Metrics for accounting for the health impacts of black carbon and methane interventions

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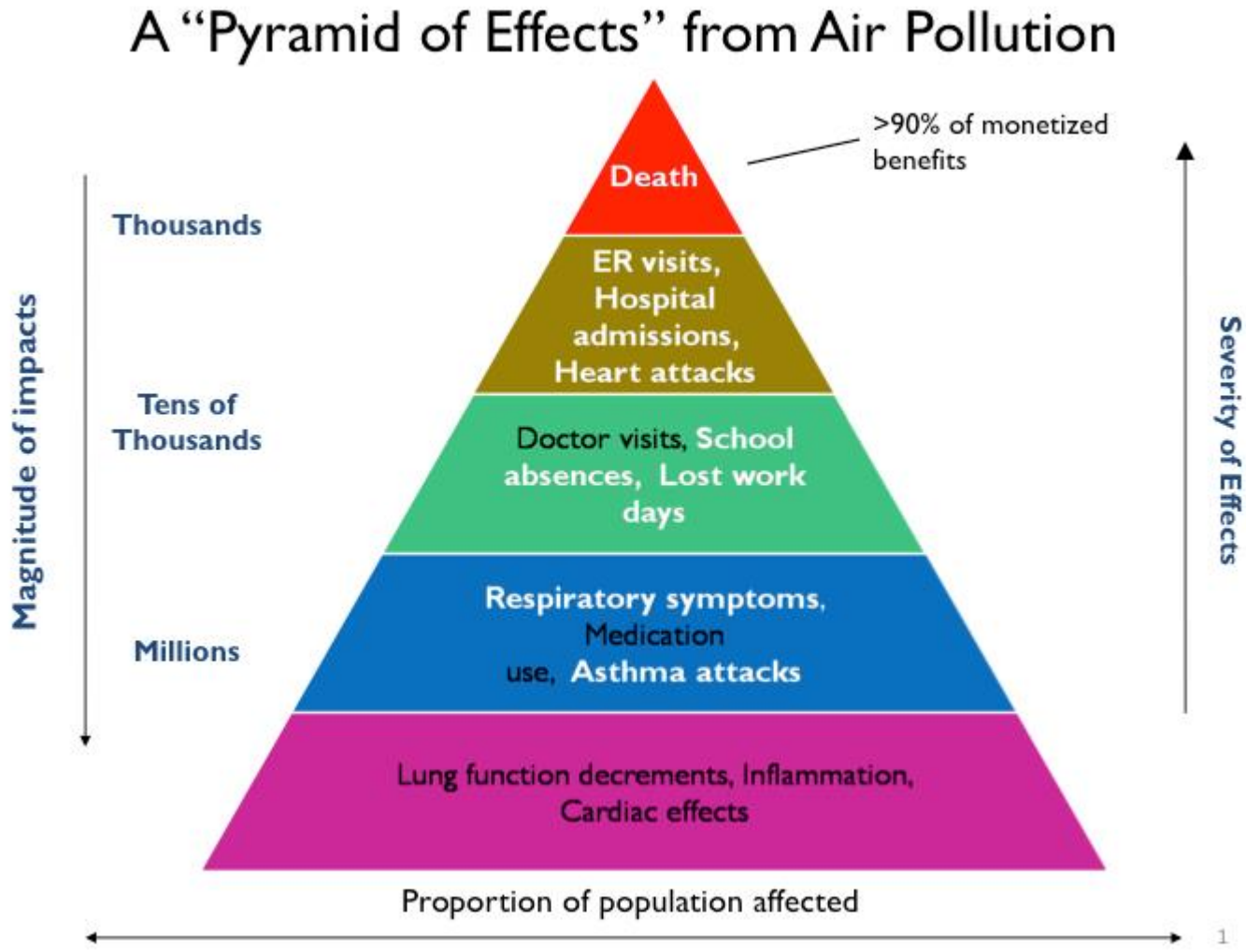
Health impacts of SLCPs and their mitigation

- BC is a component of $PM_{2.5}$
  - Ischemic heart disease
  - Stroke
  - Chronic obstructive pulmonary disease
  - Lung cancer
  - Acute lower respiratory infections in kids age <5 years
  - Other morbidity impacts
- Methane is a precursor to tropospheric ozone
  - Respiratory disease among adults
  - Short-term morbidity impacts
- Other health impacts
  - Climate change
  - Agriculture/food security
  - Physical activity



Health is a major driver for SLCP mitigation

	CH_4 measures	BC Tech measures	BC Reg measures
Physical Impacts			
Avoided warming in 2050 (°C)	0.28 ± 0.10	0.12 (+0.06/–0.09)	.07 (+.04/–0.09)
Annually avoided crop yield losses (millions metric tons; sum of wheat, rice, maize, and soy)	27 (+42/–20)	24 (+72/–21)	2 (+13/–3)
Annually avoided premature deaths (thousands)	47 (+40/–34)	1720 (+1529/–1188)	619 (+639/–440)
Valuation			
Climate, billions $US	331 ± 118	142 (+71/–106)	83 (+47/–106)
($US per metric ton CH_4)	(2381 ± 850)		
Crops, billions $US	4.2 ± 1.2	3.6 ± 2.6	0.4 ± 0.6
($US per metric ton CH_4)	(29 ± 8)		
Health, billions $US	148 ± 99	3717 (+3236/–2563)	1425 (+1475/–1015)
($US per metric ton CH_4)	(1080 ± 721)		

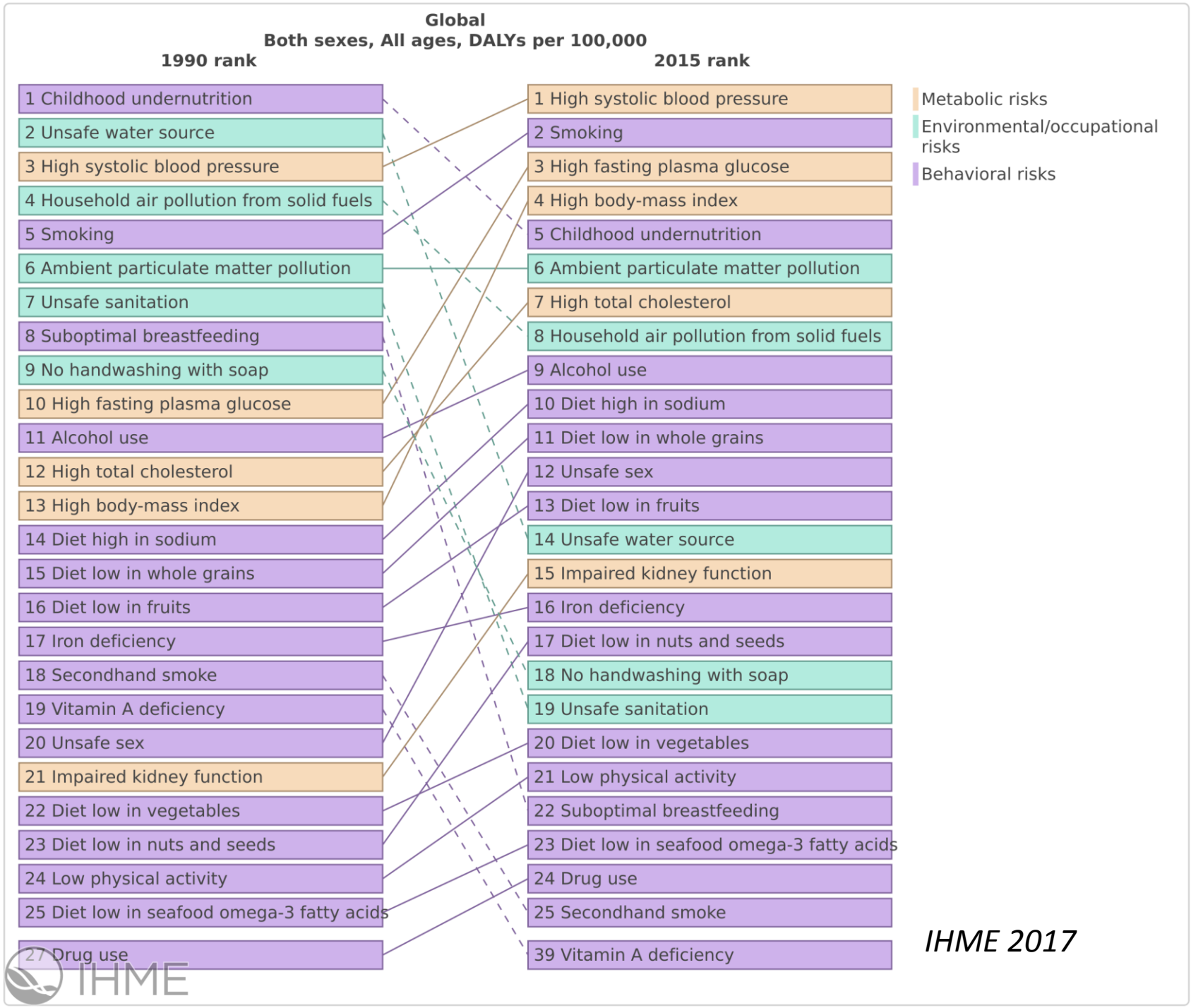
Shindell et al. 2012

U.S. EPA Regulatory Impact Analysis

Severity

	Incidence (cases)			Valuation		
	Revised and Alterative Annual Standards (95th percentile confidence interval)			Revised and Annual Standards (95th percentile confidence interval)		
Health Effect	13 µg/m³	12 µg/m³	11 µg/m³	13 µg/m³	12 µg/m³	11 µg/m³
Avoided Mortality						
Krewski et al. (2009) (adult mortality age 30+)	140 (100--190)	460 (320--590)	1,500 (1,000--1,900)	$1,300 ($120--$3,500)	$4,000 ($370--$11,000)	$13,000 ($1,200--$35,000)
Lepeule et al. (2012) (adult mortality age 25+)	330 (180--480)	1,000 (560--1,500)	3,300 (1,800--4,800)	$2,900 ($250--$8,100)	$9,000 ($800--$26,000)	$29,000 ($2,600--$82,000)
Woodruff et al. (1997) (infant mortality)	0 (0--1)	1 (1--2)	4 (2--6)	$3.4 ($0.29--$10)	$11 ($0.91--$32)	$35 ($3.0--$100)
Avoided Morbidity						
Non-fatal heart attacks						
Peters et al. (2001) (age >18)	160 (49--260)	480 (150--800)	1,600 (480--2,600)	$18 ($3.0--$46)	$55 ($9.1--$140)	$180 ($31--$460)
Pooled estimate of 4 studies (age >18)	17 (8--41)	52 (24--130)	170 (78--410)	$2.0 ($0.43--$6.8)	$6.0 ($1.3--$21)	$20.0 ($4.4--$68)
Hospital admissions—respiratory (all ages)[b]	31 (-9--58)	110 (-30--200)	380 (-100--720)	$0.86 (-$0.22--$1.6)	$3.0 (-$0.8--$5.5)	$11 (-$2.7--$20)
Hospital admissions—cardiovascular (age > 18)	43 (20--76)	140 (66--240)	480 (230--0,840)	$1.70 ($0.85--$2.8)	$5.3 ($2.7--$9.2)	$18 ($10--$32)
Emergency department visits for asthma (all ages)[b]	67 (-22--140)	230 (-74--470)	810 (-260--1,600)	$0.03 (-$0.0052--$0.061)	$0.10 (-$0.018--$0.21)	$0.34 (-$0.063--$0.73)
Acute bronchitis (ages 8–12)[b]	280 (-36--580)	870 (-110--1,800)	2,700 (-350--5,500)	$0.13 (-$0.0060--$0.37)	$0.42 (-$0.019--$1.2)	$1.30 (-$0.059--$3.5)
Lower respiratory symptoms (ages 7–14)	3,500 (1500--5500)	11,000 (4,900--17,000)	34,000 (15,000--53,000)	$0.08 ($0.025--$0.10)	$0.24 ($0.078--$0.47)	$0.71 ($0.24--$1.4)
Upper respiratory symptoms (asthmatics ages 9–11)	5,100 (1300--8900)	16,000 (4,100--28,000)	49,000 (12,000--86,000)	$0.17 ($0.038--$0.42)	$0.54 ($0.12--$1.30)	$1.6 ($0.36--$4.0)
Asthma exacerbation (asthmatics ages 6–18)	13,000 (270--81000)	40,000 (850--250,000)	120,000 (2,600--770,000)	$0.7 ($0.027--$5.2)	$2.30 ($0.085--$16)	$7.0 ($0.26--$49)
Lost work days (ages 18–65)	22,000 (19000--25000)	71,000 (61,000--81,000)	230,000 (190,000--260,000)	$3.3 ($2.90--$3.70)	$11 ($9.4--$12)	$35 ($30--$39)
Minor restricted-activity days (ages 18–65)	130,000 (110,000--150,000)	420,000 (350,000--490,000)	1,300,000 (1,100,000--1,600,000)	$8.8 ($4.70--$13)	$29 ($15--$43)	$91 ($48--$140)

Global Burden of Disease Study

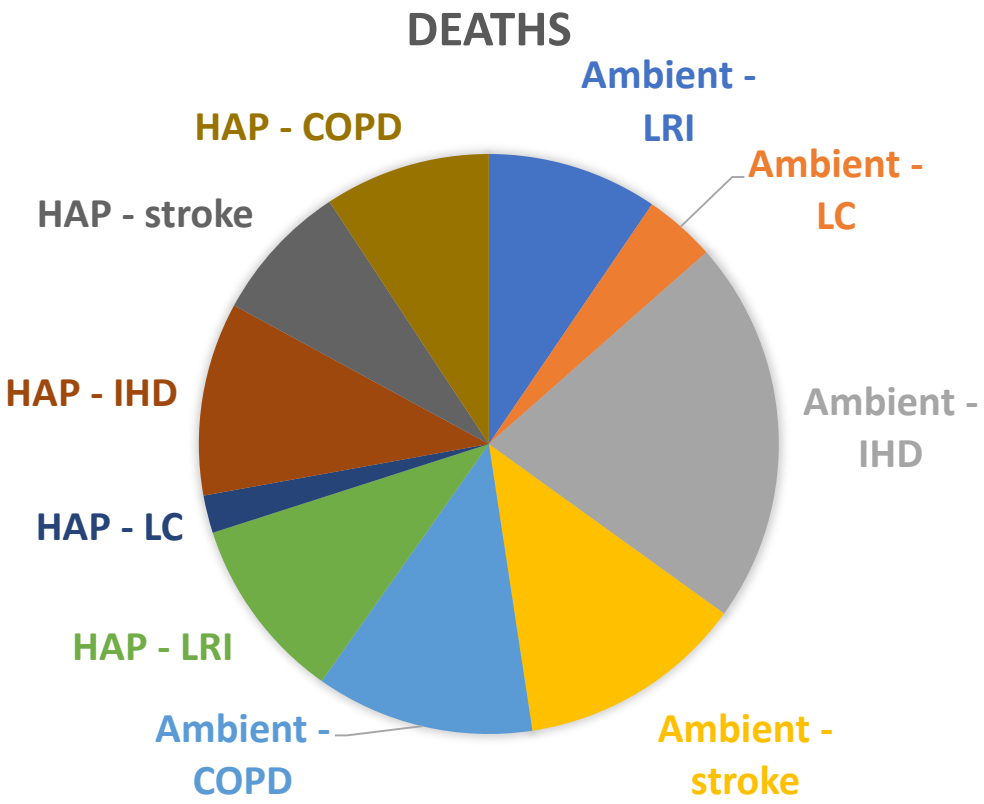


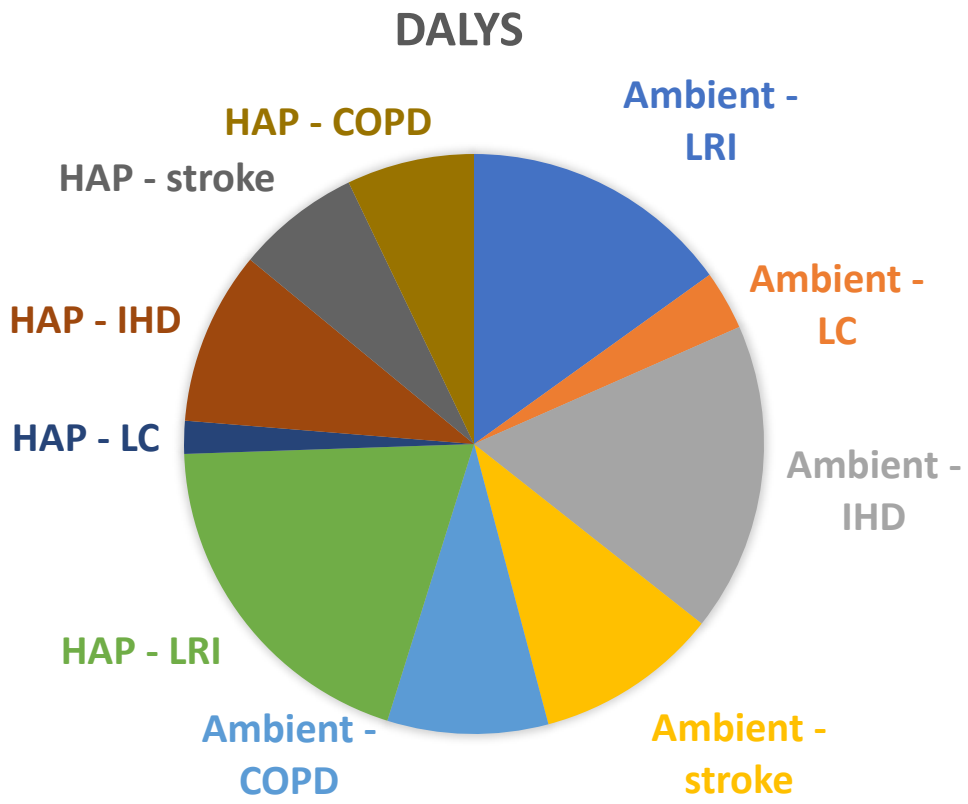
IHME 2017

Metrics used by Global Burden of Disease study

Metric	Definition
Premature deaths	A death that would not have occurred in the absence of the air pollution exposure
Years of life lost (YLL)	Years lost due to premature mortality, calculated by subtracting the age of death from the longest possible age-specific life expectancy
Years lived with disability (YLD)	Years lived in less than ideal health, calculated as prevalence multiplied by disability weight
Disability-adjusted life years (DALYs)	One year of healthy life lost, calculated as YLL+YLD

Deaths vs. Disability-adjusted life years (DALYs)



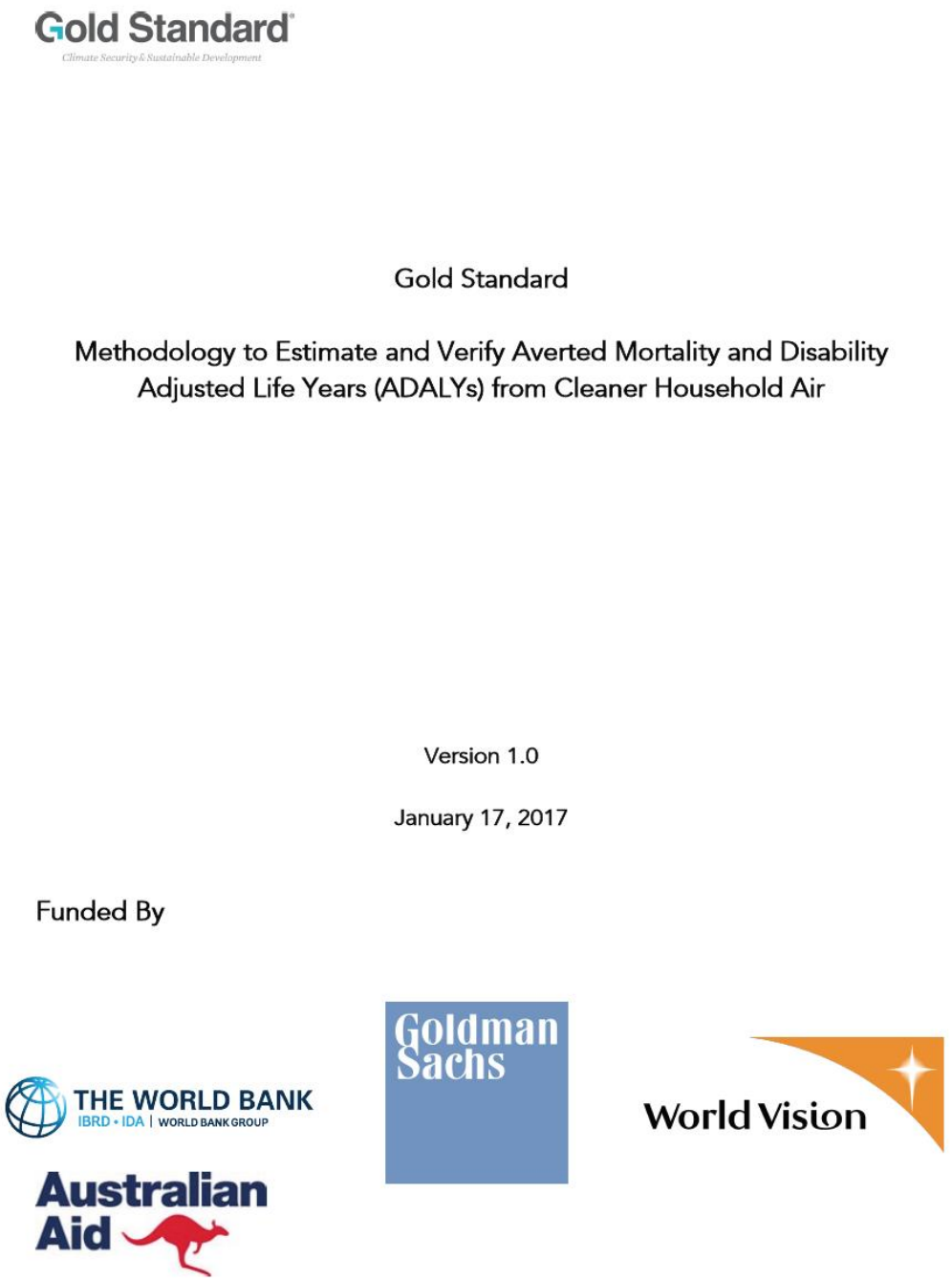


Global risk factor rank:
Ambient $PM_{2.5}$ = 5
Household air pollution (HAP) = 10

Global risk factor rank:
Ambient $PM_{2.5}$ = 6
Household air pollution (HAP) = 8

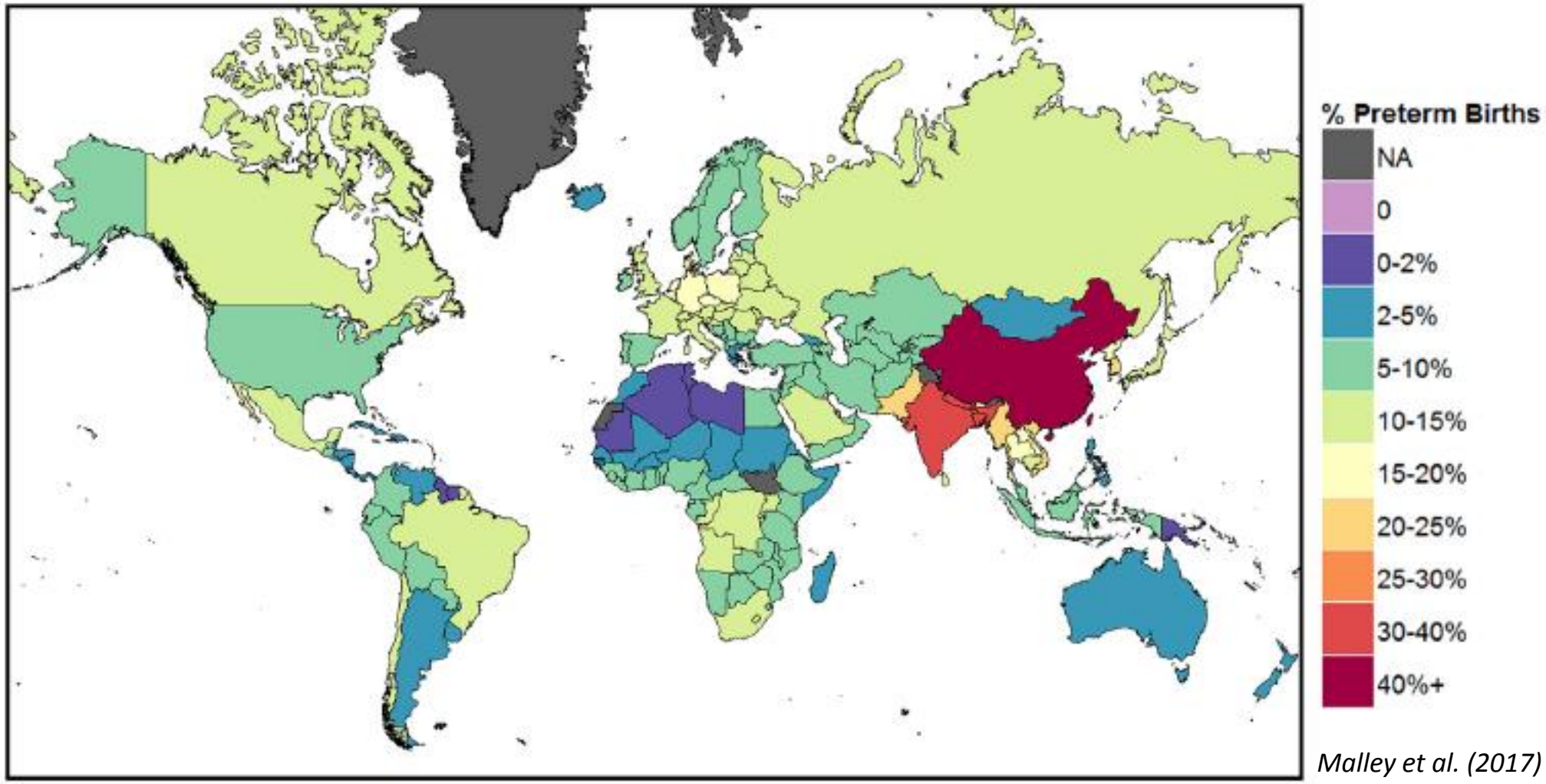
Gold Standard Averted DALY (ADALY) methodology

- Requires personal exposure measurements and use of model (HAPIT) to estimate impact of exposure on mortality and DALYs
- Deaths of children are not easily added to those for adults and the non-lethal impacts vary by disease.
- The DALY is a single metric that combines both mortality and morbidity.
- It is a common metric used by public health and development entities globally.
- Using DALYs enables the development of methodologies to quantify the health benefits of other types of interventions (e.g., water and sanitation) using a common and comparable metric.



Practical considerations: health outcomes evolve

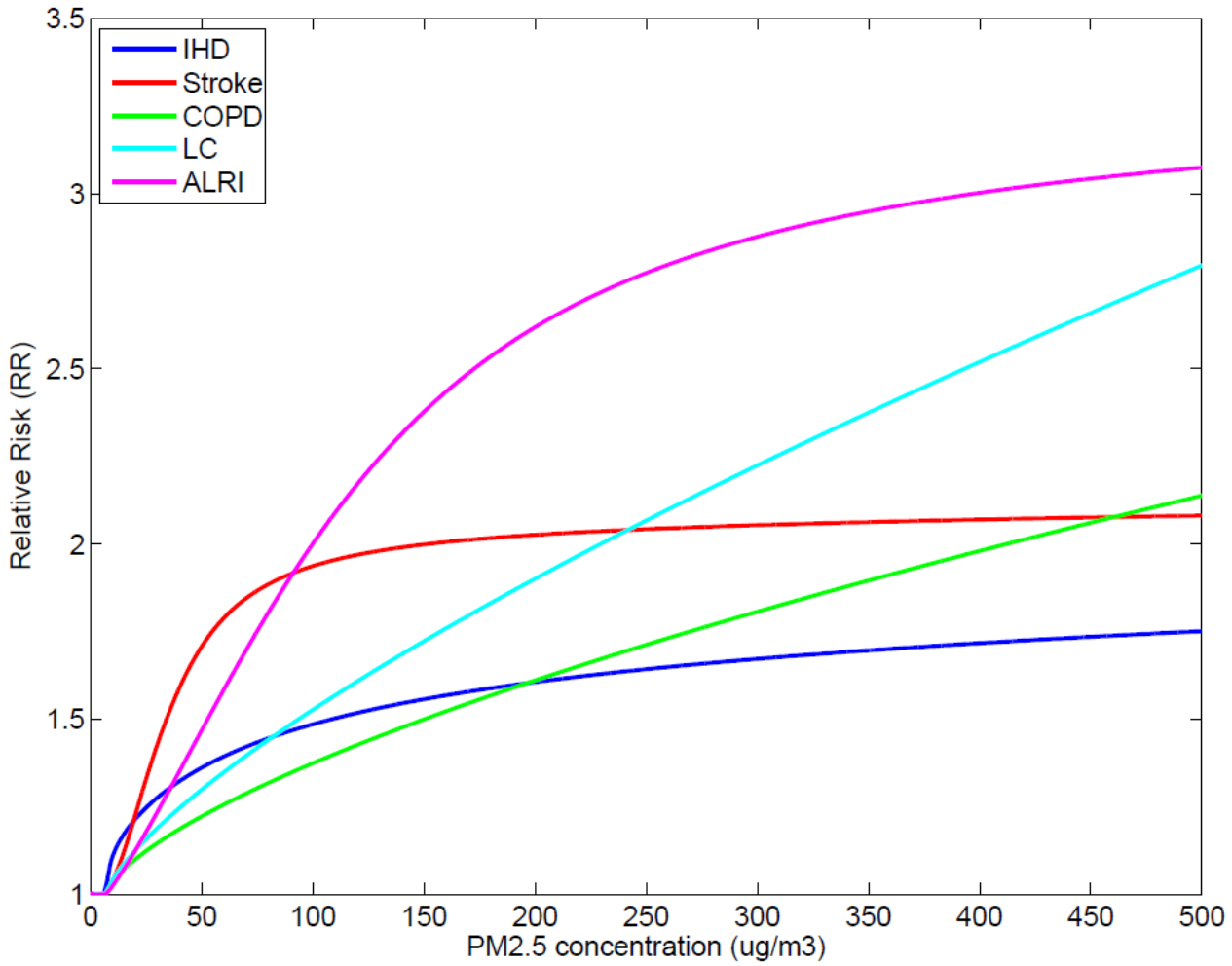
% of total preterm births which were associated with $PM_{2.5}$ in 2010



Malley et al. (2017)

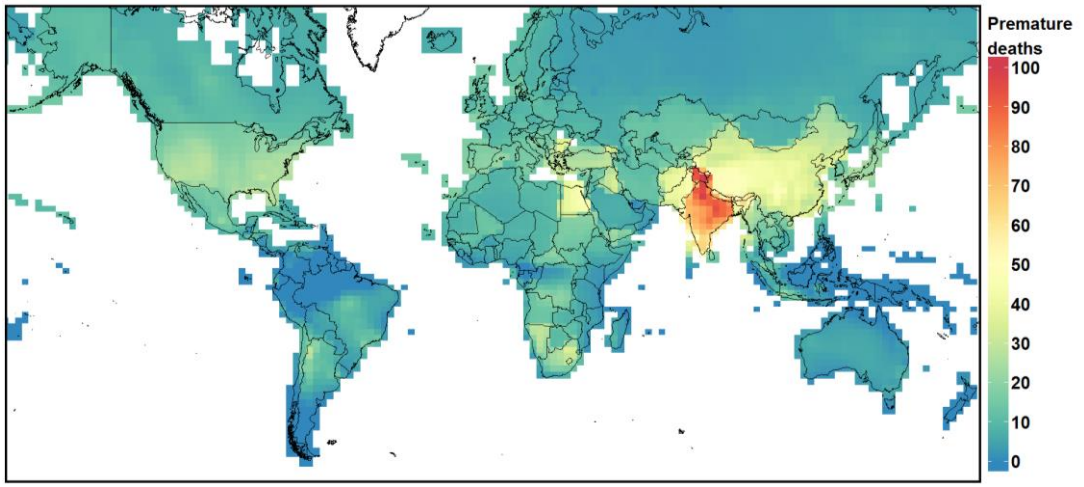
Practical considerations: exposure-response curves evolve

$PM_{2.5}$ Integrated Exposure Response curves

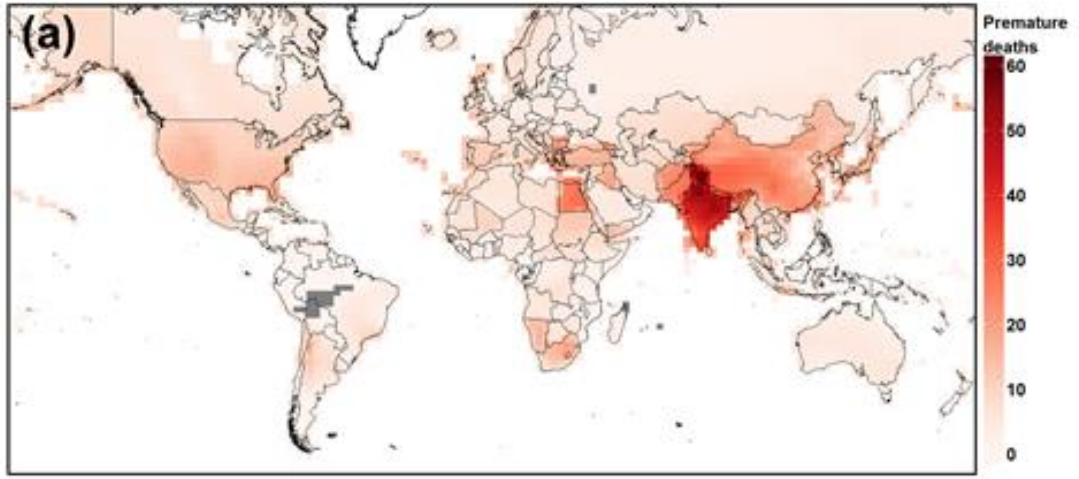


Data from Burnett et al. (2014)

Ozone premature deaths using updated ACS results



Increase from using previous ACS study

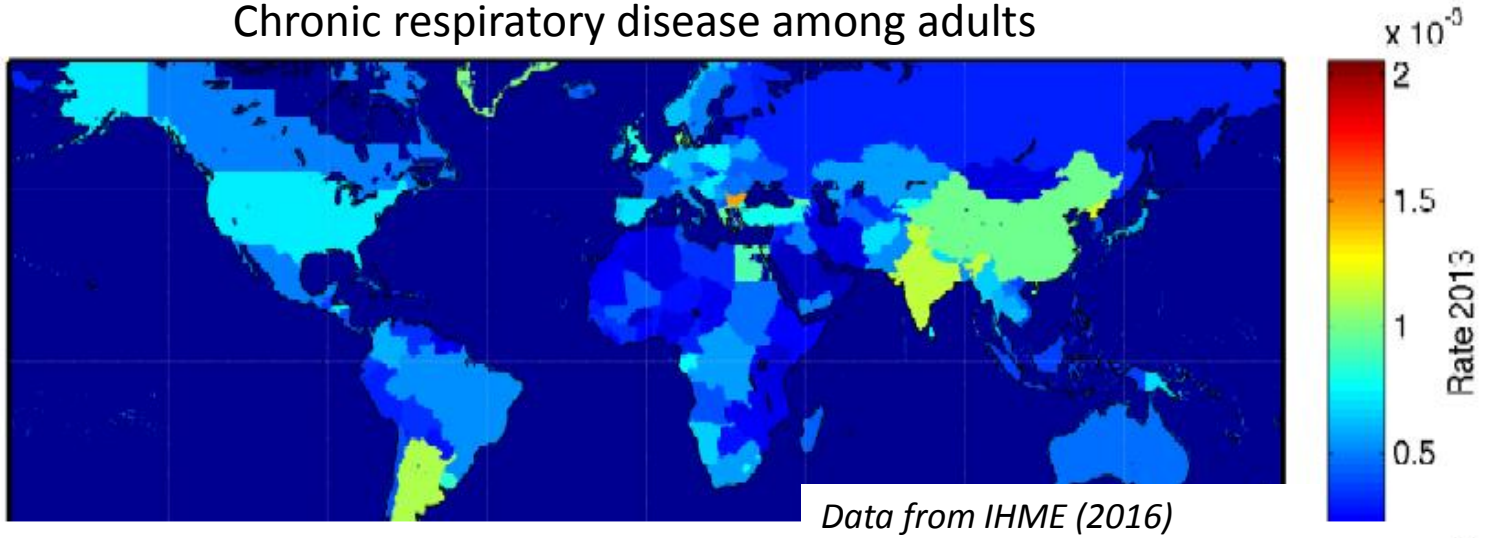


Malley et al. (submitted)

Practical considerations: incidence rates evolve

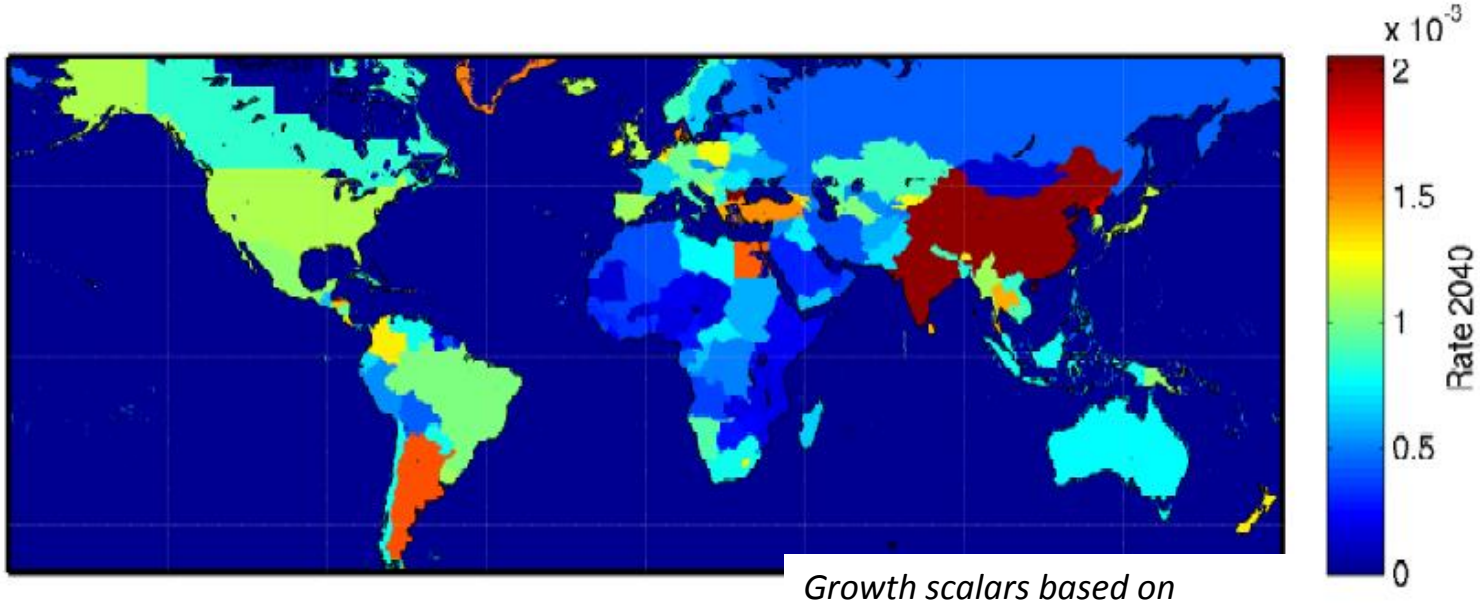
Chronic respiratory disease among adults

2013



Data from IHME (2016)

2040



Growth scalars based on International Futures Model

Practical considerations: Wide variation in methods among air pollution health impact assessment tools

Exposure Information Source	User Input	Global Scope	Regional Scope
Any concentration input by user	Concentration	BenMAP-CE[a] AirQ2.2 IOMLIFET	EBD
In situ monitor	Concentration		Aphekom[b]
Global chemical transport model (input by user)	Concentration		EVA
Regional or urban atmospheric chemistry model (input by user)	Emissions	SIM-Air	EVA
Reduced-form chemical transport model	Emissions	LEAP-IBC[c] TM5-FASST[d]	EcoSense[d]
Reduced-form econometric model	Economic and climate indicators	GMAPS[e]	
Intake fraction (primary $PM_{2.5}$ only)	Emissions	AirCounts™ [f]	

Anenberg et al., Risk Analysis, 2016

Advantages and Disadvantages of alternative metrics

Metric	Definition	Advantages	Disadvantages
Premature deaths	A death that would not have occurred in the absence of the air pollution exposure	Straightforward, equitable across populations and time, captures most severe impact	No dimension of time
Years of life lost (YLL)	Years lost due to premature mortality, subtract age of death from longest possible age-specific life expectancy	Adds dimension of time to premature death metric	Harder to interpret, adds assumption of equal life expectancy across populations
Years lived with disability (YLD)	Years lived in less than ideal health, calculated as prevalence multiplied by disability weight	Accounts for non-fatal outcomes	Difficult to estimate due to data limitations, could require subjectivity
Disability-adjusted life years (DALYs)	One year of healthy life lost	Universal, can compare across different populations, health conditions, time	Stronger emphasis on premature death at young age
Health-adjusted life expectancy (HALE)	Healthy life expectancy, accounts for both YLL and YLD	Accounts for both mortality and non-fatal outcomes	Relatively unknown, must calculate using age-specific life expectancy
Non-fatal outcomes	Cases (hospital admissions, asthma attacks, lost work days)	More tangible and easier to understand	Limited data on incidence rates and exposure-response functions globally

References

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