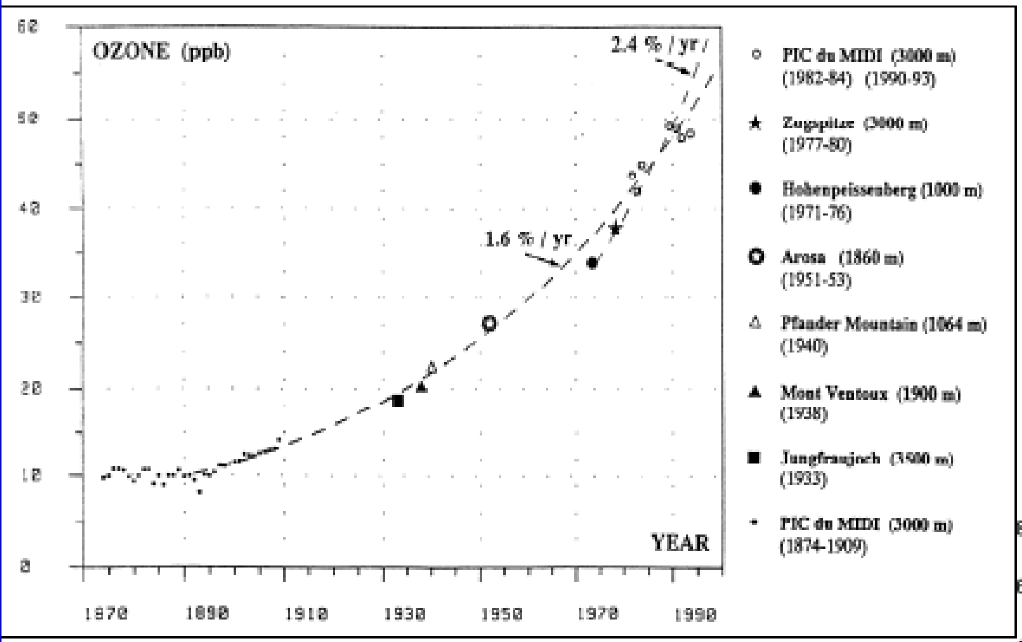
Future Warming from 2008 Chinese Methane and CO2 Emissions
Chinese methane released in 2008 creates 67% of the warming over the next 20 years as the CO2 released in 2008
Fraction of CO2 Warming from Methane
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
2008
2010
2012
2014
2016
2018
2020
2022
2024
2026
2028

Methane as a Global Ozone Precursor



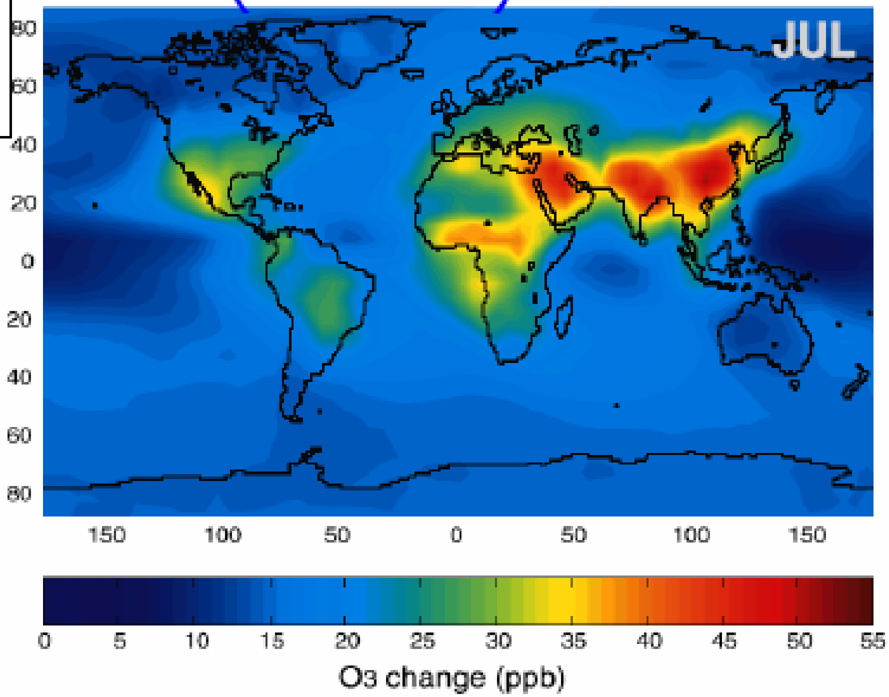
Background Ozone is Growing …

… and Will Continue to Grow!



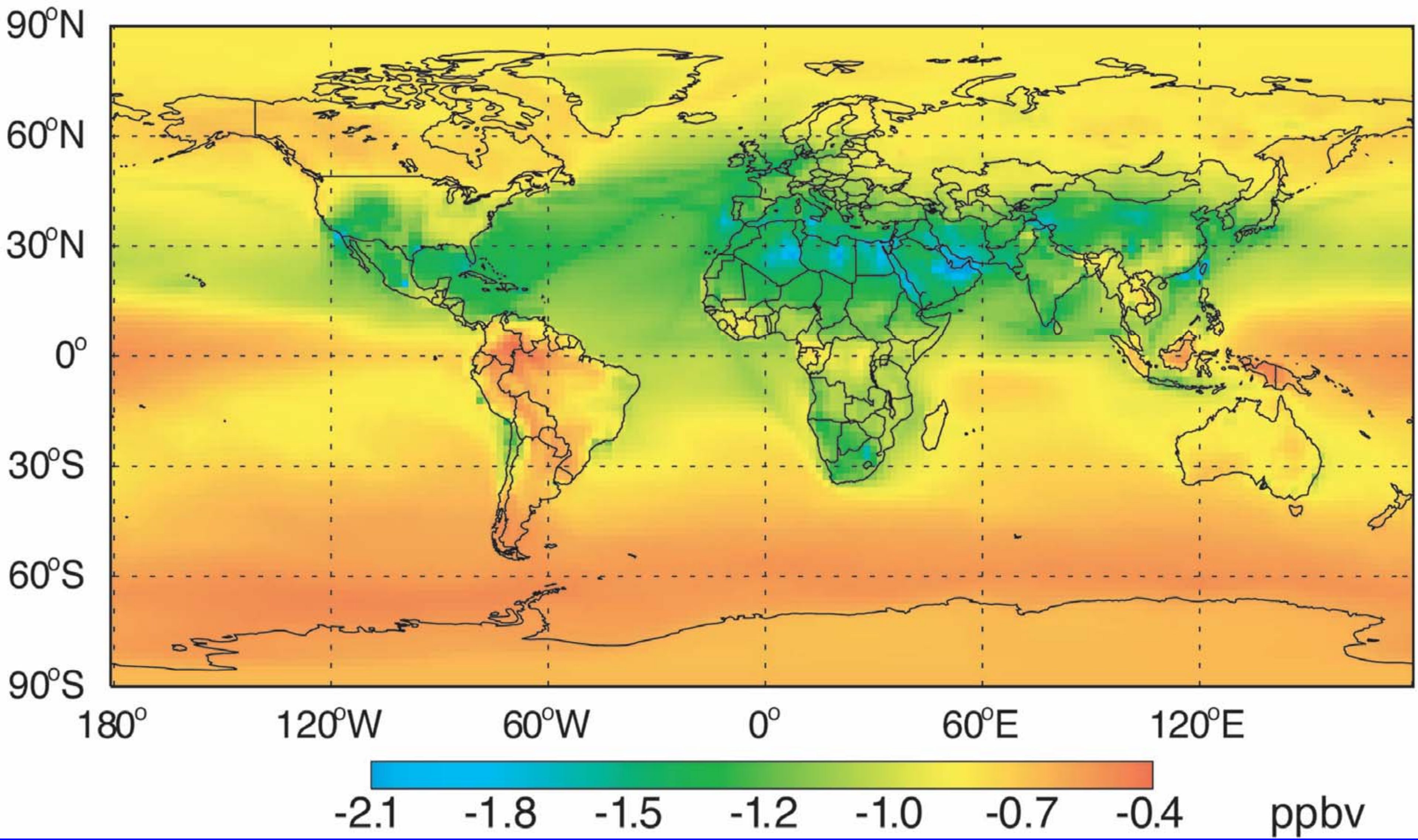
Historic and future increases in background ozone are due mainly to increased methane and NO_X emissions (Wang *et al.*, 1998; Prather et al., 2003).

2100 (IPCC A2) - 2000



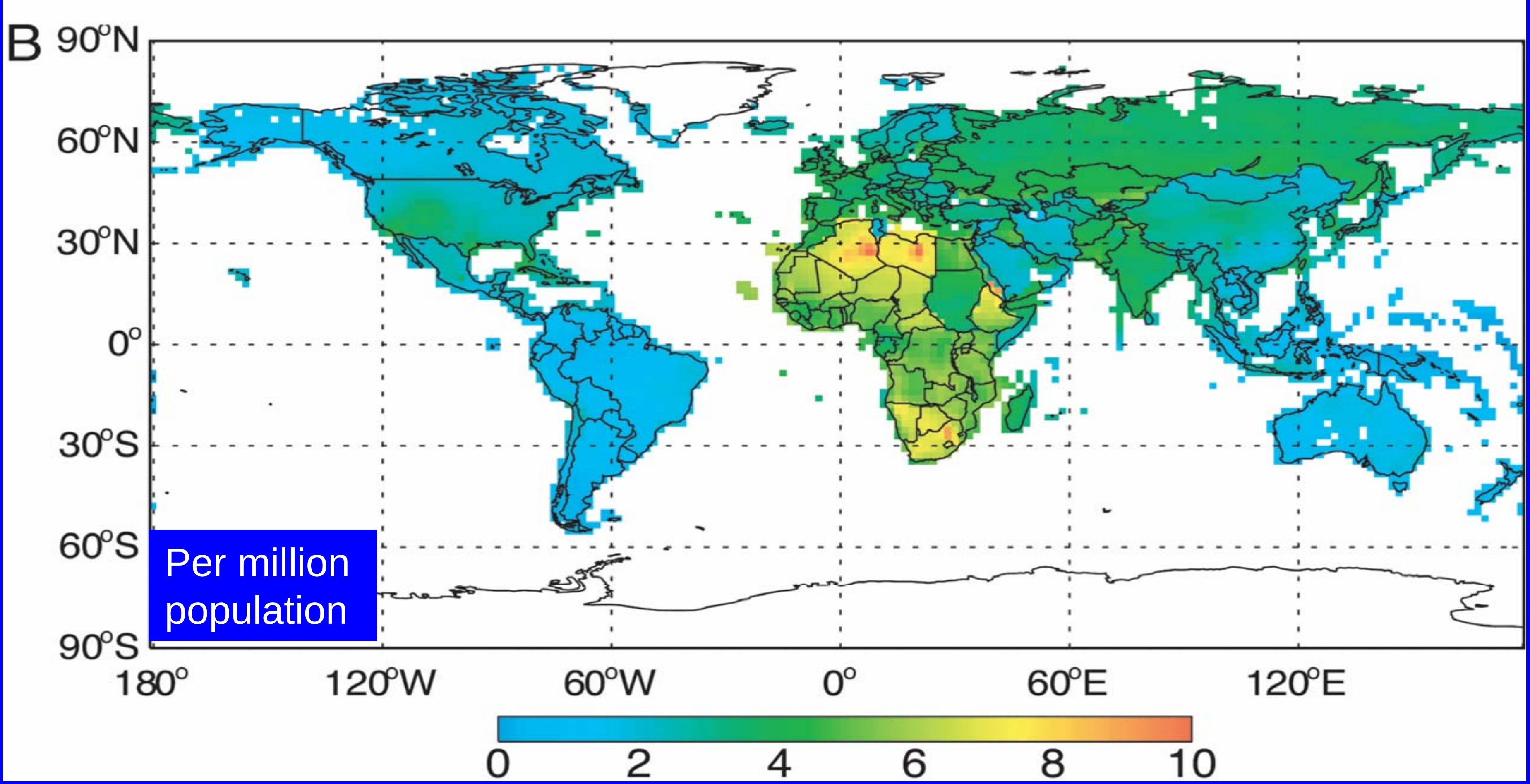
Ozone trend at European mountain sites, 1870-1990 (Marenco et al., 1994).

Mauzerall 2007



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

West et al., PNAS, 2006

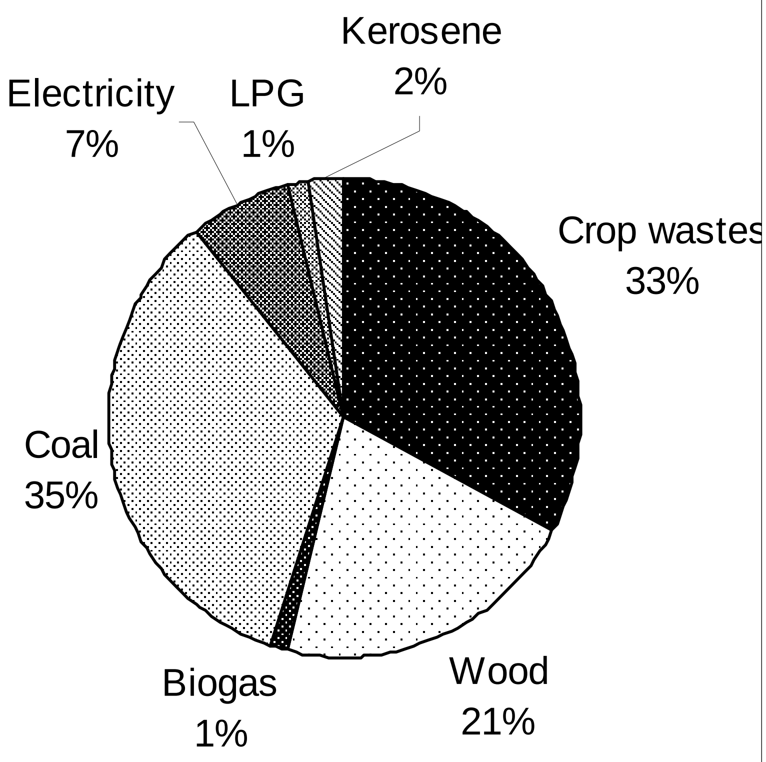


Reduction in ozone mortality from 20% reduction in methane emissions

West et al, PNAS, 2006

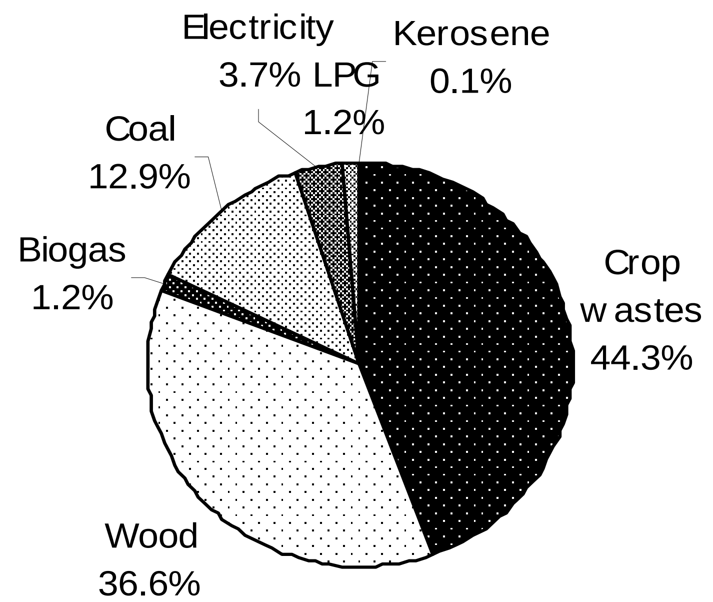
Rural Energy in China: 2004

Total



Ministry of Agriculture

Households

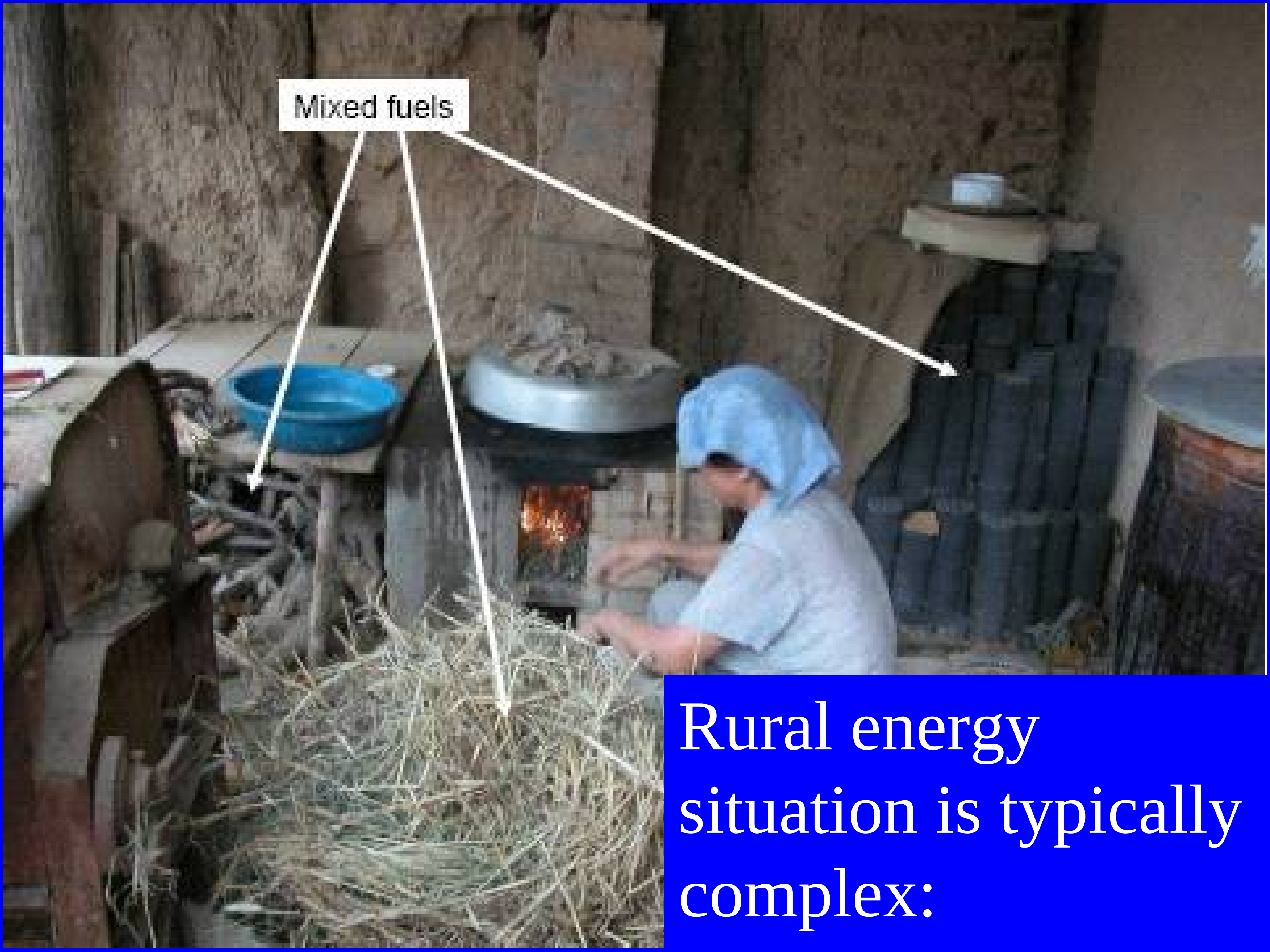


70% of total

National Bureau of Statistics

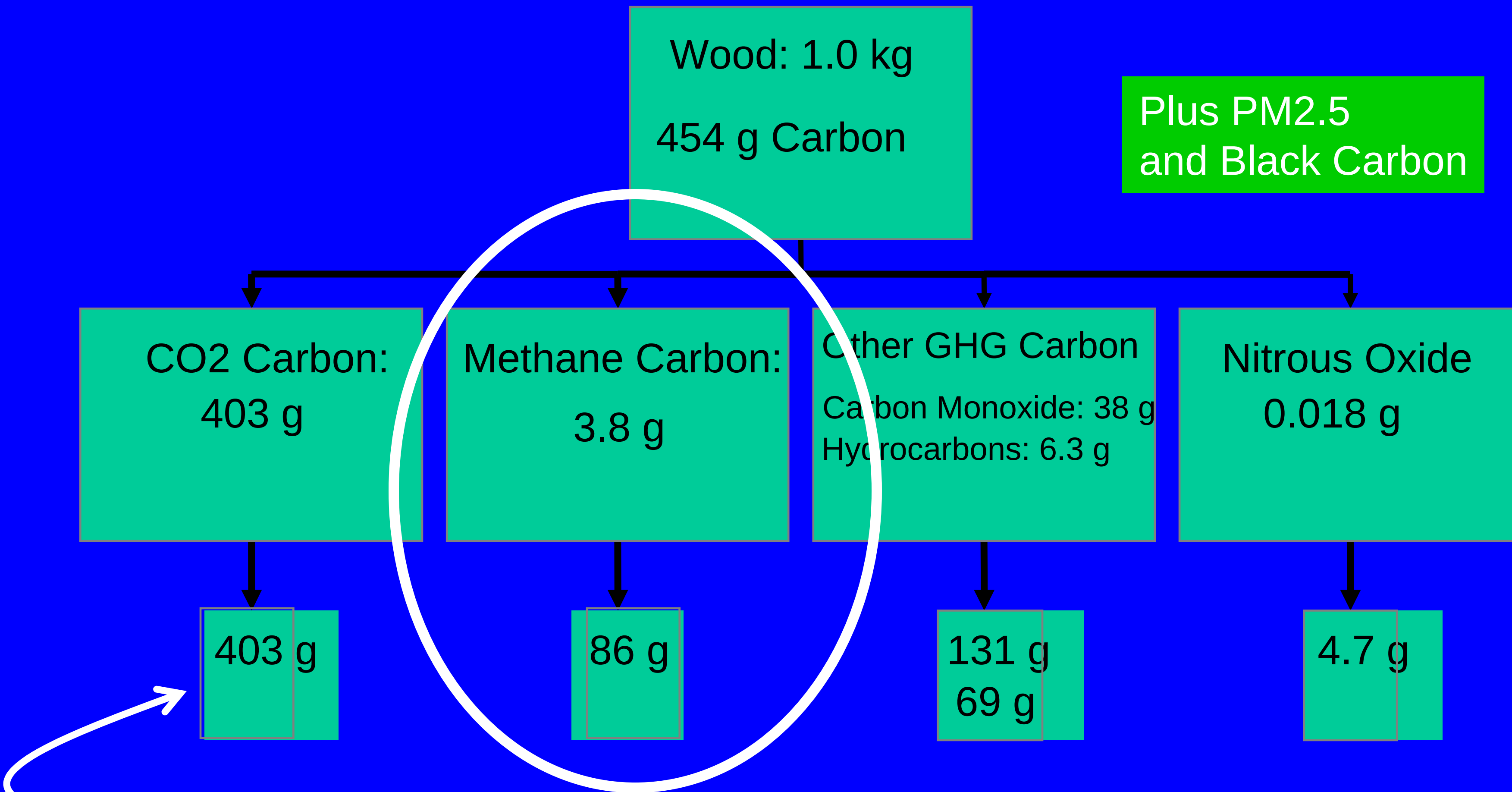
Household Energy in China

- >65% of China's population is rural.
- ~ 80% of energy use is simple solid biomass (wood, agricultural wastes)
- ~13% as coal
- Thus, it is still true to say that in China most people rely on biomass fuels for most of their energy
- A situation that has not changed since the mastery of fire by the human race



Rural energy situation is typically complex:

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

Role of Technology: Co-benefits

Improved Biomass Cookstoves

- Reduction in air pollution and GHGs
- Improvement in health outcomes
- Increase in fuel efficiency
- Solution to rural biomass fuel shortage
- Reallocation of time for women and kids
- Decrease in forest degradation

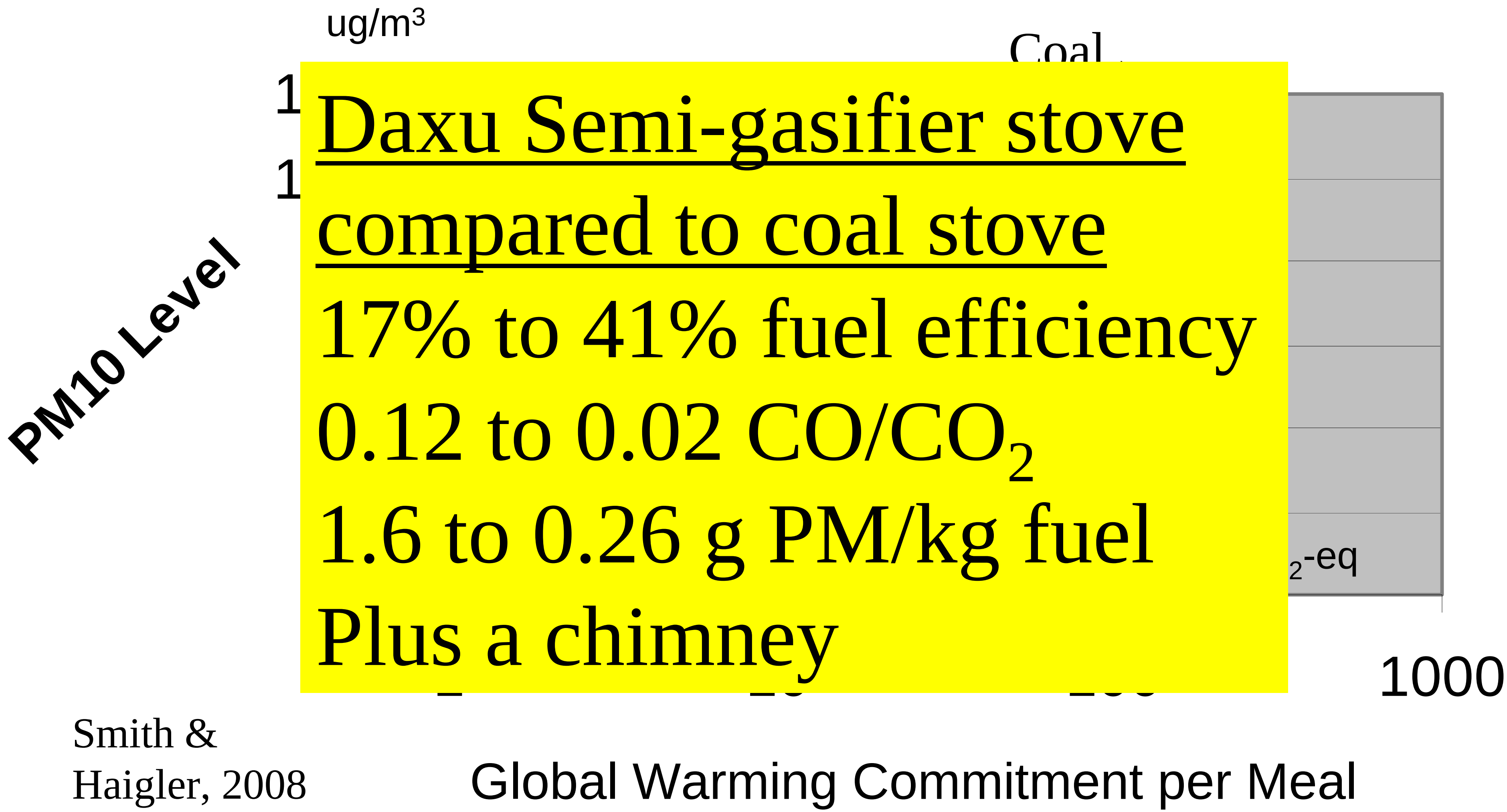
China National Stove Contest - 2007

	CO/CO2	Efficiency %	PM g/kg
Coal#	0.12	17.1	1.6
Traditional Biomass#	0.13	19.1	4.0
Biomass Stove Contest Winners			
Daxu	0.020	41.9	0.28
Luoyang	0.019	35.2*	0.24
Xintai	0.025	32.6*	0.36
Zhenghong	0.019	35.9	0.24

Zhang, et al., 2000

*Not including water heating function

Health and Greenhouse Gas Benefits of Biomass Stove Options



<u>Daxu Semi-gasifier stove compared to coal stove</u>

17% to 41% fuel efficiency

0.12 to 0.02 CO/CO_2

1.6 to 0.26 g PM/kg fuel

Plus a chimney

Smith & Haigler, 2008

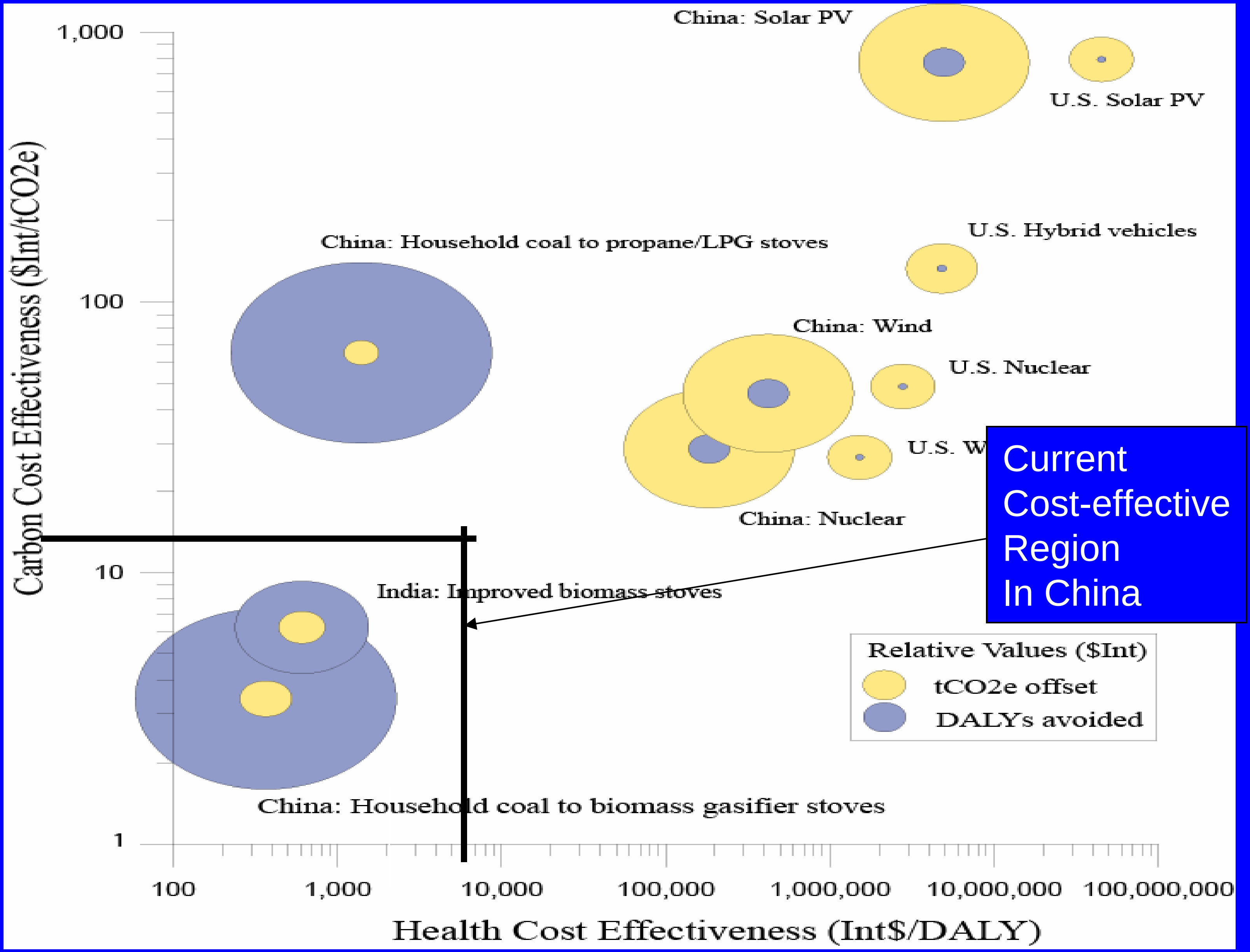
Exposure-Response Relationships in China: Global Comparative Risk Assessment

Table 2 Risks from outdoor and indoor air pollution with example from China. Disability-adjusted life years (DALYs)/exposure will be different in other countries because of different background disease risks. Sources: References 12 and 64

	Population	Exposure metric	Relative risk per unit	DALYs/exposure[a]	
Outdoor		1000 people		3% DALY	0% DALY
Cardiovascular	Adults >30	10 μg/m³ PM2.5	1.059	1.56E-01	3.1E-01
Lung cancer	Adults >30	10 μg/m³ PM2.5	1.082	2.26E-02	4.4E-02
Acute lower respiratory infections (ALRI)	Children <5	10 μg/m³ PM10	1.01	1.64E-02	3.8E-02
Indoor		Household (HH)			
Chronic obstructive pulmonary disease (COPD)	Adults >30	Solid fuel use	3.2	2.72E-02	5.4E-02
Lung cancer	Adults >30	Solid fuel use	1.9	1.00E-03	2.0E-03
ALRI	Children <5	Solid fuel use	2.3	1.48E-02	3.4E-02

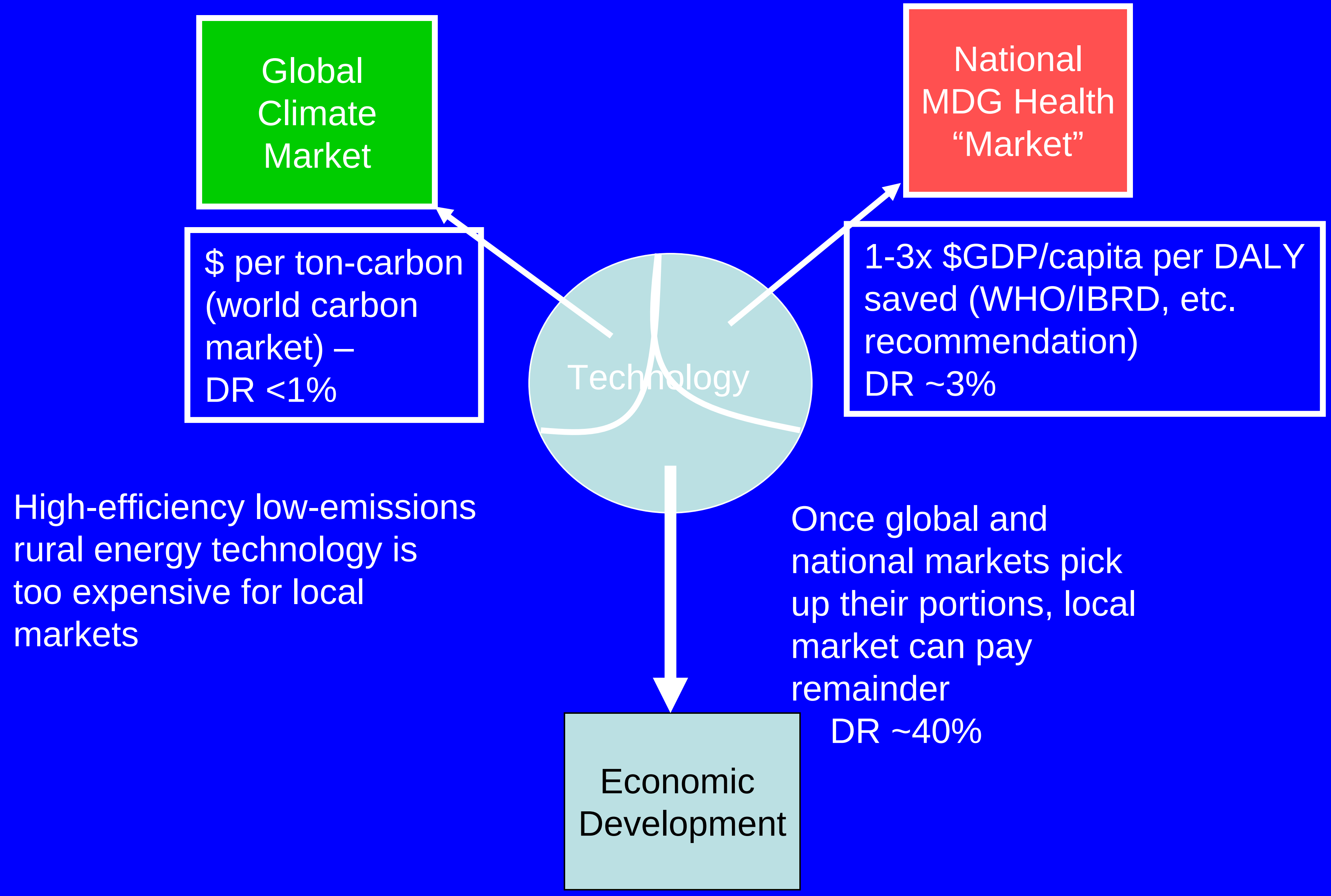
[a]These values would be different in other parts of the world. See References 17 and 55.

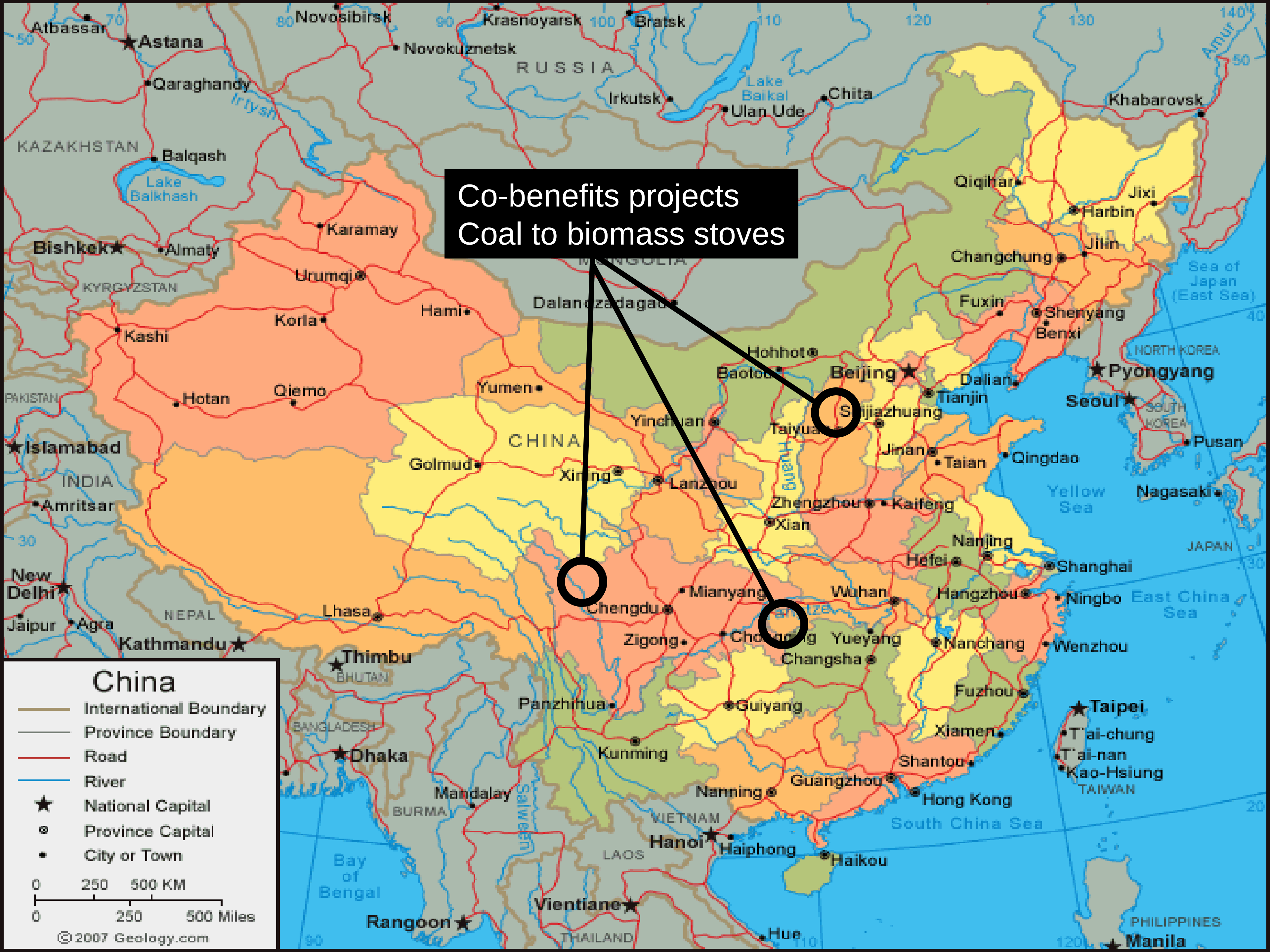
Smith and Haigler, 2008



Smith & Haigler, 2008

Paying for Rural Energy Development




Co-benefits projects
Coal to biomass stoves
China
International Boundary
Province Boundary
Road
River
National Capital
Province Capital
City or Town
0 250 500 KM
0 250 500 Miles
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Lake Baikal
Lake Balkhash
Irtysh
Amur
Huang
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Salween
Sea of Japan (East Sea)
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Jilin
Changchung
Fuxin
Shenyang
Benxi
Dalian
Pyongyang
Seoul
Pusan
Nagasaki

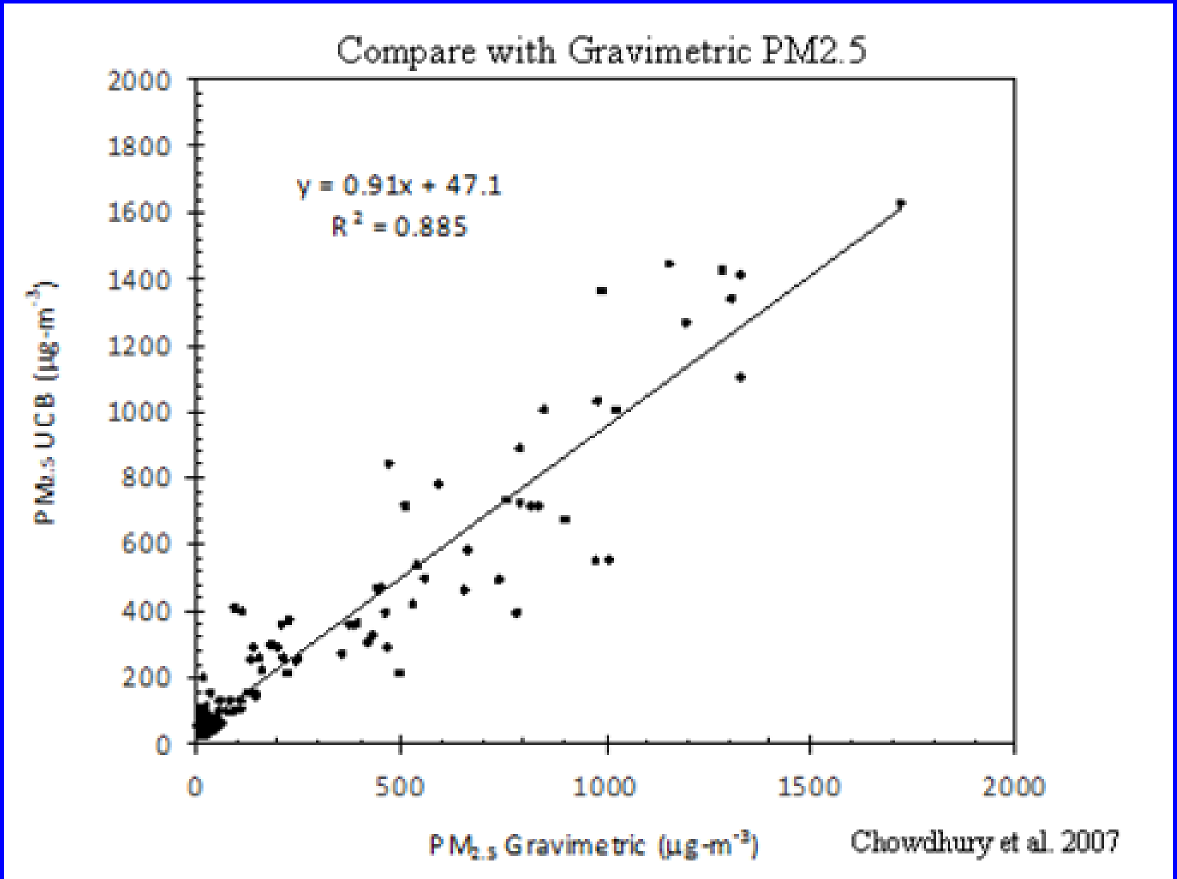
Monitoring Requirements

- Fuel Use and Savings
- GHG Emissions
- Air Pollution Exposures

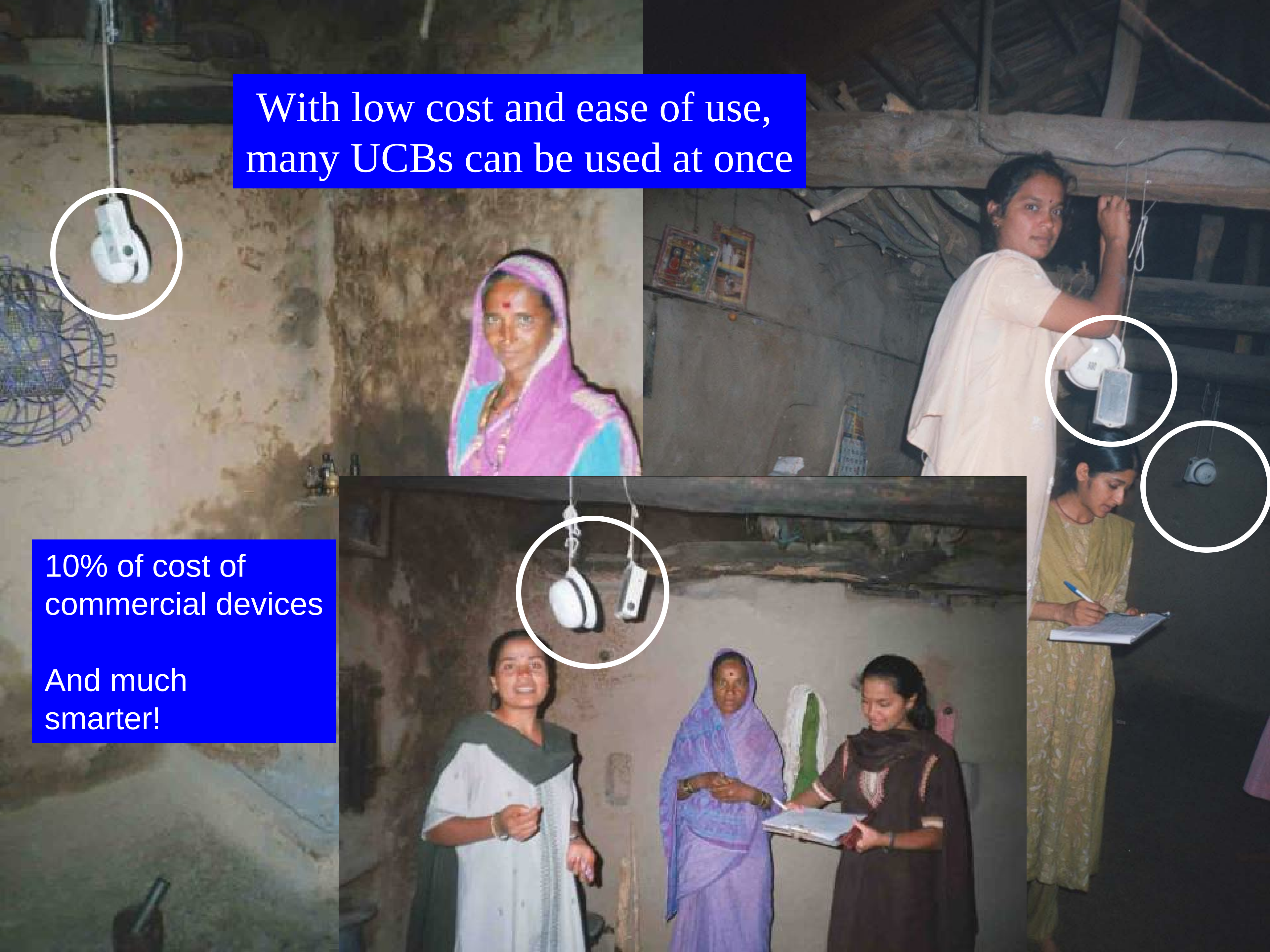
- You don't get
  what you expect,
  but what you inspect.

Monitoring: Indoor Air Pollution

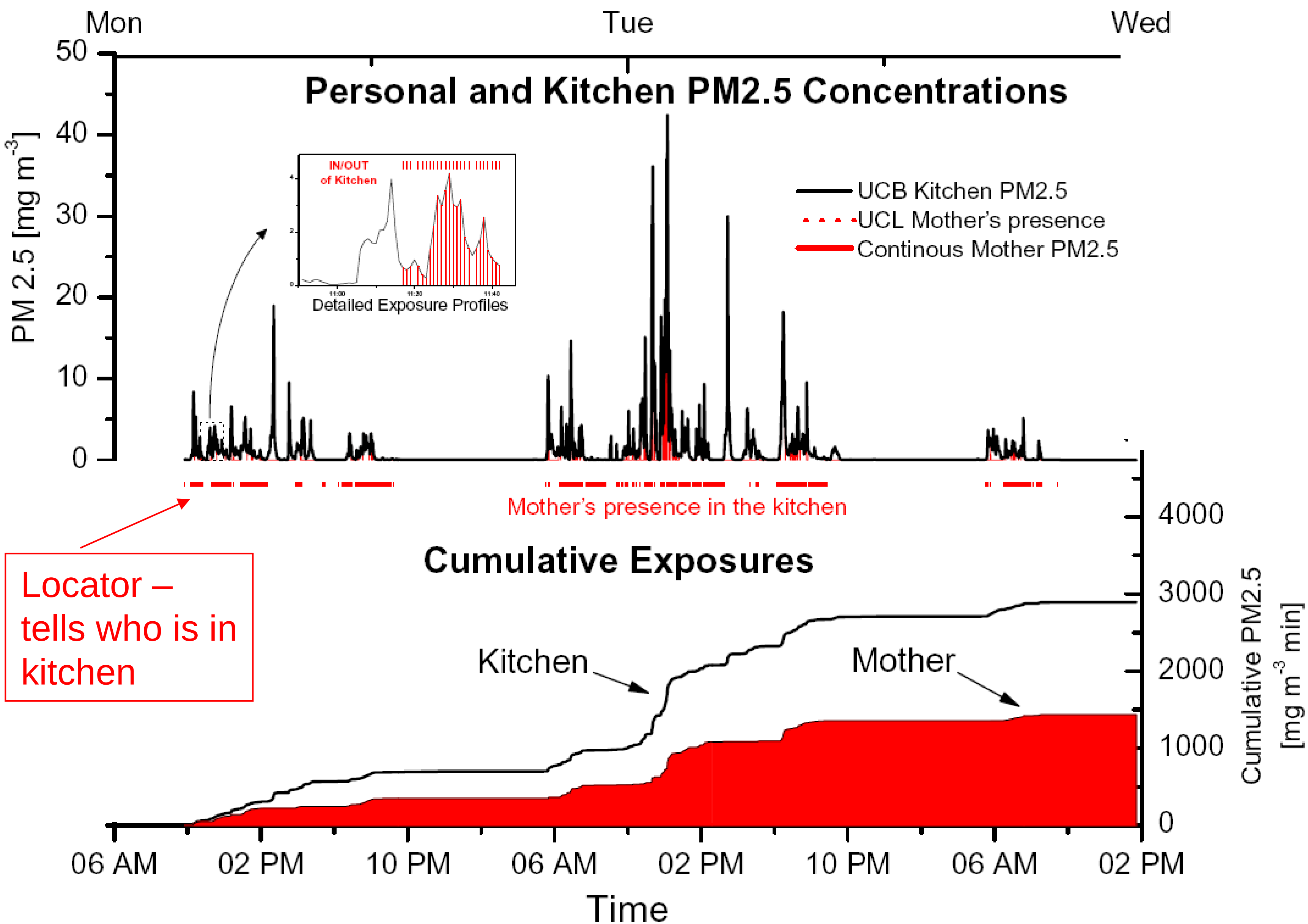
- $PM_{2.5}$: Pump/filter is standard method, but cumbersome, slow, and poor resolution
- Need new method: Small, smart, fast, and cheap
- UCB Monitor using smoke detector technology is an example



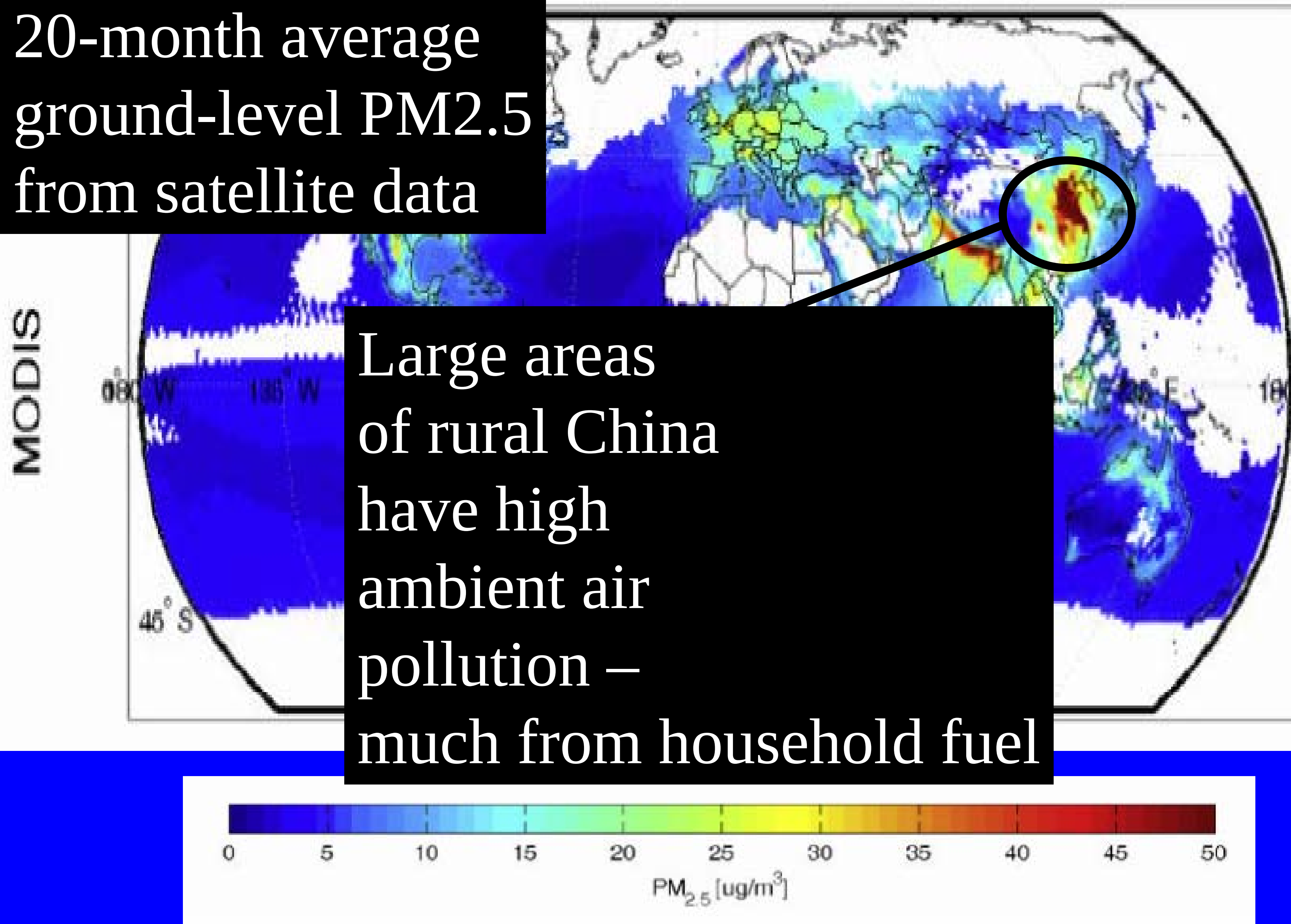
Source: Chowdhury, Z., R. D. Edwards, et al. (2007). "An inexpensive light-scattering particle monitor: field validation." Journal of Environmental Monitoring **9**(10): 1099-1106.


With low cost and ease of use,
many UCBs can be used at once
10% of cost of
commercial devices
And much
smarter!

Measuring Personal Exposure to PM2.5 from Woodsmoke with the UCB-Particle Monitor and the UCB-Personal Locator



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



Large areas of rural China have high ambient air pollution – much from household fuel

Conclusion

- Methane emissions are more important than current official weighting factors indicate because of its large effect over the next generation
- Contributes directly to global tropospheric ozone levels
- Methane is emitted as part of the poor combustion process of solid fuels: Chinese stoves produce ~2 MT of the 300 MT global human methane emissions.
- This incomplete combustion also produces much directly health-damaging pollution and wastes fuel
- Improving this combustion offers substantial GHG as well as health and other benefits in a cost-effective manner – using carbon offsets provides a mechanism
- Focuses on the poorest communities in the country

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