# Current and future burden of disease from major air pollution sources in India

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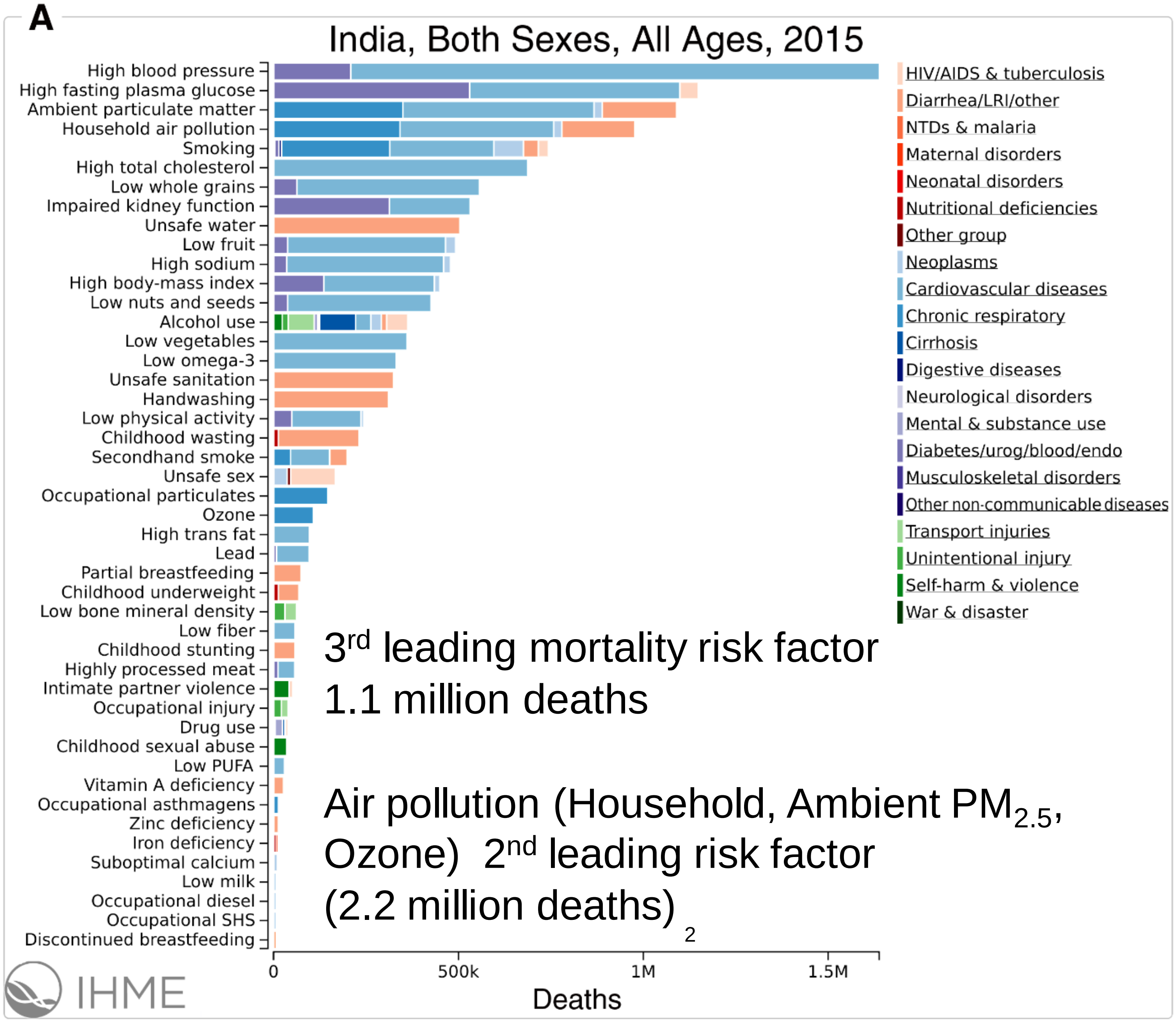
Photo: Sajjad Hussain/Agence France-Presse — Getty Images

# Air pollution is a major health risk factor in India

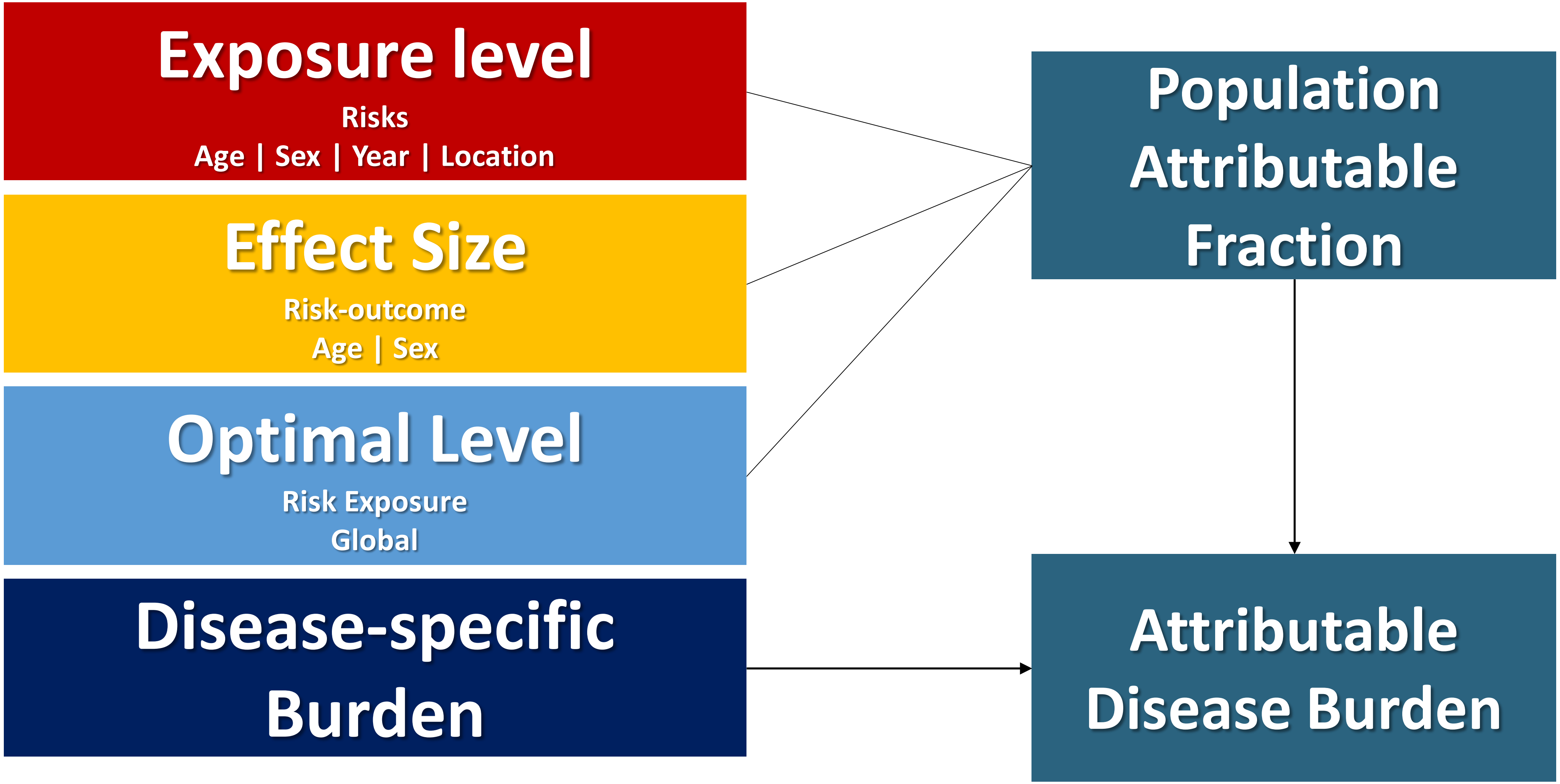



3rd leading mortality risk factor

1.1 million deaths

Air pollution (Household, Ambient $PM_{2.5}$, Ozone) 2nd leading risk factor (2.2 million deaths)

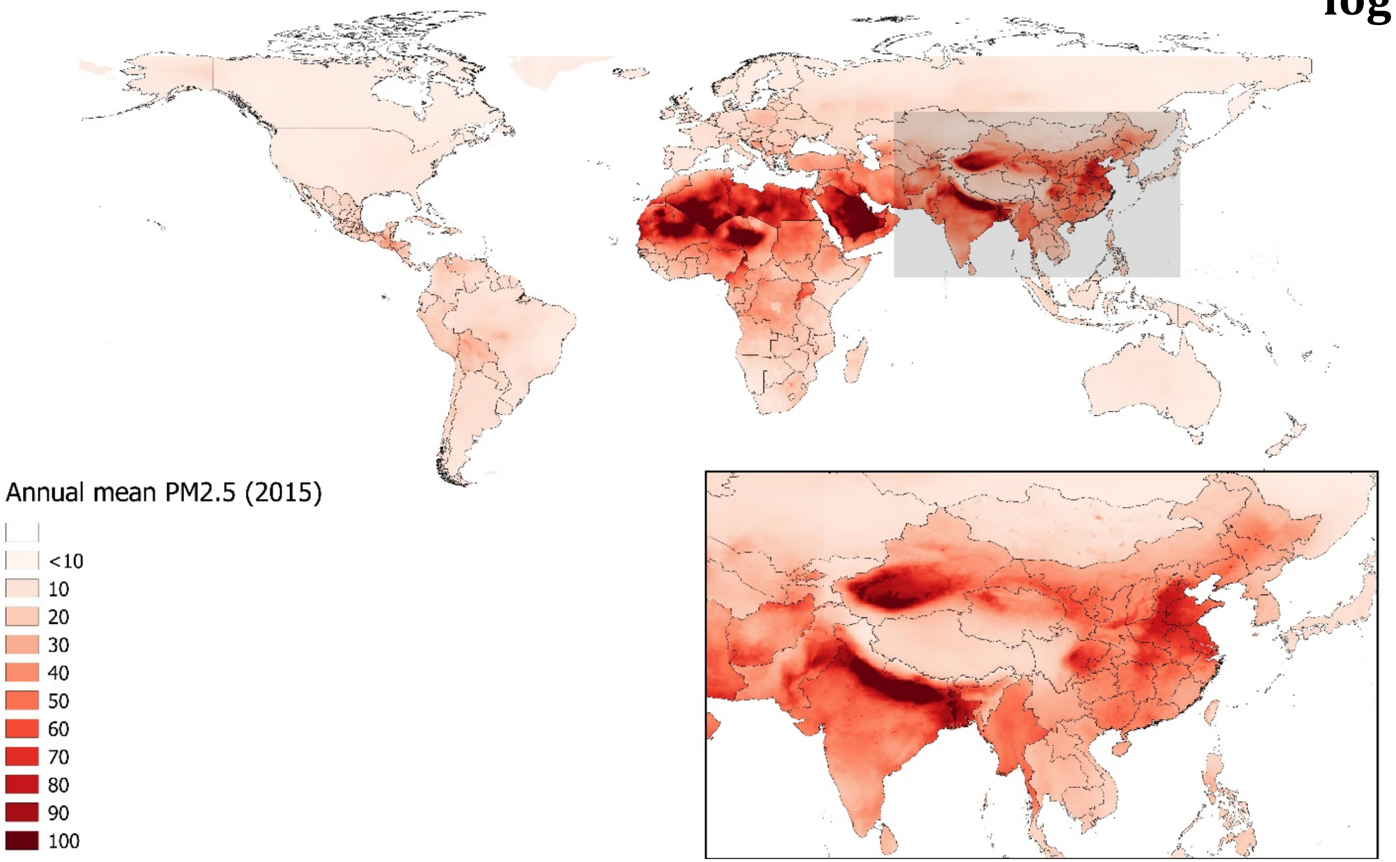
# Estimating (global) disease burden from air pollution



# Combining satellite and ground monitoring to estimate exposure

**Bayesian Hierarchical Model**

$$\log(PM_{2.5}) = \beta_0 + \beta_1 \log(SAT_i) + \beta_{3..n} + \varepsilon_i$$




**Spatially varying determinants of AOD – PM2.5 relationship + hierarchical random effects**

Ground measurements
**N = 6003,** from 107 countries

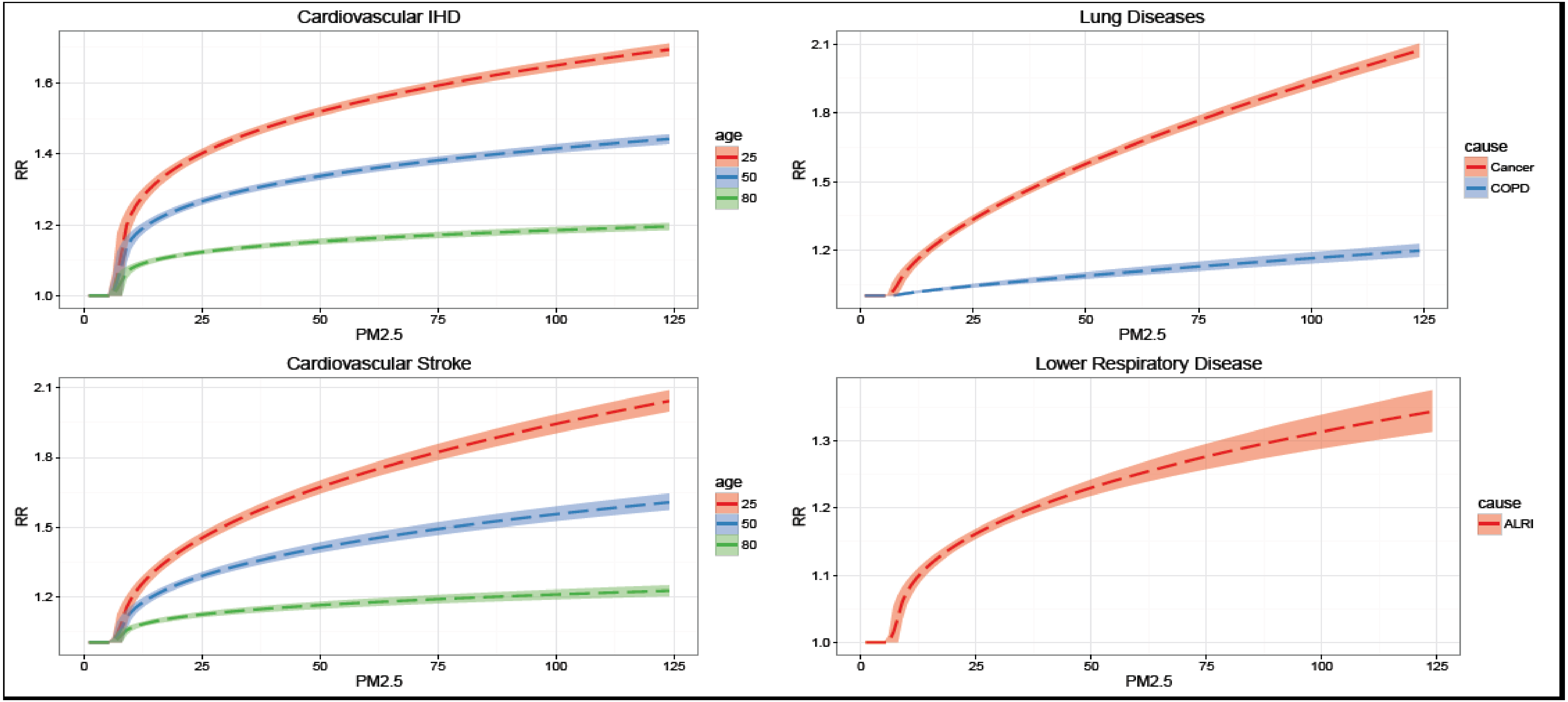
**25 $PM_{2.5}$ 411 $PM_{10}$ from India**

Median $R^2$ = 0.91
Median popwtd RMSE = 12.1 µg/m$^3$

~11 x 11 km resolution, annual average

Shaddick et al. 2018. Data integration model for air quality: a hierarchical approach to the global estimation of exposures to ambient air pollution. J. R. Stat. Soc. C, 67: 231–253. doi:10.1111/rssc.12227

# Using worldwide health data to relate exposure to disease risk





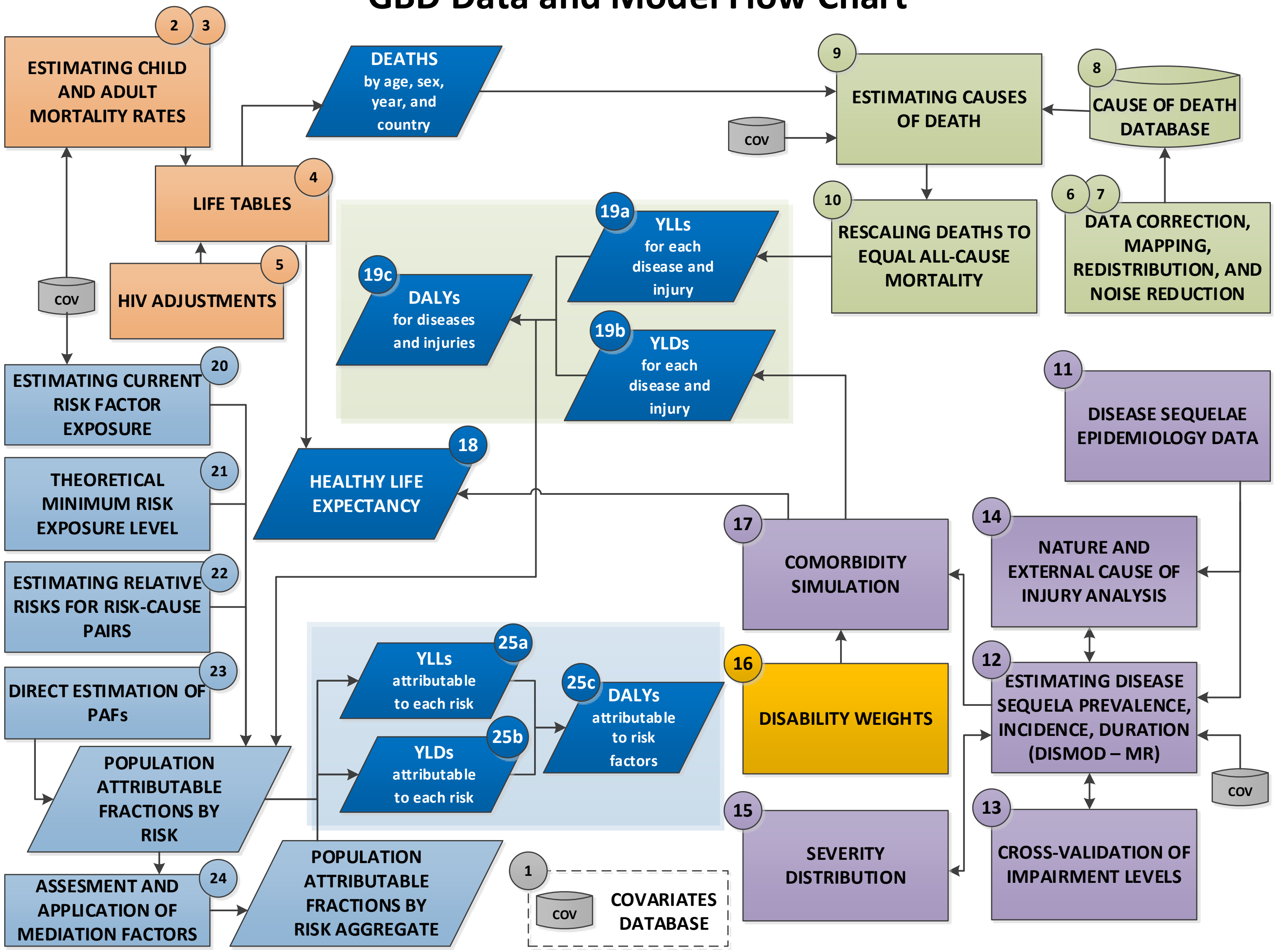

Burnett et al. 2014; Cohen/Brauer et al. 2017

# GBD disease burden modeling

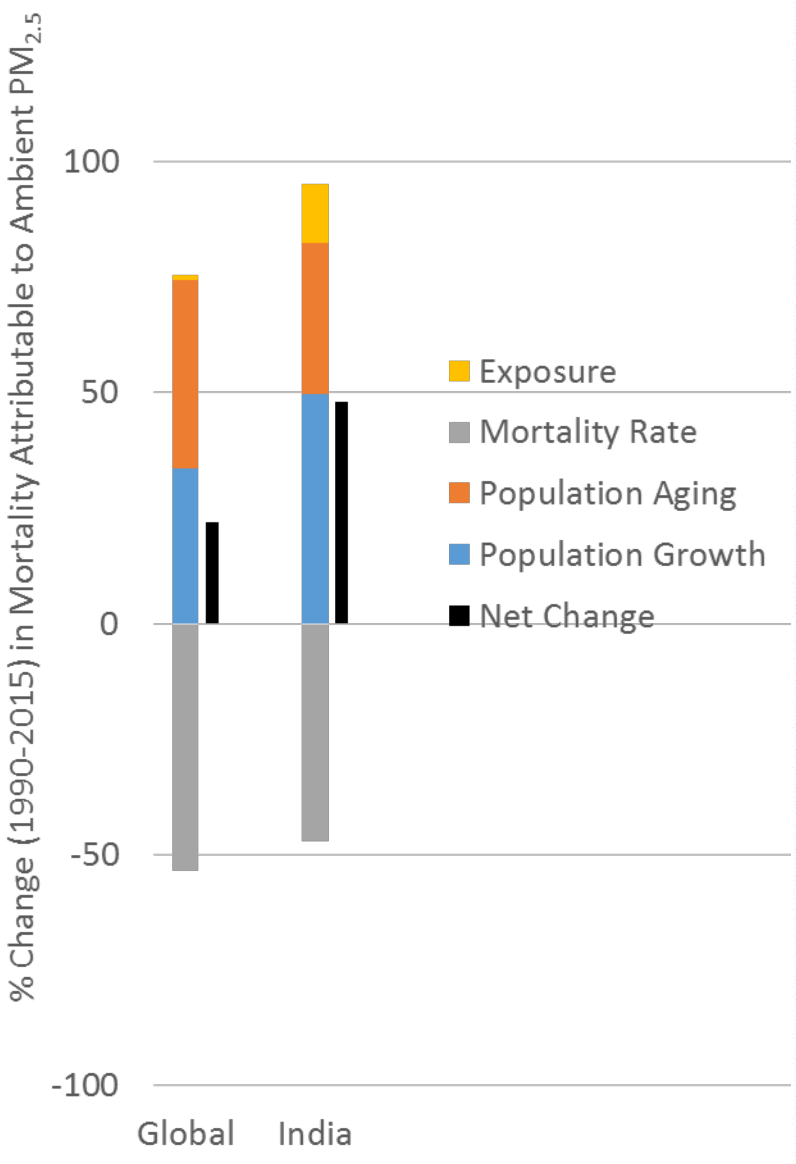
1. Identifies all accessible data sources on diseases, injuries, risks, sequelae and mortality.
2. Translates data into comparable units, definitions and categories, map variants of the ICD.
3. Assesses samples and definitions for potential errors and inconsistencies.
4. Statistically checks relationships among data sources, correct for known biases.
5. Improves predictions where data are sparse, by using covariates and interpolations across time or space.
6. Checks validity of statistical methods by using out-of-sample prediction.

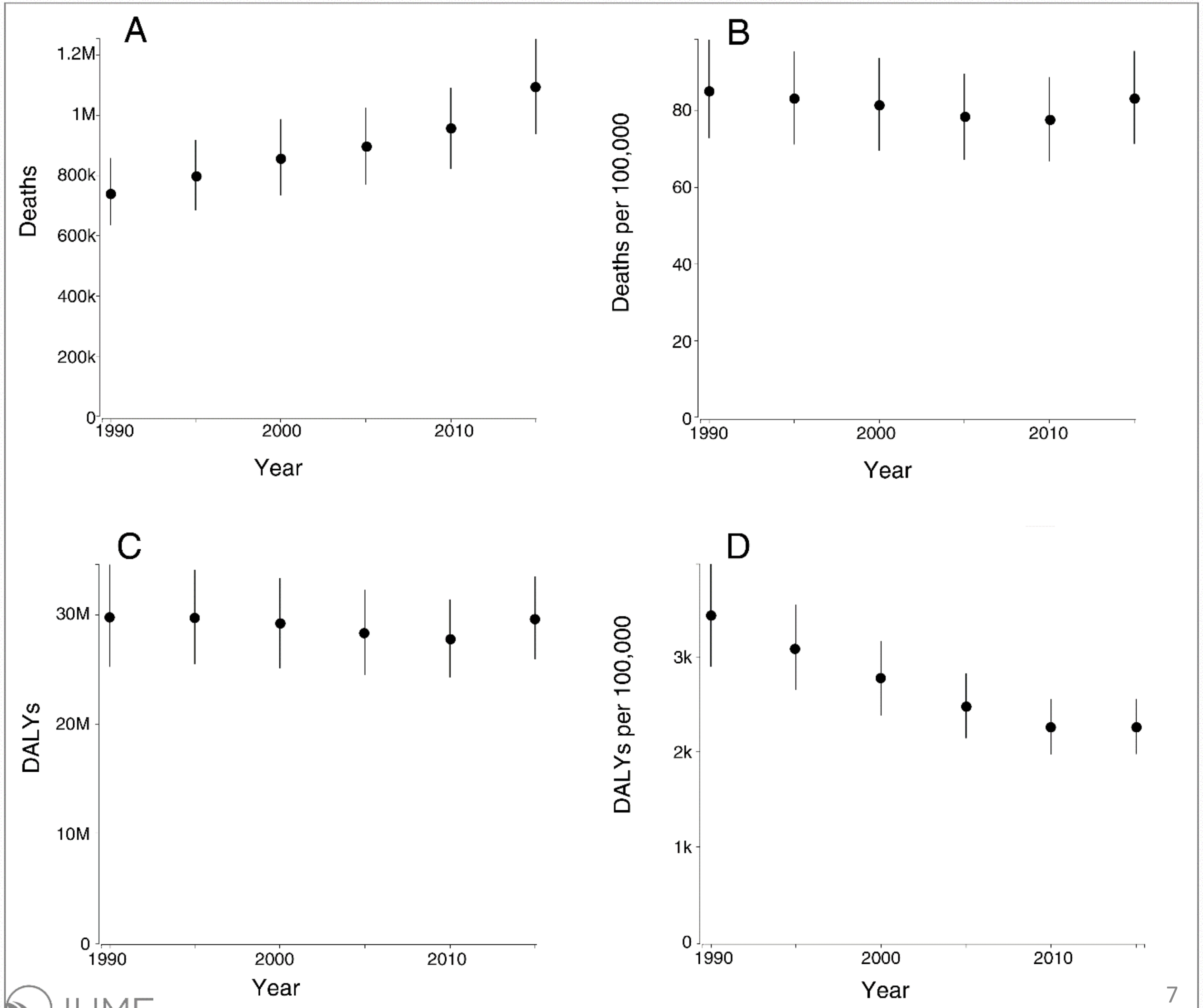
**All GBD data presented with 95% uncertainty intervals.**

## GBD Data and Model Flow Chart



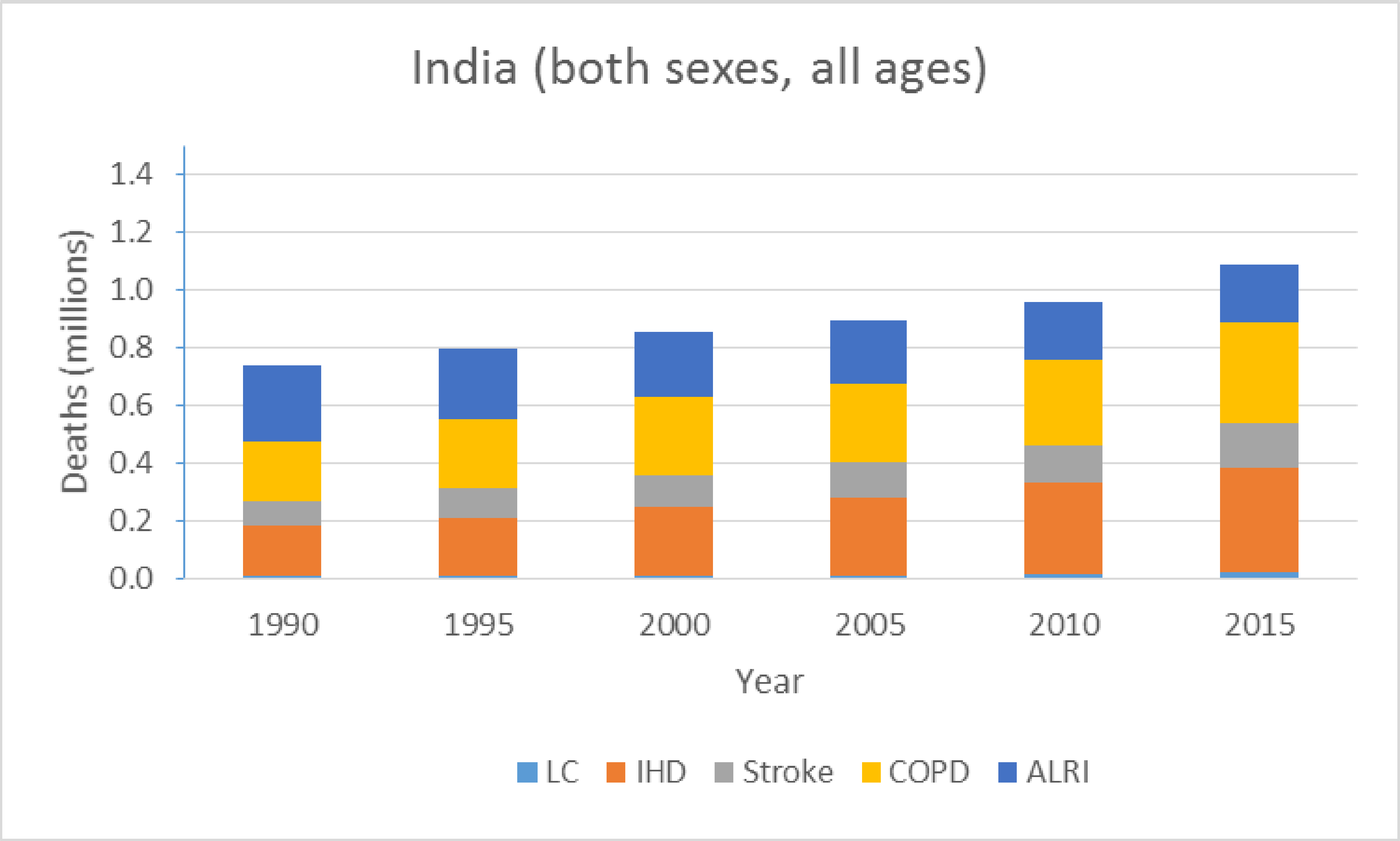
# Demographics play an important role



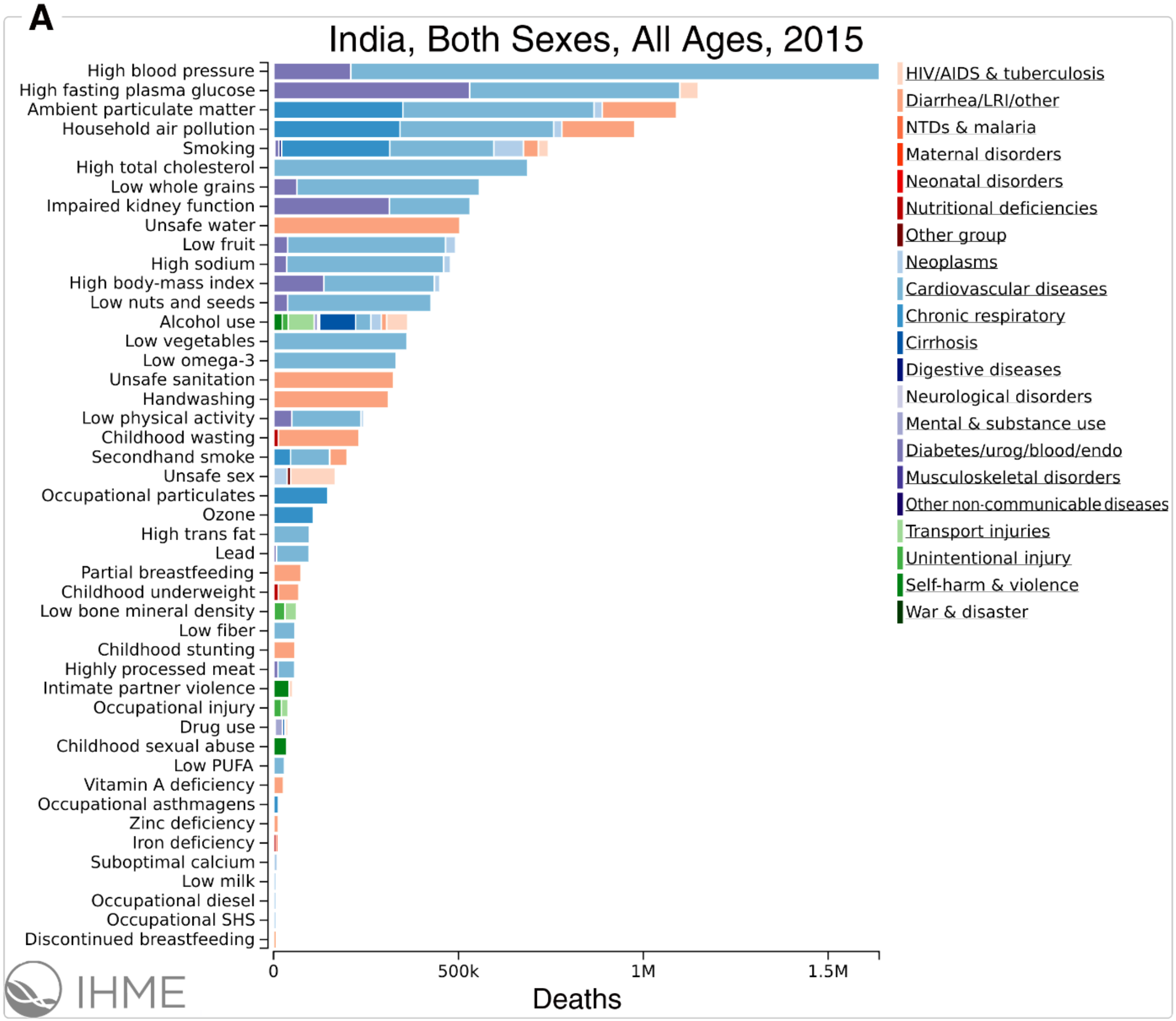




IHME

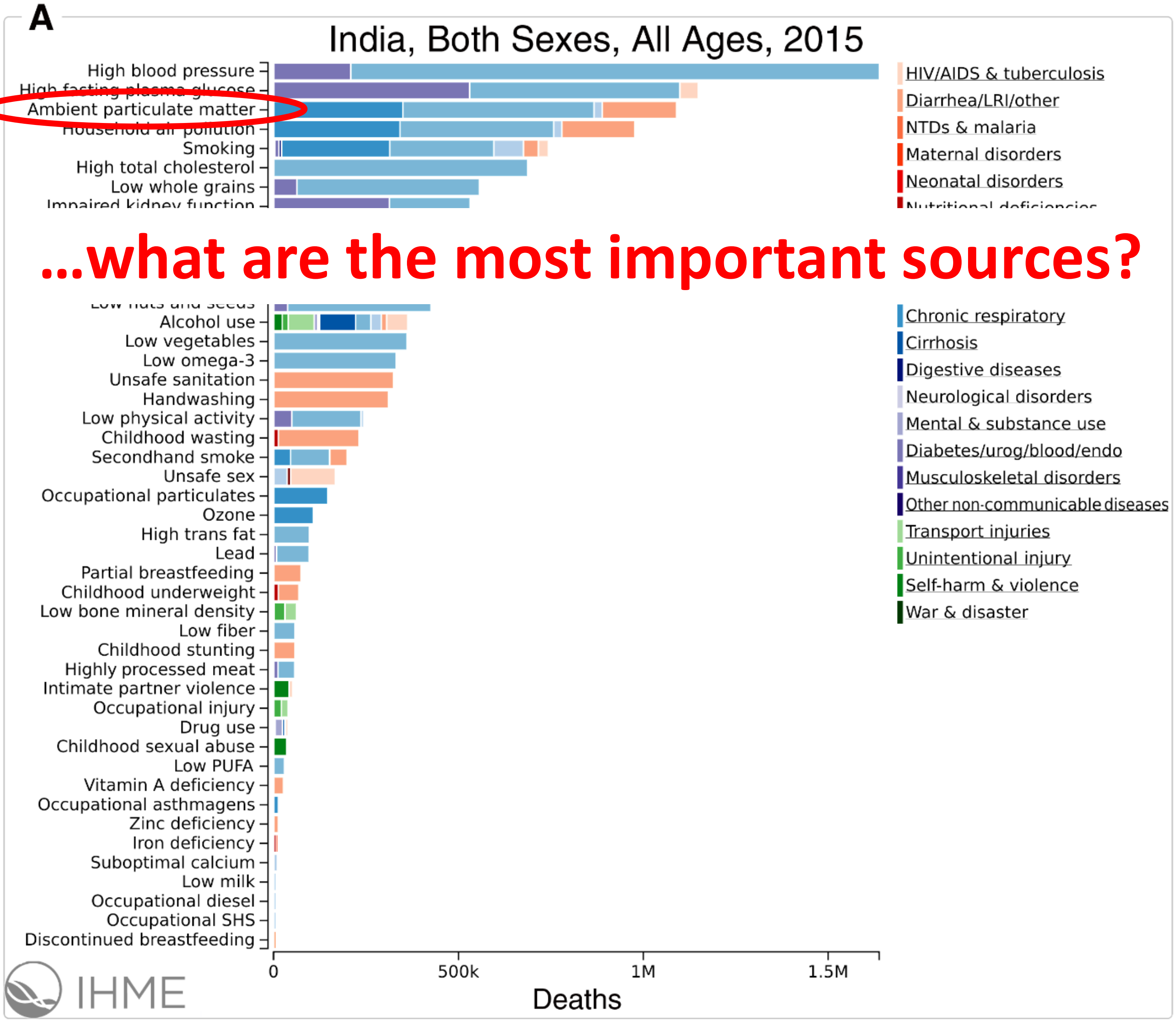
# Increasing non-communicable diseases



# If air pollution is a major health risk factor....

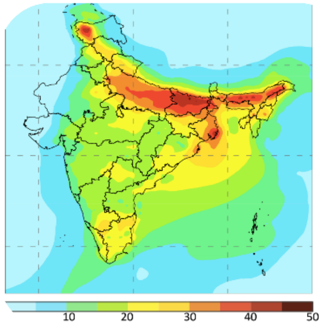


# If air pollution is a major health risk factor….

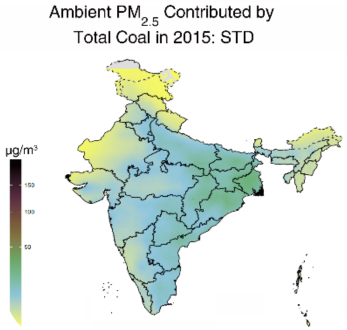



## …what are the most important sources?

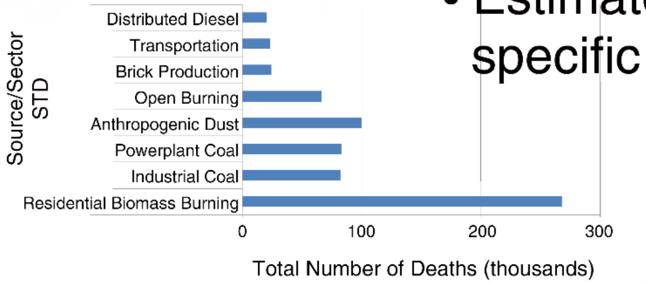
- Develop current and future emissions inventories




- Simulate the fraction of ambient $PM_{2.5}$ due to each major source

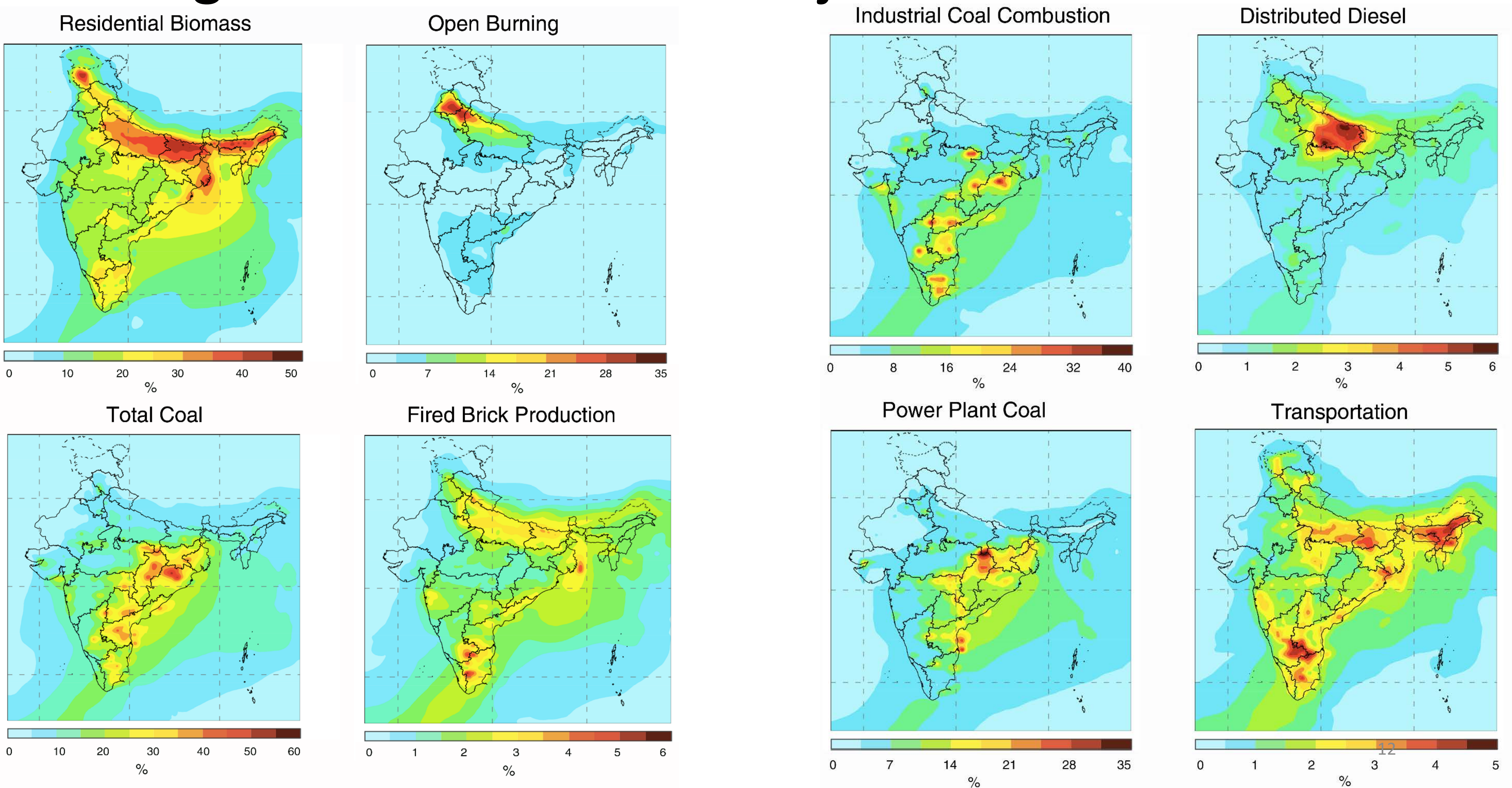



- Estimate the GBD 2015 population exposure to each source

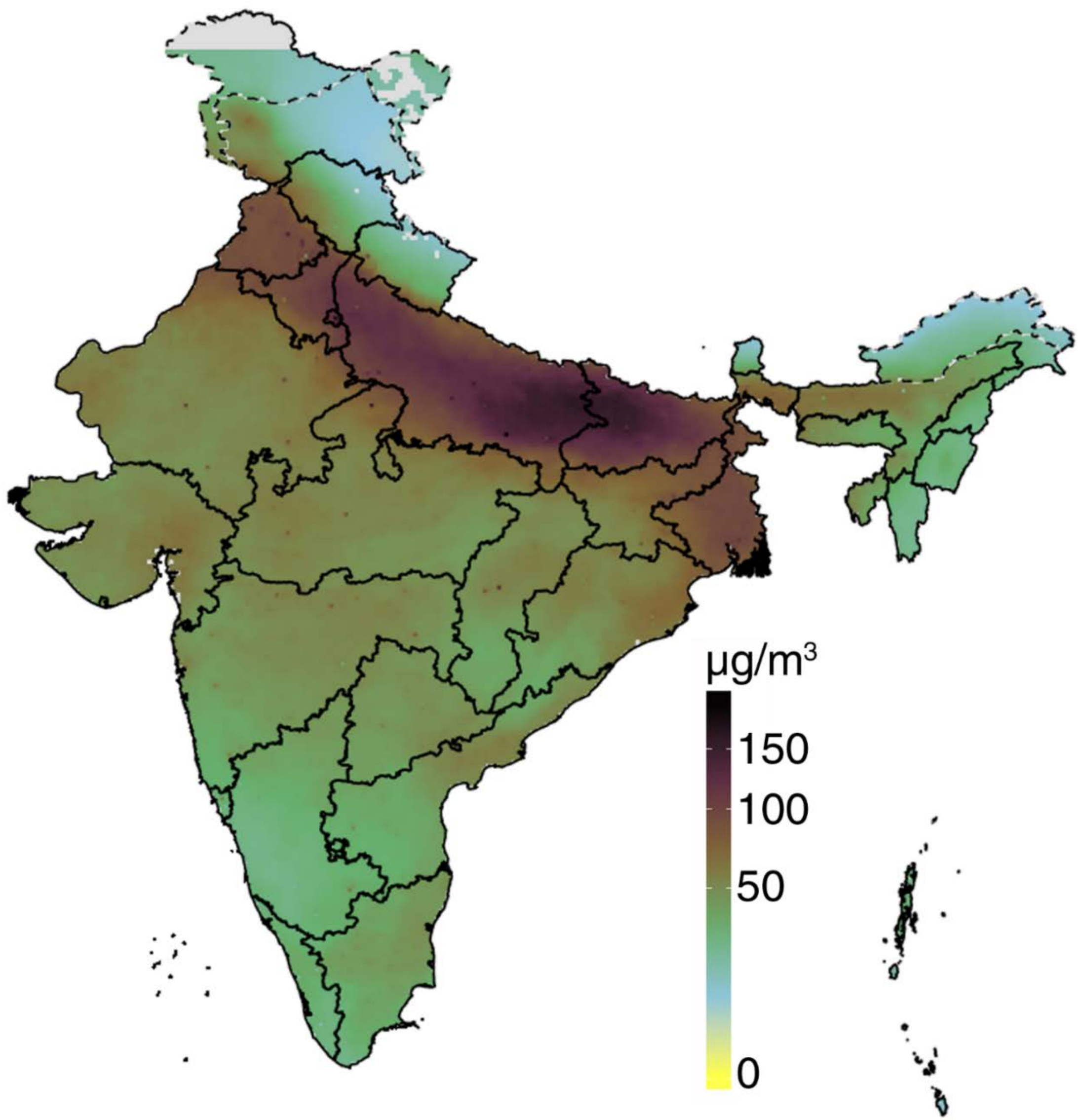


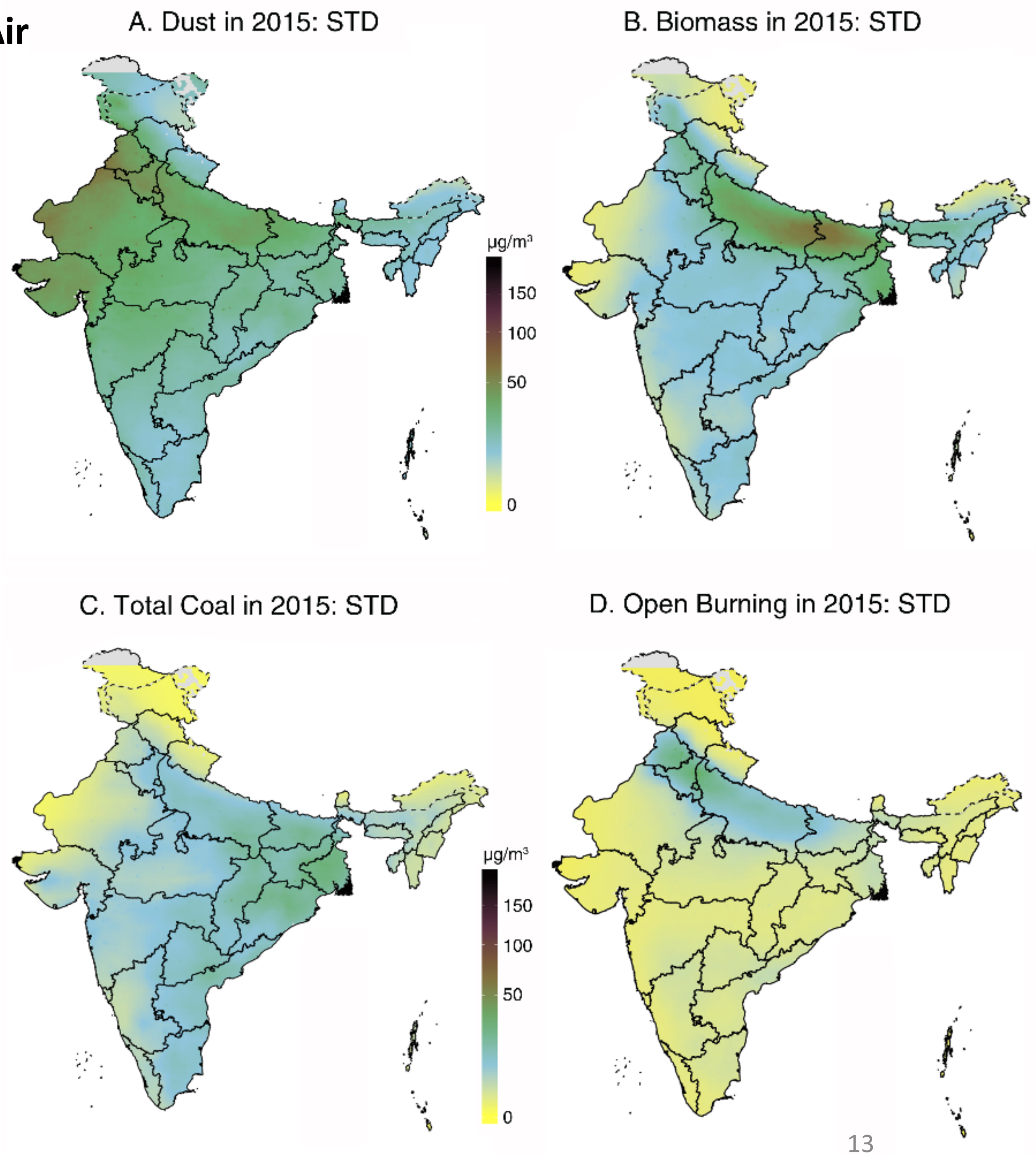

- Estimate source-specific burden

# Isolating the contributions of major sources



**99.9% of Indian population lives in areas > WHO (annual average) Air Quality Guideline (90% in areas > WHO Interim Target 1 (35 µg/m³)**



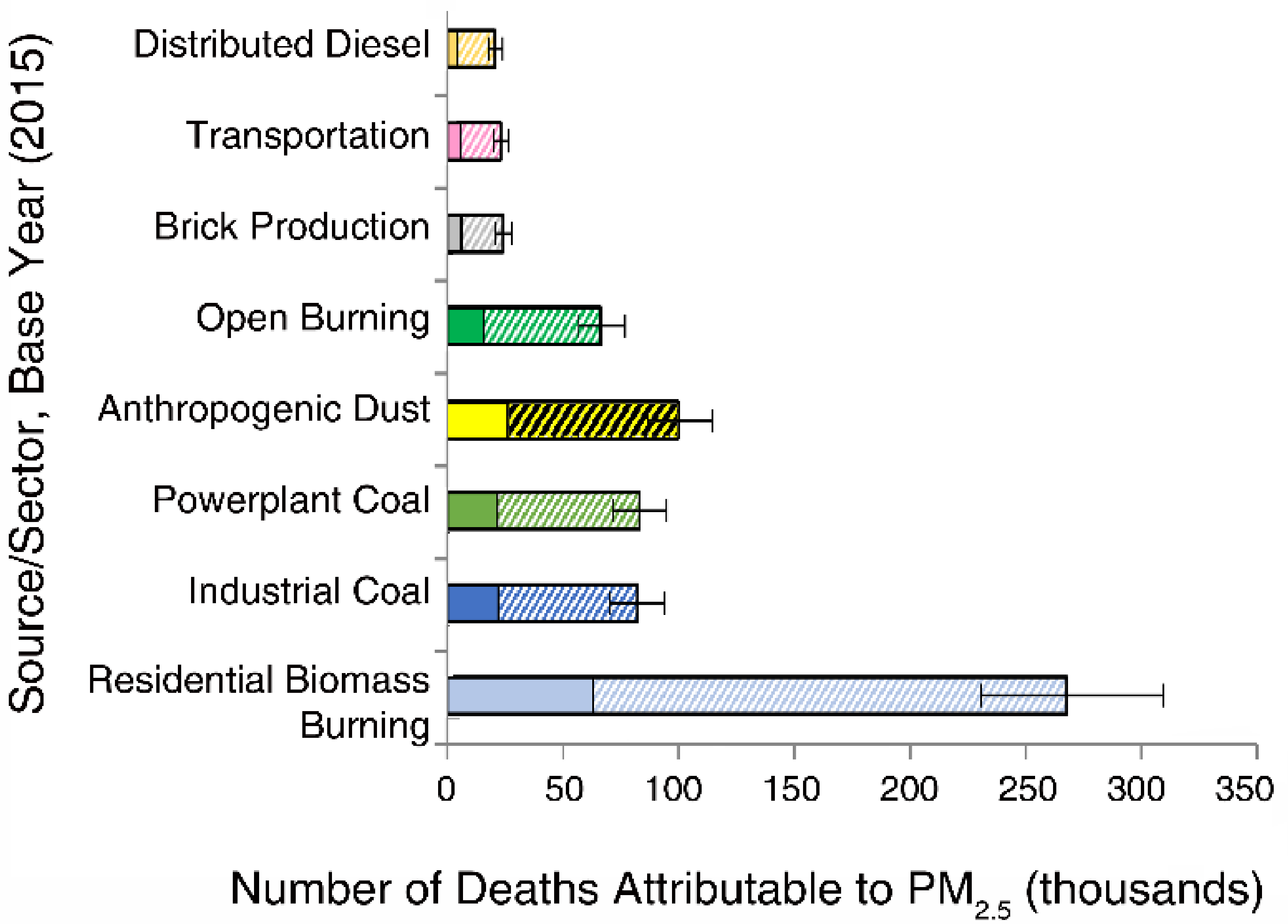
# Population-weighted $PM_{2.5}$ source contributions

| Source Sector | % Contribution | | |
|---|---|---|---|
| | All India | Rural | Urban |
| Residential Biomass | 23.9 | 24.2 | 22.1 |
| Anthropogenic Dust | 8.9 | 8.8 | 9.6 |
| 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 |
| Brick Production | 2.2 | 2.1 | 2.2 |
| Transport | 2.1 | 2.1 | 2.1 |
| Distributed Diesel | 1.8 | 1.8 | 1.4 |

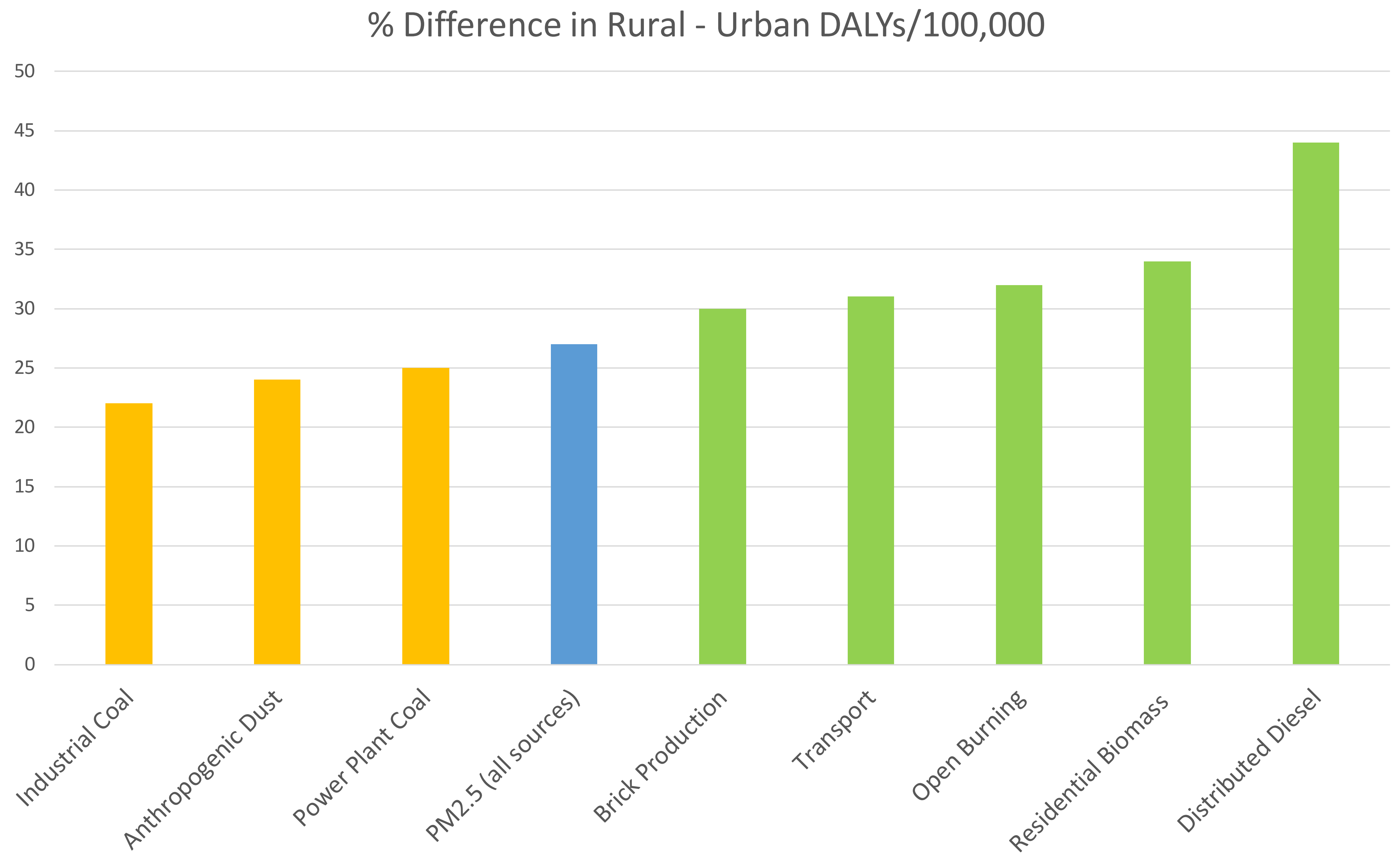
# $PM_{2.5}$ attributable mortality in 2015

| Source Sector | Deaths |
|---|---|
| **$PM_{2.5}$ (all sources)** | **1,090,000** |
| Residential Biomass | 268,000 |
| Anthropogenic Dust | 100,000 |
| Industrial Coal | 82,000 |
| Power Plant Coal | 83,000 |
| Open Burning | 66,000 |
| Brick Production | 24,000 |
| Transport | 23,000 |
| Distributed Diesel | 20,000 |

# Majority of burden falls on rural population



# Larger impact of specific sources on rural populations



# Evaluating future scenarios (2030, 2050)

| Scenario | Energy and emission control policy |
| --- | --- |
| **REF (reference)** | Current legislation and (2005-2015) technology diffusion rates. |
| **S2 (ambitious)** | Energy efficiency (NDC) targets for GHG emissions (thermal power and industry); environmental legislation through auto-fuel policy; emission standards in brick production; cleaner technologies in residential and informal industry sectors. |
| **S3 (aspirational)** | Total shift away from traditional biomass technologies (residential and informal industry) and from open field burning; 80-85% non-coal electricity generation |

# Shifts in technologies and practices

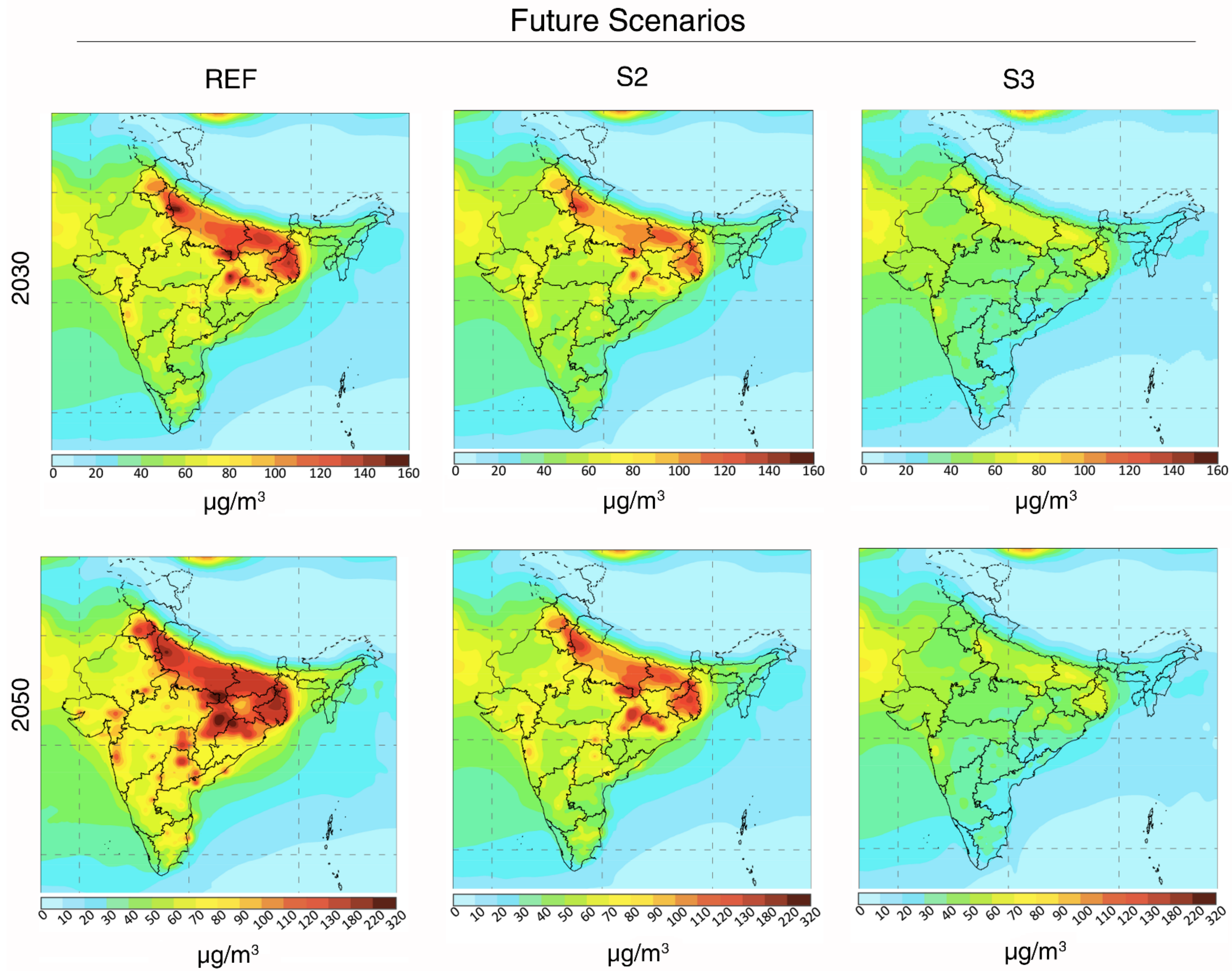
**S2 - Promulgated policies**

| | |
|---|---|
| **Power plant** | Share of renewable energy (40% by 2030) as targeted in India's NDC; negligible flue gas desulphurization from a slow adoption of recent regulation (MoEFCC, 2015). |
| **Industry** | Modest increases in energy efficiency (62-84%) under the Perform Achieve and Trade (PAT) scheme (Level 2, IESS, Niti Aayog, 2015). |
| **Transport** | Promulgated growth in public vehicle share (25-30%) (NTDPC, 2013; Guttikunda and Mohan, 2014; NITI Aayog, 2015); slow shifts to BS-VI standards (MoRTH, 2016 ICRA, 2016). |
| **Bricks & Informal Ind.** | Modest increases in non-fired-brick walling materials (30-45%) (UNDP, 2009; Maithel, personal communication, 2016); slow shift to zig-zag fired brick kilns / clean tech in informal industry. |
| **Residential** | Modest shift (55% in 2030 and 70% in 2050) to energy efficient technologies and fuels (Level 2, IESS, Niti Aayog, 2015). |
| **Open burning** | No shift away from agricultural residue burning. |

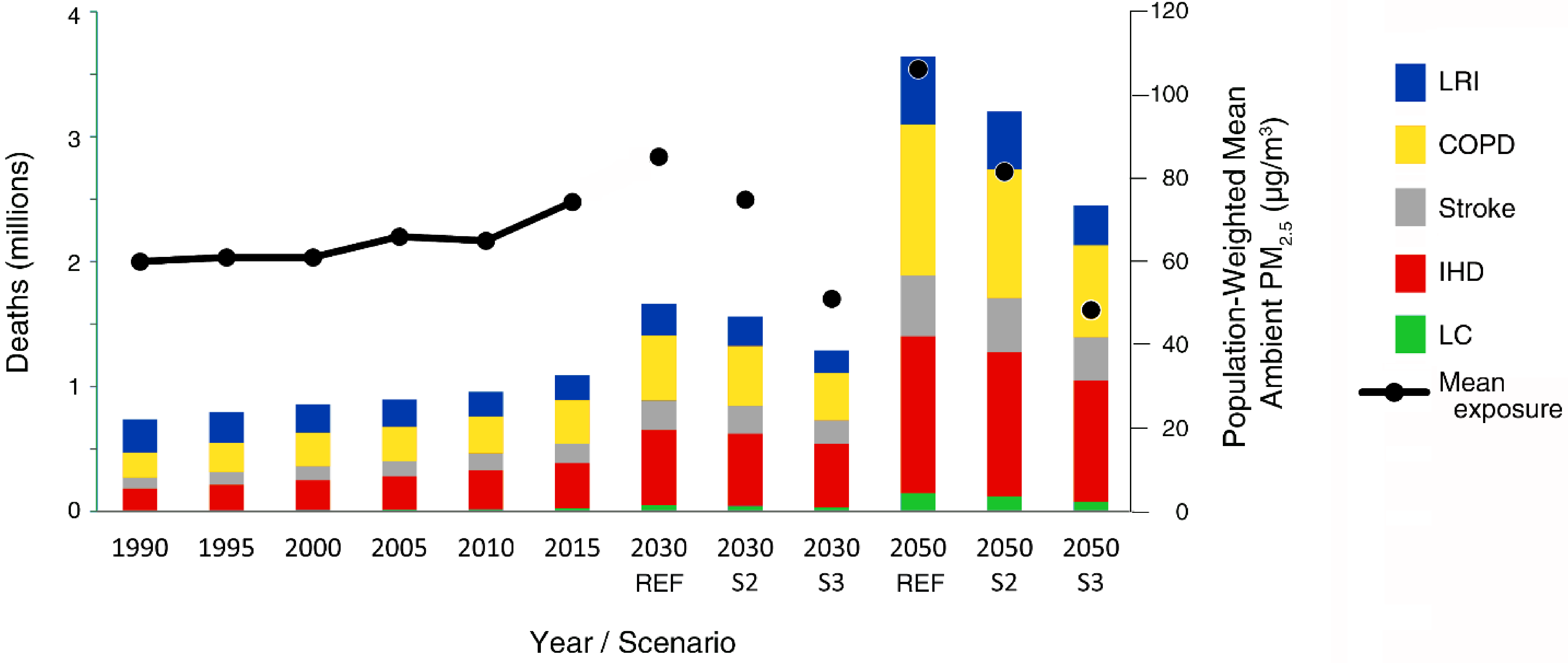
**S3 - Future policies**

| | |
|---|---|
| **Power plant** | Large shift (75-80%) to non-fossil power generation (Anandarajah and Gambhir 2014; Shukla and Chaturvedi 2012; Level 4, IESS, Niti Aayog, 2015); 80-95% use of flue gas desulphurization. |
| **Industry** | Near complete shift to high efficiency (85-100%) industrial technologies (Level 4, IESS, Niti Aayog, 2015). |
| **Transport** | Large shifts to public vehicles (40-60%) (NITI Aayog, 2015), BS-VI syandards, efficient engine technology (MoP, 2015), electric/CNG vehicle share (20-50%) (NITI Aayog, 2015). |
| **Bricks & Informal Ind.** | Large share of non-fired brick walling materials (40-70%), complete move to zig-zag fired / VSBK kilns; gasifiers / clean technologies in informal industries (65-80%). |
| **Residential** | Large shifts (90% in 2030 and 100% in 2050) to LPG/PNG/electric cooking (Level 4, IESS, Niti Aayog, 2015), (100% in 2030) electric and solar lighting (National Solar Mission 2010). |
| **Open burning** | Shift away from (35% phase out by 2030) and complete phase-out (2050) of agricultural residue burning to mulching/deep-sowing technologies/practices (Gupta, 2014). |

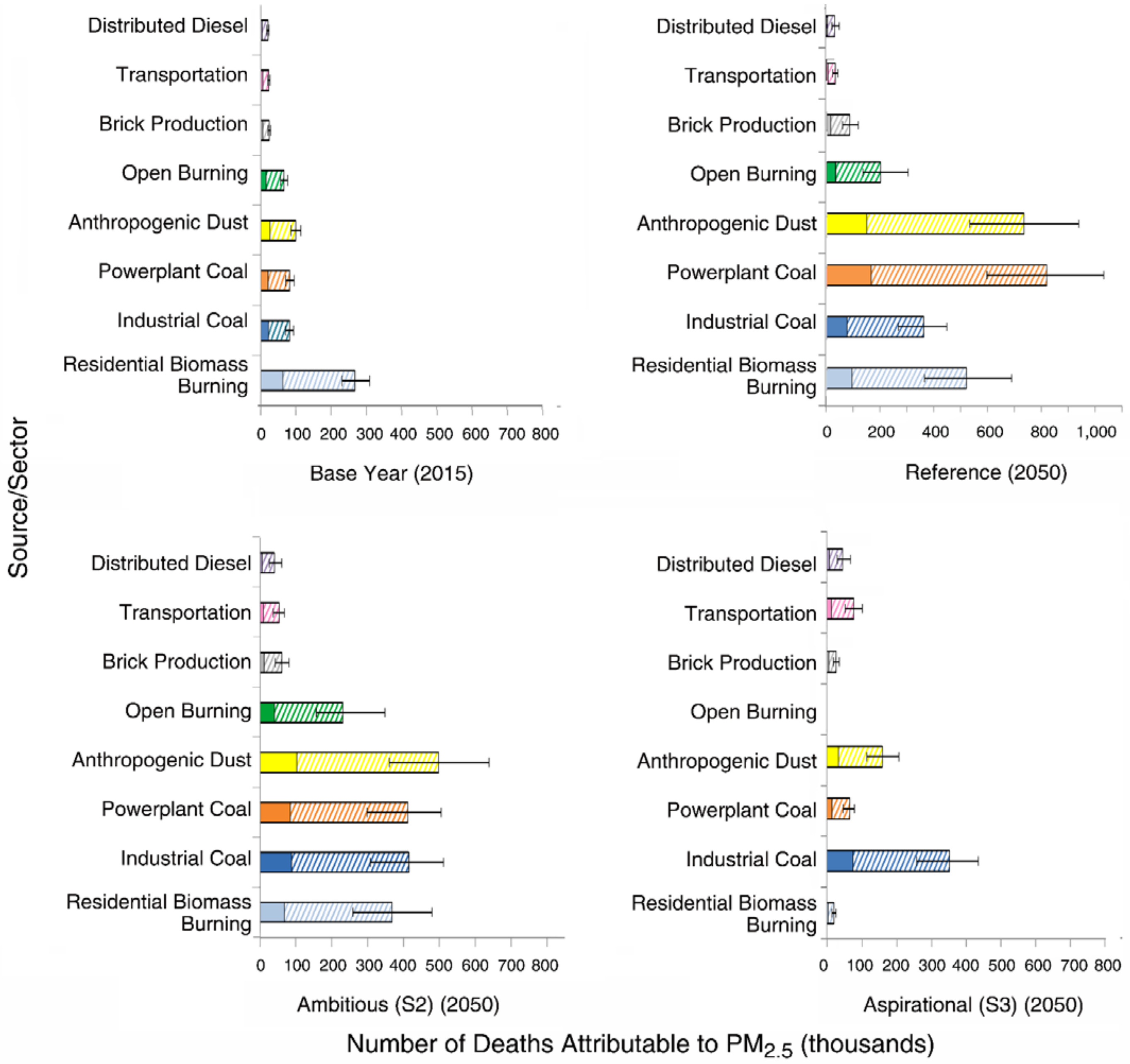
# Management can effectively reduce concentrations…



# …but continuing challenge of demographics



# Source contributions will also change

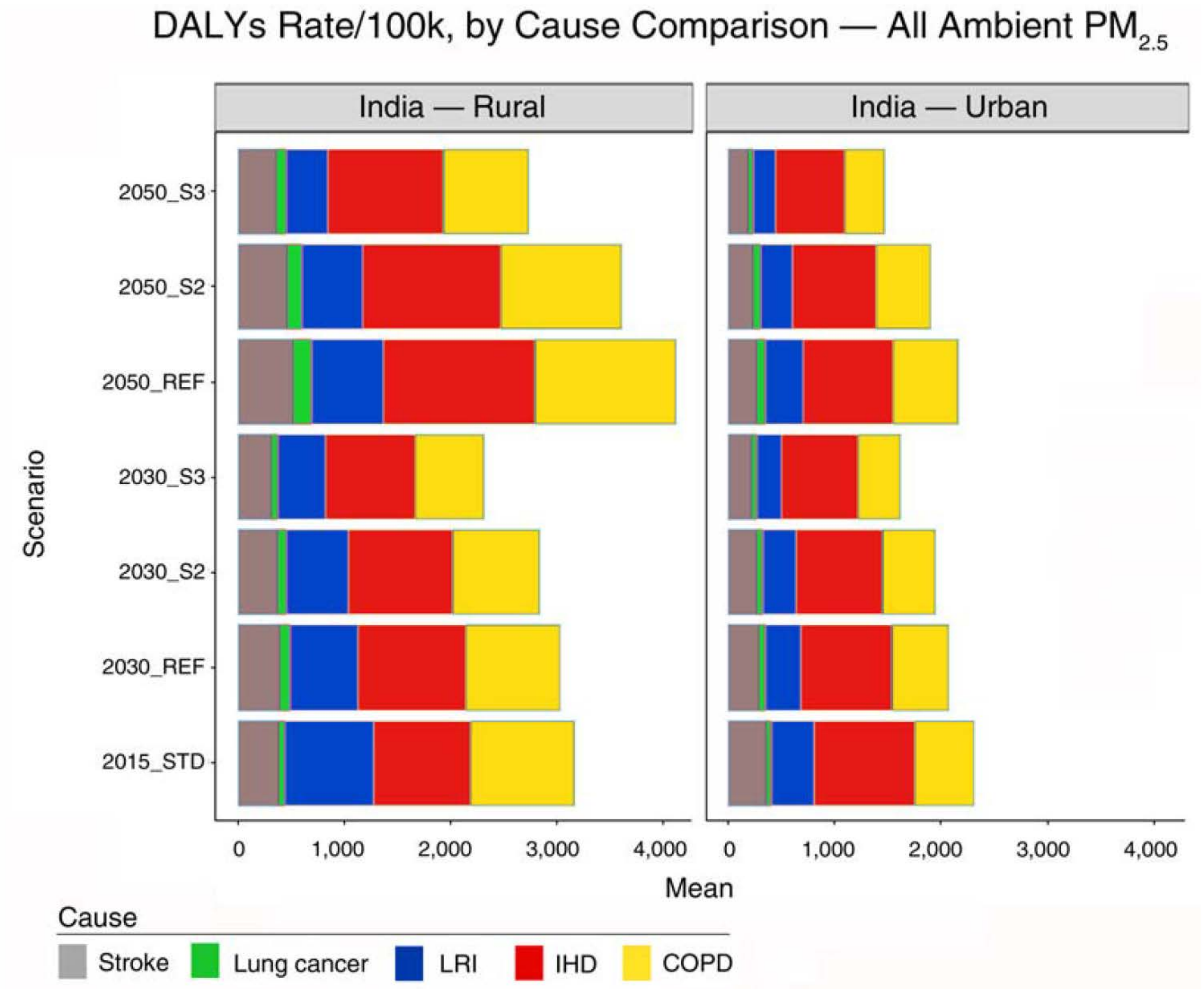



Increasing importance of coal

Challenge of open burning

Dust

# Exposure reductions do make a difference!



# Strengths

- **Utilizes state-of-the-art Indian data on emissions, exposure, health burden**
- **Comprehensive, national/sub-national**
- **Future scenarios**

Photo: Ecobrick.in

# Strengths and Limitations

- Utilizes state-of-the-art Indian data on emissions, exposure, health burden
- Comprehensive, national/sub-national
- Future scenarios

- **Emissions scenarios**
- **Health and demographic trends**
- **Assumption of equitoxicity**
- **Resolution of source contributions likely underestimates transportation impacts in urban areas**
- **Transboundary pollution (and impacts)**
- **Other pollutants (Ozone, NOx)**



Photo: Ecobrick.in

# Summary

- **In 2015, $PM_{2.5}$ air pollution responsible for ~10 % of deaths in India**
  - ~1.1. million deaths (75% amongst rural population)

- **Residential biomass burning is the largest contributing source**
  - coal combustion, agricultural burning, dust
  - transportation, distributed diesel, brick production also important

- **Without action in 2050:**
  - population exposures increase > 40%
  - attributable deaths more than triple

- **1.2 million deaths in 2050 can be avoided by aggressive action in major sectors**



Photo: Ecobrick.in

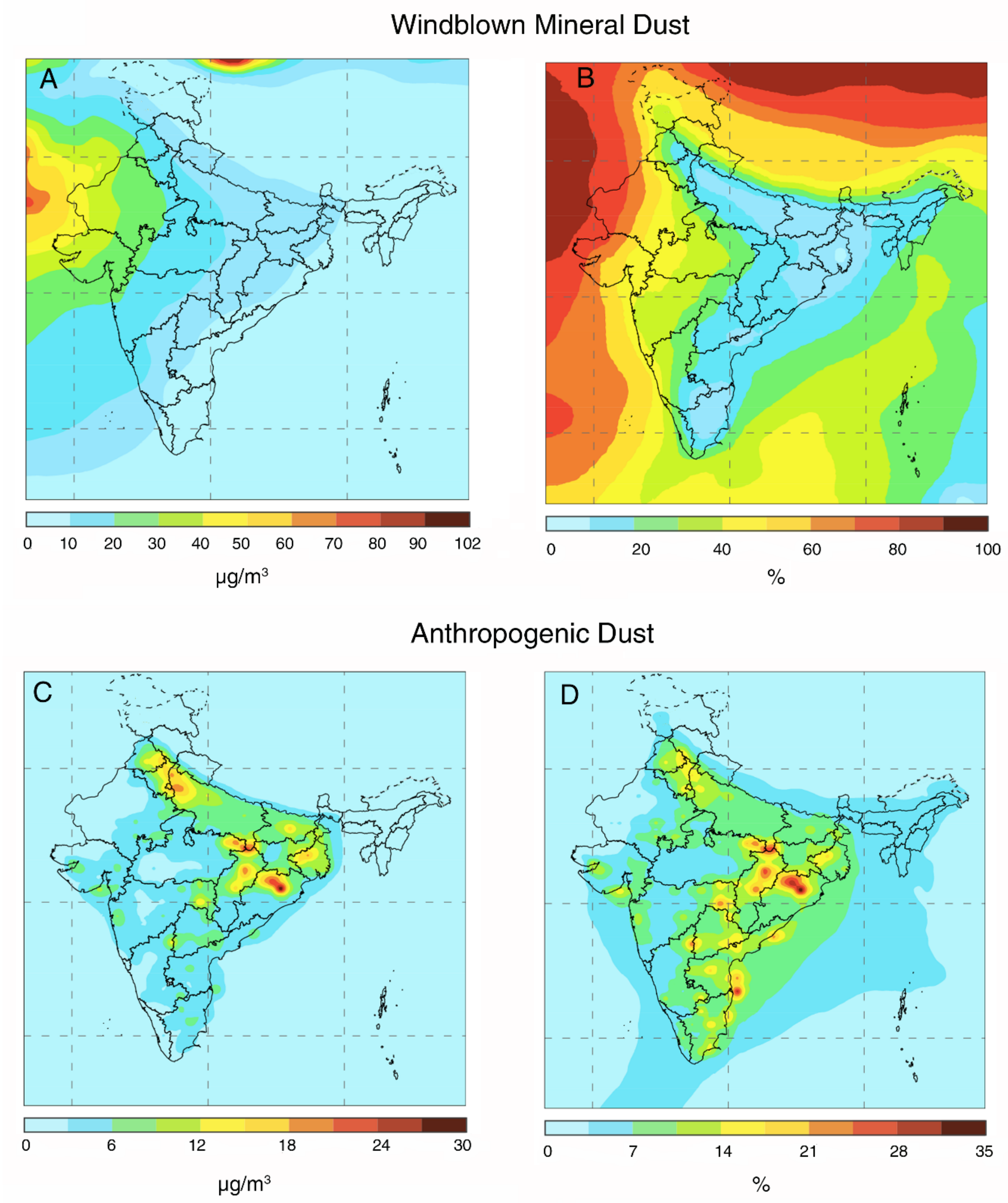
# Thank you!

# Questions?

Photo: Ecobrick.in

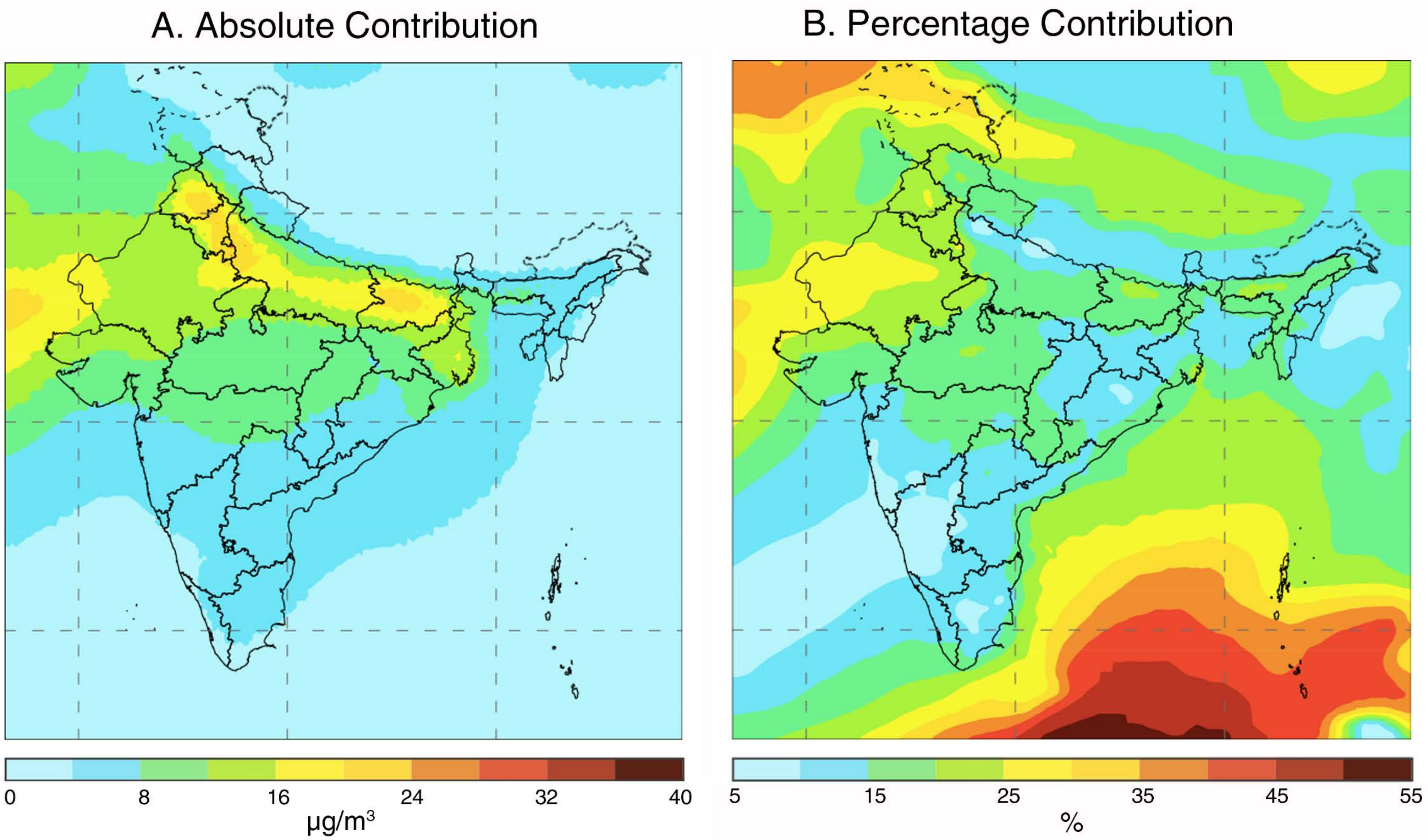
# EXTRA SLIDES

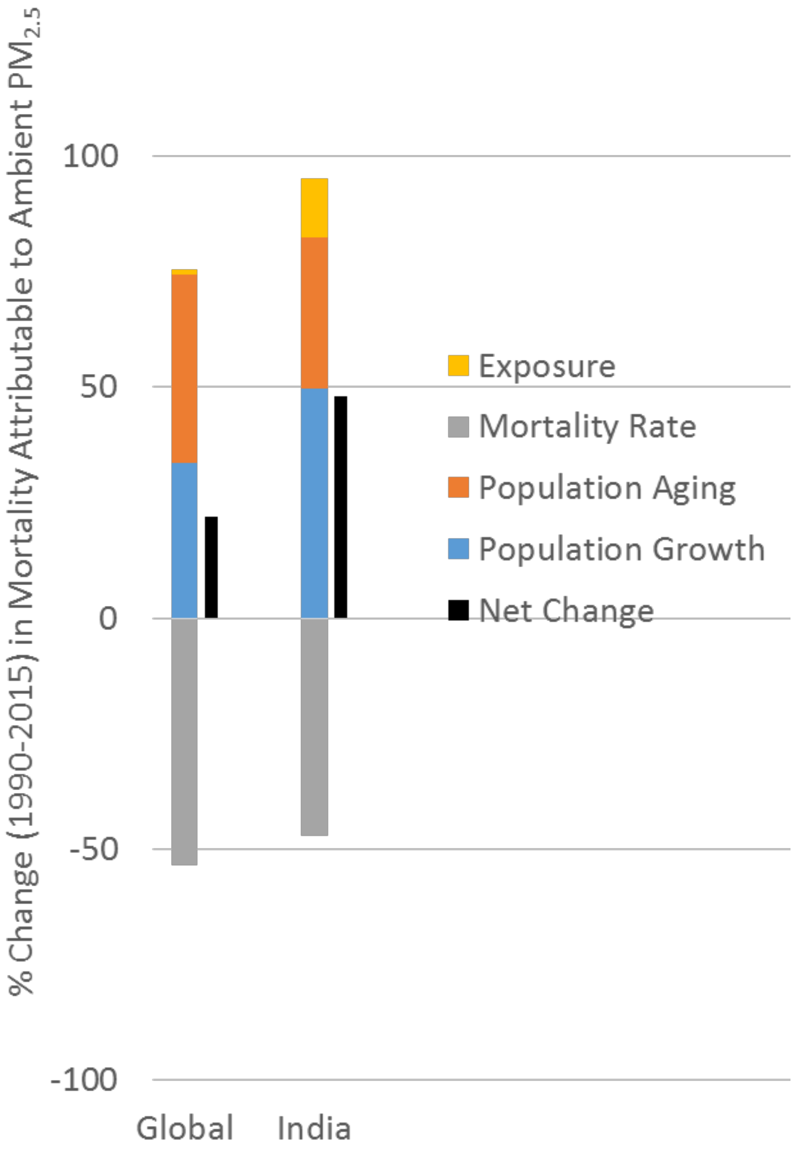
# Dust



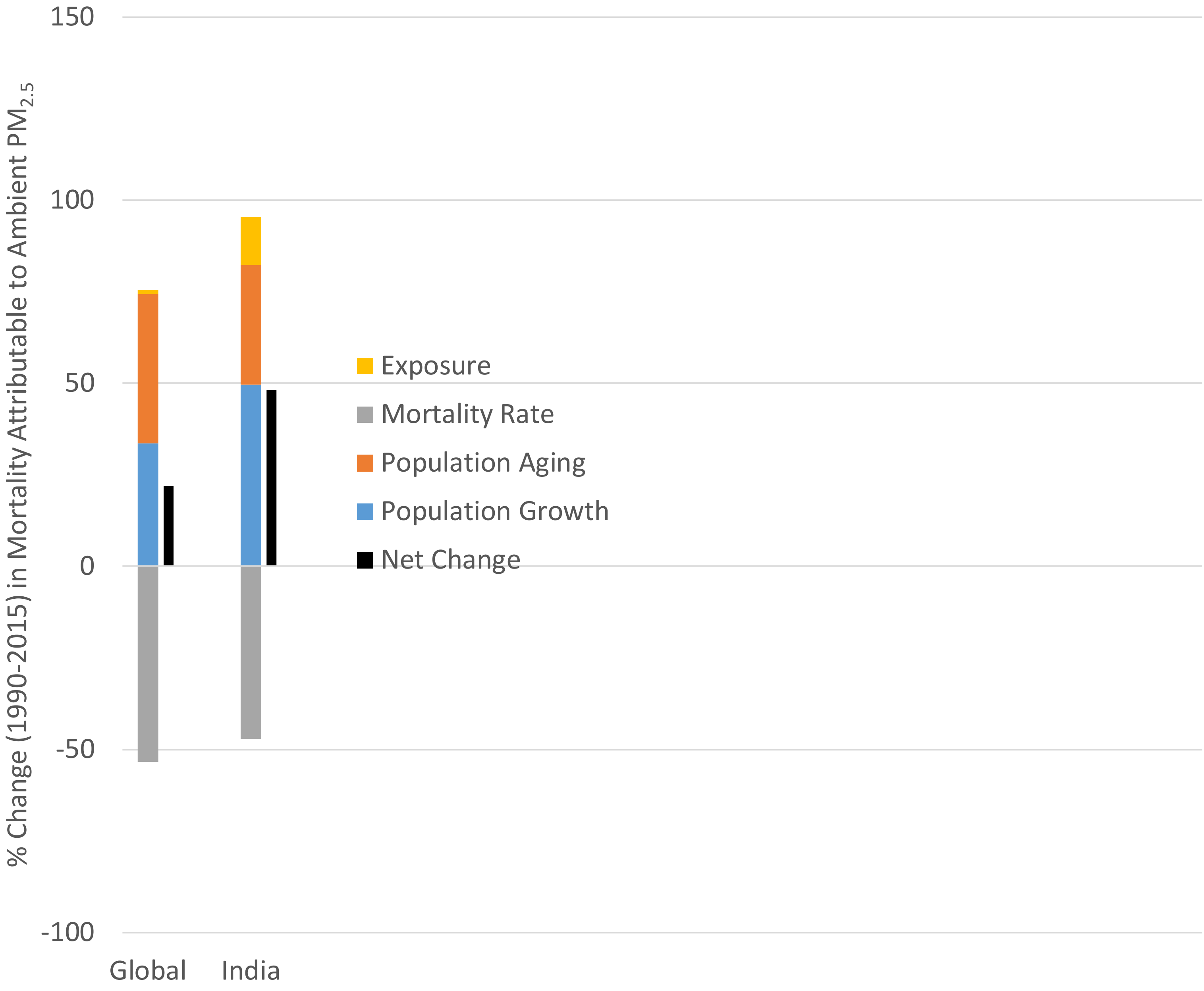
Windblown Mineral Dust
A
B
0 10 20 30 40 50 60 70 80 90 102
μg/m³
0 20 40 60 80 100
%
Anthropogenic Dust
C
D
0 6 12 18 24 30
μg/m³
0 7 14 21 28 35
%

# Transboundary pollution

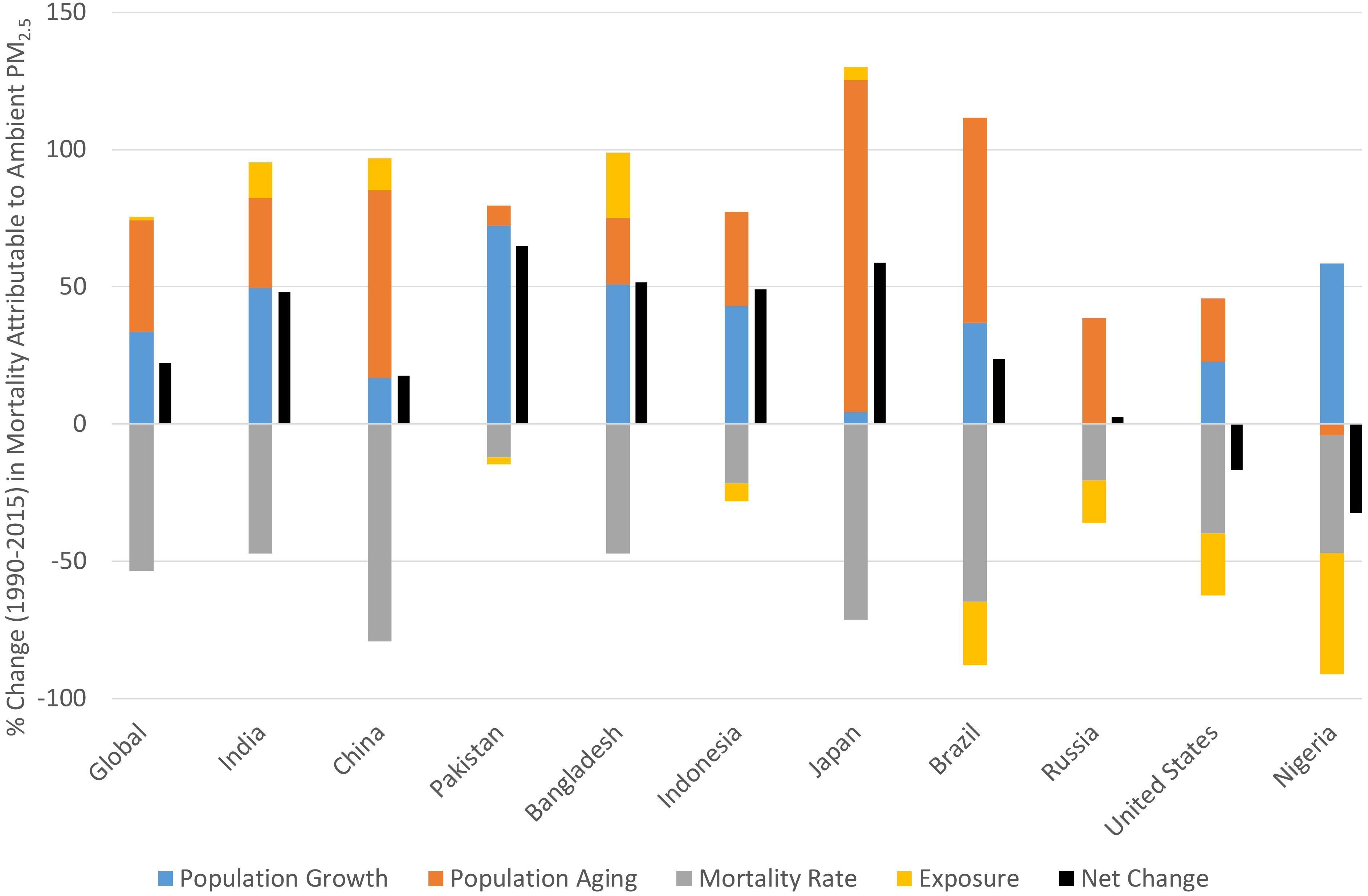



% Change (1990-2015) in Mortality Attributable to Ambient $PM_{2.5}$
100
50
0
-50
-100
Global
India
Exposure
Mortality Rate
Population Aging
Population Growth
Net Change

# Demographics plays a key role

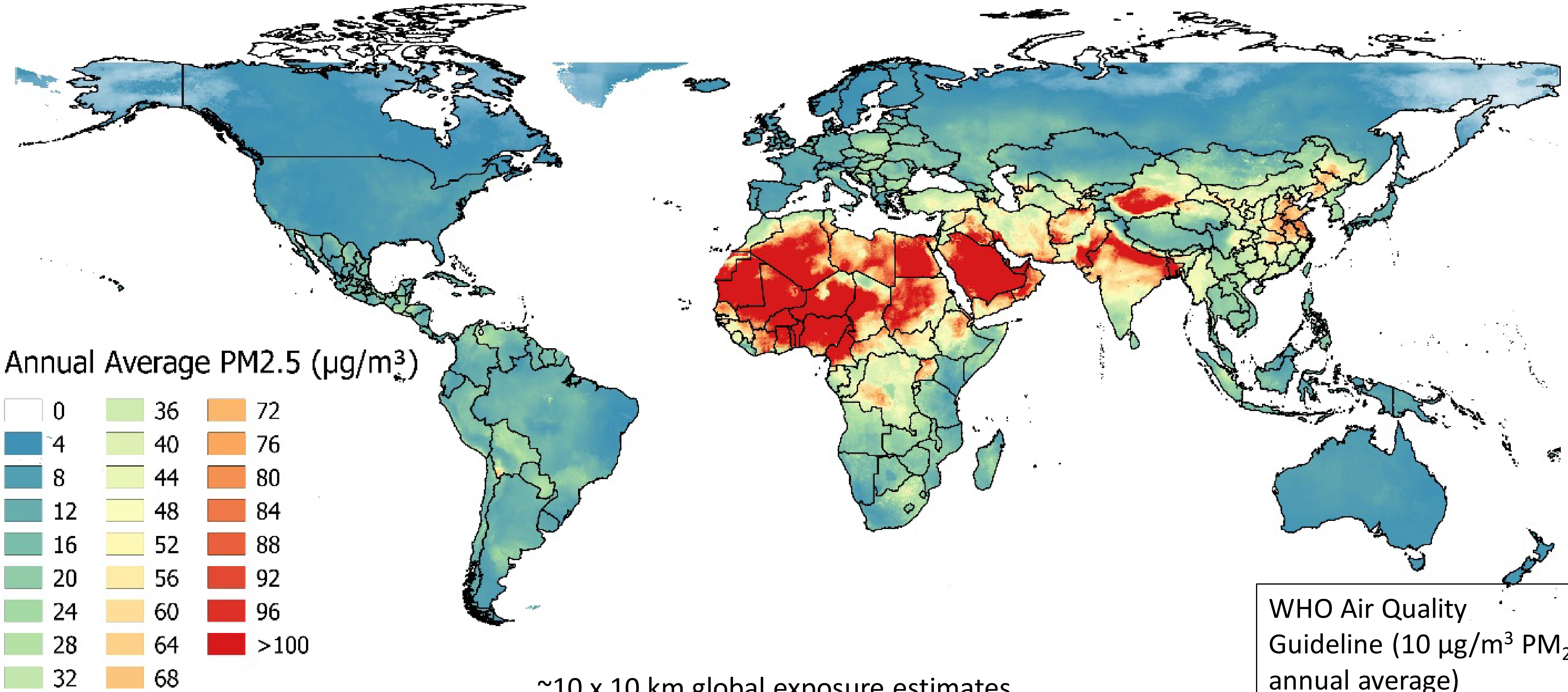


# Demographics plays a key role



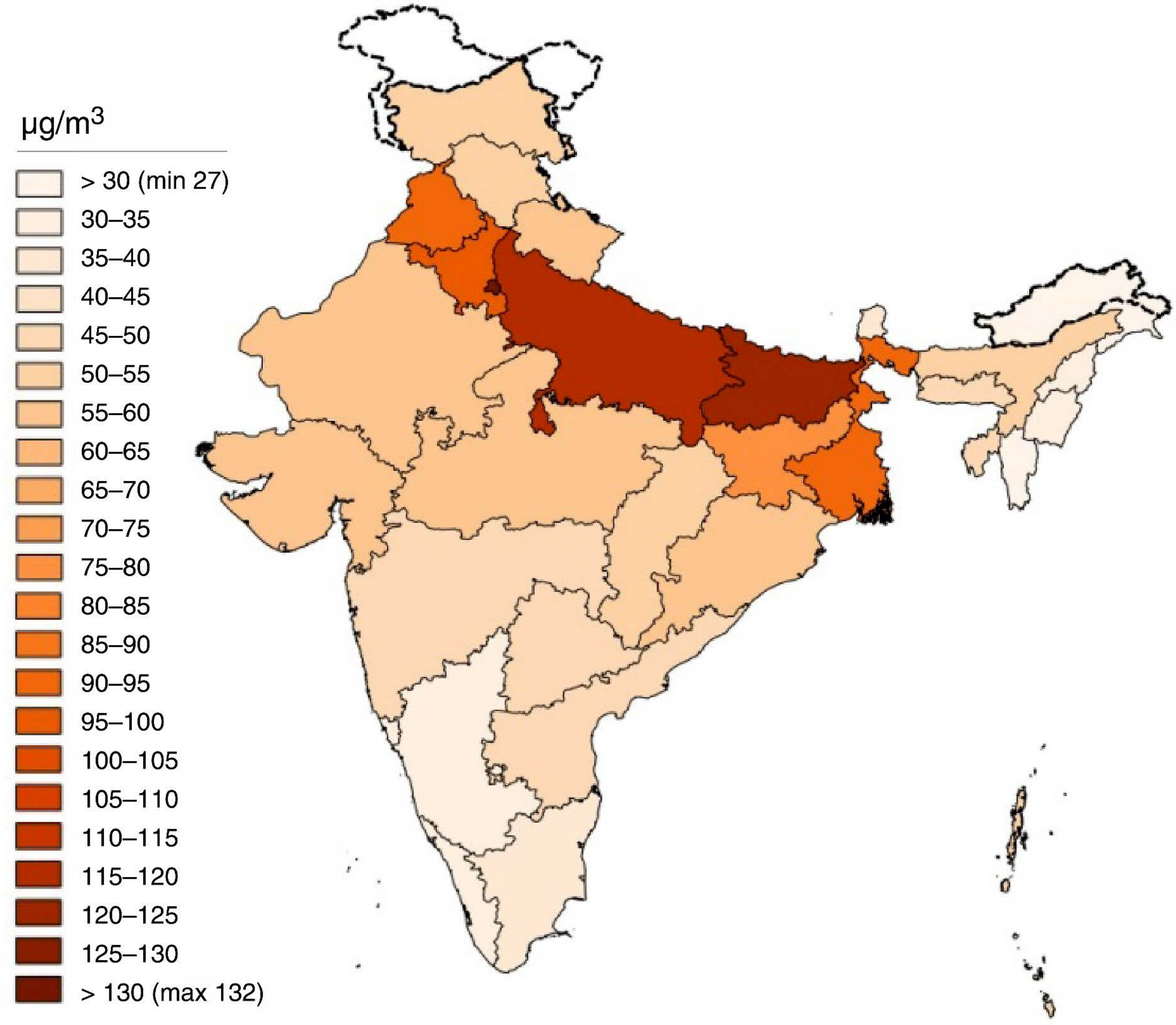
# Estimated disease burden in 2015, India

| Source Sector | Urban – Rural % Difference |
|---|---|
| **$PM_{2.5}$ (all sources)** | **27** |
| Residential Biomass | 34 |
| Anthropogenic Dust | 24 |
| Industrial Coal | 22 |
| Power Plant Coal | 25 |
| Open Burning | 32 |
| Brick Production | 30 |
| Transport | 31 |
| Distributed Diesel | 44 |




~10 x 10 km global exposure estimates

WHO Air Quality Guideline (10 μg/$m^3$ $PM_{2.5}$ annual average)



μg/m3
> 30 (min 27)
30–35
35–40
40–45
45–50
50–55
55–60
60–65
65–70
70–75
75–80
80–85
85–90
90–95
95–100
100–105
105–110
110–115
115–120
120–125
125–130
> 130 (max 132)

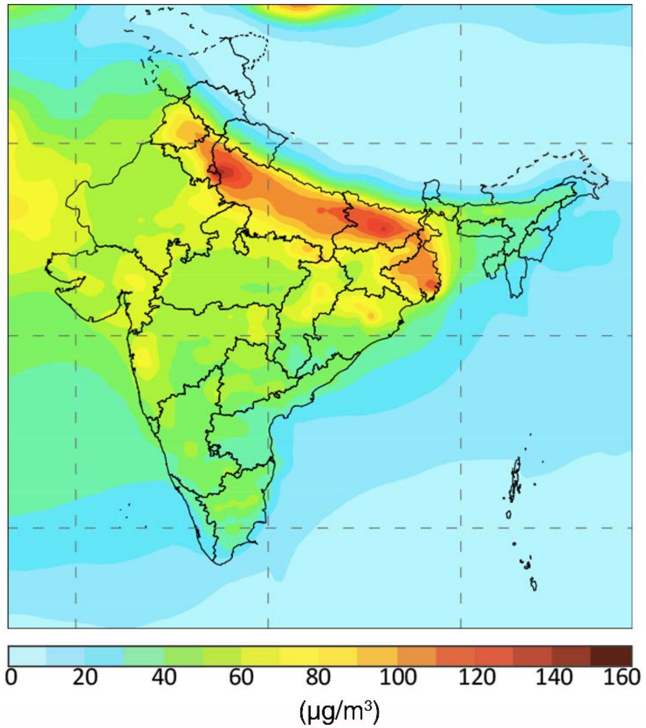

0
20
40
60
80
100
120
140
160
(µg/m³)

**Table 4.** Source Sector Contributions to $PM_{2.5}$-Attributable Deaths (95% UI) in India, 2015

| Source Sector | All India (95% UI) | Rural India (95% UI) | Urban India (95% UI) |
|---|---|---|---|
| All ambient $PM_{2.5}$ | 1,090,400 (939,600 to 1,254,600) | 815,300 (693,200 to 944,300) | 275,000 (240,800 to 310,900) |
| Residential biomass | 267,700 (230,600 to 309,300) | 204,800 (175,000 to 238,700) | 62,900 (54,600 to 71,100) |
| Total coal | 169,300 (145,900 to 193,000) | 124,500 (106,100 to 143,300) | 44,800 (39,000 to 50,800) |
| Industrial coal | 82,100 (70,400 to 93,900) | 60,200 (51,400 to 69,300) | 21,900 (19,000 to 24,900) |
| Powerplant coal | 82,900 (71,600 to 94,700) | 61,400 (52,300 to 70,500) | 21,500 (18,700 to 24,500) |
| Open burning | 66,200 (56,700 to 76,800) | 50,500 (42,800 to 59,500) | 15,700 (13,700 to 17,700) |
| Transportation | 23,100 (19,900 to 26,400) | 17,400 (14,800 to 20,200) | 5,600 (4,900 to 6,400) |
| Brick production | 24,100 (20,700 to 27,800) | 18,100 (15,500 to 21,100) | 5,900 (5,100 to 6,700) |
| Distributed diesel | 20,400 (17,600 to 23,800) | 16,200 (13,700 to 19,100) | 4,200 (3,600 to 4,800) |
| Anthropogenic dust[a] | 99,900 (86,500 to 114,400) | 74,000 (63,100 to 85,500) | 25,900 (22,700 to 29,300) |
| Total dust[b] | 412,500 (353,300 to 474,600) | 303,700 (256,600 to 351,300) | 108,900 (94,900 to 123,700) |

[a] Anthropogenic dust includes only anthropogenic fugitive, combustion, and industrial dust.

[b] Total dust includes anthropogenic dust and windblown mineral dust.

**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 |

[a] Appendix C Table C.1 (available on the HEI website) provides the breakdown of these sector contributions to $PM_{2.5}$ for each of the Indian states.

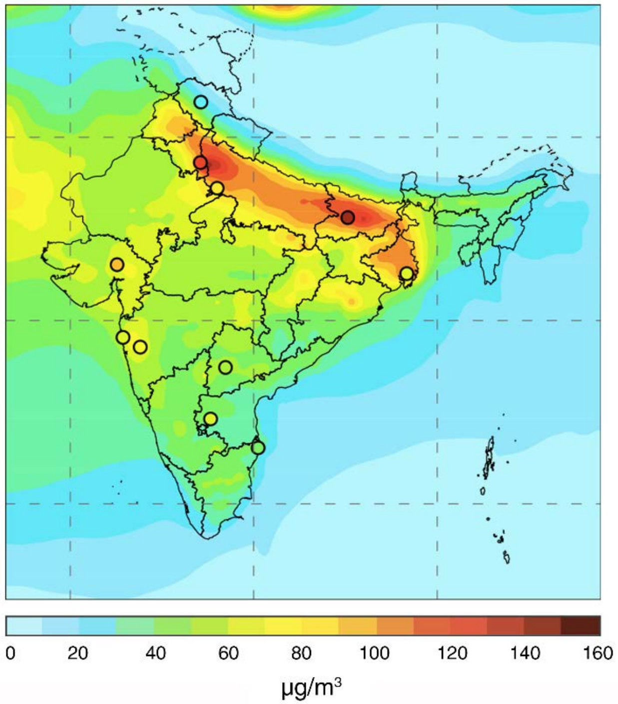
[b] Anthropogenic dust includes anthropogenic fugitive, combustion, and industrial dust.

[c] Total anthropogenic dust and windblown mineral dust.

| | CHINA OUTDOOR PM | CHINA HOUSEHOLD | INDIA OUTDOOR PM | INDIA HOUSEHOLD | USA OUTDOOR PM |
|---|---|---|---|---|---|
| IHD | **291,796** **20%** | **149,659** **10%** | **365,642** **23%** | **283,158** **18%** | **43,160** **9.3%** |
| Stroke | **322,230** **17%** | **165,101** **9%** | **152,488** **19%** | **133,088** **17%** | **10,881** **6.2%** |
| COPD | **281,744** **31%** | **163,542** **18%** | **348,988** **33%** | **341,550** **33%** | **1,710** **9.0%** Ozone: 11,662 |
| Lung Cancer | **145,983** **25%** | **73,482** **13%** | **22,530** **27%** | **22,106** **27%** | **17,363** **4.5%** |
| ALRI | **66,302** **32%** | **38,258** **19%** | **200,742** **38%** | **197,192** **37%** | **5,718** **6.9%** |
| | **1,108,055** | **590,042** | **1,090,391** | **977,094** | **88,434** |

http://vizhub.healthdata.org/gbd-compare

| REF, or Reference Scenario |
|---|
| Where the sectoral energy demand is met through sectoral technology-mix evolution at rates corresponding to changes observed during 2005–2015. |
| **S2, or Ambitious Scenario** |
| Assumes that the technology mix will reflect (1) the energy-efficiency targets for thermal power and industry as desired in India's INDC; (2) the emissions standards in transport as proposed in auto-fuel policy; and (3) the emissions controls expected from an influx of cleaner technologies in residential, brick production, and informal industry sectors. |
| **S3, or Aspirational Scenario** |
| Aimed at more profound energy efficiency targets, represented by published high-efficiency–low-carbon-growth pathways in industrial, electricity-generation, and transport sectors; high rates of shifting away from traditional biomass technologies (residential and informal industry); and including a complete end to agricultural field burning. |


0
20
40
60
80
100
120
140
160
μg/m³

HEALTH
EFFECTS
INSTITUTE

January 2018

SPECIAL REPORT 21

# Burden of Disease Attributable to Major Air Pollution Sources in India

GBD MAPS Working Group