RURAL ENERGY IN CHINA:

Opportunities to Promote Health, Development, and Climate

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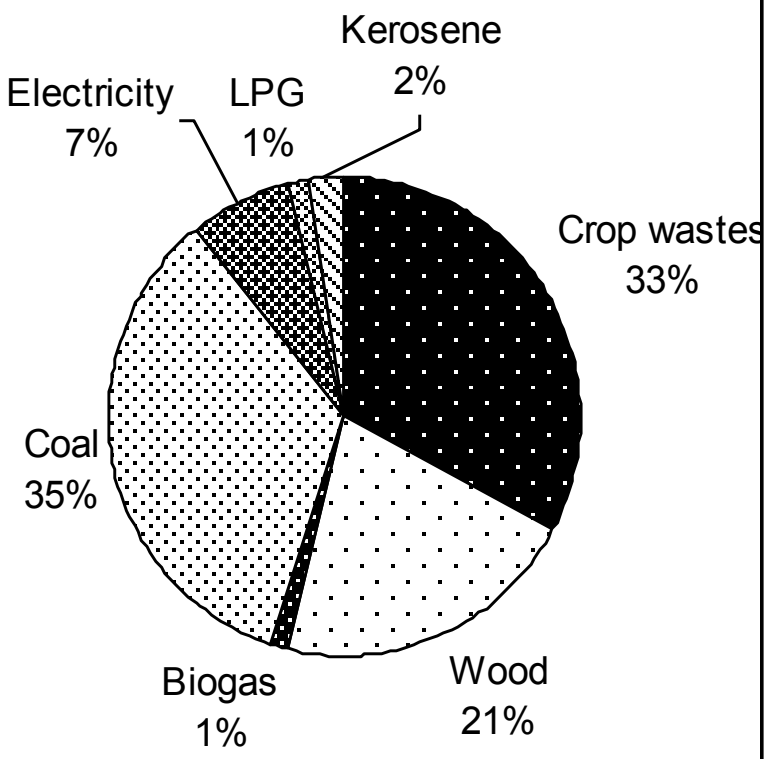
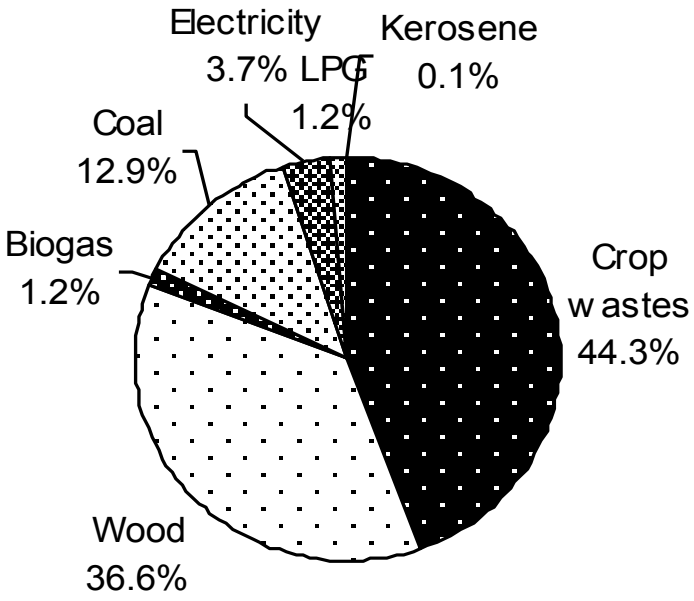
Rural Energy in China: 2004

Total



Ministry of Agriculture

Households

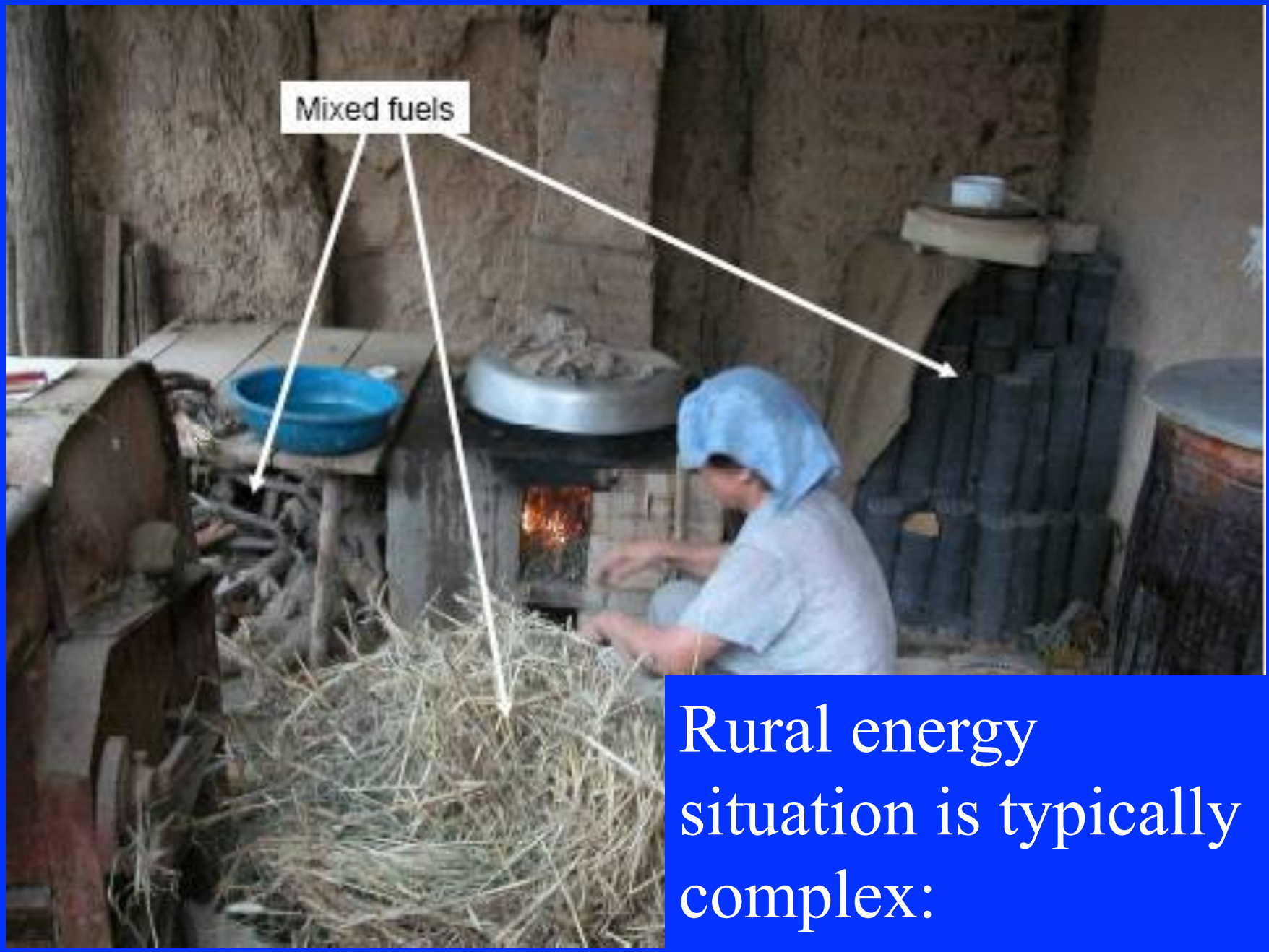


70% of total

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:

HOUSEHOLD SOLID FUEL COMBUSTION

- Why is there so much pollution?
- What are the major constituents of the smoke?
- What adverse health effects have been measured?
- What interventions have been evaluated?

Woodsmoke is natural – how can it hurt you?

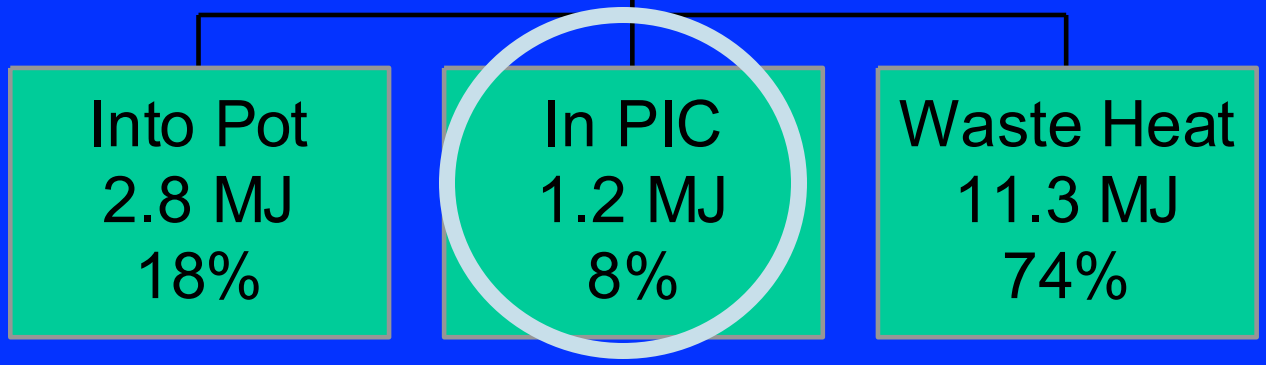
Or, since wood is mainly just carbon, hydrogen, and oxygen, doesn't it just change to CO_2 and H_2O when it is combined with oxygen (burned)?

Reason: the combustion efficiency is far less than 100%

Energy flows in a well-operating traditional wood-fired Chinese cooking stove

A Toxic Waste Factory!!

Typical biomass cookstoves convert 6-30% of the fuel carbon to toxic substances



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

Source: Zhang, 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

Hazardous Chemicals Identified in Biomass and Coal Smoke

- **Carcinogens/mutagens**: benzene, *1,3*-butidiene, styrene, PAHs, methylated or alkylated PAHs, nitrogen-containing heterocyclic aromatic compounds, etc.
- **Irritants**: formaldehyde, acrolein, etc.
- **Emissions from "poisonous" coal**: sulfur (S), nickel (Ni), chromium (Cr), micro fibrous quartz and silica, arsenic (As), fluorine (F), selenium (Se), mercury (Hg), lead (Pb)

Pollution and health effects of indoor coal smoke exposure*

- Lung cancer
- Respiratory illnesses
- Lung function impairment
- Immune system weakening
- CO poisoning
- Endemic arsenism and fluorosis

*120+ publications from studies conducted in China

China:

Interpretation:
Women who live in households using coal have about 2 times more lung cancer compared to those living with other fuels

[illegible]	[illegible]	-2.46)
Women	1.17 (1.02-1.35)	1.94 (1.09-3.47)
Combined	1.86 (1.48-2.35)	2.55 (1.58-4.10)

*Adjusted for smoking and chronic respiratory disease.

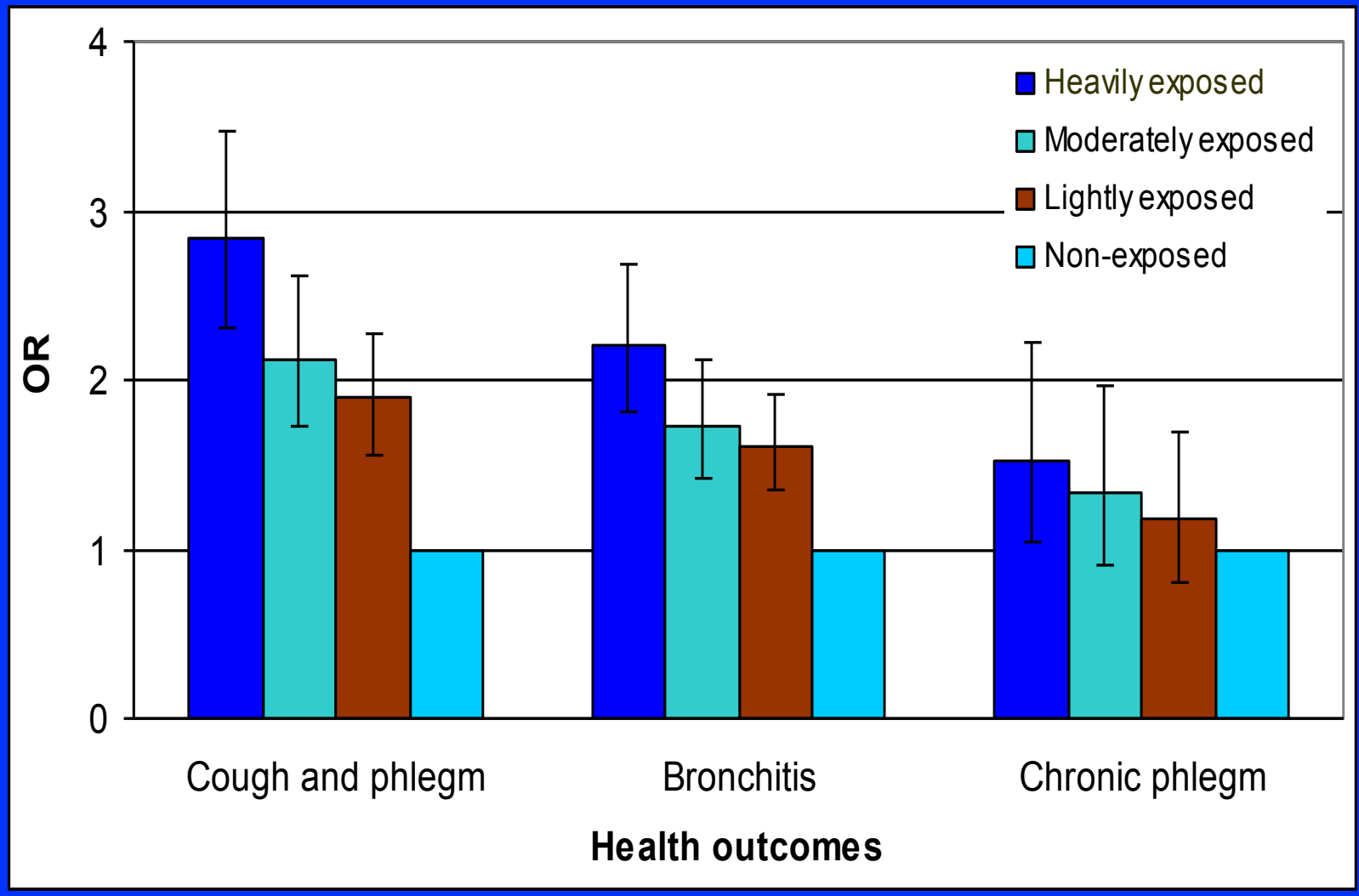
(Smith et al. 2004)

Children's Respiratory Illness (Salo et al. 2004, Zheng et al. 2002)

Odds Ratios	Coal for cooking/ heating	Coal for heating	Coal for cooking w/o vent
Wheezing w/ colds	1.57 (1.07-2.29)		
Wheezing w/o cold	1.44 (1.05-1.97)		
Asthma		1.5 (1.1-1.9)	2.3 (1.5-3.5)

Other illnesses reported include: rhinitis, faucitis, tonsillitis, and pneumonia (Cheng et al. 2002, Zhou et al. 1994).

Lifetime exposure to heating coal smoke and health outcomes children (Qian and Zhang et al, 2004)



n = 7,058 school children in four Chinese cities.

Adults' Respiratory Illnesses
(Zhou et al. 1995)

Odds Ratios	"Smoky" coal vs. "smokeless" coal	"Smokeless" coal vs. wood
Shortness of breath	1.73	
Cough	3.30	1.35
Phlegm	4.23	1.67

*Coal and passive smoking together increase prevalence rates of chest illness, cough, phlegm, and shortness of breath in women (Pope and Xu 1993).

CO Poisoning

- Acute CO poisoning including fatal cases
- CO is known neurotoxin
- Pre-natal and early post-natal mortality (from mother's exposure during pregnancy)
- Low growth in children (from mother's exposure during pregnancy)

Endemic Arsenism and Fluorosis

(Jin et al. 2003, He et al. 2005, Shraim et al. 200, Finkelman et al. 1999, Yan 1990, Wu and Li 1990, Watanable et al. 1997)

- Burning arsenic contaminated coals occurs in Guizhou and Shaanxi Provinces, affecting some 300,000 people.
- Use of high-fluorine coals and/or clay binders results in dental and skeletal fluorosis, affecting >10 million people in Guizhou Province and surrounding areas.

Health Effects of Indoor Biomass Combustion*

Use of biomass fuels in households increases risk of

- Chronic Obstructive Pulmonary Disease in adult women by a factor of 3.2 (95% CI: 2.3-4.8) .
- Pneumonia in children under 5 years old by a factor of 2.0 (95% CI: 1.7-2.5).

***Review of many dozen studies worldwide by World Health Organization (WHO, 2002,2004)**

Health Benefits of Fuel/stove Intervention

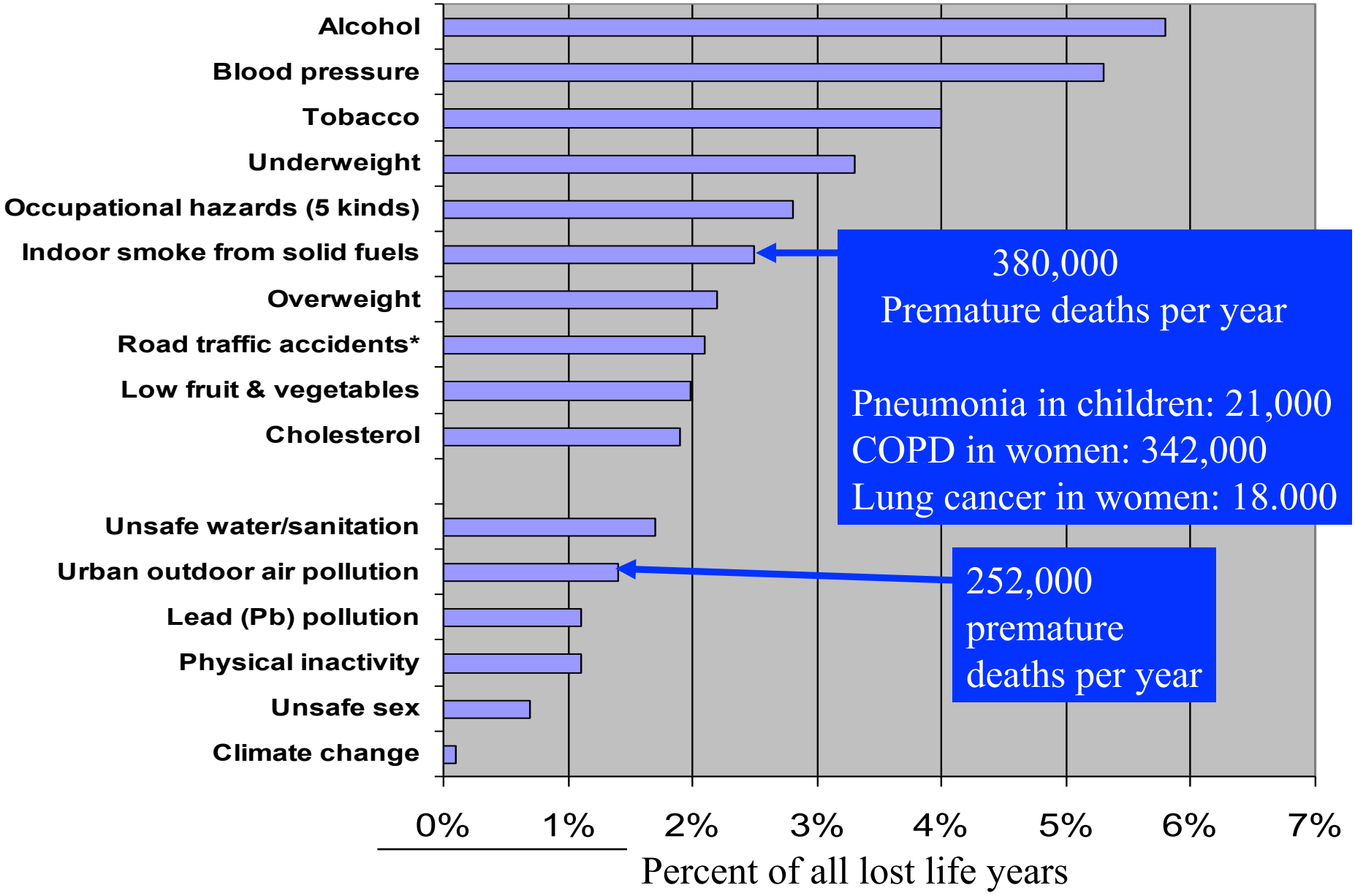
Best published studies in the world were done by examining introduction of improved coal stoves in China

Improved Stoves Brought to Xuanwei County in early 1980s

- The reduction in particle levels was ~a factor of about three.
- Reduction in lung cancer was ~40% in men and ~45% in women. (*Journal of the National Cancer Institute)*
- Reduction in COPD rates was also significant at about 50% in both men and women (*British Medical Journal*)
- Reduction in lung cancer and COPD took 10 years to fully develop after IAQ improvement.

Chinese Burden of Disease from Top 10 Risk Factors

Plus Selected Other Risk Factors



Diseases for which we have epidemiological studies

ALRI/ Pneumonia (meningitis)

Asthma

Low birth weight & stillbirth

Early infant death

Cognitive Effects?

Chronic obstructive lung disease

Interstitial LD

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

Blindness (cataract trachoma)

Tuberculosis

Heart disease

Conclusions: Health

- Household solid fuel combustion leads to high pollutant levels, from both coal and biomass

- Although some improvement has occurred, this pollution still contributes significantly to the national burden of ill health
  - hundreds of thousands of premature deaths annually
  - equal to or greater than that from outdoor air pollution

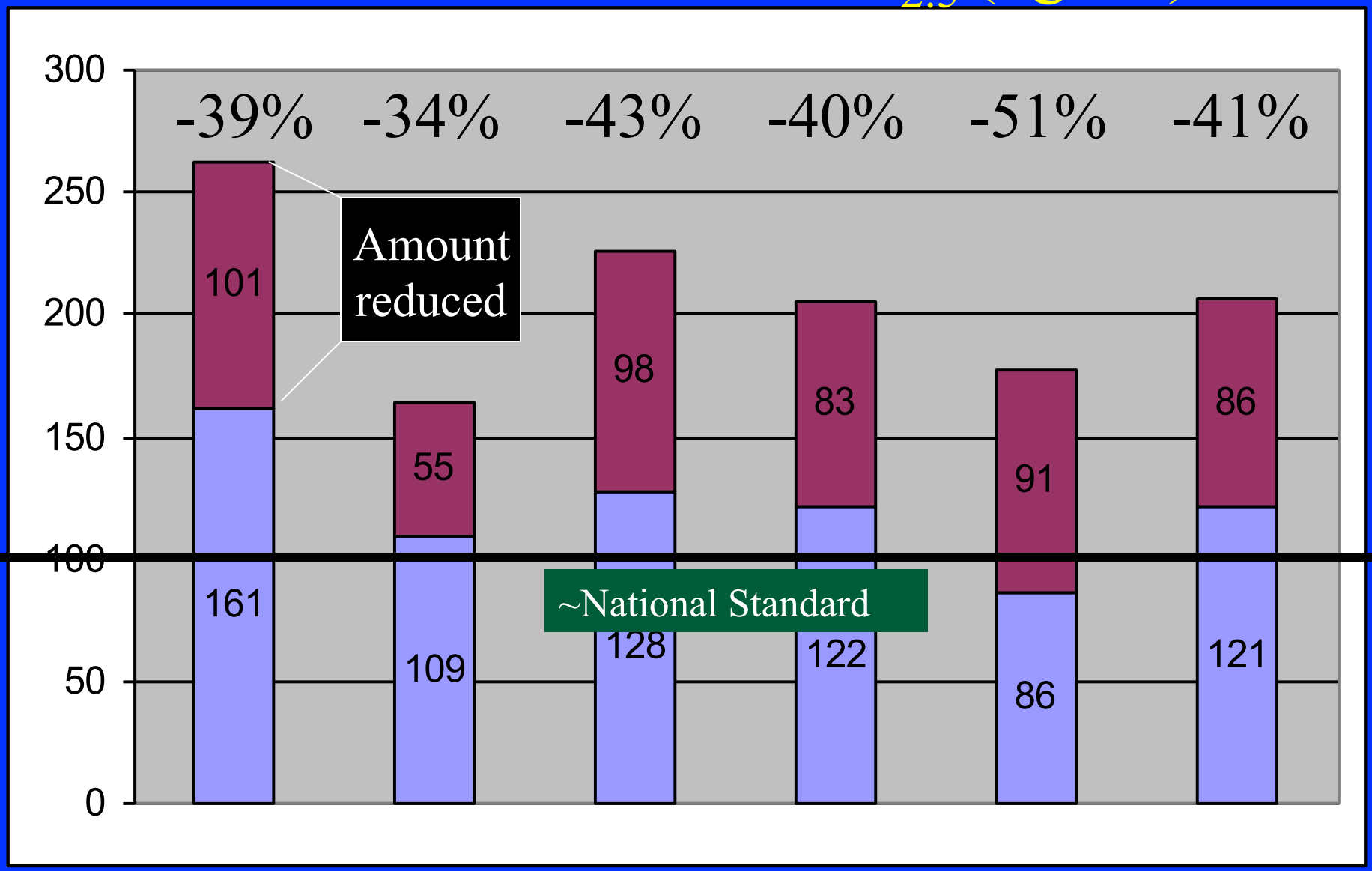
- Evidence for many adverse health outcomes resulting from smoke exposure is strong worldwide, including lung cancer, respiratory symptoms and diseases, pneumonia, and COPD.

- Although much work has been done in China on lung cancer, there is need for additional work on the range of other diseases to be able to confidentially apply information from other countries

Air pollution measurement studies of Chinese Stove Improvements Only 3 done, all since 2000

- Review of National Improved Stove Program: ~ 400 households in 3 provinces
- World Bank Study: ~460 households in 4 provinces
- Sino-Dutch Study: 140 households in 3 provinces

Reduction in 24-h $PM_{2.5}$ (ug/m^3)



Coal stoves

A Chinese Biomass Gasifier Stove

Tests show PIC emissions nearly at LPG levels.

Winner of Chinese national contest announced March 2007 for best stove meeting emissions and reliability criteria:
cost 300Y

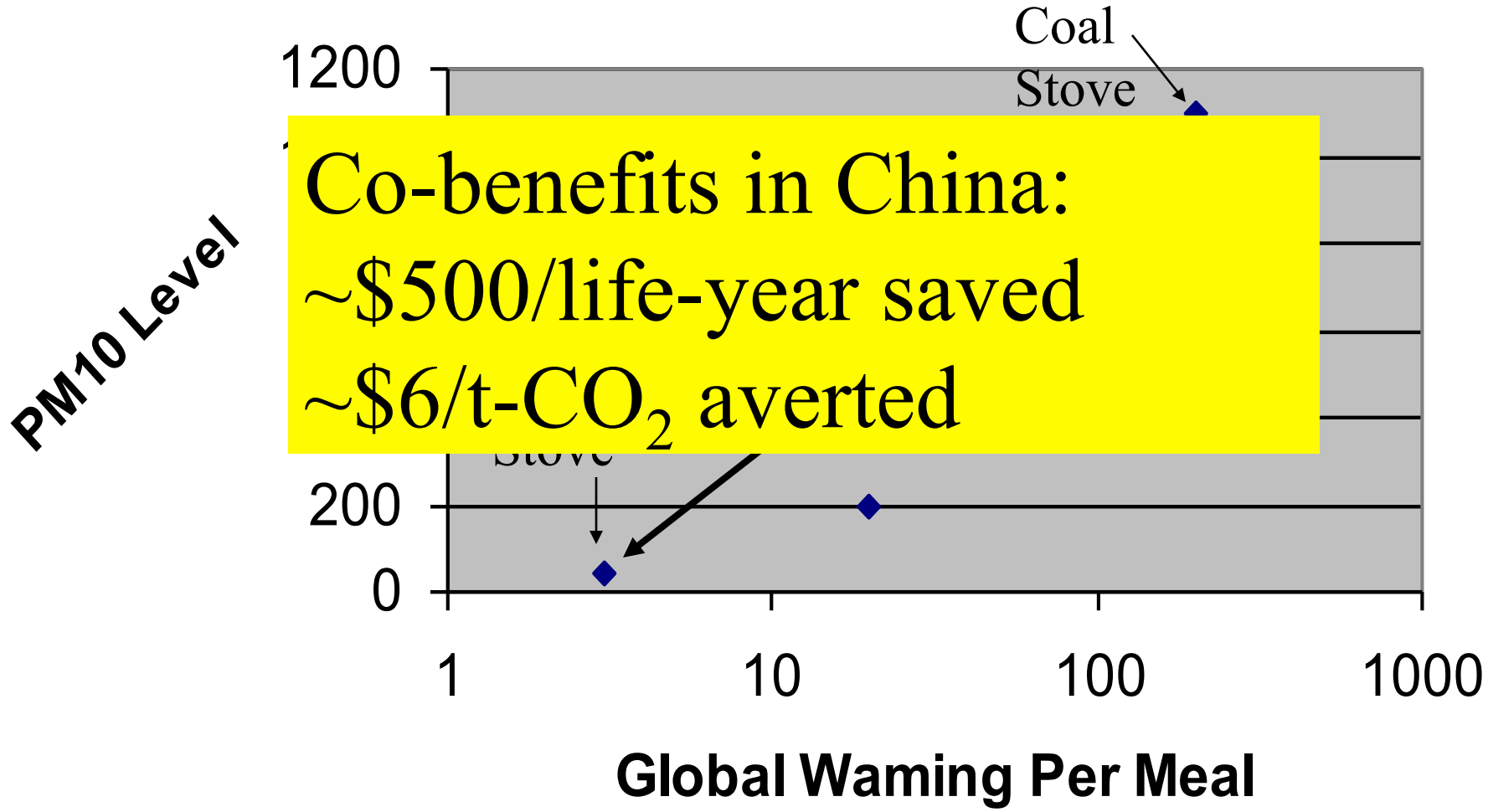
Consider the substitution of coal stoves in rural China with advanced biomass gasifier stoves, now commercially available in several provinces

- 300Y retail cost/stove + 50% program cost
- 50% of performance in lab
- Typical household fuel use
- Kyoto greenhouse gases only
- Financial calculations as in CDM requirements
- Health calculations based on Chinese data using WHO methods

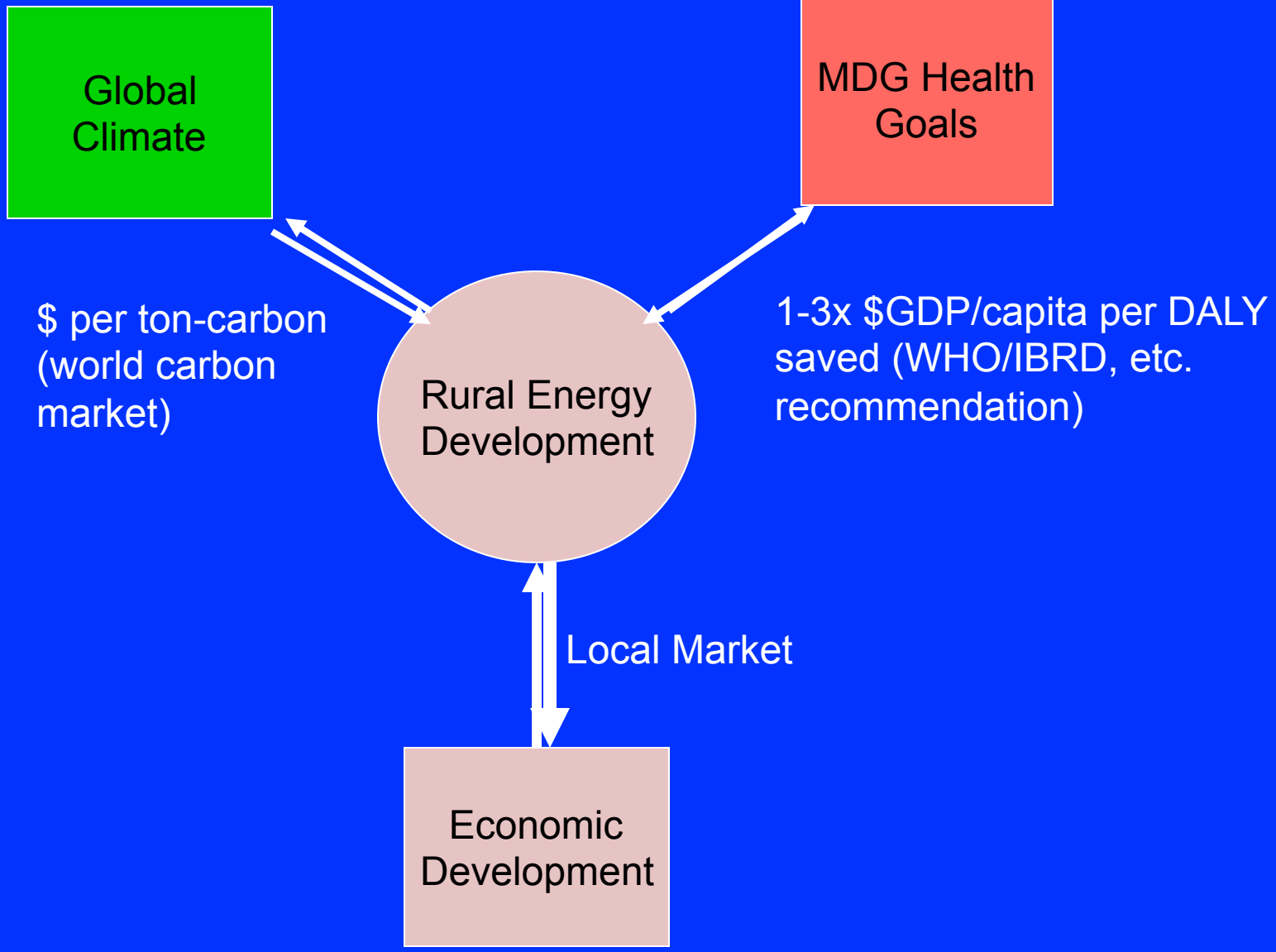
Results of Calculations

- Cost per saved lost life year: $480
  - WHO/World Bank recommend that China spend up to GDP/capita per lost life year saved, $1500 in 2004.
- Cost per ton CO_2: $5.64
  - Current price on international exchange 18€
- Value of benefits from stove (discounted)
  - $430, 79% from health benefits
- Benefit cost ratio based on present value calculations: 8

Health and Greenhouse Gas Benefits of Biomass Stove Options



Rural Energy is Linked to Three Major Sectors ED?

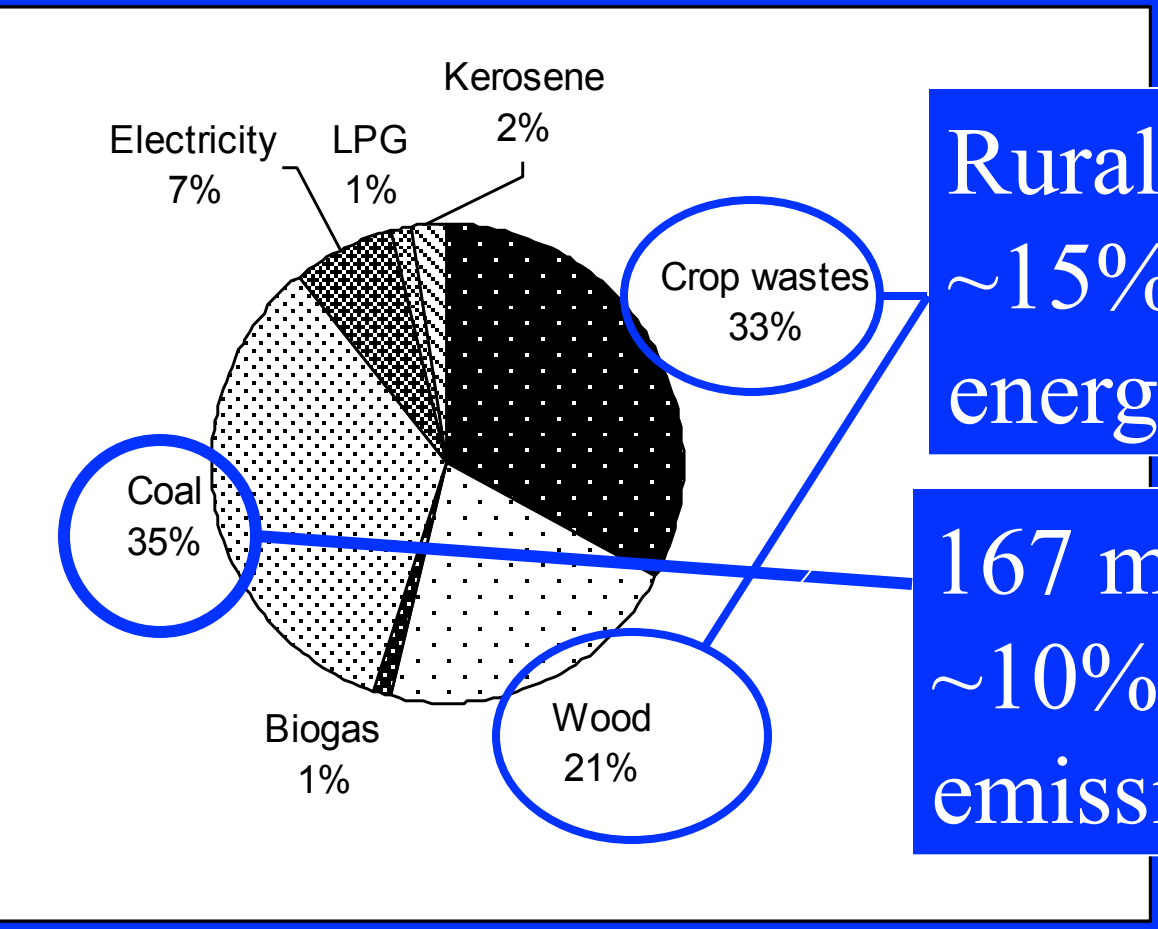


Conclusions: Intervention.

- Improved stoves can lower pollution levels substantially, with 40-50% reduction documented
- Reductions in exposures through simple improvements, such as chimney stoves, are intrinsically limited because smoke from the solid fuel is still around the household.
- Future improvements should focus on stoves and fuels that reduce emissions, such as the biomass gasifier stoves being developed in the country.
- Possible to link with international funding for greenhouse gas reductions.
- Substituting cleaner fuels for the poisonous coals used in tens of millions of households should have an especially high priority.

Rural Energy in China: 2004

Total



Rural biomass ~15% of all Chinese energy use

167 million tons ~10% Chinese CO_2 emissions

Ministry of Agriculture

China's Rural Development

- China now has the largest income inequity in Asia,
  - a ratio approaching 20 between the income of the richest 10% and the poorest 10% (UNDP data)
  - Japan: 5; India: 7; the Philippines: 16
- This is a direct indication of the rural-urban gap in the country
- Closing this gap is vital to achieving a Harmonious Society in China

Rural Energy as Necessary Condition to Improving Rural Life

- Reliable, efficient, affordable energy needed for rural economic development
- Increasing economic prospects and quality of life in rural areas
  - Reducing inequity
  - Slowing urbanization
- Possible to reduce pressure on fossil fuel resources, both coal and petroleum by use of local renewable resources
- Improve health cost-effectively
- Reduce greenhouse-gas emissions cost-effectively

After independence, China had special concerns for rural areas than were reflected in energy programs for decades

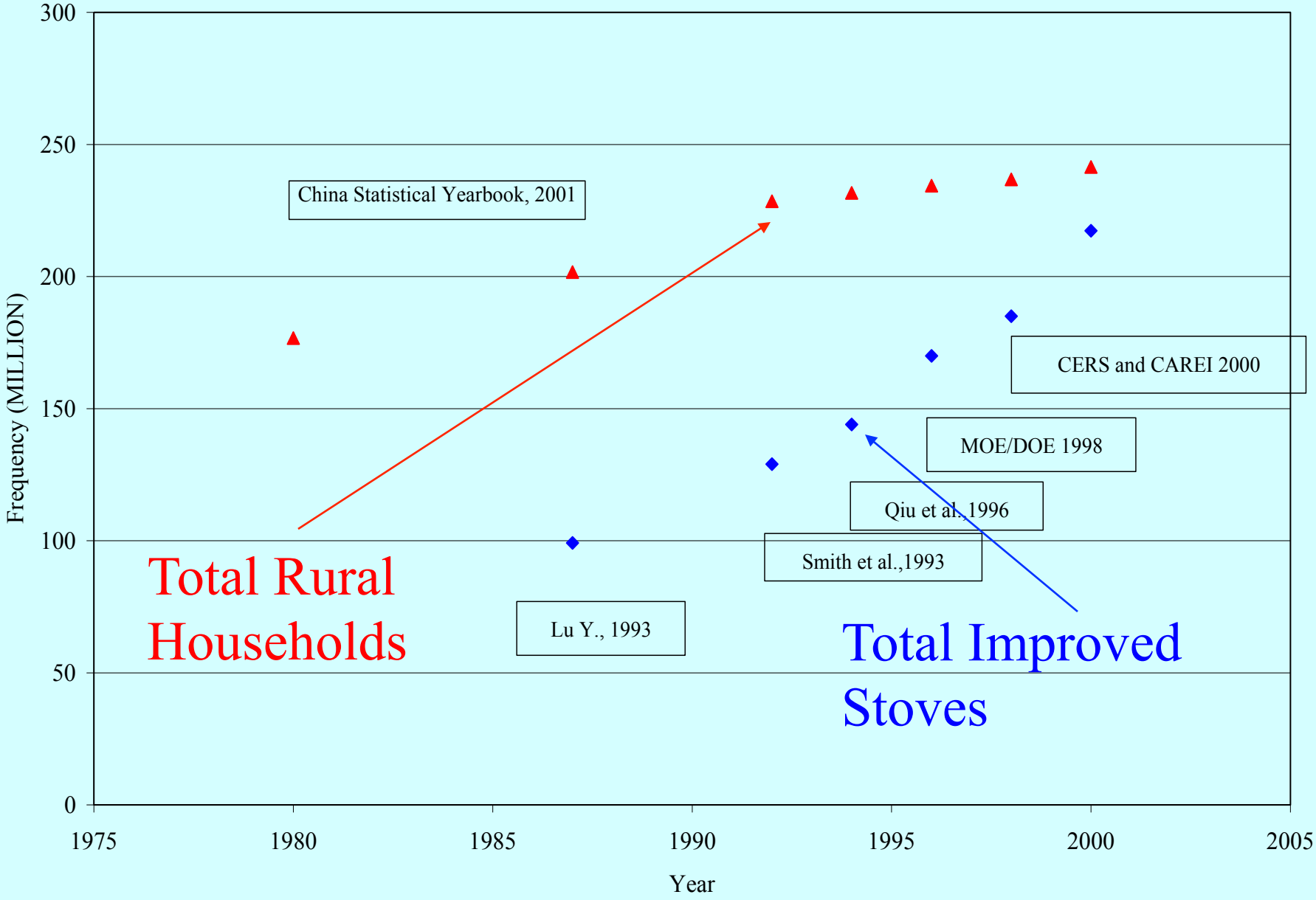
- China led the world in rural energy development in the 1970s and 80s
- It introduced >180 million improved biomass stoves, for example – one of the largest rural development projects in world history

China's National Improved Stove Program (NISP)

- More than 180 million improved stoves with chimneys were introduced from early 80s to mid 90s
- Evaluation showed that NISP improved energy efficiency and IAQ in rural households, but not sufficiently to meet current Chinese air pollution standards.
- It focused on biomass; the rising coal use in rural areas is threatening to erode the benefits unless action is taken soon. This is particularly a problem in the areas of "poisonous coals".

Improved Stove in Shanxi

China's National Improved Stove Program (NISP) 1981-1998



Origins of the Chinese Rural Energy Program

At a biogas stove exhibit in Wuhan on April 11, 1958, Mao Zhedong instructed,

"This should be well promoted."

1958年4月11日毛主席视察武汉地方工业展览馆观看沼气灶演示，指示"这要好好地推广"

Being demonstrated of biogas stove on Wuhan local industry exhibition on April 11, 1958, Chairman Mao Zhedong instructed " This should be well promoted"

Today, to help achieve China’ Harmonious Society, a new round of rural energy development is required:

- Electrification
- Energy for industry
- Improved household fuels
- All with
  - Advanced technology
  - Recognition of health benefits
  - Tapping global resources for climate mitigation
  - More use of the market

This review based on the article being published in the English and Chinese editions of the journal:

Environmental Health Perspectives Vol. 115 #6, June 2007

Zhang J & Smith KR, "Household Air Pollution from Coal and Biomass Fuels in China: Measurements, Health Impacts, and Interventions."

Thank You