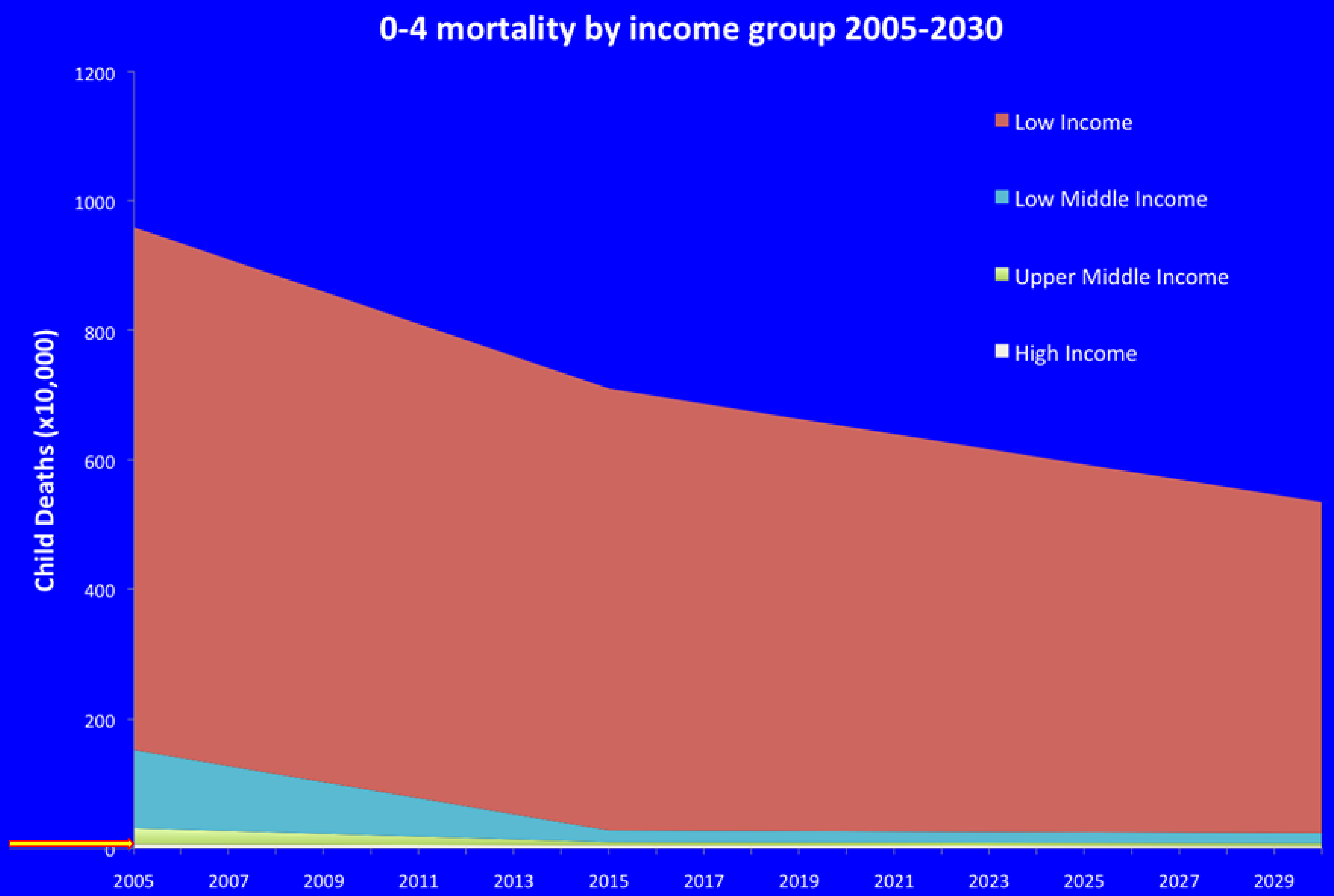
Indoor Air Pollution and Child Health
What do we know, what should we know and what are some of the systems relationships?

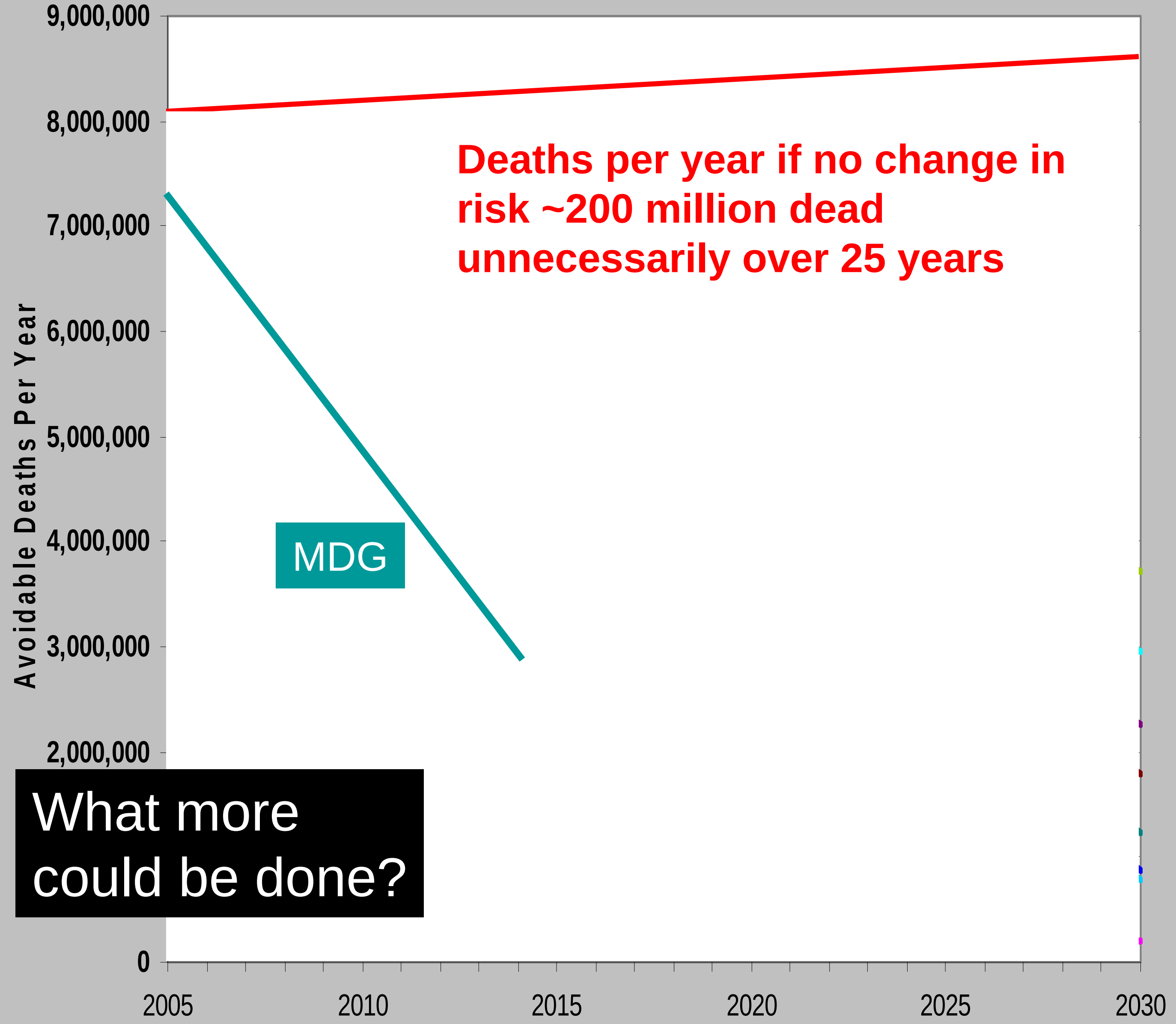
Kirk R. Smith, PhD, MPH
Professor of Global Environmental Health
University of California, Berkeley

NICHD/NIEHS, Bethesda
September 26, 2008


0-4 mortality by income group 2005-2030
Child Deaths (x10,000)
1200
1000
800
600
400
200
0
2005
2007
2009
2011
2013
2015
2017
2019
2021
2023
2025
2027
2029
Low Income
Low Middle Income
Upper Middle Income
High Income

Child Mortality Wedges: 2005-2030

Children in the poorest nations with 2.7 billion people: <$750/year-person (WHO databases)



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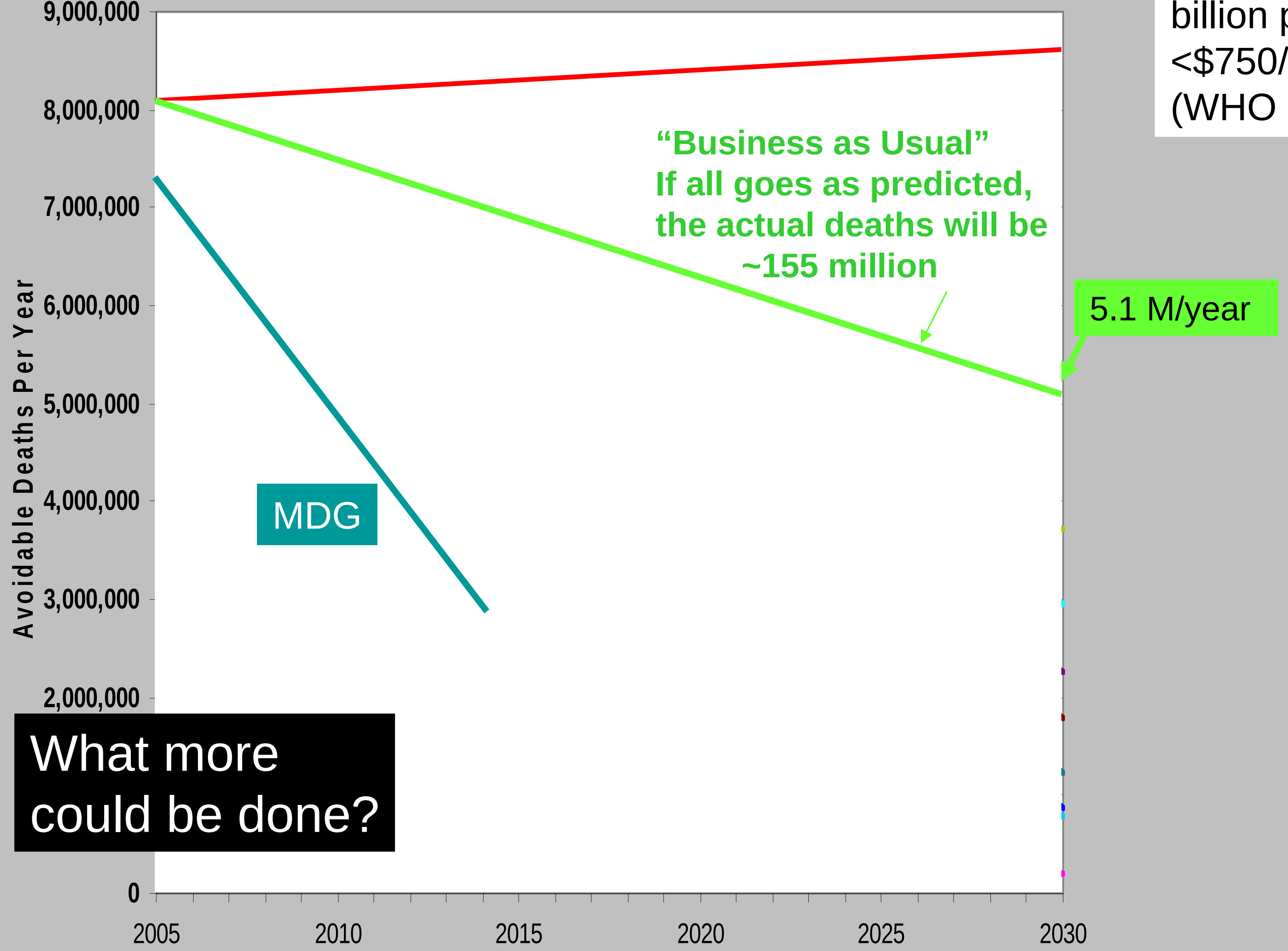

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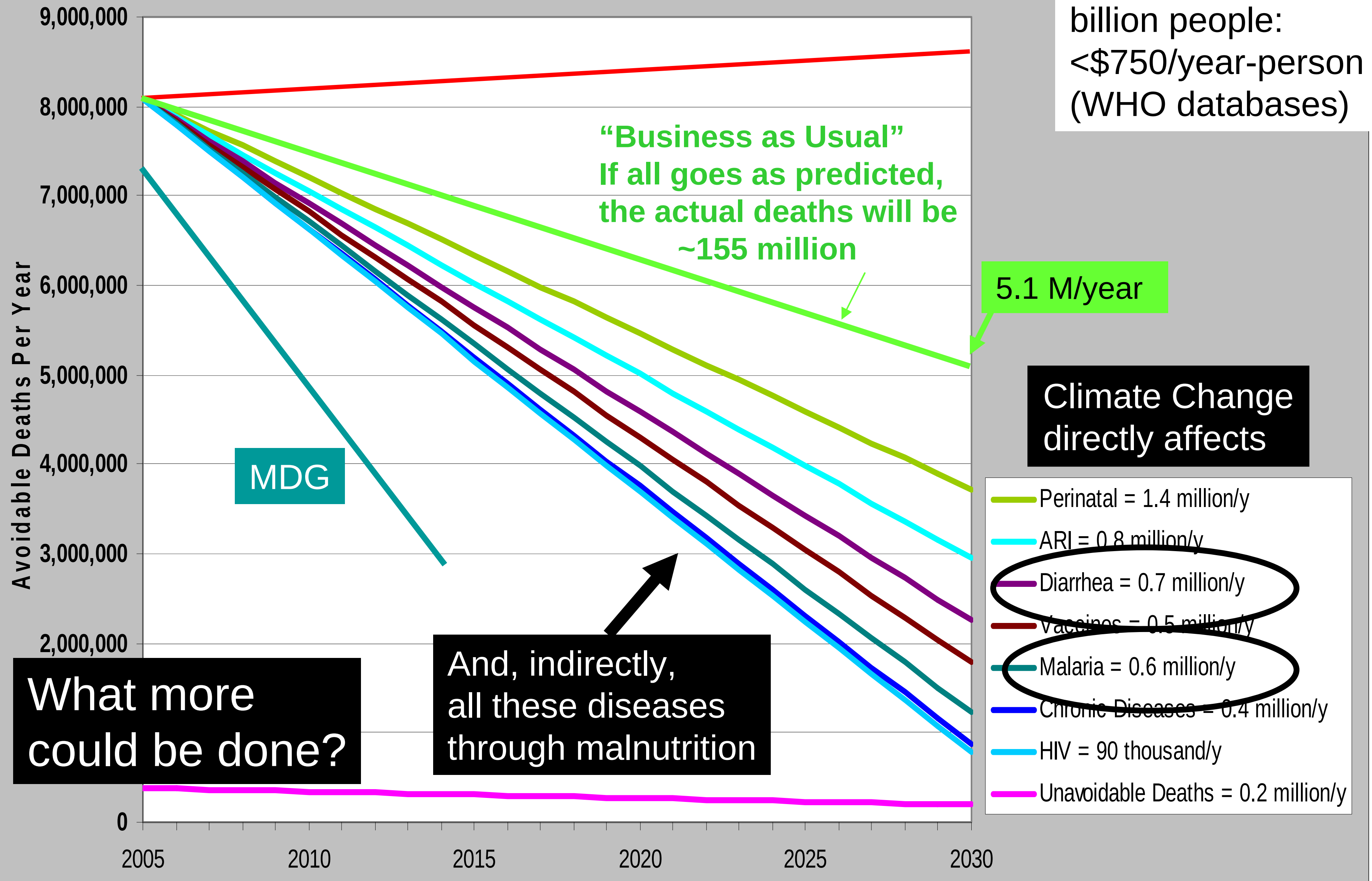

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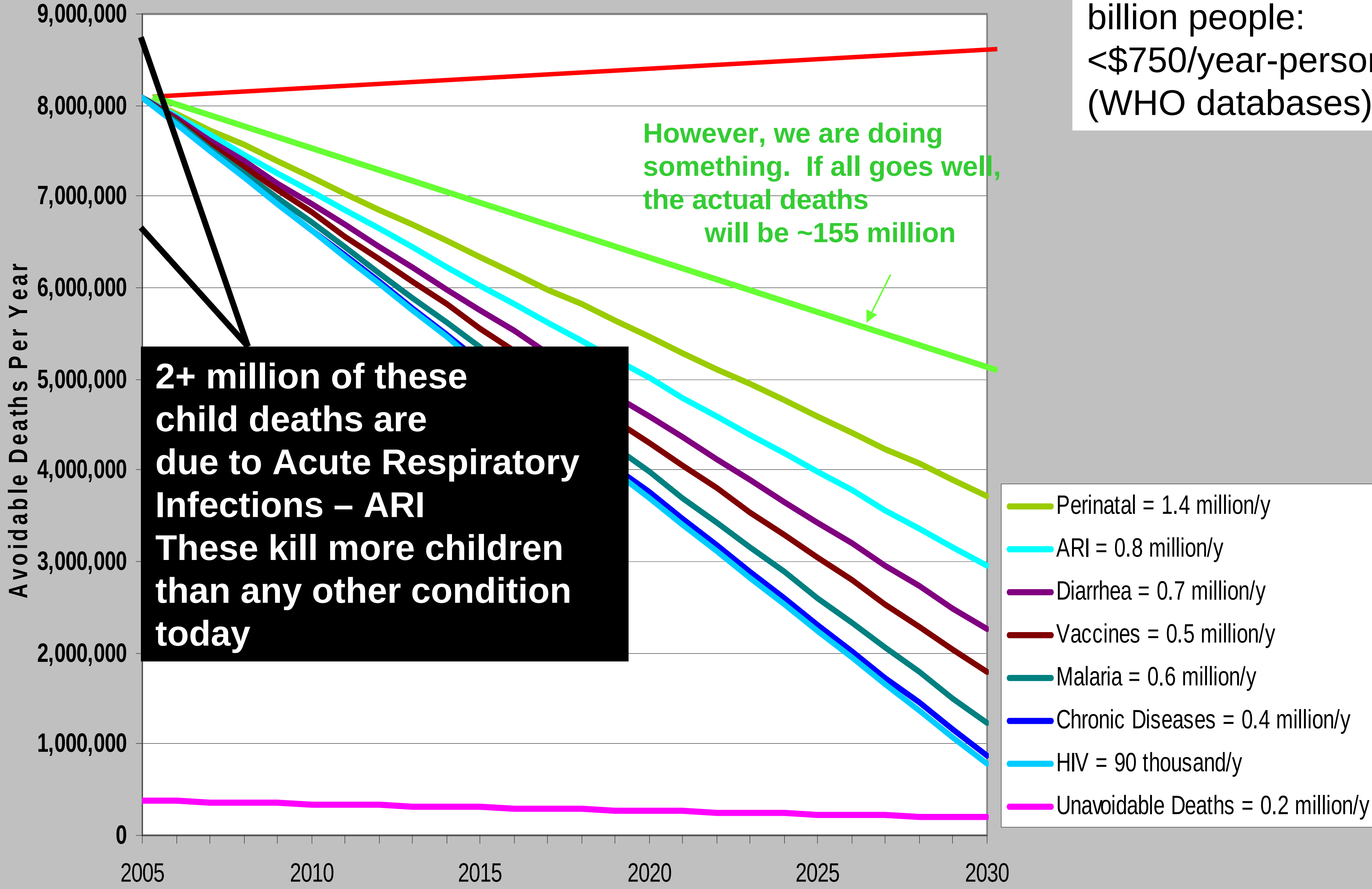

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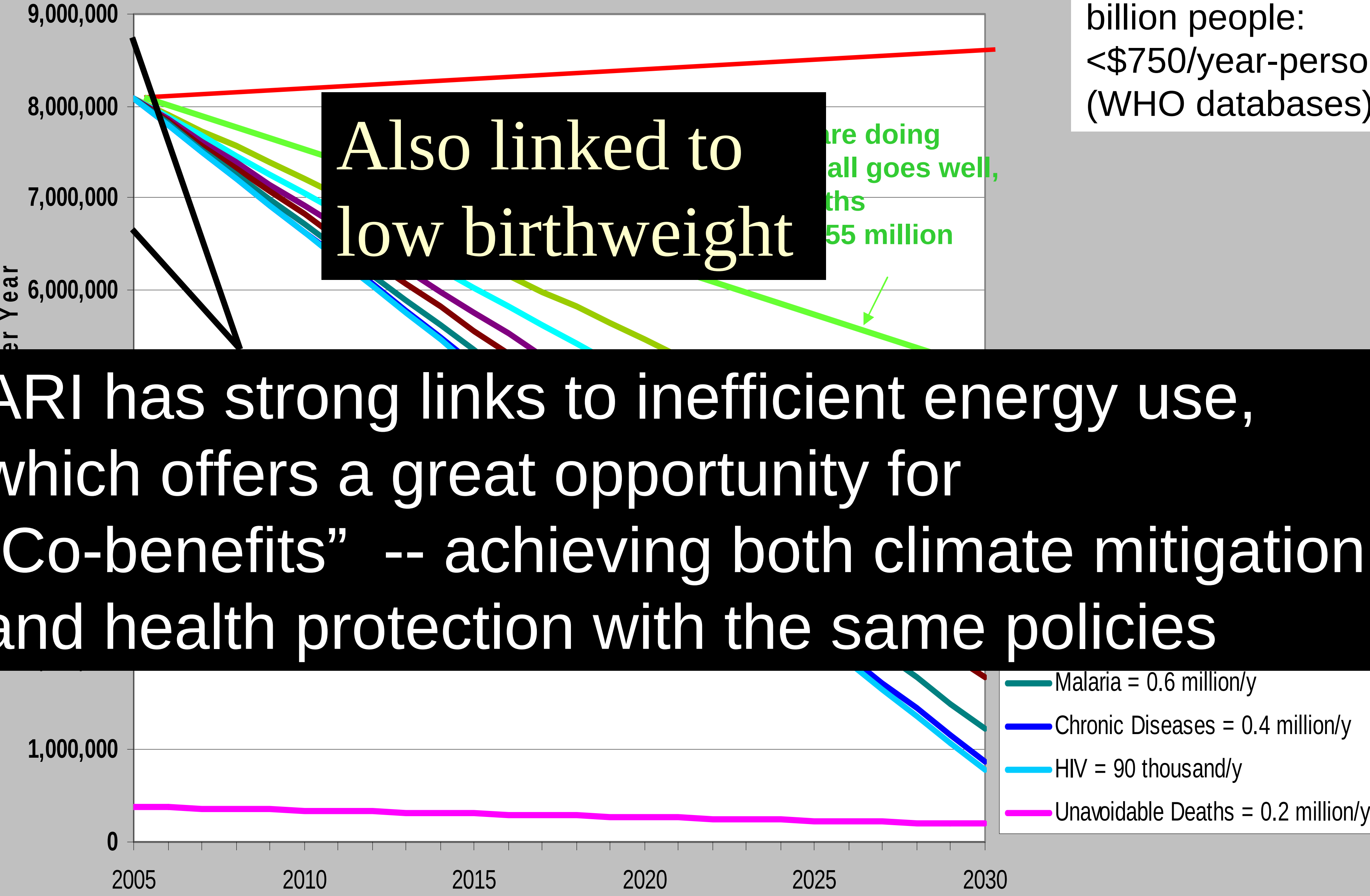
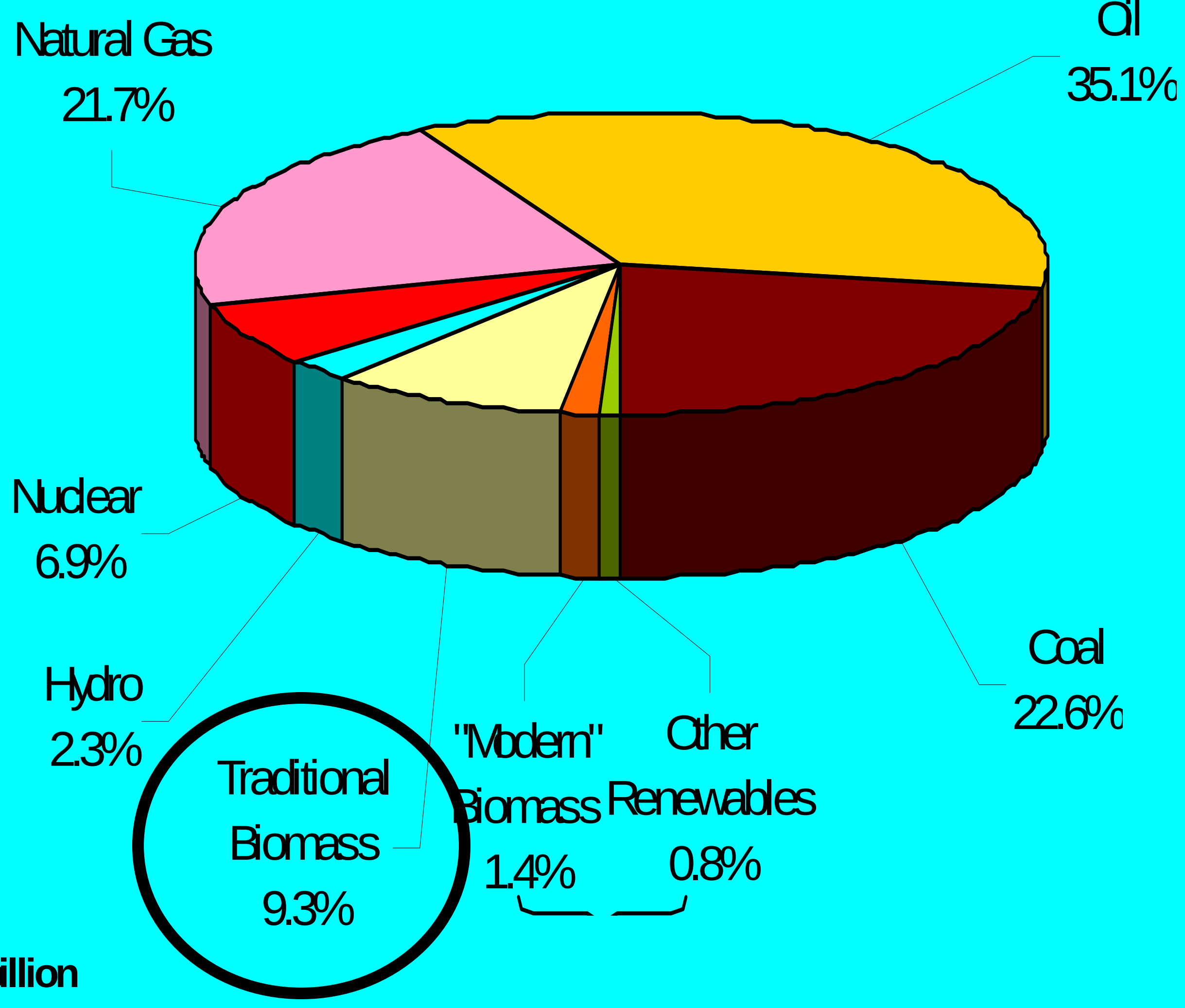


Also linked to low birthweight

ARI has strong links to inefficient energy use, which offers a great opportunity for "Co-benefits" -- achieving both climate mitigation and health protection with the same policies

World Energy – 2001



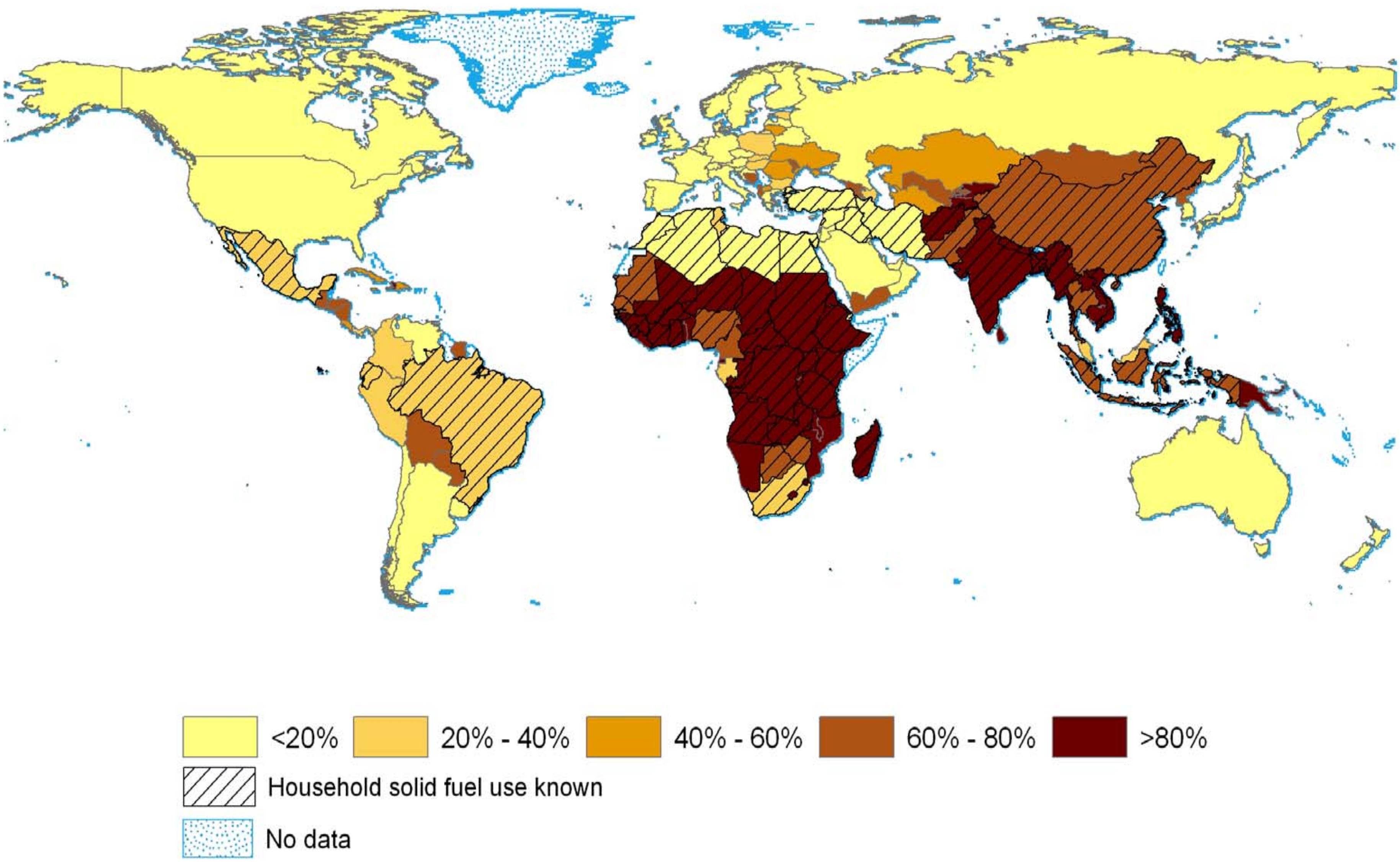
Population: 6.102 billion

Total energy use: 10.2 Gtoe

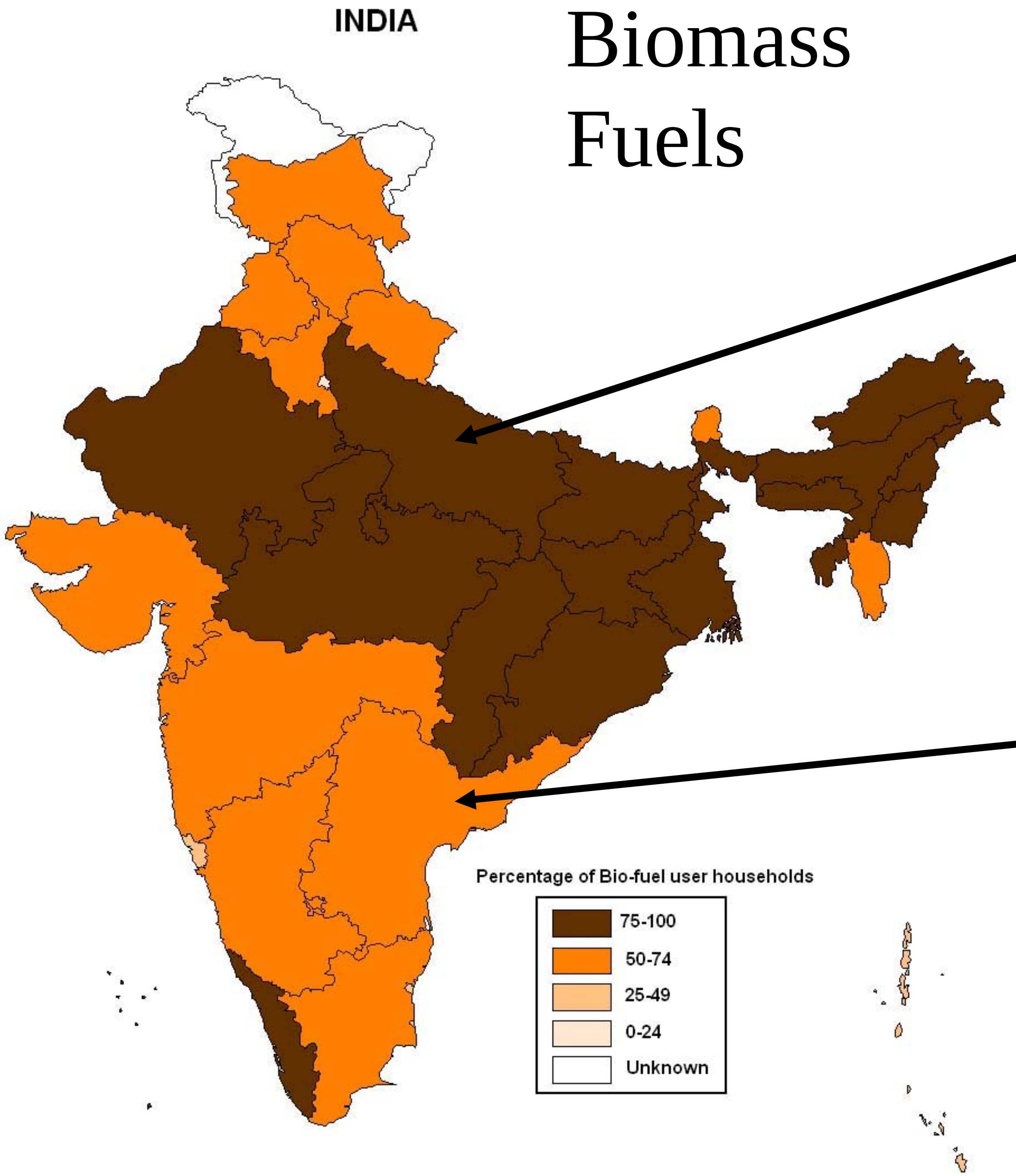
Per capita energy consumption: 1.67 toe

World Energy Assessment, 2004

National Household Solid Fuel Use, 2000



Biomass Fuels



More than 75% of households

50-74% of households

2000 Census

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

Into Pot	In PIC	Waste Heat
2.8 MJ	1.2 MJ	11.3 MJ
18%	8%	74%

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

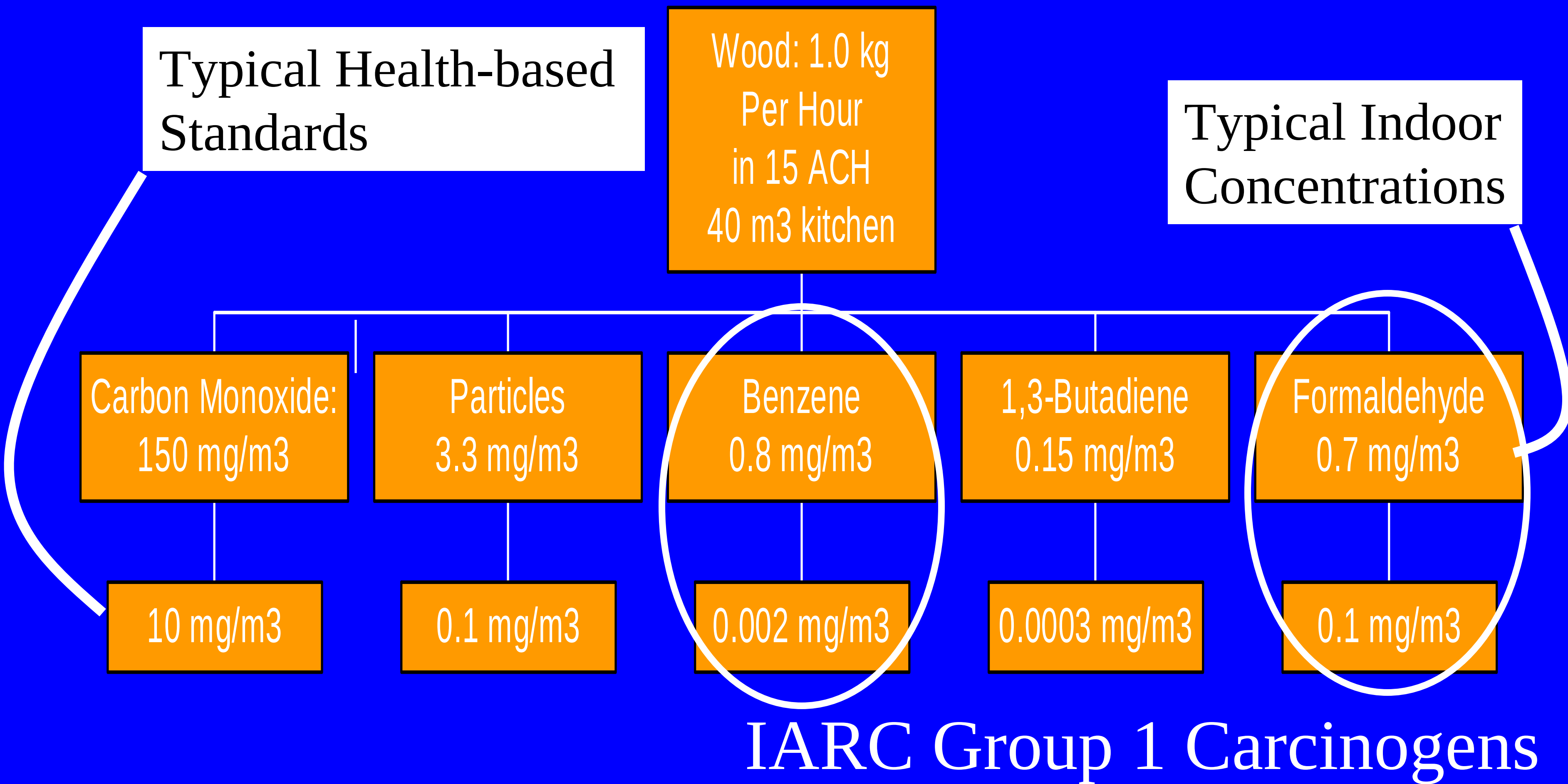
Source: Smith, et al., 2000

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

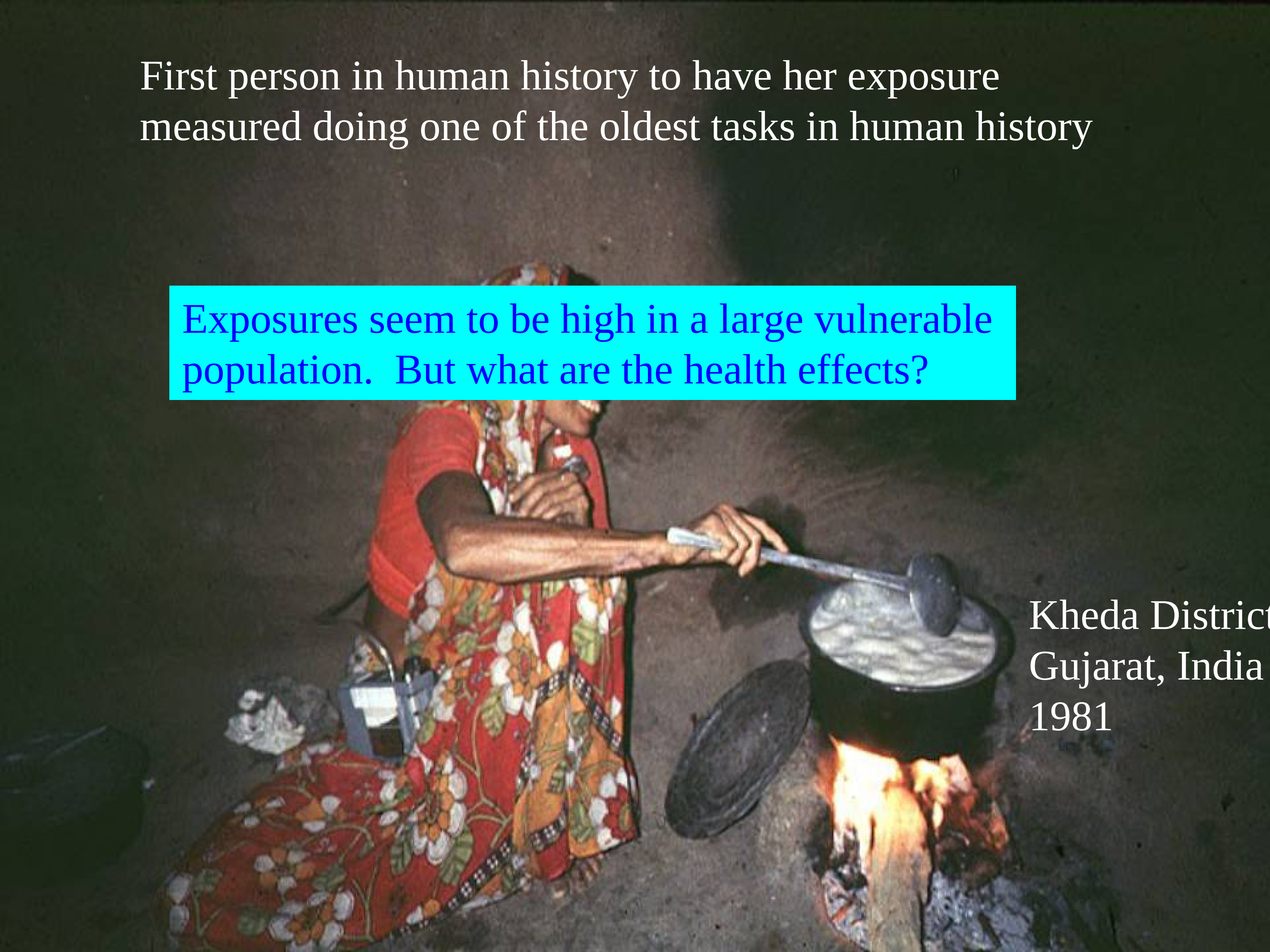
- Small particles, CO, NO_2
- Hydrocarbons
  - 25+ saturated hydrocarbons such as *n-hexane*
  - 40+ unsaturated hydrocarbons such as *1,3 butadiene*
  - 28+ mono-aromatics such as *benzene & styrene*
  - 20+ polycyclic aromatics such as *benzo(α)pyrene*
- Oxygenated organics
  - 20+ aldehydes including *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

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



First person in human history to have her exposure measured doing one of the oldest tasks in human history



Exposures seem to be high in a large vulnerable population. But what are the health effects?

Kheda District
Gujarat, India
1981

Diseases for which we have epidemiological studies linking indoor air pollution to disease

ALRI/ Pneumonia (meningitis)

Low birth weight & stillbirth

Asthma

Early infant Death?

Cognitive Effects?

Chronic obstructive lung disease

Interstitial LD

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

Blindness (cataracts, trachoma)

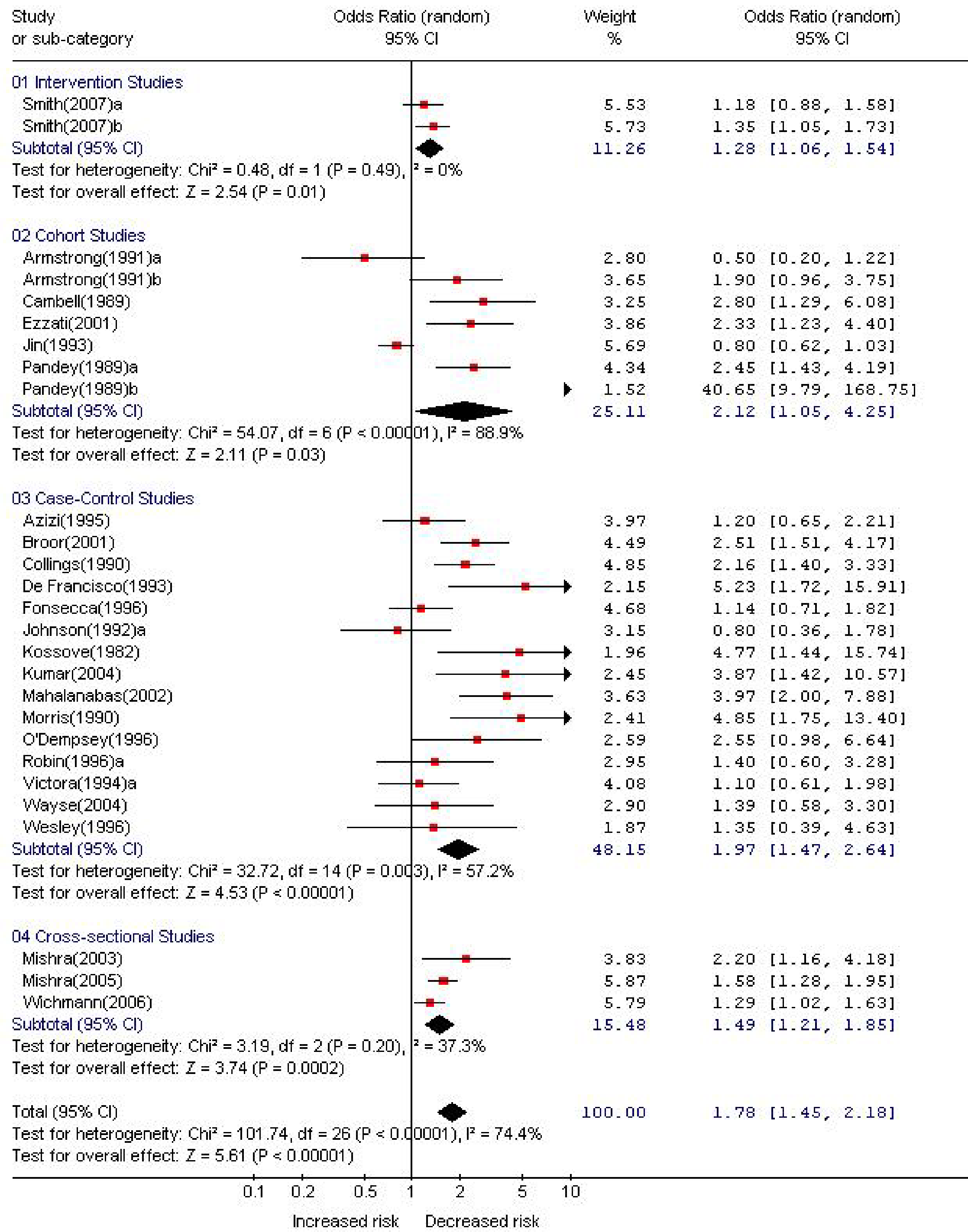
Tuberculosis

Heart disease?

New ALRI-IAP Systematic Review and Meta-Analysis

Dherani et al. Bull WHO, 2008

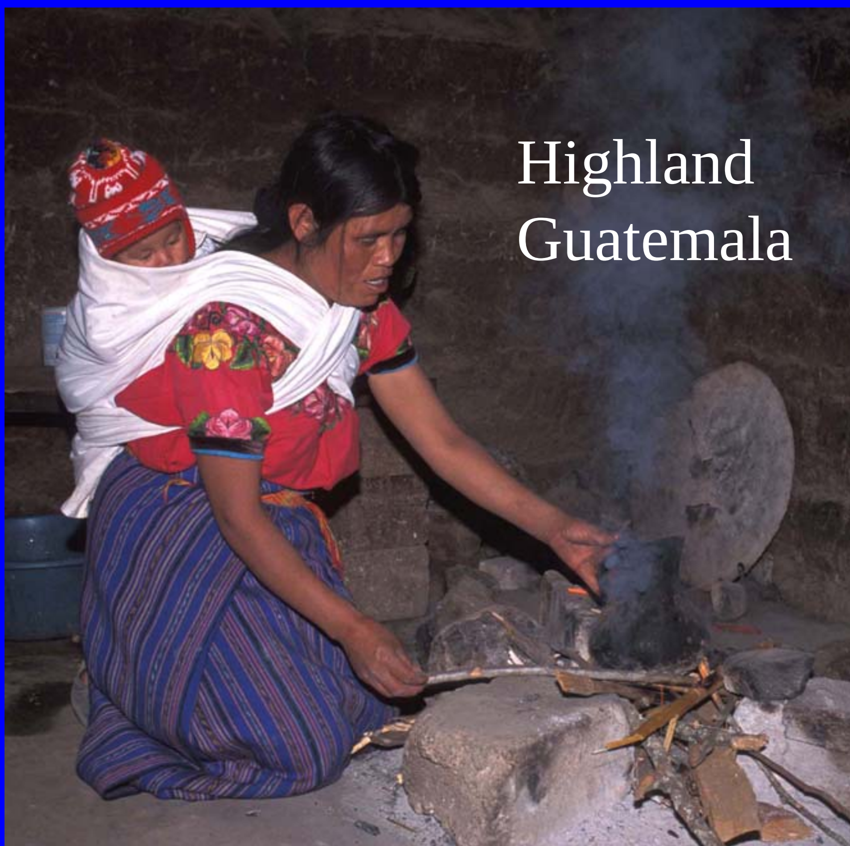
Study design	N *	OR	95% CI
Intervention	2	1.28	1.06, 1.54
Cross-sectional	3	1.49	1.21, 1.85
All	26	1.78	1.45, 2.18



History of a RCT

- ~1980: early studies of health effects in Nepal and elsewhere
- 1981: first measurements of pollution levels in India
- 1984: international meeting to decide on needed research
  - Chose randomized control trial (RCT) of ALRI
- 1986-89: unfunded proposals to do RCT in Nepal
- 1990: WHO establishes committee to find best sites
- 1992: Guatemala chosen
- 1991-1999: Pilot studies to establish data needed for proposal
- 1996-1999: unfunded proposals
- 2001: NIH funds first randomized control trial for air pollution in highland Guatemala
- 2002-2005: fieldwork completed
- 2007: first results published
- 23 years from deciding to conduct RCT to results!

First Randomized Control Trial in Air Pollution History



Traditional 3-stone open fire

Plancha chimney wood stove

RESPIRE - Guatemala

RCT Study flow chart

October 2002 - Eligible homes: open fire; pregnant; child <4 months: n=777

Declined n=243 (31%)

Consent & baseline questionnaire: n=534 (69%)

Randomization

Intervention (n=271)

Control (n=263)

Plancha built: needs 5 weeks to ‘cure’

6 losses:
1 miscarriage
2 stillbirths
3 deaths

10 losses:
4 miscarriages
2 stillbirths
4 deaths

Child health surveillance starts: (n=518)

Continues until child 18 months, death, declined to continue, or cessation of surveillance in December 2004

27 losses:
4 refusals
16 migration
6 broke stove
1 other

19 losses:
10 refusals
8 migration
1 switch to plancha

14,756 child weekly visits

14,369 child weekly visits

Offered plancha

Guatemala RCT Results

[Unpublished results presented showing that with ITT analysis, all outcomes showed improvement, but only severe ALRI outcomes were significant. With exposure-response analysis using personal pollution monitoring, however, nearly all outcomes significant, including primary outcome: MD-diagnosed pneumonia]

Respiratory Disease - other

- Minor burden, but important economic impact
  - Otitis Media – 0.08% of global burden
  - AURI – 0.11%
- Compared to 3% and 6% for LBW and ALRI

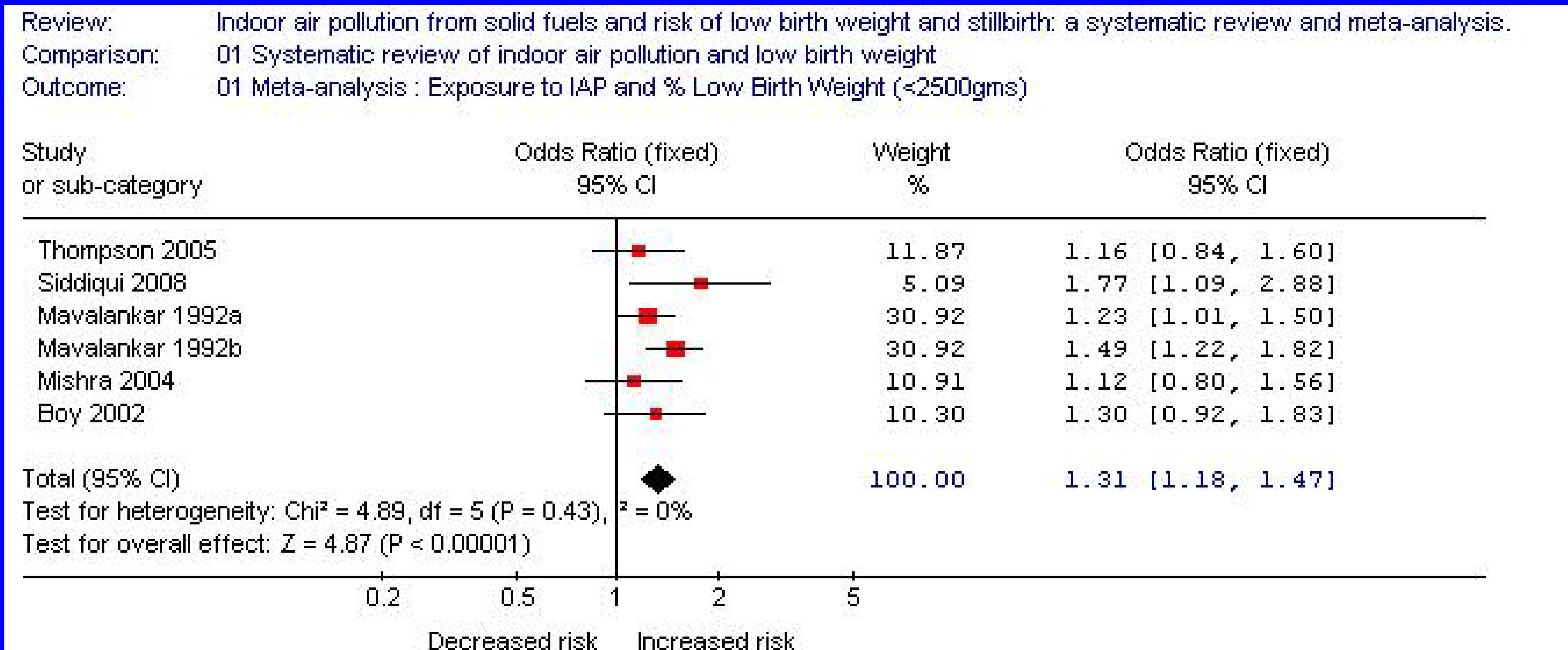
Low birth weight (associated with IAP)

- Large direct impact on child mortality
- Of which perhaps 25% is ALRI
- Barker-type effect has been found on chronic disease over life time, including COPD

Low Birth Weight

- Small number of studies conducted appearing to show results for IAP consistent with evidence from ETS and ambient air pollution.
- Pregnant women in countries with high rates of (a) solid fuel use, and (b) adverse pregnancy outcomes rarely able to avoid activities that expose them and their unborn children to IAP
- Hence, even modest increase in RR for these conditions can be expected to translate into a substantial population attributable risk.
- Systematic review carried out in order to:
  - summarise the extent and quality of the evidence for the relationship between IAP from solid fuel use and adverse pregnancy outcomes
  - quantify these associations by meta-analysis.

Results: IAP and LBW (<2500gms)

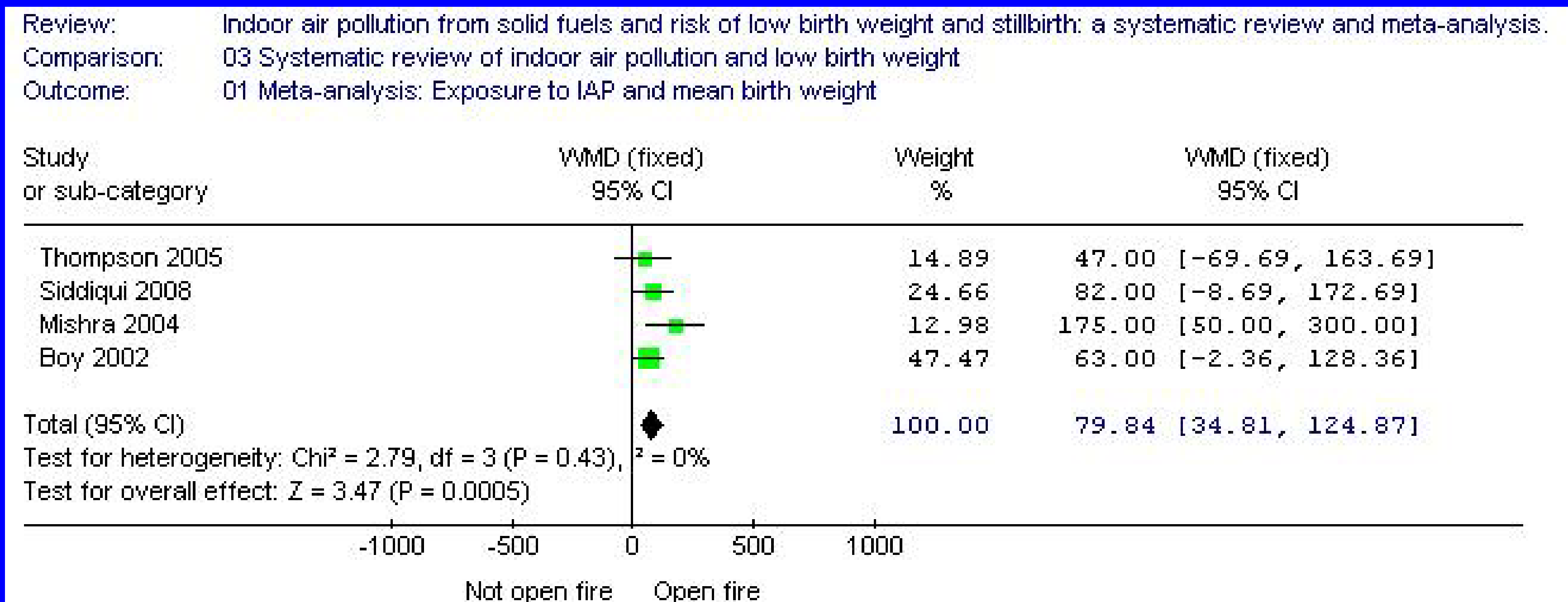


Heterogeneity - (I^2 = 0%; Chi^2 (df=5) = 4.89, p=0.43)

Funnel plot asymmetry - Begg's test (p = 0.566) Egger's test (p=0.989)

Pope et al., in prep

Results: IAP and birth weight

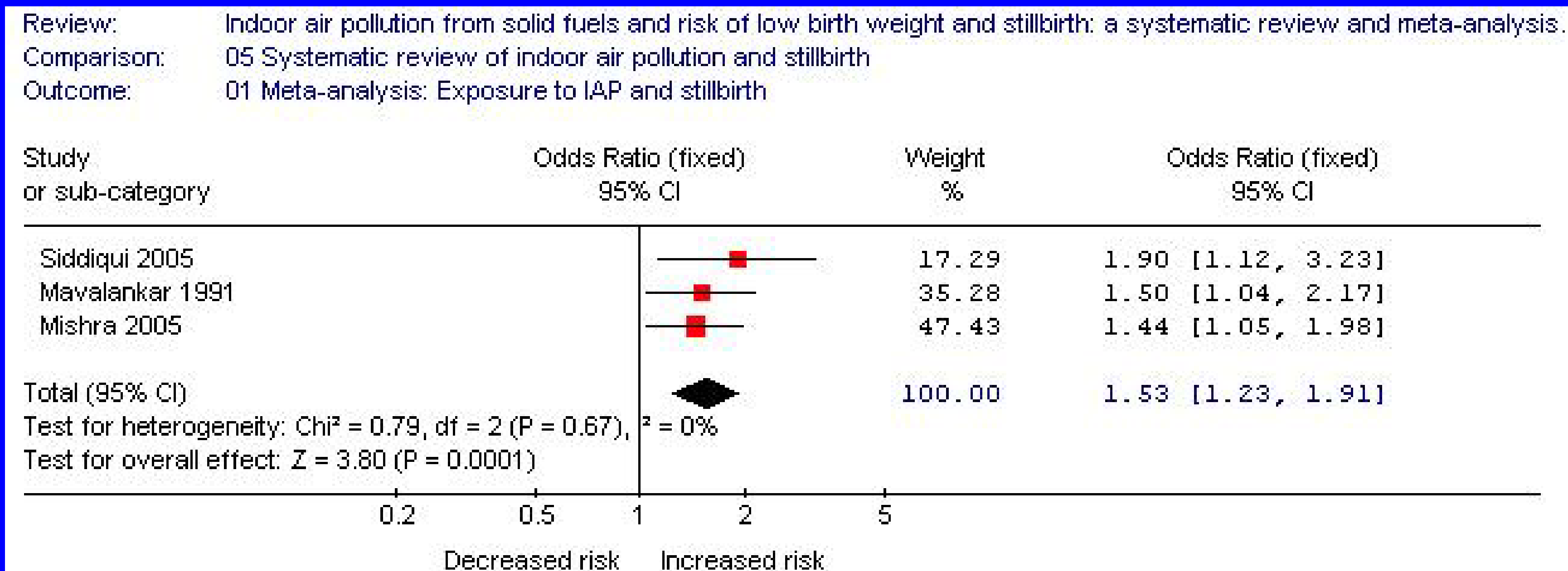


Heterogeneity - (I^2 = 0%; Chi^2 (df=3) = 2.79, p=0.43)

Funnel plot asymmetry - Begg's test (p = 0.308) Egger's test (p=0.479)

Pope et al., in prep

Results: IAP and still birth



Heterogeneity - (I^2 = 0%; Chi^2 (df=2) = 0.79, p=0.67)

Funnel plot asymmetry - Begg's test (p = 0.296) Egger's test (p=0.083)

Pope et al., in prep

Discussion

- Paucity of studies, conducted using a variety of study designs and across a range of settings.
- Despite this, results remarkably consistent with little evidence of statistical heterogeneity.
- Possibility of residual confounding.
- Variation in exposure measurement (need direct measurement for exposure-response analysis).
- Lack of information on gestational age in some of LBW studies.
- Results consistent with literature on ETS, ambient air pollution and LBW.
- Mechanisms: (i) CO (ii) PM
- Few studies on ETS/ ambient air pollution and still birth.

Conclusions

- Population Attributable Risks (%):

  LBW = 17.8%
  Still birth = 27.1%
  (70% prevalence of solid fuel use)

- Primary or secondary outcome for CRA?
- Strong case for additional studies.

Interactions with IAP

- Arsenic in water – “largest poisoning in human history”
  - Causes COPD, lung cancer, and ALRI
  - Much common exposure with IAP
- High occupational exposures to various dusts including silica, asbestos,
- Malnutrition
- Smoking

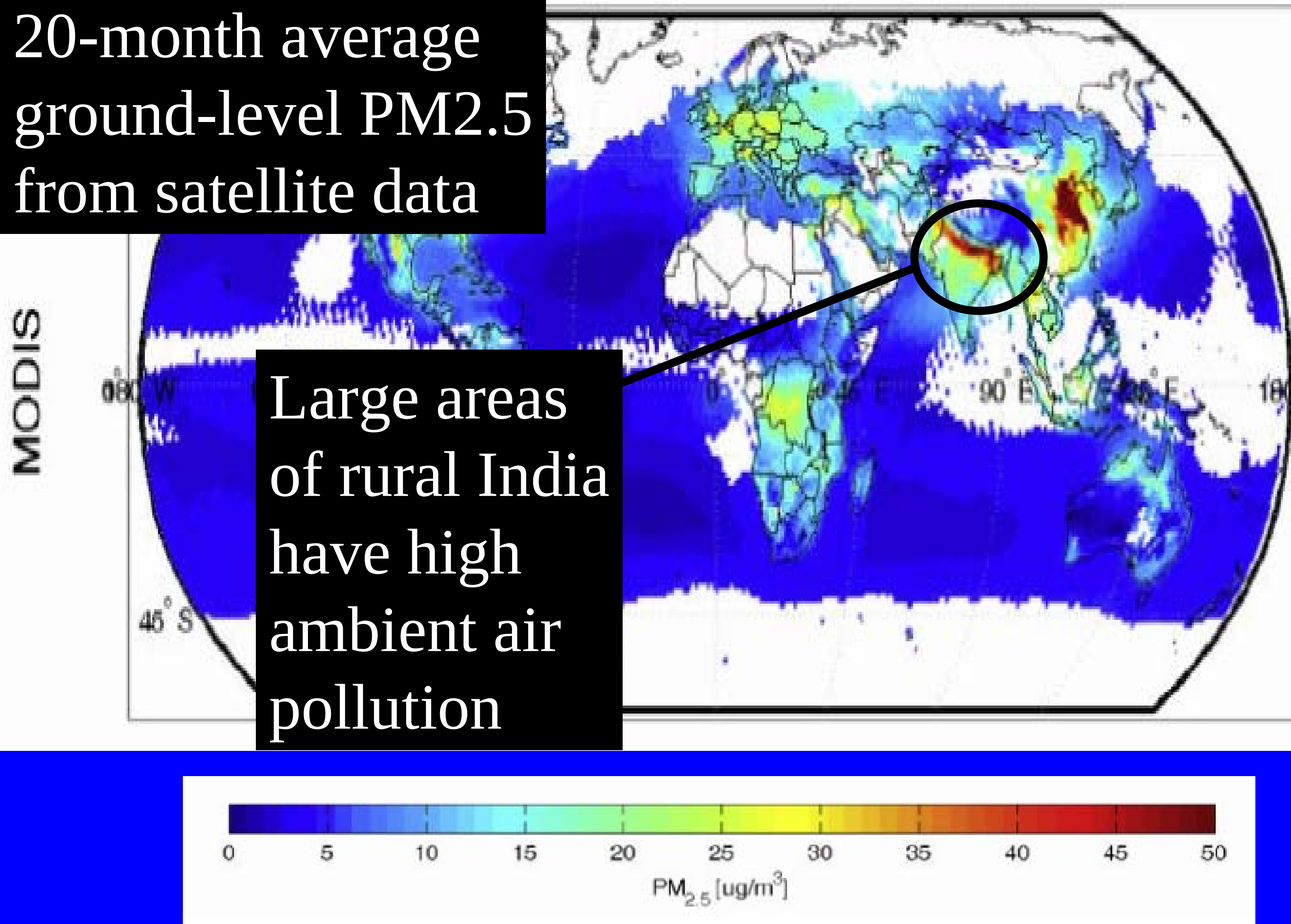
Large Global Exposures to some surprising pollutants – perhaps largest

- Ultrafine particles – fresh and combustion-generated
- Formaldehyde
- Benzene
- PAH
- Dioxin
- Etc.

Biomass smoke – a global concern

- A significant contribution to PM2.5 emissions around the world – more than half in many developed countries (Canada, Denmark, much of USA, etc.)
  - Ag burning a function of ag production, not income - California
  - Wood heating and fireplace use common in many developed countries – Silicon Valley
- Growing because of energy prices
- And climate change
- Not clear whether effects across all major health outcomes are the same as those found in urban studies of PM
  - Chronic and Acute Respiratory
  - Cardiovascular
  - Cancer
- Households in LDCs perhaps only widespread exposure to nearly pure biomass smoke

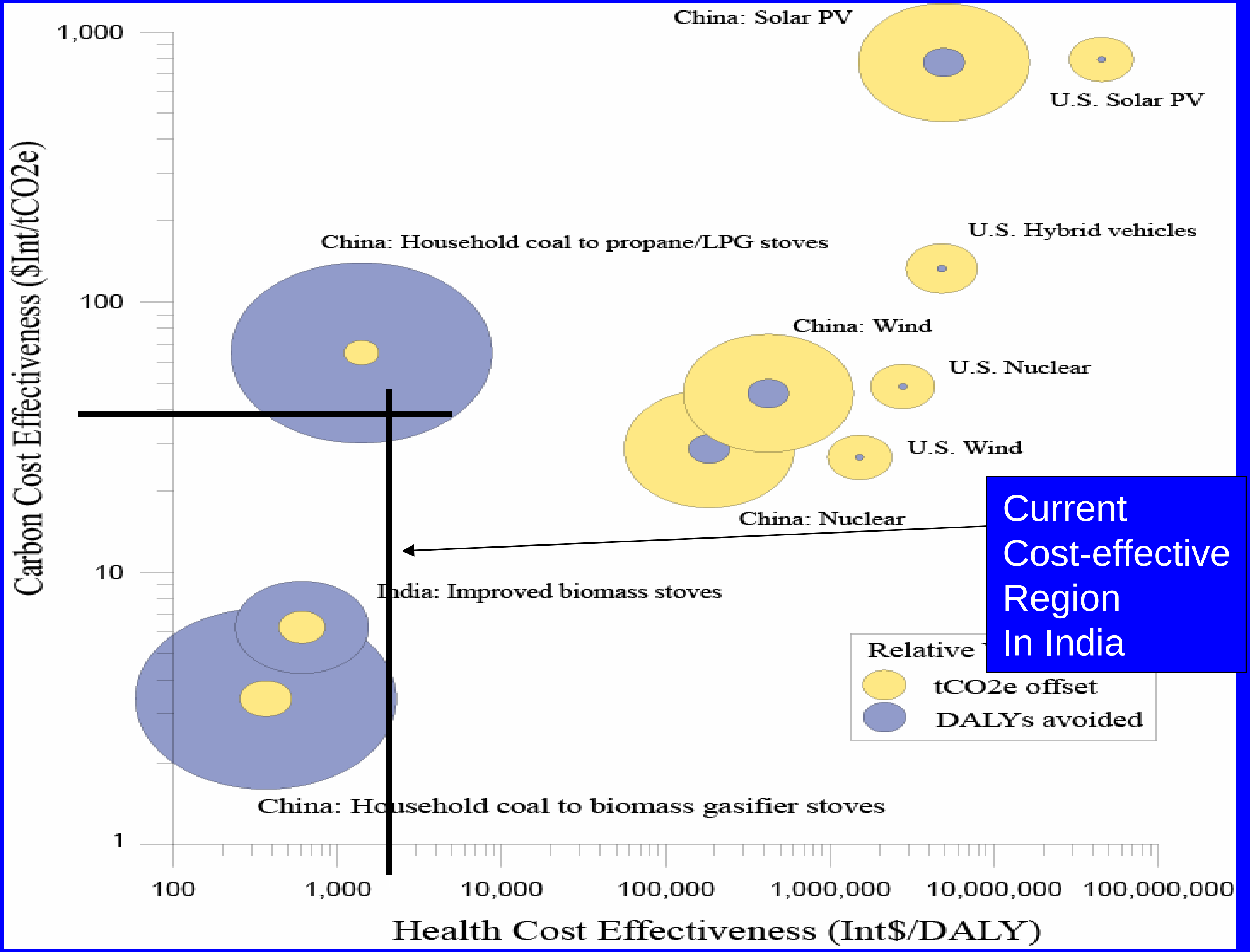
20-month average ground-level PM2.5 from satellite data



Large areas of rural India have high ambient air pollution

Climate Change – Co-benefits

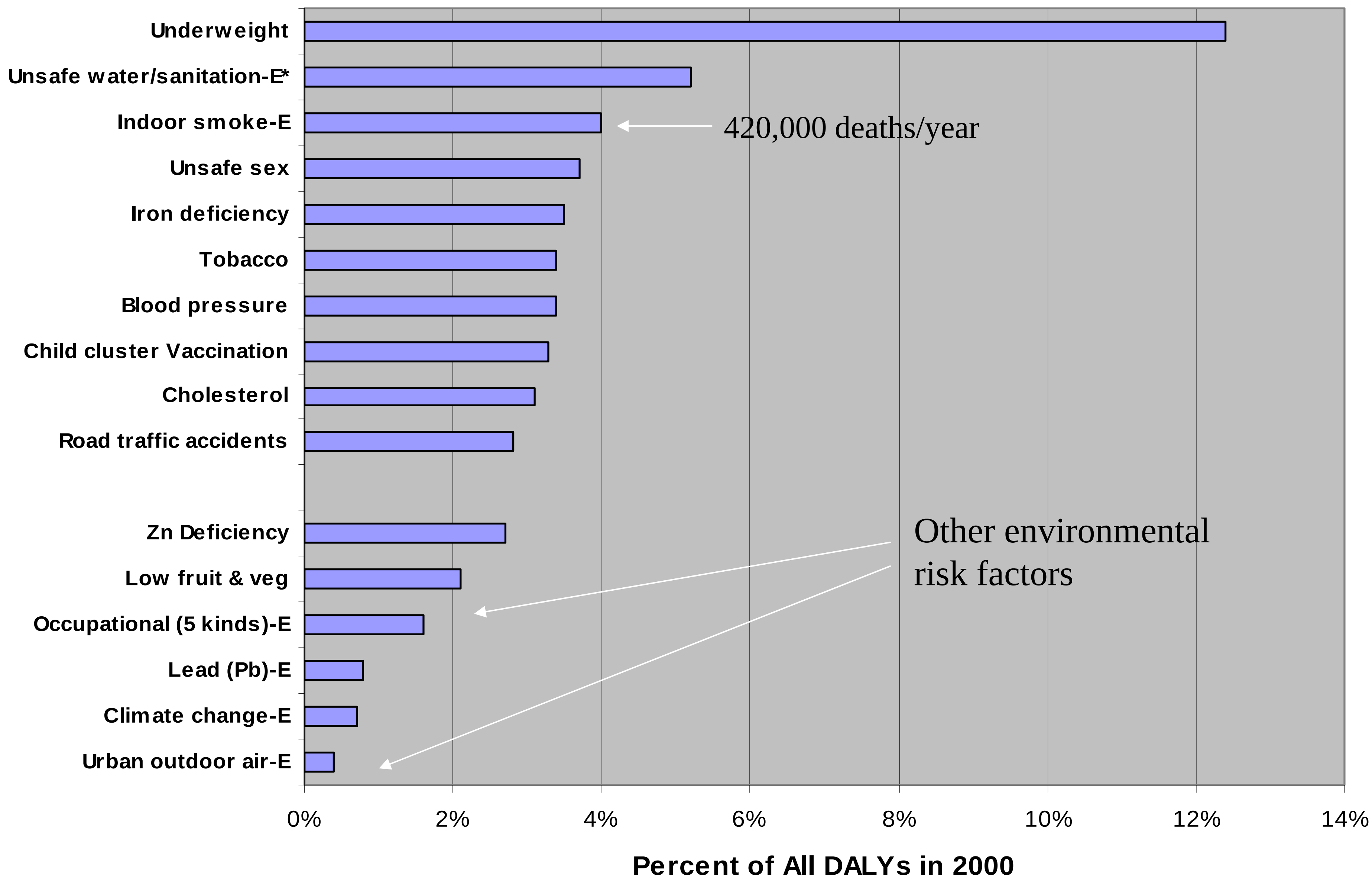
- Products of incomplete combustion are both health damaging and climate warming
- Efforts to reduce them in household combustion can be highly effective for both goals – co-benefits



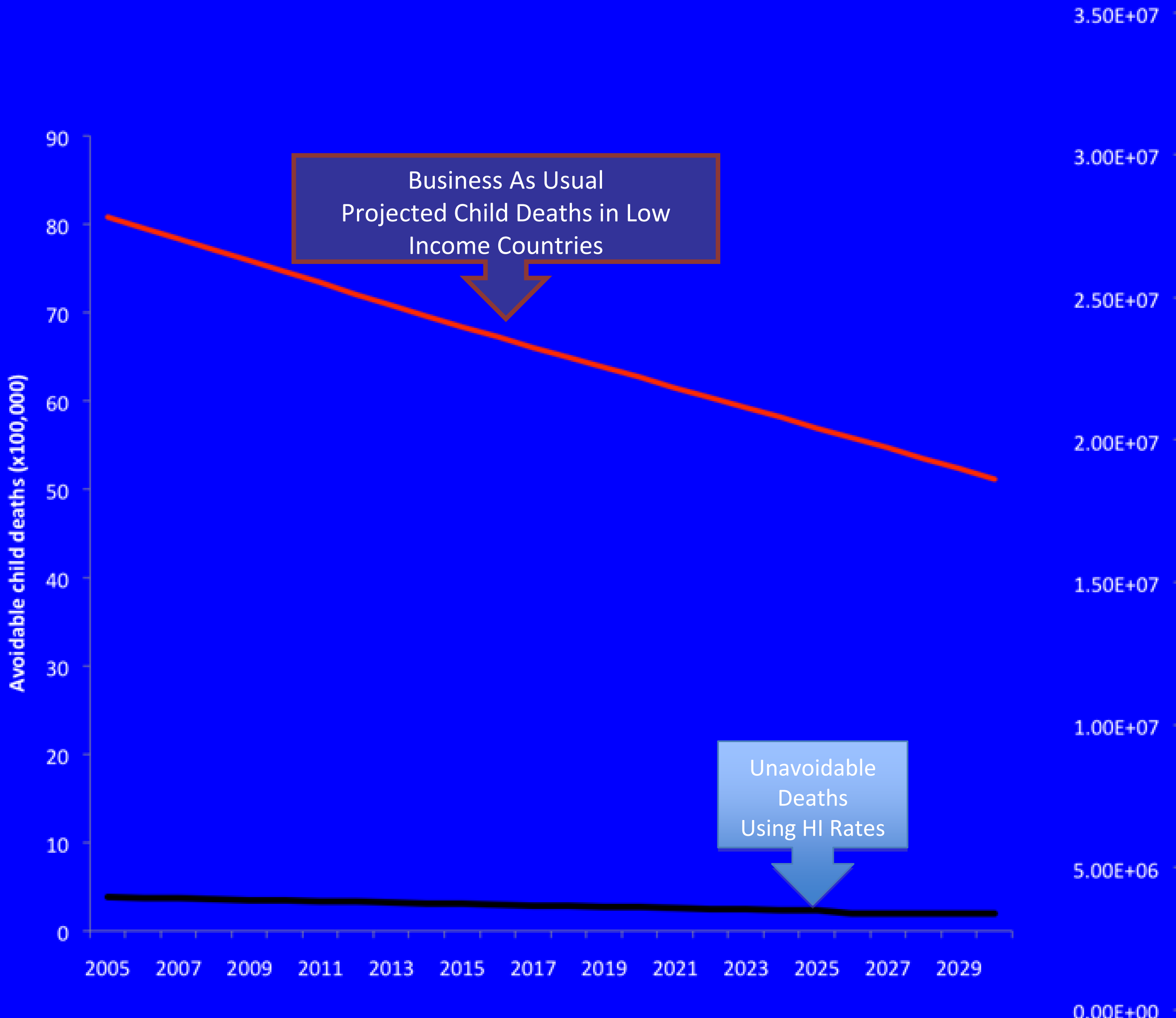
Smith & Haigler, 2008

Indian Burden of Disease from Top 10 Risk Factors

and Selected Other Risk Factors

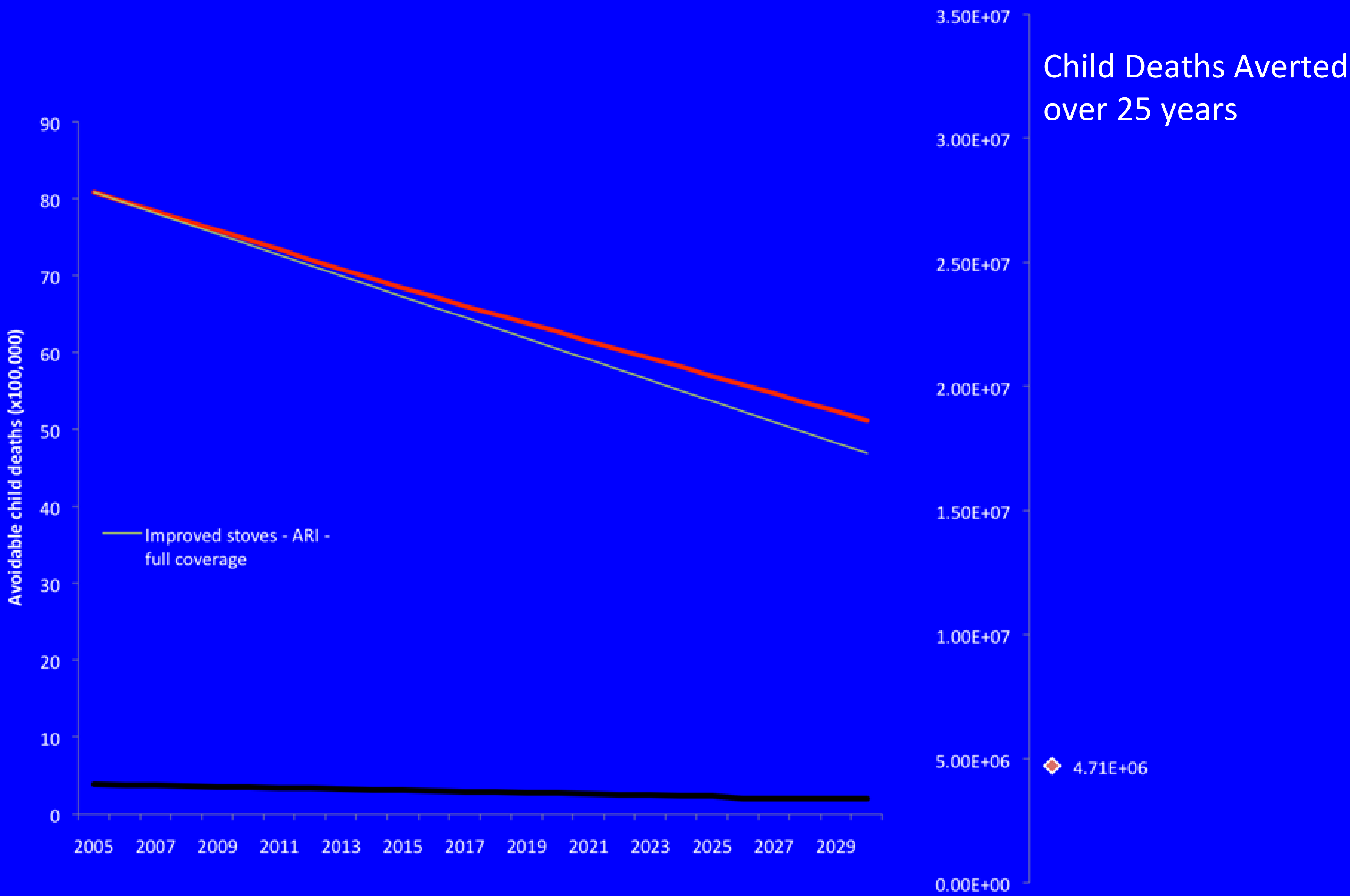


Potential Impacts of Health Interventions on Child Mortality in Low Income Countries

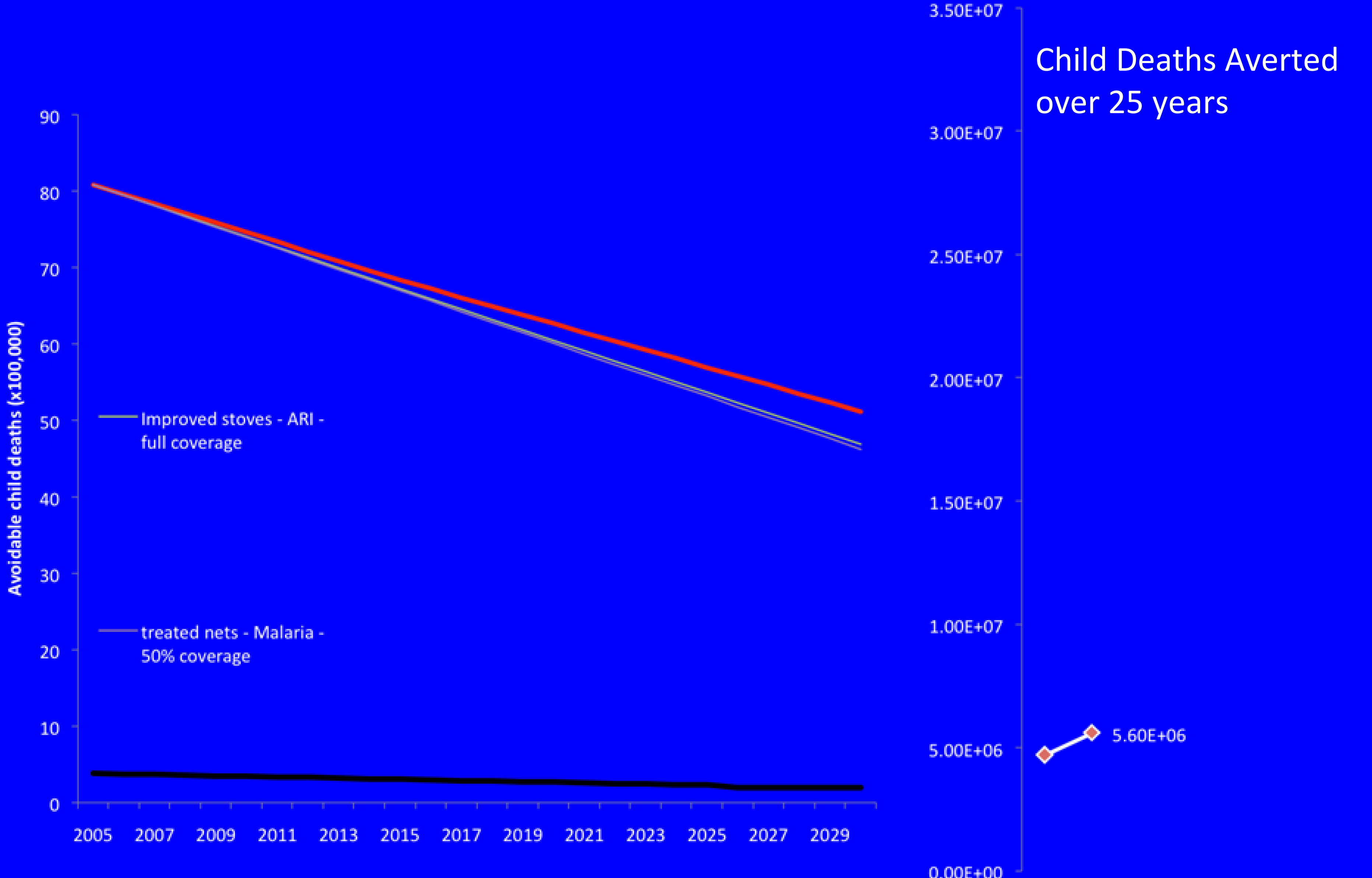


Child Deaths Averted over 25 years

Potential Impacts of Health Interventions on Child Mortality in Low Income Countries



Potential Impacts of Health Interventions



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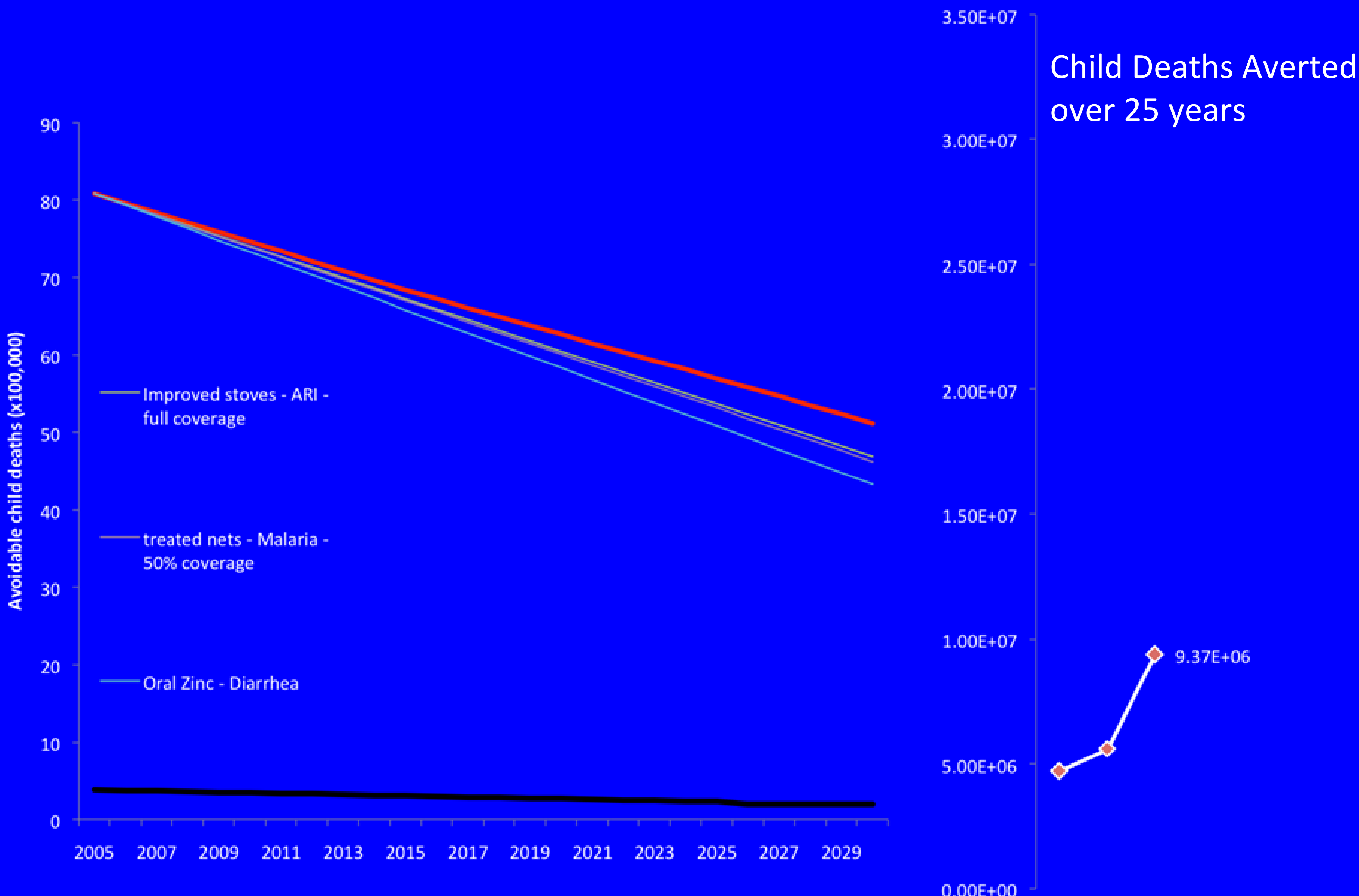

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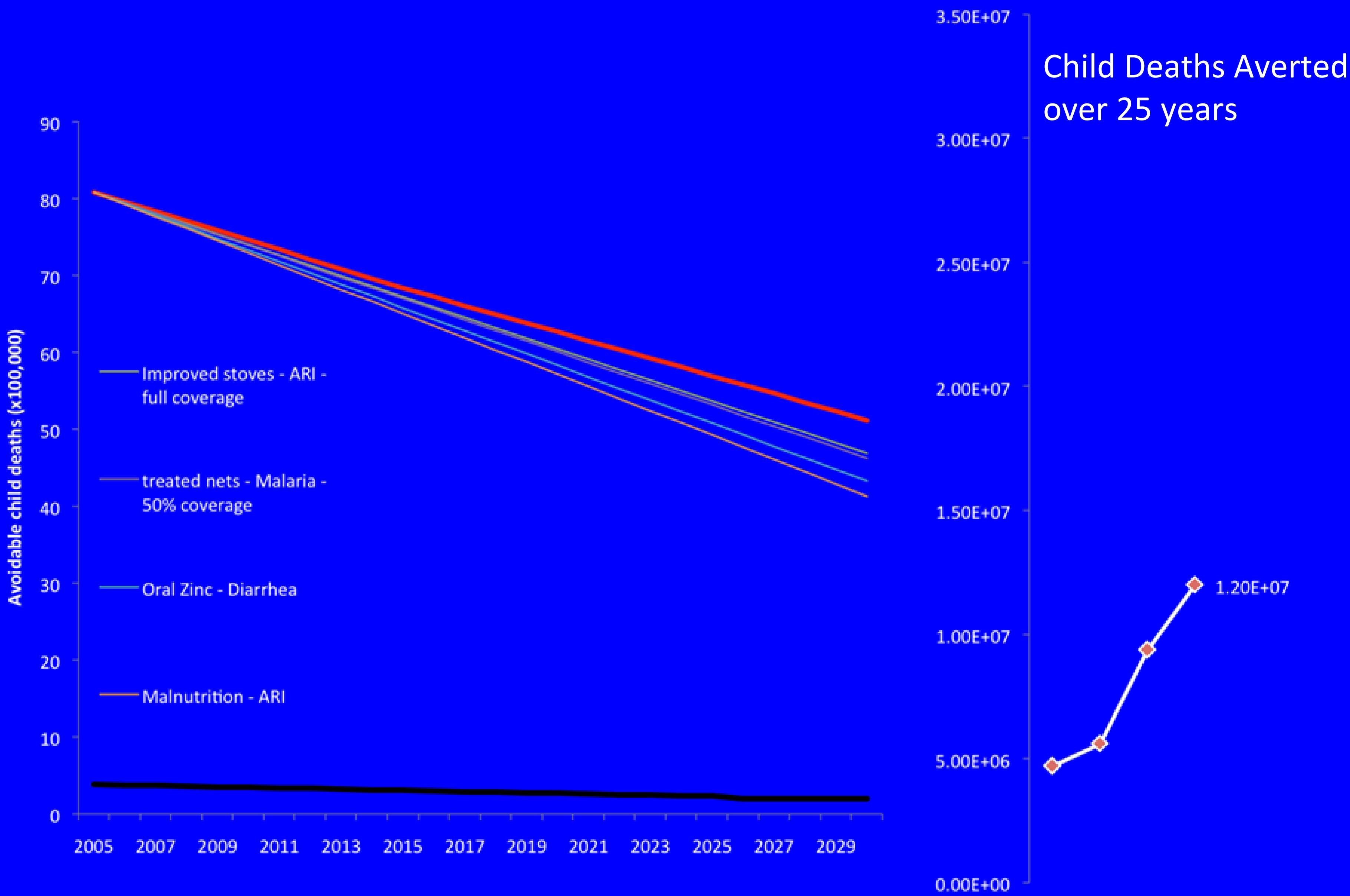

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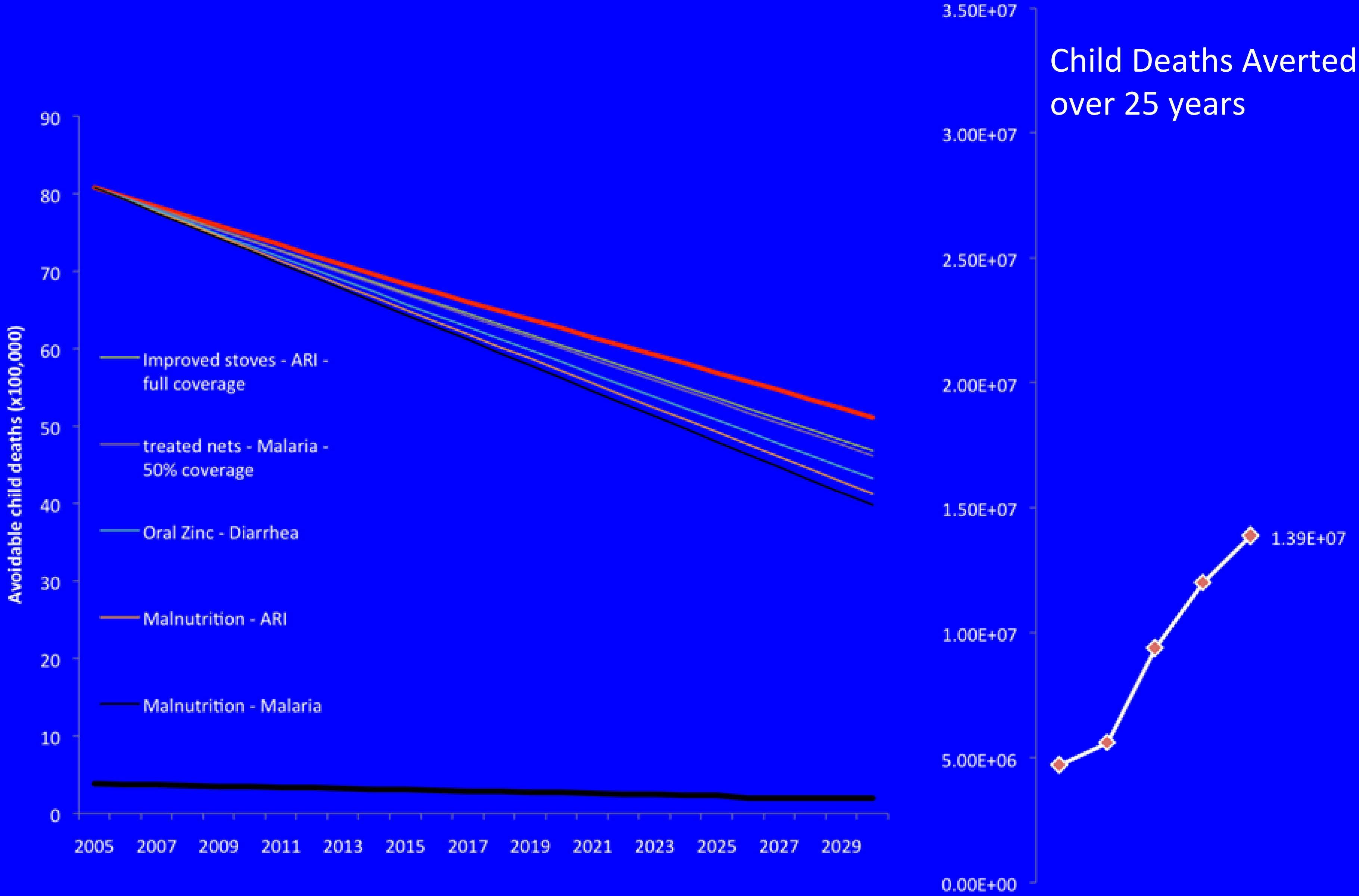

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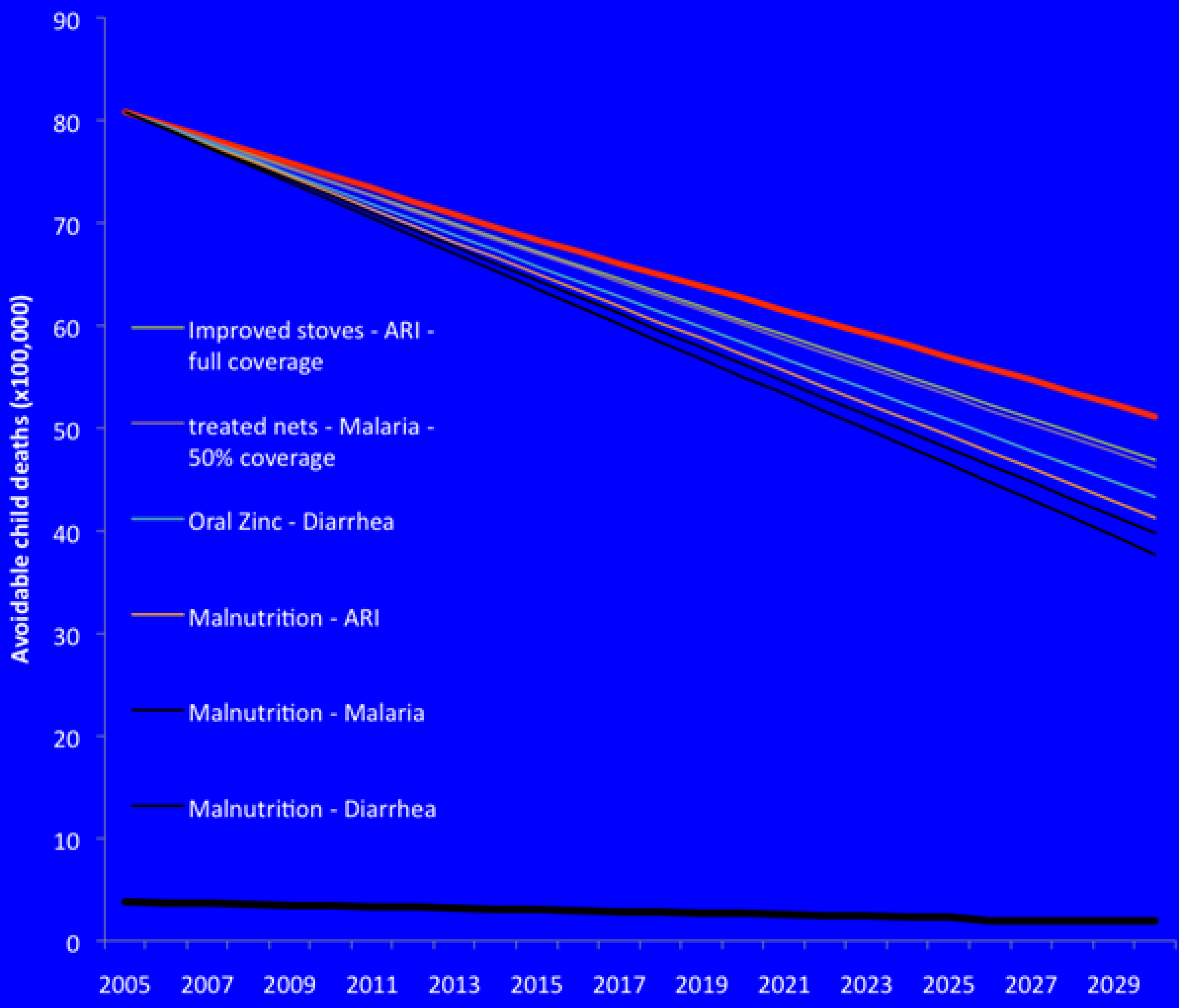

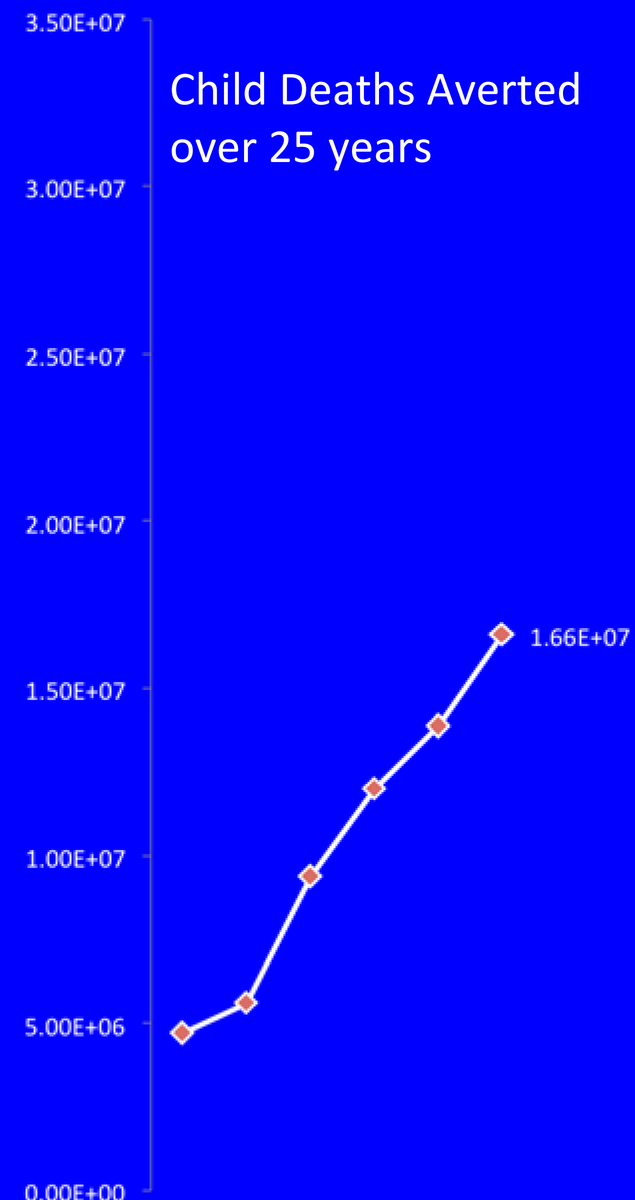

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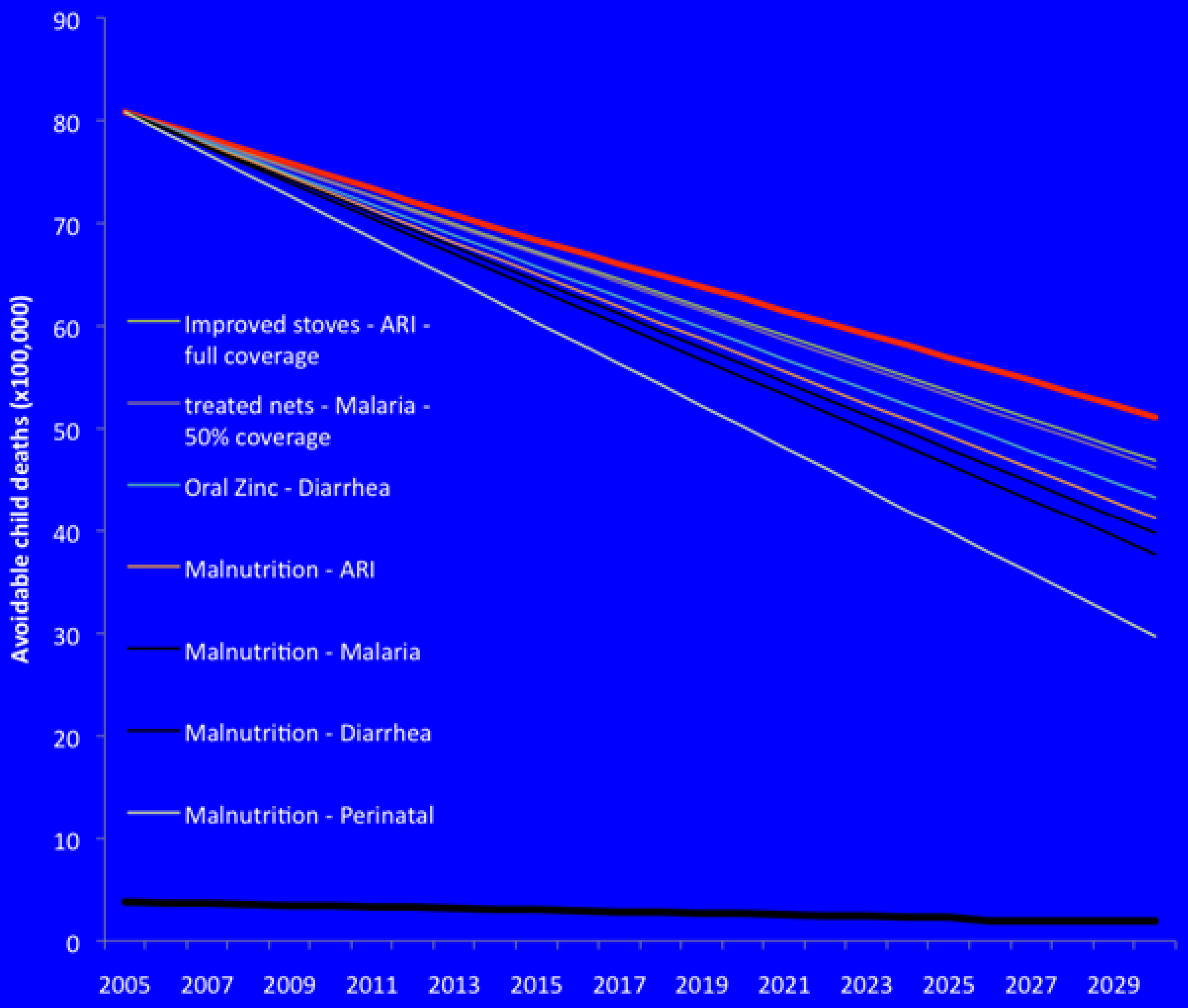

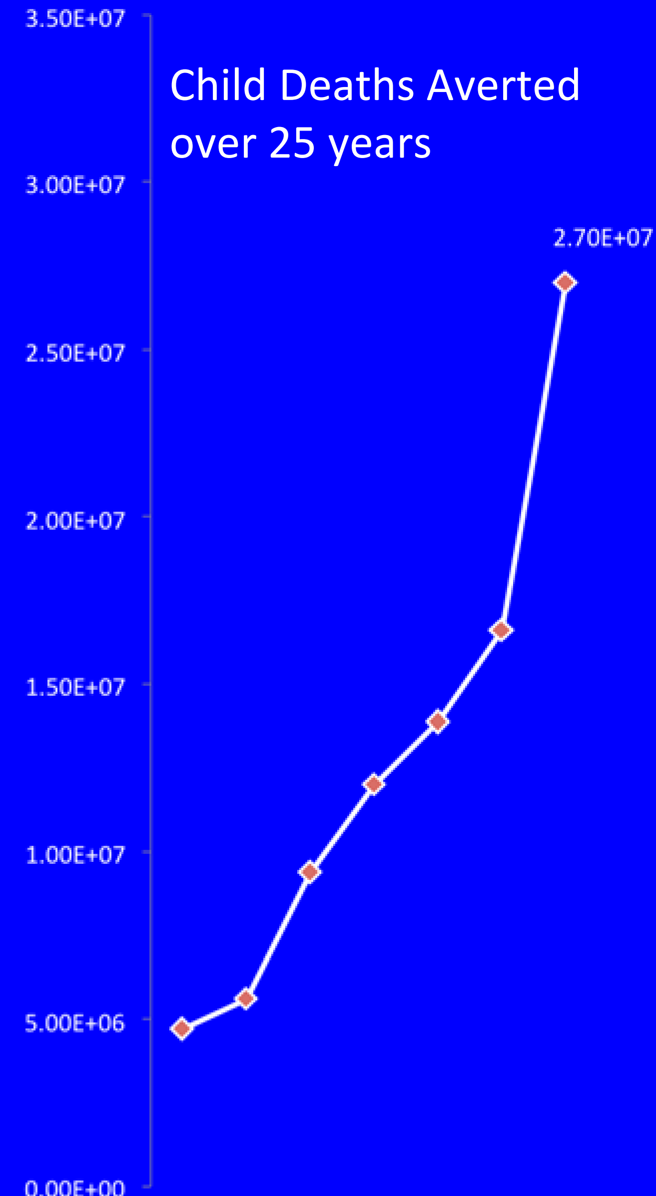

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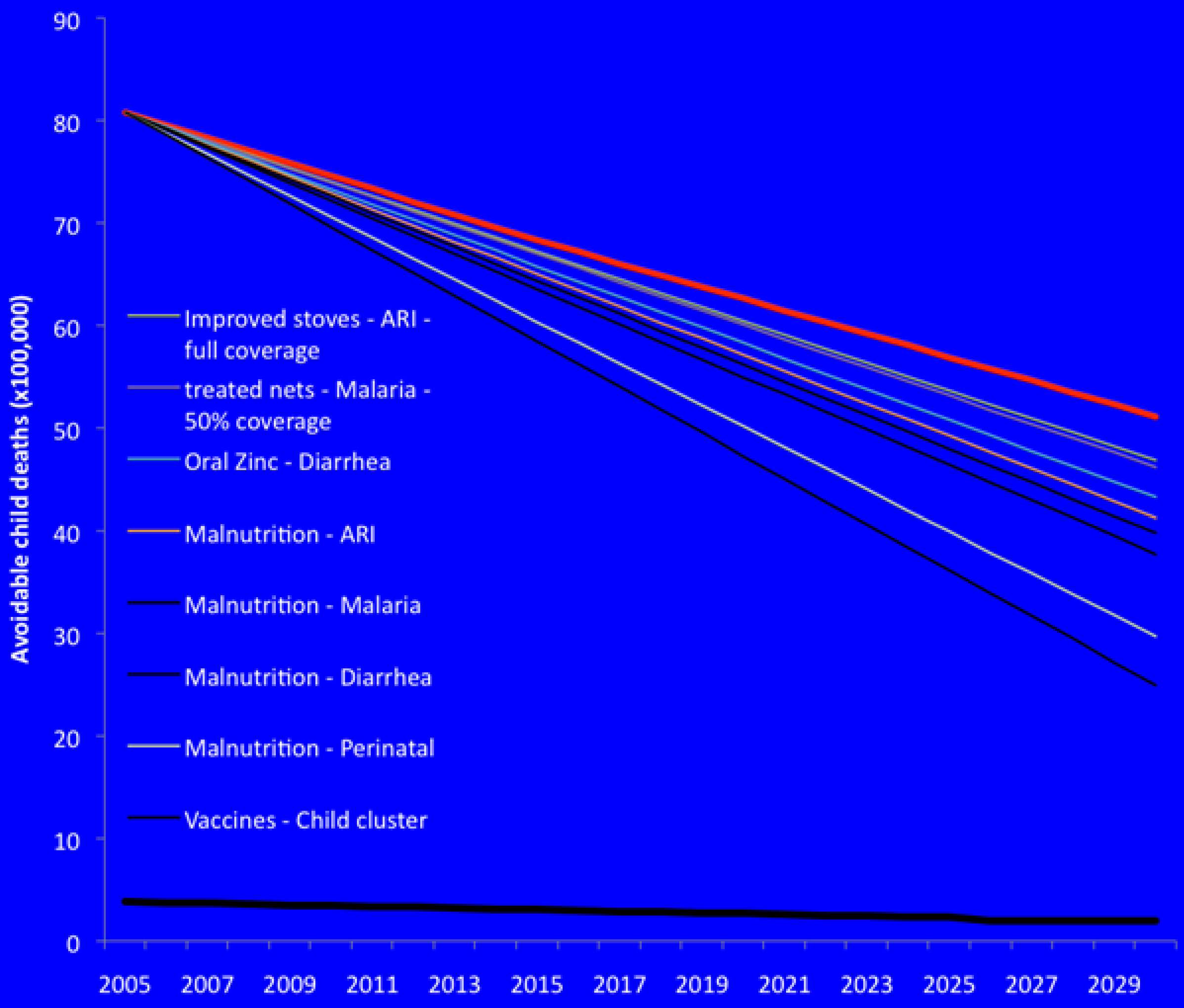
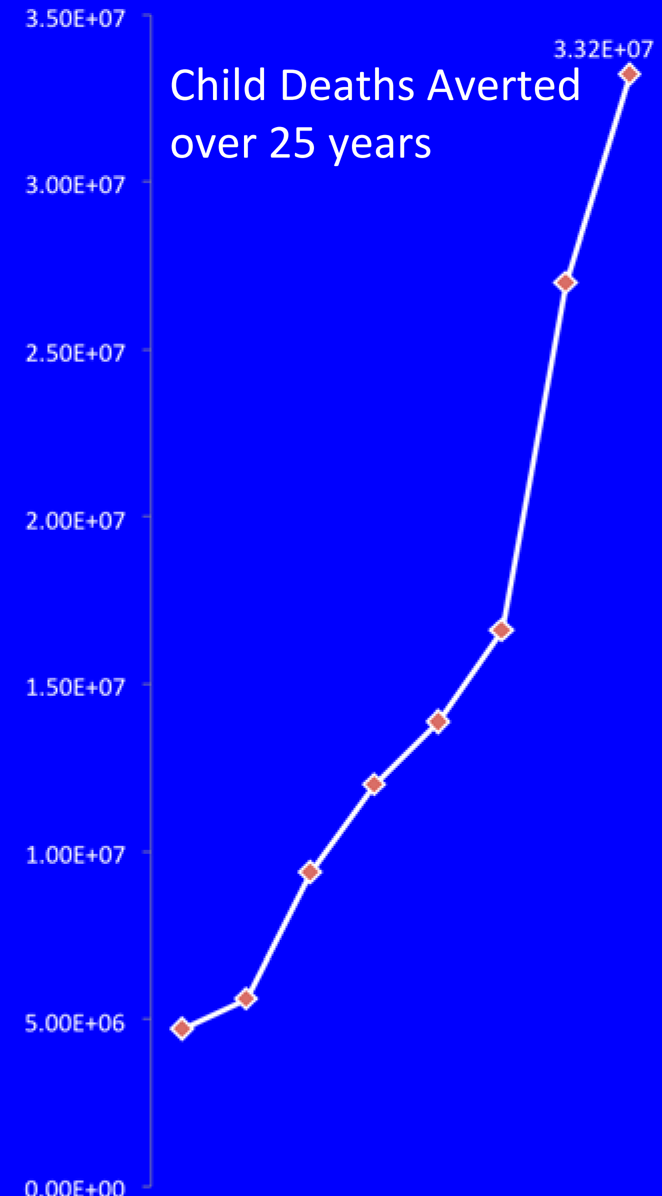
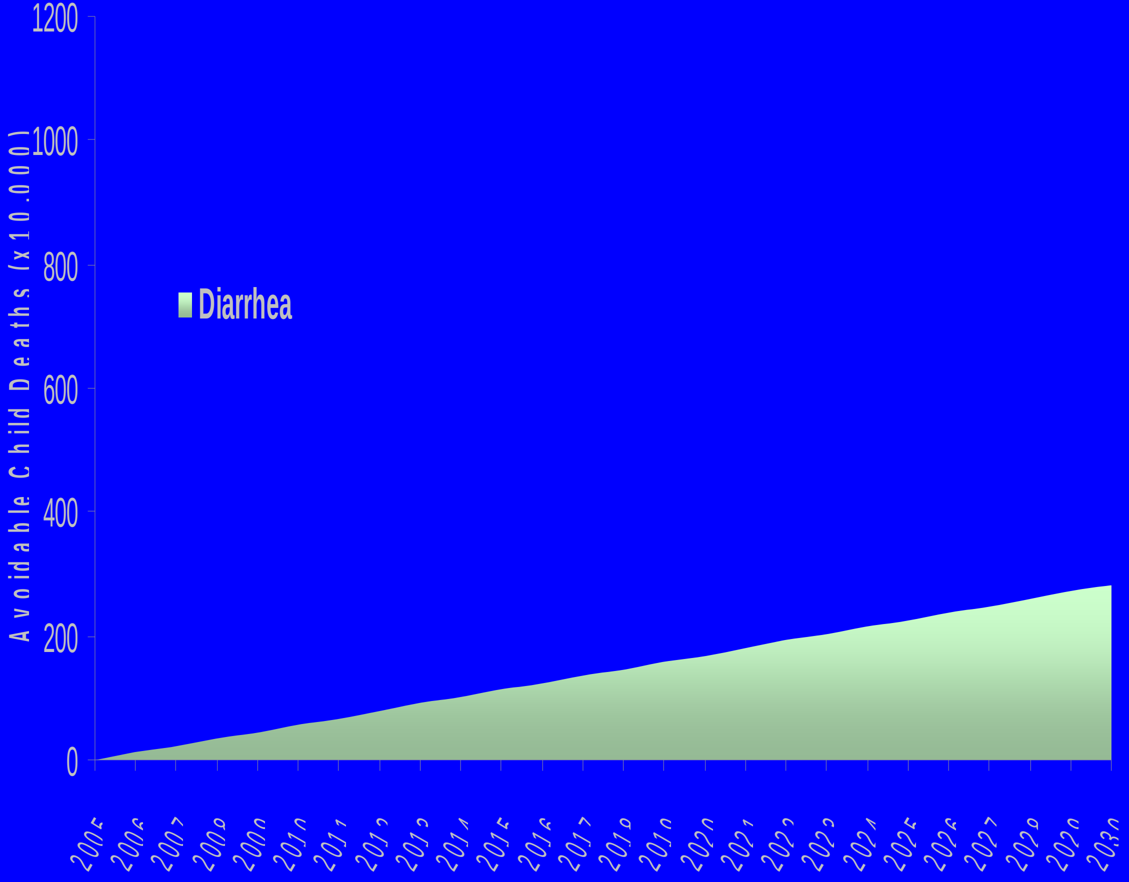


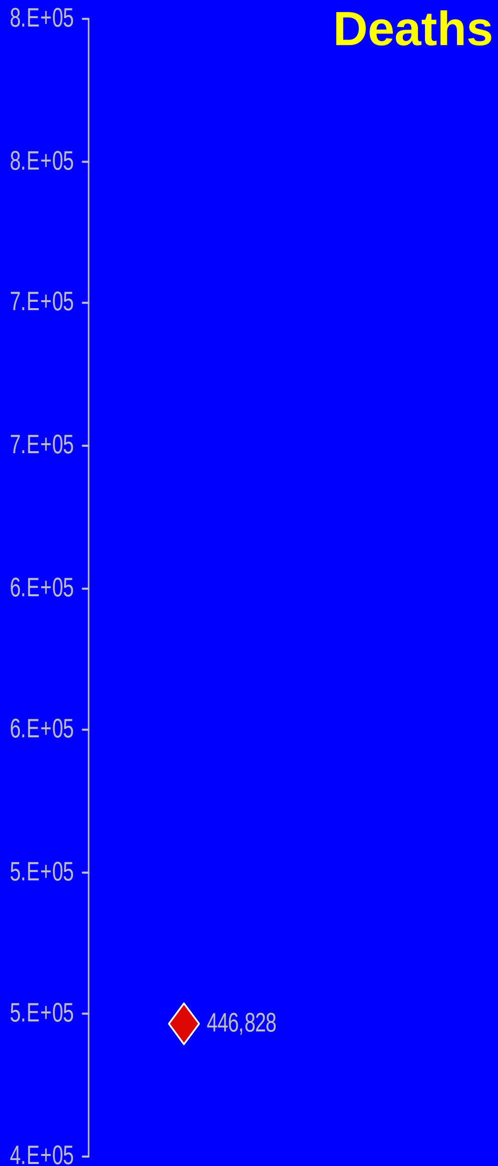


Based mainly on *Lancet* Child Mortality Series

Potential Impacts of Climate Change on Child Mortality in Low Income Countries

550ppm





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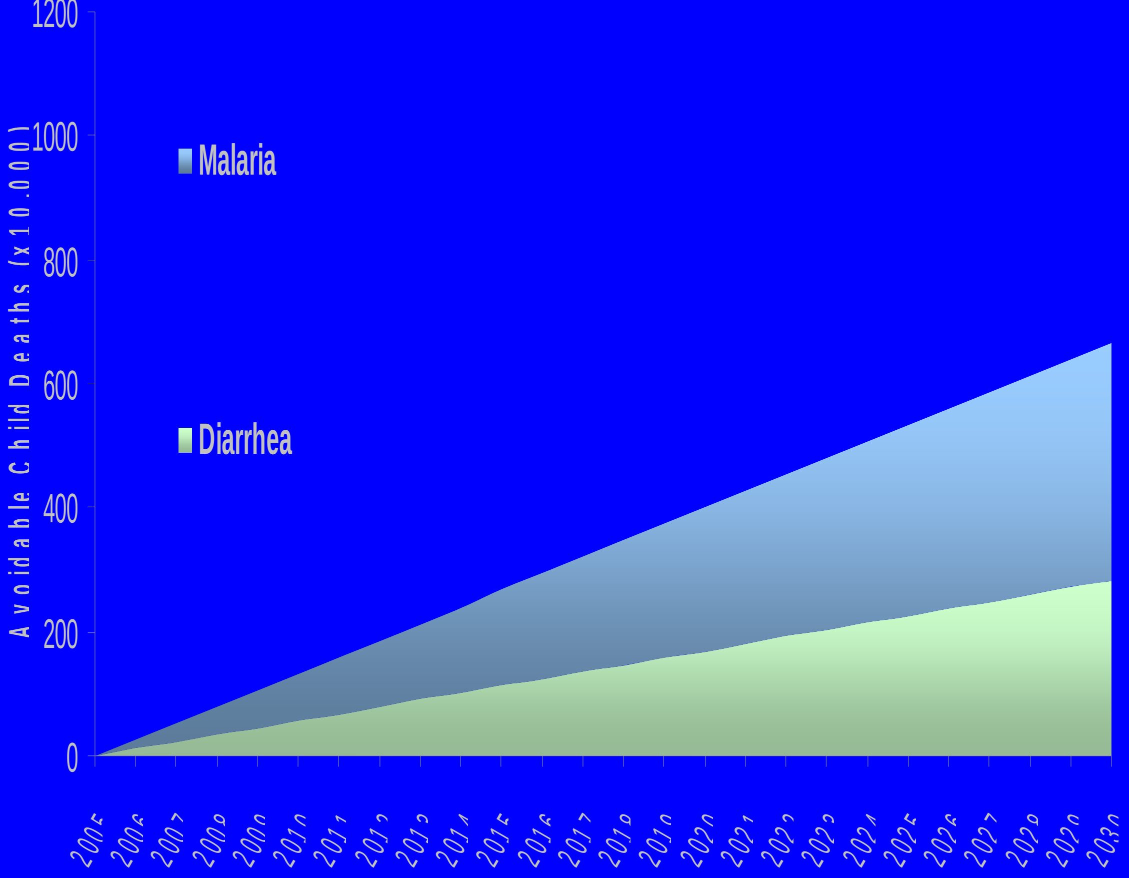

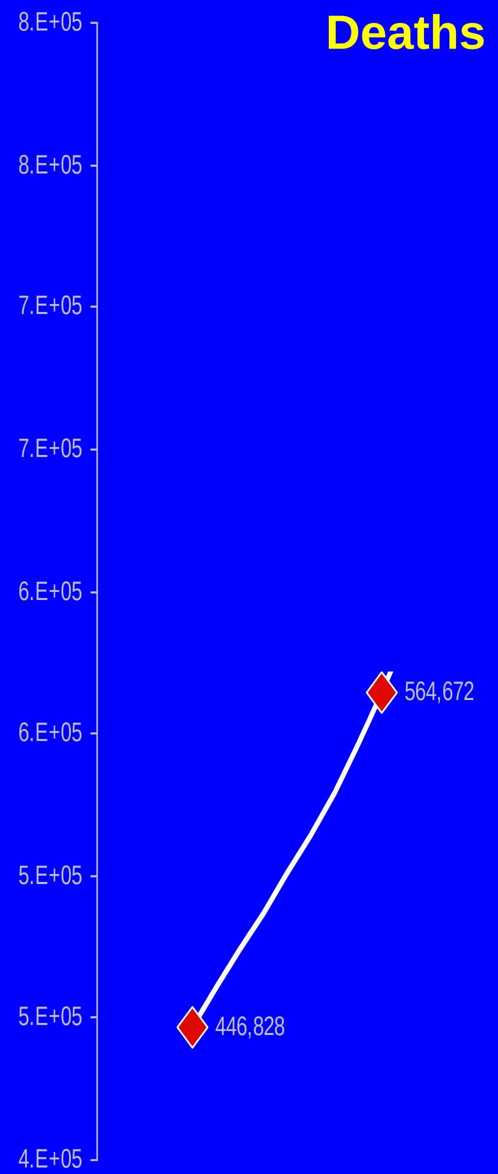

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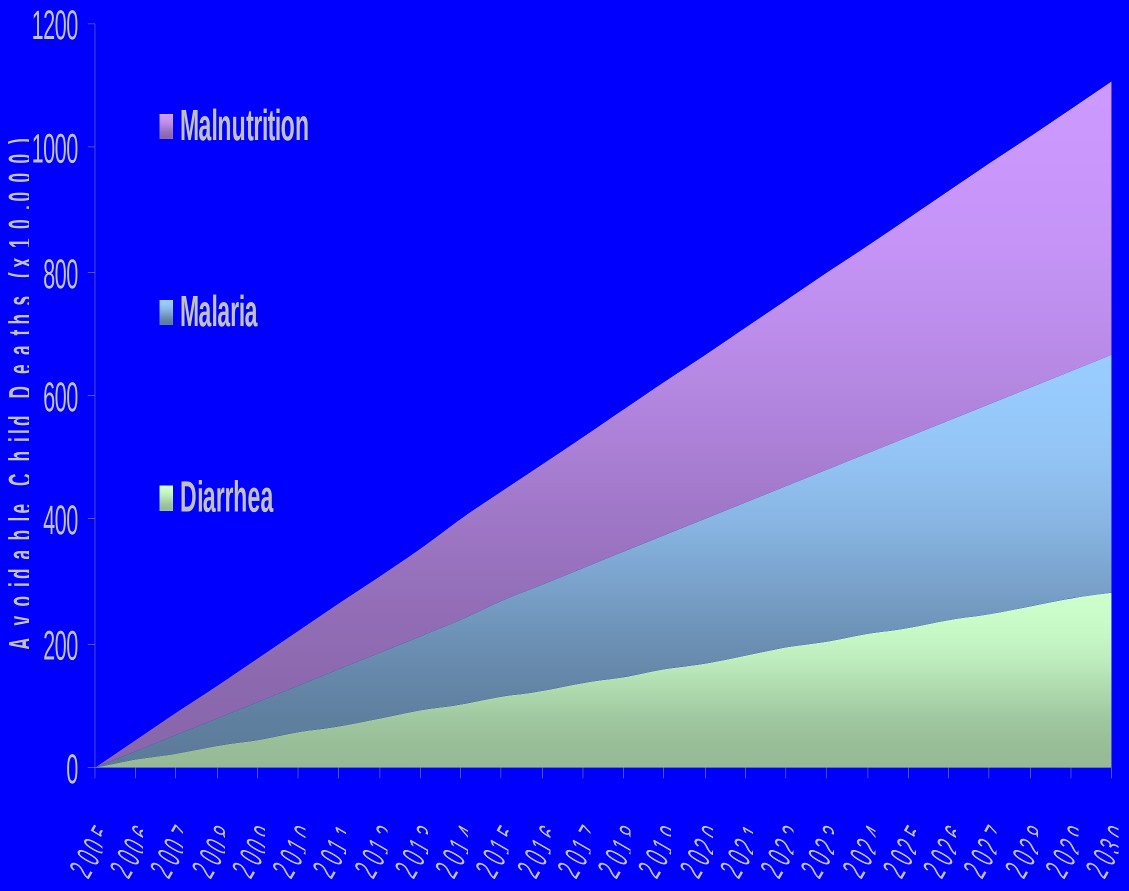
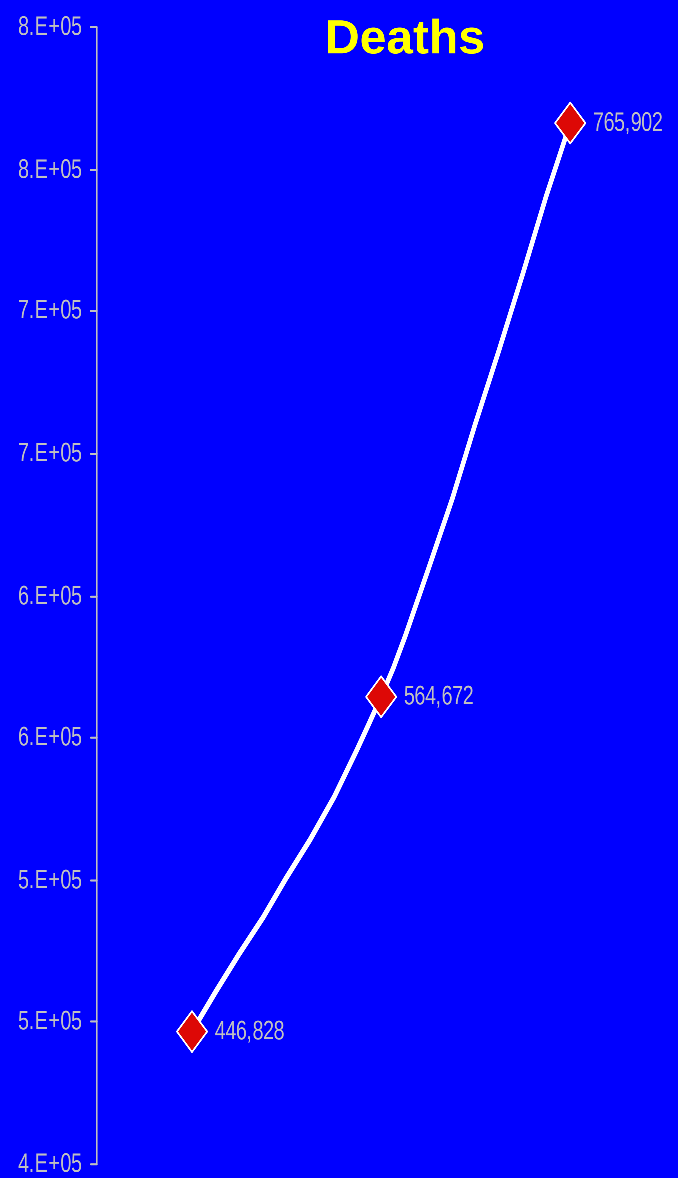
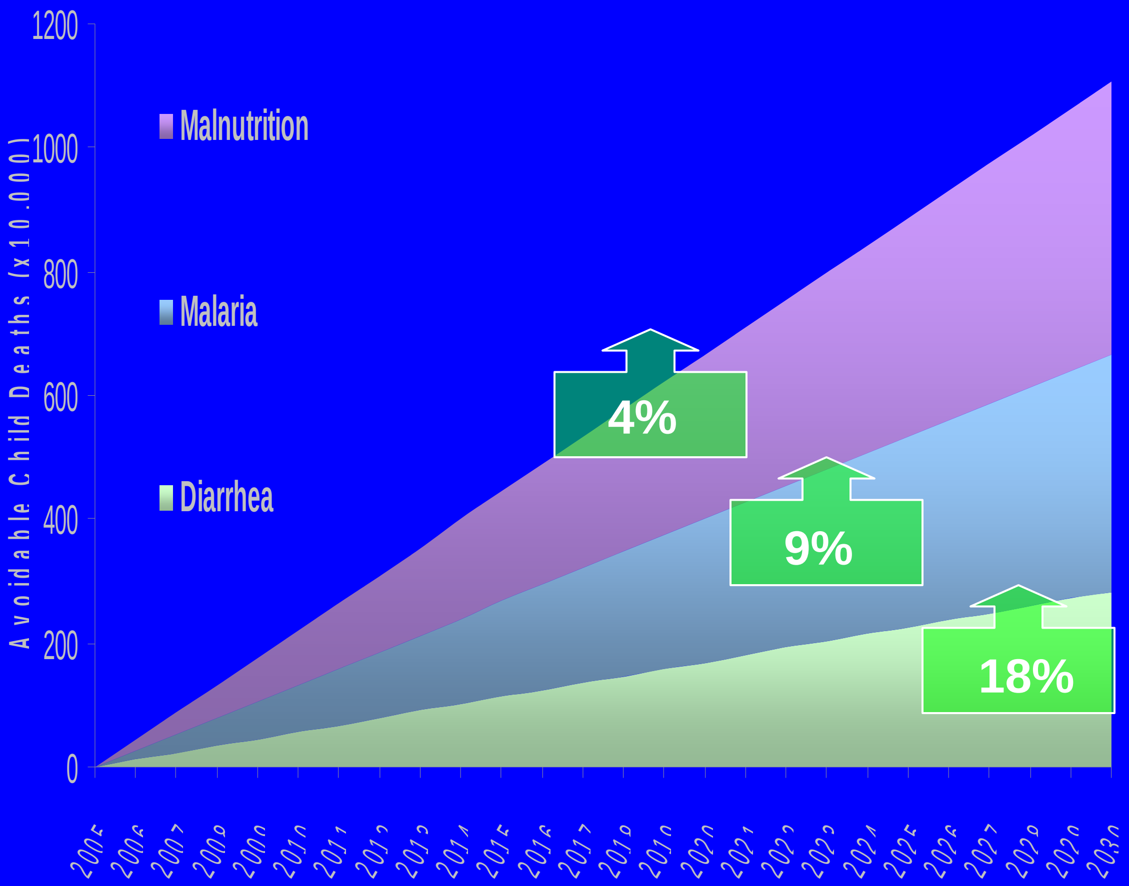
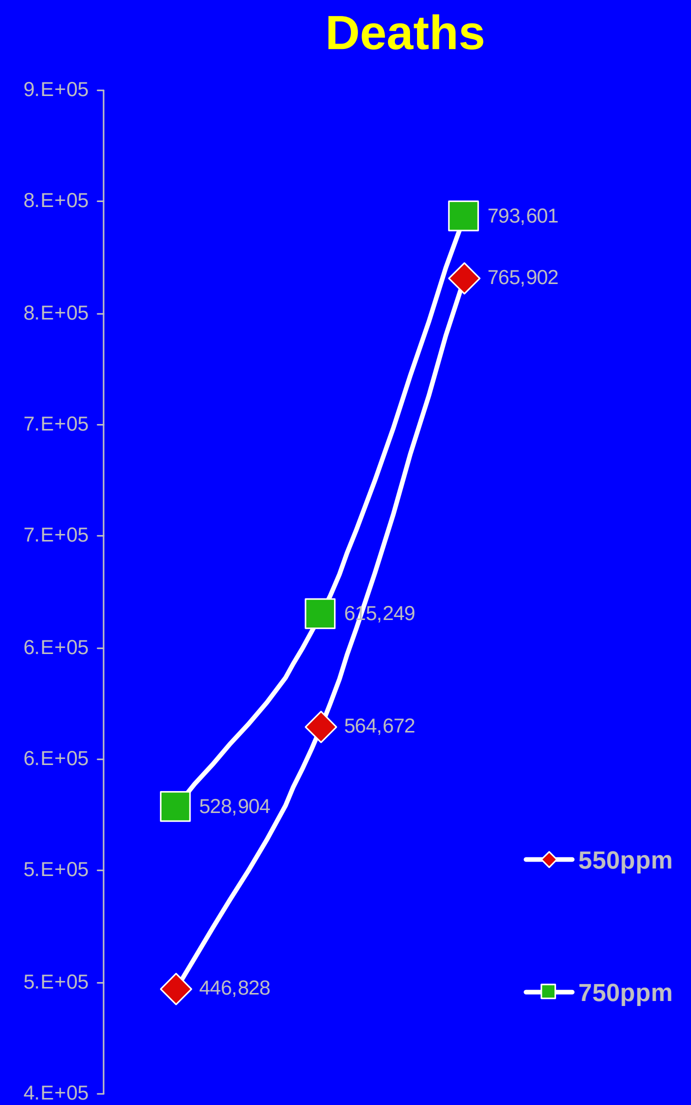




Potential Impacts of Climate Change on Child Mortality in Low Income Countries

750ppm

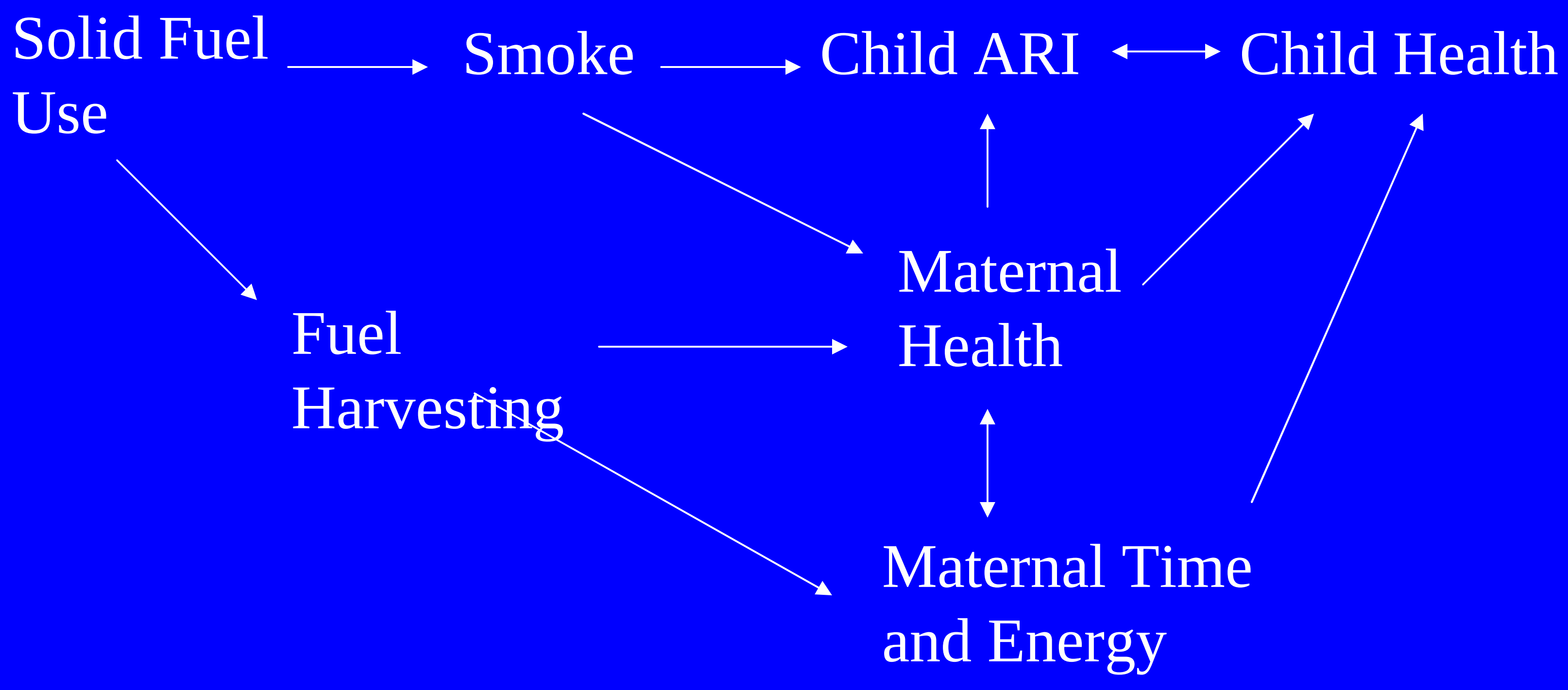




McMichael et al., Climate Change CRA

Thank you.

The Unhealthy Mother Effect



Mark Twain on Casual Pathways

"Soap and education are not as sudden as a massacre, but they are more deadly in the long run"

- Facts Concerning the Recent Resignation, 1867