A global snapshot of the air pollution-related health impacts of transportation sector emissions in 2010 and 2015

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www.theicct.org/publications/health-impacts-transport-emissions-2010-2015

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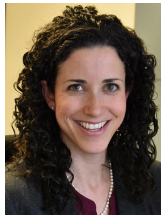

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Methods overview

All emissions by source category → **Ambient $PM_{2.5}$ and ozone concentrations** → **Ambient $PM_{2.5}$ and ozone related deaths** → **Valuation of $PM_{2.5}$ and ozone damages**

Emissions from four transportation subsectors (on-road diesel vehicles, on-road non-diesel vehicles, international shipping, non-road mobile sources) and non-transportation sources

State-of-the-science global atmospheric model accounting for meteorology and chemistry, combined with satellite observations (GEOS-Chem)

Established health impact assessment methods consistent with Global Burden of Disease 2017 Study

Welfare loss associated with premature deaths using Value of a Statistical Life (VSL) and benefit-transfer approach

The study evaluated only the impacts of tailpipe emissions and excluded other transportation health impacts. Applying GBD 2017 methods, it considered health impacts from direct exposure to $PM_{2.5}$ and ozone, not NO_2, which is associated with asthma incidence among children and asthma emergency department visits. Estimated $PM_{2.5}$ and ozone health impacts are likely undercounted for several reasons; see the paper for discussion.

The study evaluated the health burden attributable to tailpipe emissions of four transportation subsectors.

- **On-road diesel vehicles** include passenger cars, light commercial vehicles, trucks, and buses with diesel engines. In China and India, this category includes three-wheeled freight vehicles used for on-road applications. Diesel is the principal fuel; these activities also include a small share of biodiesel typically blended into diesel fuels.
- **On-road non-diesel vehicles** include passenger cars, light commercial vehicles, two-wheeled vehicles, and three-wheeled vehicles, as well as trucks and buses fueled by gasoline, LPG, CNG, electricity, or other non-diesel fuels.
- **Non-road mobile sources** include rail, agricultural equipment, construction machinery, inland shipping, and other non-road mobile machinery. Most of these activities are fueled by diesel; some are fueled by gasoline, LPG, electricity, or other fuels. Rail is the principal source of electricity consumption.
- **International shipping** includes container ships, bulk carriers, cargo ships, tankers, cruise ships, fishing vessels, ferries, and other service vessels. The main fuels for these activities are residual fuels, which include heavy fuel oil; diesel, also referred to as distillates; and a smaller amount of LNG.

Table 1. Definition of transportation subsectors evaluated in this study.

Transportation Subsector	Main Fuel Types	Data Source
On-road diesel vehicles	Diesel	ICCT (Miller & Jin, 2018)
On-road non-diesel vehicles	Gasoline, LPG, CNG	IIASA (ECLIPSE v5a)
Non-road mobile sources	Diesel, gasoline, LPG, electricity	IIASA (ECLIPSE v5a)
International shipping	Residual fuels, diesel, LNG	ICCT (Comer et al, 2017)

Six air quality simulations estimate concentrations (1) with all emissions and (2-5) zeroing out each subsector and (6) all transportation emissions.

These simulations allowed the calculation of, for each pollutant ($PM_{2.5}$ and ozone), country, source category, and year:

- **Transportation Attributable Concentration (TAC).** The difference in concentrations from zeroing out a given source category compared with the base case (i.e. the absolute contribution of that source category to ambient air pollution, in units of concentration).

- **Transportation Attributable Fraction (TAF).** The fractional difference in total mortality from the zero-out scenario compared to the baseline (i.e. the percent of total air pollution mortality attributable to transportation tailpipe emissions and each subsector).

Unlike TAC, TAF is influenced by non-transportation emission sources, since the denominator is total $PM_{2.5}$ and ozone mortality, which are affected by many different emission sources.

Gridded transportation health impacts were calculated using gridded total ambient $PM_{2.5}$ and ozone burdens and TAF.

1. Gridded burden of disease from total ambient $PM_{2.5}$ and ozone
   - Mortality, disability adjusted life years (DALYs), years of life lost (YLL)
   - $PM_{2.5}$ health impacts: ischemic heart disease, stroke, chronic obstructive pulmonary disease, lung cancer, lower respiratory infection
   - Ozone health impacts: chronic respiratory disease
   - Baseline disease rates from IHME for 2010 and 2015
   - Gridded impacts (0.1 x 0.1 degree) summed to national and urban boundaries
2. Health impacts from transportation tailpipe emissions
   - Multiply gridded $PM_{2.5}$ and ozone health impacts by TAF for each subsector
   - Avoids dependency of results on order in which emissions were zeroed out
   - Avoids potential biases in air quality modeling, which largely cancel out in TAF
   - TAF could be applied to future estimates as health impact methods advance

Figure 3. National population-weighted transportation-attributable fraction (TAF) for $PM_{2.5}$ and ozone in 2010 and 2015.

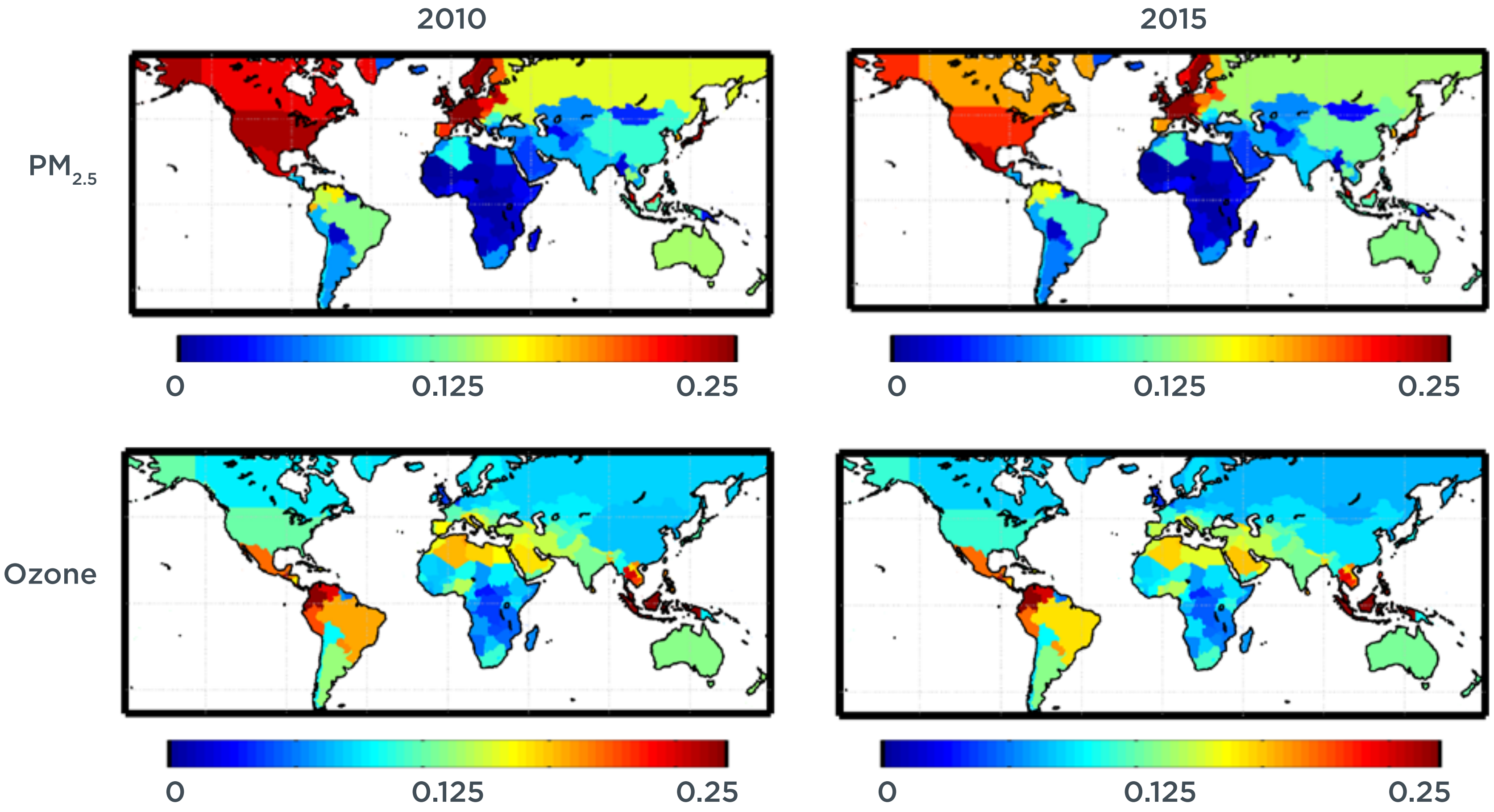

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Figure 4. Maps showing the change in national population-weighted average transportation-attributable concentrations from 2010 to 2015 (annual average for $PM_{2.5}$, 6-month average of the 8-hour daily maximum for ozone).

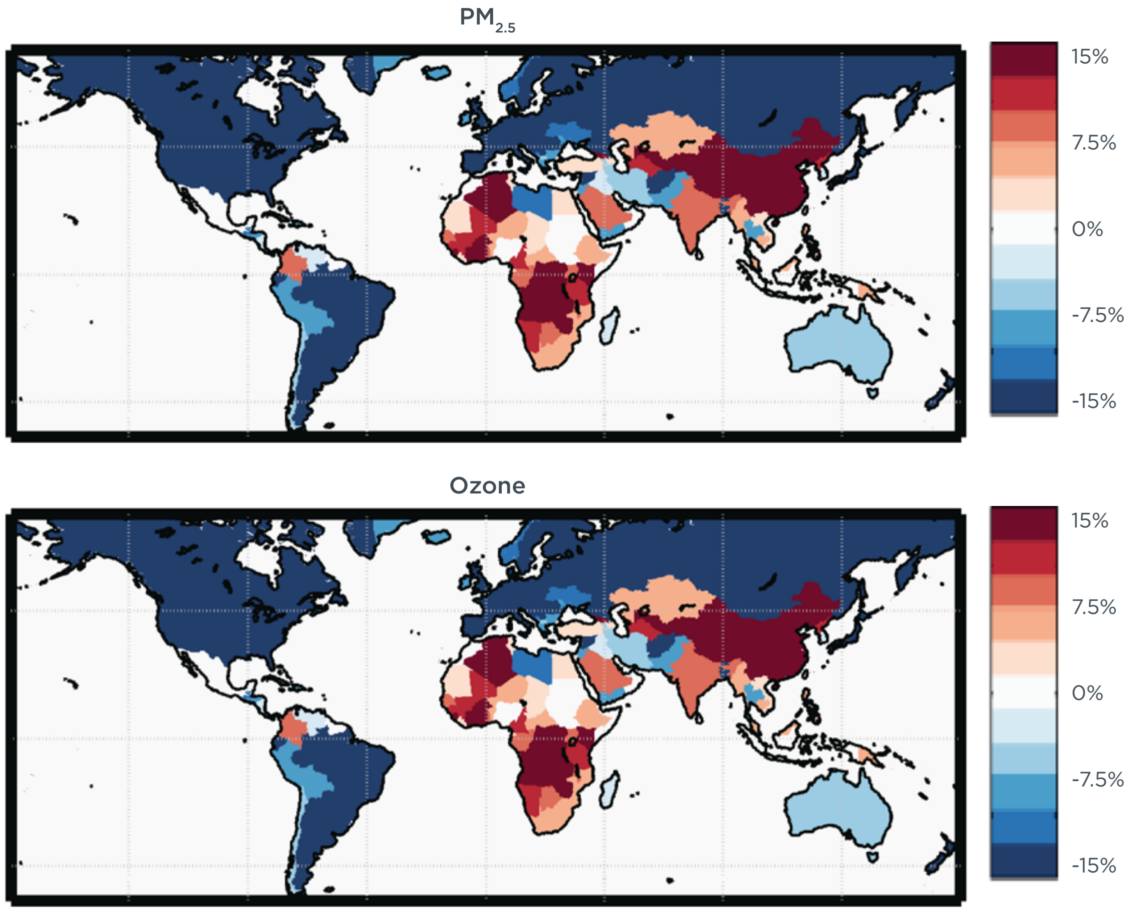

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Table 3. Global air quality and health impacts of transportation tailpipe emissions in 2010 and 2015. For premature deaths, 95% confidence intervals reflect uncertainty in the relative risk estimate only.

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Measure	Description	Metric	2010	2015
Transportation-attributable concentration (TAC)	How much do tailpipe emissions from transportation sources contribute to global population-weighted air pollutant concentrations? Units: depends on pollutant	annual average $PM_{2.5}$	2.9 µg/m³	3.0 µg/m³
		6-month average of the 8-hour daily maximum ozone	5.5 ppb	5.6 ppb
		annual average BC	0.2 µg/m³	0.2 µg/m³
Transportation-attributable deaths	How many premature deaths are associated with global transportation-attributable concentrations of $PM_{2.5}$ and ozone? Units: thousands (95% confidence interval)	ambient $PM_{2.5}$ deaths	312 (240–386)	330 (255–408)
		ambient ozone deaths	49 (18–76)	55 (20–85)
		total ambient $PM_{2.5}$ and ozone deaths	361 (258–462)	385 (274–493)
Transportation-attributable fraction (TAF)	What fraction of ambient air pollution deaths are attributable to tailpipe emissions from transportation sources? Units: percent	$PM_{2.5}$	11.9%	11.6%
		ozone	10.4%	10.7%
		total $PM_{2.5}$ and ozone	11.7%	11.4%
Transportation health damages	What is the welfare loss due to global transportation-attributable deaths? Units: 2015 US$	$PM_{2.5}$	$900 billion	$891 billion
		ozone	$70 billion	$85 billion
		total $PM_{2.5}$ and ozone	$970 billion	$976 billion

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Figure 8. Transportation-attributable $PM_{2.5}$ and ozone deaths, associated mortality rates, and population in G20 economies in 2015.

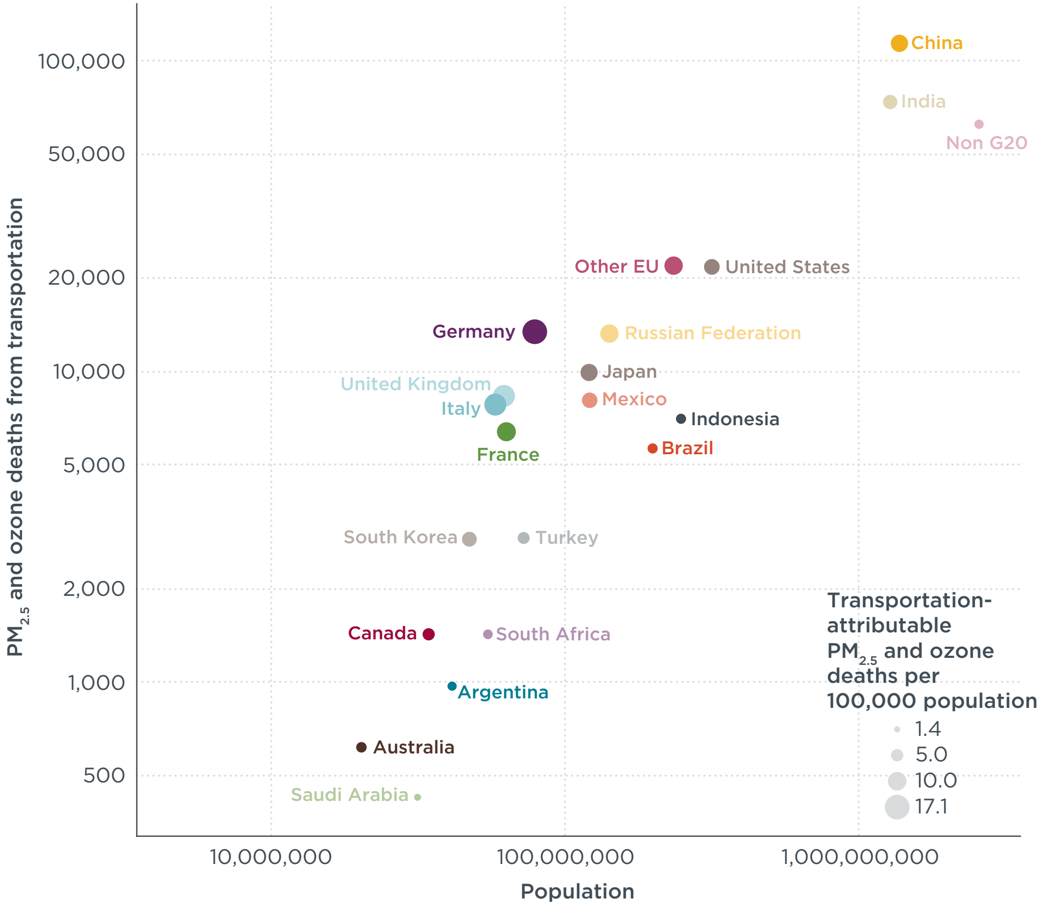

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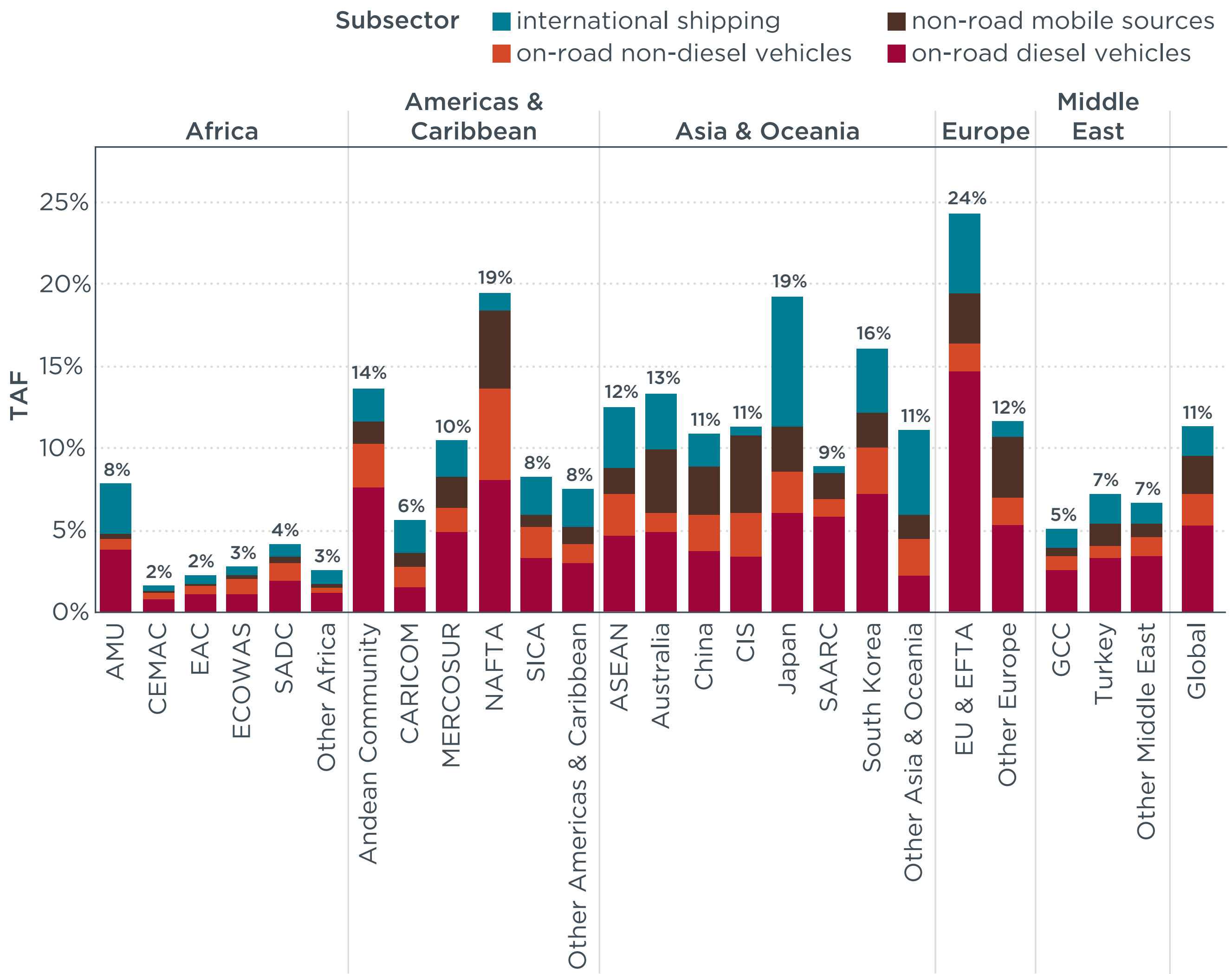
Figure 10. Globally and for each trade bloc, transportation-attributable fractions (TAF) of combined $PM_{2.5}$ and ozone deaths in 2015, broken out by subsector.



AMU = Arab Maghreb Union (North Africa); ASEAN = Association of Southeast Asian Nations; CARICOM = Caribbean Community; CEMAC = Central African Economic and Monetary Community; CIS = Commonwealth of Independent States; EAC = East African Community; ECOWAS = Economic Community of West African States; EU & EFTA = European Union and European Free Trade Association; GCC = Gulf Cooperation Council; MERCOSUR = Southern Common Market (South America); NAFTA = North American Free Trade Agreement; SAARC = South Asian Association for Regional Cooperation; SADC = Southern African Development Community; SICA = Central American Integration System.

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Figure 11. National total $PM_{2.5}$ and ozone mortality that is attributable to transportation emissions in 2015 in major trade blocs globally, using central relative risk estimates.

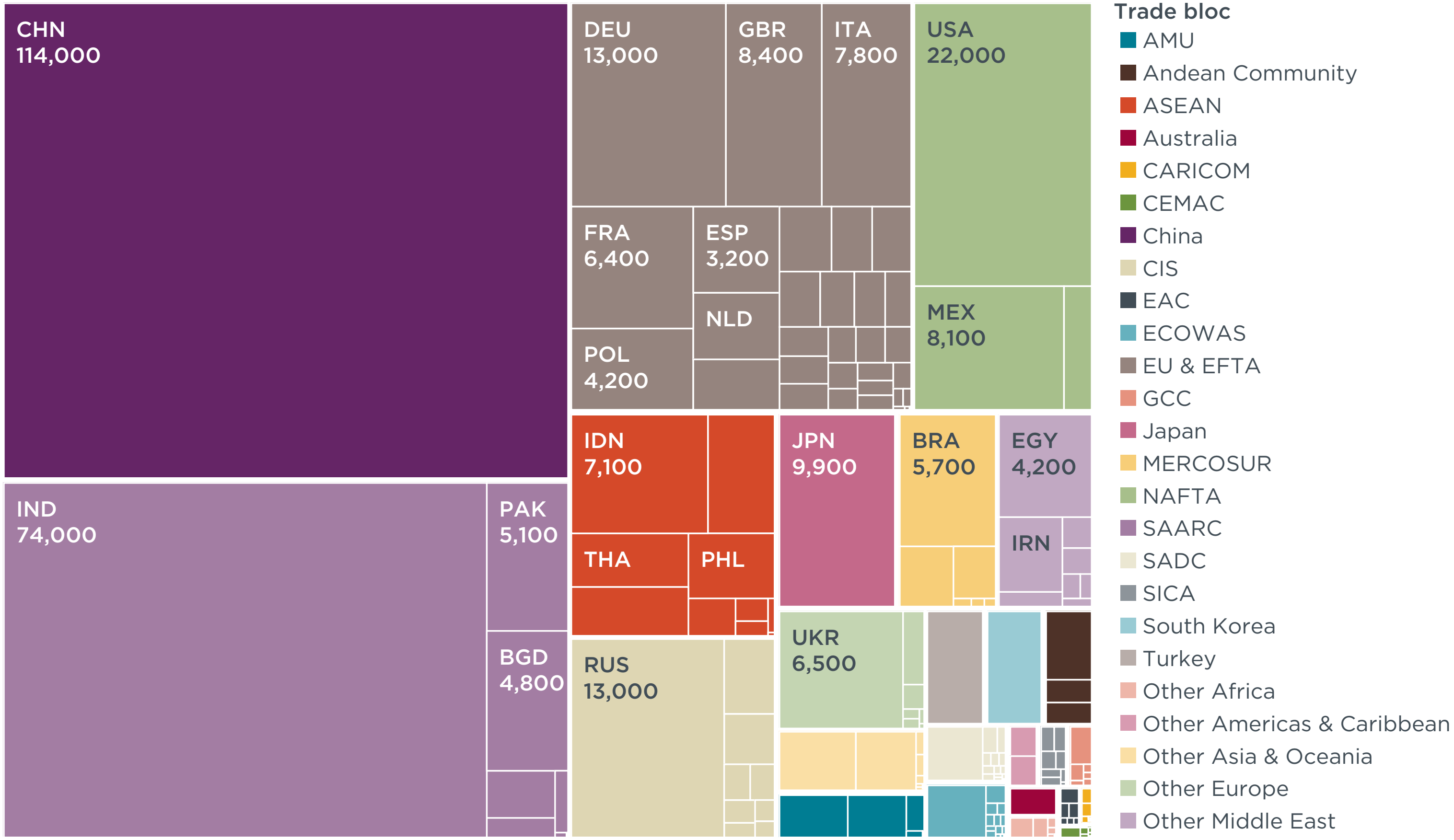

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Figure 13. Transportation-attributable $PM_{2.5}$ and ozone deaths, associated mortality rates, and population by trade bloc in 2015.

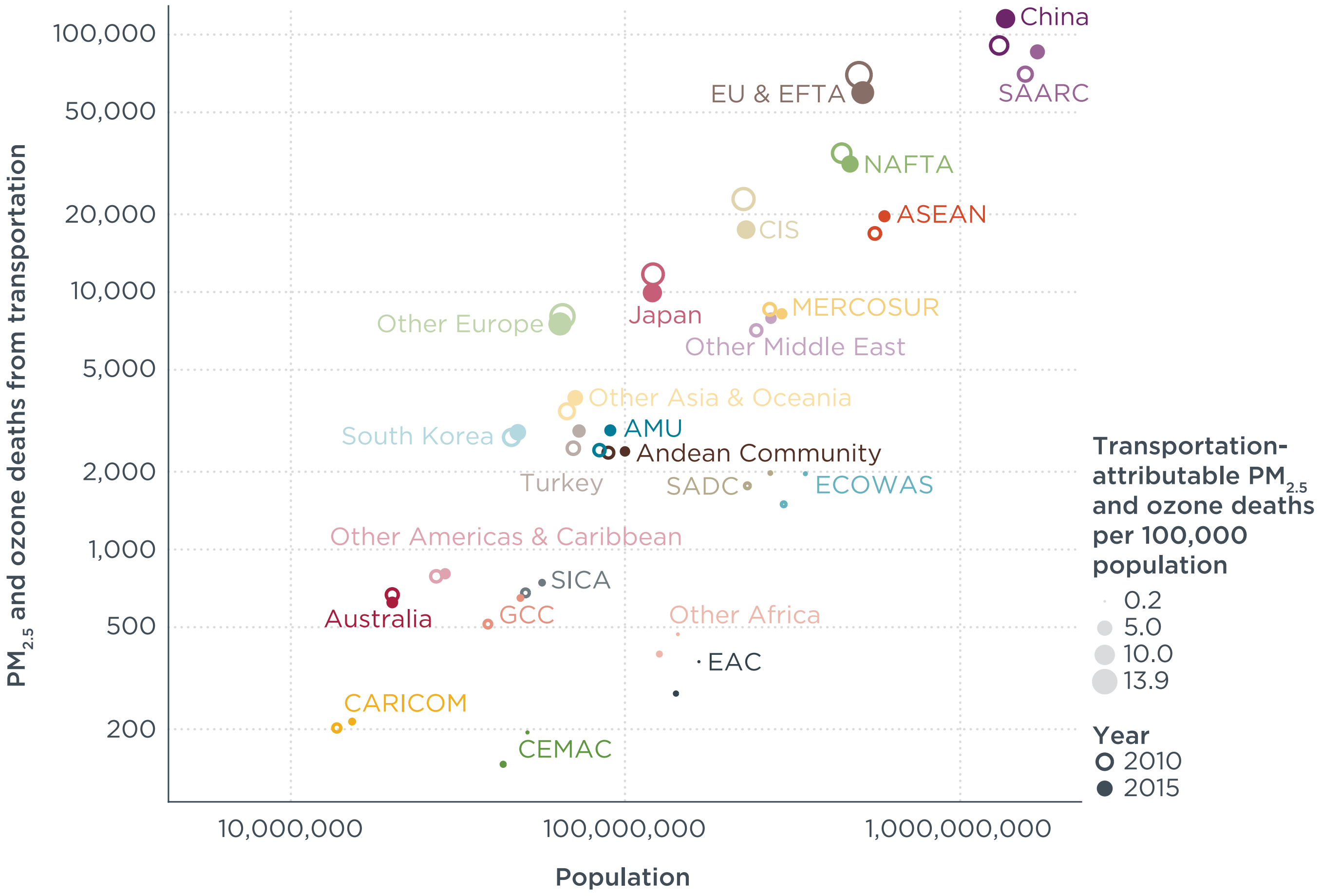

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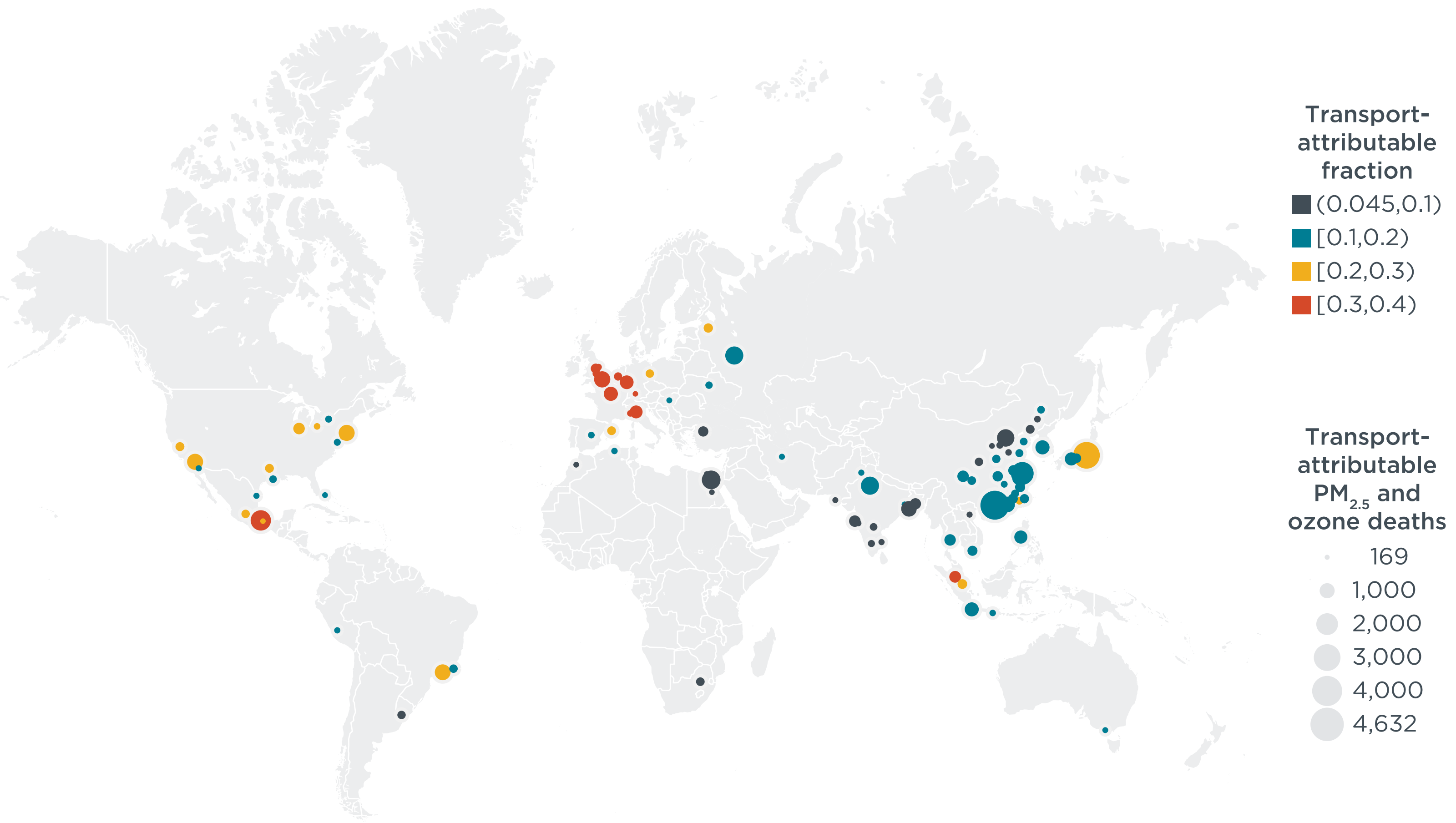
Figure 14. Total number of transportation-attributable $PM_{2.5}$ and ozone deaths in 2015 by urban area.



Bubble size indicates total number of transportation-attributable $PM_{2.5}$ and ozone deaths using central relative risk estimates. Bubble color indicates transportation-attributable fraction (TAF) of total $PM_{2.5}$ and ozone deaths.

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Table A3. Comparison of global results from this study with other estimates in the literature.

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Study	Analysis year	Sector description	Methods	Result
This study	2010	Tailpipe emissions from on-road diesel, other on-road, shipping, non-road mobile sources	$PM_{2.5}$ RR: GBD 2017 IER Ozone RR: GBD 2017 Resolution: 0.1°x0.1° Emissions: ICCT (Miller & Jin, 2018), ECLIPSE (Klimont et al., 2017; Stohl et al., 2015)	Deaths: 361,000 (258,000–462,000) TAF: 11.7%
This study	2015	Tailpipe emissions from on-road diesel, other on-road, shipping, non-road mobile sources	Same as row 1	Deaths: 385,000 (274,000–493,000) TAF: 11.4%
Chambliss et al. (2014)	2005	all mobile equipment powered by gasoline and diesel engines such as on-road passenger vehicles and commercial trucks, rail transportation, off-road agricultural and construction equipment	$PM_{2.5}$ only: GBD2010 IER Resolution: 0.5° x 0.67° Emissions: Representative Concentration Pathway 8.5 (van Vuuren et al., 2011)	Deaths: 242,000 TAF: 8.5%
Lelieveld et al. (2015)	2010	Road and non-road transport on land	$PM_{2.5}$ RR: GBD2010 IER Ozone RR: Ostro (2004) Resolution: 1.1° x 1.1° Emissions: Emissions Database for Global Atmospheric Research (EDGAR)	Deaths: 165,000 TAF: 5%
Silva et al. (2016)	2005	Land transportation, shipping, and aviation	$PM_{2.5}$ RR: GBD2010 Ozone RR: Jerrett et al. (2009) Resolution: 0.5° x 0.67° Emissions: Representative Concentration Pathway 8.5 (van Vuuren et al., 2011)	Deaths: 376,000 TAF: 13.8% of anthropogenic $PM_{2.5}$- and ozone-related deaths
Weagle et al. (2018)	2014	Transportation	Concentration only Resolution: 0.1° x 0.1° Emissions: EDGAR v4.3 (Crippa et al., 2016), MIX (Li et al., 2017)	TAF: 8.6%

Note: RR = relative risk; IER = Integrated Exposure Response curve; ICCT = International Council on Clean Transportation; GBD = Global Burden of Disease; TAF = Transportation-attributable fraction.

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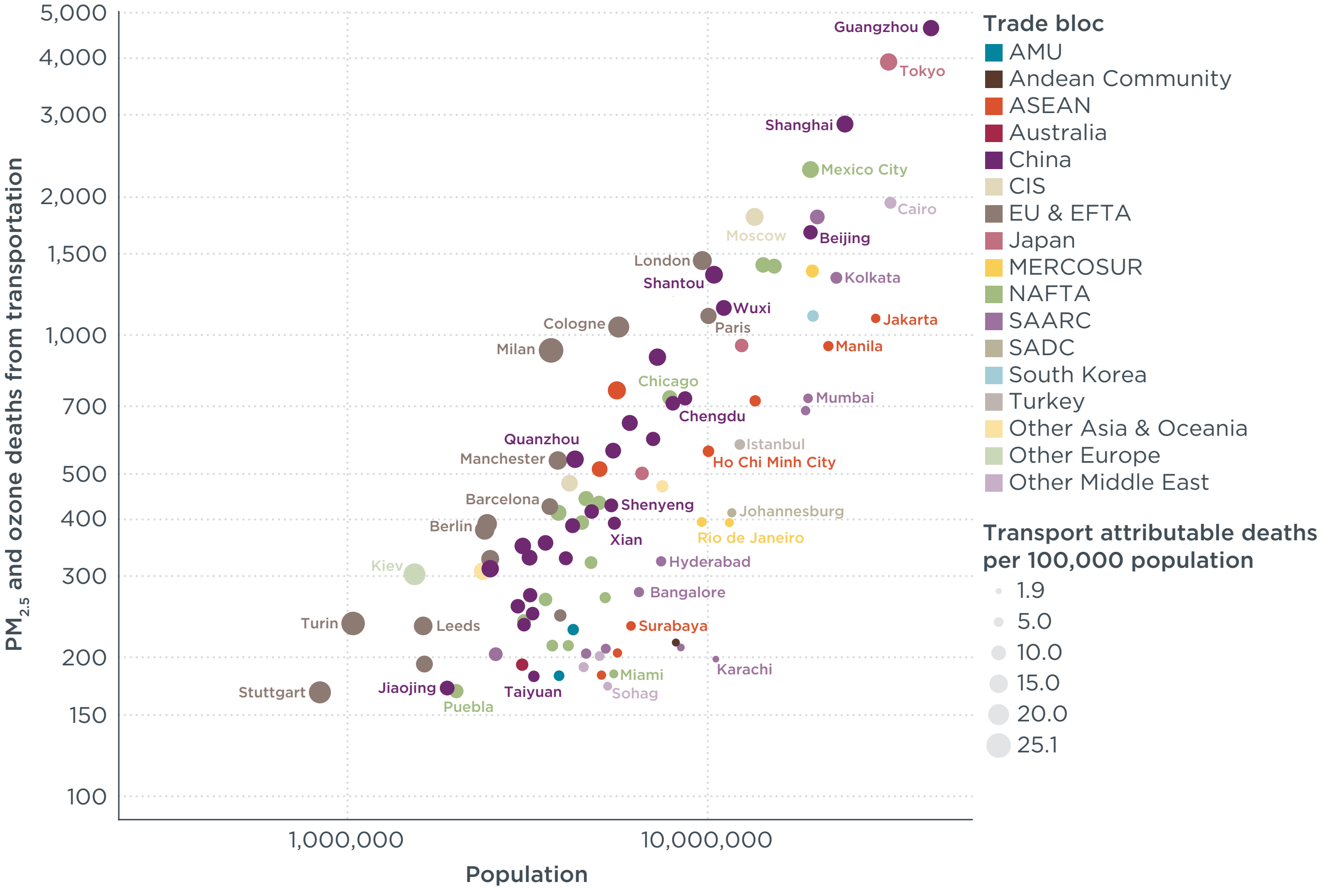
Total number of transportation-attributable $PM_{2.5}$ and ozone deaths in 2015 for select urban areas in Europe.

Total number of transportation-attributable $PM_{2.5}$ and ozone deaths in 2015 for select urban areas in Europe. Bubble size indicates total number of transportation-attributable $PM_{2.5}$ and ozone deaths using central relative risk estimates. Bubble color indicates transportation attributable fraction (TAF) of total $PM_{2.5}$ and ozone deaths.

Fact Sheet: Health Impacts of Air Pollution from Transportation Sources in Germany

Full Report: Anenberg, A., Miller, J., Henze, D., and Minjares R. (2019) A Global Snapshot of the Air Pollution-Related Health Impacts of Transportation Sector Emissions in 2010 and 2015. Washington, DC: International Council on Clean Transportation. https://www.theicct.org/publications/health-impacts-transport-emissions-2010-2015

Transportation-attributable deaths from $PM_{2.5}$ and ozone pollution, mortality rates, and population in 100 major urban areas, 2015.



Bubble color indicates the trade bloc in which an urban area is located. Bubble size indicates the transportation-attributable mortality rate per 100,000 population.

Top 10 in 2015 (bubble size): Milan, Turin, Stuttgart, Kiev, Cologne, Haarlem, Berlin, Rotterdam, London, and Leeds.

Fact Sheet: Health Impacts of Air Pollution from Transportation Sources in Paris

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