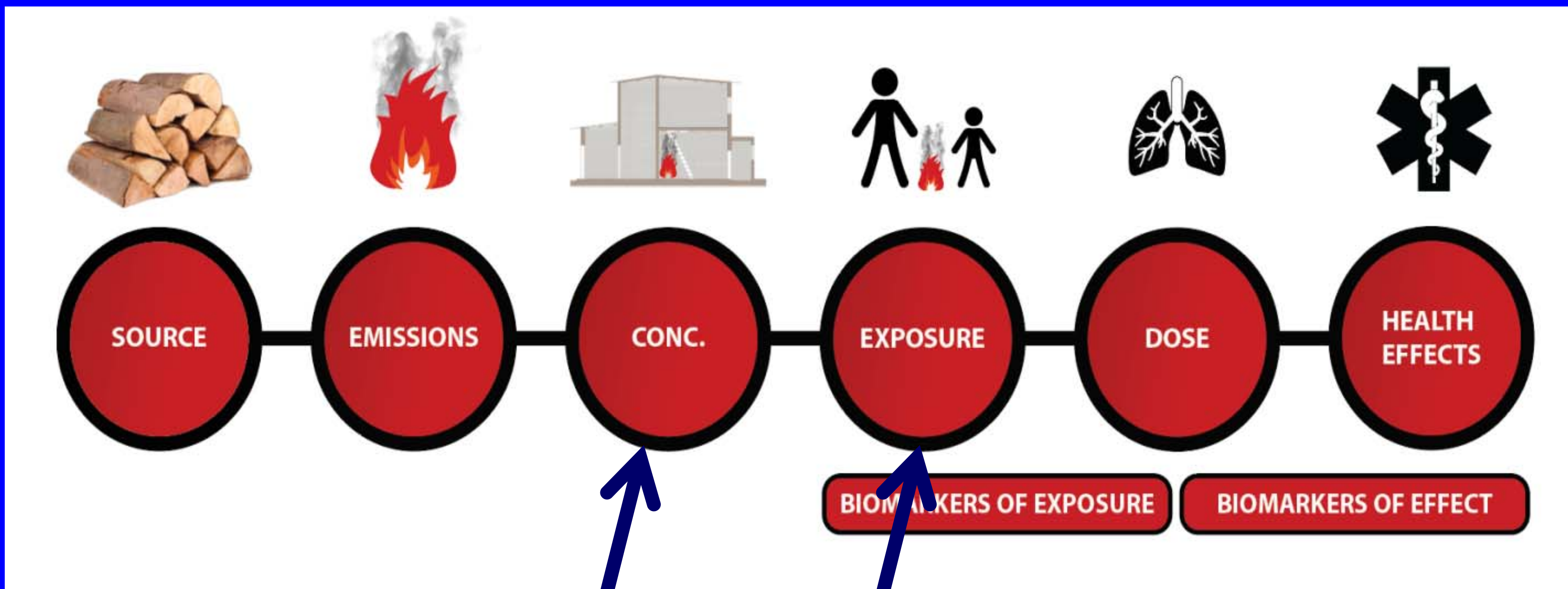
The Prospects for Exposure Management of Air Pollution: India, China, Mongolia, and California

Kirk R. Smith
Professor of Global Environmental Health
University of California Berkeley
Director, Collaborative Clean Air Policy Centre
New Delhi

WHO SEARO Meeting on Air Pollution
Bangkok, June 18, 2018



Classic air pollution control focuses on concentrations in fixed locations

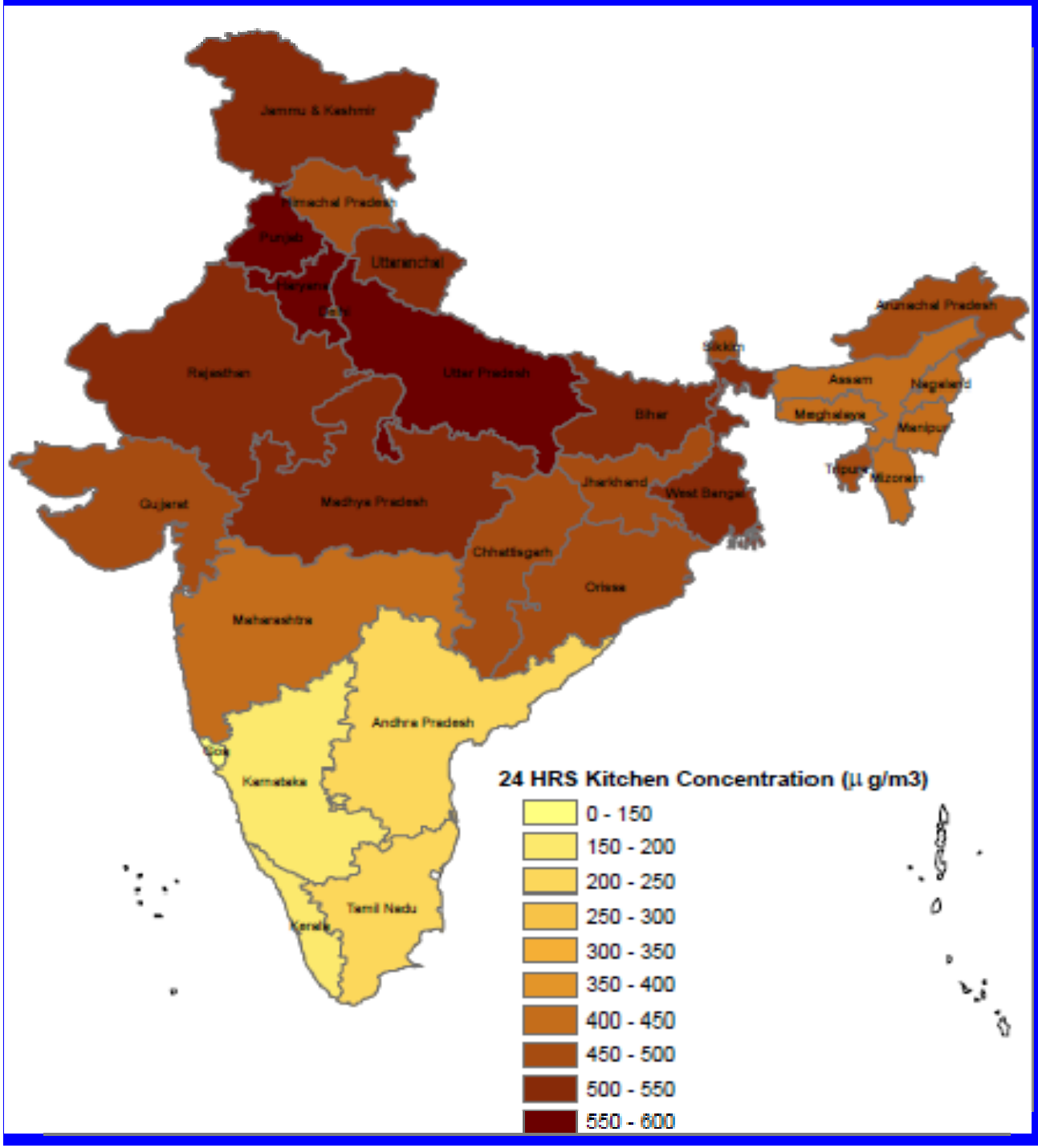
Exposure is a much better metric for understanding and controlling health risk

Exposure is what we can measure that most directly relates to health

- But generally countries only use concentration as the metric for air pollution monitoring and control measures
- What progress is being made in adding metrics of exposure?

India

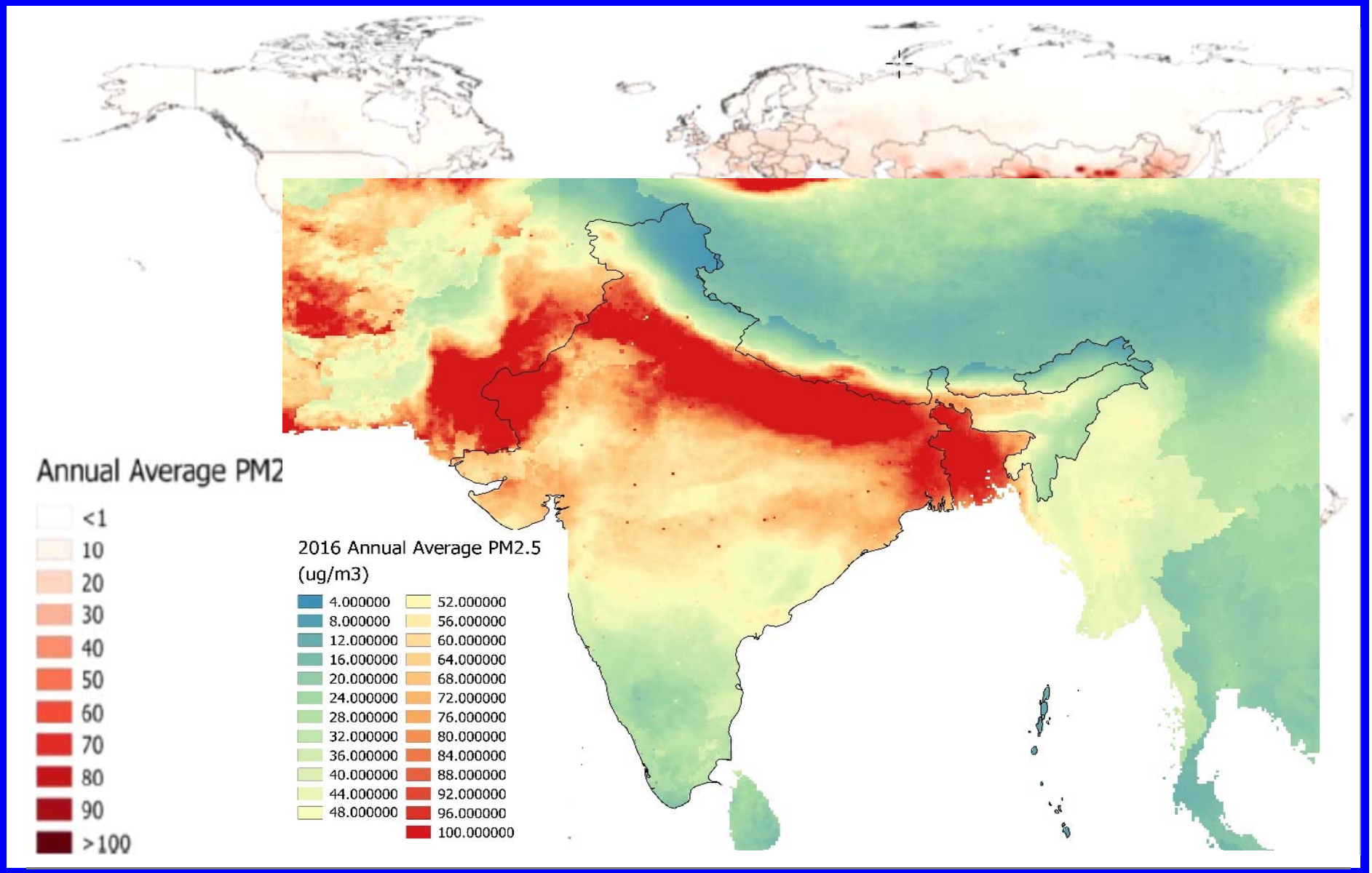
- ~Two-thirds of people use solid cookfuels
- Most polluted cities in the world -- now understood to be worse than China
- Highest burden of disease from air pollution in the world as a result
- Highest total air pollution burden/capita of all middle-income countries – 2x China



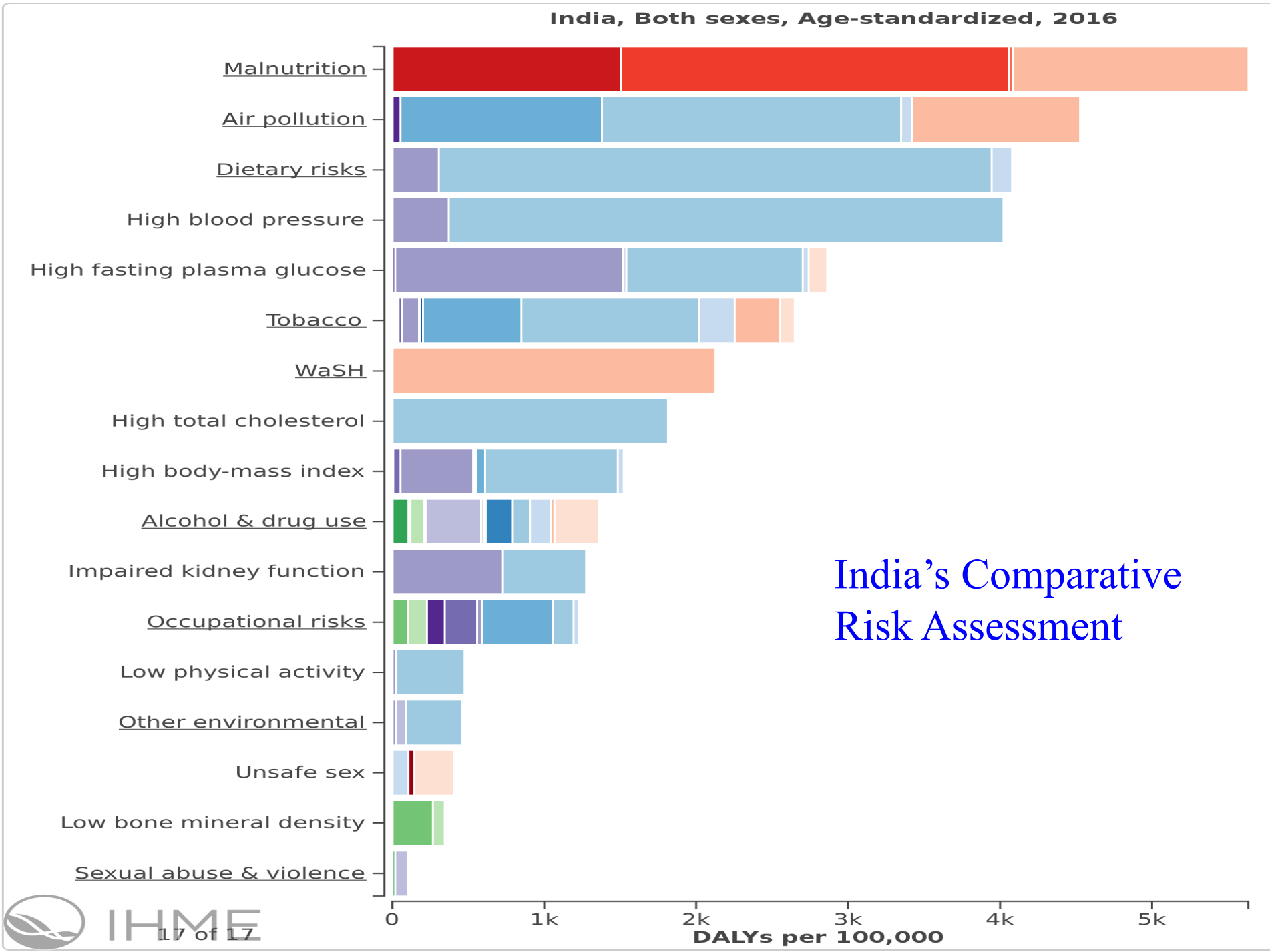
State-wise estimates of 24-h kitchen concentrations of PM2.5 in India

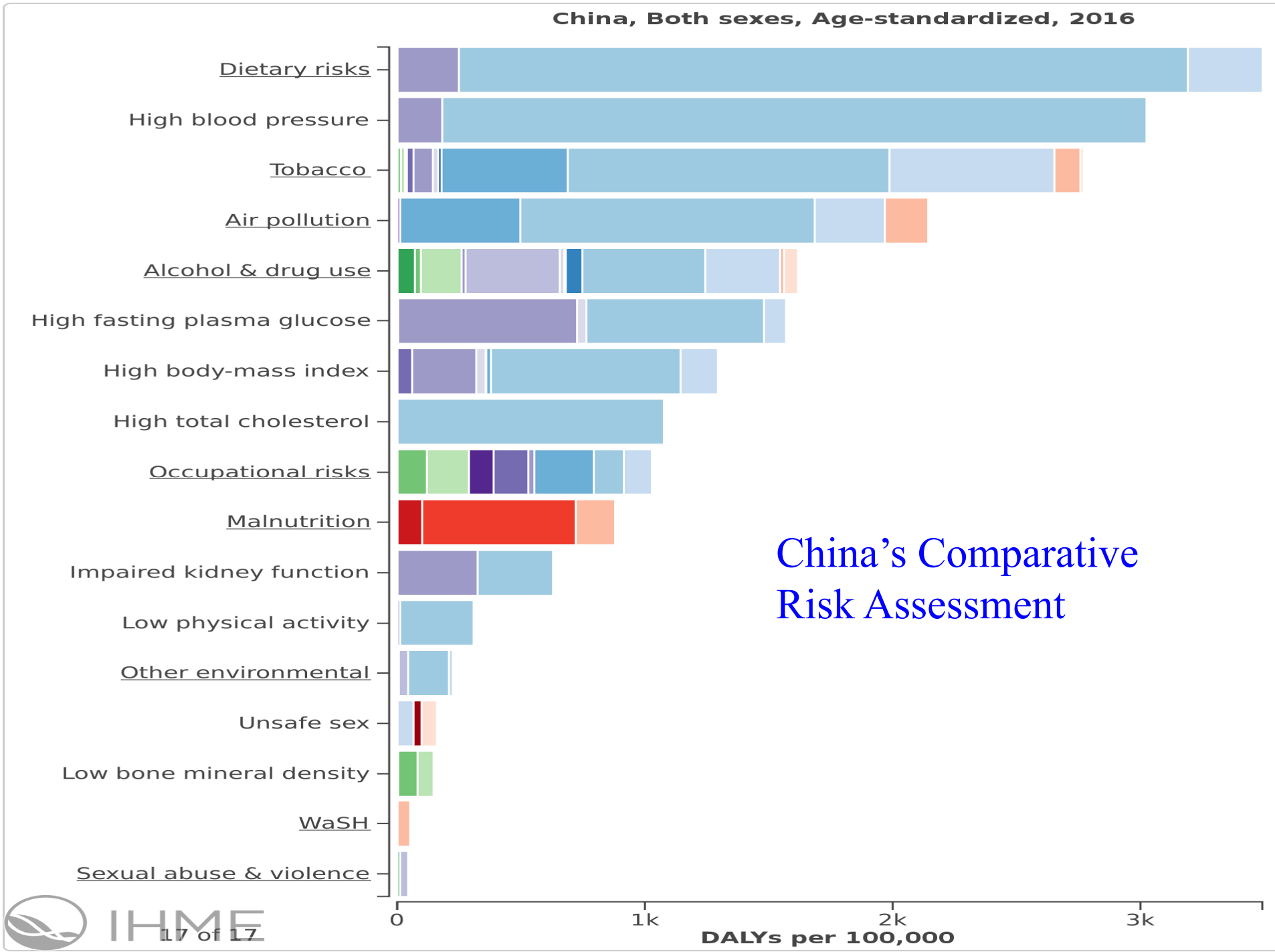
Solid-fuel using households

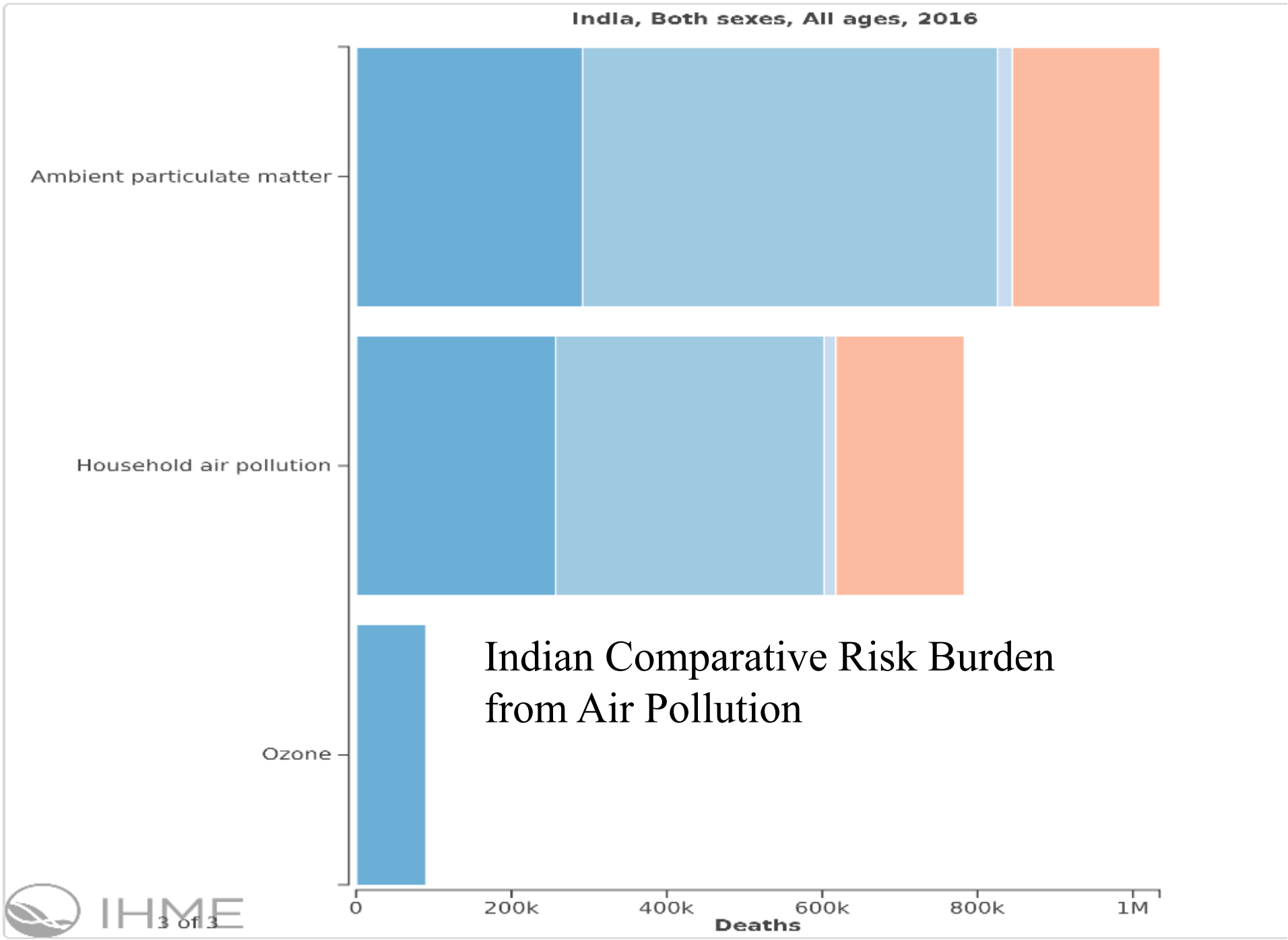
Balakrishnan et al. 2013



Brauer et al., EST, 2015


India, Both sexes, Age-standardized, 2016
Malnutrition
Air pollution
Dietary risks
High blood pressure
High fasting plasma glucose
Tobacco
WaSH
High total cholesterol
High body-mass index
Alcohol & drug use
Impaired kidney function
Occupational risks
Low physical activity
Other environmental
Unsafe sex
Low bone mineral density
Sexual abuse & violence
0
1k
2k
3k
4k
5k
DALYs per 100,000
India's Comparative Risk Assessment


China, Both sexes, Age-standardized, 2016
Dietary risks
High blood pressure
Tobacco
Air pollution
Alcohol & drug use
High fasting plasma glucose
High body-mass index
High total cholesterol
Occupational risks
Malnutrition
Impaired kidney function
Low physical activity
Other environmental
Unsafe sex
Low bone mineral density
WaSH
Sexual abuse & violence
0
1k
2k
3k
DALYs per 100,000
China's Comparative Risk Assessment



Indian Comparative Risk Burden from Air Pollution

SPECIAL REPORT 21

HEALTH EFFECTS INSTITUTE

January 2018

Burden of Disease Attributable to Major Air Pollution Sources in India

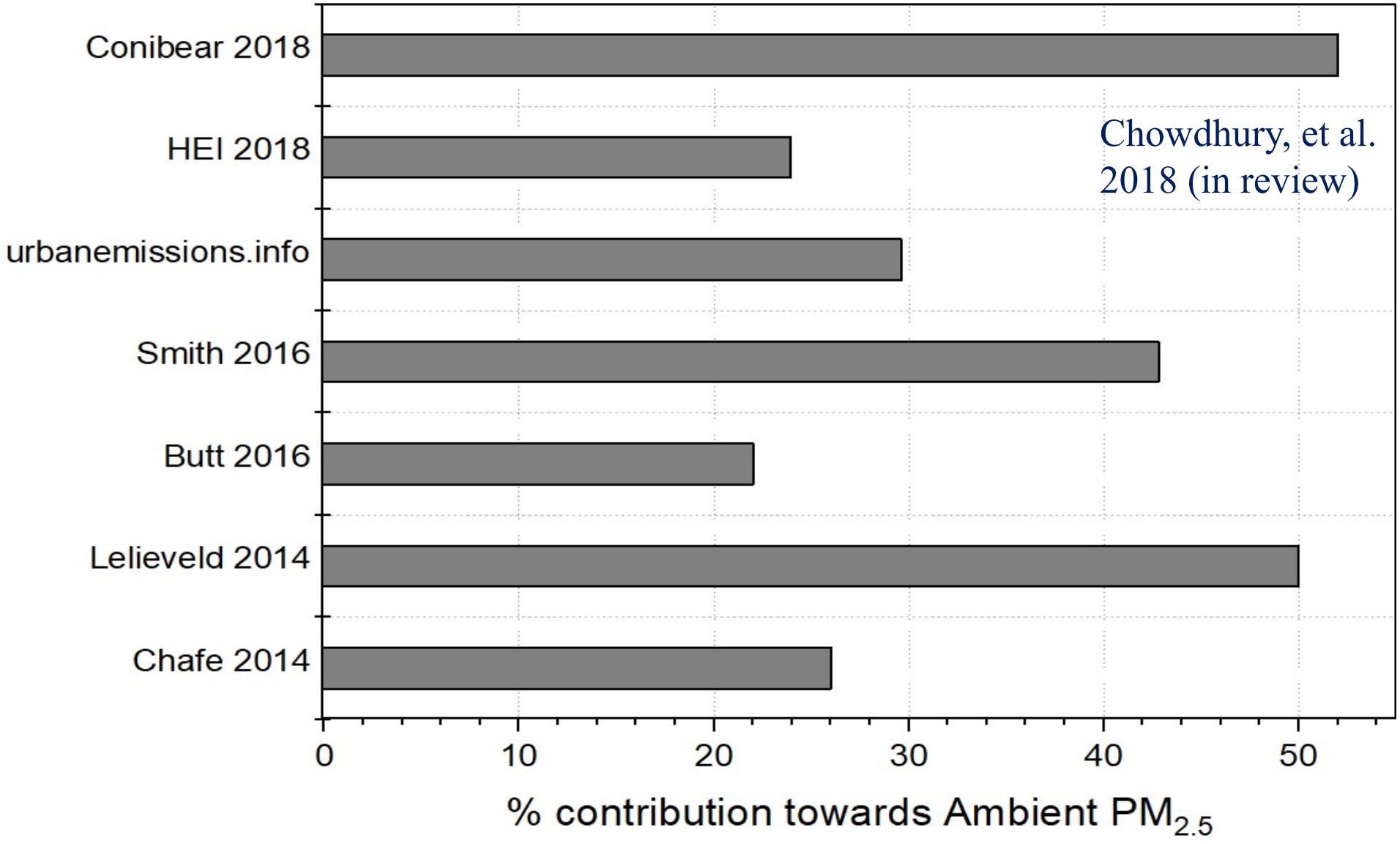
GBD MAPS Working Group

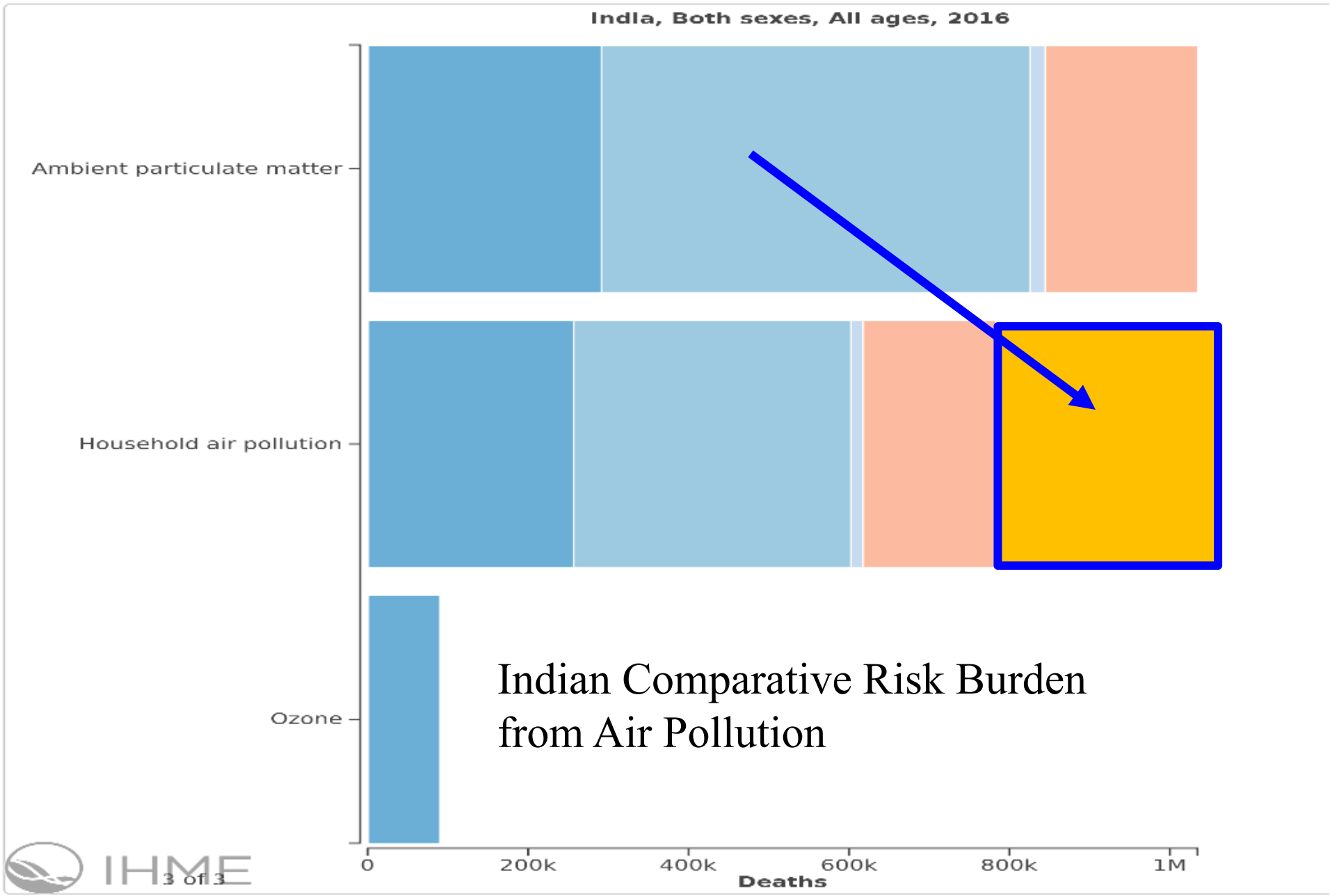
Table 2. Mean Percentage Contribution of Different Source Sectors to Population-Weighted Ambient $PM_{2.5}$ in India for 2015[a]

Source Sector	All India (%)	Rural India (%)	Urban India (%)
Residential biomass	23.9	24.2	22.1
Total coal	15.7	15.5	17.1
Industrial coal	7.7	7.6	8.5
Power plant coal	7.6	7.5	8.0
Open burning	5.5	5.5	5.6
Transportation	2.1	2.1	2.1
Brick production	2.2	2.1	2.2
Distributed diesel	1.8	1.8	1.4
Anthropogenic dust[b]	8.9	8.8	9.6
Total dust[c]	38.8	38.7	39.5

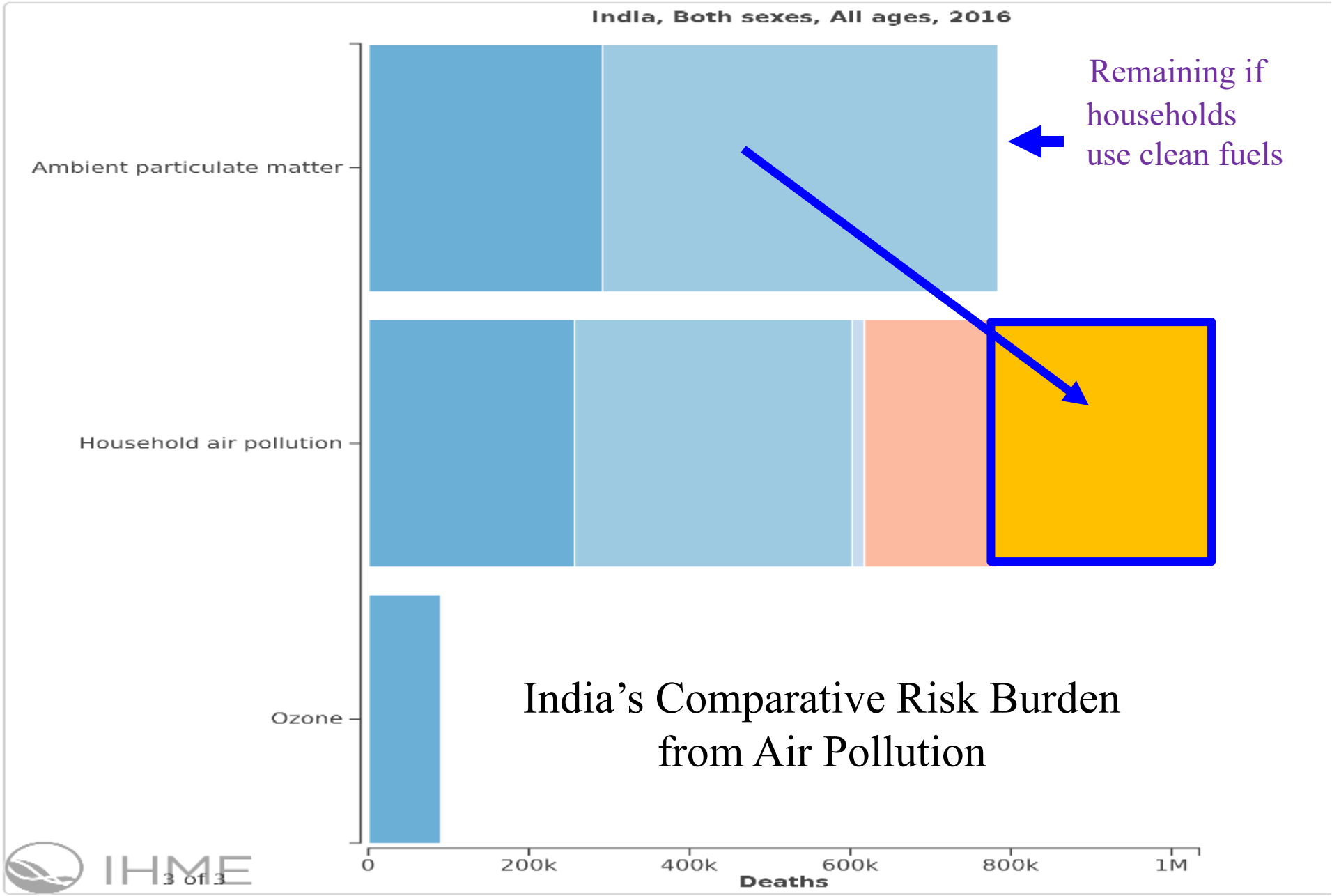
GBD MAPs Study, Jan 2018

How much do households contribute to ambient PM2.5 exposures in India?



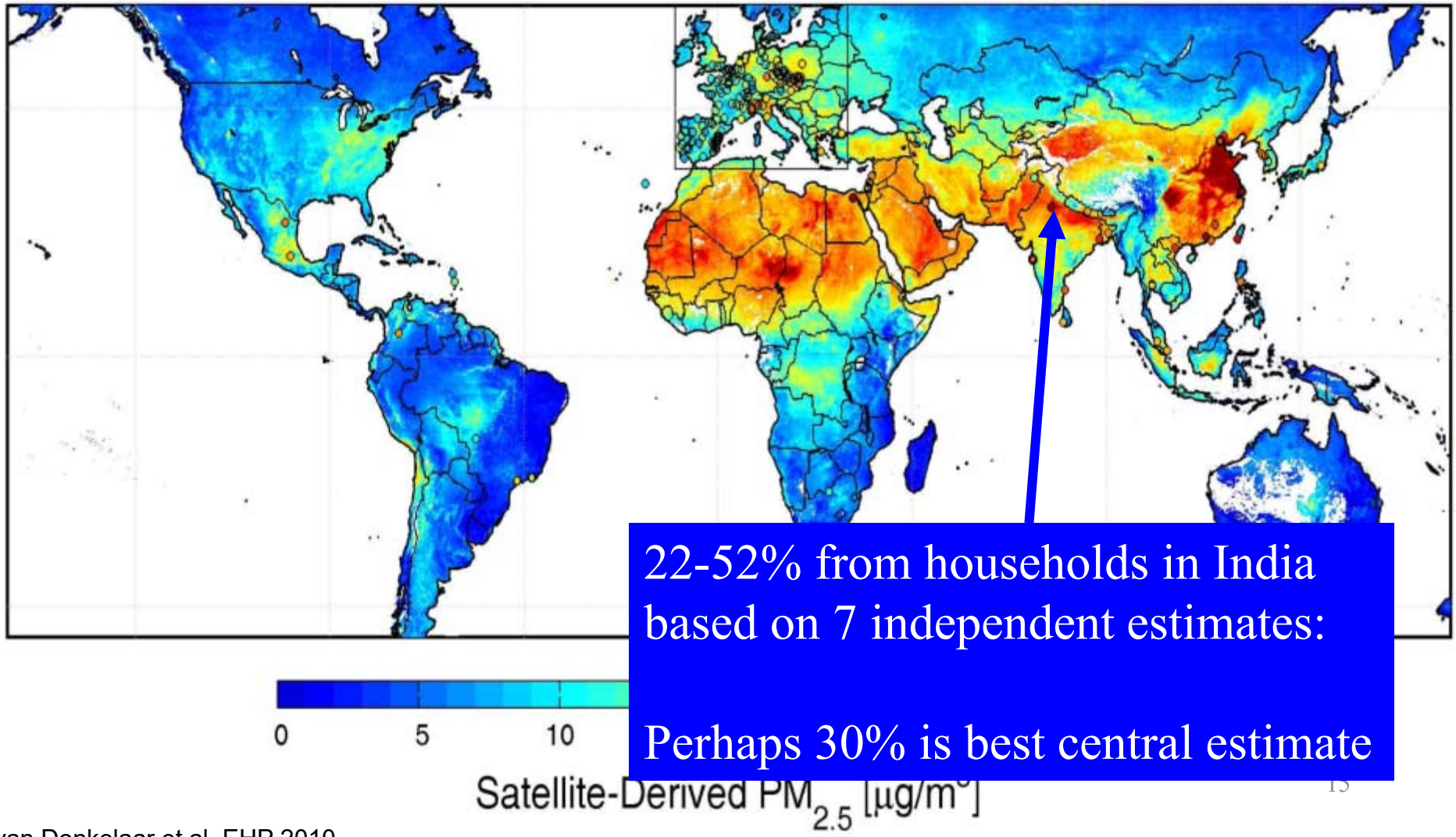


Indian Comparative Risk Burden from Air Pollution



India's Comparative Risk Burden from Air Pollution

Satellite-based estimates of ambient $PM_{2.5}$



22-52% from households in India based on 7 independent estimates:

Perhaps 30% is best central estimate

van Donkelaar et al, EHP 2010

A Section 508–conformant HTML version of this article is available at http://dx.doi.org/10.1289/EHP90

India Leads the Way: A Health-Centered Strategy for Air Pollution

http://dx.doi.org/10.1289/EHP90


Ambuj Sagar


Kalpana Balakrishnan


Sarath Guttikunda


Anumita Roychowdhury


Kirk R. Smith

The Government of India has recently initiated unprecedented efforts to address the substantial national health burden attributable to ambient and household air pollution. The key first step was the constitution by the Ministry of Health and Family Welfare (MHFW) of an expert committee on air pollution and health. This committee put together a landmark report (MHFW 2015) released earlier this year that outlined targeted actions aimed at providing the largest exposure reductions (and consequent health benefits), instead of traditional approaches to air quality management. India's health ministry is perhaps the first among low- and middle-income countries to initiate steps that directly address air pollution as a national health concern. Discussions initiated through this process have led to a number of concrete policy actions consistent with these recommendations, the most recent of which

using solid fuels in India does not seem to have changed significantly in the past 30 years (Bonjour et al. 2013), although it now constitutes a smaller fraction of the overall population. Vehicles and power plants—key contributors to urban ambient air pollution—historically have been the only sources to be addressed in national ambient air quality management efforts. The report addresses both household (indoor) and outdoor air pollution in an integrative fashion instead of treating them as separate issues—the first time by a government agency, to our knowledge. This is especially relevant given that household cookstoves also contribute an estimated 25% of ambient air pollution in India (Chafe et al. 2014).

Notably and importantly, the report invokes a new paradigm of exposure management instead of concentration management as a national air pollution control strategy, and

Ministry of Health and Family Welfare Air Pollution Task Force – 2015/16

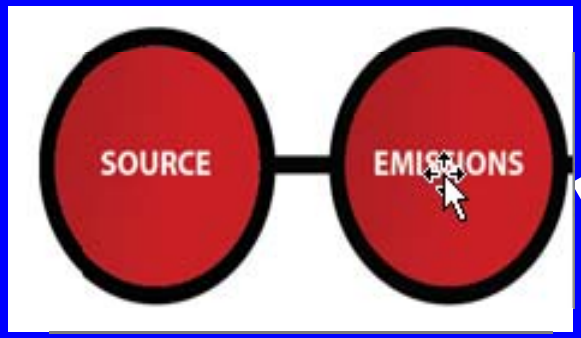
- First Ministry of Health in world to consider AP as one of its major priorities and consider along with other risk factors
- First government agency in the world not to address AP by location, but by total exposure – a true health focus
- Thus, not indoor/household, not outdoor, but by what will give the most health benefit

MoHFW AP Task Force

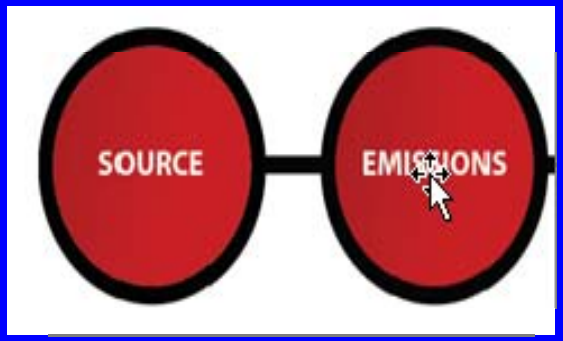
- Total exposure approach requires utilizing estimates of relation between emissions of each source category and exposure.
- Emissions weighted essentially by proximity to population
- Goal is to change source apportionment to exposure apportionment

Source – Exposure Relationships

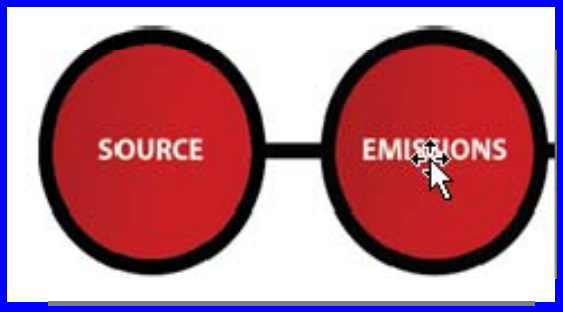
Vehicles



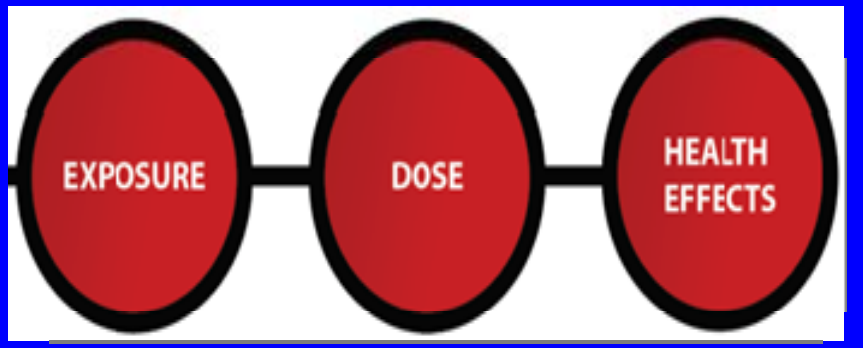
Power plants



Stoves



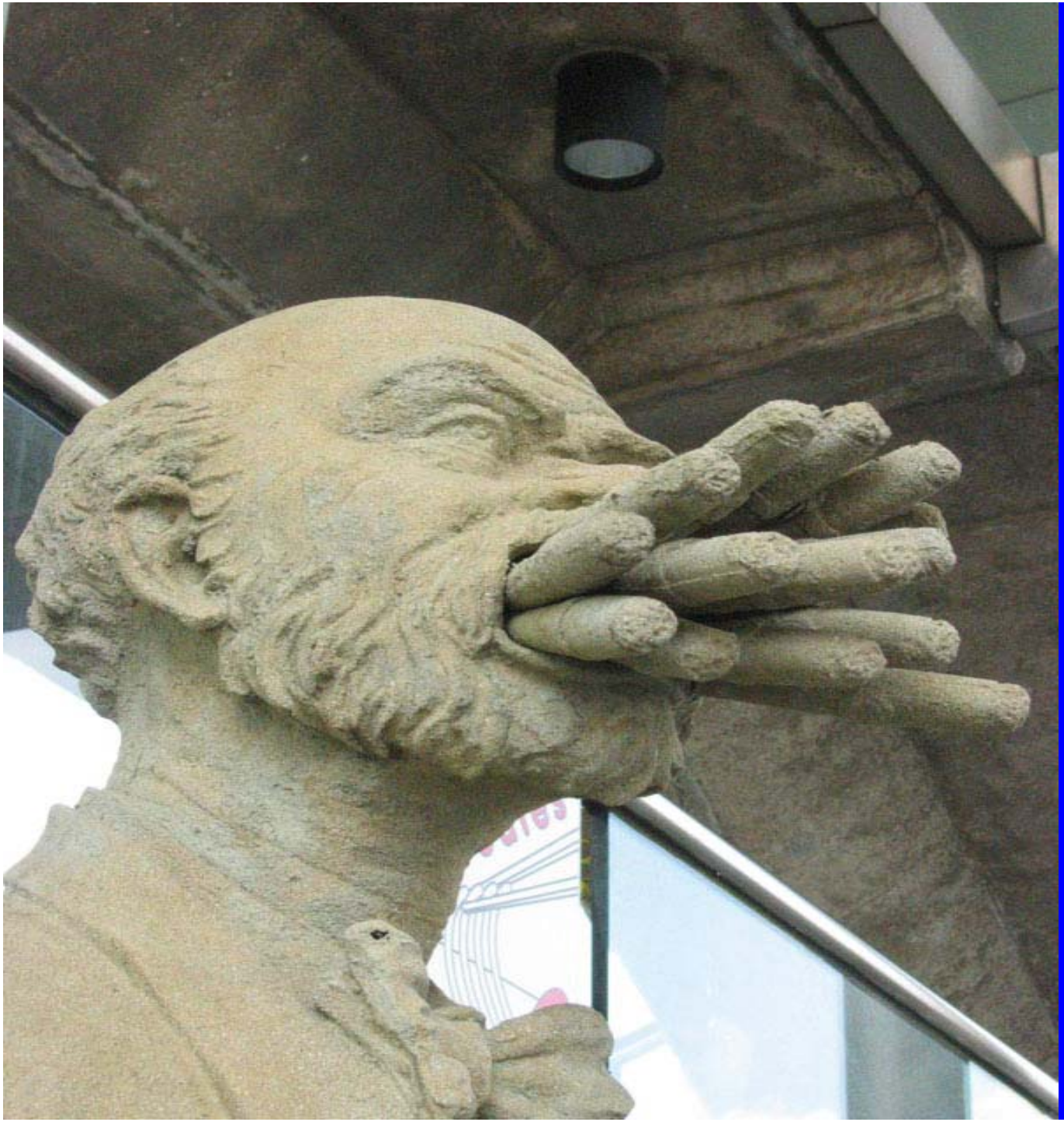
How different?
Does it matter?



Much of the essence of exposure assessment can be captured by the concept of *Intake Fraction (IF)*

- For air pollution, *IF* is the amount breathed in by the exposed population compared to the amount emitted.

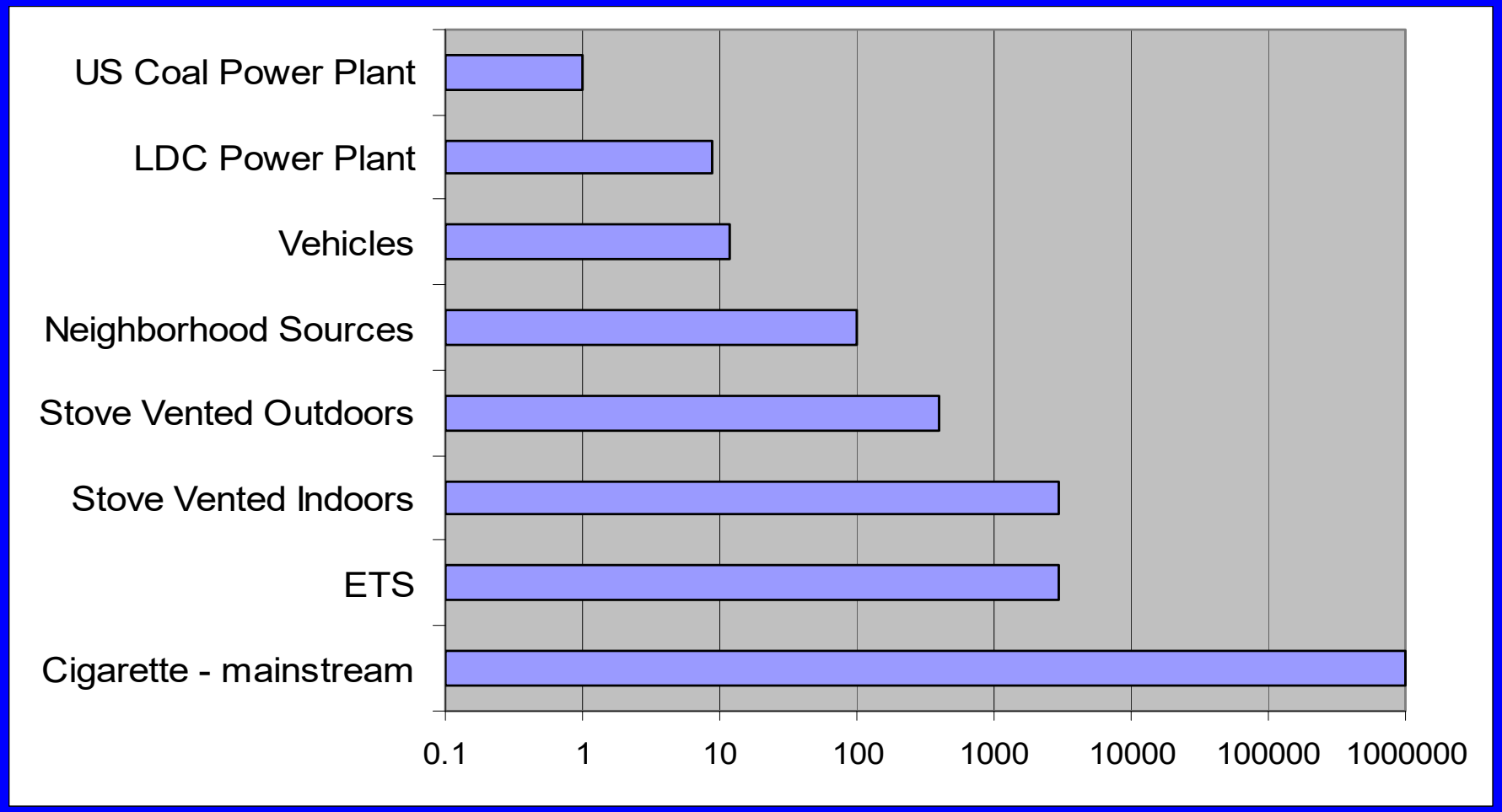
- Dimensionless and often determined in ppm



IF = 1.0

(one million ppm)

Intake Fraction Varies as More than Toxicity (these are rough calculations for typical examples of sources in each class)



Smith, 1993

Parts per million (ppm)

Farfield Intake Fractions in Hyderabad

ppm – grams inhaled per tonne emitted

	Average	SD
Households	175	97
Construction	175	93
Waste.burn	140	74
Veh.exhaust	130	64
Gen.sets	123	53
Industries	65	17
Dust	18	4
Power plants	7.4	7.0
Brick.kilns	6.8	1.9

ENVIRONMENTAL Science & Technology

ACS AuthorChoice

Article

pubs.acs.org/est

Characterizing Aggregated Exposure to Primary Particulate Matter: Recommended Intake Fractions for Indoor and Outdoor Sources

Peter Fantke,[*,†] Olivier Jolliet,[‡] Joshua S. Apte,[§] Natasha Hodas,[∥] John Evans,[⊥,#] Charles J. Weschler,[∇,○] Katerina S. Stylianou,[‡] Matti Jantunen,[◆] and Thomas E. McKone[¶,∞]

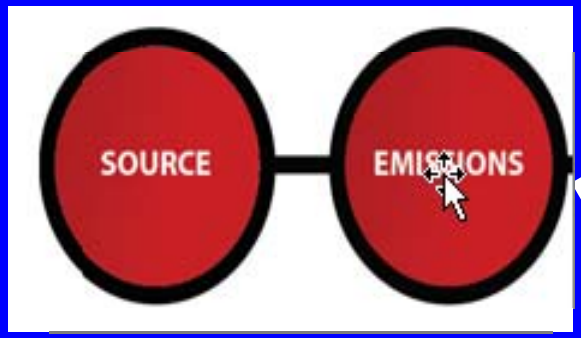
Environ. Sci. Technol. 2017, 51, 9089−9100

MoHFW AP Task Force, cont.

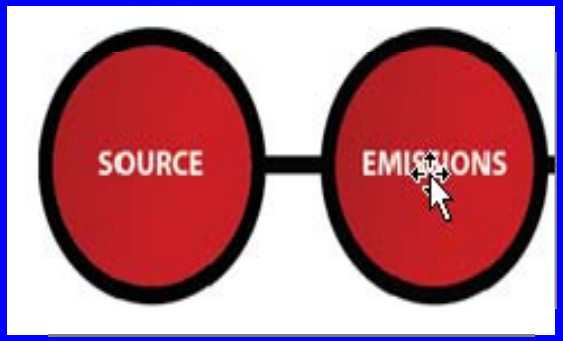
- Far field intake fractions are higher for some sources: secondary particle creation
- Nearfield intake fractions are also important for local sources, eg
  - Vehicles
  - Neighborhood waste burning
  - Gen sets
  - Households
- Nearfield intake fractions for households are about 5x those from ambient (downwind exposures) in Hyderabad (850 vrs 175 ppm)

Source – Exposure Relationships

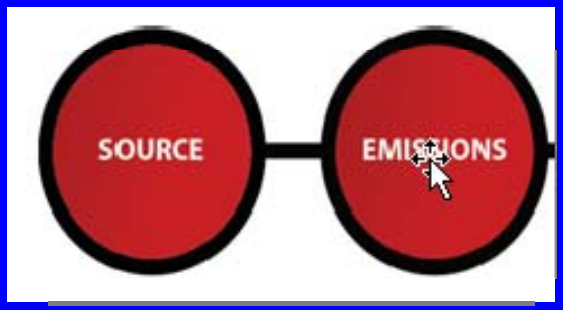
Vehicles



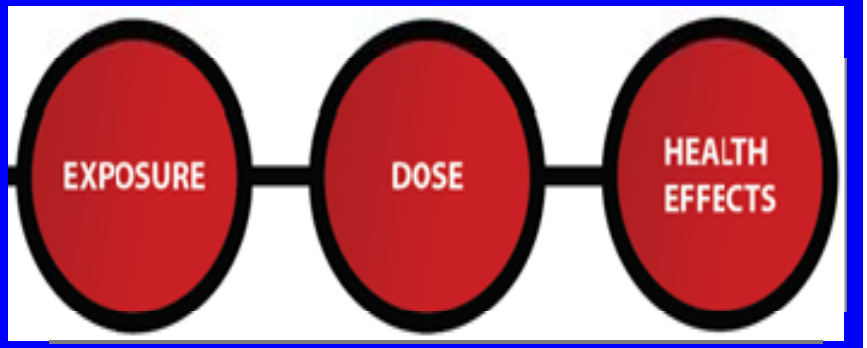
Power plants



Stoves



How different?
Does it matter?



Yes, perhaps a factor of 100

Initiated by Ministry of Petroleum & Natural Gas
Government of India

ABOUT PMUY

पेट्रोलियम और प्राकृतिक गैस मंत्रालय
भारत सरकार

The PMUY Program is connecting ~90 million poor households to LPG in 4 years

>500 million people

Chinese struggle through 'airpocalypse' smog

Pollution has hit record levels recently, prompting citizens to ask if they're paying for economic growth with their health

▲ Children wear masks as a thick haze of air pollution envelopes Tiananmen Square in January. Photograph: Alamy

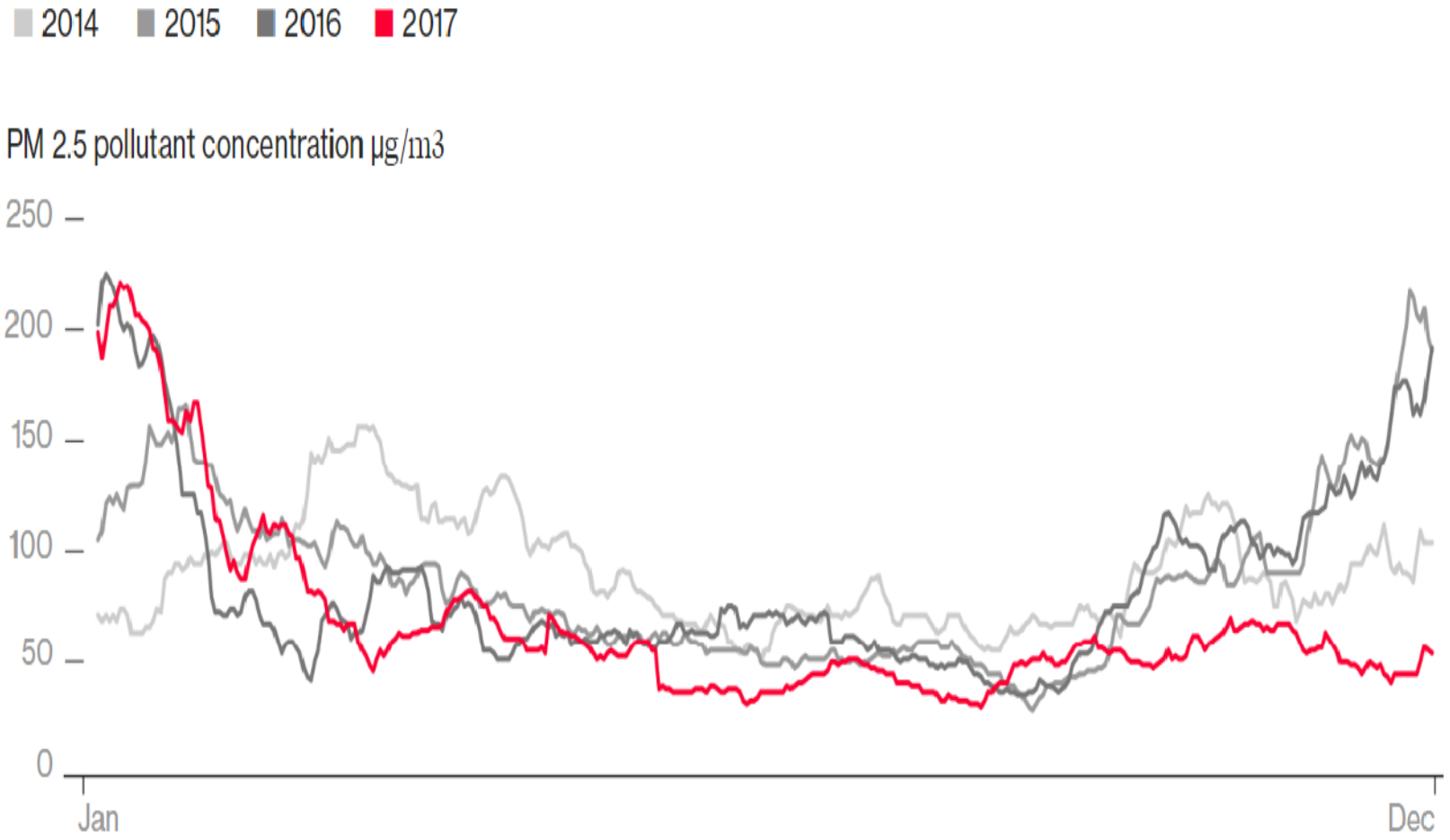
The Guardian, Feb 16, 2013

The standard international measurement for air quality - the US Air Quality Index, or AQI - rates air quality on a scale of zero to 500. With experience, it becomes possible to guess the AQI in Beijing without looking at official readings. One hundred correlates to a thin grey gauze hovering above the horizon. When the index hits 200, the sky is visible only in a small patch directly overhead. An AQI reading of 300 blots out the sun, smothering the city in drab uniformity. When the AQI reached 755 on 12 January, the worst day on record, the air felt like industrial smoke - chemical-tasting, eye-watering.

Peak PM in Chinese history?

The Guardian, Feb 16, 2013

Beijing's 30-Day Average Air Pollution Levels



China's Five Year Plan to radically tighten air pollution targets

270 Shares

Published on 11/03/2016, 11:02am

China's draft economic plan for the next five years contains new targets that will need to be met if the country is to solve its environmental crises

The government will limit factory emissions of PM2.5

Other main targets include:

– reduction of emissions from coal burning industries and vehicles
– boost cleaner and more efficient use of coal
– promote the use of electricity and natural gas in place of coal
– support for wind, solar and bio power sectors; increase in proportion of clean energy
– encourage the use of waste straw as a resource
– reduction in-field burning
– implementation of control measures to deal with air pollution

Other aspects

- Focus on sources that affect exposure, including households
- Redesign scale of control efforts that reflect the scale of air pollution

China's War on Pollution Will Change the World

By Jeff Kearns, Hannah Dormido and Alyssa McDonald
March 9, 2018

China is cracking down on pollution like never before, with new green policies so hard-hitting and extensive they can be felt across the world, transforming everything from electric vehicle demand to commodities markets.

Four decades of breakneck economic growth turned China into the world's biggest carbon emitter. But now the government is trying to change that without damaging the economy—and perhaps even use its green policies to become a leader in technological innovation. So, as lawmakers attend the annual National People's Congress, here's a look at the impact of the environmental focus, at home and abroad.

Bloomberg Report, Mar 2018

Mongolia

RESEARCH ARTICLE

Health assessment of future $PM_{2.5}$ exposures from indoor, outdoor, and secondhand tobacco smoke concentrations under alternative policy pathways in Ulaanbaatar, Mongolia

L. Drew Hill[1]*, Rufus Edwards[2], Jay R. Turner[3], Yuma D. Argo[4,5], Purevdorj B. Olkhanud[4,6], Munkhtuul Odsuren[4], Sarath Guttikunda[7], Chimedsuren Ochir[4], Kirk R. Smith[1]

Hill et al 2017, PLOSOne

This is half of Mongolia today

The coldest capital city in the world, and heats with coal in a valley with air inversions. Thus, in the winter

Background of the Project

- UB has some of the worst winter outdoor air pollution in the world, a problem of great concern among the public, media, and policy makers.
- To a considerable extent, this pollution is due to coal heating in the residential sector, although other sources such as power plants, vehicles, and industry play roles.
- Indoors, outdoors – the pollution is everywhere

Aim

- **“What health benefits could be expected from cleaner household stoves and fuels and associated emissions reductions in other sectors by 2024?”**

Innovations in the Assessment Exposure Assessment

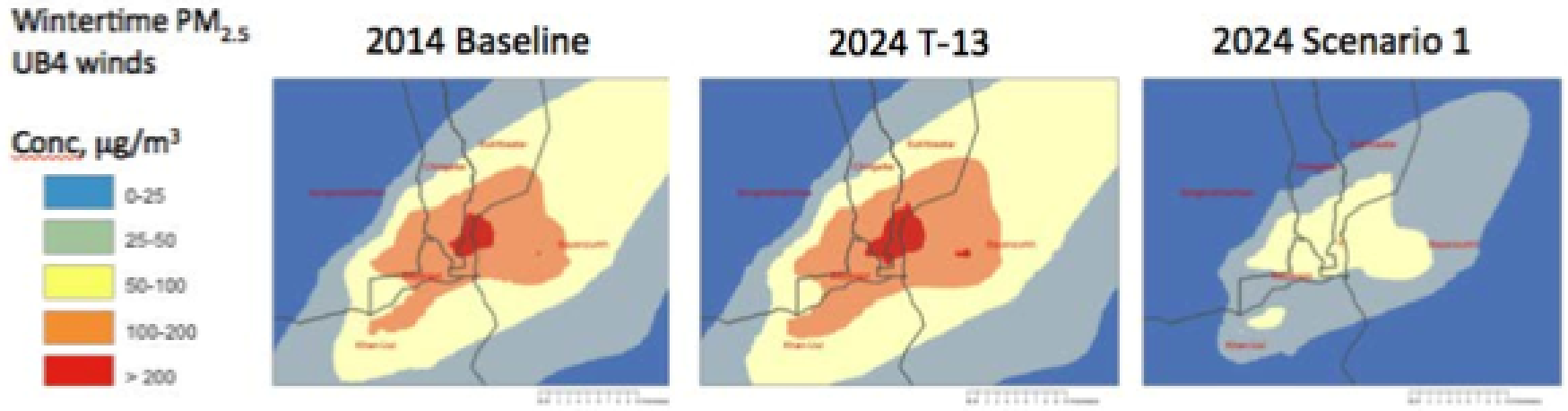
- We assess "total exposure" of the UB population over the 10 years of the assessment for each scenario
- This includes both indoor and outdoor exposures
- And is distinguished separately for young children since they have special sensitivities

Exposure Assessment, cont.

- To do this required estimating the effect of indoor and outdoor sources on pollution levels throughout the year
- And estimating how much outdoor air pollution penetrates indoors
- By household type (ger, apartment, house)
- And the amount of time spent by population groups in each location
- Requires projections of socio-demographic changes and background health conditions

Exposure Assessment, cont.

- This was necessary because of the special character of UB pollution, particularly in the winter, when outdoor pollution is so high from household sources and penetrates everywhere.
- It is, we believe, the first air pollution health analysis in the world for a city based on total exposure assessment.



- Outdoor air pollution was estimated for each of 6298 1 km x 1 km grid cells in the city for 2014 and again for 2024 under T-13 and the two scenarios.
- The model was calibrated against actual measurements in 2013.
- City-wide population-weighted concentrations were determined based on population living in each grid cell
- Excluded were heating stoves in kiosks, industrial emissions including kilns, resuspended road and windblown dust.

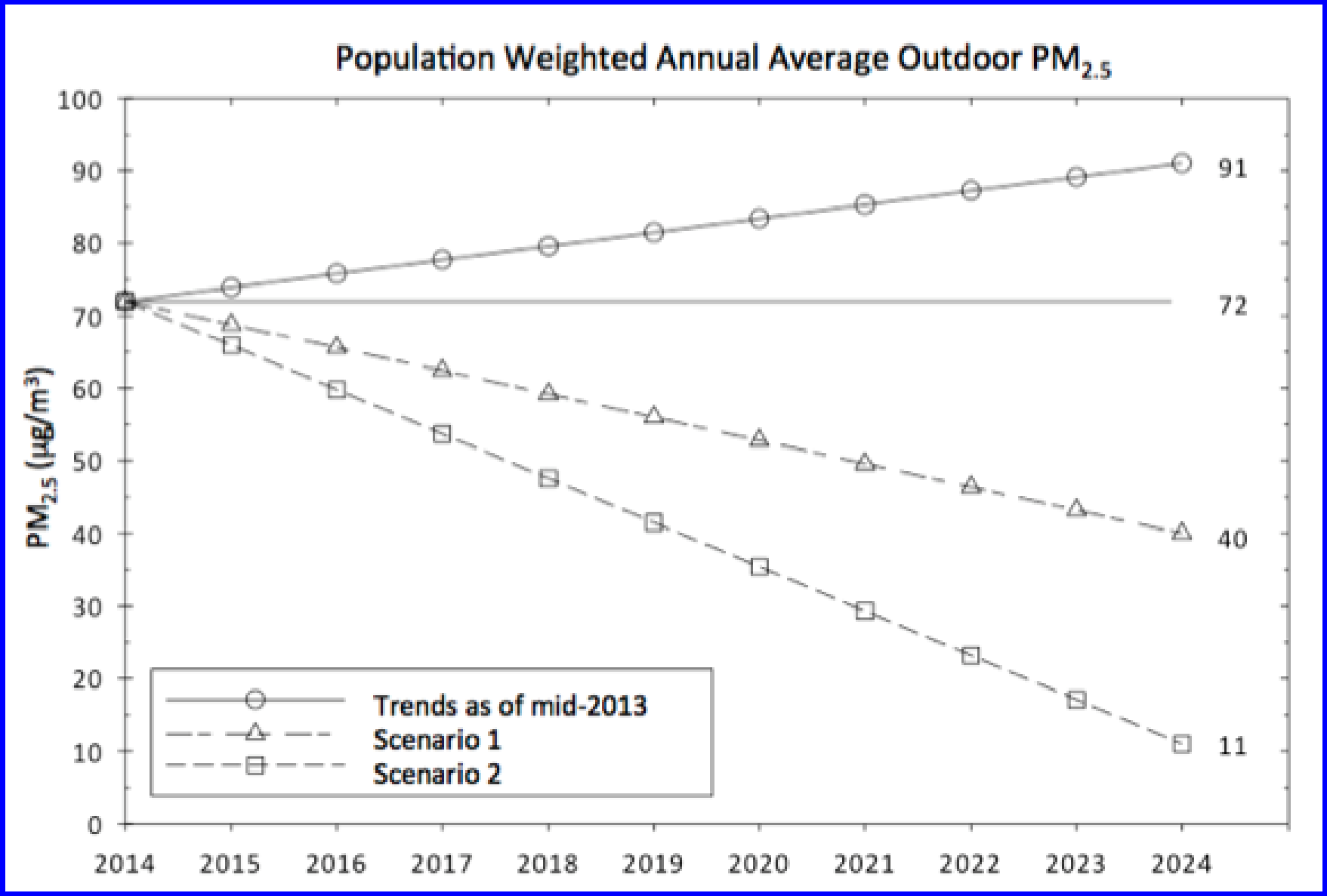
Comparison of Scenario 2 with T-13 in 2024

Population Weighted Exposure Estimates -- Annual Average				
	Annual Average ($\mu g/m^3$)	Percentage of Annual Average from:		
		Outdoor Exposures	Outdoor Exposures	Environmental Smoking Exposures
T-13 (2024) - All Population	74.7	72	9.2	19
Scenario 2 (2024) - All Population	21.5	30	4.4	66
Ger Population	23.5	36	4.0	60
House Population	21.0	28	4.5	67
Apartment Population	21.2	28	4.6	67

A major (>70%) drop in exposures in spite of population and and economic growth. Levels are within the range of international health-protective norms. ETS now most prominent

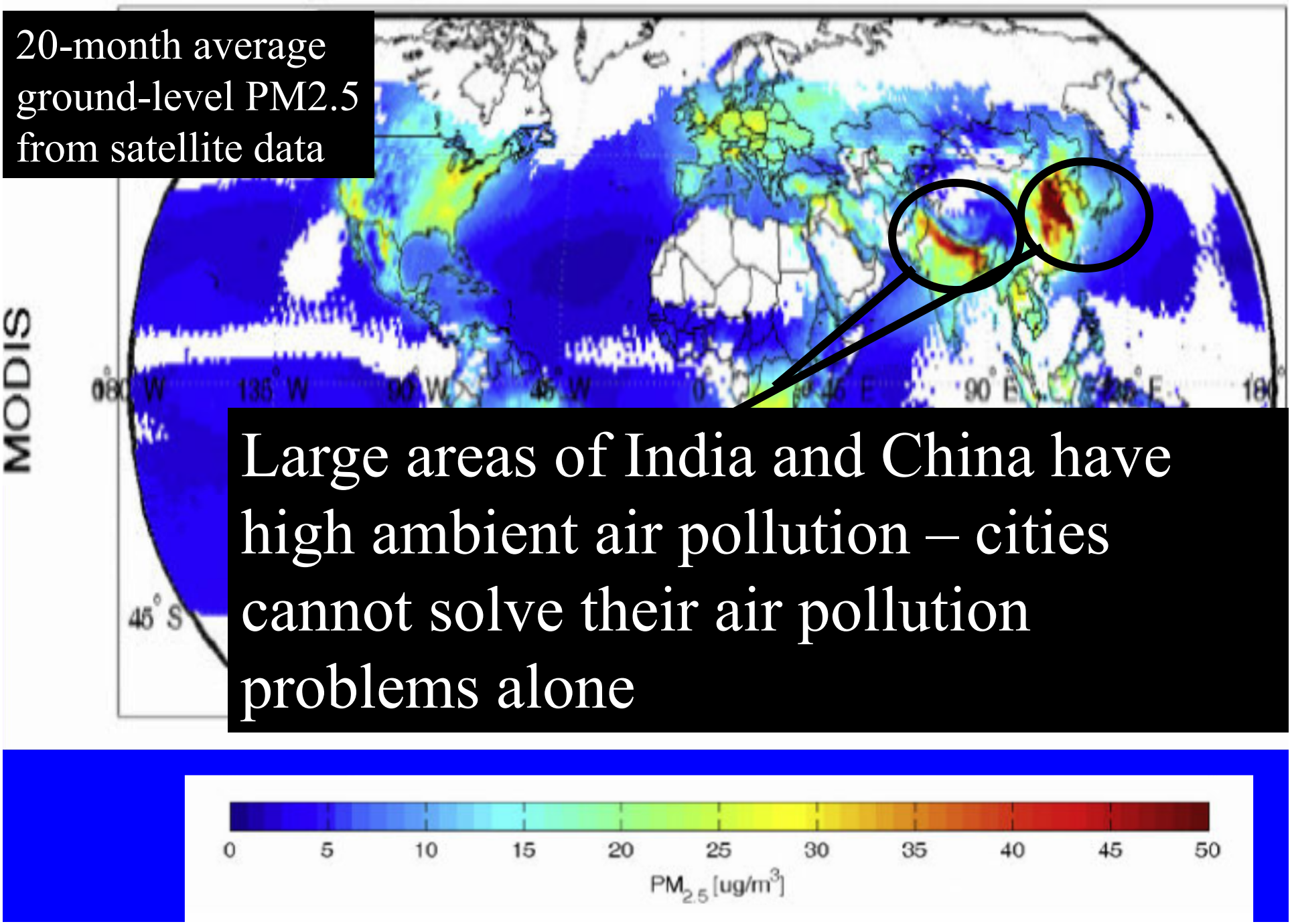
Recommendations

- As nearly1400 premature deaths a year are caused by air pollution in UB, we urge serious consideration by UB authorities be given to taking aggressive actions soon to bring UB close to international air pollution norms sometime next decade.
- ***Elimination of coal in household heating is the most urgent immediate action needed – 70% and more of exposure***
- A number of efforts now underway to implement clean household space-heating



Note: models were run for only 2014 and 2024 and a linear change is assumed between the two results

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



Large areas of India and China have high ambient air pollution – cities cannot solve their air pollution problems alone

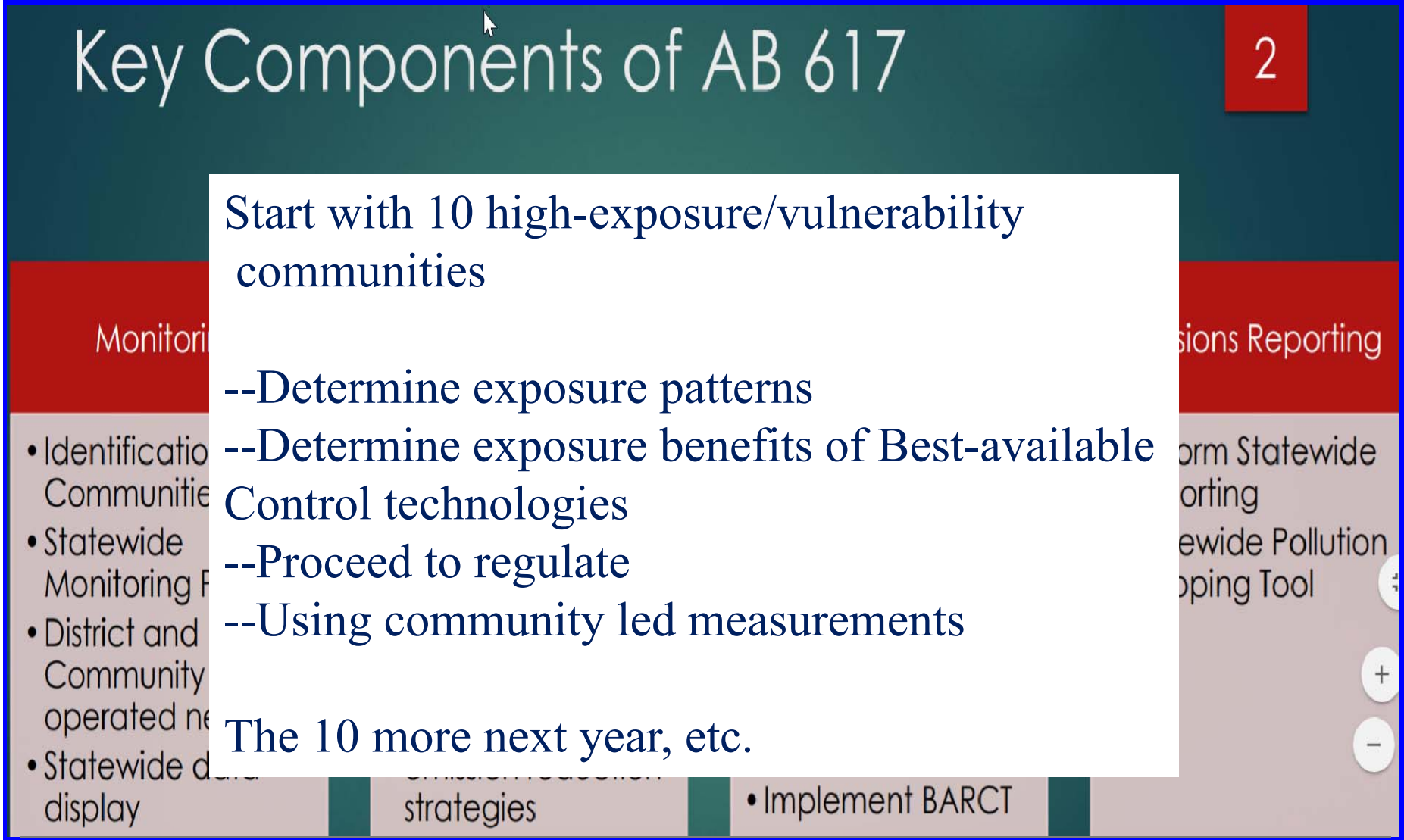
Unlike Beijing and Delhi, because Mongolia is the least densely population country in the world,

Ulaanbaatar
holds its destiny in
its own hands.

California's Community Air Protection Program (2017)

- "The Program's focus is to **reduce exposure** in communities most impacted by air pollution. CARB staff has already begun…. to develop a new community-focused action framework for community protection."

California's New AP Control Law



Start with 10 high-exposure/vulnerability communities

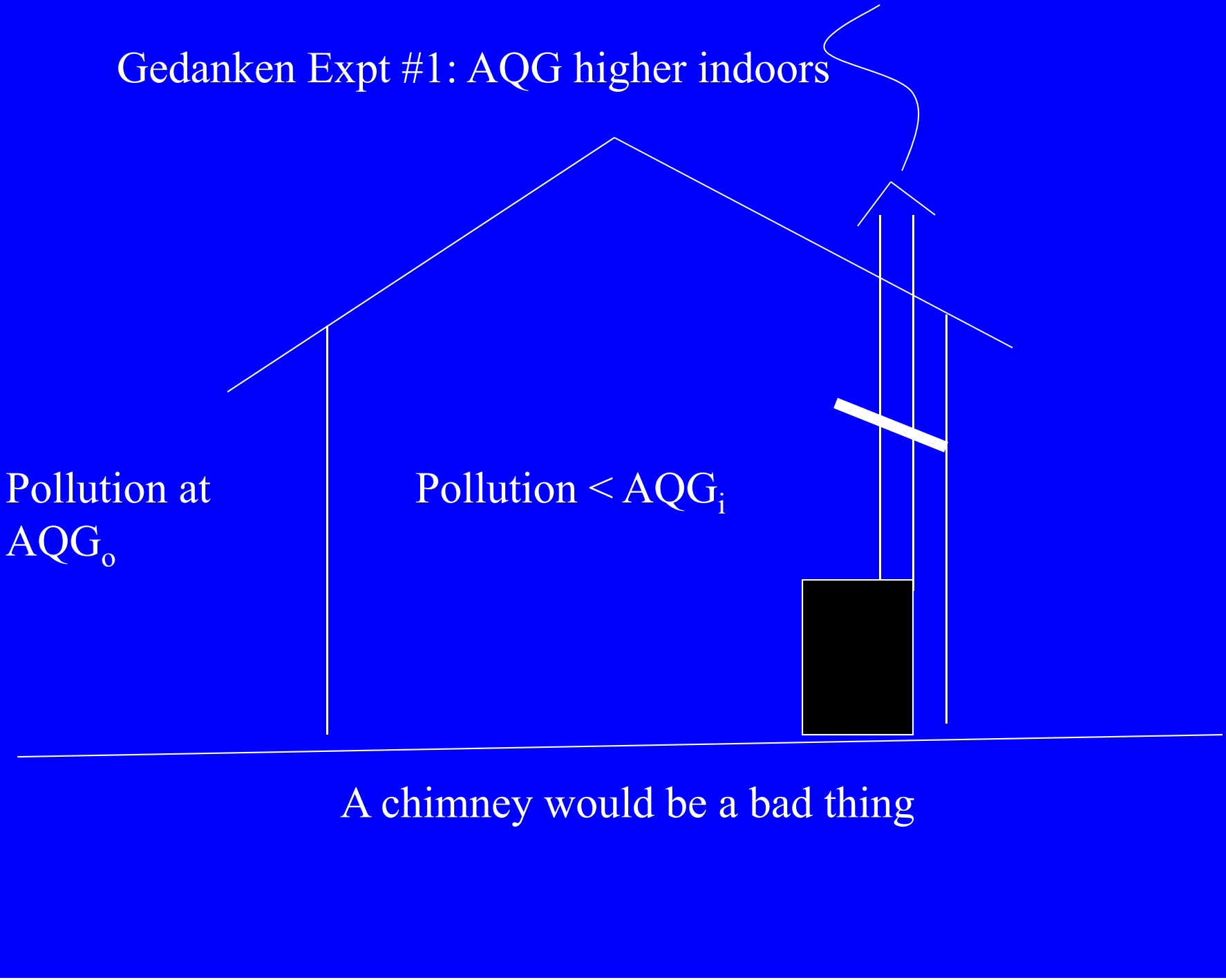
--Determine exposure patterns
--Determine exposure benefits of Best-available Control technologies
--Proceed to regulate
--Using community led measurements

The 10 more next year, etc.

Air Quality Guidelines: Big Issues

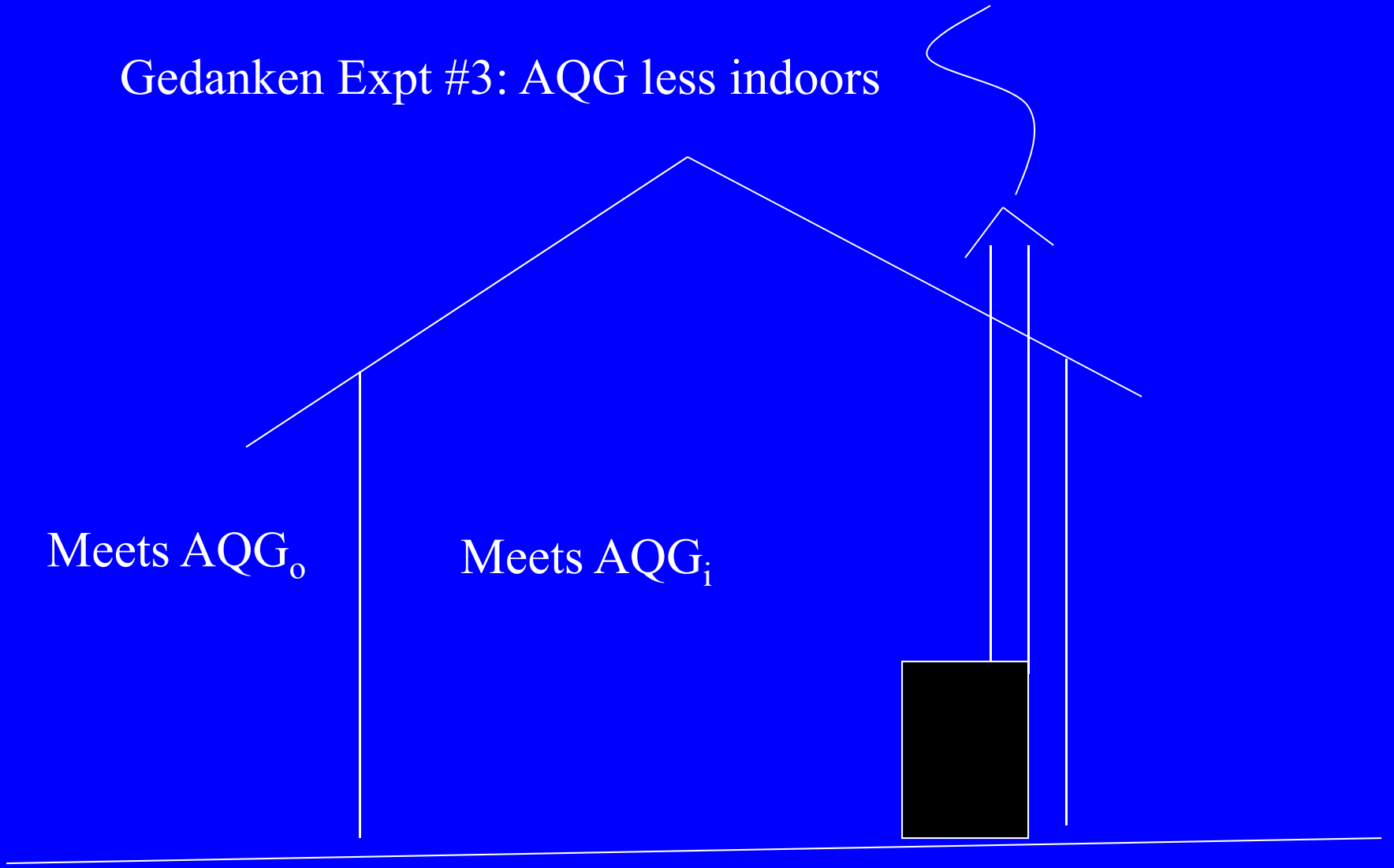
1. How to deal with no zero effect level? – nothing is completely safe
2. Should there be different AQGs for Indoors and Outdoors?
3. Should particles remain an undifferentiated class?

Gedanken Expt #1: AQG higher indoors



A chimney would be a bad thing

Gedanken Expt #3: AQG less indoors



Opening window is ok from the outside, but not from the inside

“consensual pretense of undifferentiated PM”

Need to consider from the standpoint of the people (exposure), not the particular location.

Protect people wherever they are breathing

What methods can be used for including exposure?

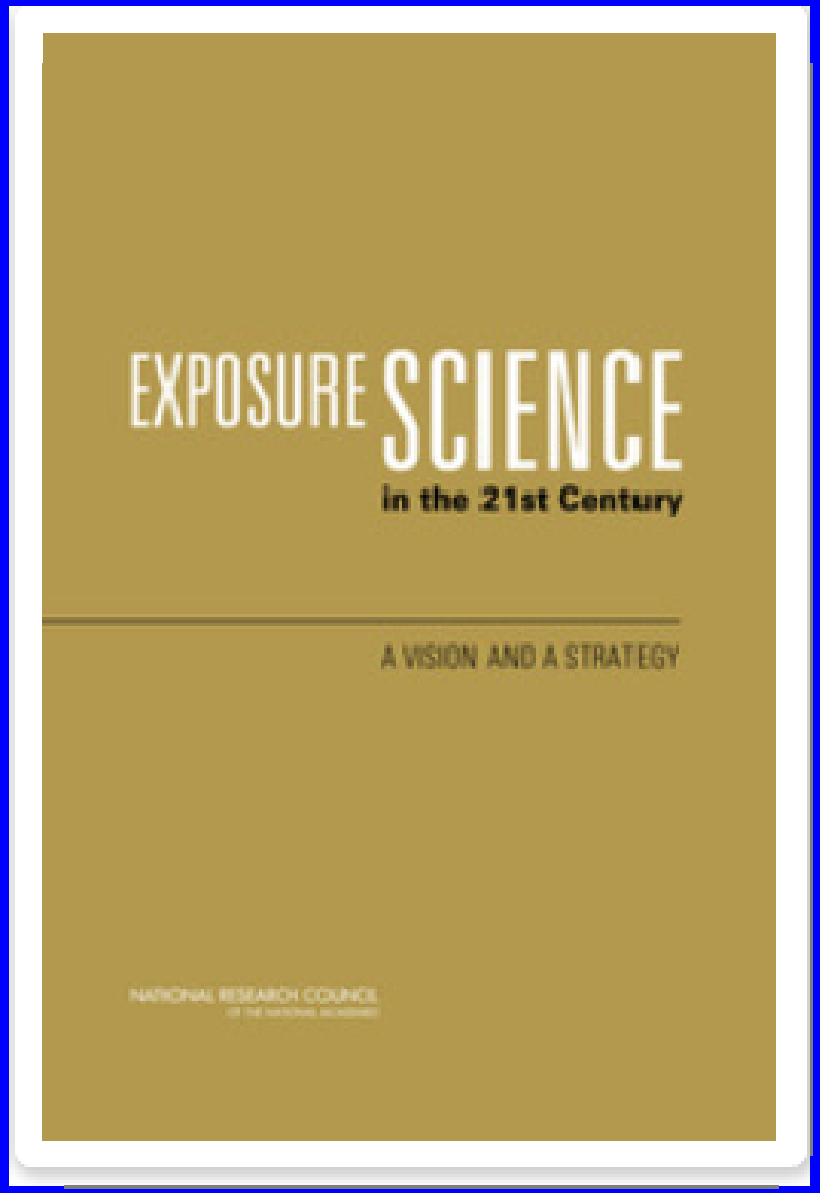
- Intake Fraction by source category -- India
- Modeling based on micro-environmental measurements -- Mongolia
- Hot spots of exposure based on community action - California
- Personal measurements done in carefully designed probabilistic sampling frameworks

Summary

- Eventually, we wish to control all sources of air pollution, all the time, everywhere.
- But we cannot afford to do so immediately
- What metric gives the optimal pathway such that the most health protection is occurring at each stage of investment?
- Metrics of exposure are a practical way to do so

At least

- Include households as major sources of pollution exposure
- And work to design the control and monitoring governance to the scale of the problem
- As in China



Exposure Science in the 21st Century

US National Academy of Sciences/National Research Council, 2012

KR Smith, Chair of the Expert Committee

Best to google “Kirk R. Smith” to find my website with publications