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Center for Advancing Research in Transportation Emissions, Energy, and Health

A USDOT University Transportation Center

14 Pathways Between Urban Transportation and Health

VIRTUAL

2nd Transportation, Air Quality, and Health SYMPOSIUM

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May 18–20, 2021

Agenda

Welcome and Introduction
Dr. Joe Zietsman, Texas A&M Transportation Institute

14 Pathways Between Urban Transportation and Health
Dr. Haneen Khreis, Texas A&M Transportation Institute

Questions, Answers, and Discussion Session

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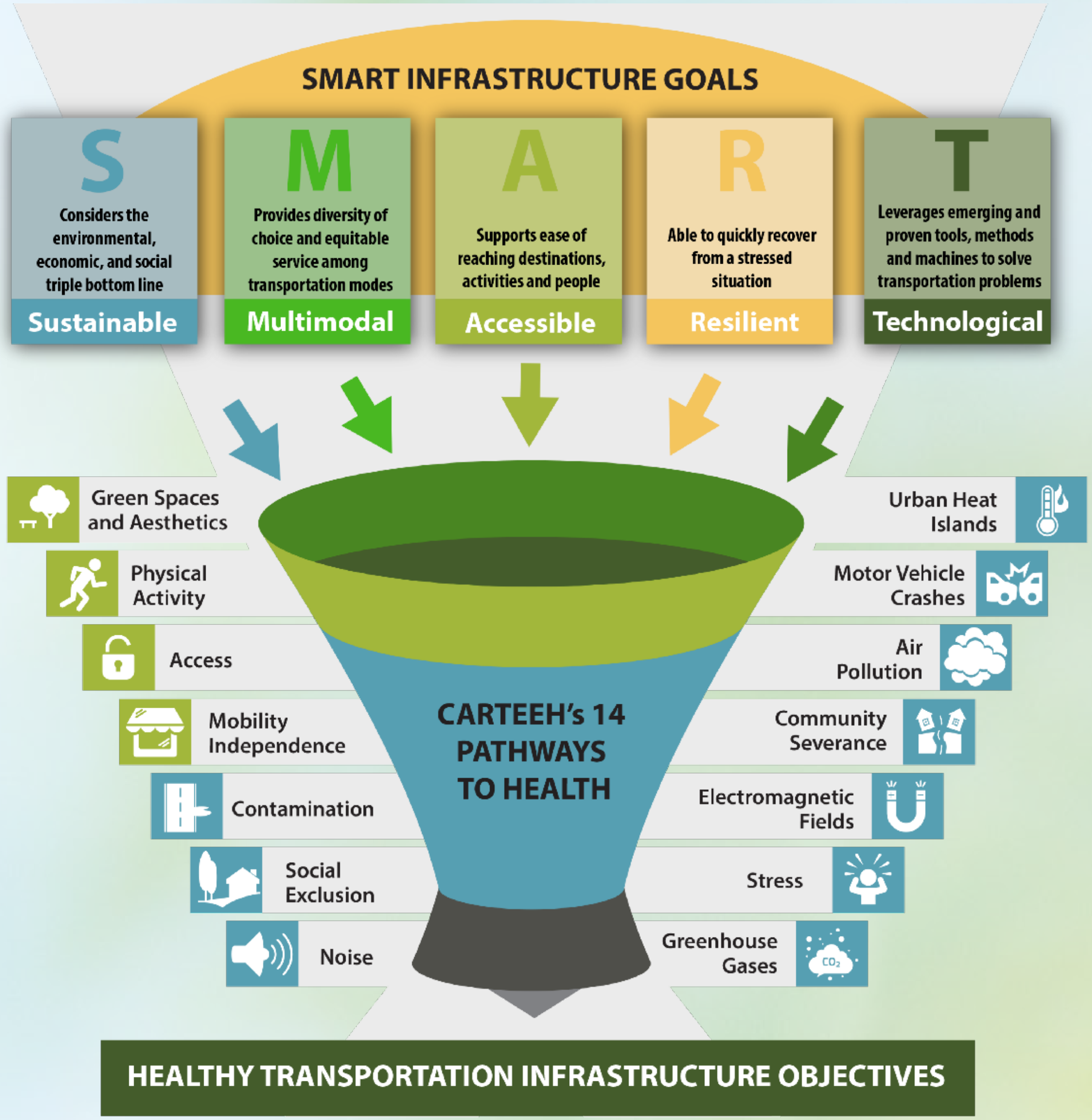
SMART Infrastructure to Improve Health Equity



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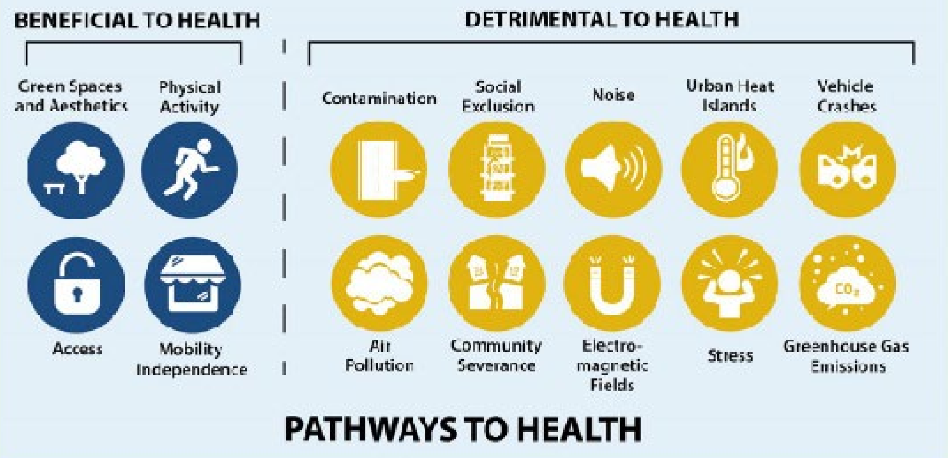
FOURTEEN PATHWAYS BETWEEN URBAN TRANSPORTATION AND HEALTH: A CONCEPTUAL MODEL, LITERATURE REVIEW AND BURDEN OF DISEASE ASSESSMENT



February 15, 2021

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Journal of Transport & Health

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Fourteen pathways between urban transportation and health: A conceptual model and literature review

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ARTICLE INFO

Keywords:
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Mortality
Morbidity

ABSTRACT

Introduction: Transportation is an integral part of our daily lives, giving us access to people, education, jobs, services, and goods. Our transportation choices and patterns are influenced by four interrelated factors: the land use and built environment, infrastructure, available modes, and emerging technologies/disruptors. These factors influence how we can or choose to move ourselves and goods. In turn, these factors impact various exposures, lifestyles and health outcomes.
Aim and methods: We developed a conceptual model to clarify the connections between transportation and health. We conducted a literature review focusing on publications from the past seven years. We complemented this with expert knowledge and synthesized information to summarize the health outcomes of transportation, along 14 identified pathways.
Results: The pathways linking transportation to health include those that are beneficial, such as when transportation serves as means for social connectivity, independence, physical activity, and access. Some pathways link transportation to detrimental health outcomes from air pollution, road travel injuries, noise, stress, urban heat islands, contamination, climate change, community severance, and restricted green space, blue space, and aesthetics. Other possible effects may come from electromagnetic fields, but this is not definitive. We define each pathway and summarize its health outcomes. We show that transportation-related exposures and associated health outcomes, and their severity, can be influenced by inequity and intrinsic and extrinsic effect modifiers.
Conclusions: While some pathways are widely discussed in the literature, others are new or under-researched. Our conceptual model can form the basis for future studies looking to explore the transportation-health nexus. We also propose the model as a tool to holistically assess the impact of transportation decisions on public health.

International Journal of *Environmental Research and Public Health*

MDPI

Article

Burden of Disease Assessment of Ambient Air Pollution and Premature Mortality in Urban Areas: The Role of Socioeconomic Status and Transportation

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Abstract: With recent rapid urbanization, sustainable development is required to prevent health risks associated with adverse environmental exposures from the unsustainable development of cities. Ambient air pollution is the greatest environmental risk factor for human health and is responsible for considerable levels of mortality worldwide. Burden of disease assessment (BoD) of air pollution in and across cities, and how these estimates vary according to socioeconomic status and exposure to road traffic, can help city planners and health practitioners to mitigate adverse exposures and promote public health. In this study, we quantified the health impacts of air pollution exposure ($PM_{2.5}$ and NO_2) at the census tract level in Houston, Texas, employing a standard BoD assessment framework to estimate the premature deaths (adults 30 to 78 years old) attributable to $PM_{2.5}$ and NO_2. We found that 631 (95% CI: 366–809) premature deaths were attributable to $PM_{2.5}$ in Houston, and 159 (95% CI: 0-609) were attributable to NO_2, in 2010. Complying with the World Health Organization air quality guidelines (annual mean: 10 μg/m^3 for $PM_{2.5}$) and the US National Ambient Air Quality standard (annual mean: 12 μg/m^3 for $PM_{2.5}$) could save 82 (95% CI: 42–95) and 8 (95% CI: 6–10) lives in Houston, respectively. $PM_{2.5}$ was responsible for 7.3% of all-cause premature deaths in Houston, in 2010, which is higher than the death rate associated with diabetes mellites, Alzheimer's disease, or motor vehicle crashes in the US. Households with lower income had a higher risk of adverse exposure and attributable premature deaths. We also showed a positive relationship between health impacts attributable to air pollution and road traffic passing through census tracts, which was more prominent for NO_2.

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Burden of disease from transportation noise and motor vehicle crashes: Analysis of data from Houston, Texas

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[b] *Zachery Department of Civil Engineering, Texas A&M University, TX, USA*
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[d] *Universitat Pompeu Fabra (UPF), Barcelona, Spain*
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ARTICLE INFO

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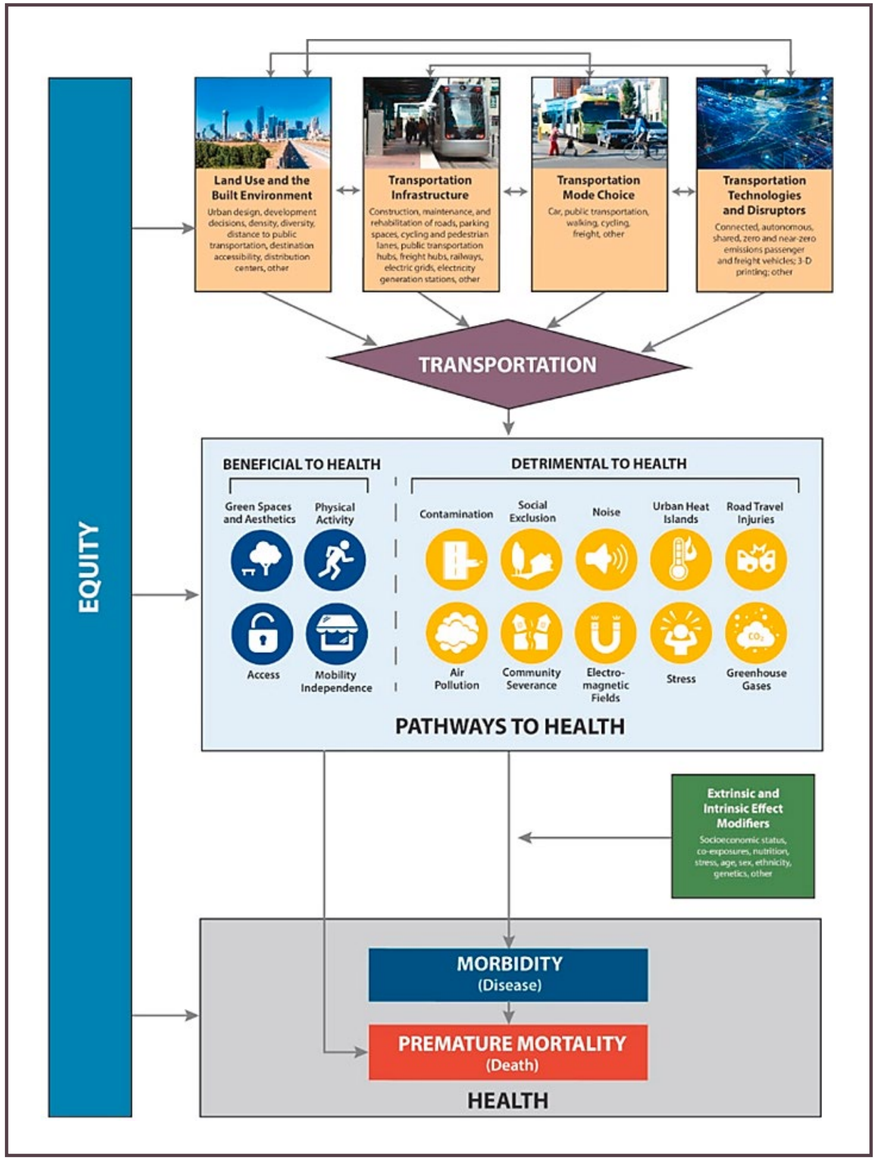
Keywords:
Burden of disease
Transportation noise
Premature death
Attributable deaths
Motor vehicle crashes

ABSTRACT

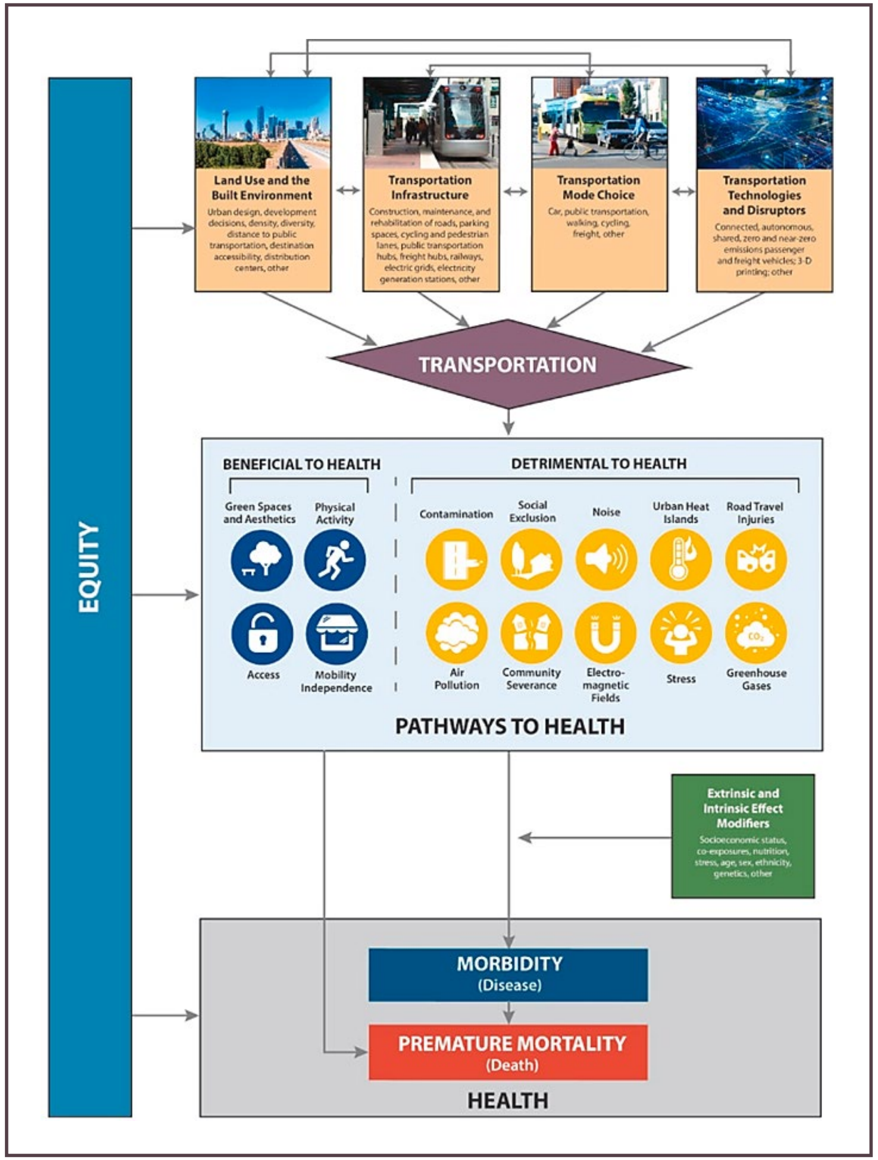
Background: Transportation systems have an essential role in satisfying individuals' needs for mobility and accessibility. Yet, they have been linked to several adverse health impacts, with a large, but modifiable, burden of disease. Among the several transportation-related health risk factors, this study focused on transportation-related noise as an emerging exposure whose burden of disease remains partially recognized. We compared premature deaths potentially attributable to transportation-related noise with deaths from motor vehicle crashes, a well-researched and widely recognized transportation risk factor.
Method: We employed a standard burden of disease assessment framework to quantify premature cardiovascular diseases mortality attributable to transportation-related (road and aviation) noise at the census tract level ($n = 592$) in Houston, Texas. The results were compared to motor vehicle crash fatalities, which are routinely observed and collected in the study area. We also investigated the distribution of premature deaths across the city and explored the relationship between household median income and premature deaths attributable to transportation-related noise.
Results: We estimated 302 (95% CI: 185–427) premature deaths (adults 30–75 years old) attributable to transportation-related noise in Houston, compared to 330 fatalities from motor vehicle crashes (adults younger than 75 years old). Transportation-related noise and motor vehicle crashes were responsible for 1.7% and 1.9% of all-cause premature deaths in Houston, respectively. Households with lower median income had a higher risk of adverse exposure and premature deaths potentially attributable to transportation-related noise. A larger number of premature deaths was associated with living in the central business district and the vicinity of highways and airports.
Conclusion: This study highlighted the significant contribution of transportation-related noise and motor vehicle crashes to premature deaths in the city of Houston. The analogy between the estimated premature deaths attributable to transportation-related noise and motor vehicle crashes showed that the health impacts of transportation-related noise were as significant as motor vehicle crashes. The estimated premature death rate attributable to transportation-related noise was also comparable to the death rate caused by suicide, influenza, or pneumonia in the US. There is an urgent need for imposing policies to reduce transportation noise emissions and human exposures and to equip health impact assessment tools with a noise burden of disease analysis function.

Purpose and features of the conceptual model

- **Formulating the ways by which transportation decisions affect health will help in:**
  - Studying transportation and health holistically
  - Addressing the impacts of transportation on health holistically
  - Support policy making that prioritizes health
  - Aid practitioners in evaluating impacts of transportation
  - Make recommendations for research and practice
    - Highlight knowledge and research gaps
  - Promote awareness and cross-disciplinary work

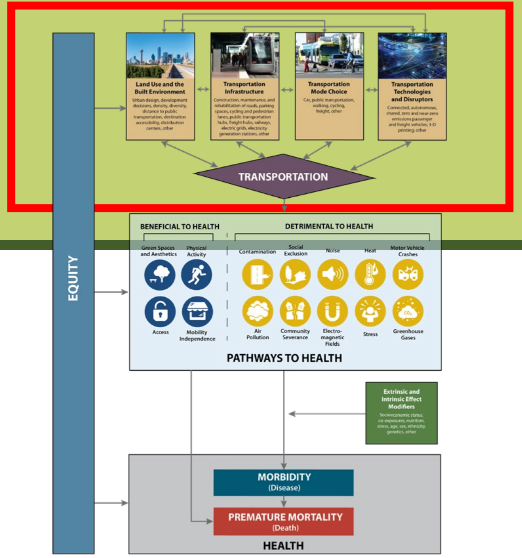


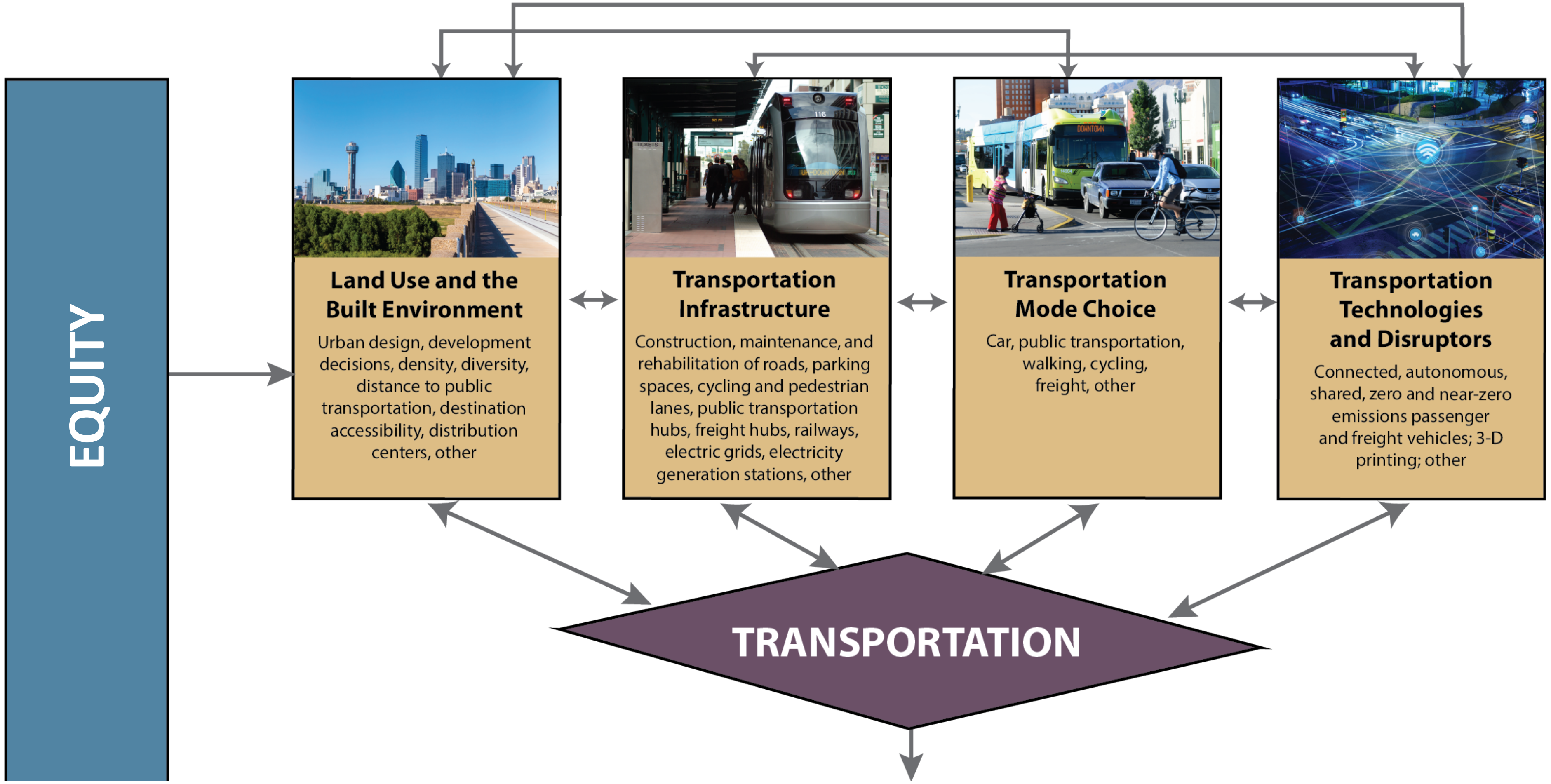
Purpose and features of the conceptual model



- **Features of the model:**
  - Underlined by an international evidence base
    - Studies from high, middle and low-income countries
  - Builds on a literature review of 294 published papers and reports
  - Complemented by cross-disciplinary expert assessment with international peer-review and perspectives

Framing Transportation





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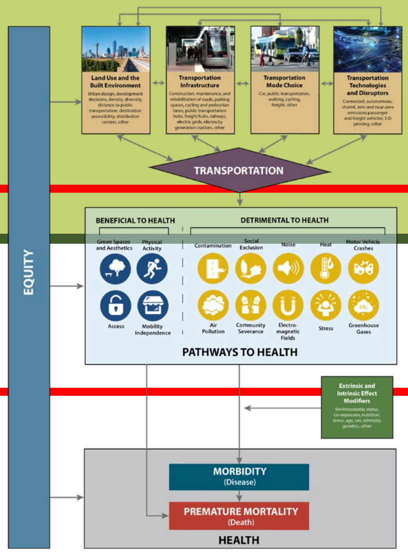
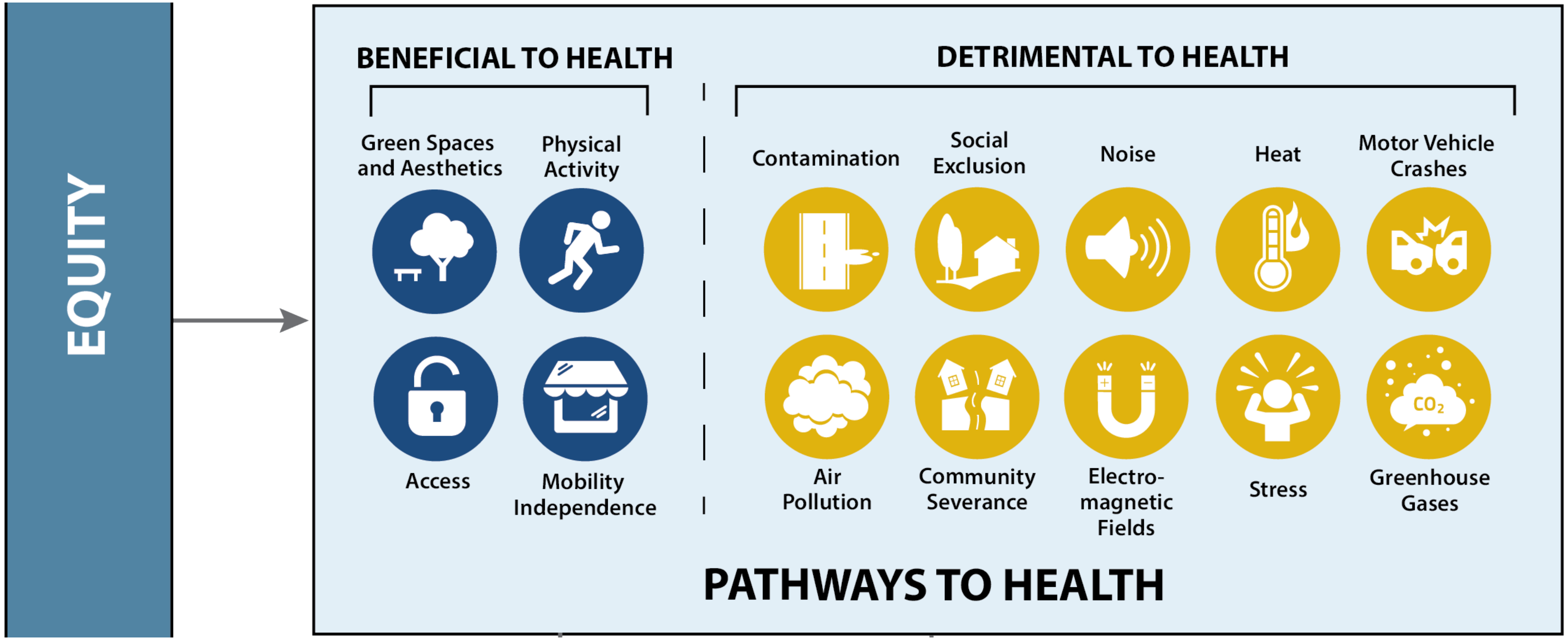
Framing Pathways to Health





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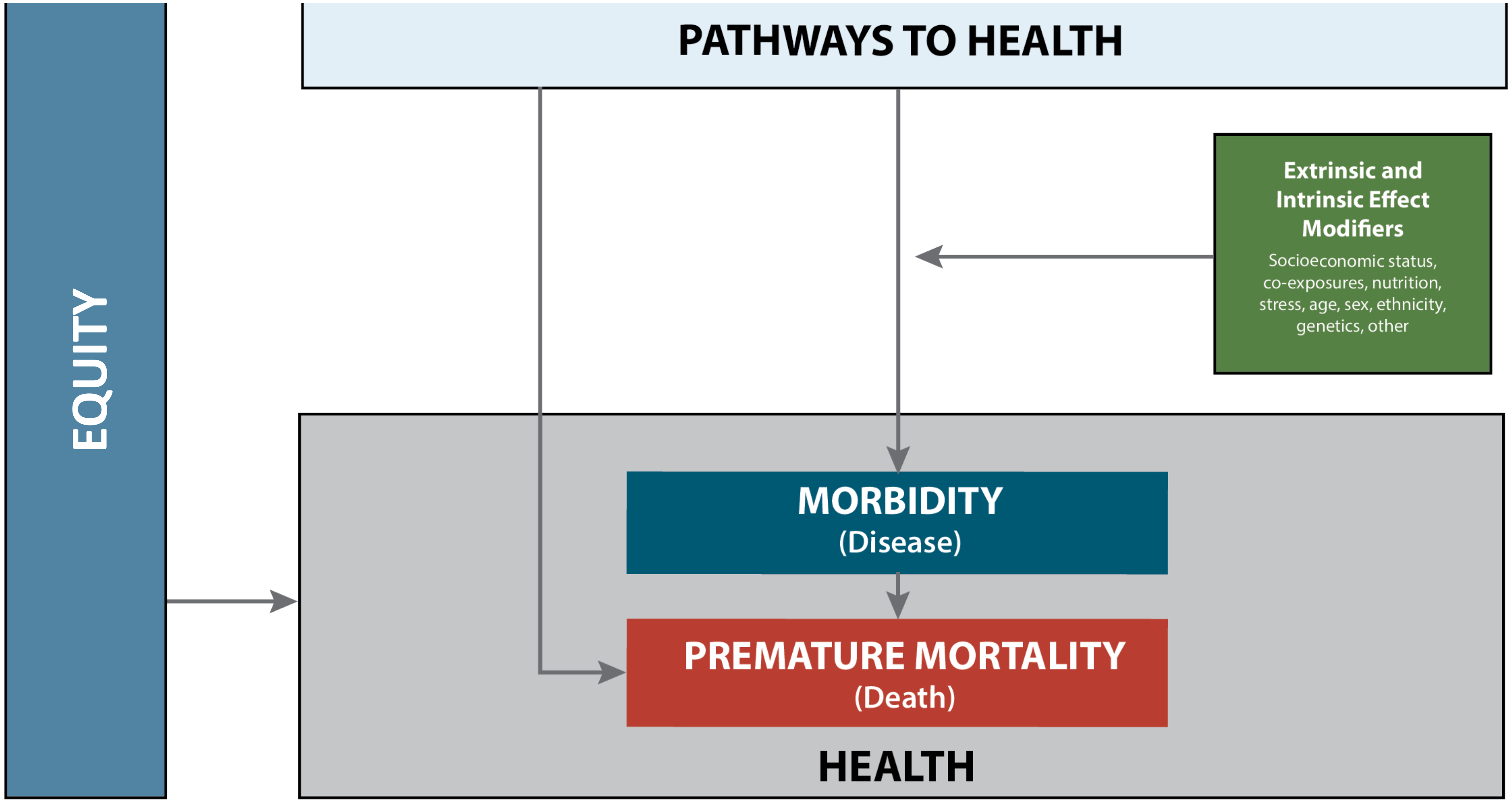
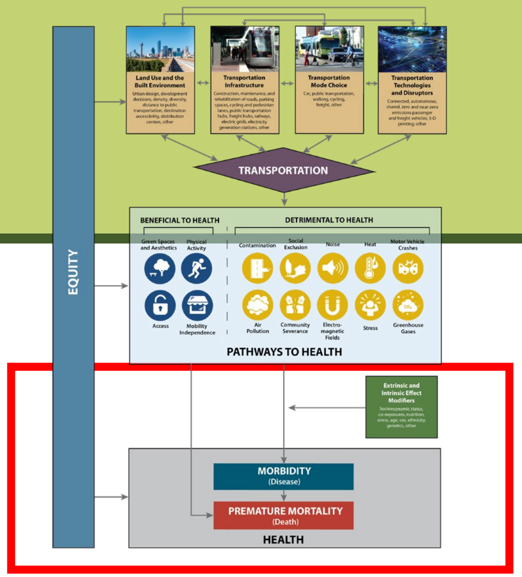
Defining Health Outcomes, their Severity and Distribution





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1. Green and Blue Space and Aesthetics

The highway that covered up the stream was stripped and the area became a city park after a major reconstruction. (Photo courtesy of Google Images)

Definition	Link to transportation	Documented health benefits
• Land partially/completely covered with grass, trees, or other vegetation • Space covered by water • Visual integration of transportation facilities into surrounding landscape	• Uptake of land for transportation may reduce green space and aesthetics • Green and blue space views can be blocked by urban transportation	• Through direct pathways and mitigation of stress, urban heat, air pollution, and noise and increases in physical activity and social interactions • Access to, quality and safety of green space are important

Health Effects

Green Spaces, Blue Space, and Aesthetics
Decreased risk of all-cause and premature mortality
Decreased risk of respiratory disease
Decreased risk of cardiovascular disease (including stroke)
Decreased risk of high blood pressure
Decreased risk of type-2 diabetes
Decreased risk of stress
Decreased risk of anxiety
Improved immune function
Improved cognitive function
Improved mental health
Improved sleep patterns
Improved pregnancy outcomes
Improved self-reported health

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2. Physical Activity

- **Definition**
  - Body movement requiring energy expenditure
- **Link to transportation**
  - Policies that promote high-density, diversity, connectivity, and active transportation can boost activity
  - In a review of 148 U.S. cities, modal diversity was inversely associated with obesity and physical inactivity
- **Documented health benefits**
  - Active transportation contributes to a more physically active lifestyle
    - Minor risks from air pollution or vehicle crashes
  - Health benefits are well-established and documented
  - Physical inactivity is a leading contributor to global mortality resulting in 3.2 million deaths/year

Health Effects

Physical Activity
Decreased risk of premature mortality
Decreased risk of cardiovascular disease (including stroke and ischemic heart disease)
Decreased risk of hypertension
Decreased risk of cancer
Decreased risk of diabetes
Decreased risk of obesity
Decreased risk of cognitive decline and dementia (including Alzheimer's disease)
Decreased stress
Decreased risk of mental health problems (including anxiety and depression)
Improved mental well-being

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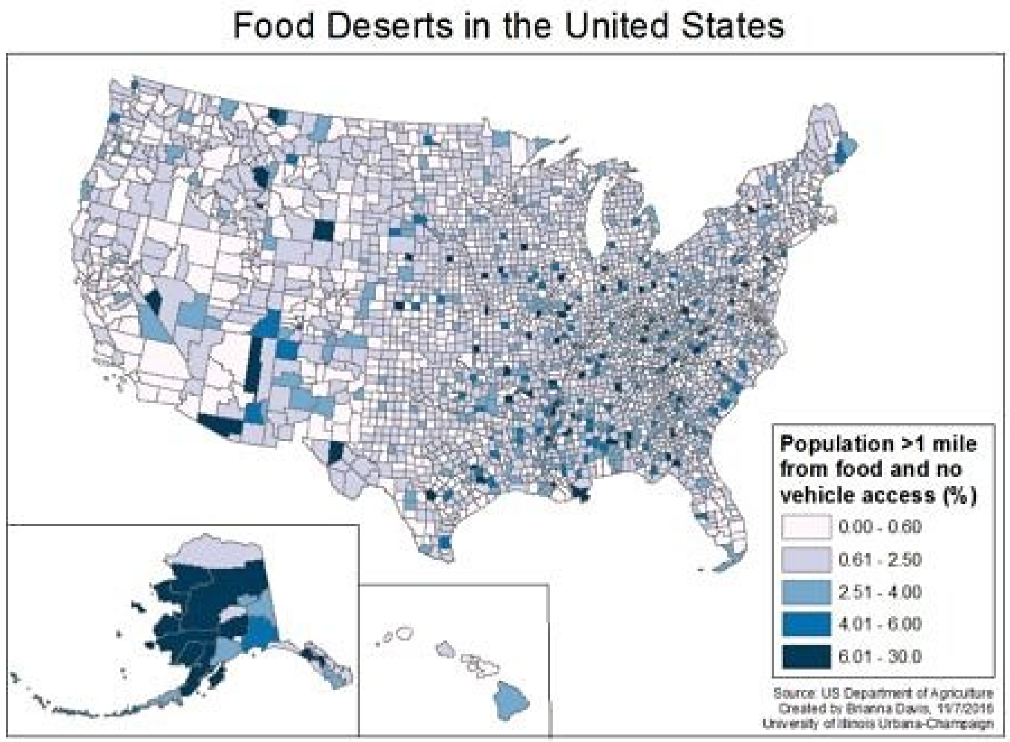
3. Access

- **Definition**
  - Ability to reach education, jobs, goods and services including health care, pharmacies and health promoting opportunities
- **Link to transportation**
  - Connective transportation including public transportation can increase access
  - Land-use interventions (e.g. complete streets), densification, diversity and transit-oriented development
- **Documented health benefits**
  - A systematic review of 108 studies found an association between living further away from health care and worse health outcomes including survival rates, length of stay in the hospital, and not attending follow-up



Health Effects

Access
Decreased risk of all-cause mortality
Decreased risk of cardiovascular disease
Decreased risk of cancer
Decreased risk of inadequate nutrition
Decreased risk of obesity
Decreased risk of mental health decline
Protection against adverse effects of air pollution

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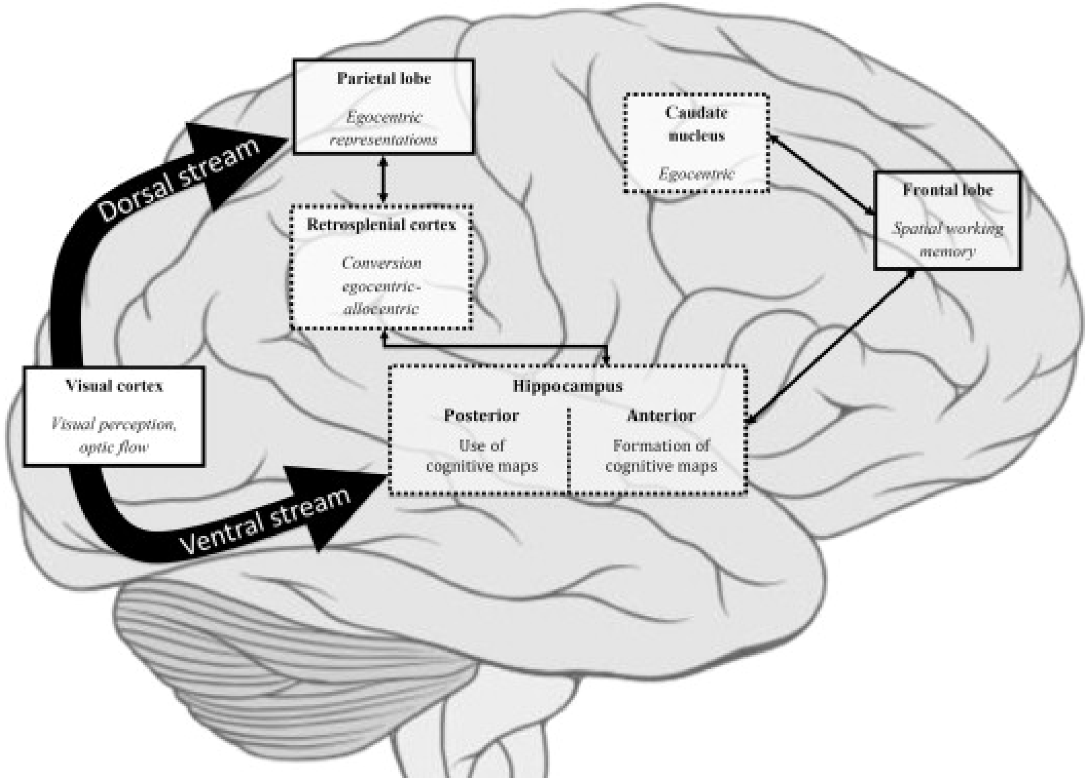
4. Mobility Independence

- **Definition**
  - Ability to utilize transportation modes without assistance or supervision
- **Link to transportation**
  - Built environment, infrastructure, and mode choice influence independence
- **Documented health benefits**
  - Impacts quality of life
  - Impacts development and sustainability of motor skills and awareness
  - Sustains cognitive abilities in the elderly
  - Improves mental well-being and self-esteem



Health Effects

Mobility Independence
Improved mental well-being
Improved motor skills development
Improved self-esteem
Improved quality of life
Sustained cognitive ability

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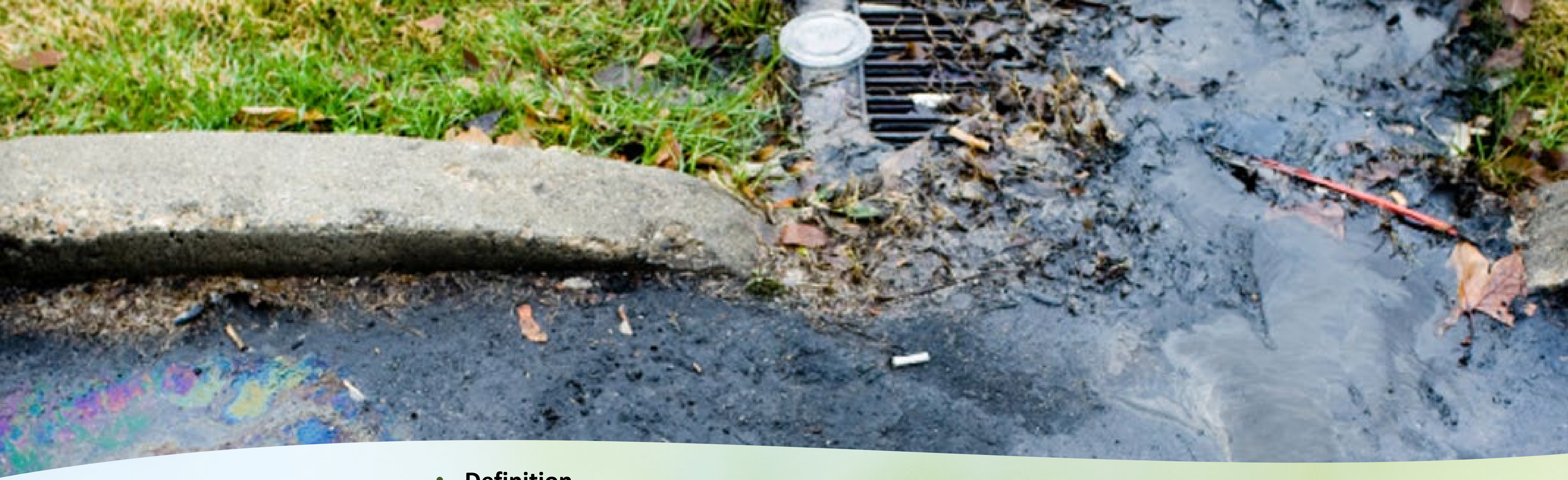

5. Contamination

- **Definition**
  - Oils, gasoline, heavy metals, particulate matter, lead, and polycyclic aromatic hydrocarbons: can contaminate water sources, soil, and food
- **Link to transportation**
  - Chemicals and pollutants can be found on roadway surfaces due to traffic
  - They also result from road surface, brake, and tire wear
  - Roads and parking lots which do not allow rainfall absorption are sprawling and increase the volume and velocity of polluted runoff
  - Green spaces and biodegradable vehicle and road surface materials could mitigate effects
- **Documented health effects**
  - Carcinogens have been found in agricultural fields near highways

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Health Effects

Contamination
Hypertension
Low blood pressure
Renal dysfunction (including kidney failure)
Liver failure
Premature birth
Low birthweight
Abdominal pain
Nausea
Ulcers
Fatigue
Headache
Memory loss
Sleeplessness
Depression
Arthritis
Rashes

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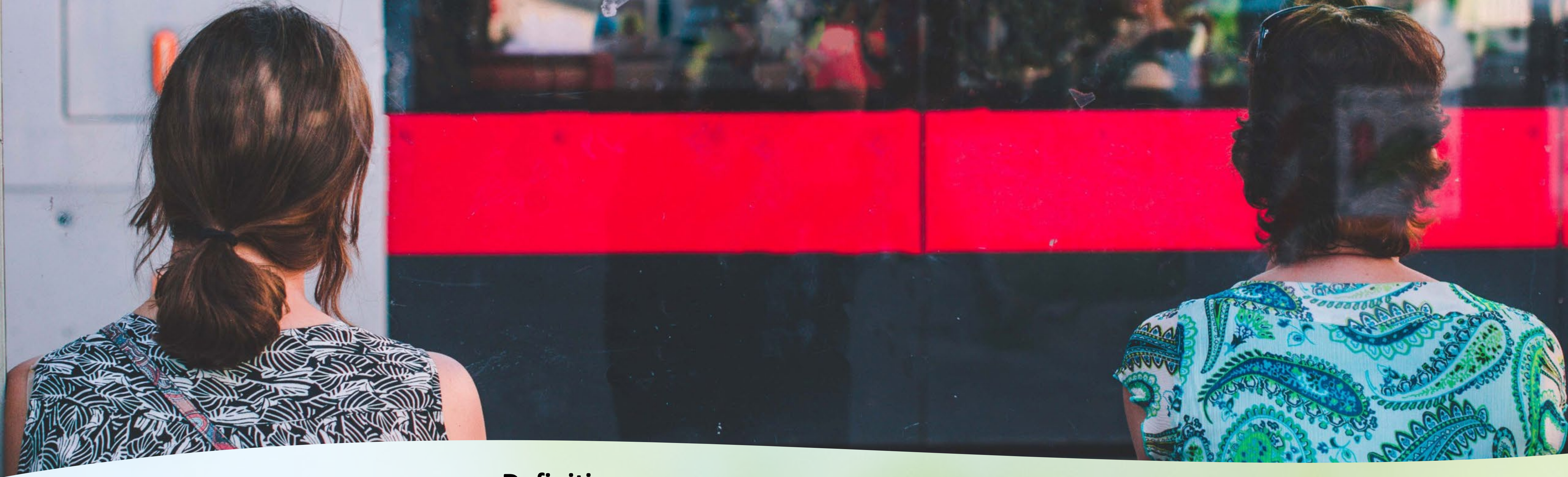

6. Social Exclusion

- **Definition**
  - Culmination of transportation-related inhibitions and/or deprivations which limit opportunities to participate in community activities and be socially engaged
  - Exacerbated in low-income groups, the disabled, elderly, adolescents, women, and ethnic minorities
- **Link to transportation**
  - Fear of crime and sexual harassment when using public transportation
- **Documented health effects**
  - Contributes to social isolation and loneliness which lead to e.g. premature mortality

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Health Effects

Social Exclusion
Premature mortality
Cardiovascular disease
Mental health problems
Stress

7. Noise

- **Definition**
  - Motorized vehicle sounds at levels that are detrimental to health
- **Link to transportation**
  - Dependent on for example, road networks, junctions, traffic flow and speed, and prevalent mode
- **Documented health effects**
  - Highlighted after the WHO series of systematic reviews and meta-analyses in 2018
  - Has a burden of disease comparable to that of air pollution and motor vehicle crashes in some cities (Barcelona, Houston)
  - Numerous health effects and plausible biological pathways

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Health Effects

Noise
Cardiovascular disease (including stroke, heart attack, and other ischemic heart diseases)
Hypertension
Diabetes
Obesity
Exacerbation of asthma
Reproductive complications (including premature birth and low birth weight)
Cognitive impairment
Disruption to concentration and educational attainment
Mental health problems
Stress
Annoyance
Sleep disturbance

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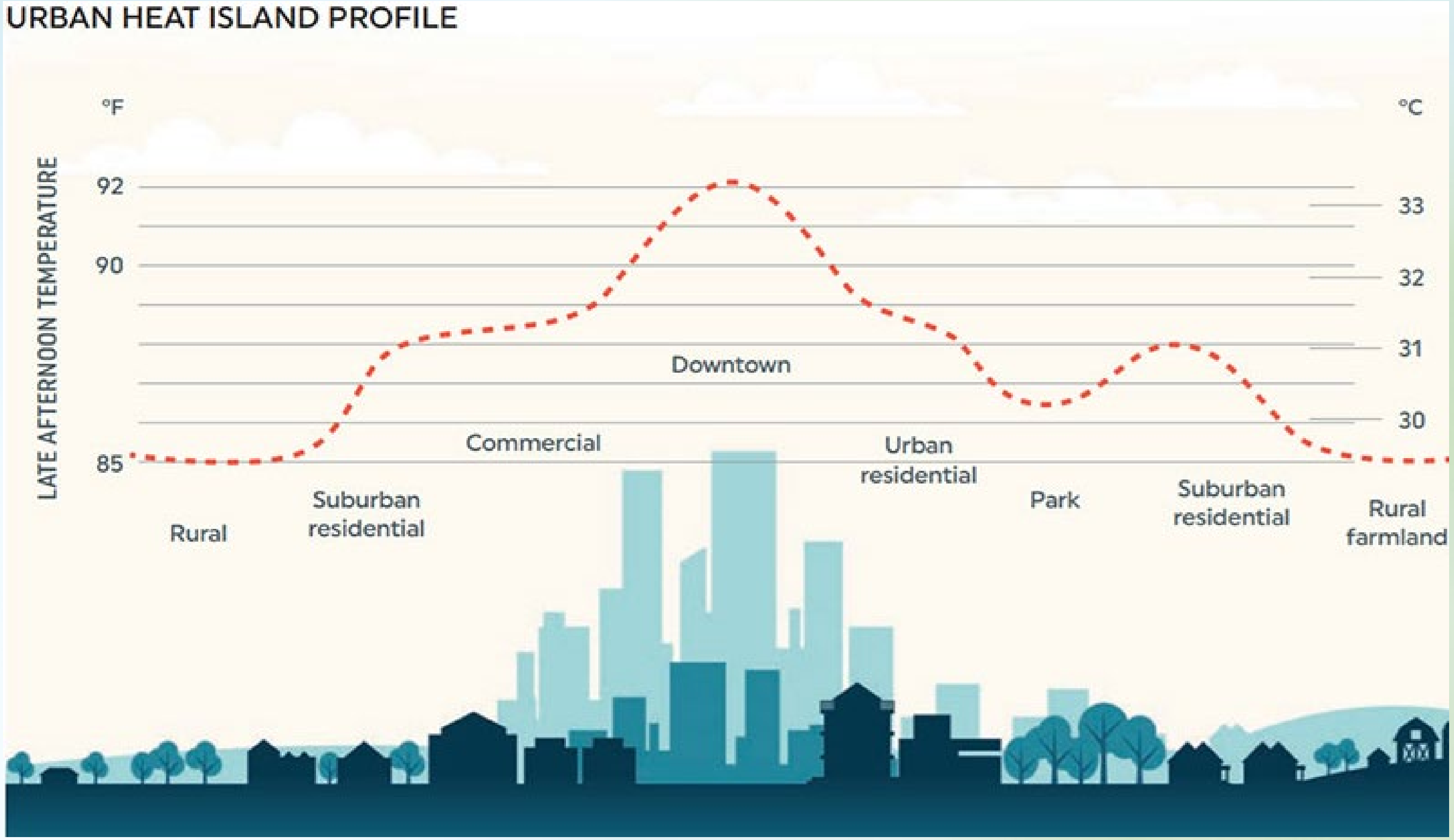
8. Urban Heat Islands



- **Definition**
  - Urban areas with greater surface and air temperatures, compared with rural areas
  - Temperature differences up to 8°C
- **Link to transportation**
  - Partly produced by heat-absorbing asphalts and concretes used for transportation infrastructure and heat from engine combustion
  - Replacing trees, vegetation, open and green spaces exacerbates urban heat
- **Documented health effects**
  - Heat waves can be fatal: 2003 Paris heat wave resulted in 15,000 premature deaths and 2006 in California resulted in 600 deaths and 16,000 ER visits

Health Effects

Urban Heat
Premature mortality
Cardiovascular disease (including stroke and arrhythmia)
Hypertension
Respiratory disease (including COPD and asthma)
Diabetes
Premature birth
Heat stress
Hospitalizations

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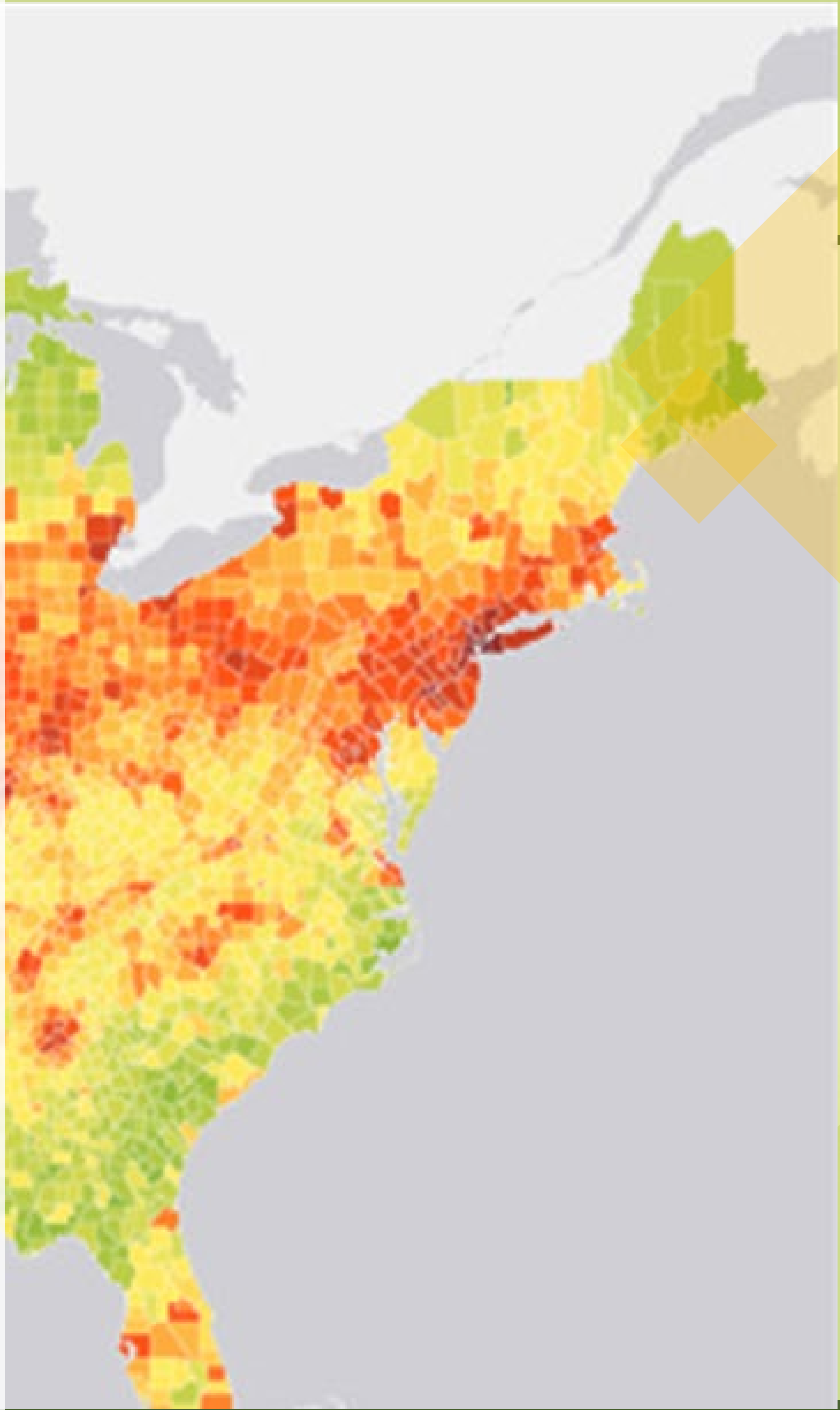
9. Road Travel Injuries

- **Definition**
  - Collisions involving a motor vehicle which may result in death, injury, or disability
  - Most severely affect vulnerable road users like pedestrians, cyclists, and motorcyclists who account for over 50% of all traffic deaths worldwide
  - Pedestrian and cyclists experience premature mortality or injury from falls where no motor vehicle was involved
- **Link to transportation**
  - Greater VMT increases the risk of road travel deaths and injuries
  - Increased volume of active transportation users can improve safety
- **Documented health effects**
  - 8th leading cause of death worldwide
  - Leading cause of death for people aged 5-29 years old
  - Injuries and hospitalizations

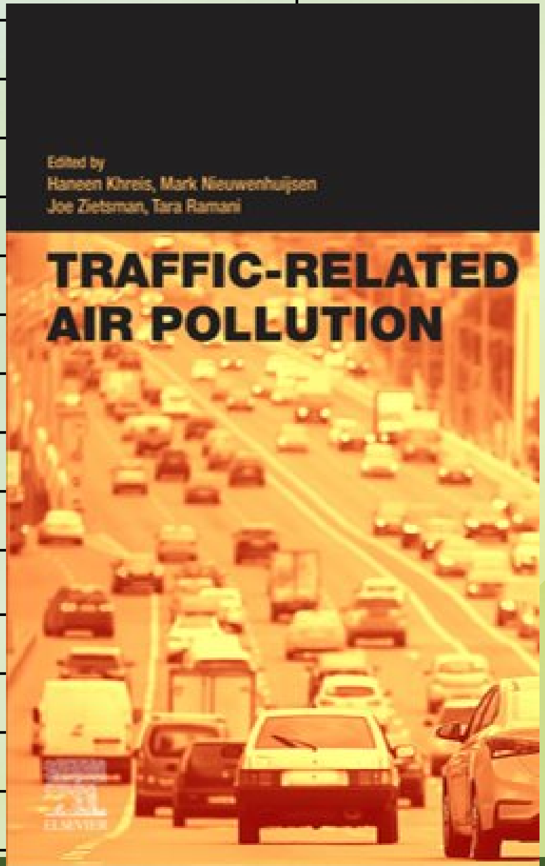
10. Air Pollution

- **Definition**
  - Emission and dispersion of toxic substances into the air we breathe
- **Link to transportation**
  - Results from motor vehicle exhaust and non-exhaust emissions, in addition to formation of secondary pollutants in ambient air
  - Total VMT and number of vehicles increase negating benefits of emission reduction technologies
  - Non-exhaust emissions remain largely unaddressed and may increase from electric vehicles
- **Documented health effects**
  - Numerous adverse health effects
  - Documented at levels well-below guidelines and standards



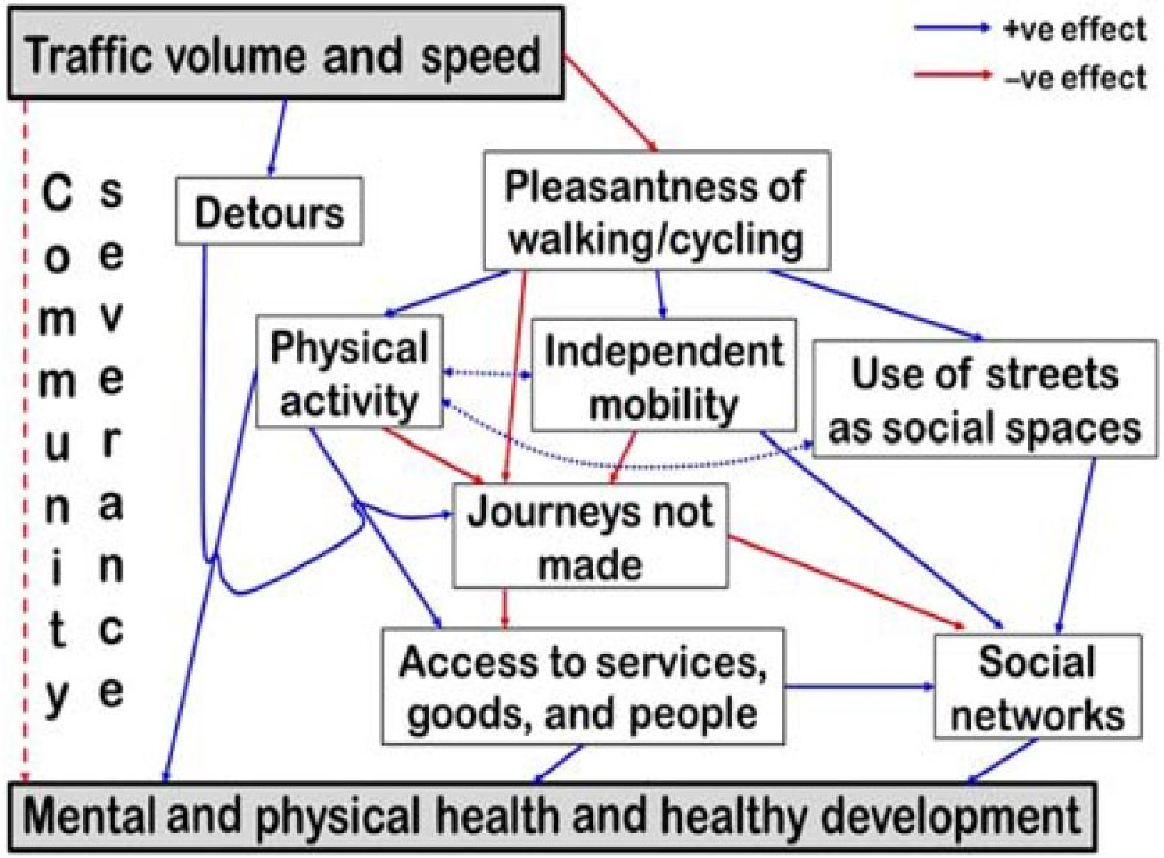
Health Effects

Air Pollution
Premature mortality
Cardiovascular disease (including stroke, arrhythmia, congestive heart failure, and heart attack)
Deep venous thrombosis
Cancers (especially lung cancer)
Respiratory diseases and infections (including COPD, childhood asthma, and pneumonia)
Respiratory inflammation
Allergies
Diabetes
Obesity
Reduced sperm quality
Premature birth
Low birthweight
Congenital anomalies
Autism and child behavior problems
Dementia
Neurodegenerative disease
Mental health problems
Bone conditions
Fungal infection



11. Community Severance

- **Definition**
  - Transportation infrastructure and/or motorized traffic that divides space and people
  - It limits social interaction and reduces access and independence
- **Health effects**
  - Strongly associated with reduced social interactions, social exclusion; reductions in physical activity; stress; increases in air pollution and reduced mobility independence and access



Theoretical paths from traffic-related severance to health impacts, Source: Mindell and Karlsen, 2012

Health Effects

Community Severance
Premature mortality
Cardiovascular disease
Mental health problems
Stress

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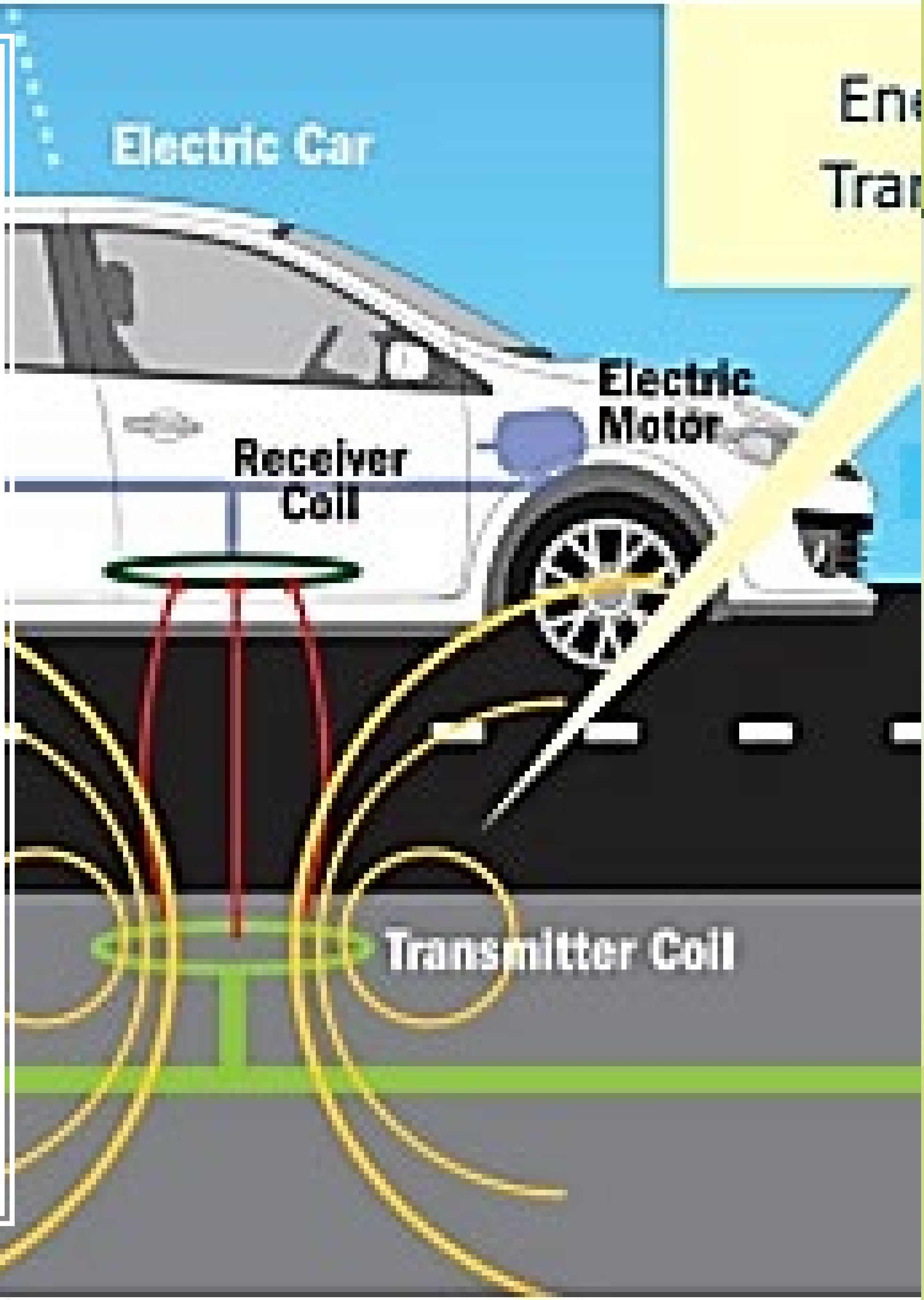
12. Electromagnetic Fields

- **Definition**
  - Moving electrically charged particles that can be created by a difference in voltage for example, near electricity generation stations
- **Link to transportation**
  - Can increase from new infrastructure used to accommodate transportation technologies and disruptors
- **Potential Health effects**
  - May contribute to adverse health effects, although this evidence base is under-developed and inconsistent
  - May affect electronic and biomedical implanted devices



13. Stress

- **Definition**
  - The body's response to any demand which may result in mental, emotional and phycological adverse strain or tension
  - Labeled the "Health Epidemic of the 21st Century" and was estimated to cost Americans $300 billion annually
- **Link to transportation**
  - Stress is associated with travel mode and time
  - Driving is the most stressful mode
  - Inverse relationship between stress and commuting via bicycle, even after adjustments
- **Health effects**
  - Time spent in traffic reduces the opportunities to be engaged in health-promoting activities
  - Direct effects of chronic stress

Health Effects

Stress
Stroke
Heart disease
Hypertension
High cholesterol
Obesity
Mental health problems
Depression
Anxiety
Insomnia
Substance abuse
Unhealthy diet and weight gain

14. Greenhouse Gases

- **Definition**
  - Gases including carbon dioxide (CO_2), methane, nitrous oxide, and fluorinated gases which trap heat in the atmosphere
  - 72% and 82% of global and U.S. greenhouse gases are from CO_2
- **Link to transportation**
  - 30% of CO_2 in the U.S. is from motor vehicles and the transportation sector is the largest contributing source
  - Transportation accounts for 23% of total energy-related CO_2 emissions globally
- **Health effects**
  - Global warming exacerbates the health effects from air pollution, heat, and physical inactivity
  - Extreme weather events negatively impact health
  - Increased infectious disease transmission

Health Effects

Greenhouse Gases
Premature mortality
Physical injury
Adverse mental and physical health outcomes
Change in vector-pathogen relations and vector-borne disease
Poor nutrition

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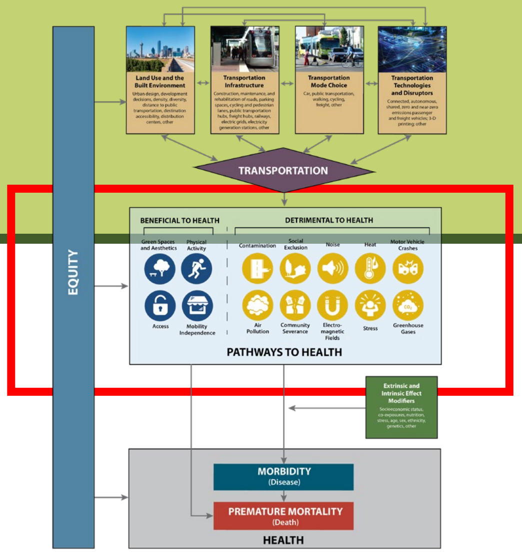
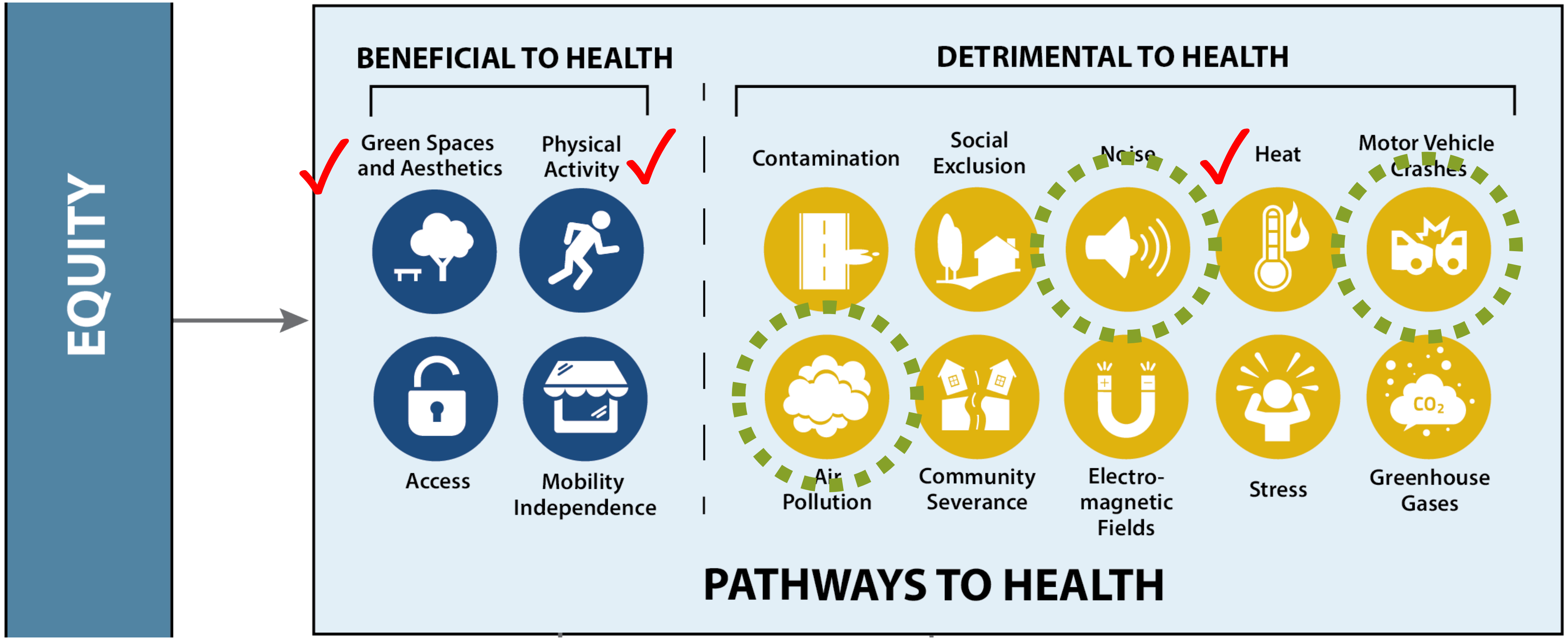
14 Pathways to Health





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Questions, Answers, and Discussion

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Back-Up Slides

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Equity and Modifiers

- There is inequity in the distribution of the 14 pathways and their health impacts
  - The placement of, proximity, and access to transportation facilities, services, infrastructure, and activities is inequitable
- Intrinsic and extrinsic individual characteristics, also alter the impacts
  - Sex, age, race/ethnicity, genetics, nutrition, stress, violence, etc., influence susceptibility and subsequently the severity of health outcomes

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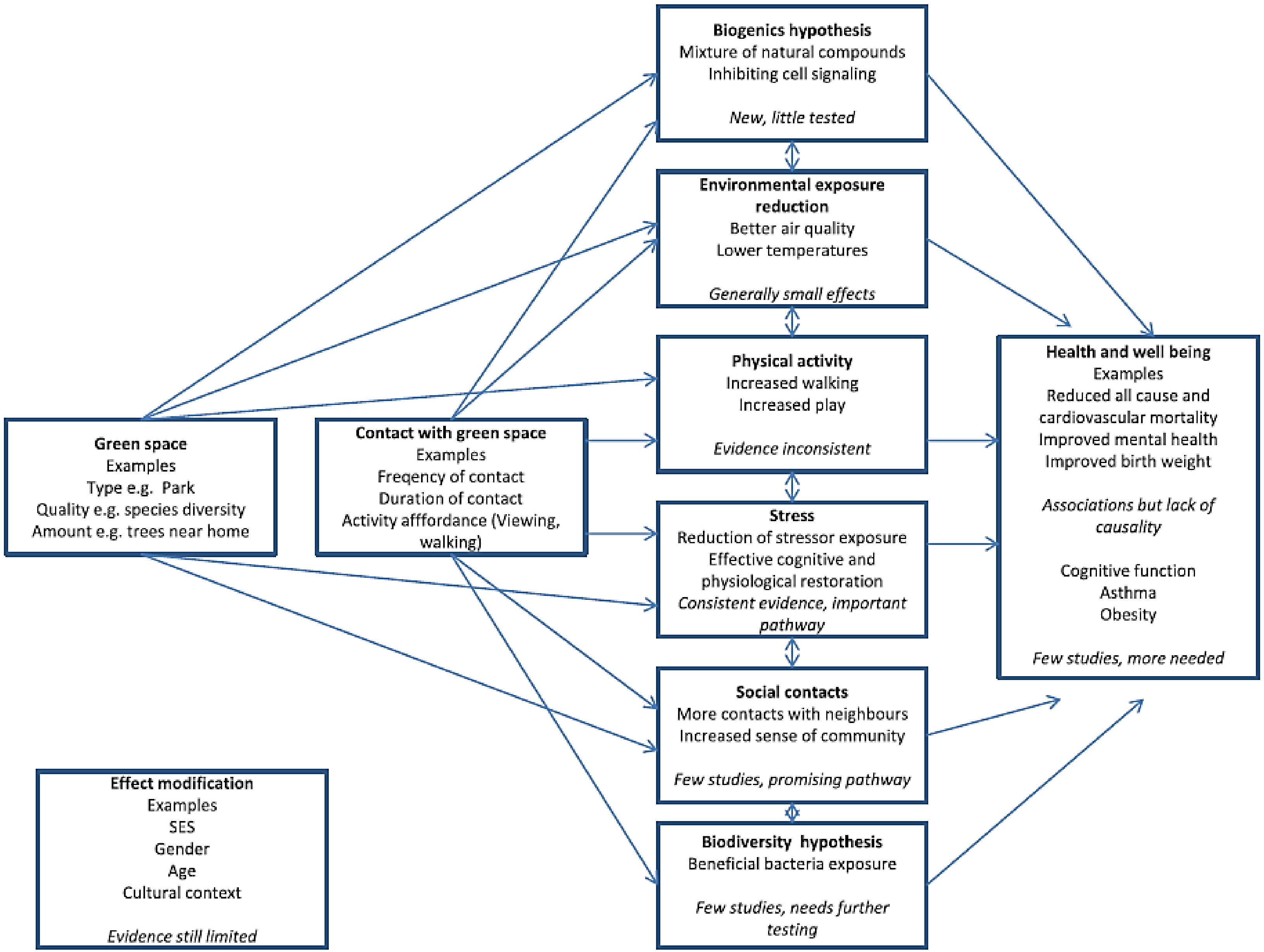
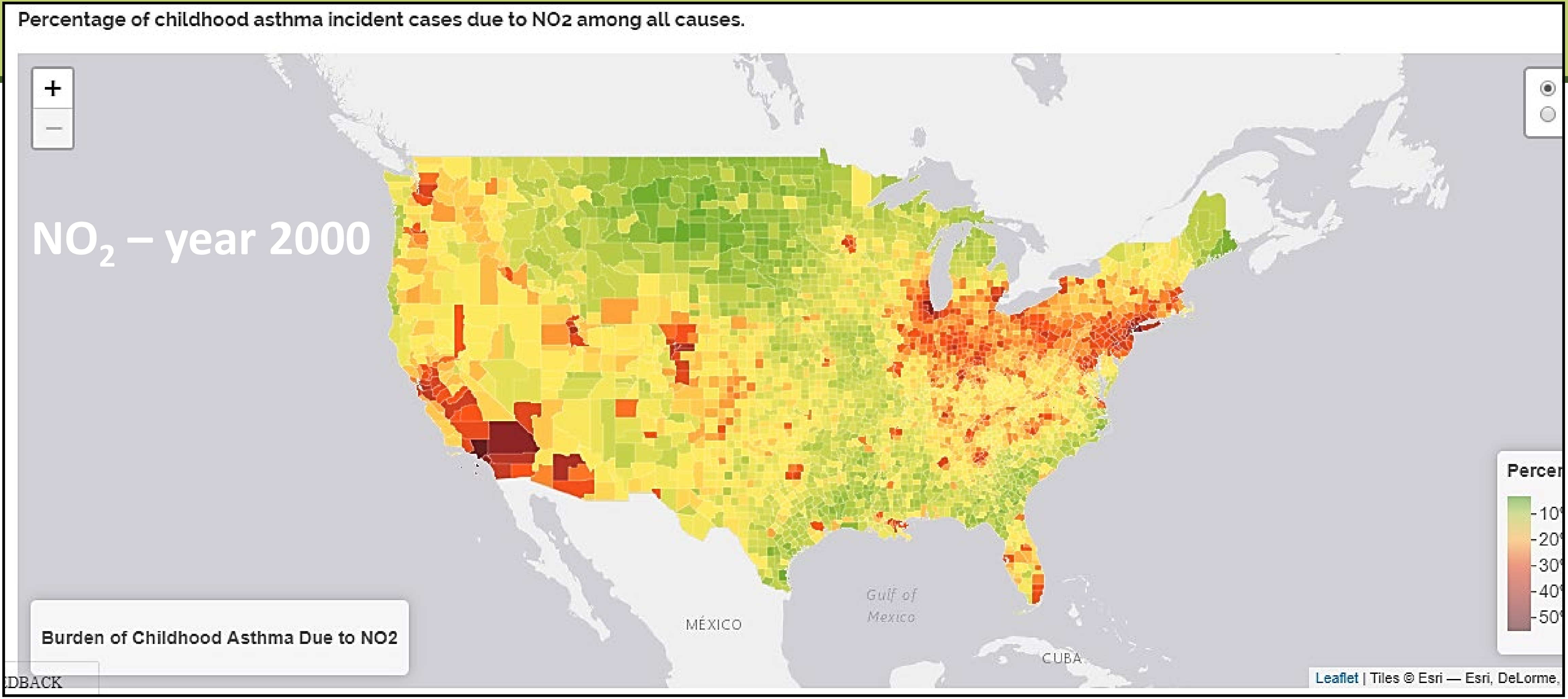
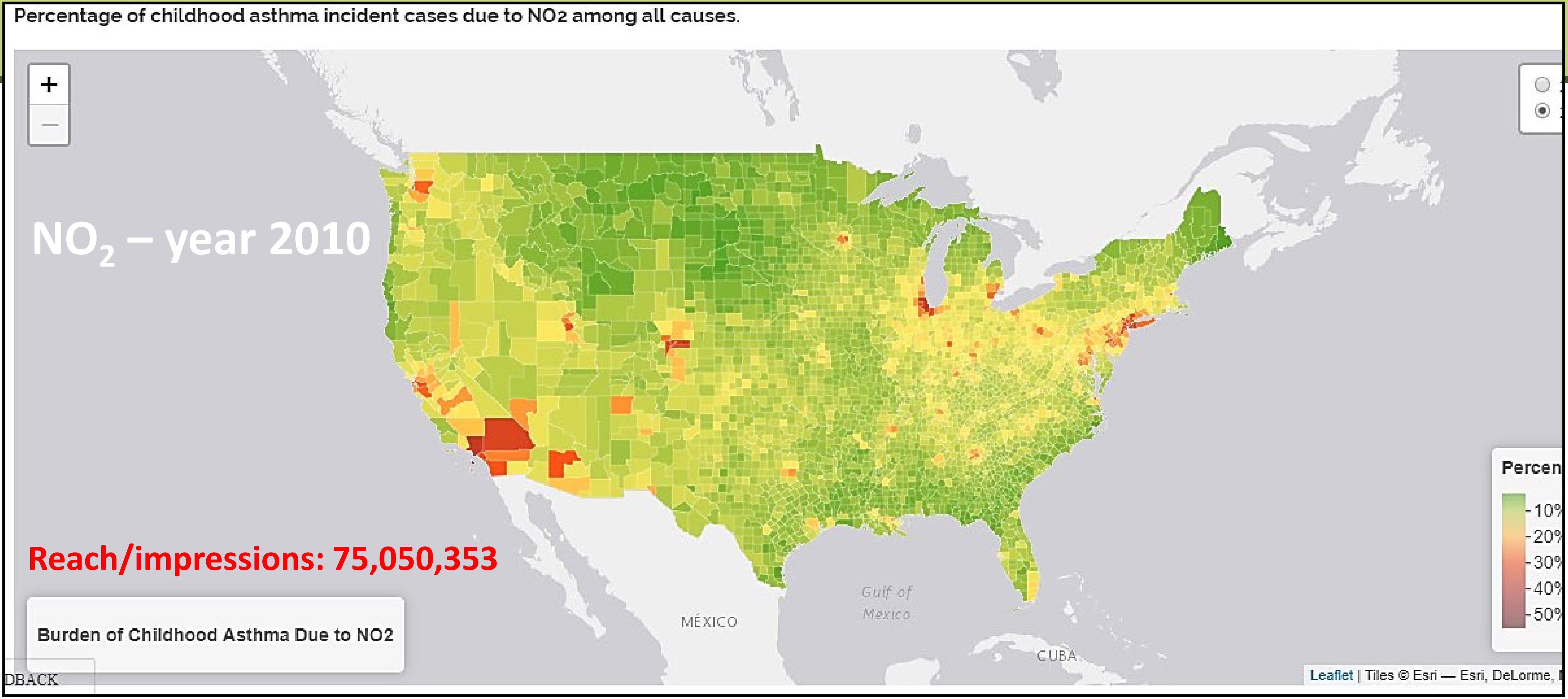

Biogenics hypothesis
Mixture of natural compounds
Inhibiting cell signaling
New, little tested
Environmental exposure reduction
Better air quality
Lower temperatures
Generally small effects
Physical activity
Increased walking
Increased play
Evidence inconsistent
Stress
Reduction of stressor exposure
Effective cognitive and physiological restoration
Consistent evidence, important pathway
Social contacts
More contacts with neighbours
Increased sense of community
Few studies, promising pathway
Biodiversity hypothesis
Beneficial bacteria exposure
Few studies, needs further testing
Green space
Examples
Type e.g. Park
Quality e.g. species diversity
Amount e.g. trees near home
Contact with green space
Examples
Freqency of contact
Duration of contact
Activity afffordance (Viewing, walking)
Health and well being
Examples
Reduced all cause and cardiovascular mortality
Improved mental health
Improved birth weight
Associations but lack of causality
Cognitive function
Asthma
Obesity
Few studies, more needed
Effect modification
Examples
SES
Gender
Age
Cultural context
Evidence still limited

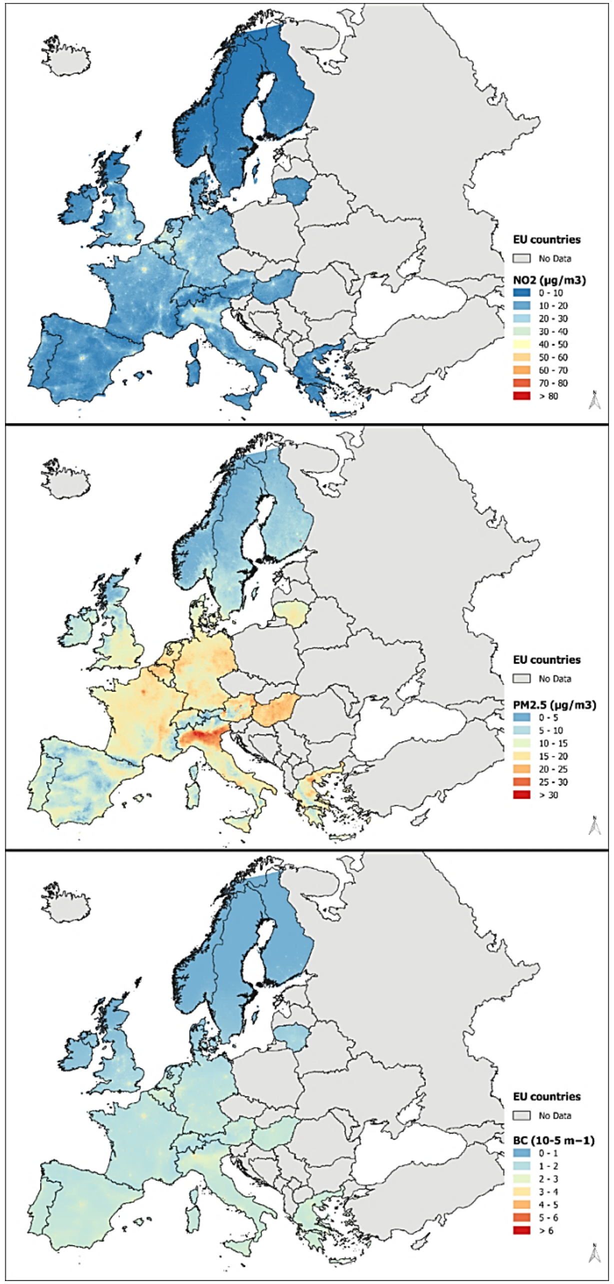


https://carteehdata.org + Analysis of the largest 498 CDC cities (interactive tables)



https://carteehdata.org + Analysis of the largest 498 CDC cities (interactive tables)

CARTEEH



- Compliance with the NO_2 WHO guideline may prevent 2,434 (**0.4%**) incident cases
- Compliance with the $PM_{2.5}$ WHO guidelines may prevent 66,567 (**11%**) incident cases

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Environment ▸ Climate change Wildlife Energy **Pollution**

Air pollution

This article is more than **2 months old**

Hitting clean air targets 'could stop 67,000 child asthma cases a year'

Staying within WHO pollution limits would prevent 11% of new diagnoses, study says

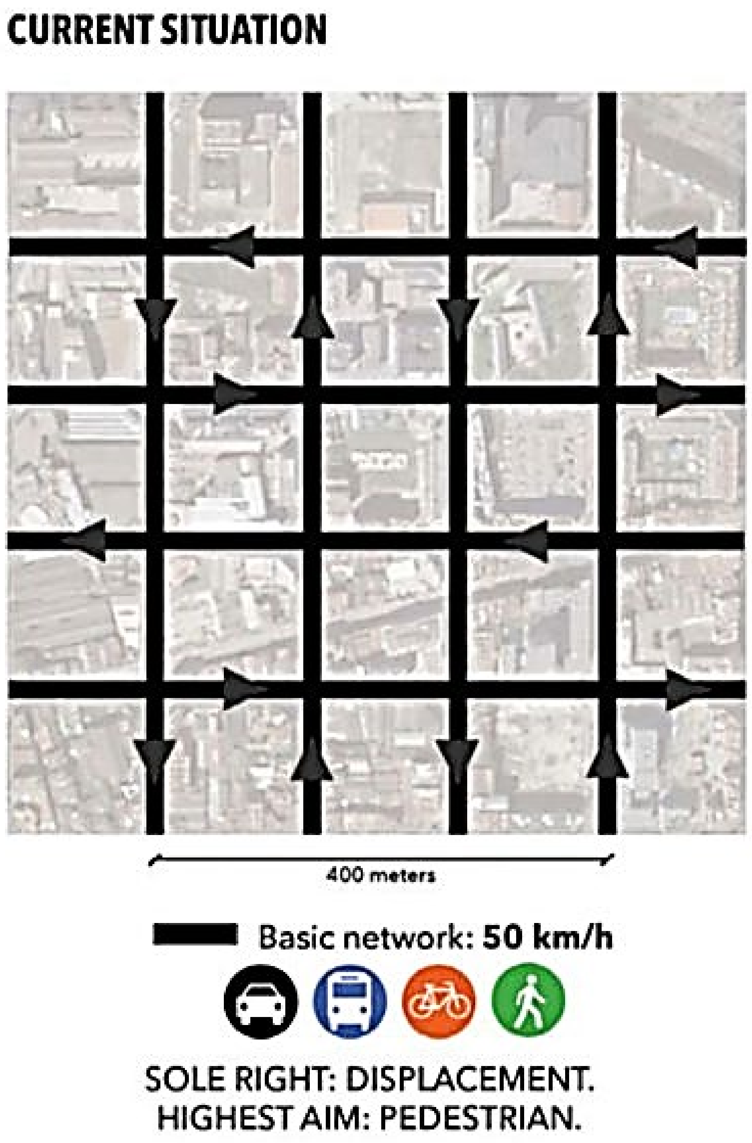
Nicola Davis
@NicolaKSDavis
Thu 8 Aug 2019 00.01 BST

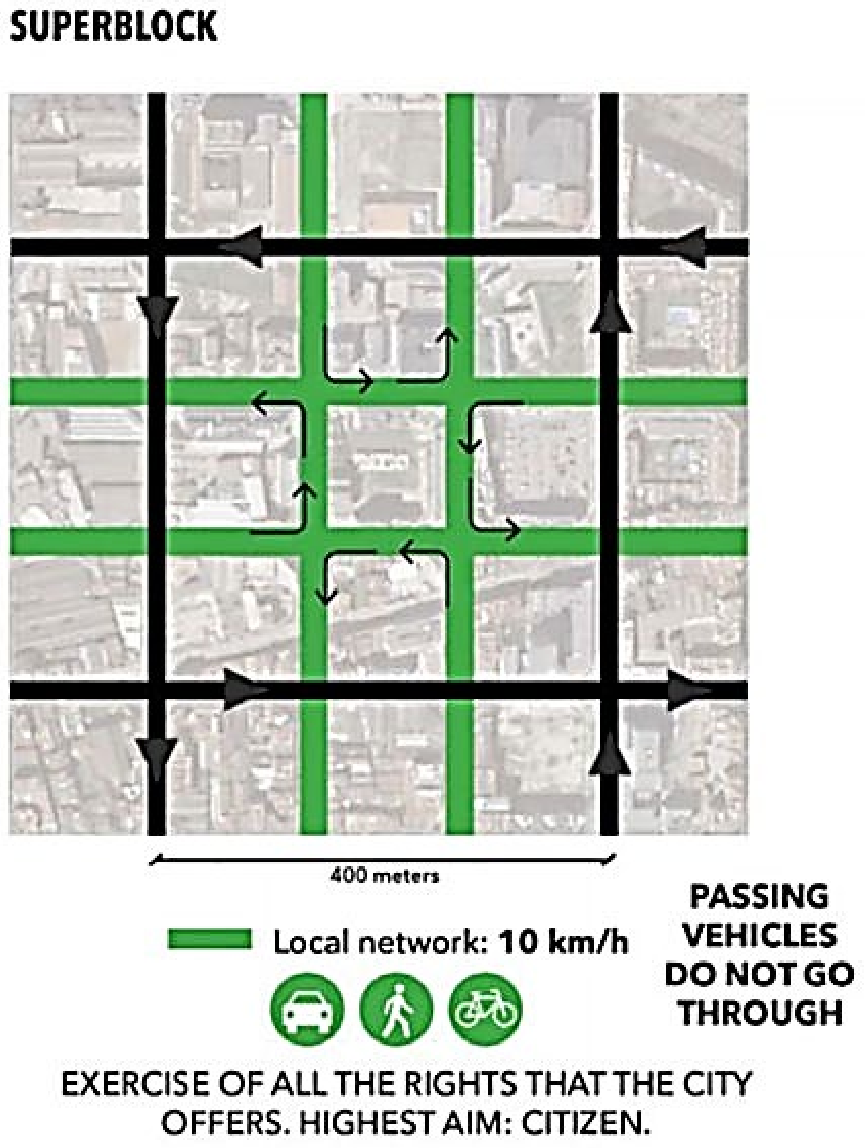
123

Khreis, Haneen; Cirach, Marta; Mueller, Natalie; de Hoogh, Kees; Hoek, Gerard; Nieuwenhuijsen, Mark J.; Rojas-Rueda, David (2018). "Outdoor Air Pollution and the Burden of Childhood Asthma across Europe". European Respiratory Journal, 54, 3, (Impact Factor = 12.2).

Road hierarchy in a Superblock model

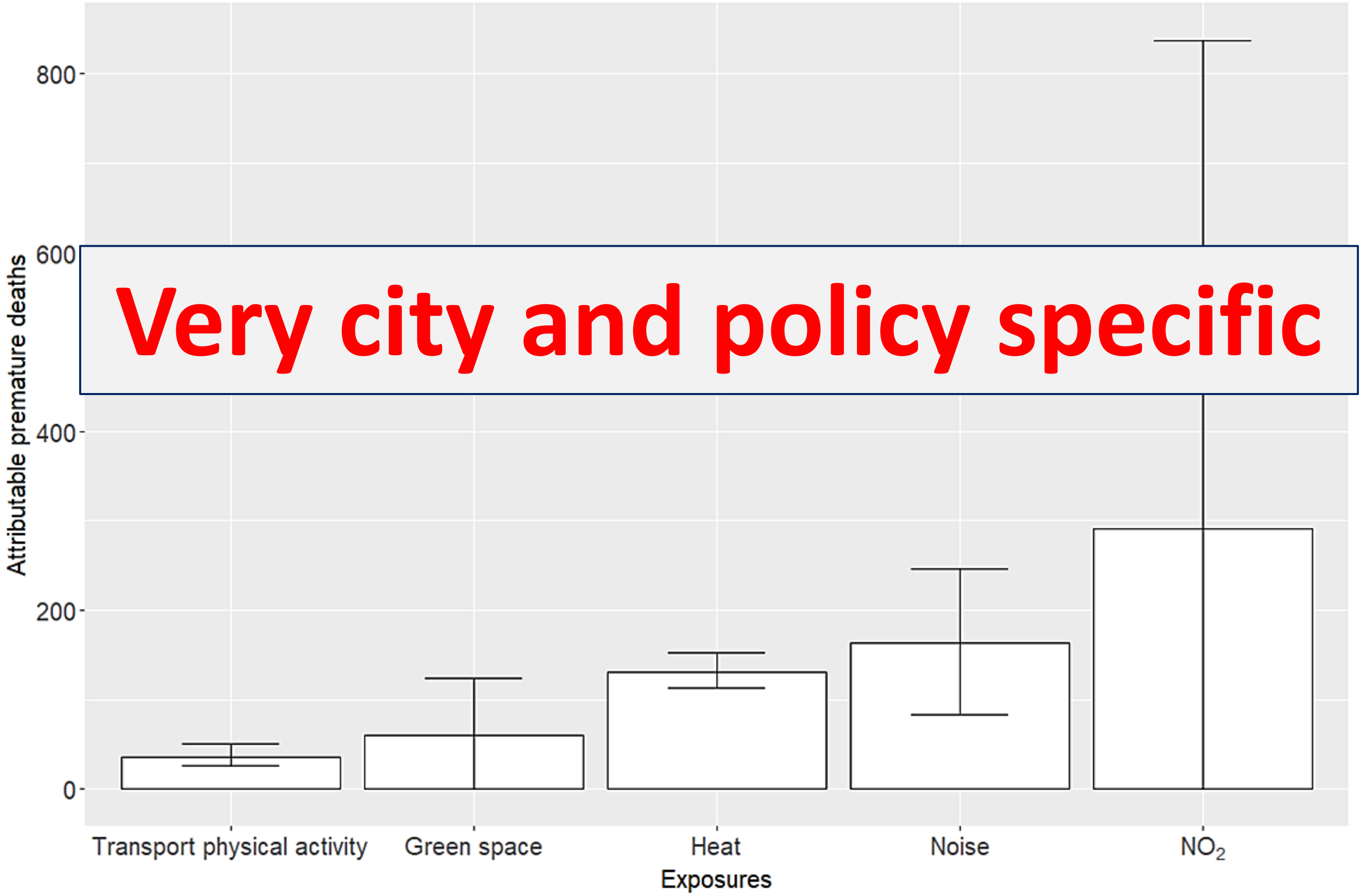
- Segregated bus, cycling and pedestrian lanes on basic network
- Bus stops at each superblock intersection
- Buses at high frequency
- Development of public open and green space





Results - Attributable Premature Mortality

Economic benefits > €1.6 billion ($1.8 billion) per year



Very city and policy specific

670 premature deaths could be prevented annually:

- NO_2 → 291 deaths (0-838)
- Noise → 163 deaths (83-246)
- Heat → 119 deaths (103-139)
- Green space (Eixample) → 61 deaths (0-123)
- Physical activity → 36 deaths (26-50)

Mueller, N., Rojas-Rueda, D., **Khreis**, H., Cirach, M., Andrés, D., Ballester, J., ... & Milà, C. (2019). "Changing the urban design of cities for health: the superblock model". Environment international, 105132, (Impact Factor = 7.9).

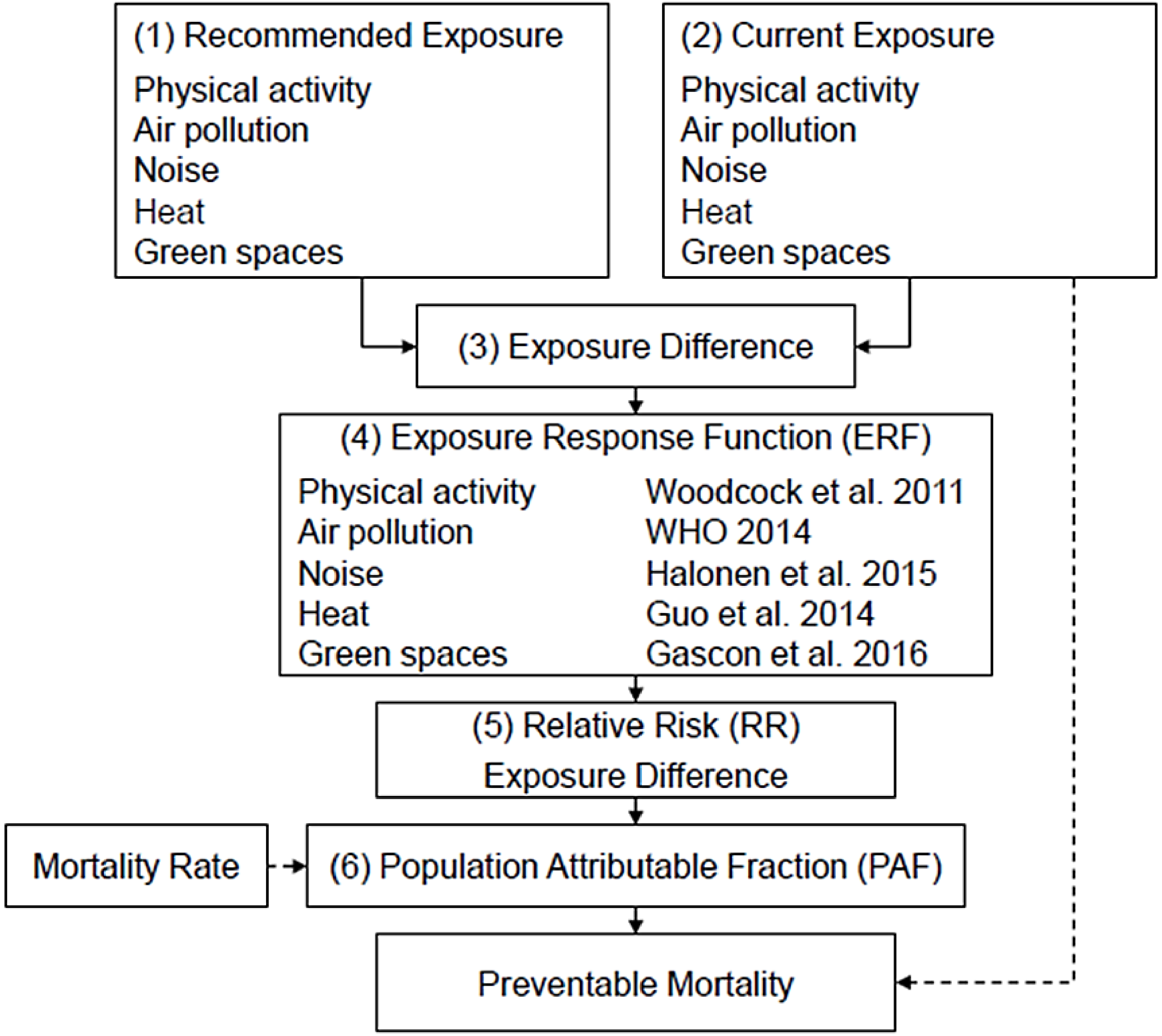
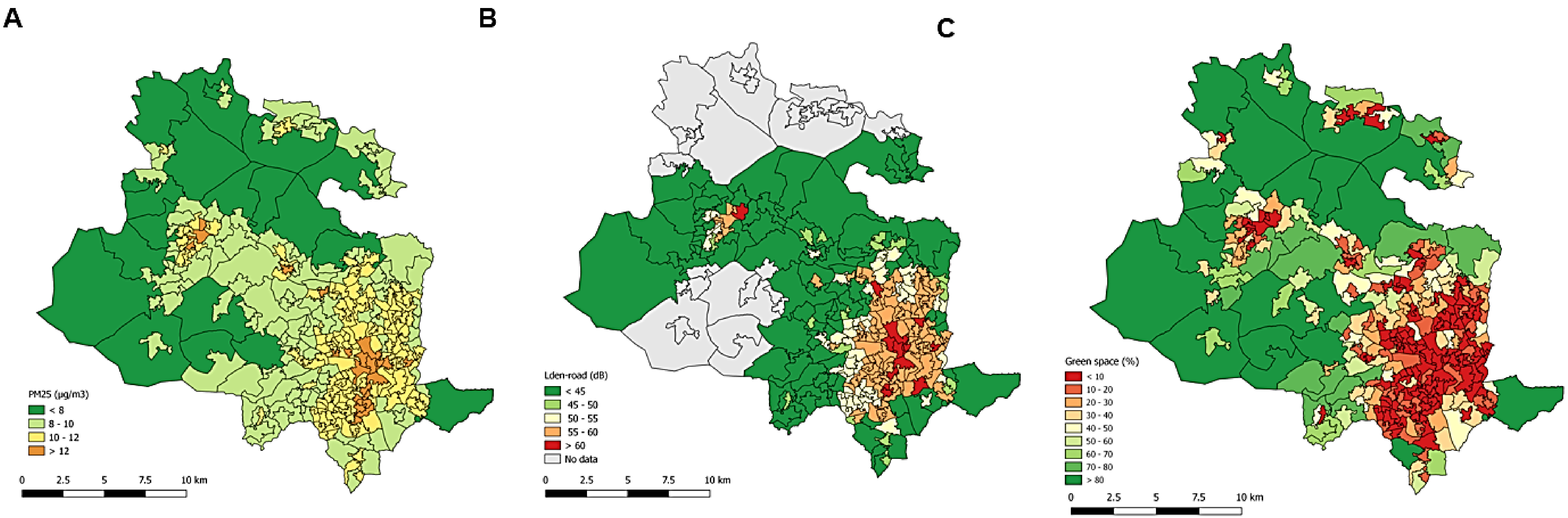

(1) Recommended Exposure
Physical activity
Air pollution
Noise
Heat
Green spaces
(2) Current Exposure
Physical activity
Air pollution
Noise
Heat
Green spaces
(3) Exposure Difference
(4) Exposure Response Function (ERF)
Physical activity
Air pollution
Noise
Heat
Green spaces
Woodcock et al. 2011
WHO 2014
Halonen et al. 2015
Guo et al. 2014
Gascon et al. 2016
(5) Relative Risk (RR)
Exposure Difference
Mortality Rate
(6) Population Attributable Fraction (PAF)
Preventable Mortality

Figure 1. Environmental exposures at LSOA level



A = $PM_{2.5}$ concentrations (2009/ 2010)at LSOA level
B = Noise levels L_{den}(Road) (2006) at LSOA level
C= % green space (2012) at LSOA level

310 lower super output areas
393,091 adults

Table 2. Recommended and actual exosure levels in Bradford

Exposures	WHO (counterfactual)	Bradford (city-wide average)
Physical activity	150 min moderate intensity or 75 min vigorous intensity physical activity weekly = 600 MET min/ week	49.4% of population is insufficiently active (=194,187 persons) 124 MET min/ week[a]
$PM_{2.5}$	10 µg/m³ annual mean	10.12 µg/m³ annual mean
NO_2	40 µg/m³ annual mean	21.18 µg/m³ annual mean
Noise	[55 dB day time (7:00-23:00 h) 40 dB night time (23:00-7:00 h)] → 55 dB L_{den}(Road) annual mean	44.41 dB L_{den}(Road) annual mean
Green space	Universal access to green space ≥ 0.5 ha within 300 m linear distance	17.84 % of residents without access to green space ≥0.5 ha within 300 m linear distance

Note: dB, decibel; L_{den}, EU noise indicator with 5 dB weights for the evening time and 10 dB weights for the night time; MET, metabolic equivalents of taks.

[a] weekly mean physical activity level of the insufficiently active population.

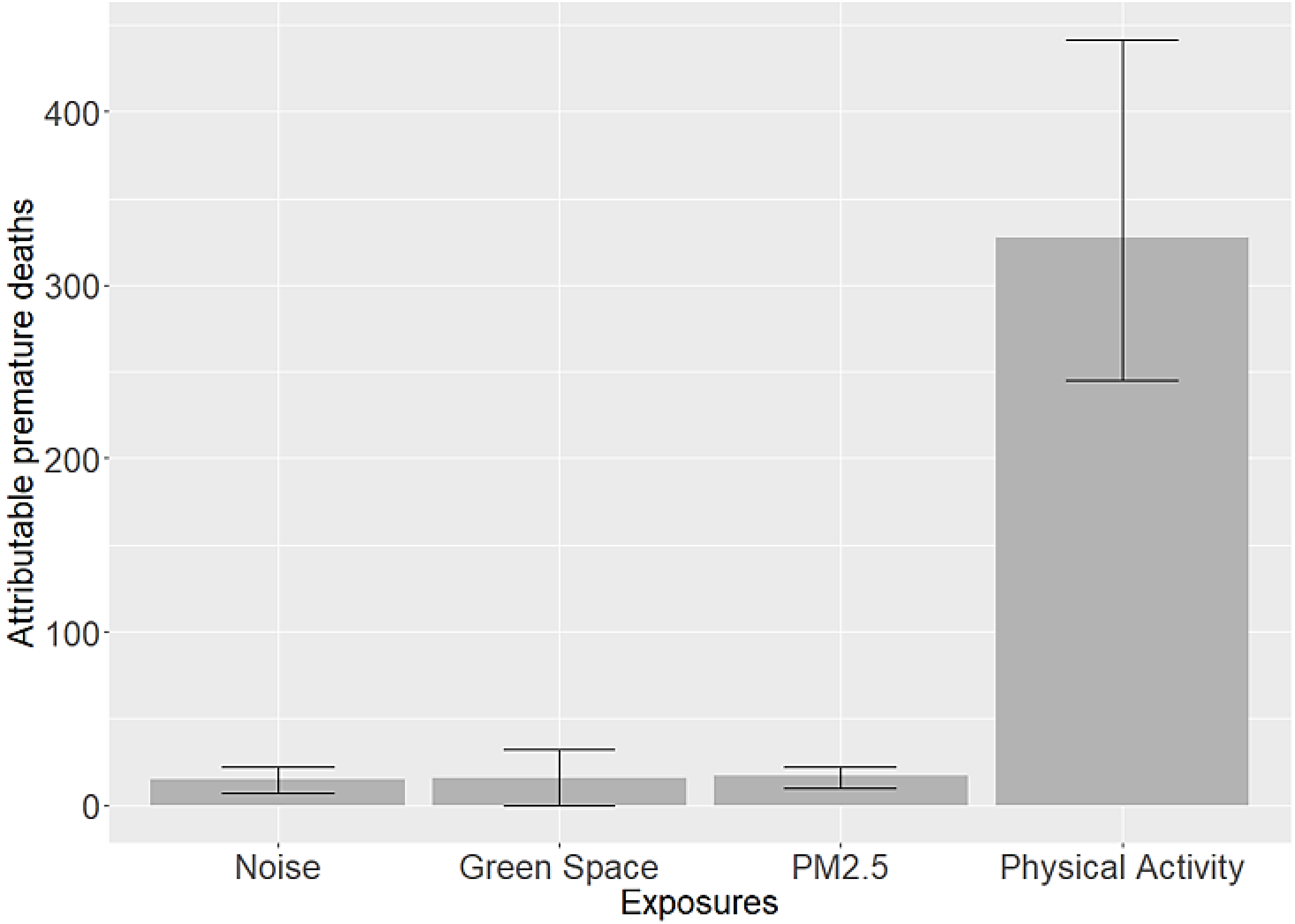
Attributable Premature Mortality

- Exposures prevalence
  - *Half of adult population insufficiently active*
  - *$PM_{2.5}$ only exceeded in 172 LSOAs by 1.03 μg/m^3*
  - *L_{den}(road) noise only exceeded in 113 LSOAs by 2.43 dB*
  - *18% of adult population did not live within 300 m to a green space ≥ 0.5 ha*

Attributable Premature Mortality

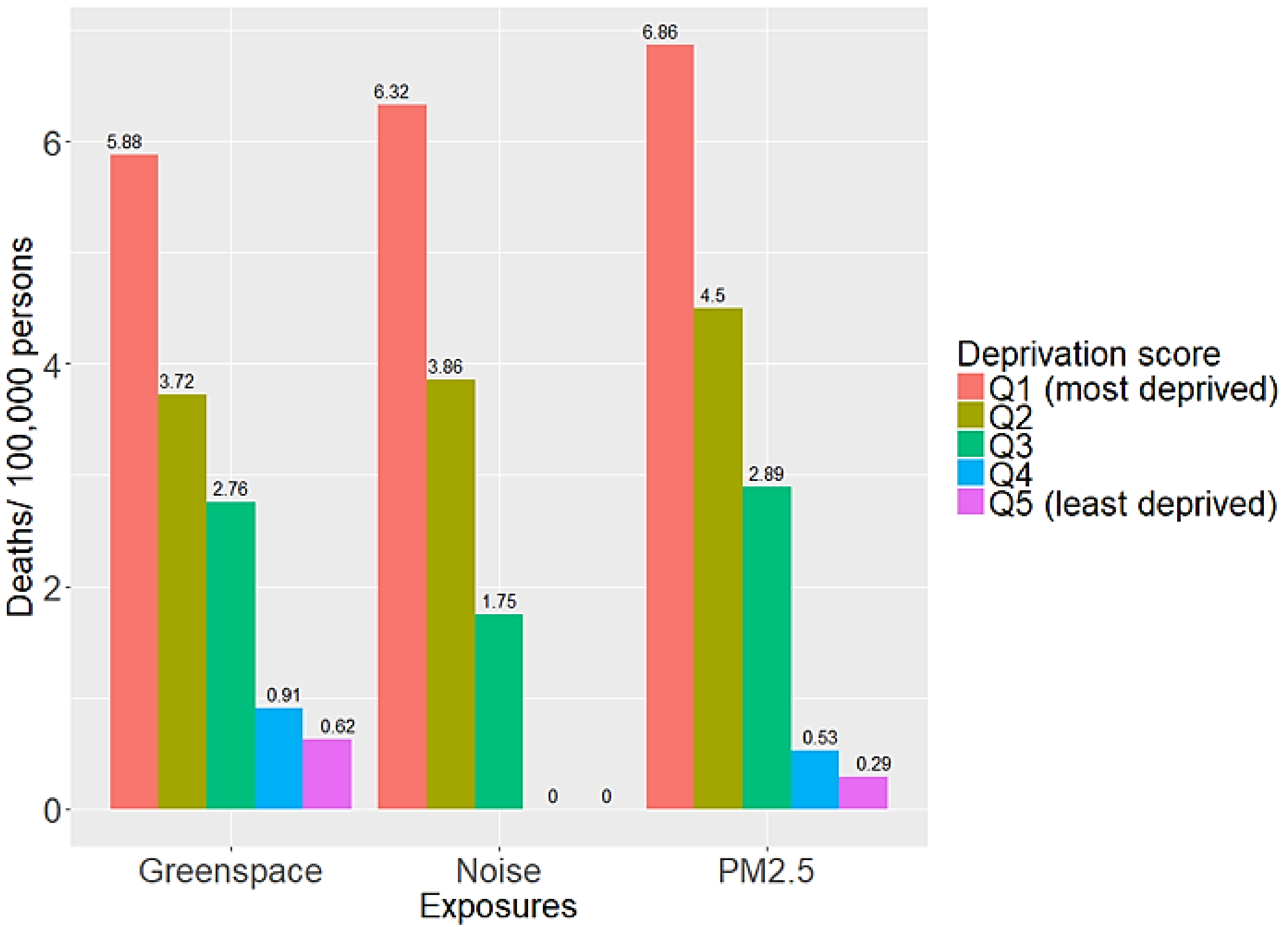
- 375 premature deaths (95% CI: 245 - 474) could be preventable with compliance
    - Physical activity → 327 deaths
    - Air pollution → 15 deaths
    - Green space → 16 deaths
    - Noise → 15 deaths

Figure 2. Attributable premature mortality due to incompliance of exposure recommendations



Economic losses > £55,000 per person

Figure 4. Standardized mortality impacts by deprivation score



International Journal of
Environmental Research and Public Health

MDPI

Review

New Opportunities to Mitigate the Burden of Disease Caused by Traffic Related Air Pollution: Antioxidant-Rich Diets and Supplements

Jillian Barthelemy [1], Kristen Sanchez [1], Mark R. Miller [2] and Haneen Khreis [1,3,*]

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Received: 2 December 2019; Accepted: 14 January 2020; Published: 18 January 2020

check for updates

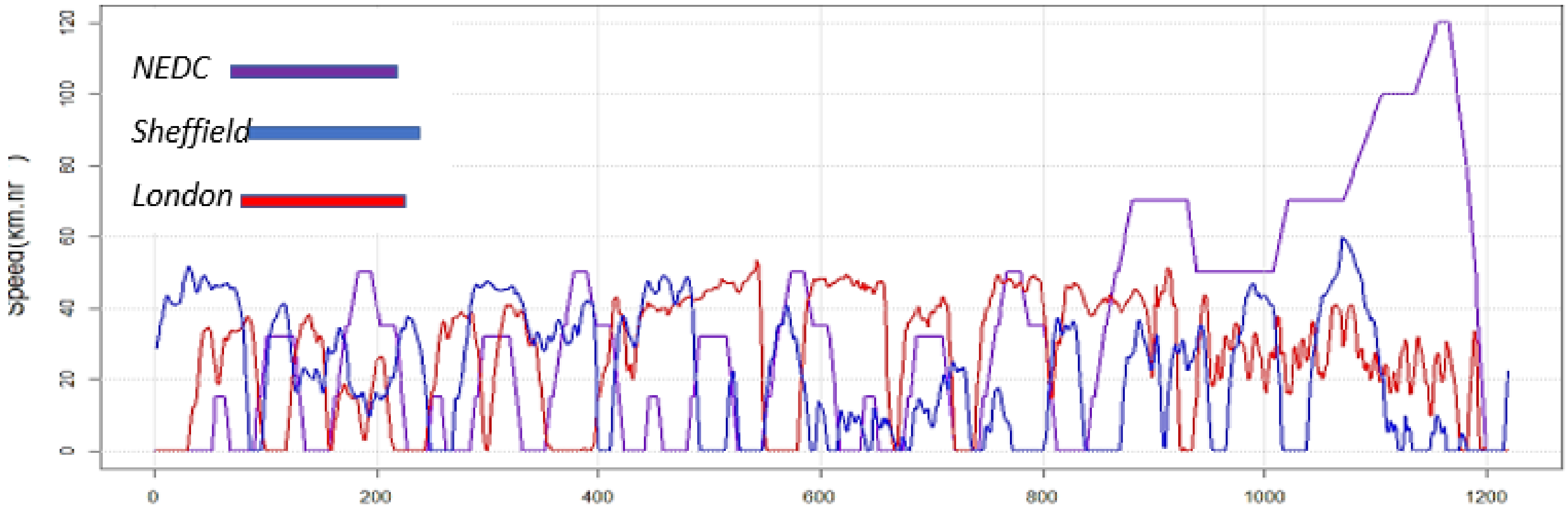
Abstract: Air pollution is associated with premature mortality and a wide spectrum of diseases. Traffic-related air pollution (TRAP) is one of the most concerning sources of air pollution for human exposure and health. Until TRAP levels can be significantly reduced on a global scale, there is a need for effective shorter-term strategies to prevent the adverse health effects of TRAP. A growing number of studies suggest that increasing antioxidant intake, through diet or supplementation, may reduce this burden of disease. In this paper, we conducted a non-systematic literature review to assess the available evidence on antioxidant-rich diets and antioxidant supplements as a strategy to mitigate adverse health effects of TRAP in human subjects. We identified 11 studies that fit our inclusion criteria; 3 of which investigated antioxidant-rich diets and 8 of which investigated antioxidant supplements. Overall, we found consistent evidence that dietary intake of antioxidants from adherence to the Mediterranean diet and increased fruit and vegetable consumption is effective in mitigating adverse health effects associated with TRAP. In contrast, antioxidant supplements, including fish oil, olive oil, and vitamin C and E supplements, presented conflicting evidence. Further research is needed to determine why antioxidant supplementation has limited efficacy and whether this relates to effective dose, supplement formulation, timing of administration, or population being studied. There is also a need to better ascertain if susceptible populations, such as children, the elderly, asthmatics and occupational workers consistently exposed to TRAP, should be recommended to increase their antioxidant intake to reduce their burden of disease. Policymakers should consider increasing populations' antioxidant intake, through antioxidant-rich diets, as a relatively cheap and easy preventive measure to lower the burden of disease associated with TRAP.


Monsieur Macron
C'est le « Bordel »!
LE BRUIT
NOUS TUE

Exhaust Vehicle Emissions: General Consensus

- Over the past 30–40 years, vehicle tailpipe emissions of CO, HC, NO_x and PM have decreased significantly
  - Increasingly stringent regulations since the 1970s
  - Development of advanced emission after-treatment technologies including three-way catalytic converters, lean NO_x traps, selective catalytic reduction (SCR), and diesel particulate filters (DPFs)
  - Improved fuel efficiency
  - Despite increased vehicle population and travel
- These absolute reductions resulted in marked improvements in ambient air quality in the developed world (the US and Europe)
- However, predictions are highly sensitive to modeling methodologies

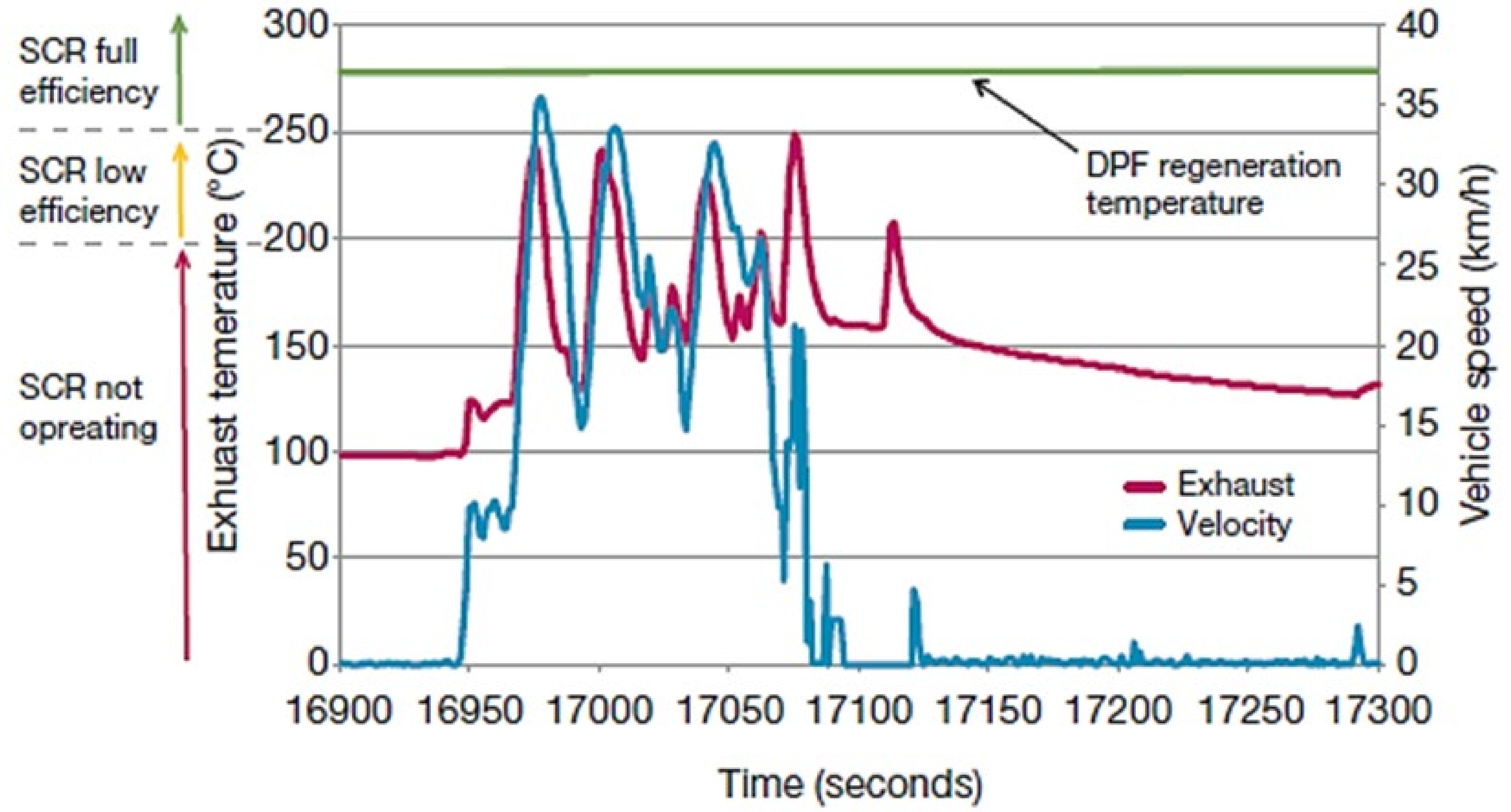
NEDC (speed profile used for type approval purposes) vs. two real worlds driving cycles on London's and Sheffield's road networks



- On-road measurements show substantial declines in real-world emissions of HC, NO_x, and CO at four US urban locations since the late 1990s
- Declines in emissions in Europe have generally been predicted by modeling and real-world measurements do not agree with modeling results
- In the EU the New European Drive Cycle (NEDC) and test procedure did not fully reflect on-road emissions

Exhaust Vehicle Emissions: Important Considerations

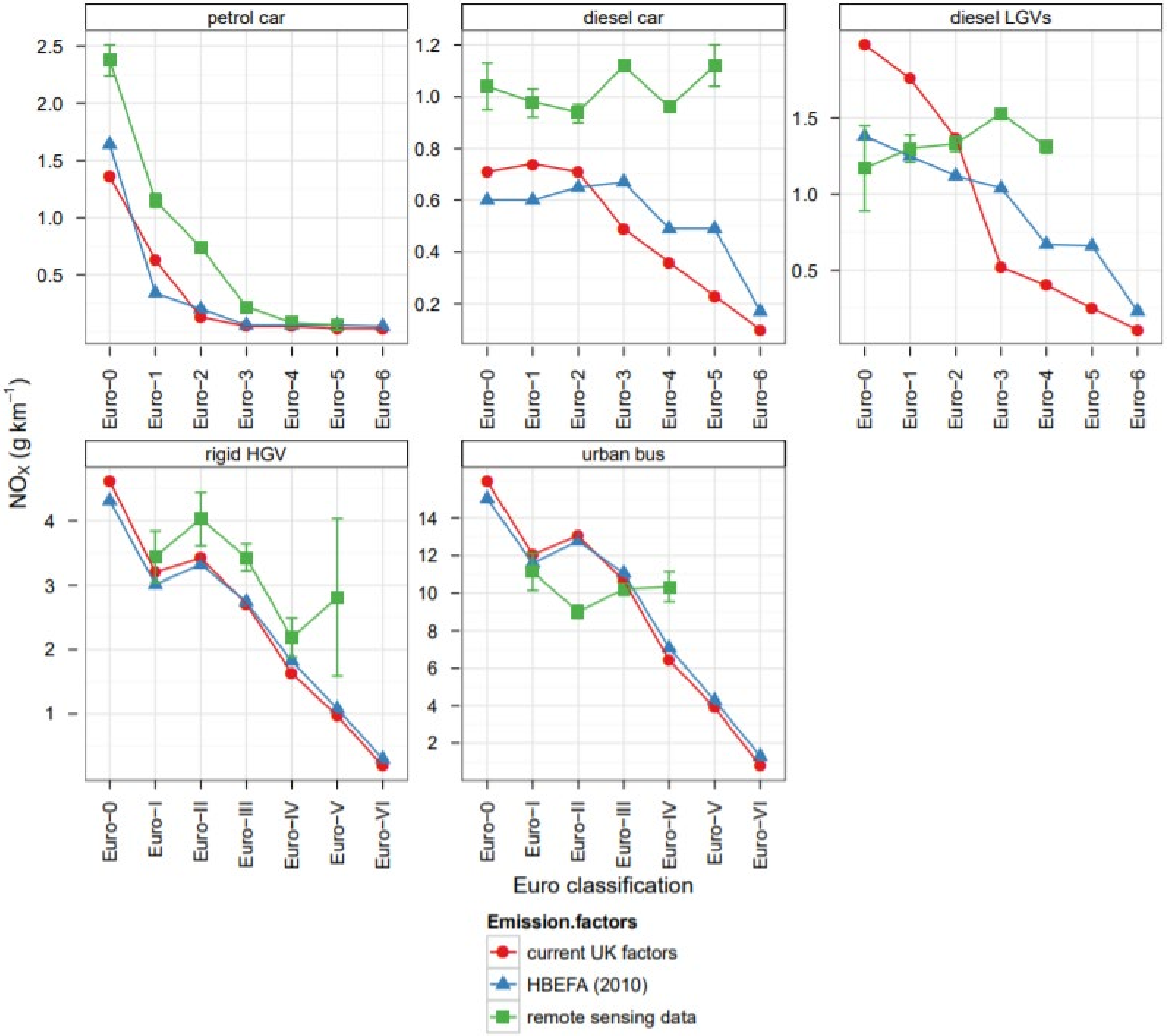
Exhaust Vehicle Emissions: Important Considerations



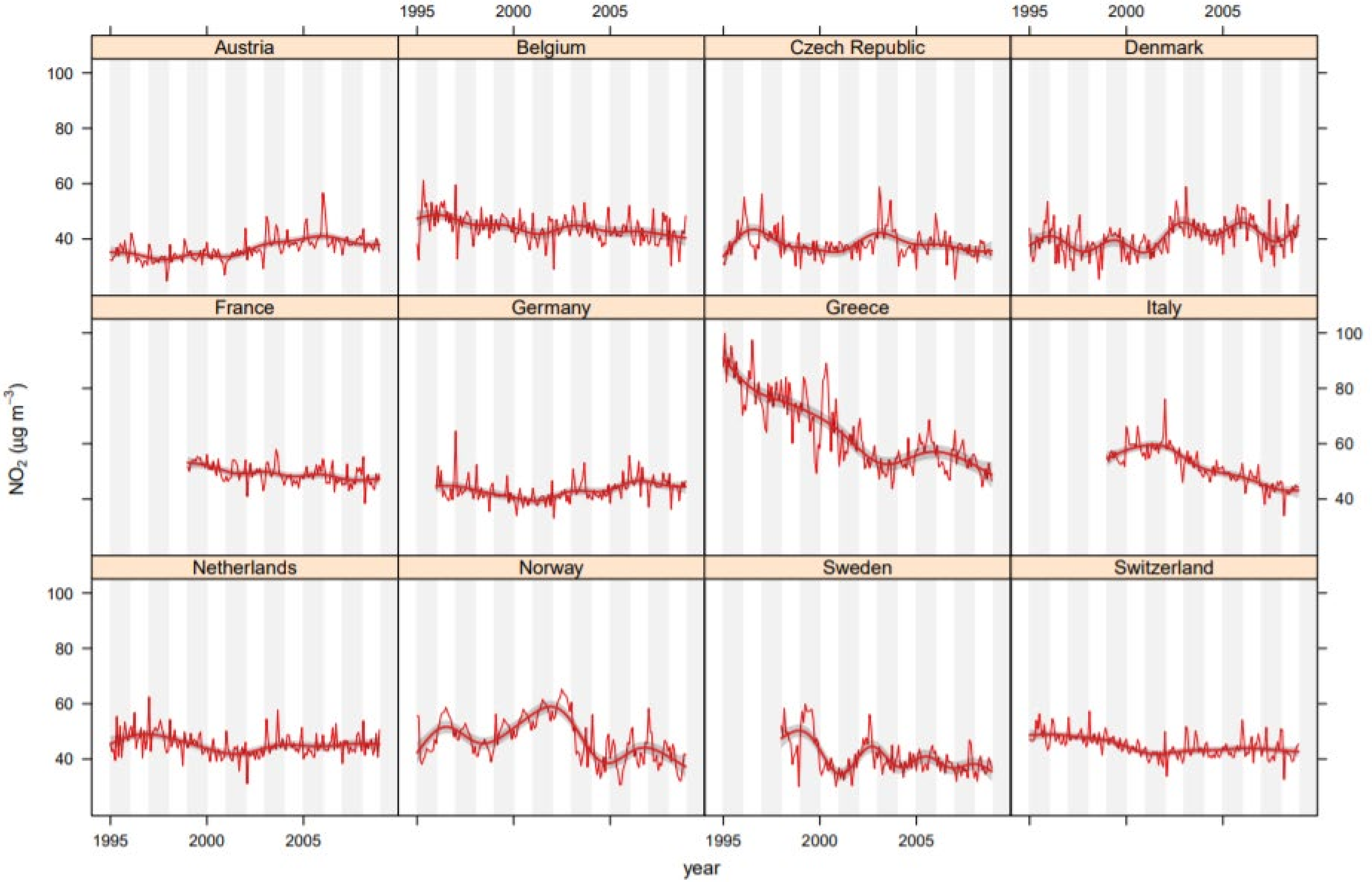
SCR and DPF operating temperature related to Heathrow drive cycle, source: Hitchcock et al. (2014)

Exhaust Vehicle Emissions: Important Considerations

- The decrease in NO_x emissions from diesel vehicles in the real world has been less than expected based on emission standards as tested under laboratory conditions or predicted by emission models
- Diesel light duty vehicles on-road NO_x emission rates in the EU have not improved relative to the 1990s and the measured NO_2 share of NO_x has increased
- Gasoline vehicle on-road NO_x emission rates have decreased by a factor of 8–10 since pre-Euro 1 emission controls
- In 2017, the severity of Euro 6 regulations increased substantially by including a Real Driving Emissions component to bring on-road diesel NO_x close to the laboratory standard

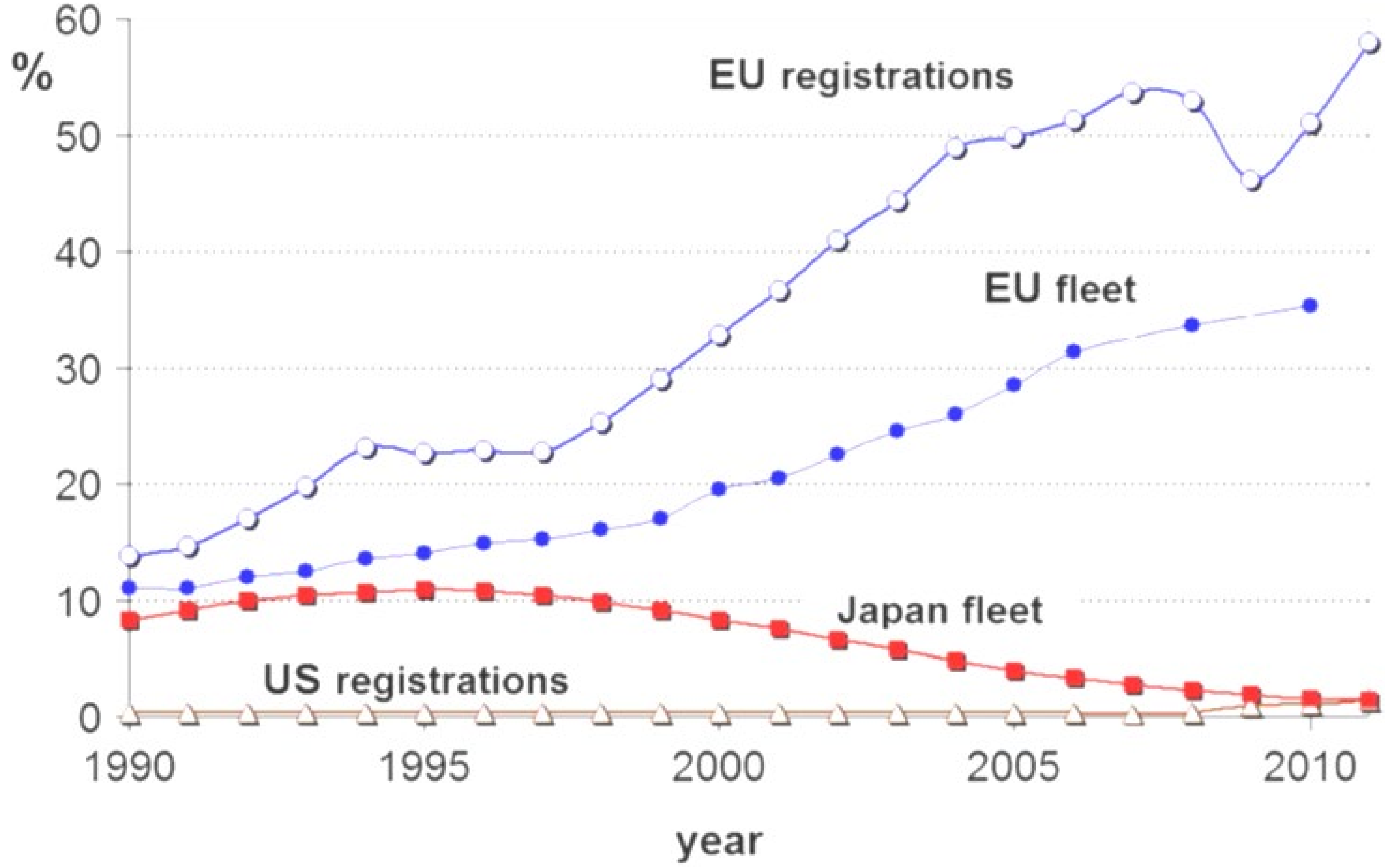


Comparison of different emission factors estimates. Three emission sources are compared: current UK factors, HBEFA (2010), and estimates based on the analysis of remote sensing data, source: Carslaw et al. (2011)



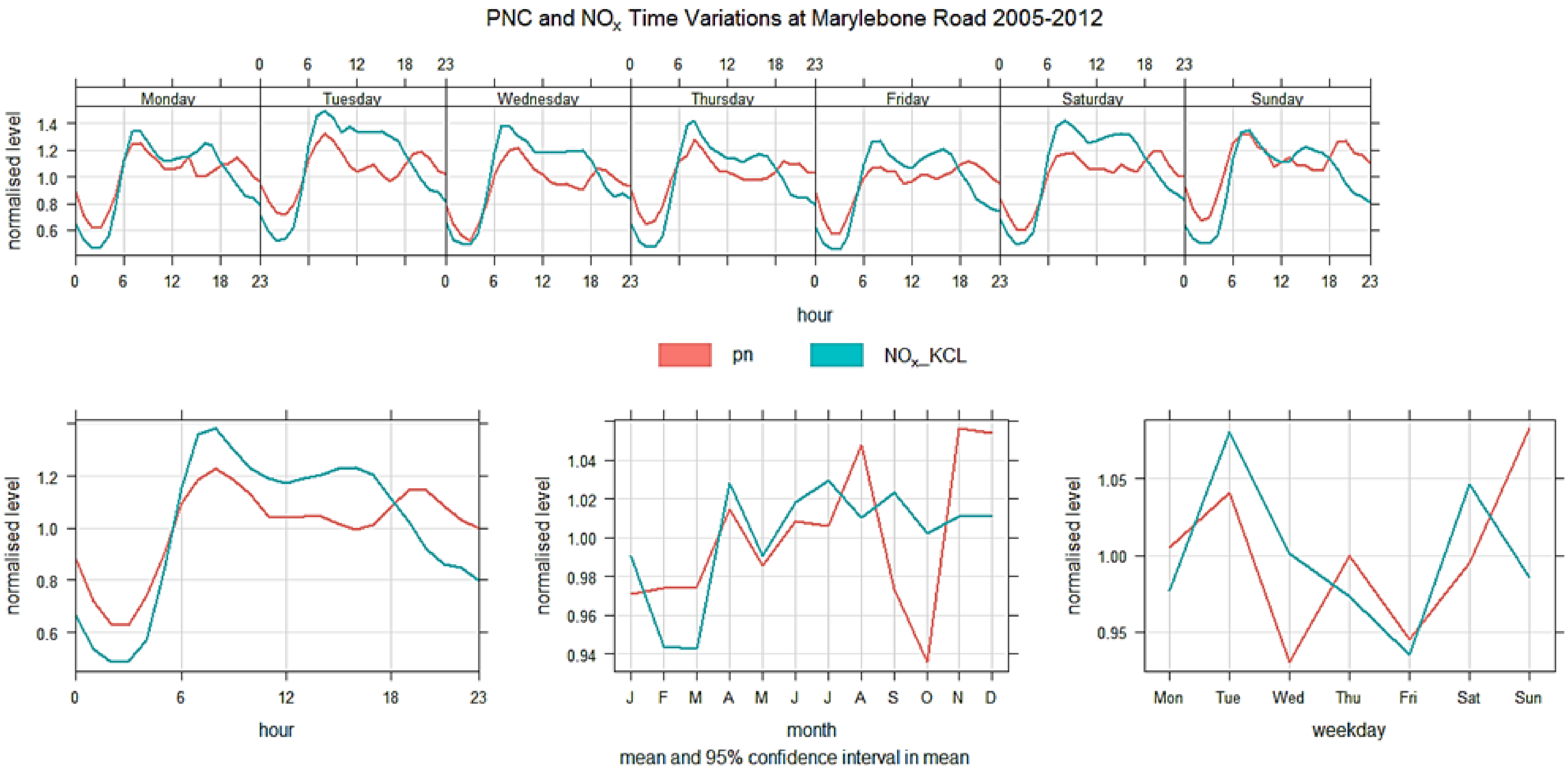
Monthly de-seasonalised trends in NO_2 at roadside sites for select European Countries, source: Carslaw et al. (2011)

Exhaust Vehicle Emissions: Important Considerations



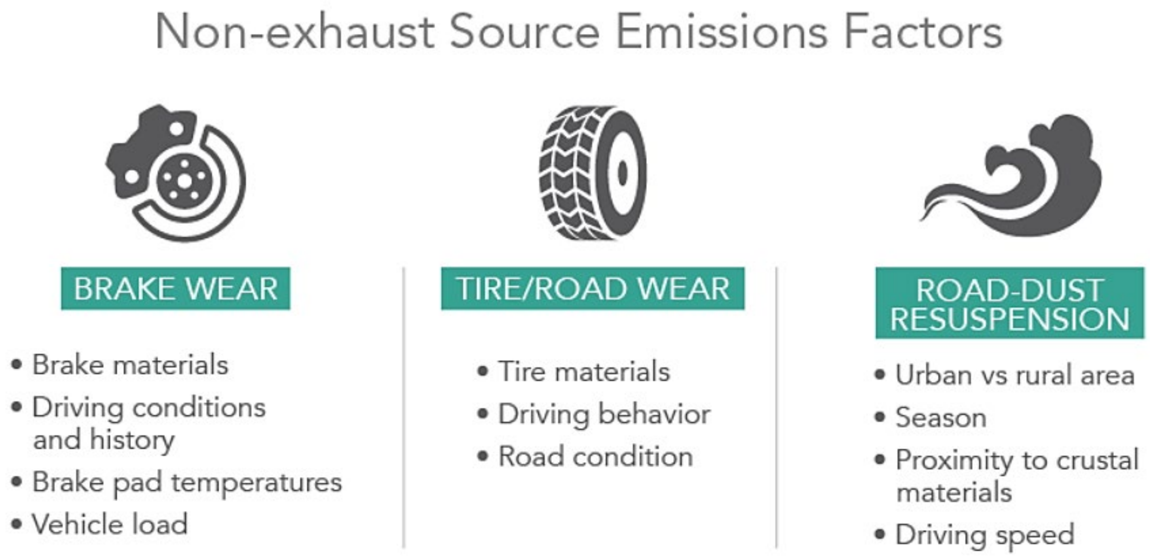
Diesel car penetration in major world markets, expressed as percentages, either annual new car registrations or annual entire car fleet composition, source: Cames and Helmers (2013)

Exhaust Vehicle Emissions: Important Considerations



PNC and NOx time variations at Marylebone road (2005-2012)

Non-Exhaust Vehicle Emissions



Source: California Air Resources Board

- Results from tire wear, brake wear, road surface wear and resuspension of road dust
- (larger) PM emissions
- The ratio of non-exhaust to exhaust particles has strongly increased in the last two decades, due to exhaust emission reductions
- More than 20 years of research showing that the contribution of non-exhaust primary particles to the total traffic generated primary particles is significant in urban areas

Non-Exhaust Vehicle Emissions

- **<u>Tire wear</u>**: tires generate particles both through the wear of the rubber and through the wear of road surfaces. These processes may depend on tire type, size, and age, vehicle speed and <u>weight</u>, road surface properties, and meteorological conditions (temperature, road wetness, etc.)
- Tire wear contributes to PM_{10} even though most of the wear results in larger particles

Non-Exhaust Vehicle Emissions

- **Brake wear** is due to large frictional heat generation by brake linings. Detailed laboratory tests have shown that 50% of the total wear is emitted as airborne material; the other half directly deposits on the (road) surface and the wheel of the car

Non-Exhaust Vehicle Emissions

- Wear of the road surface varies significantly based on the properties of the asphalt as well as tire type, vehicle type and <u>weight</u>, and speed, as well as road surface conditions
- <u>**Road wear**</u>—pavement-derived PM_{10}—mainly consists of small mineral fragments and therefore is dominated by crustal elements like Si, Ca, K, Fe, and Al. The composition therefore differs depending on the rock material use

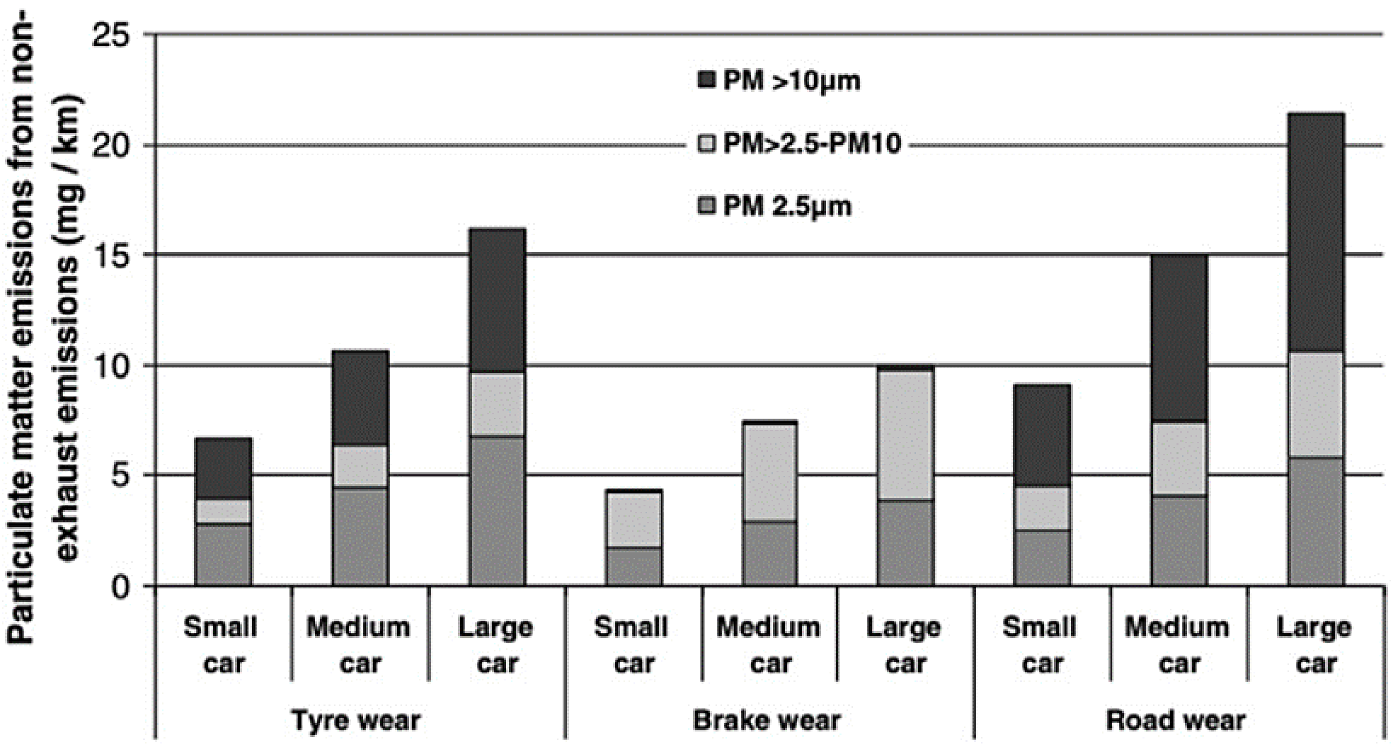
Non-Exhaust Vehicle Emissions

- Non-exhaust and exhaust vehicle emissions vary significantly in size and composition but studies characterizing non-exhaust PM and their relative contribution are few
- The exhaust component consists predominantly of externally mixed soot particles and soot internally mixed with secondary particles
- The abrasion component contained all particles with characteristic tracer elements (Fe, Cu, Ba, Sb, Zn) for brake and tire abrasion
- The resuspension component comprises all internally mixed particles with a high proportion of silicates or Fe oxides/hydroxides which contain soot or abrasion particles as minor constituent

Non-Exhaust Vehicle Emissions

- The total contribution of traffic to PM_{10} was **27%** at the urban background station and **48%** at the curbside station (Weinbruch et al., 2014)
- The corresponding values for PM_1 were **15% and 39%**
- The relative share of the different traffic components for PM_{10} at the curbside station was 27% exhaust, 15% abrasion, and 58% resuspension (38%, 8%, 54% for PM_1)
- For the urban background, the following relative shares were obtained forPM_{10}: 22% exhaust, 22% abrasion and 56% resuspension (40%, 27%, 33% for PM_1)
- Compared to earlier studies, Weinbruch et al. observed a significantly lower portion of exhaust and a significantly higher portion of resuspension particles
- Other model predictions (both MOVES and EMFAC) suggest that traffic-related emissions of both $PM_{2.5}$ and PM_{10} will eventually be dominated by non-exhaust sources (Reid et al., 2016)

Non-Exhaust Vehicle Emissions



- Non-exhaust emissions are also a factor of vehicle weight as road abrasion and tire wear are caused by friction
- Tire, brake and road wear increase by around 50% when comparing a medium (1600 kg) and small (1200 kg) car
- Compared to a small car, large cars (2000 kg) emitted more than double the amount of PM_{10} (Simons, 2013)

Non-exhaust PM emissions by source and car size, source: Simons (2013)

Contents lists available at ScienceDirect

Atmospheric Environment

journal homepage: www.elsevier.com/locate/atmosenv

Review article

Non-exhaust PM emissions from electric vehicles

Victor R.J.H. Timmers [a,*], Peter A.J. Achten [b]

[a] vrjhtimmers@gmail.com
[b] INNAS BV, 15 Nikkelstraat, 4823 AE Breda, Netherlands

HIGHLIGHTS

- A positive relationship exists between vehicle weight and non-exhaust emissions.
- Electric vehicles are 24% heavier than their conventional counterparts.
- Electric vehicle PM emissions are comparable to those of conventional vehicles.
- Non-exhaust sources account for 90% of PM_{10} and 85% of $PM_{2.5}$ from traffic.
- Future policy should focus on reducing vehicle weight.

ARTICLE INFO

ABSTRACT

Electric Vehicles

- Electric vehicles are generally heavier than internal combustion vehicle engines
- On average, the electric versions are 280 kg or 24% heavier than their internal combustion engine counterparts

EV	ICEV	Mass in running order EV (kg)	Mass in running order ICEV (kg)	Weight difference (kg)	Weight difference (%)
Ford focus electric	Ford focus	1719	1500	+219	+14.6
Honda fit EV	Honda fit	1550	1215	+335	+27.6
Fiat 500e	Fiat 500	1427	1149	+278	+24.2
Smart electric drive coupe	Smart coupe	1055	820	+235	+28.7
Kia soul EV	Kia soul	1617	1306	+311	+23.8
Volkswagen e-Up!	Volkswagen Up	1289	1004	+284	+28.3
Volkswagen e-golf	Volkswagen golf	1617	1390	+227	+16.3
Chevrolet spark EV	Chevrolet spark	1431	1104	+327	+28.6
Renault fluence EV	Renault fluence	1618	1300	+318	+24.4

Comparison of weight between EVs and their ICEV counterparts, based on manufacturer information, source: Timmers and Achten (2016)

Electric Vehicles

- When factoring in the additional weight and non-exhaust PM factors, total PM_{10} emissions from electric vehicles (EVs) are equal to those of modern internal combustion engine vehicles (ICEVs)
- For $PM_{2.5}$ emissions, EVs deliver only a negligible reduction in emissions (Timmers and Achten, 2016)
  - Compared to an average gasoline ICEV, the EV emits 3% less $PM_{2.5}$
  - Compared to an average diesel ICEV, the EV emits 1% less $PM_{2.5}$

Comparison between PM emissions from EVs and ICEVs

Comparison between expected PM_{10} emissions of EVs, gasoline and diesel ICEVs.

Vehicle technology	Exhaust	Tyre wear	Brake wear	Road wear	Resuspension	Total
EV	0 mg/vkm	7.2 mg/vkm	0 mg/vkm	8.9 mg/vkm	49.6 mg/vkm	**65.7 mg/vkm**
Gasoline ICEV	3.1 mg/vkm	6.1 mg/vkm	9.3 mg/vkm	7.5 mg/vkm	40 mg/vkm	**66.0 mg/vkm**
Diesel ICEV	2.4 mg/vkm	6.1 mg/vkm	9.3 mg/vkm	7.5 mg/vkm	40 mg/vkm	**65.3 mg/vkm**

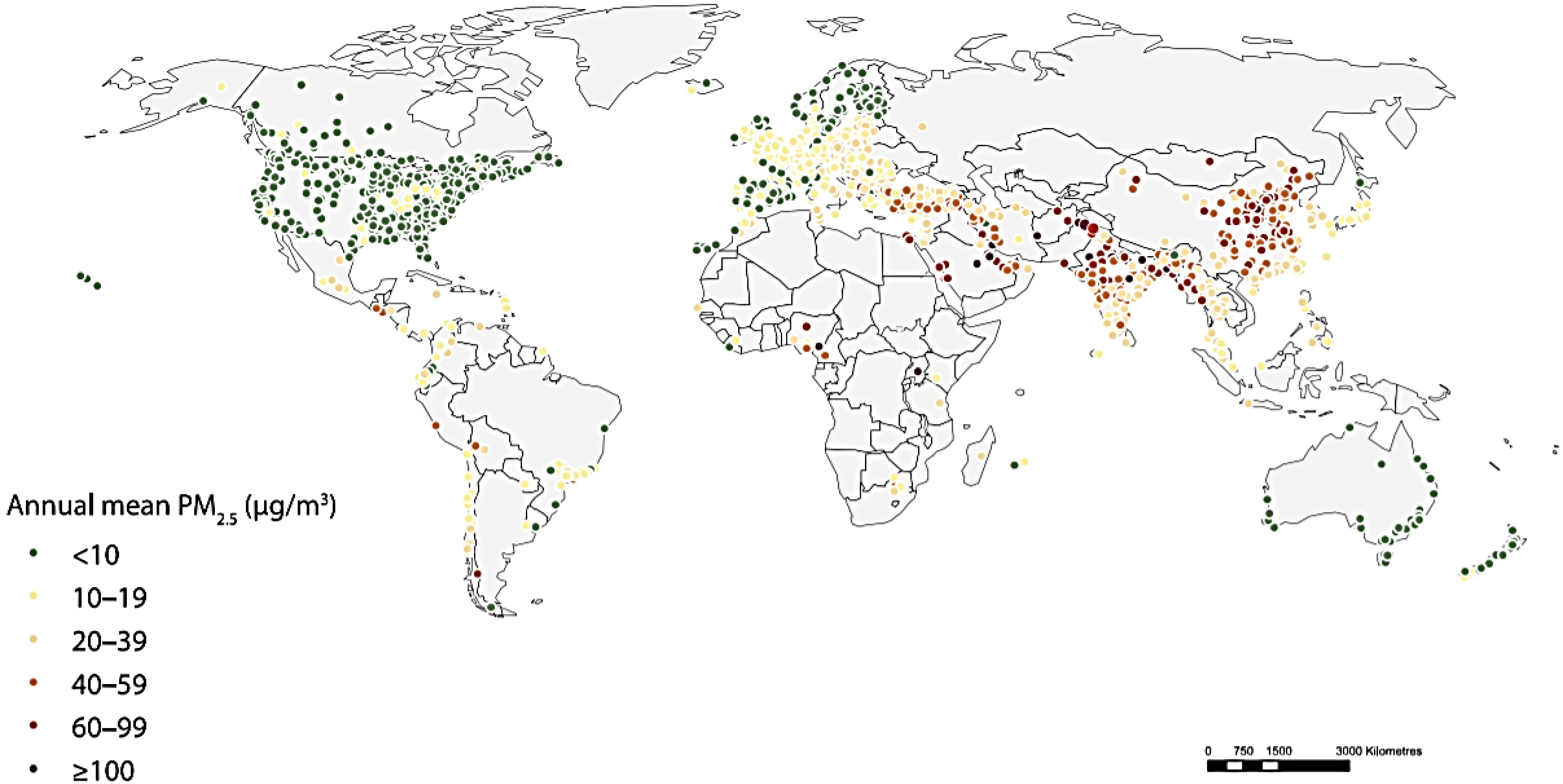
Comparison between expected $PM_{2.5}$ emissions of EVs, gasoline and diesel ICEVs.

Vehicle technology	Exhaust	Tyre wear	Brake wear	Road wear	Resuspension	Total
EV	0 mg/vkm	3.7 mg/vkm	0 mg/vkm	3.8 mg/vkm	14.9 mg/vkm	**22.4 mg/vkm**
Gasoline ICEV	3.0 mg/vkm	2.9 mg/vkm	2.2 mg/vkm	3.1 mg/vkm	12.0 mg/km	**23.2 mg/vkm**
Diesel ICEV	2.4 mg/vkm	2.9 mg/vkm	2.2 mg/vkm	3.1 mg/vkm	12.0 mg/vkm	**22.6 mg/vkm**

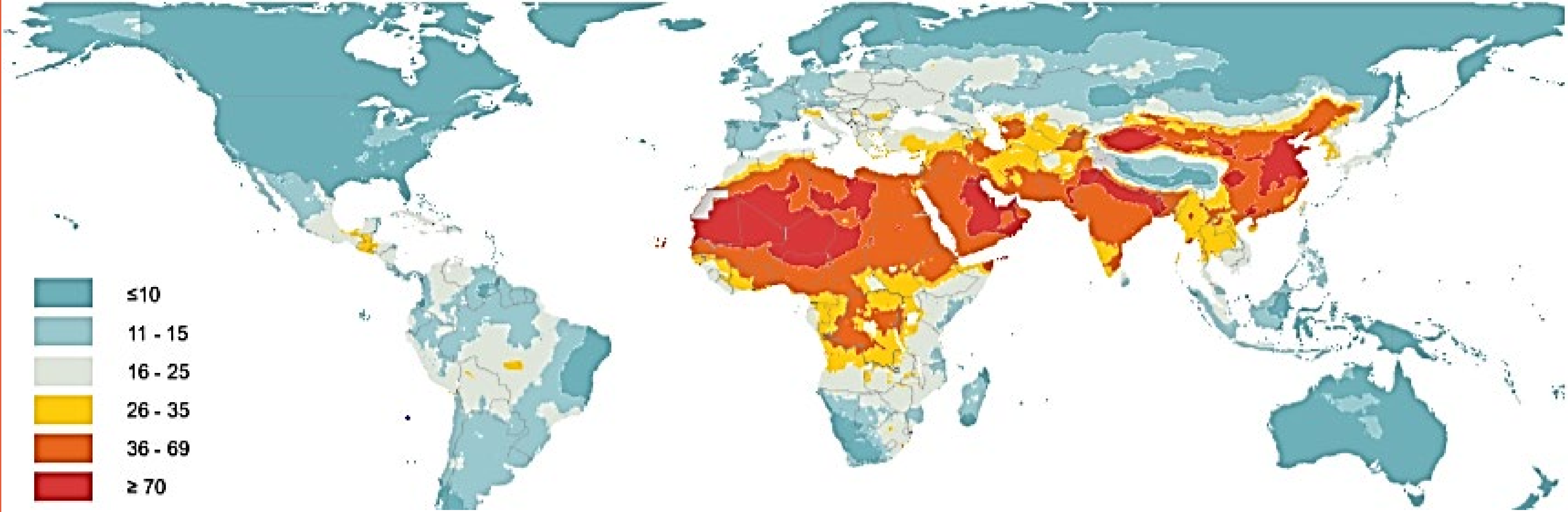
Health Effects

Electromagnetic Fields
Adverse and beneficial impacts regarding: Cell growth Genes Neural system Immune system Circulatory system Endocrine system
Behavioral development issues in children
Cognitive development issues in children
Nerve tissue stimulation
Reproductive complications
Retinal phosphene occurrence

CARTEEH



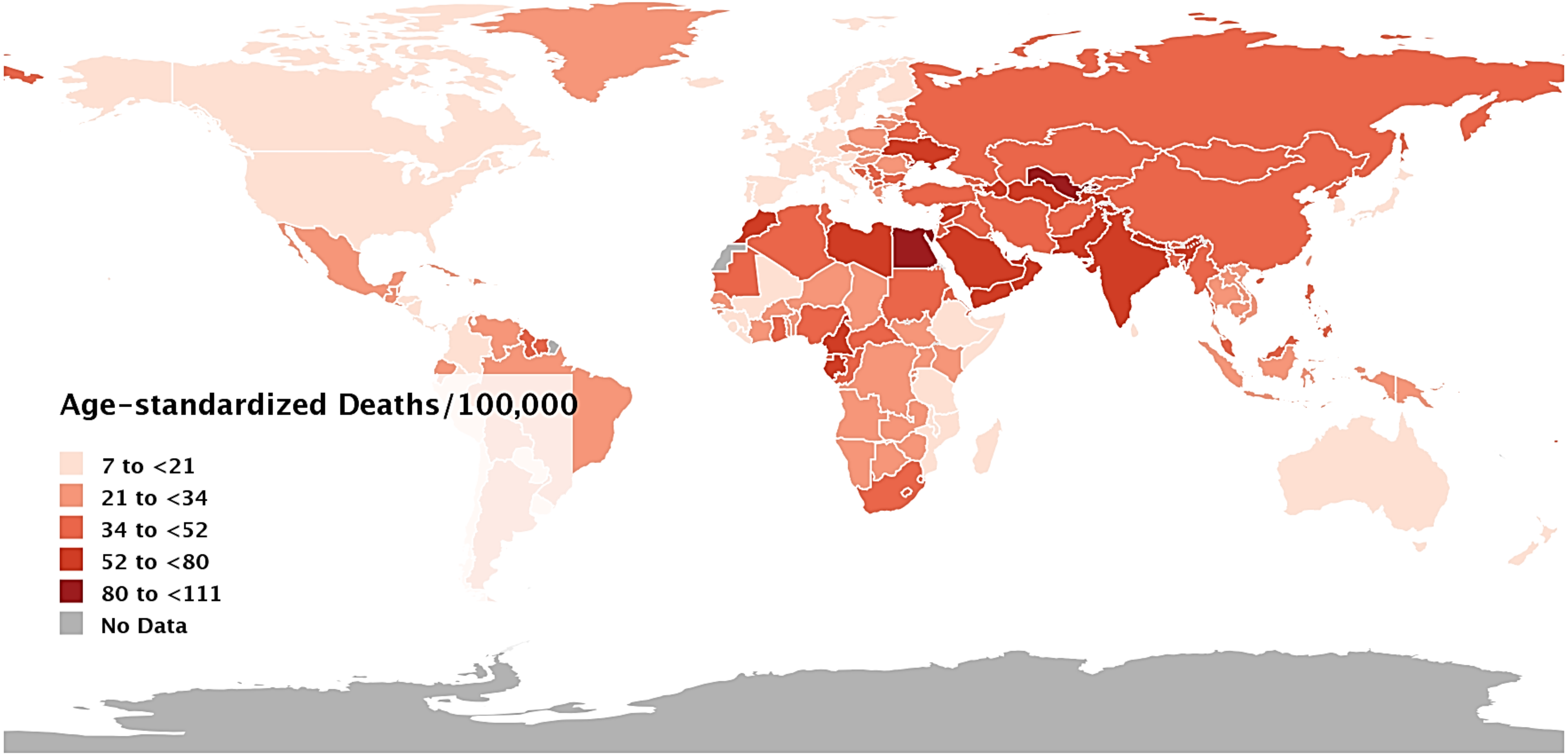
Location of monitoring stations and $PM_{2.5}$ concentration in nearly 3000 human settlements, 2008-2015, Source: World Health Organization, 2016



Global map of modelled annual median concentration of $PM_{2.5}$, in µg/m^3, Source: World Health Organization, 2016

Global Trends in Air Quality

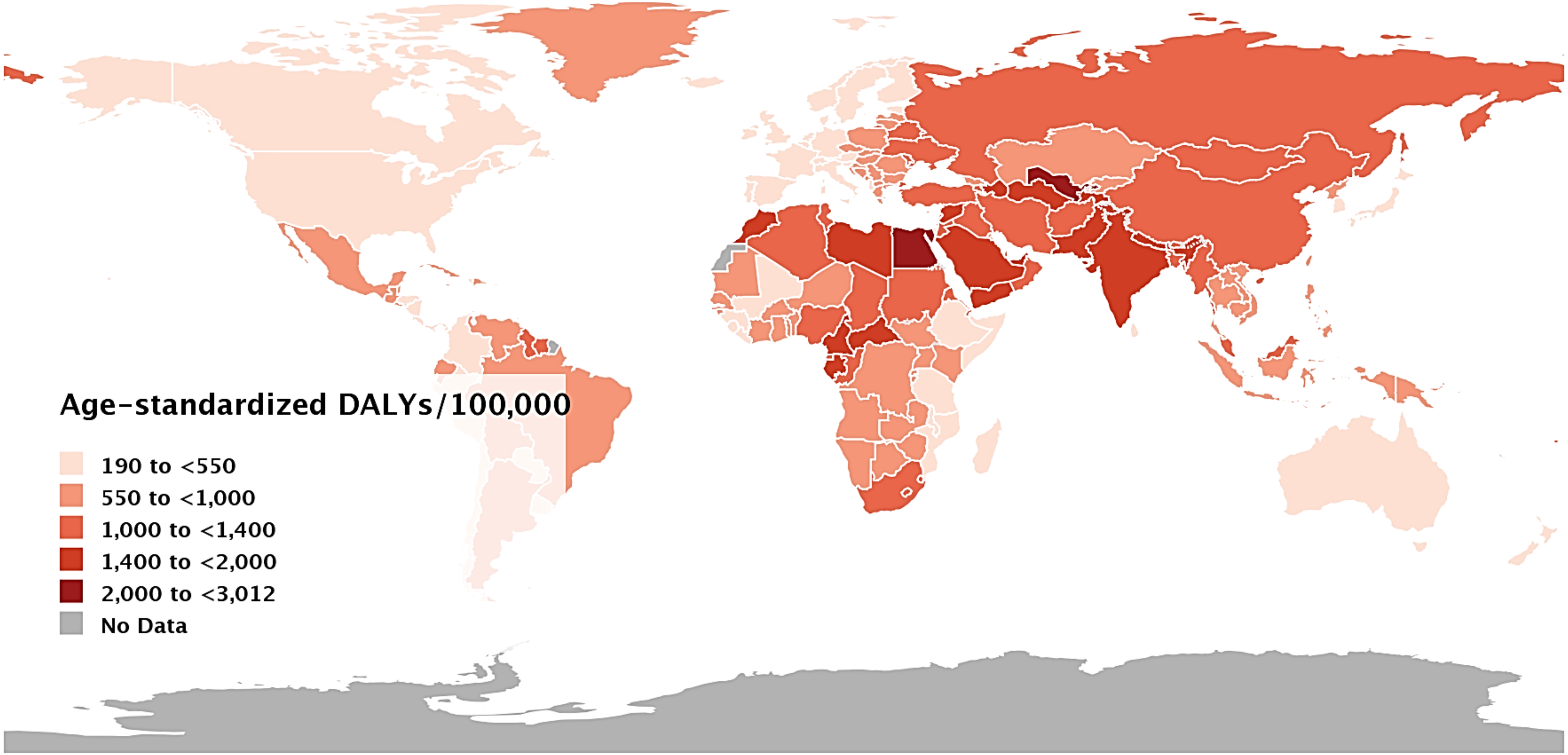
Age-standardized Deaths/100,000 Attributable to PM2.5 in 2017



Global age-standardized death rates attributable to $PM_{2.5}$, Source: Health Effects Institute, 2019

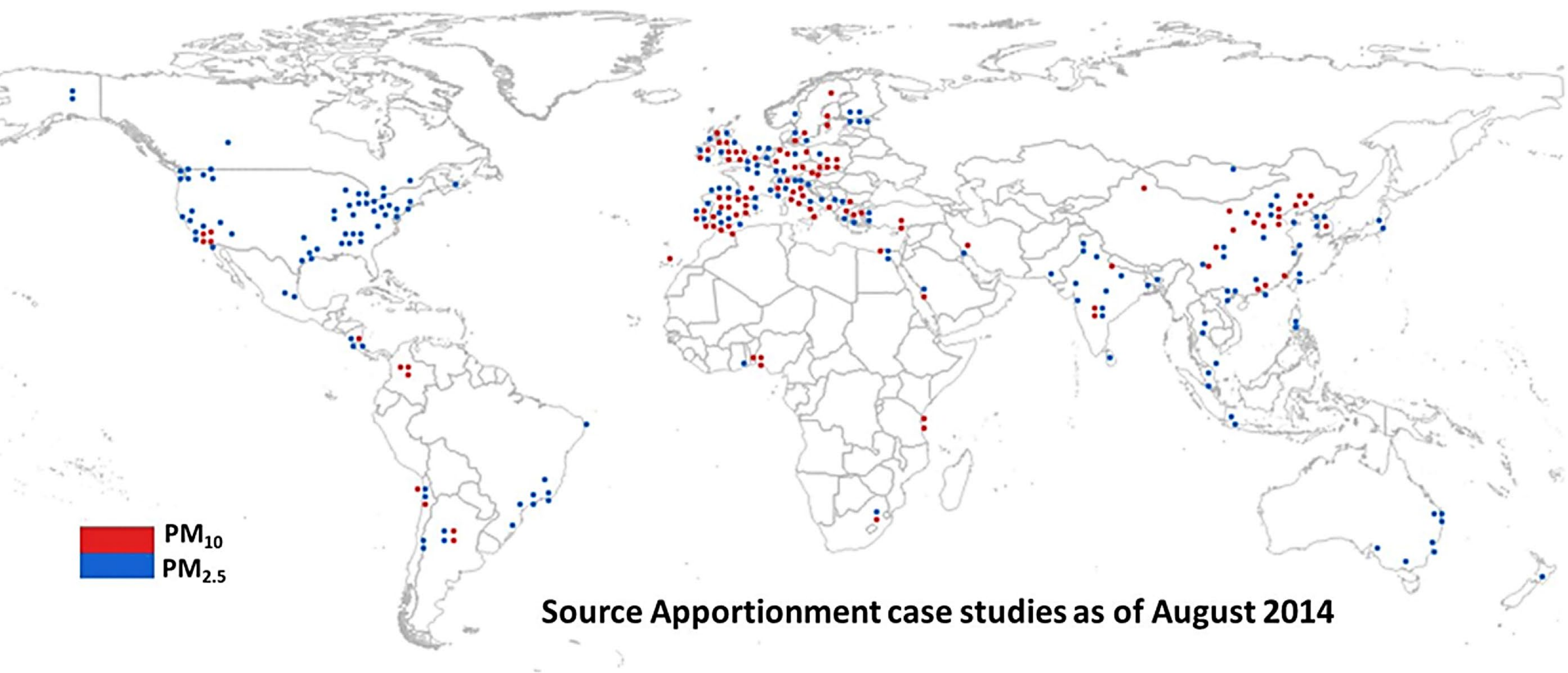
State of Global Air

Age-standardized DALYs/100,000 Attributable to PM2.5 in 2017



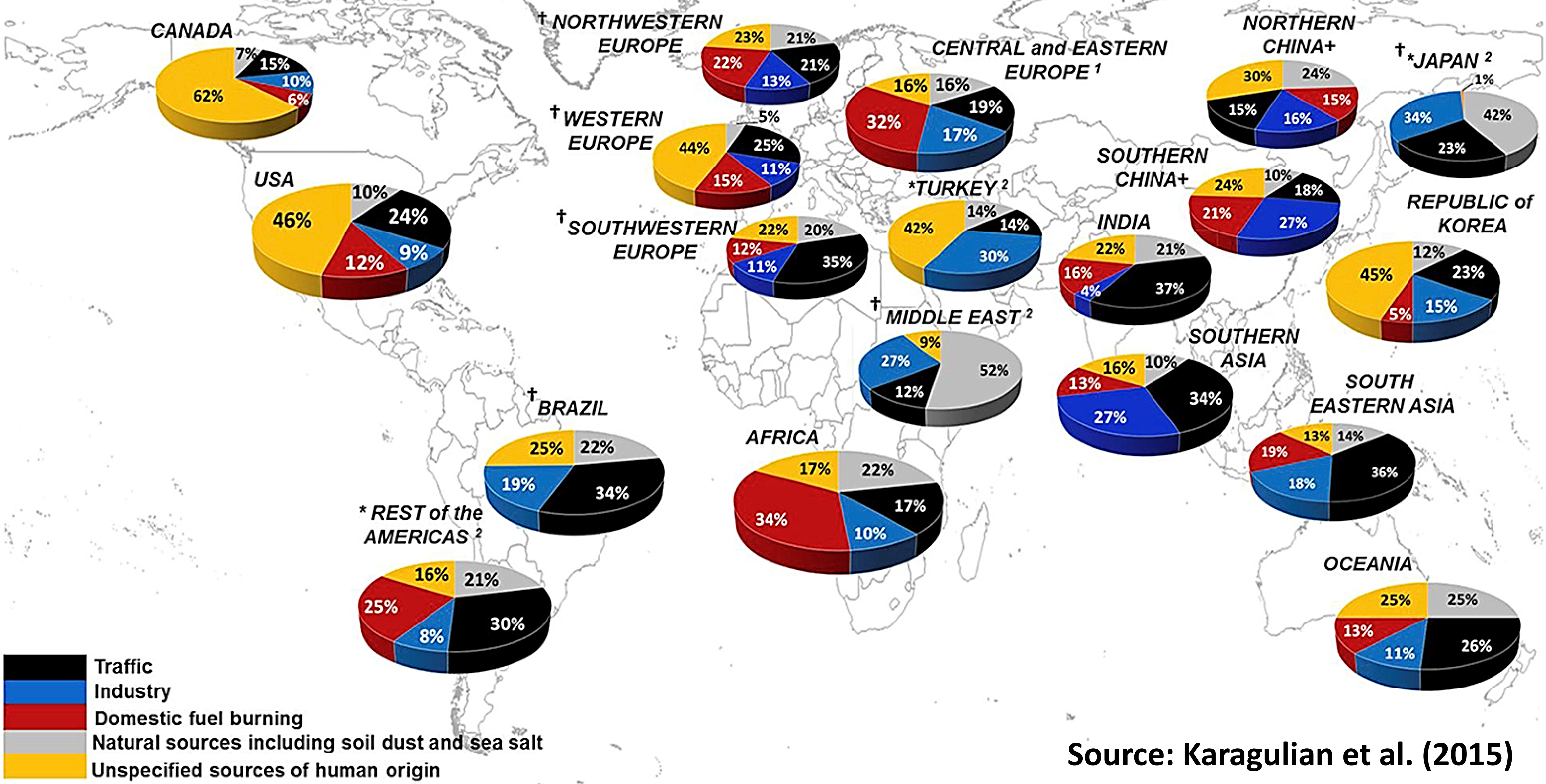
Global age-standardized DALY rates attributable to $PM_{2.5}$, Source: Health Effects Institute, 2019

State of Global Air

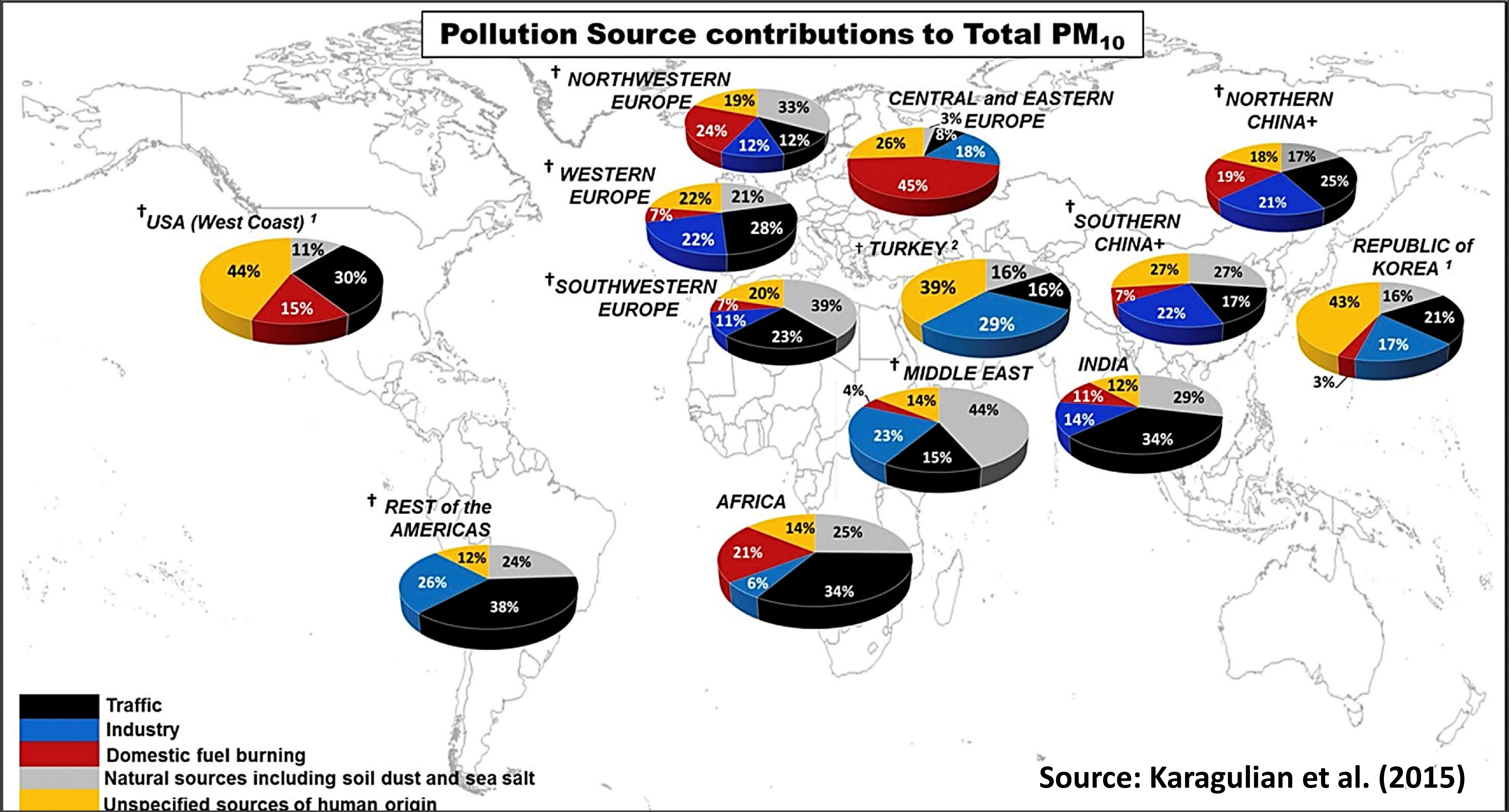


Geo-location of Source Apportionment studies for $PM_{2.5}$ and PM_{10} considered for the regional averages of source contributions performed in a recent systematic review, Source: Karagulian et al. (2015)

Pollution Source contributions to Total $PM_{2.5}$



Source: Karagulian et al. (2015)

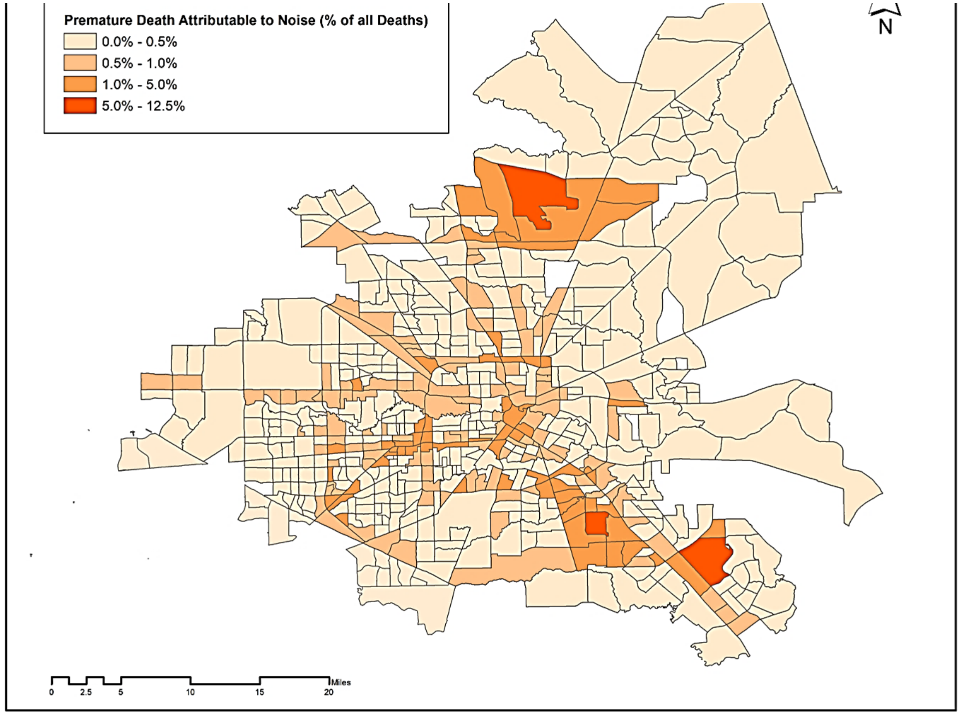


Pollution Source contributions to Total PM_{10}
† NORTHWESTERN EUROPE
19% 33% 24% 12% 12%
CENTRAL and EASTERN EUROPE
3% 8% 26% 18% 45%
† NORTHERN CHINA+
18% 17% 19% 25% 21%
† WESTERN EUROPE
22% 21% 7% 22% 28%
† USA (West Coast) 1
44% 11% 30% 15%
† SOUTHERN CHINA+
27% 27% 7% 17% 22%
† TURKEY 2
39% 16% 16% 29%
REPUBLIC of KOREA 1
43% 16% 21% 17% 3%
† SOUTHWESTERN EUROPE
20% 7% 39% 11% 23%
† MIDDLE EAST
4% 14% 44% 23% 15%
INDIA
12% 11% 29% 14% 34%
† REST of the AMERICAS
12% 24% 26% 38%
AFRICA
14% 25% 21% 6% 34%
Traffic
Industry
Domestic fuel burning
Natural sources including soil dust and sea salt
Unspecified sources of human origin
Source: Karagulian et al. (2015)

Where Do We Want to Go?

Estimate sub-population exposure-response functions by sex, ethnicity, socio-economic status

Develop integrated BoD/HIA models for mortality/morbidity for urban and transport policies and parameterize with local data and ERF



Where Do We Want to Go?

Measure impacts of policies/interventions

Investigate impacts of, and leverage, new technologies and innovations

Engage stakeholders and communicate the evidence