Traffic-Related Air Pollution: A Moving Target

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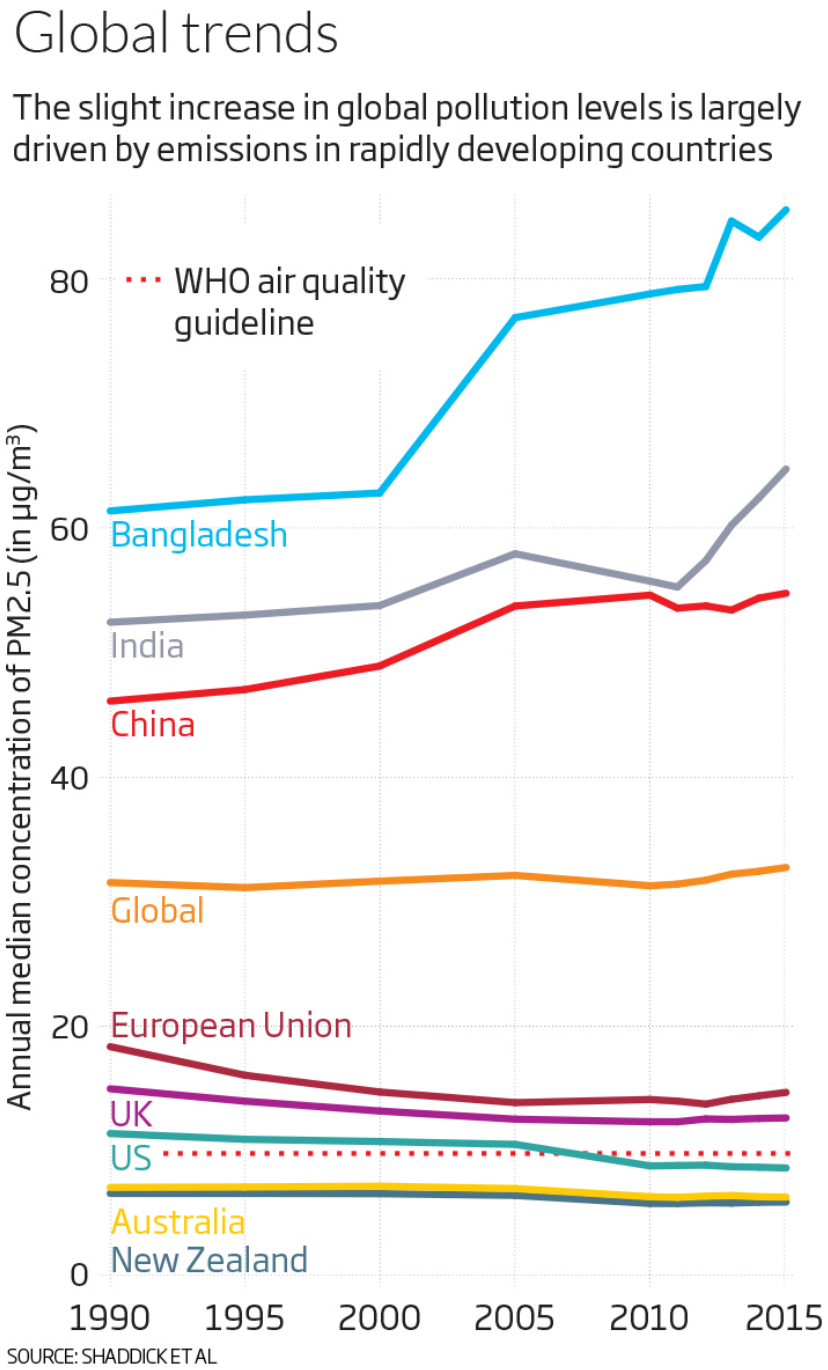
Outline

- Air Quality and Emissions Trends
- Real world complexity of exposure to traffic-related air pollution (TRAP)
- Conceptual model of TRAP
- Exposure framework to identify studies suitable for the systematic review
- Traffic Specificity Rankings



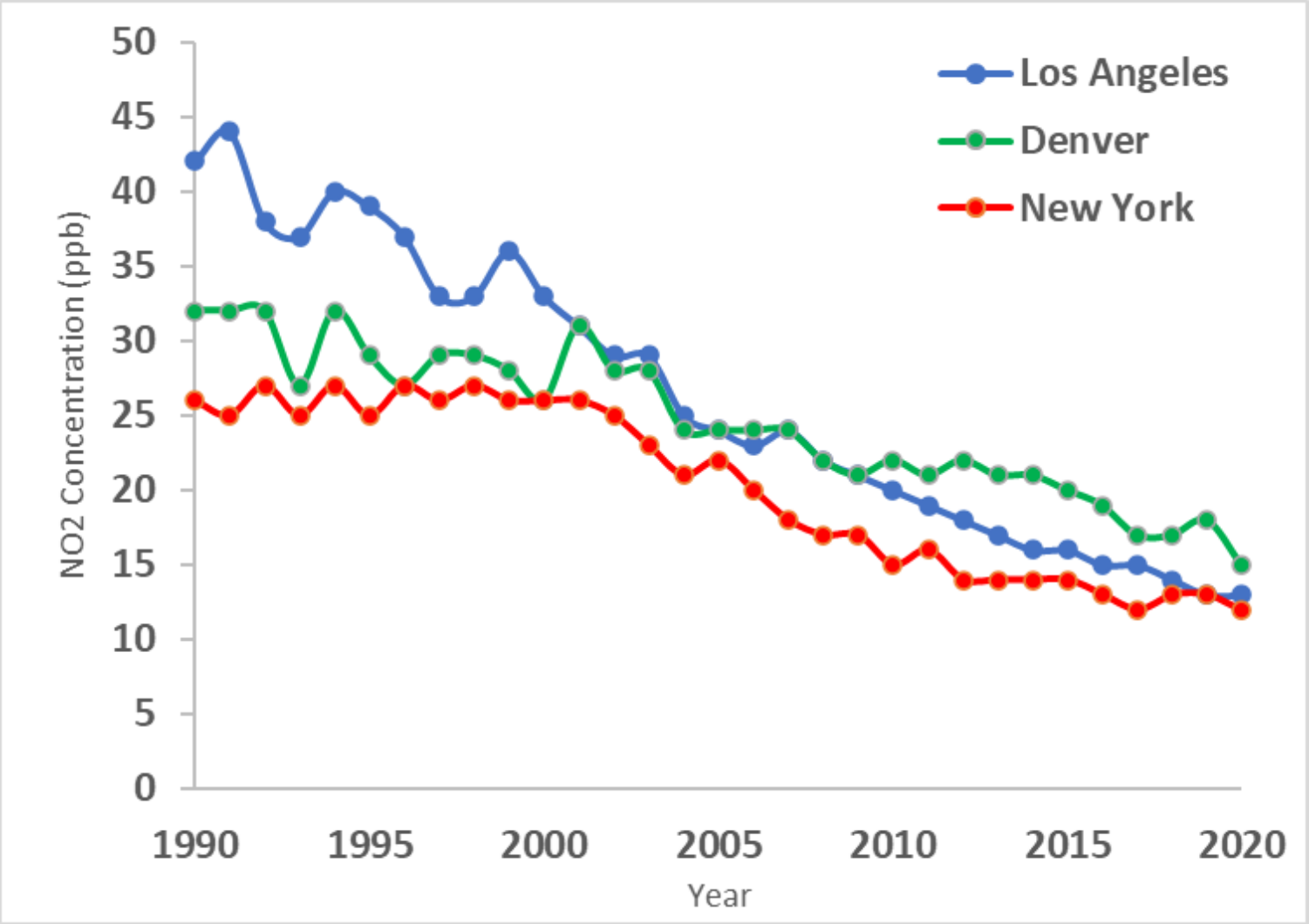
Air Quality Trends

The systematic review relies on studies of exposures during a period (1985-2015) with diverse temporal trends in air pollution

The trends vary by pollutant and a country's development status

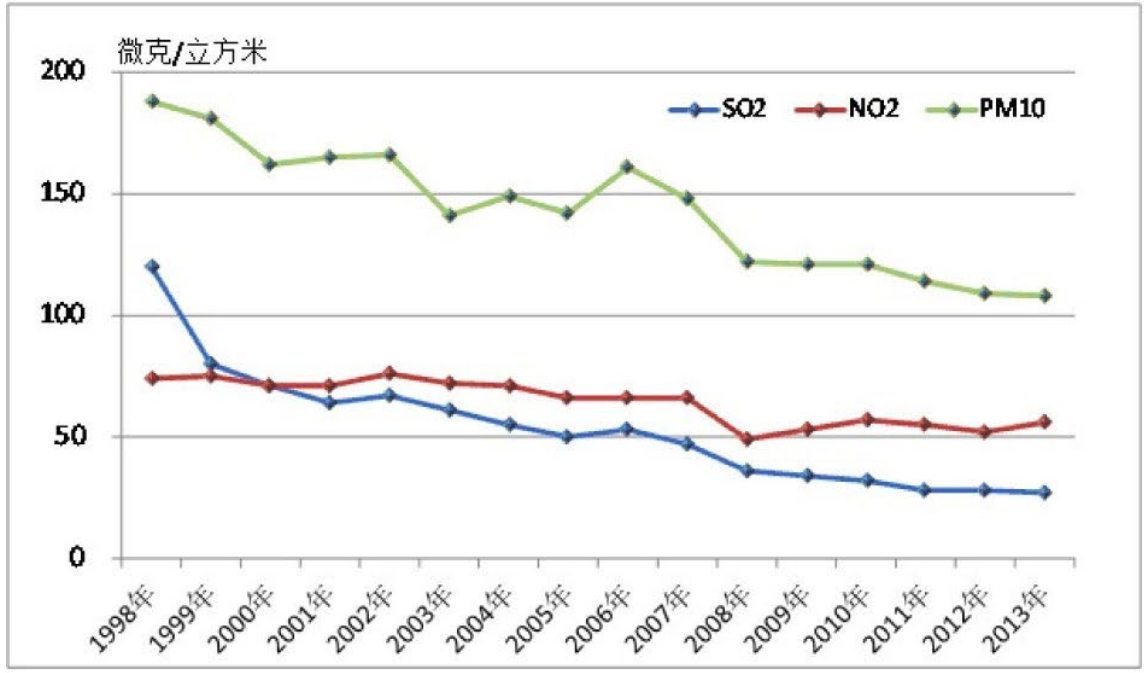
Most studies available for the Systematic Review were from Europe, U.K., North America, China, and Australia

1990-2020 Ambient NO_2 Trends in United States



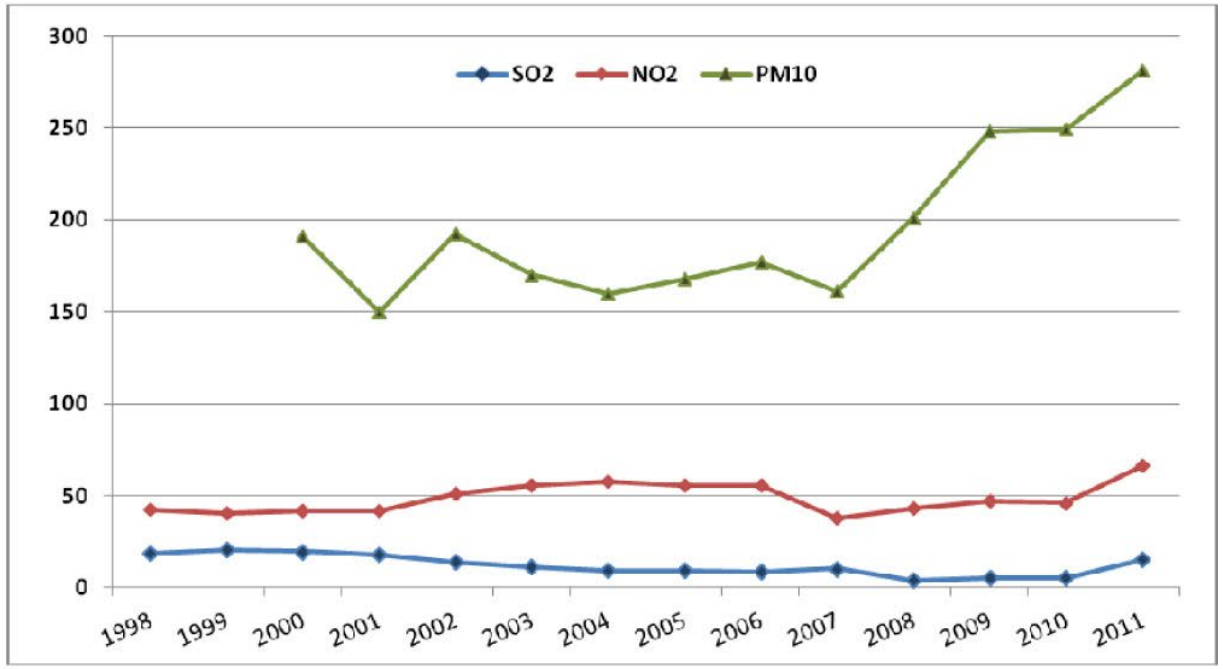
1998-2013 Ambient NO_2 Trends Beijing and Delhi

Beijing



Source: Beijing Environmental Protection Bureau

Delhi



Source: Dept of Environment, Govt. of NCT Delhi

TRAP Emissions Trends

- TRAP emissions have declined very substantially during the past several decades in most high-income countries (due to new technology, fuels, and aggressive regulatory actions).
- In most middle- and low-income countries TRAP emissions trends have shown modest decreases or increases during the past decades and deserves more attention.
- Many vehicle emissions challenges remain:
  - Technological issues (e.g., cold starts, older and high- emitting vehicles, ultrafine particles),
  - Poor compliance (e.g., tampering) and emissions cheating
  - Non-tailpipe emissions
  - Traffic noise
- Concerns for exposure to TRAP emissions will persist for decades due to the slow rates of fleet turnover to cleaner technologies, including electrification.

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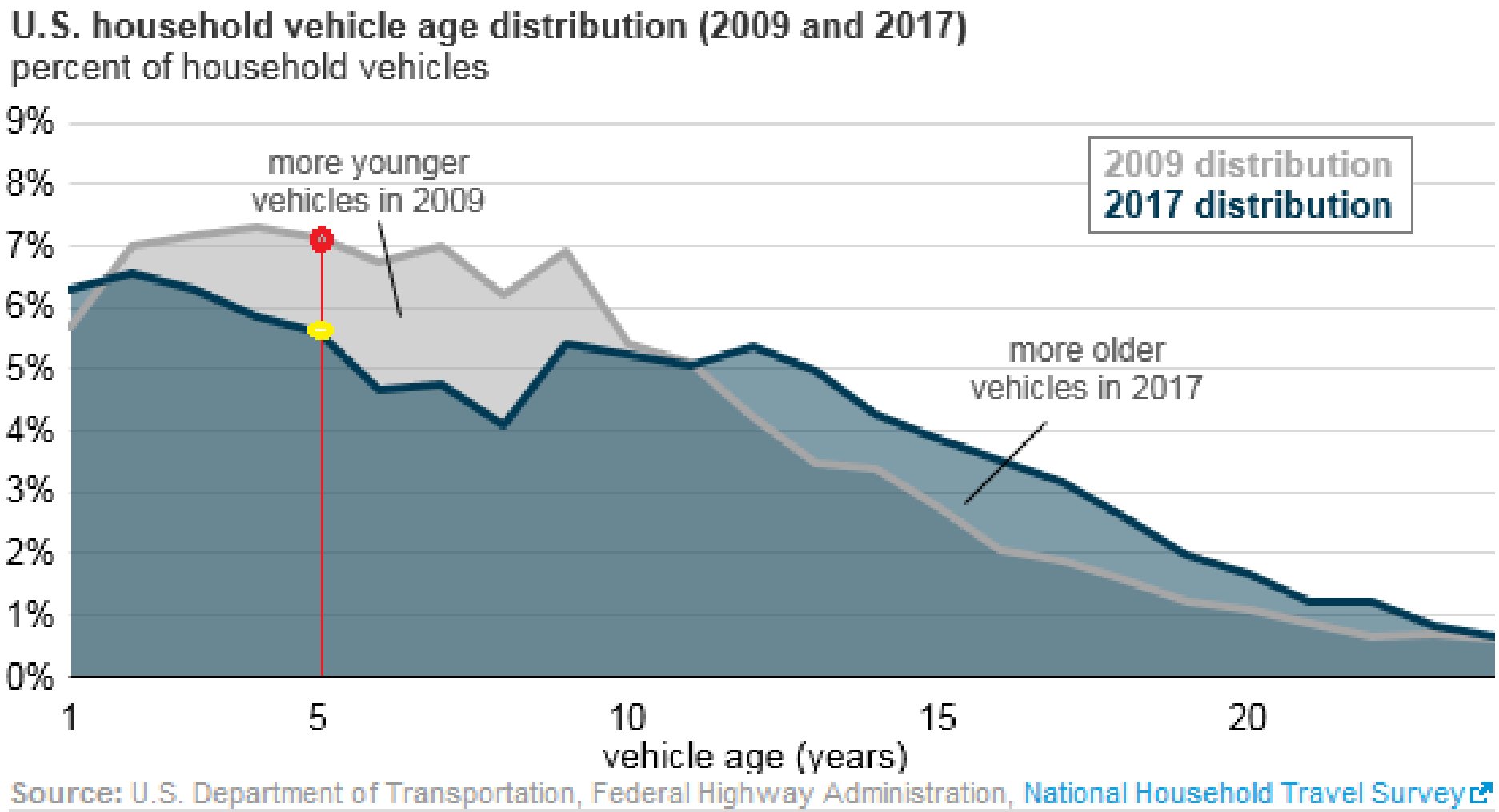
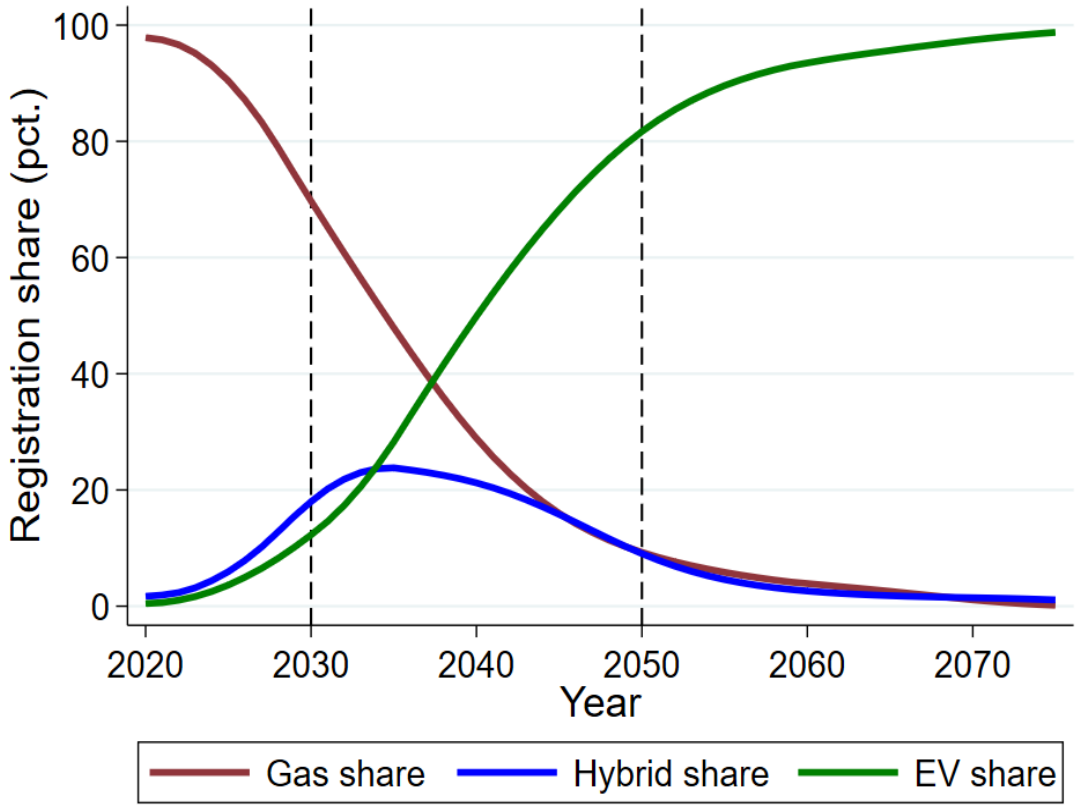
Vehicles are Lasting Longer



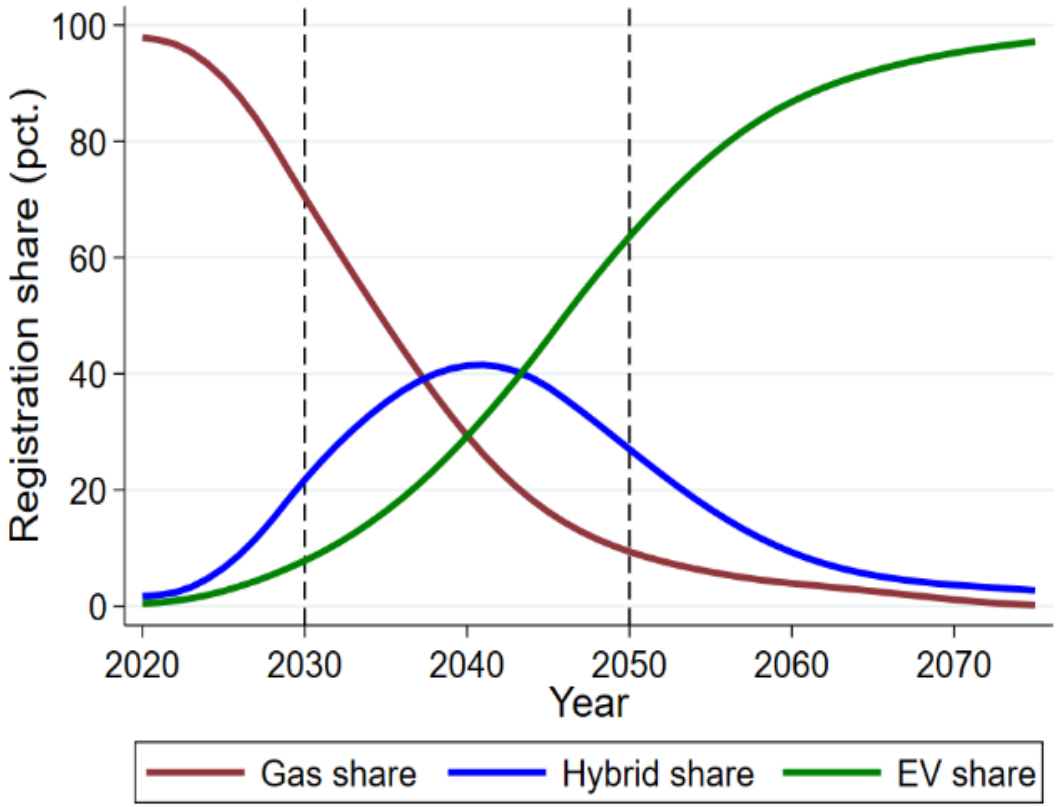
(from Leard and Greene, HEI AC 2022)

On-road Vehicle Projections for U.S. Fleet Turnover and Electric Vehicle Penetration

100% new EV market share by 2035

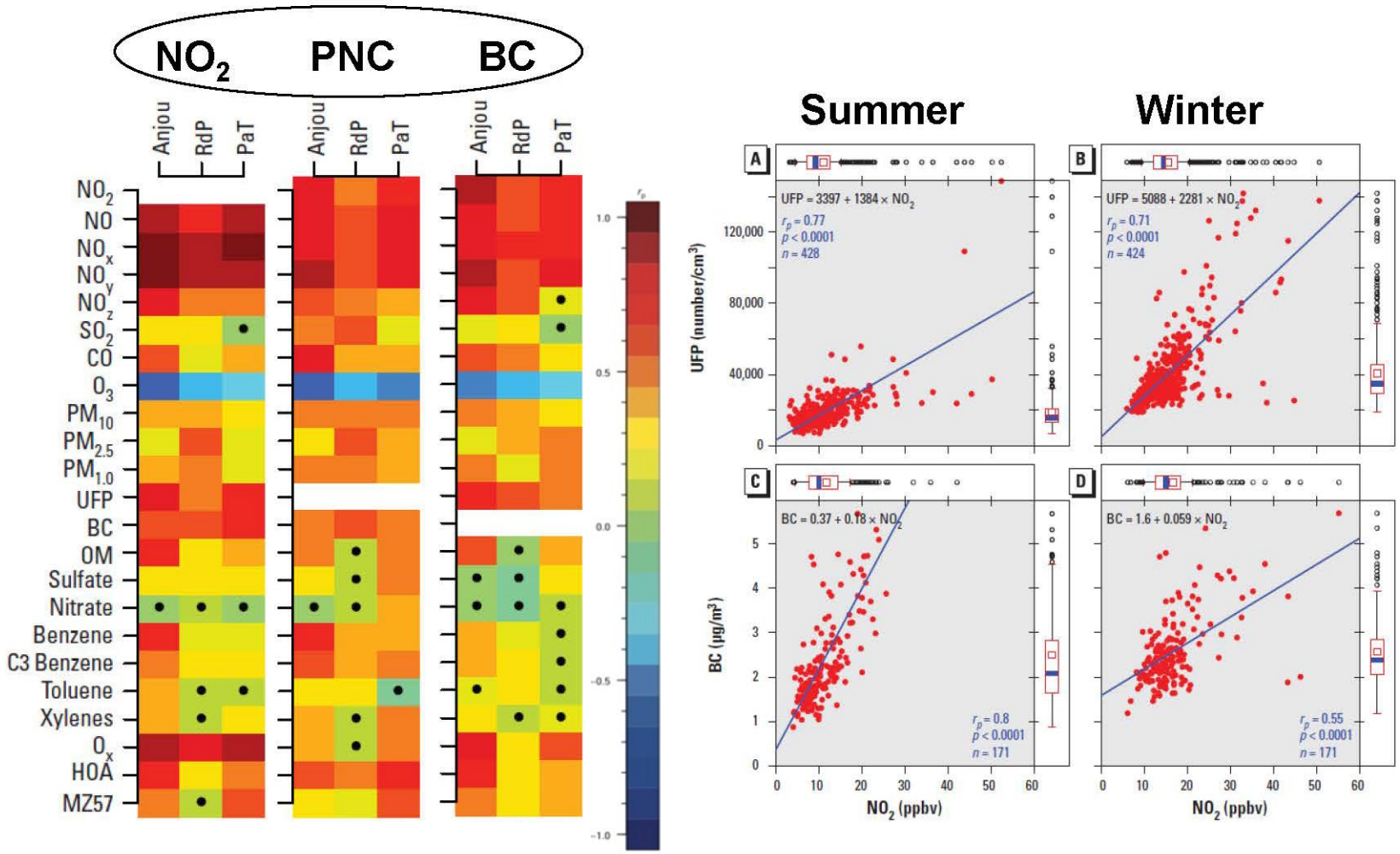


100% new EV market share by 2045



(from Leard and Greene, HEI AC 2022)

Numerous Chemical Components of Traffic Mixture are Highly Correlated

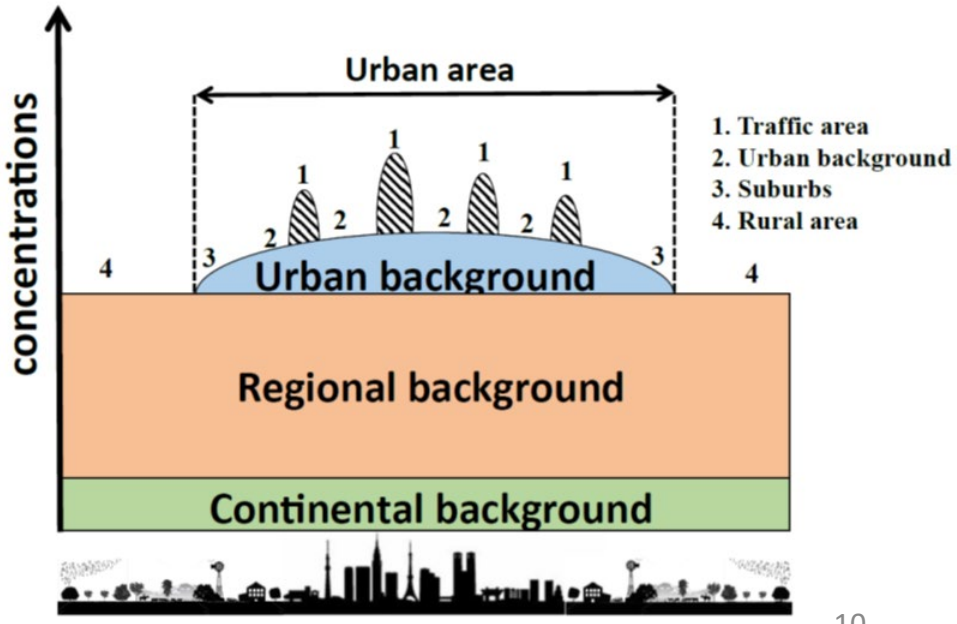


Correlation of species with NO_2, Particle number concentration (PNC), and Black Carbon (BC) in Montreal neighborhoods (from Levy et al. 2014)

Conceptual Model of Traffic Exposures

- Motor vehicle emissions are the dominant air pollution source in many cities.
- Motor vehicles emit a complex mixture of particles and gases, many of which are also emitted by other sources. There is no unique tracer for TRAP but there are numerous indicator species for tailpipe and non-tailpipe emissions.
- TRAP is characterized by high spatial and temporal variability

- TRAP contributes to exposure on multiple spatial scales, including near-road, neighborhood, urban, regional, and global scales.
- TRAP is distinguishable from the background within cities; mixing and reacting with contributions from other sources obscures contributions downwind of cities.



Exposure Framework for Long-term Exposure to TRAP

- The goal of the exposure framework is to identify epidemiologic studies where the exposure contrast is primarily from differences in TRAP exposures
- Three characteristics are used to select 'traffic-related' studies
  1) Selection of traffic-related pollutant(s)
  2) Exposure assessment method
  3) Spatial resolution of indicator pollutant and subject's locations
- Qualifying studies need to meet acceptance criteria all 3 areas
- The framework is designed to be inclusive of many different types of studies

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Definition of traffic-related pollutants

- Indicator pollutants include selected gases, PM mass from certain types of models, and PM chemical components
- Indirect measures of traffic are allowed
- No self-reported exposures

Pollutant
NO_2, NO_x, NO
CO
$PM_{2.5}$, PM_{10}, and PM_{coarse} mass if exposure assessment is linked to traffic, for example by CTM, source apportionment, or LUR
Non-tailpipe PM trace metals
UFP, PNC, quasi-ultrafine, different particle modes, particle size distribution
EC, BC, BS, PM absorption ('soot')
PAH
Benzene
Measures based upon distance / length of roads / traffic density

Protocol Table 4
https://www.healtheffects.org/system/files/TrafficReviewProtocol.pdf

Definition of specific exposure assessment methods

Exposure metric	Spatial scale "pollution surface"	Spatial scale "address" data
Measures based on distance	<1000 m away from a highway or a major road	<100 m
Measures of traffic density or length of roads	Buffers with radius of <1000 m around address	<100 m
Dispersion / CTM models of traffic	<5 km	<5 km
Traffic-specific source apportionment	< 5 km	<5 km
LUR of traffic, including hybrid and other statistical models	<5 km	<5 km
Surface monitoring, including interpolations	< 5 km	<5 km
Satellite monitoring	< 5 km	< 5 km
Personal exposure	Not applicable	Not applicable

Occupational studies and ecological designs are not accepted - From Protocol Table 6
https://www.healtheffects.org/system/files/TrafficReviewProtocol.pdf

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Definition of indicative scale of exposure contrasts related to specific study design

Scale (area of impact)	Within scope of review
Increase in regional scale (>50 km) average background concentration	No, for secondary pollutants and for traffic pollutants when this is the only source of spatial contrast
Increase in neighborhood (1-5 km) and urban scale (5-50 km) average background concentration (including nationwide epidemiological studies)	Yes, if the study is within-city only, or within- and between-city, traffic is a documented important source, and an adjustment is made for city/area
Increase in local scale (<1 km) average concentration	Yes, if the contrast between study locations has an important traffic source contribution
Increase in commuting exposures	Yes, but likely few studies on long-term exposure
Increase in occupational exposure	No

From Protocol Table 5
https://www.healtheffects.org/system/files/TrafficReviewProtocol.pdf

Traffic Specificity: Criteria for High Ranking

1. Analyses that incorporate ≤ 1 km spatial resolution for exposure models and subject locations (this resolution captures traffic exposures on a local scale; maximizes contrast)
2. Dispersion model or CTM with emissions from traffic sources alone; traffic-specific source apportionment models
3. Dispersion model or CTM with emissions from all sources; LUR model; hybrid model; and traffic-specific source apportionment models if the pollutant was very closely related to traffic (e.g., NO_2 was acceptable, but PAH, benzene, or PM mass was not)
4. High accuracy traffic density or distance to road GIS models with exact subject address geocoding and accurate roadway data

79% of the studies ranked high for one or more pollutant

Concluding Remarks

- TRAP emissions and exposures are complex and represented simplistically in models
- A new exposure framework, based on our conceptual model of TRAP, was developed and applied to select epidemiological studies
- The framework allowed for inclusion of a wide variety of studies
- A majority of studies had one or more pollutants that met the stricter criteria for high traffic specificity
- TRAP emissions are declining in most high-income countries
- Concerns for exposure to TRAP emissions will persist for decades due to the slow rates of fleet turnover to cleaner technologies, including electrification