# Household Air Pollution and Chronic Disease Among the Bottom Billion

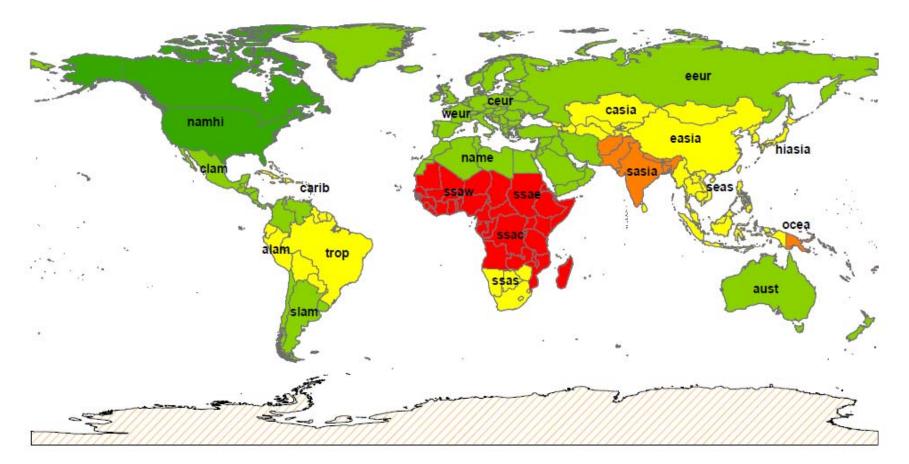
Kirk R. Smith, PhD, MPH Professor of Global Environmental Health University of California, Berkeley

Tackling the Endemic Non-Communicable Diseases of the Bottom Billion Harvard University, March 3, 2011

# What NCD risk factor is shared by all billion people in the bottom billion?

- Diet?
- Physical inactivity?
- Smoking?
- Appropriate infectious agents?
- No
- So ubiquitous, in fact, that it is one of the best quick indicators of poverty?

## Households Using Solid Cooking Fuels

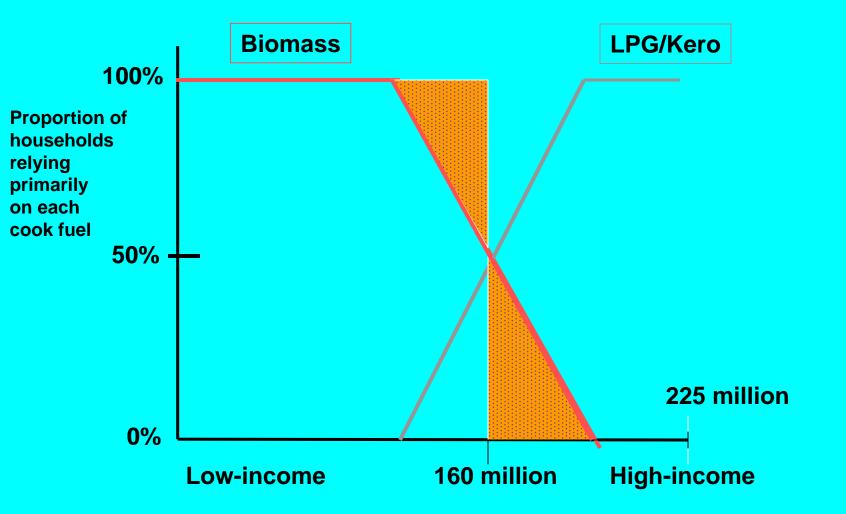


#### % of HH Exposed to HAP



#### For 2005, CRA-10 preliminary

#### **Proportion of Household Meals Cooked by Fuel Type in India**



2005 NFHS

# **Road Map**

- Intro what's wrong with biomass smoke?
- COPD several new meta-analyses
- Lung cancer new meta-analyses for both biomass and coal smoke [not further discussed].
- Cataracts/opacity a major burden
- LBW new meta-analysis, life-long chronic risks?
- Cardiovascular disease interpolation backed up by physiological evidence
- "Epidemiologic" transition do NCD risks rise with development?

## 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)?

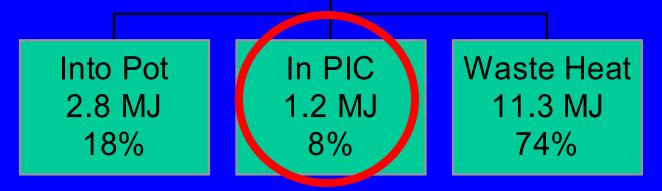


Reason: the combustion efficiency is far less than 100%

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



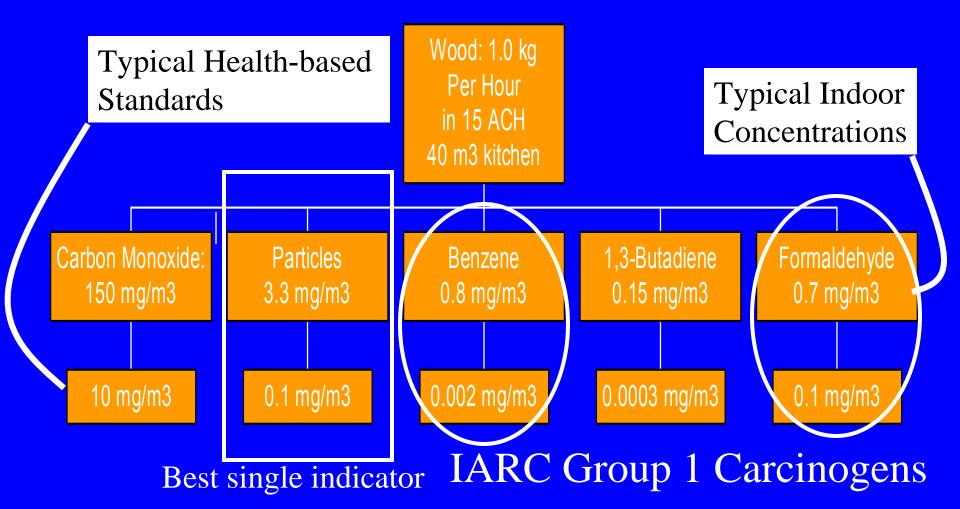
PIC = products of incomplete combustion = CO, HC, C, etc.

Source: Smith, et al., 2000

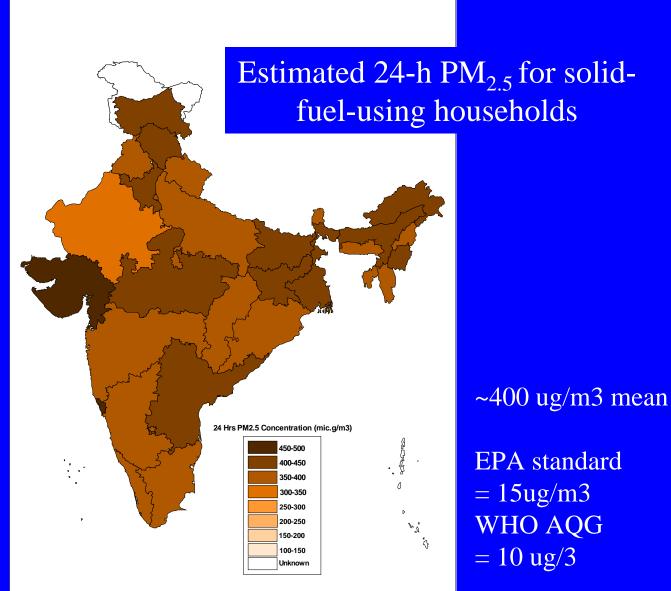
# Toxic Pollutants in Biomass Fuel Smoke from Simple (poor) Combustion

- Small particles, CO, NO<sub>2</sub>
- 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
- Source: Naeher et al, J Inhal Tox, 2007
- Chlorinated organics such as *methylene chloride* and *dioxin*

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



### Household Air Pollution Comparative Risk Assessment, 2011 Preliminary Estimates for India



Balakrishnan et al., in prep 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 ALRI/ Pneumonia (meningitis)

Low birth weight

Stillbirth Cognitive Impairment? Asthma?

Birth defects?

Diseases for which we have epidemiological studies - 2011 Chronic obstructive lung disease

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

Blindness (cataracts, opacity)

Tuberculosis?

Heart disease\* Blood pressure ST-segment

\*Interpolated

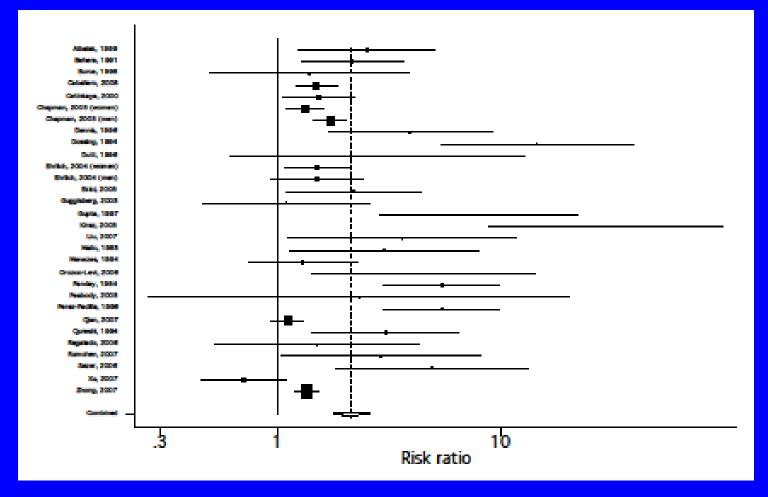
# Biomass Smoke and COPD: Meta-analysis

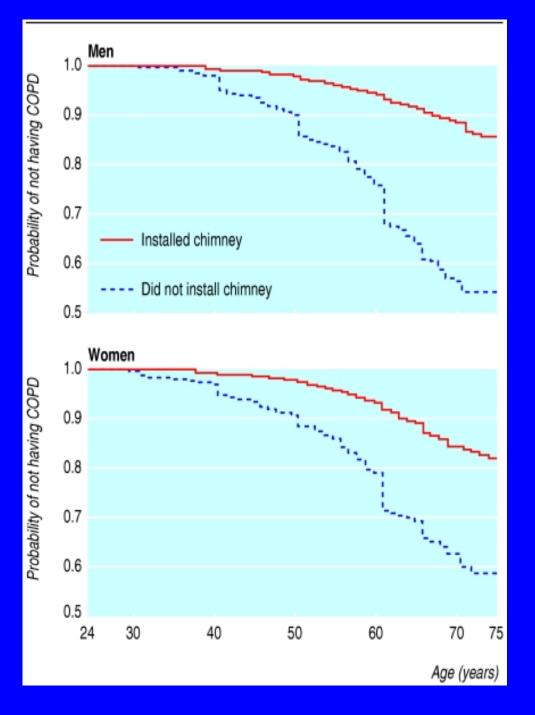
- Summary RR estimates calculated using both fixed effects and random effects models
- Heterogeneity among studies assessed using general variancebased methods
- Publication bias assessed using funnel plot, Eggers and Begg's tests

Exposure Assessment Used for Analysis	# of Final Studies
Fuel Type	19
Coal Only	7
Wood Only	6
Stove Type	2
Years Exposed	5
Urban v. Rural	2
	2
Outcome Assessment	<pre># of Final Studies</pre>
	# of Final
Outcome Assessment Chronic Bronchitis,	# of Final Studies

### **Forest Plot for All Studies Included in Meta-analysis**

- Random effects model was used to account for significant heterogeneity between studies X<sup>2</sup>=150.329, *df*=29 (*p*=0.000)
- Overall effect measure for all studies, OR=2.140 (1.777, 2.577)





**Risk of COPD:** Vented vs. unvented coal stoves

Xuan Wei County China, retrospective cohort, 1976-1992, 20,453 subjects 81% added chimneys

Chapman et al. Br Med J 2005; 331: 1050.

# Cataracts

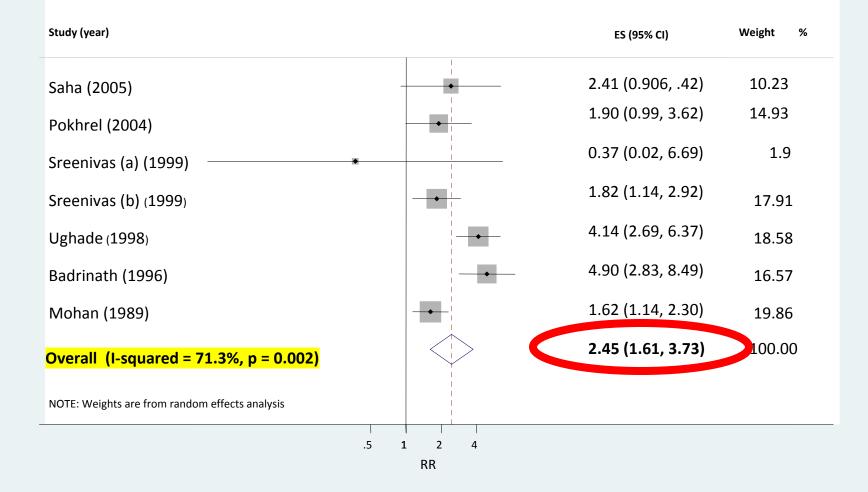
- Major burden of disease in developing countries
- In South Asia, 2.8% of total DALYs in 2005
- Half that of ischaemic heart disease
- Roughly same as TB or stroke
- Greater than COPD or maternal conditions
- Women suffer 40% more than men

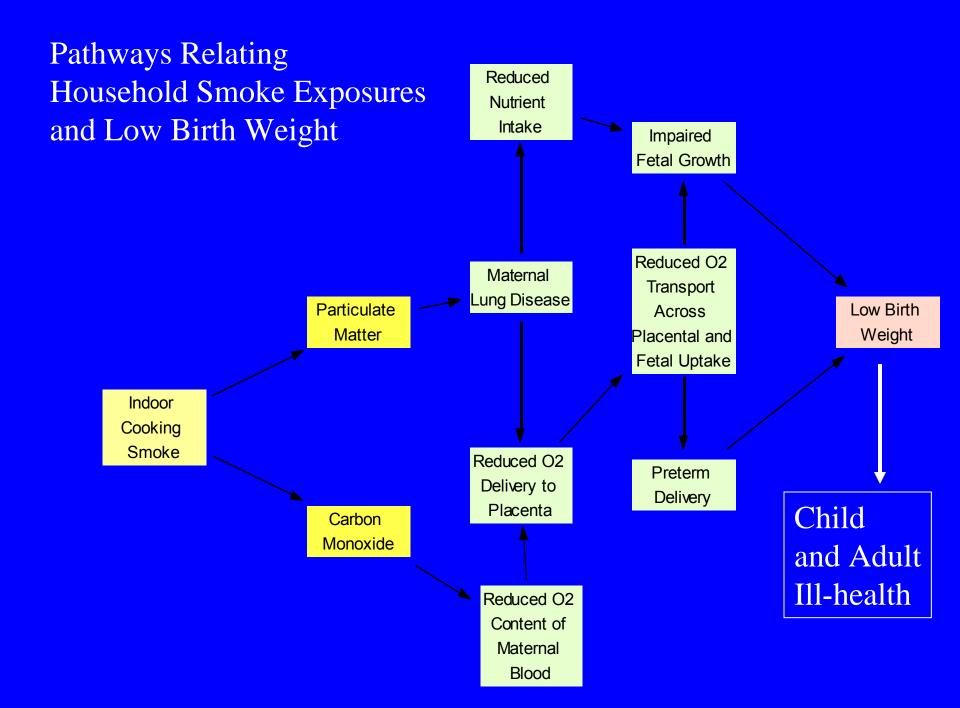
## HAP and cataract: biological plausibility

- Cataracts have several known risk factors: UV, diabetes, tobacco smoke
- Napthalene, a prevalent product of incomplete biomass combustion, is a reactive oxidative species (ROS) causing oxidative stress & damage to the eye,
- Cataract outcomes have been shown in rabbits and cows with prolonged exposure or under high doses
- Recent study in Nepal shows exposure-response with biomass smoke exposure and lens opacity, a preclinical indicator of cataracts.

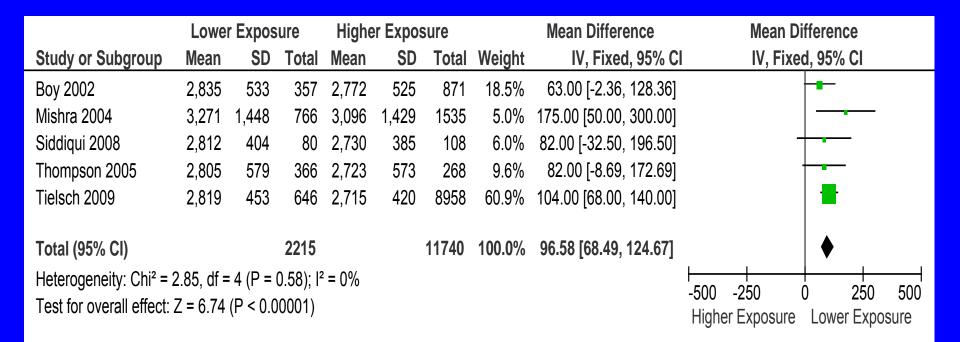
# Summary of 7 (of 9 total) studies

#### Studies adjusted for smoking (random effects)





# Pooled birth weight difference (low minus high exposure): Adjusted estimates



All estimates: +96.6g (68.5, 124.7) Excluding self-reports +93.1g (64.6, 121.6) Chimney Stove Intervention to Reduce Long-term Woodsmoke Exposure Lowers Blood Pressure among Guatemalan Women

> John P. McCracken, Kirk R. Smith, Murray A. Mittleman, Anaité Díaz, Joel Schwartz

(Published in Environmental Health Perspectives, July 2007)

# Study Design

- Study population
  - Eligible: Women  $\geq$  38 years, cooking daily
  - Excluded: pregnant, breastfeeding
- Two follow-up periods
  - Randomized trial period (7/03-12/04)
  - Echo-intervention period (3/04-3/05)

# **Personal PM<sub>2.5</sub>**



## **SBP and DBP**



# Between-Groups Results During Randomization

	Number of subj	ects (measures)	Adjusted mean difference*							
	Control group	Intervention group	Estimate	95% CI	p-value					
SBP	71 (111)	49 (115)	-3.7	-8.1, 0.6	0.10					
DBP	71 (111)	49 (115)	-3.0	-5.7, -0.4	0.02					

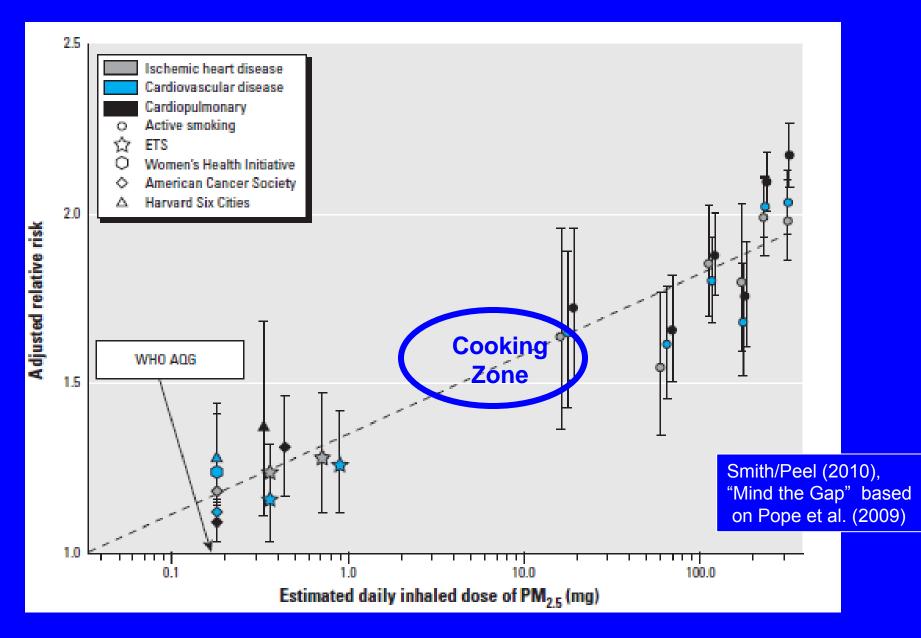
\* Adjusted for age, body mass index, daily temperature, season, day of the week, time of day, use of wood-fired sauna, household electricity, an asset index, ever smoking, and secondhand tobacco smoke exposure

# **Before-and-After Results**

Trial period     Echo-intervention     Estimate     95% CI       SDD     55 (89)     55 (65)     2 1     5 2 0 8	p-value
SDD = 55 (00) = 55 (65) = 21 = 52 0.0	
SBP       55 (88)       55 (65)       -3.1       -5.3, -0.8	0.01
DBP 55 (88) 55 (65) -1.9 -3.5, -0.4	0.01

\* Adjusted for age, body mass index, daily temperature, season, day of the week, time of day, use of wood-fired sauna, household electricity, an asset index, ever smoking, and secondhand tobacco smoke exposure

#### Heart Disease and Combustion Particle Doses



# Argument from consistency across combustion particle exposures for CVD

- Fine combustion particles are best measure of risk in each setting and seem to have similar effects per unit mass across the four source types
  - Three are mainly biomass
  - Outdoor air pollution contains significant biomass particles
  - Probably difference by outcome, however e.g., LBW and lung cancer may be related to other components as well
- Remarkable consistency across 3 orders of magnitude of dose measured in mg/day of PM<sub>2.5</sub>
- Where household air pollution has no direct epi data, seems reasonable to interpolate for outcomes where there are well established effects at both lower and higher doses.

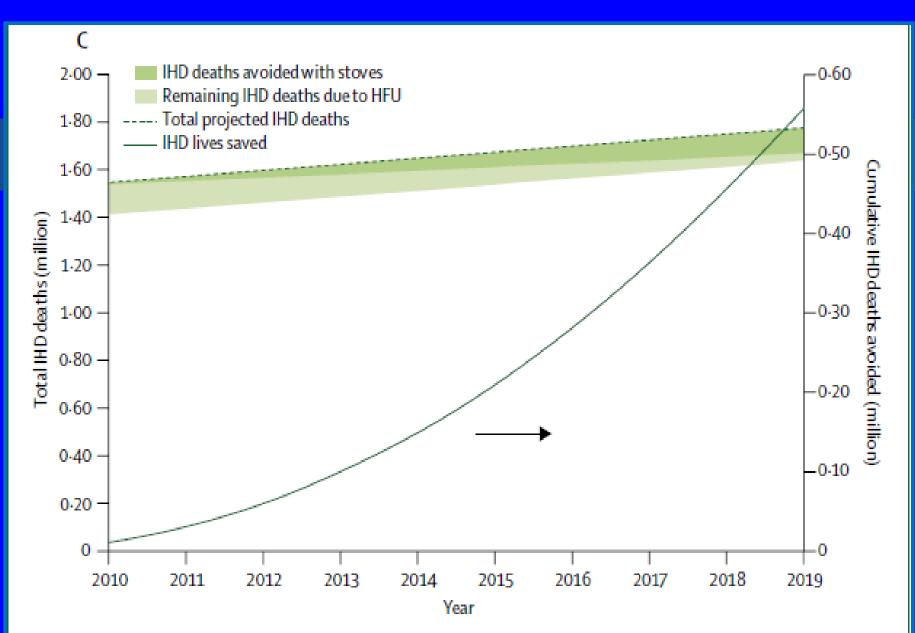
Indian National Biomass Cookstove Initiative – Dec 2, 2009

• "Our aim is to achieve the quality of energy services from cookstoves [for all Indian households] comparable to that from other clean energy sources such as LPG."

Analysis of total health benefits of 150 million advanced stoves introduced over 10 years in India Wilkinson, Smith, et al., <u>the Lancet 374</u>:1917-29, 2009

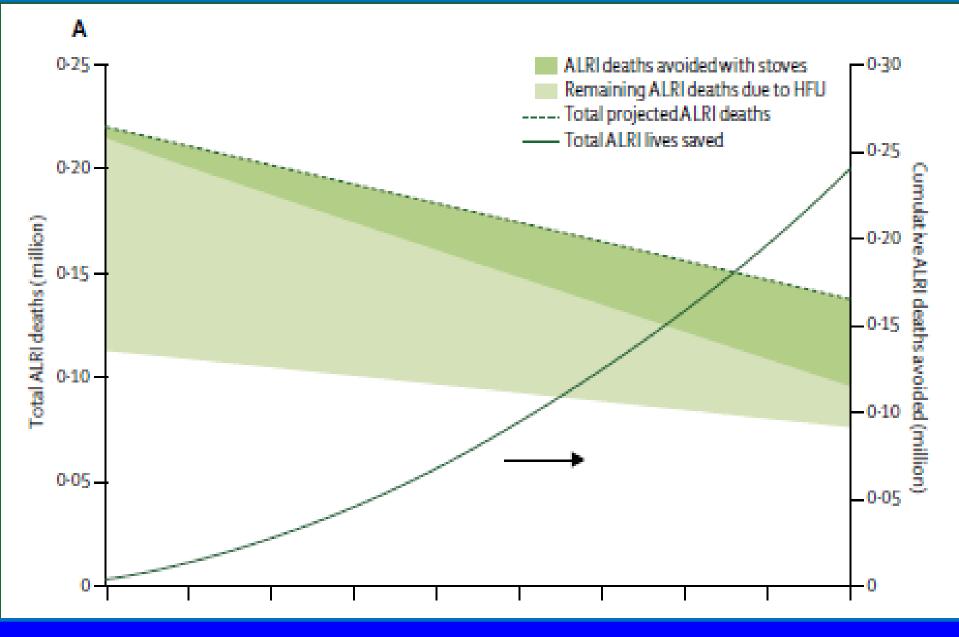
## Ischaemic Heart Disease

#### THE LANCET



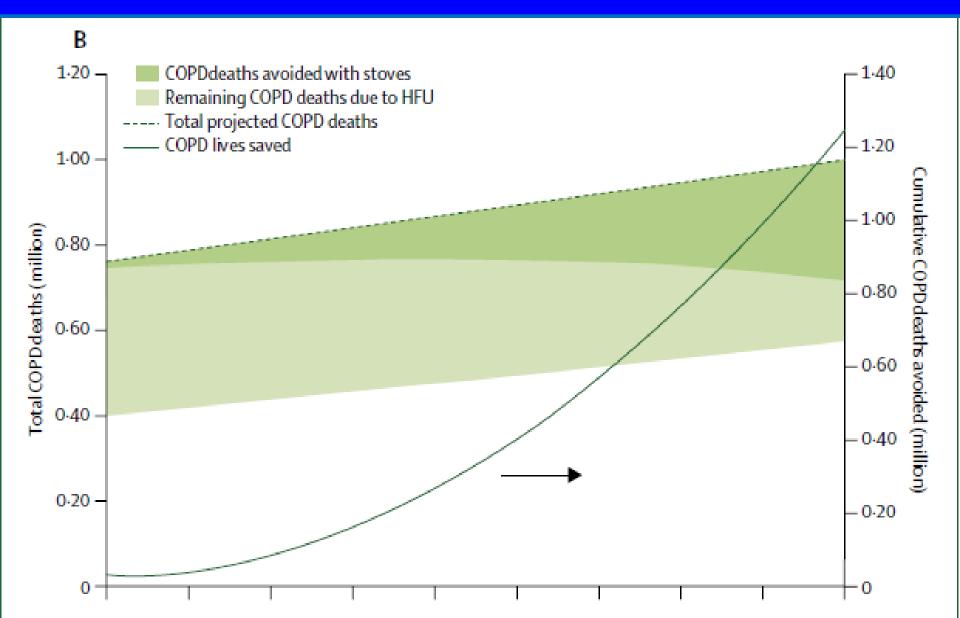
#### THE LANCE

### ALRI < 5 years

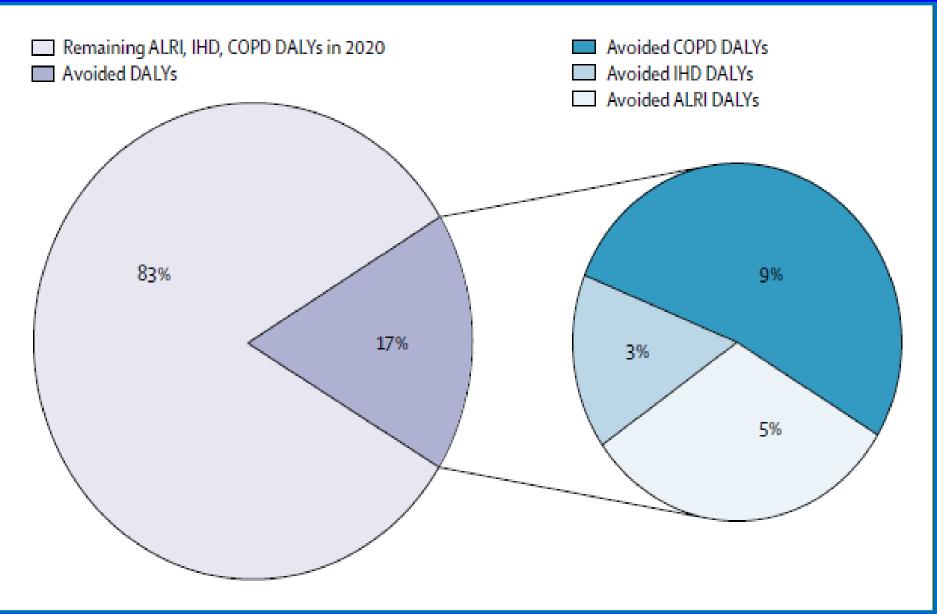


### Chronic Obstructive Pulmonary Disease

#### THE LANCET

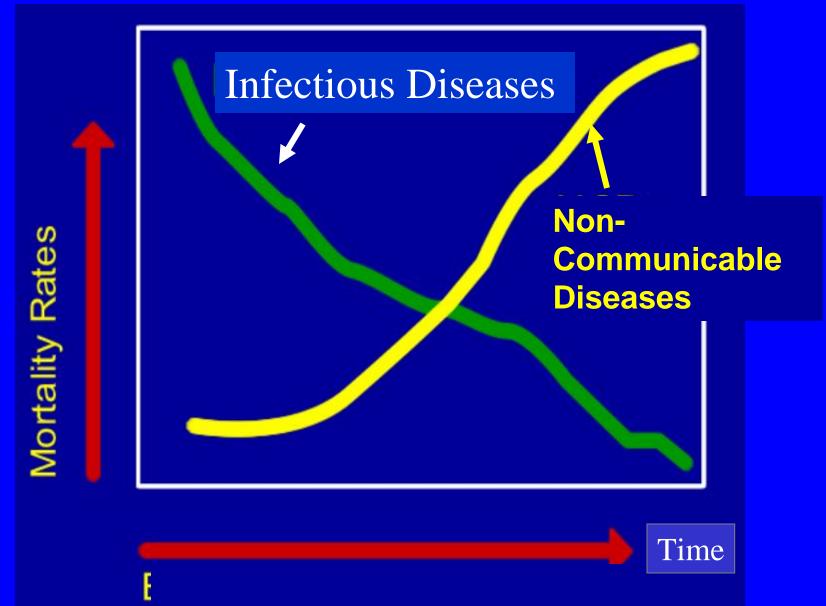


## Health Benefits Upon Completion, 2020 THE LANCET



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WORL	D																	
						100000000	Maie		1	WYNOR -					19111200-	Female		
Code	Cause	Total	0-4	5-14	15-29	30-44	45-59	60-69	70-79	80+	Totai	0-4	5-14	15-29	30-44	45-59	60-69	1
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U001	I. Communicable, maternal, per	inatal 610519250		20979812	29721889	56148775	16631072	5676094	2913759	849889			25248712	59740290	35979204	11499502	4476364	2
	and nutritional conditions																	
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U003	1. Tuberculosis 2. STDs excluding HIV	11347067	1521528	26245	1080828	660600	423721	1032063	31641	7415	3854983	1726606	97221	4158088	1147558	260537	71612	
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016	e. Tetanus														36620	14737	4192	
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023	b. Chagas disease														51644	48058	15987	
1024 1025	c. Schistosomiasis d. Leishmaniasis													128589	58850	17056		
025 1026	d. Leishmaniasis e. lymphatic filaria														67203 206680	30097 266630	11647 15772	
027	f. Onchocerciasis			D				1 - 1-							59892	46198	11380	
028	10. Leprosy			Be	ing	con	ndle	Iel		<b>D</b> ai					15828	9135	4389	
029	11. Dengue														10408	6396	2644	
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031	13. Trachoma 14. Intestinal nemato	For 2011 release												517423 5192	559520 5921	344796 3469		
033	a. Ascariasis														161	<b>3321</b> 21	3 <b>763</b> 111	
034	b. Trichuriasis														388	433	238	
035	c. Hookworm dises														4212	4859	2723	
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56																		

## The Classic Epidemiological Transition



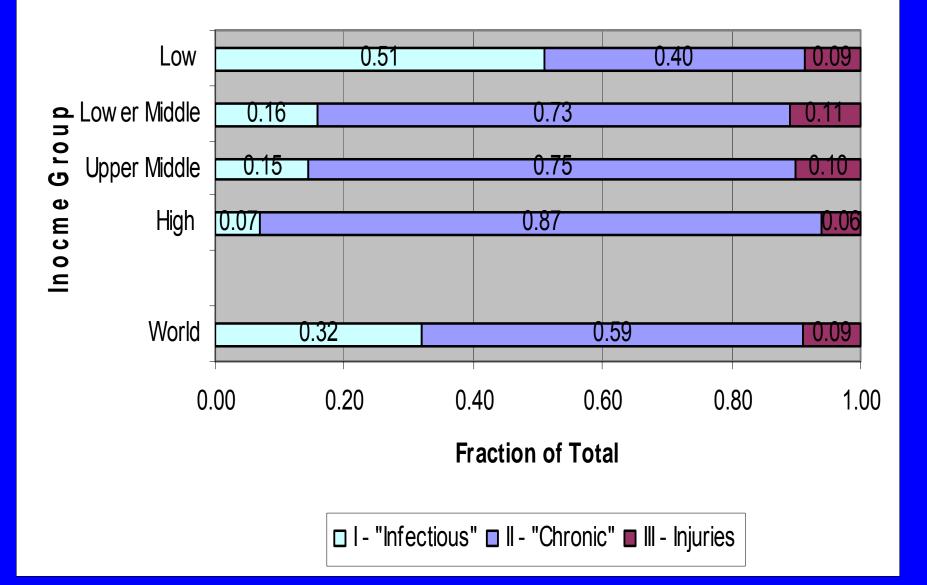
# **Disease Categories**

- I Traditional, Communicable
  - Infectious, maternal, perinatal, nutritional
- II Modern, Non-communicable
  - Cancer, heart, neuro-psychiatric, chronic lung, diabetes, congenital
- III Injuries, Non-Transitional
  - Unintentional
    - Motor vehicle, poisoning, falls, fire, drowning
  - Intentional
    - Suicide, violence, war

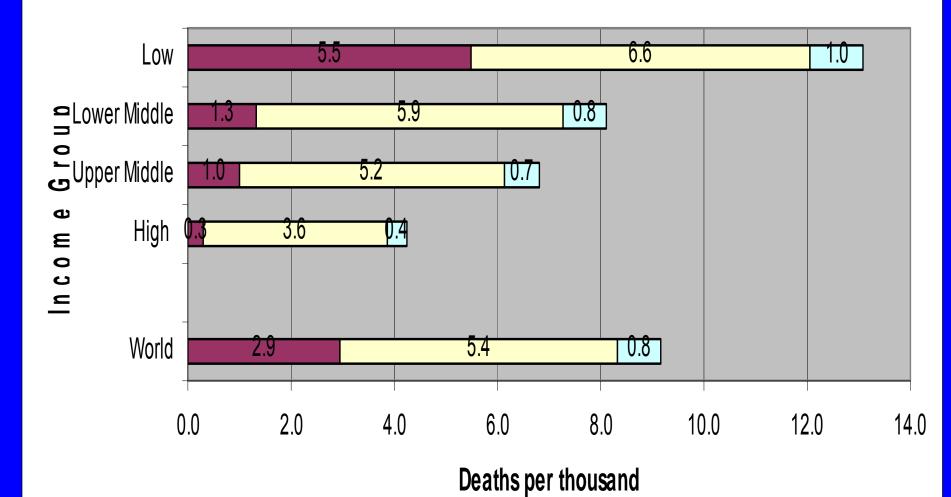
# **Classic Epi Transition**

- I. Infectious diseases decline during development
- II. Chronic disease rise during development
- III. Injuries show no pattern during development and are thus "non-transitional"
- Test using GBD databases only coherent global database for mortality and morbidity
- From Smith/Ezzati, 2005.

## **Classic Mortality Transition**

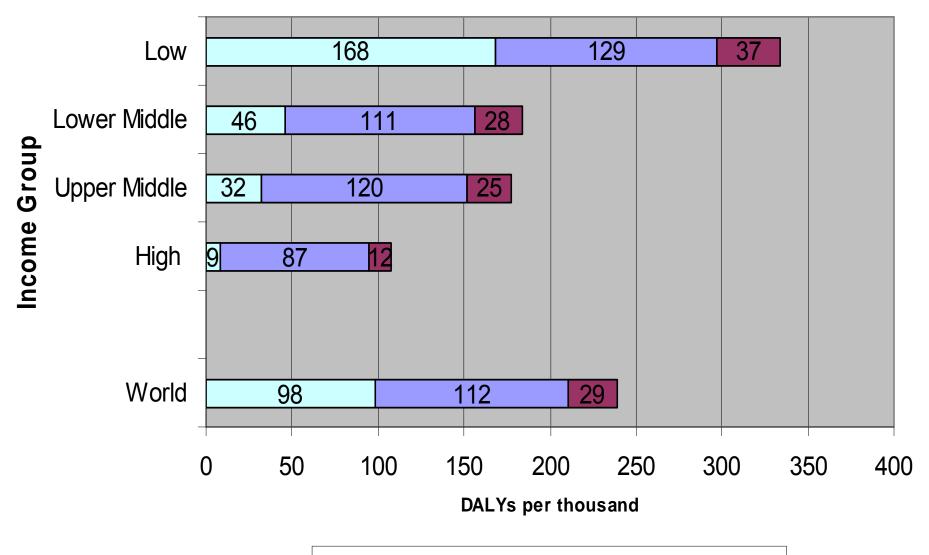


## Mortality Transition - Age Adjusted



■ I - "Infectious" ■ II - "Chronic" ■ III - Injuries

**Epidemiological Transition - Age Adjusted** 

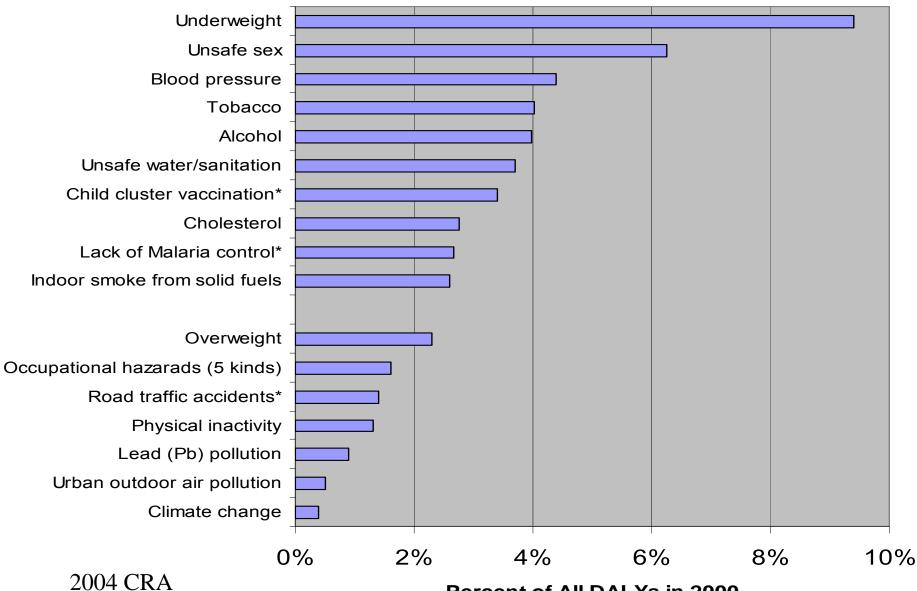


□ I - "Infectious" □ II - "Chronic" ■ III - Injuries

# Epi Transition: Updated

- In terms of actual age-adjusted impact on populations, all classes of disease decline during development
  - I. Declines dramatically at every level
  - II. Declines slowly, but with little decline seen across middle income regions
  - III. Declines in a similar way to II and thus is not "non-transitional"
- Better to be rich for all major types of ill-health, although there are exceptions for individual diseases

#### Global Burden of Disease from Top 10 Risk Factors plus selected other risk factors



Percent of All DALYs in 2000



Publications and presentations available at my website: <u>http://ehs.sph.berkeley.edu/krsmith/</u>

Or just Google "Kirk R. Smith"