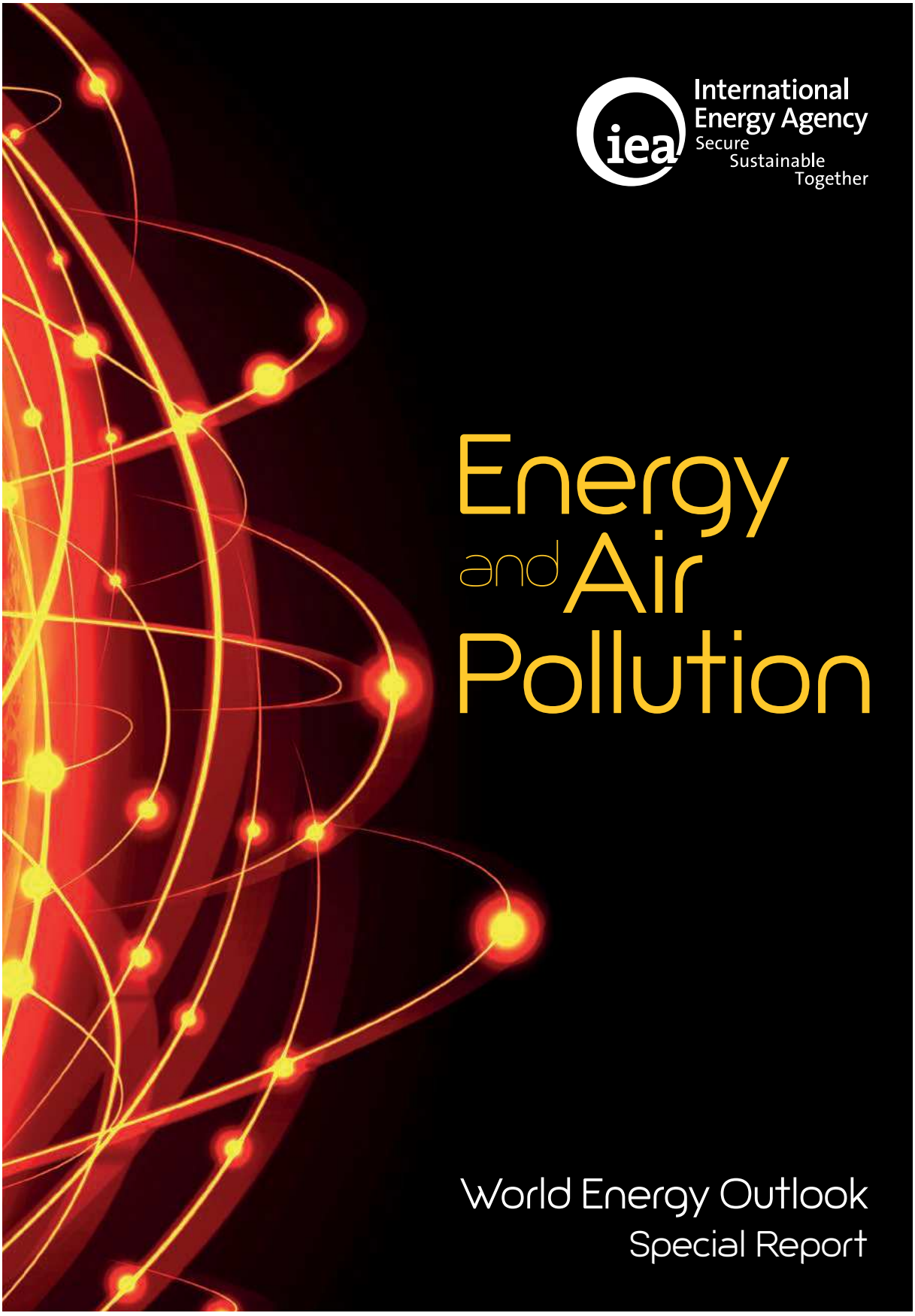

International Energy Agency
Secure Sustainable Together

Energy and Air Pollution

World Energy Outlook
Special Report

Energy and Air Pollution

World Energy Outlook
Special Report

INTERNATIONAL ENERGY AGENCY

The International Energy Agency (IEA), an autonomous agency, was established in November 1974. Its primary mandate was – and is – two-fold: to promote energy security amongst its member countries through collective response to physical disruptions in oil supply, and provide authoritative research and analysis on ways to ensure reliable, affordable and clean energy for its 29 member countries and beyond. The IEA carries out a comprehensive programme of energy co-operation among its member countries, each of which is obliged to hold oil stocks equivalent to 90 days of its net imports. The Agency's aims include the following objectives:

- Secure member countries' access to reliable and ample supplies of all forms of energy; in particular, through maintaining effective emergency response capabilities in case of oil supply disruptions.
- Promote sustainable energy policies that spur economic growth and environmental protection in a global context – particularly in terms of reducing greenhouse-gas emissions that contribute to climate change.
- Improve transparency of international markets through collection and analysis of energy data.
- Support global collaboration on energy technology to secure future energy supplies and mitigate their environmental impact, including through improved energy efficiency and development and deployment of low-carbon technologies.
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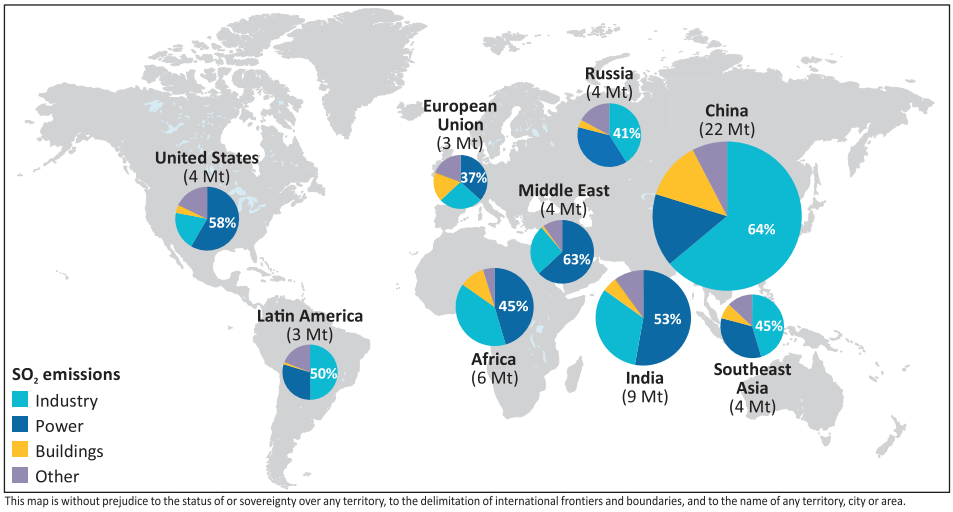
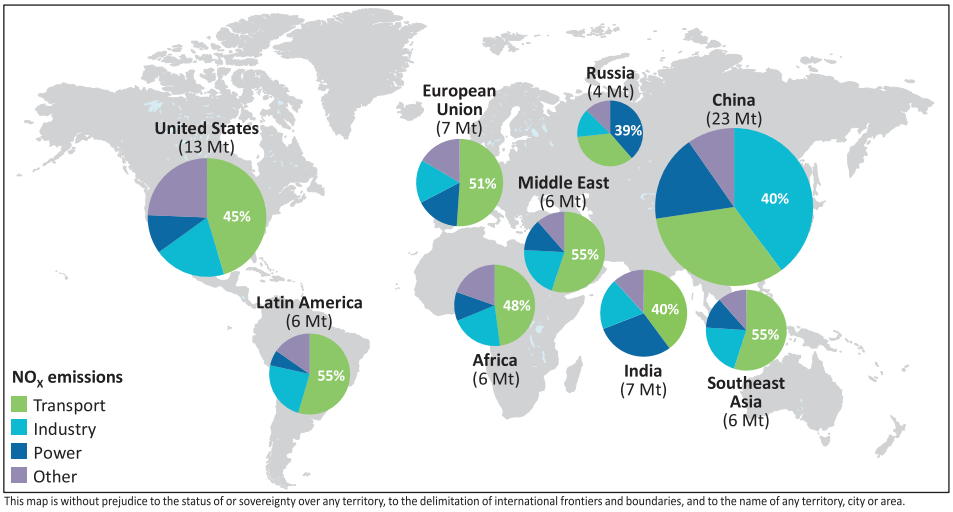
Figure 1.4 ▷ Energy-related SO_2 emissions by region and sector, 2015



This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries, and to the name of any territory, city or area.

Source: IEA analysis based on IIASA data.

Figure 1.5 ▷ Energy-related NO_X emissions by region and sector, 2015



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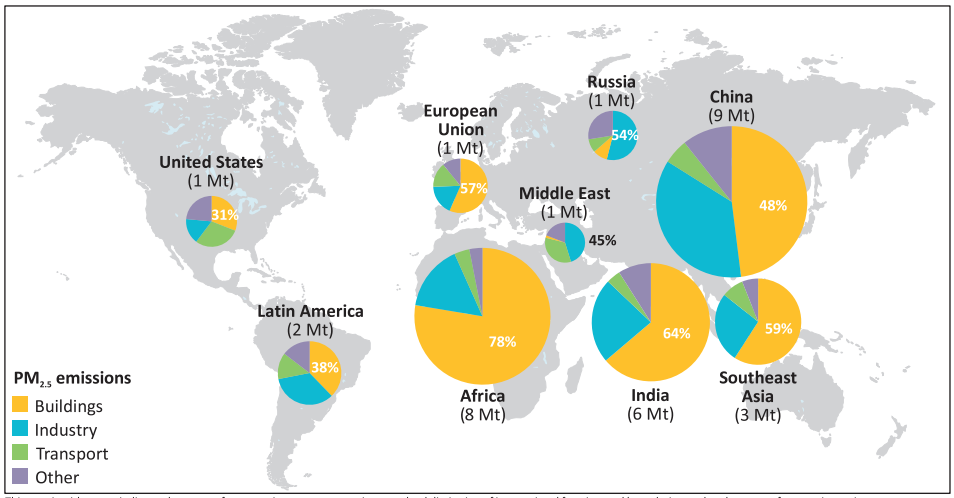
Source: IEA analysis based on IIASA data.

More than half of global energy-related particulate matter emissions come from the residential sector. The regional picture is heavily skewed towards Africa and Asia (China and India, in particular), with 80% of the global total. PM emissions are due mainly to incomplete combustion of fuels in households, particularly for cooking (bioenergy), heating (bioenergy and coal) and lighting (kerosene). More so than many other major energy-related pollutants, emissions of PM are heavily concentrated in developing countries and in one sector.

Figure 1.6 ▷ Energy-related $PM_{2.5}$ emissions by region and sector, 2015



This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries, and to the name of any territory, city or area.

Source: IEA analysis based on IIASA data.

Concentrations

The main determinants of the concentration of pollutants are the scale and composition of local economic activity, population size and density, the energy mix, the strength of local pollution regulation, and geographic and meteorological conditions that affect pollutant dispersion in the atmosphere.[2] Typically, pollutants have a lifetime of no more than a few days and high concentrations correlate with periods of high emissions. For example, transport-related emissions may peak in cities during rush-hour periods, household emissions during the cold seasons, power sector emissions at times of high electricity demand, industrial emissions during the working day and agricultural emissions at particular periods in the growing season. Climate and meteorological conditions (in particular, wind speed, the differences in temperature between atmospheric layers that trap pollutants at ground-level, and heat and sunlight, that contribute to ozone formation) play a major role in explaining the seasonal distribution of episodes of high pollutant concentrations. For instance, in the northern hemisphere, PM episodes happen mostly in winter, while ozone episodes happen in summer. Some persistent pollutants, e.g. toxic metals, get into the food chain and can affect us for years, decades or, in some cases, even centuries.

[2] A useful distinction can be made between pollution that is emitted in households (from cooking and heating with traditional biomass or lighting with kerosene) and outdoors (power plants, cars, airplanes). While the pollutants are often the same, and may move from indoors to outdoors and vice versa, the distinction can be important when analysing their impacts (as concentration levels and exposure may be higher indoors) and potential policy interventions.

Figure 1.7 ▷ **Average annual outdoor $PM_{2.5}$ concentrations in selected urban areas**

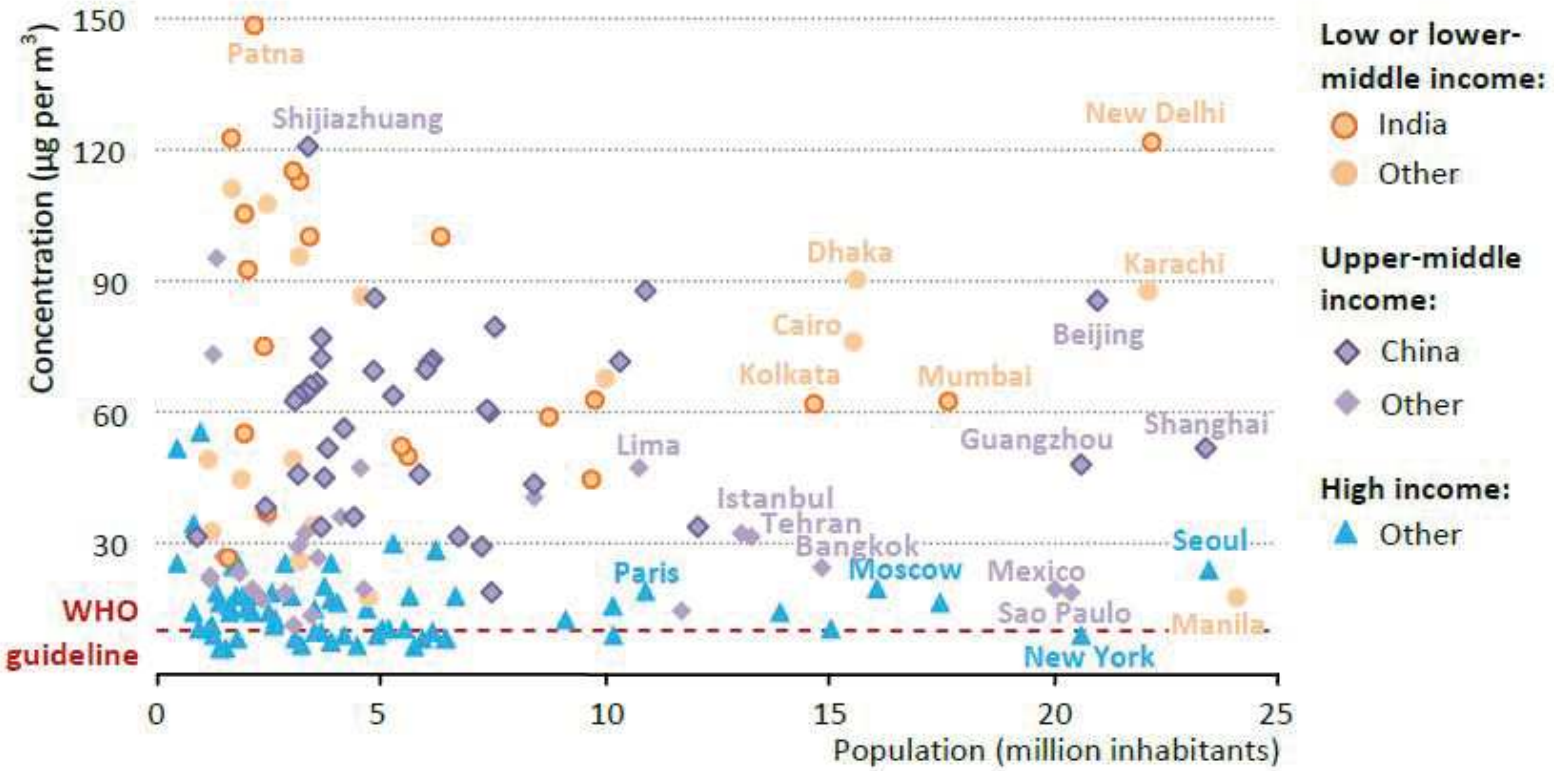
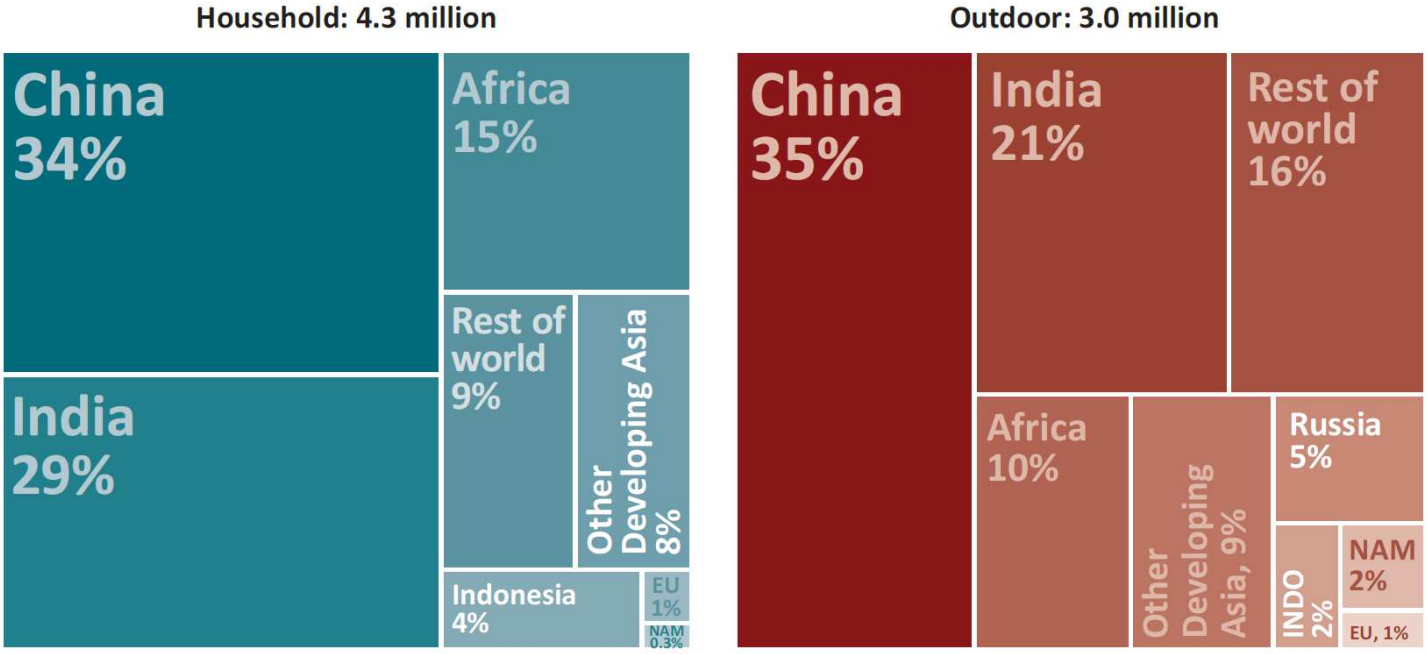


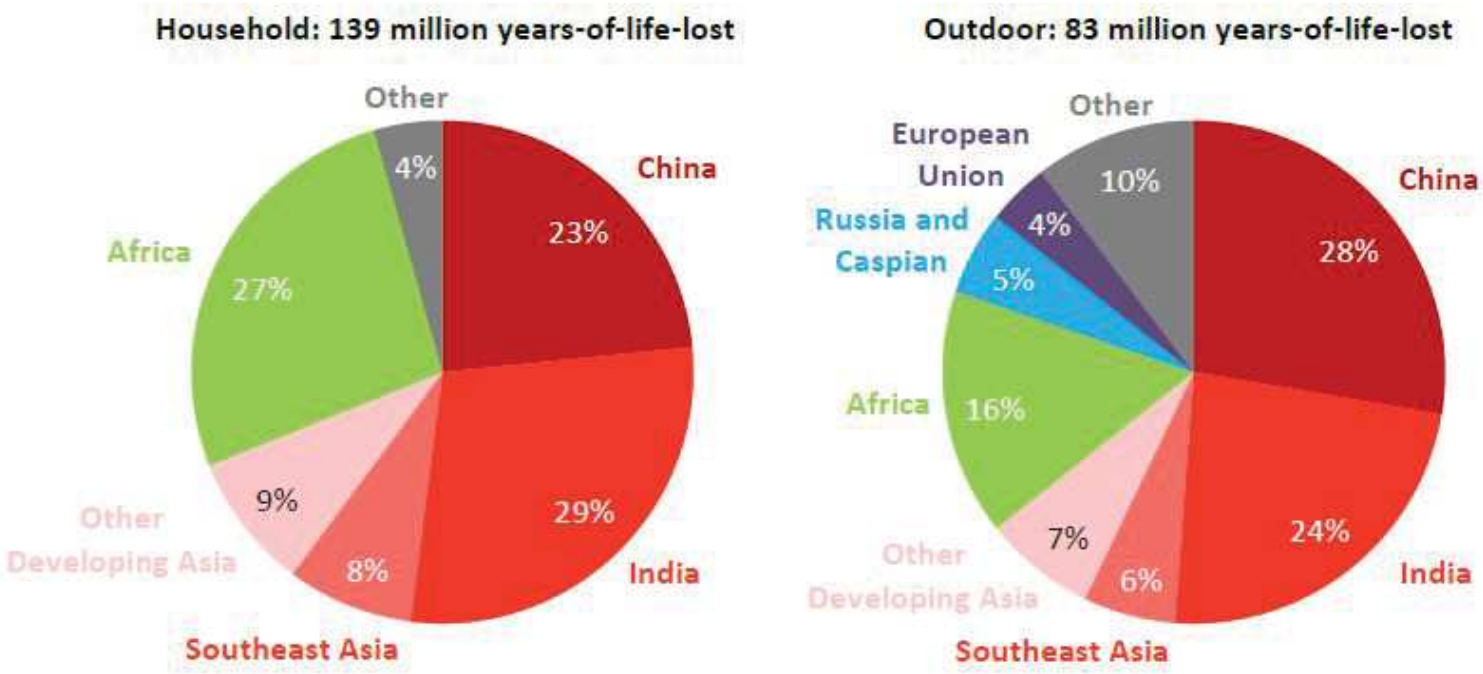
Figure 1.9 ▷ Deaths attributable to household and outdoor air pollution, 2012



Notes: EU = European Union; NAM = North America; INDO = Indonesia.

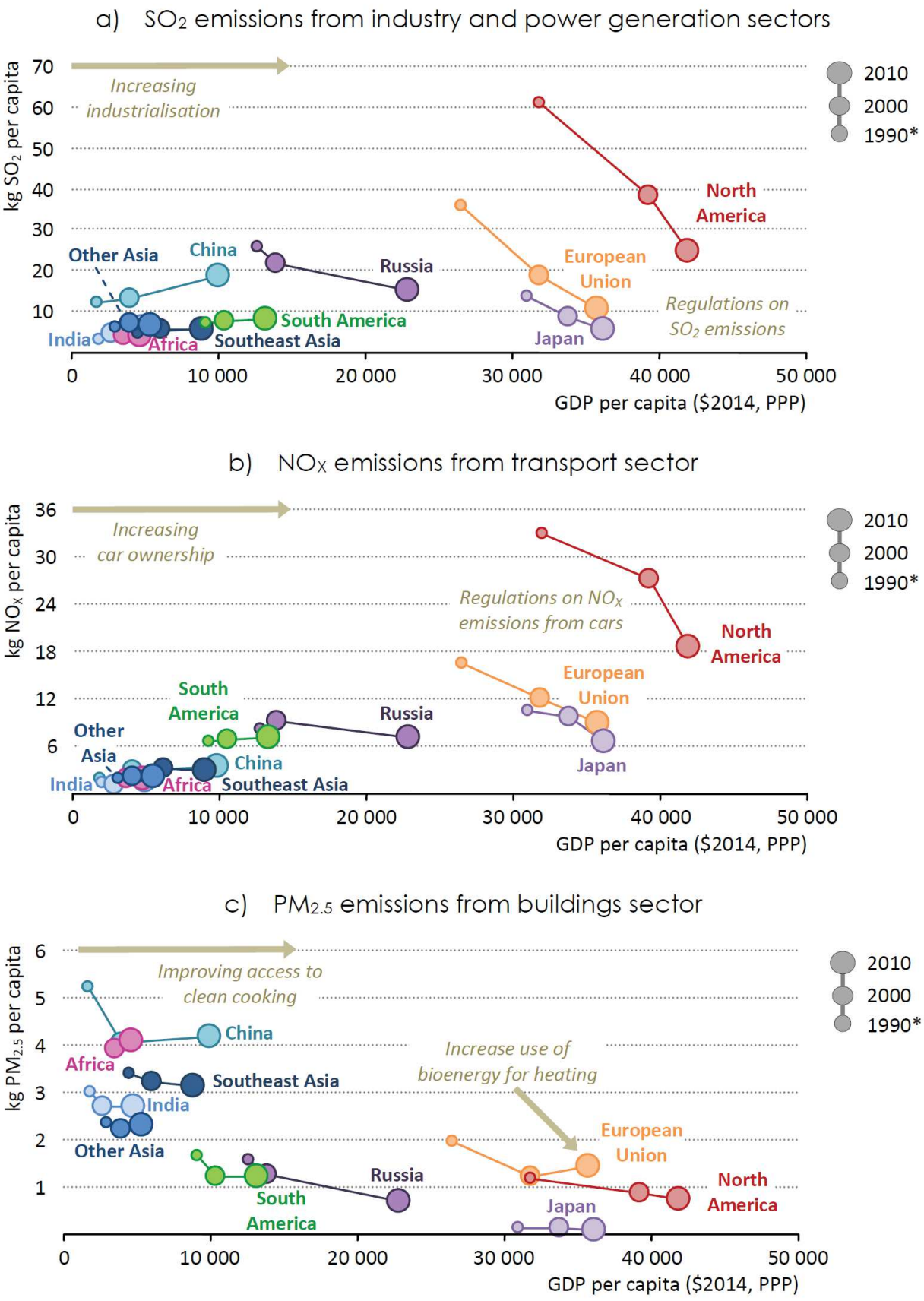
Sources: WHO (2016d, forthcoming) and IEA analysis.

Figure 1.10 ▷ Total years-of-life-lost attributed to household and outdoor air pollution by region, 2012



Sources: WHO (2016d, forthcoming) and IEA analysis.

Figure 2.1 ▷ Air pollutant emissions by type from key sectors



* For Russia, 1995 data have been taken into account as first series point.

Notes: kg = kilogrammes. Calculated based on gross domestic product expressed in year-2014 dollars in purchasing power parity (PPP) terms.

Source: Crippa, et al., (2016).

Energy and Air Pollution

- Around 6.5 million premature deaths each year can be attributed to air pollution.
- Energy production and use are by far the largest man-made sources of air pollutants.
- Technologies to tackle air pollution are well known.

Clean air is vital for good health. Yet despite growing recognition of this imperative, the problem of air pollution is far from solved in many countries, and the global health impacts risk intensifying in the decades to come.

The scale of the public health crisis caused by air pollution and the importance of the energy sector to its resolution are the reasons why the IEA is focusing on this critical topic for the first time.

Based on new data for pollutant emissions in 2015 and projections to 2040, this special report, the latest in the *World Energy Outlook* series, provides a global outlook for energy and air pollution as well as detailed profiles of key countries and regions: the United States, Mexico, the European Union, the People's Republic of China, India, Southeast Asia and Africa.

In a Clean Air Scenario, the report proposes a pragmatic and attainable strategy to reconcile the world's energy requirements with its need for cleaner air. Alongside the multiple benefits to human health, this strategy shows that resolving the world's air pollution problem can go hand-in-hand with progress towards other environmental and development goals.

World Energy Outlook
Special Report

For more information, and the free download of the report, please visit www.worldenergyoutlook.org/airpollution

HEALTHY ENVIRONMENT, HEALTHY PEOPLE

Thematic report
Ministerial policy review session
Second session of the United Nations Environment Assembly
of the United Nations Environment Programme
Nairobi, 23–27 May 2016

This report was prepared by the United Nations Environment Programme (UNEP), in collaboration with the World Health Organization (WHO), the Convention on Biological Diversity, the Montreal Protocol on Substances that Deplete the Ozone Layer, and the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal, the Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade and the Stockholm Convention on Persistent Organic Pollutants. It received contributions from other United Nations agencies and from stakeholders through an e-consultation at **www.myunea.org/.**

This report has benefited from the oversight:

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for WHO: Maria Neira, Director, Environment and Social Determinants of Health;

for the Convention on Biological Diversity: Braulio Ferreira de Souza Dias, Executive Secretary;

for the Basel Convention, the Rotterdam Convention and the Stockholm Convention: Rolph Payet, Executive Secretary;

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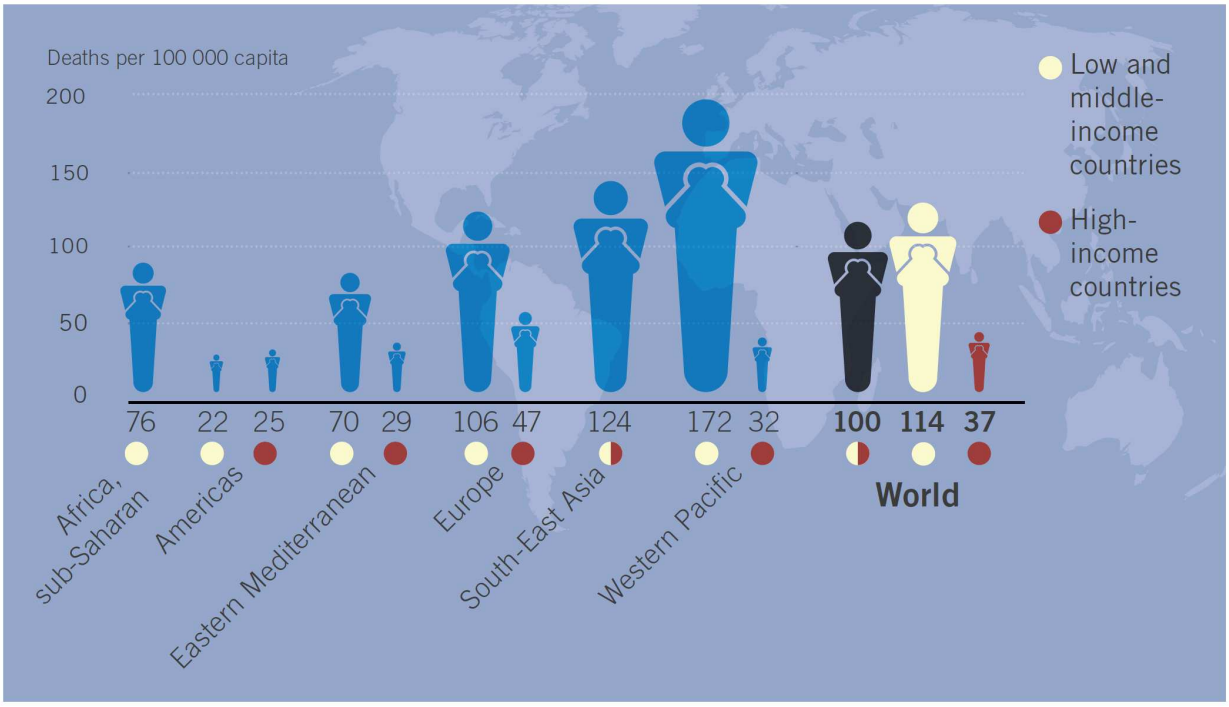
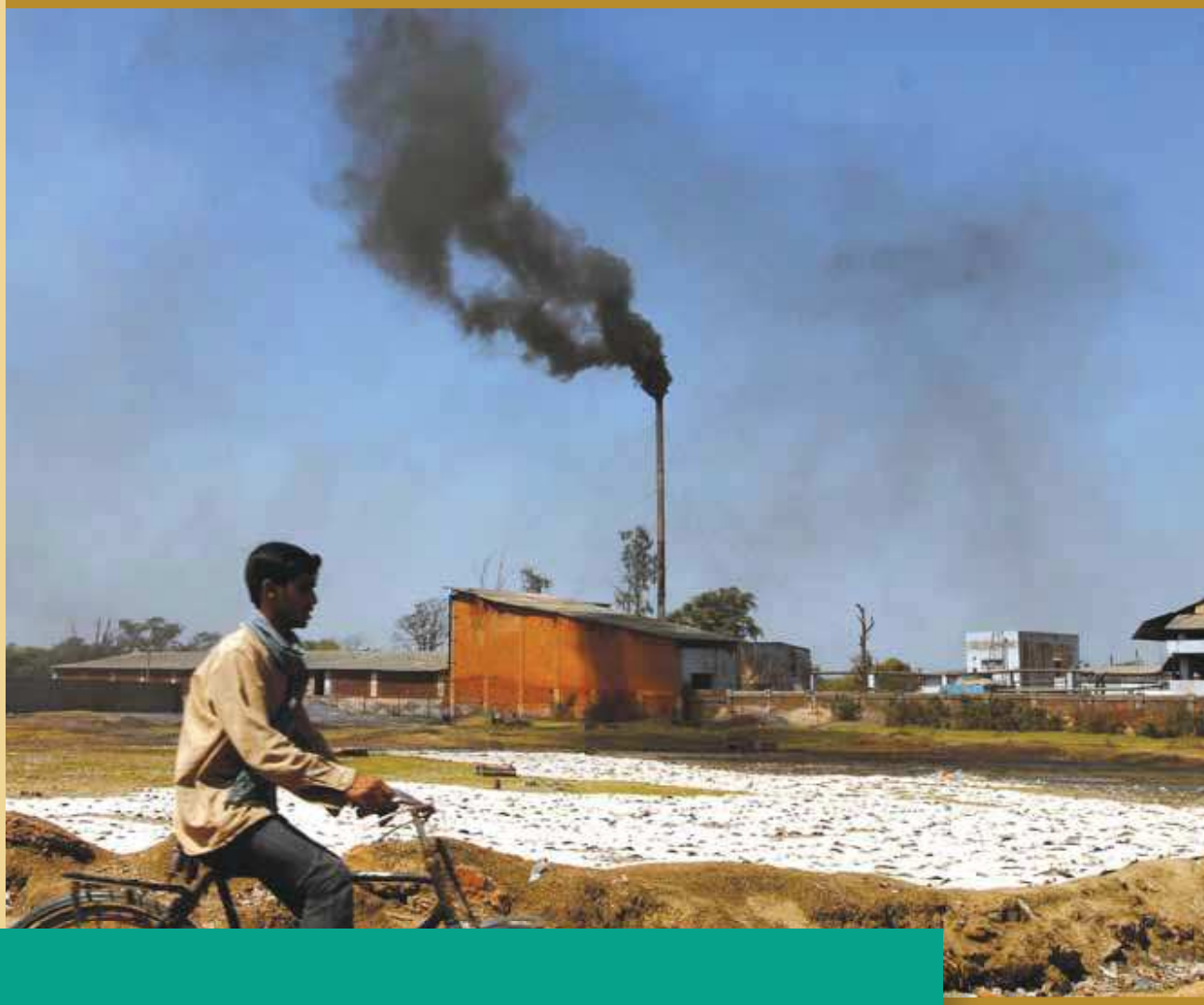
DISCLAIMER

Figure 6 Deaths per capita attributable to joint effects of household and ambient air pollution in 2012, by region



Source: World Health Organization (2014a), Burden of Disease from the Joint Effects of Household and Ambient Air Pollution for 2012.

d The World Health Organization 2016 database contains data from 3000 cities in 103 countries. Available from http://www.who.int/phe/health_topics/outdoorair/databases/cities/en/.



The Cost of Air Pollution

Strengthening the Economic Case for Action

WORLD BANK GROUP

IHME

The Cost of Air Pollution

Strengthening the Economic Case for Action

The World Bank and Institute for Health Metrics and Evaluation
University of Washington, Seattle

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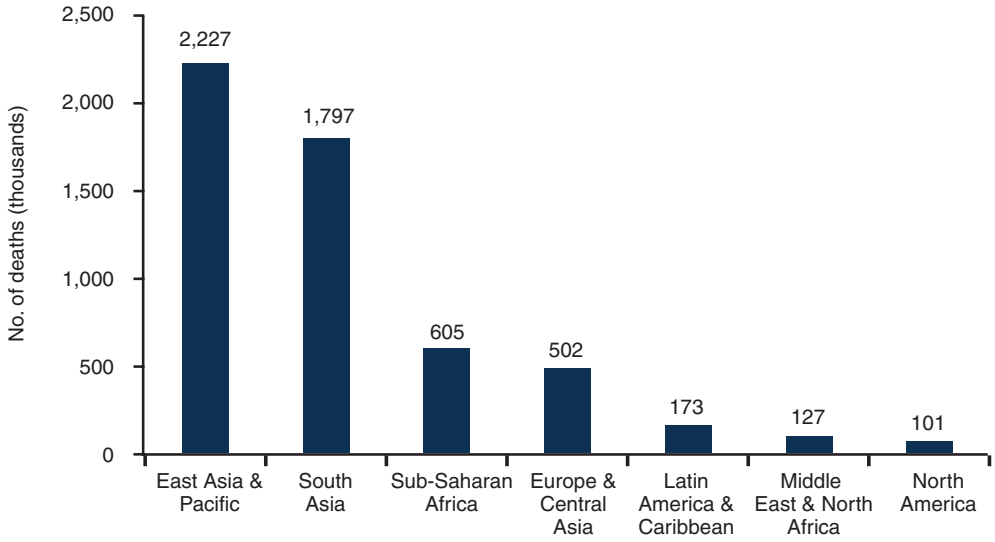
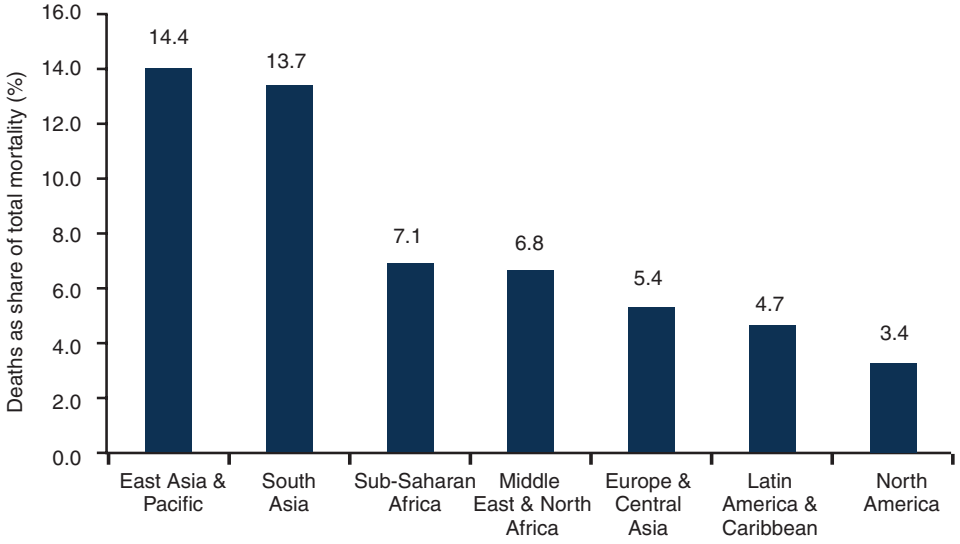
FIGURE 2.2 Total Deaths from Air Pollution by Region, 2013



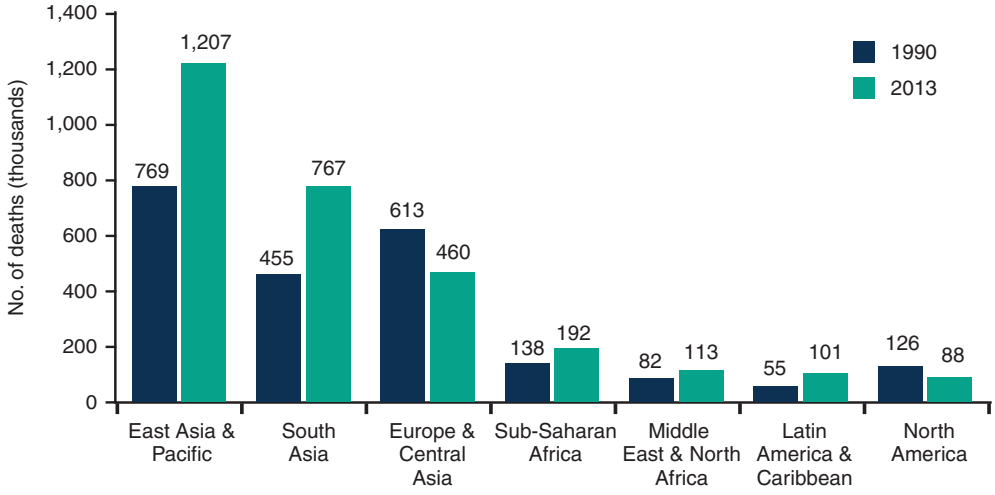
Sources: World Bank and IHME, using data from IHME, GBD 2013.

FIGURE 2.3 Percentage of Total Deaths from Air Pollution by Region, 2013



Sources: World Bank and IHME, using data from IHME, GBD 2013.

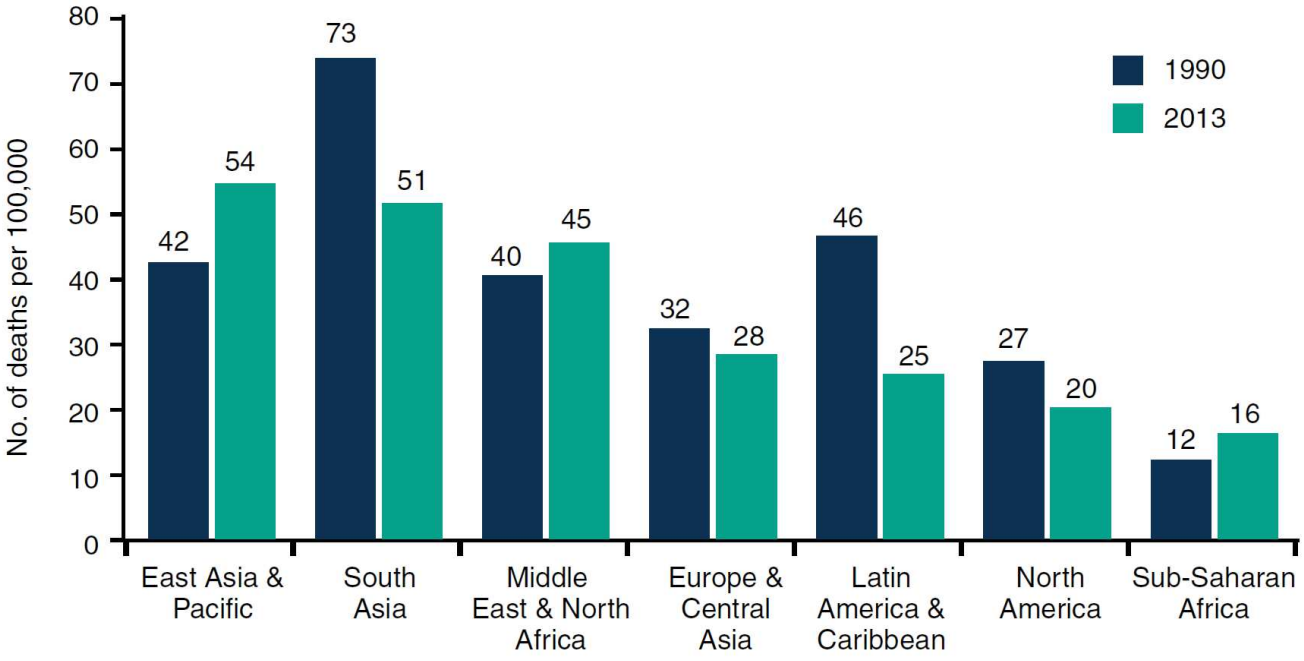
FIGURE 2.5 Total Deaths from Ambient $PM_{2.5}$ Pollution by Region, 1990 and 2013



Sources: World Bank and IHME, using data from IHME, GBD 2013.

Note: Data are for a balanced sample of countries for which data are available for both 1990 and 2013.

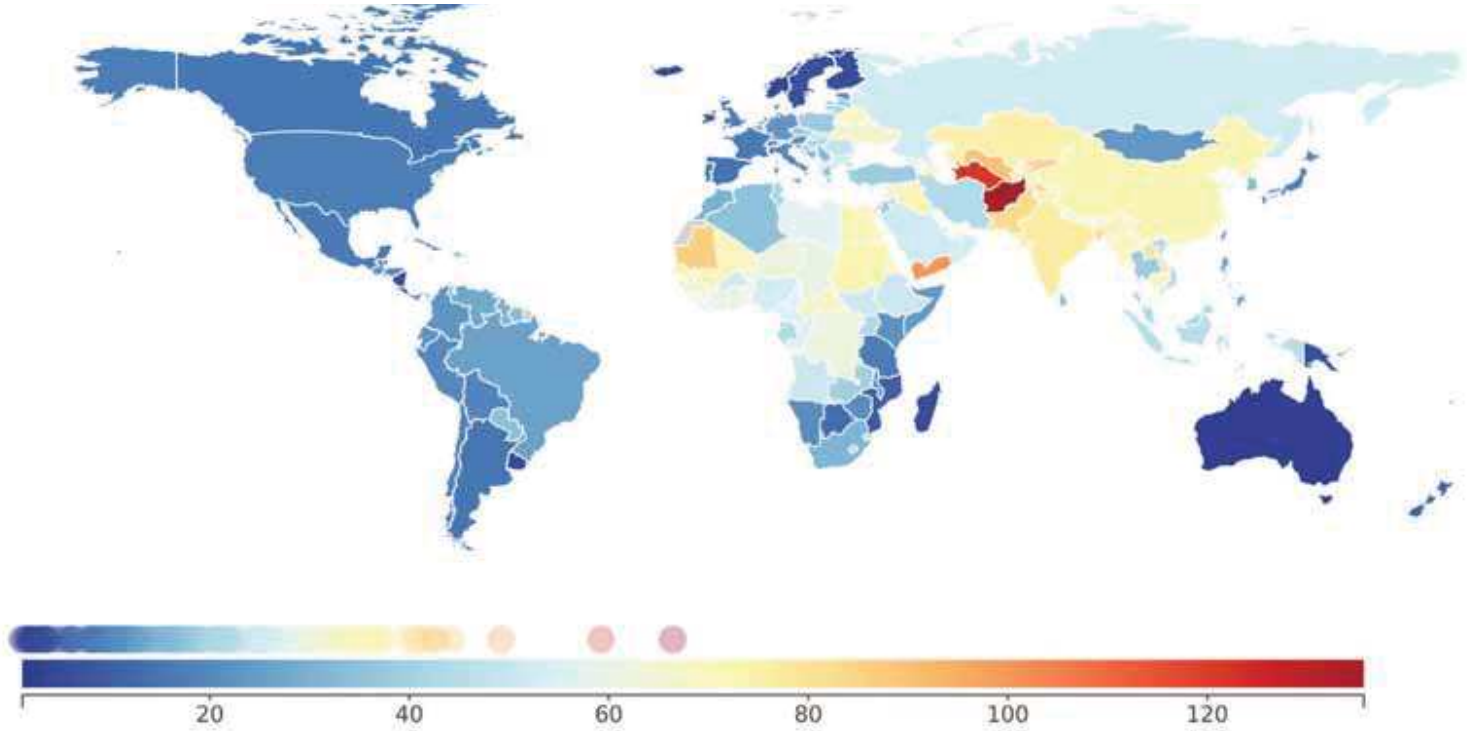
FIGURE 2.8 Deaths per 100,000 People from Ambient $PM_{2.5}$ Pollution by Region, 1990 and 2013



Sources: World Bank and IHME, using data from IHME, GBD 2013.

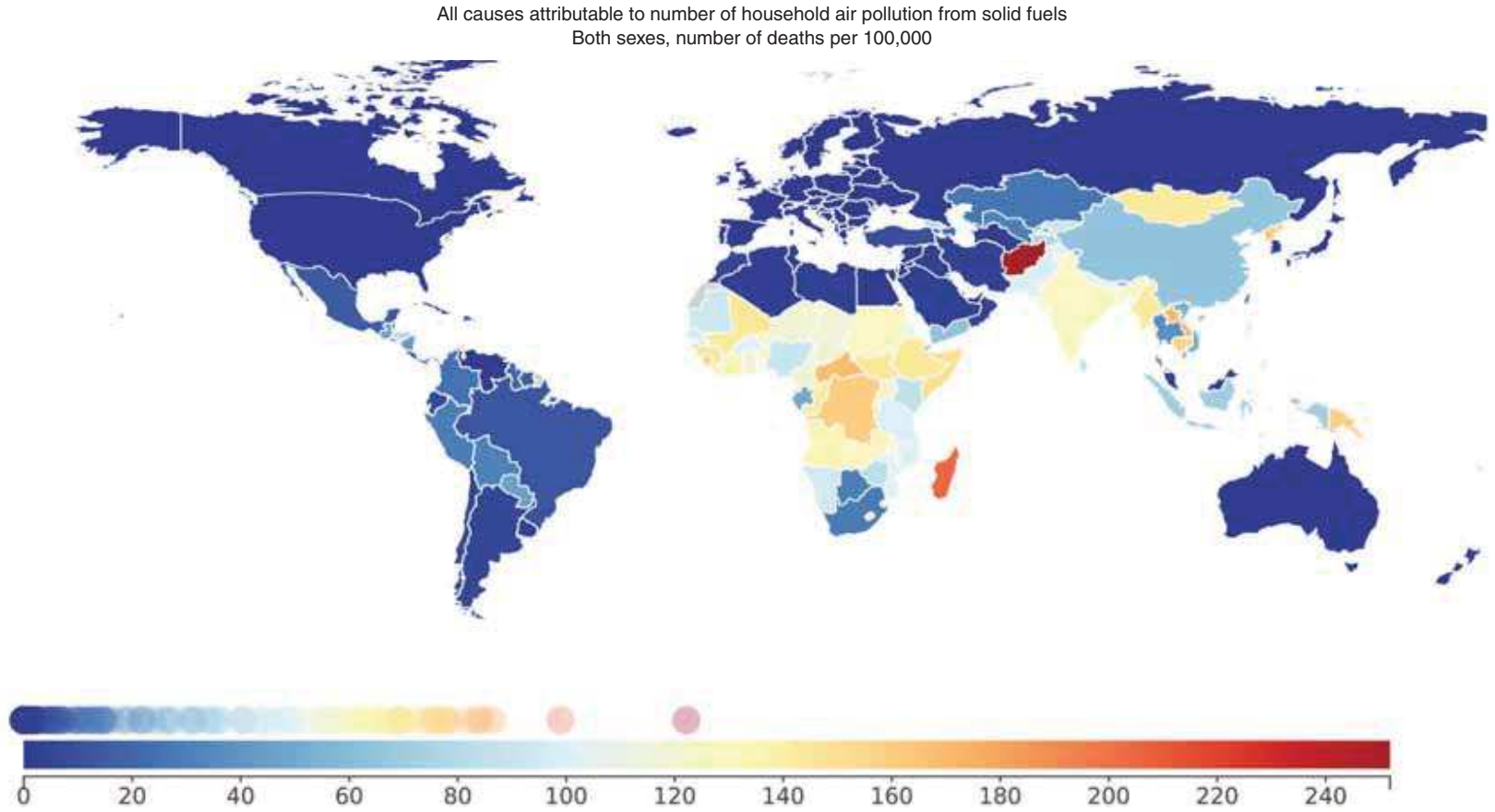
MAP 2.3 Age-Standardized Death Rates from Ambient $PM_{2.5}$ Pollution, 2013

All causes attributable to ambient particulate matter pollution: both sexes, deaths per 100,000



Source: IHME, GBD 2013.

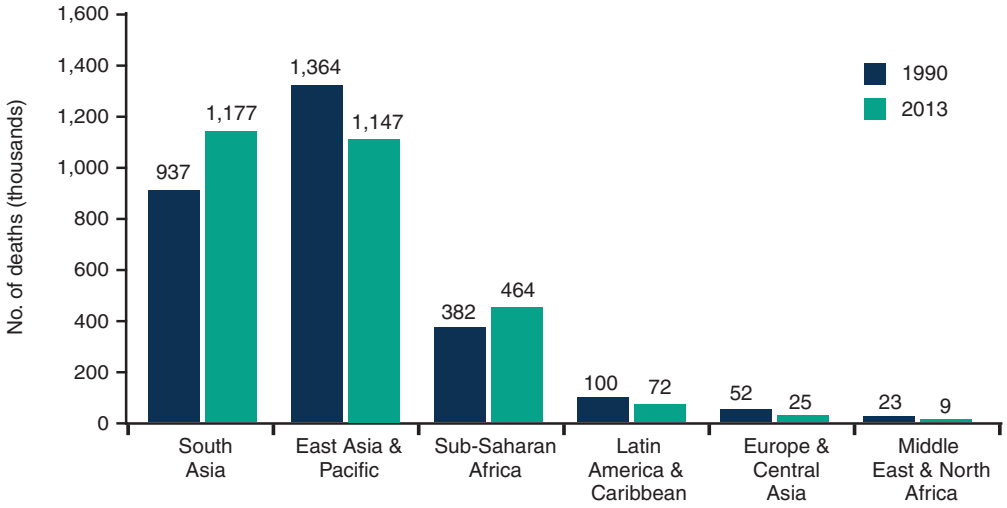
MAP 2.4 Age-Standardized Death Rates from Household Air Pollution, 2013



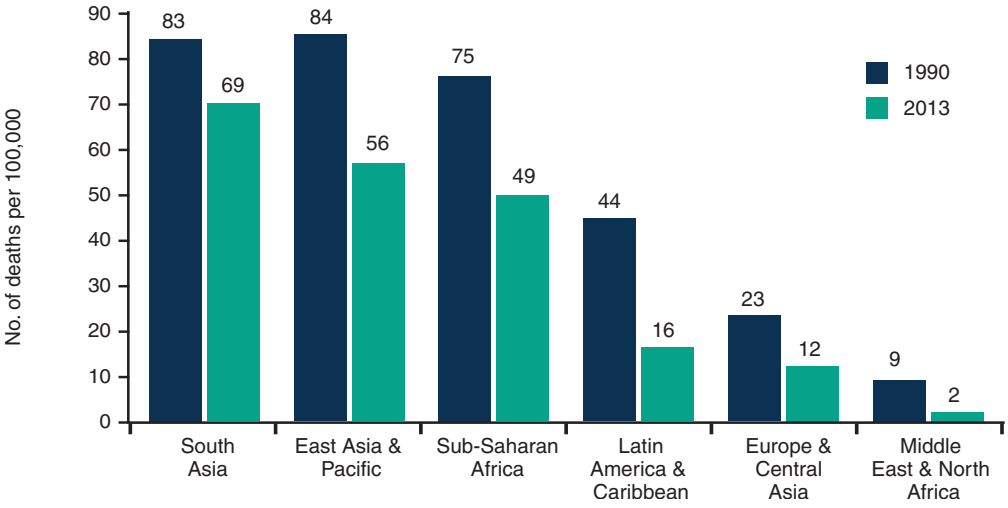
Source: IHME, GBD 2013.

FIGURE 2.16 Total Deaths (a) and Deaths per 100,000 People (b) from Household Air Pollution by Region, 1990 and 2013

a. Total deaths

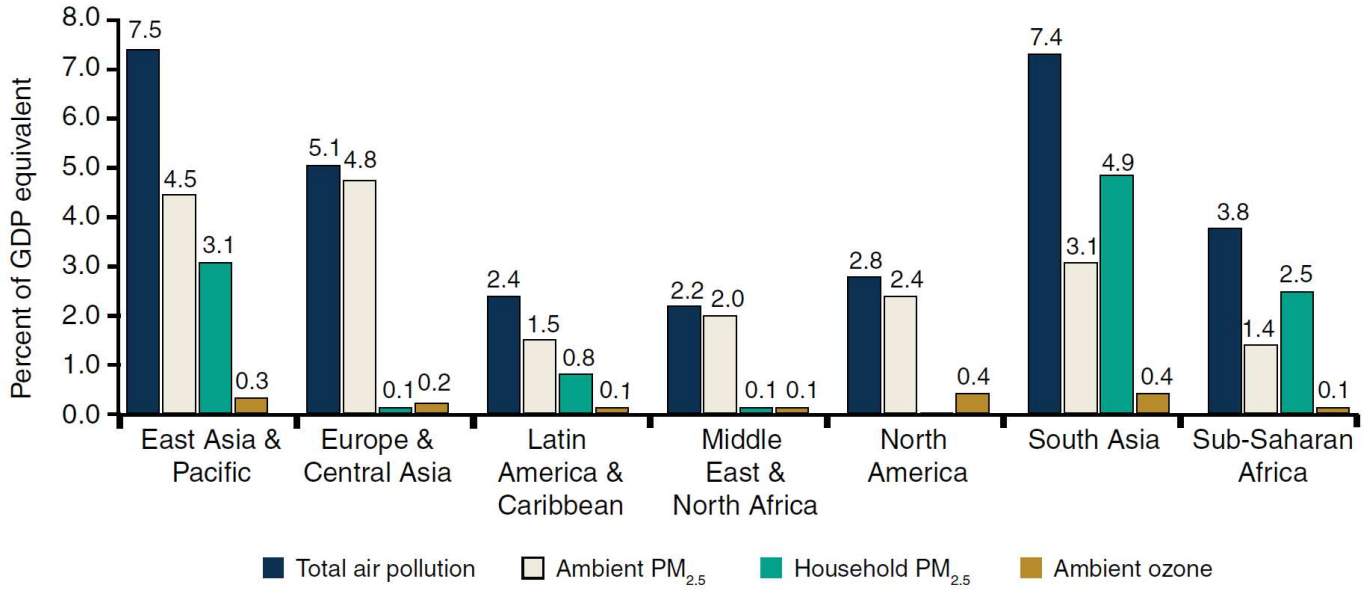


b. Deaths per 100,000 people



Sources: World Bank and IHME, using data from IHME, GBD 2013.

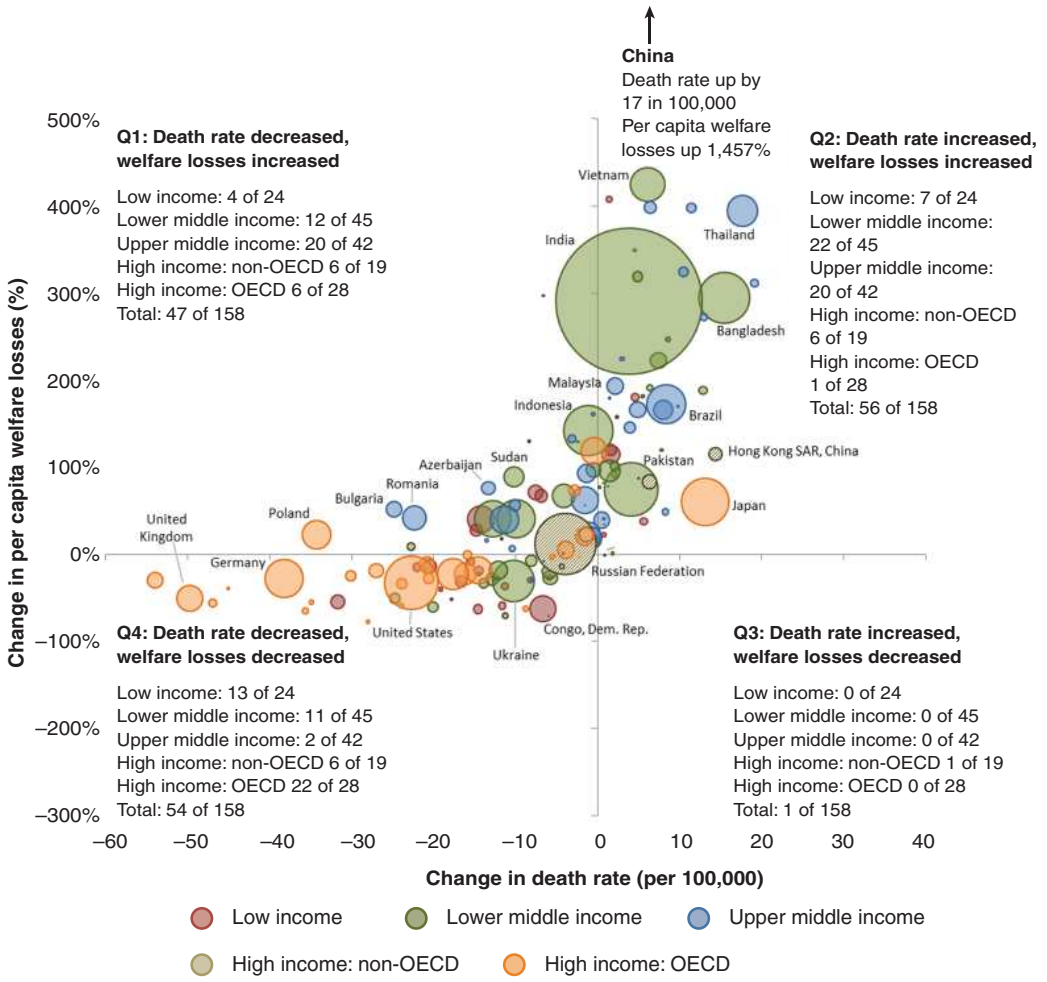
FIGURE 3.1 Welfare Losses Due to Air Pollution by Region, 2013



Sources: World Bank and IHME.

Note: Total air pollution damages include ambient $PM_{2.5}$, household $PM_{2.5}$, and ozone. GDP = gross domestic product.

FIGURE 3.7 Changes in Ambient $PM_{2.5}$ Death Rates and Per Capita Welfare Losses by Income Group, 1990–2013



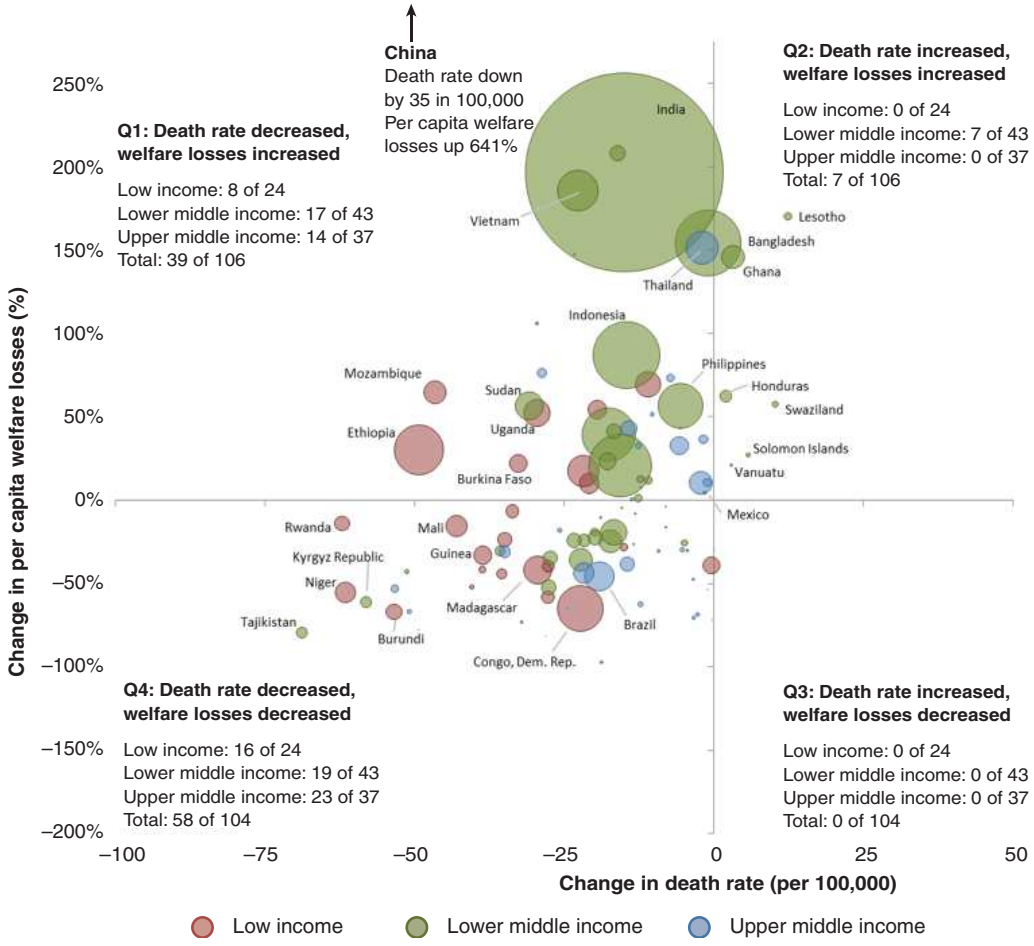
Sources: World Bank and IHME.

Note: Only countries for which data are available for 1990 and 2013 are included.

reducing their risk of death. Achieving real reductions in the costs of air pollution thus demands more ambitious action.

Estimates of welfare losses and forgone output for individual countries are presented in appendix B. In dollar terms, welfare losses from air pollution have increased the most on an annual basis in Equatorial Guinea (13.8 percent),[12] China (10.9 percent), Sri Lanka (7.5 percent), Lao People's Democratic Republic (7.2 percent), and India (7.0 percent). Welfare losses have declined the most on an annual basis in western and northern Europe, including in Norway (4.5 percent), Sweden (3.3 percent), Denmark (3.1 percent), Finland (2.6 percent), and the United Kingdom (2.5 percent).

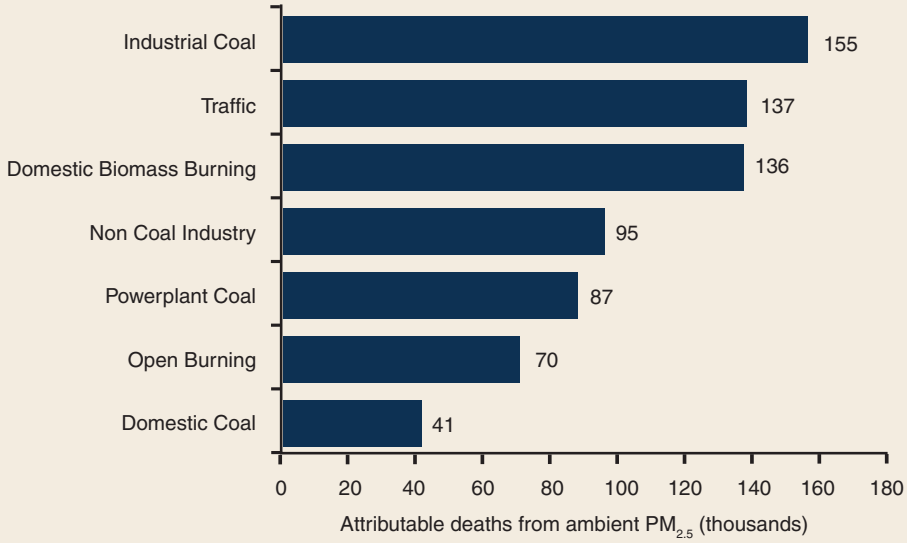
FIGURE 3.8 Changes in Household $PM_{2.5}$ Death Rates and Per Capita Welfare Losses by Income Group, 1990–2013



Sources: World Bank and IHME.

Note: Only countries for which data are available for 1990 and 2013 are included.

FIGURE B4.3.1 Deaths Attributable to Ambient $PM_{2.5}$ Pollution in China, by Source of Emissions, 2013



Source: GBD MAPS Working Group (2016).

Appendix B Country Data

TABLE B.1 Mean Annual $PM_{2.5}$, Total Deaths from Pollution, Total Welfare Losses, and Total Forgone Labor Output, by Country

	Mean annual ambient $PM_{2.5}$				*Total welfare losses*		*Total forgone labor output*	
	(μg/m³)		*Total deaths from air pollution*		*(Million 2011 U.S. dollars, PPP-adjusted; % GDP equivalent)*		*(Million 2011 U.S. dollars, PPP-adjusted; % GDP equivalent)*	
Economy	**1990**	**2013**	**1990**	**2013**	**1990**	**2013**	**1990**	**2013**
Algeria	20.68	19.26	5,726	7,845	4,750 (1.78%)	8,855 (1.74%)	472 (0.18%)	331 (0.07%)
Armenia	20.52	17.75	3,926	2,401	965 (7.29%)	1,357 (6.07%)	156 (1.18%)	114 (0.51%)
Australia	7.68	5.93	2,067	777	6,466 (1.33%)	3,361 (0.34%)	179 (0.04%)	76 (0.01%)
Austria	25.78	14.85	5,523	3,573	18,492 (7.74%)	15,797 (4.23%)	313 (0.13%)	243 (0.07%)
Azerbaijan	26.42	20.80	8,699	5,994	5,748 (9.43%)	8,823 (5.65%)	756 (1.24%)	203 (0.13%)
Bahrain	39.54	43.63	173	188	643 (3.66%)	798 (1.41%)	59 (0.33%)	38 (0.07%)
Bangladesh	29.92	48.36	92,880	154,898	6,379 (4.66%)	27,452 (6.14%)	1,195 (0.87%)	2,579 (0.58%)
Belarus	25.23	13.60	9,890	9,816	6,142 (7.46%)	14,963 (9.25%)	239 (0.29%)	470 (0.29%)
Belgium	28.62	18.53	7,844	5,858	25,788 (8.51%)	24,190 (5.35%)	461 (0.15%)	404 (0.09%)
Benin	26.23	26.71	5,325	6,350	423 (5.80%)	679 (3.52%)	166 (2.28%)	168 (0.87%)
Bolivia	5.32	10.89	2,600	2,667	634 (2.49%)	1,179 (1.86%)	.. ..	.. ..

Economy	Mean annual ambient $PM_{2.5}$ ($\mu g/m^3$) 1990	Mean annual ambient $PM_{2.5}$ ($\mu g/m^3$) 2013	Total deaths from air pollution 1990	Total deaths from air pollution 2013	Total welfare losses (Million 2011 U.S. dollars, PPP-adjusted; % GDP equivalent) 1990	Total welfare losses (Million 2011 U.S. dollars, PPP-adjusted; % GDP equivalent) 2013	Total forgone labor output (Million 2011 U.S. dollars, PPP-adjusted; % GDP equivalent) 1990	Total forgone labor output (Million 2011 U.S. dollars, PPP-adjusted; % GDP equivalent) 2013
Bosnia and Herzegovina	21.59	13.63	2,211	1,882	.. ..	1,401 (3.90%)	.. ..	73 (0.20%)
Brazil	9.68	16.50	59,606	62,246	49,389 (3.19%)	82,612 (2.66%)	6,029 (0.39%)	4,927 (0.16%)
Brunei Darussalam	7.91	9.47	14	42	96 (0.49%)	274 (0.94%)	8 (0.04%)	14 (0.05%)
Bulgaria	28.25	15.93	10,523	7,297	7,716 (9.53%)	10,299 (8.85%)	252 (0.31%)	219 (0.19%)
Burkina Faso	29.26	29.23	9,125	10,410	364 (5.04%)	877 (3.36%)	151 (2.09%)	252 (0.96%)
Burundi	14.69	17.10	7,459	7,317	400 (6.79%)	252 (3.32%)	135 (2.30%)	71 (0.93%)
Cambodia	10.18	19.74	9,935	19,595	.. ..	3,637 (8.16%)	.. ..	294 (0.66%)
Cameroon	22.78	21.34	11,432	16,392	1,962 (5.87%)	2,785 (4.57%)	590 (1.77%)	573 (0.94%)
Canada	11.48	12.14	7,839	9,466	26,280 (3.03%)	40,460 (2.73%)	764 (0.09%)	1,016 (0.07%)
Central African Republic	19.82	19.33	4,270	5,161	199 (7.25%)	134 (4.96%)	22 (0.79%)	15 (0.56%)
Chad	30.06	30.71	6,432	11,067	369 (5.58%)	1,290 (4.89%)	143 (2.17%)	534 (2.03%)
Chile	17.23	18.38	4,756	4,309	6,031 (4.96%)	10,855 (2.83%)	248 (0.20%)	369 (0.10%)
China	39.30	54.36	1,518,942	1,625,164	126,592 (7.35%)	1,589,767 (9.92%)	12,558 (0.73%)	44,567 (0.28%)

table continues next page

Economy	Mean annual ambient $PM_{2.5}$ (μg/m³) 1990	Mean annual ambient $PM_{2.5}$ (μg/m³) 2013	Total deaths from air pollution 1990	Total deaths from air pollution 2013	Total welfare losses (Million 2011 U.S. dollars, PPP-adjusted; % GDP equivalent) 1990	Total welfare losses (Million 2011 U.S. dollars, PPP-adjusted; % GDP equivalent) 2013	Total forgone labor output (Million 2011 U.S. dollars, PPP-adjusted; % GDP equivalent) 1990	Total forgone labor output (Million 2011 U.S. dollars, PPP-adjusted; % GDP equivalent) 2013
Colombia	9.15	12.63	10,635	14,636	6,068 (2.35%)	15,046 (2.58%)	961 (0.37%)	916 (0.16%)
Congo, Dem. Rep.	17.03	18.08	39,416	62,412	2,650 (5.98%)	1,964 (4.02%)	678 (1.53%)	509 (1.04%)
Congo, Rep.	16.76	13.81	2,874	3,393	1,065 (8.49%)	1,400 (5.54%)	130 (1.04%)	153 (0.60%)
Costa Rica	8.08	9.31	593	629	325 (1.44%)	748 (1.14%)	35 (0.16%)	43 (0.07%)
Côte d'Ivoire	19.50	20.30	12,265	16,264	2,524 (6.44%)	2,994 (4.72%)	848 (2.16%)	650 (1.02%)
Croatia	24.89	13.93	3,943	2,716	.. ..	6,392 (7.50%)	.. ..	125 (0.15%)
Cuba	9.49	10.97	3,838	3,052	4,486 (3.10%)	5,603 (2.47%)	178 (0.12%)	124 (0.05%)
Cyprus	20.24	16.46	312	303	843 (6.11%)	988 (3.81%)	21 (0.15%)	20 (0.08%)
Czech Republic	32.83	16.55	12,074	6,640	28,206 (13.76%)	20,521 (6.93%)	600 (0.29%)	339 (0.11%)
Denmark	18.30	11.41	3,880	1,632	13,702 (8.01%)	7,011 (2.94%)	339 (0.20%)	149 (0.06%)
Dominican Republic	11.62	12.49	2,310	3,828	869 (2.27%)	3,792 (3.09%)	169 (0.44%)	232 (0.19%)
Ecuador	8.01	13.91	2,206	3,156	1,246 (1.63%)	2,721 (1.64%)	100 (0.13%)	113 (0.07%)
Egypt, Arab Rep.	35.92	36.41	40,881	39,118	17,802 (5.25%)	31,545 (3.58%)	2,810 (0.83%)	2,367 (0.27%)
El Salvador	10.73	12.92	2,115	2,182	656 (2.76%)	1,306 (2.74%)	89 (0.37%)	85 (0.18%)

Economy	Mean annual ambient $PM_{2.5}$ (µg/m³) 1990	Mean annual ambient $PM_{2.5}$ (µg/m³) 2013	Total deaths from air pollution 1990	Total deaths from air pollution 2013	Total welfare losses (Million 2011 U.S. dollars, PPP-adjusted; % GDP equivalent) 1990	Total welfare losses (Million 2011 U.S. dollars, PPP-adjusted; % GDP equivalent) 2013	Total forgone labor output (Million 2011 U.S. dollars, PPP-adjusted; % GDP equivalent) 1990	Total forgone labor output (Million 2011 U.S. dollars, PPP-adjusted; % GDP equivalent) 2013
Estonia	14.03	9.09	1,219	504	.. ..	1,451 (4.27%)	.. ..	33 (0.10%)
Ethiopia	15.99	17.60	64,137	71,018	1,943 (6.20%)	5,059 (4.02%)	547 (1.74%)	793 (0.63%)
Finland	9.56	7.03	1,798	653	5,628 (3.95%)	2,612 (1.24%)	133 (0.09%)	50 (0.02%)
France	22.76	14.02	27,464	21,138	87,942 (5.11%)	81,840 (3.33%)	1,750 (0.10%)	1,530 (0.06%)
Georgia	20.43	15.51	10,191	7,995	6,267 (16.28%)	4,127 (13.27%)	660 (1.72%)	222 (0.71%)
Germany	29.75	15.35	71,136	41,485	240,370 (9.62%)	180,099 (5.19%)	5,358 (0.21%)	3,178 (0.09%)
Ghana	22.53	26.54	8,454	17,524	935 (3.33%)	4,446 (4.43%)	207 (0.74%)	542 (0.54%)
Greece	23.04	15.37	7,742	8,320	19,040 (8.86%)	22,681 (8.55%)	460 (0.21%)	378 (0.14%)
Guatemala	11.35	12.40	5,355	5,546	1,940 (4.11%)	2,879 (2.64%)	445 (0.94%)	323 (0.30%)
Guinea	26.62	27.02	8,139	10,147	474 (6.98%)	634 (4.45%)	122 (1.79%)	132 (0.93%)
Haiti	12.03	13.35	7,129	7,878	.. ..	716 (4.21%)	.. ..	113 (0.66%)
Honduras	8.60	8.67	2,295	4,013	470 (2.99%)	1,269 (3.51%)	120 (0.76%)	171 (0.47%)
Hong Kong SAR, China	..	..	7,069	9,235	21,116 (13.72%)	46,387 (12.49%)	.. ..	.. ..

table continues next page

Economy	Mean annual ambient $PM_{2.5}$ (μg/m³) 1990	Mean annual ambient $PM_{2.5}$ (μg/m³) 2013	Total deaths from air pollution 1990	Total deaths from air pollution 2013	Total welfare losses (Million 2011 U.S. dollars, PPP-adjusted; % GDP equivalent) 1990	Total welfare losses (Million 2011 U.S. dollars, PPP-adjusted; % GDP equivalent) 2013	Total forgone labor output (Million 2011 U.S. dollars, PPP-adjusted; % GDP equivalent) 1990	Total forgone labor output (Million 2011 U.S. dollars, PPP-adjusted; % GDP equivalent) 2013
Hungary	34.09	15.76	12,163	7,435	.. ..	19,428 (8.60%)	.. ..	407 (0.18%)
Iceland	7.07	7.18	22	21	69 (0.95%)	89 (0.67%)	3 (0.04%)	3 (0.02%)
India	30.25	46.68	1,043,182	1,403,136	104,906 (6.80%)	505,103 (7.69%)	28,742 (1.86%)	55,390 (0.84%)
Indonesia	21.02	14.77	140,373	162,410	42,900 (5.28%)	125,119 (5.15%)	7,715 (0.95%)	11,899 (0.49%)
Iran, Islamic Rep.	28.64	31.89	17,035	21,680	13,940 (2.44%)	30,599 (2.48%)	2,533 (0.44%)	1,471 (0.12%)
Iraq	29.13	32.57	6,541	10,372	6,211 (3.09%)	13,658 (2.67%)	378 (0.19%)	1,135 (0.22%)
Ireland	12.12	7.93	1,665	558	4,116 (5.50%)	2,562 (1.21%)	122 (0.16%)	65 (0.03%)
Israel	27.17	25.78	2,030	2,201	4,255 (5.27%)	7,405 (2.94%)	191 (0.24%)	234 (0.09%)
Italy	30.61	18.34	37,544	29,482	124,524 (7.14%)	105,464 (5.18%)	3,256 (0.19%)	1,584 (0.08%)
Japan	19.42	16.03	44,843	64,428	144,083 (3.95%)	240,353 (5.30%)	5,406 (0.15%)	4,414 (0.10%)
Jordan	26.47	25.64	870	1,055	459 (2.05%)	990 (1.34%)	88 (0.39%)	93 (0.13%)
Kazakhstan	16.43	14.22	17,130	12,317	18,342 (8.81%)	26,084 (6.81%)	1,107 (0.53%)	886 (0.23%)
Kenya	10.09	11.43	13,690	18,237	1,956 (3.51%)	3,102 (2.58%)	746 (1.34%)	901 (0.75%)
Korea, Rep.	35.59	29.08	17,198	20,370	27,028 (5.22%)	70,948 (4.32%)	1,870 (0.36%)	2,482 (0.15%)

Economy	Mean annual ambient $PM_{2.5}$ (µg/m³) 1990	Mean annual ambient $PM_{2.5}$ (µg/m³) 2013	Total deaths from air pollution 1990	Total deaths from air pollution 2013	Total welfare losses (Million 2011 U.S. dollars, PPP-adjusted; % GDP equivalent) 1990	Total welfare losses (Million 2011 U.S. dollars, PPP-adjusted; % GDP equivalent) 2013	Total forgone labor output (Million 2011 U.S. dollars, PPP-adjusted; % GDP equivalent) 1990	Total forgone labor output (Million 2011 U.S. dollars, PPP-adjusted; % GDP equivalent) 2013
Kuwait	36.50	49.13	329	547	.. ..	3,671 (1.38%)	.. ..	149 (0.06%)
Kyrgyz Republic	19.55	18.34	6,712	4,952	1,513 (9.92%)	981 (5.50%)	218 (1.43%)	83 (0.47%)
Lao PDR	14.64	27.48	5,211	7,251	471 (6.83%)	2,409 (7.63%)	87 (1.26%)	235 (0.74%)
Latvia	19.78	12.02	2,605	1,407	.. ..	3,482 (8.11%)	.. ..	76 (0.18%)
Lebanon	24.39	23.56	1,160	1,816	683 (3.27%)	2,660 (3.58%)	82 (0.39%)	148 (0.20%)
Liberia	14.20	22.72	2,291	2,985	98 (5.36%)	118 (3.38%)	32 (1.76%)	25 (0.72%)
Libya	30.25	27.82	1,178	1,956	.. ..	3,506 (2.86%)	.. ..	314 (0.26%)
Lithuania	23.26	13.75	3,187	2,270	.. ..	6,343 (8.64%)	.. ..	113 (0.15%)
Luxembourg	27.18	14.80	305	188	1,646 (7.64%)	1,468 (3.01%)	41 (0.19%)	27 (0.06%)
Macao SAR, China	..	..	369	359	1,420 (10.68%)	3,915 (5.06%)	.. ..	.. ..
Macedonia, FYR	25.70	17.00	1,073	1,294	822 (4.28%)	1,272 (5.18%)	96 (0.50%)	57 (0.23%)
Madagascar	5.81	6.20	12,764	18,718	1,187 (6.19%)	1,377 (4.40%)	224 (1.17%)	228 (0.73%)
Malawi	7.20	9.13	7,576	10,184	184 (3.60%)	373 (3.02%)	56 (1.10%)	87 (0.70%)

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	Mean annual ambient $PM_{2.5}$ ($\mu g/m^3$)		Total deaths from air pollution		Total welfare losses (Million 2011 U.S. dollars, PPP-adjusted; % GDP equivalent)		Total forgone labor output (Million 2011 U.S. dollars, PPP-adjusted; % GDP equivalent)	
Economy	**1990**	**2013**	**1990**	**2013**	**1990**	**2013**	**1990**	**2013**
Malaysia	18.49	14.40	4,452	7,612	3,763 (1.98%)	16,940 (2.45%)	436 (0.23%)	1,263 (0.18%)
Mali	33.65	35.93	12,028	14,057	679 (7.30%)	1,125 (4.63%)	215 (2.31%)	319 (1.31%)
Malta	21.96	14.09	175	159	355 (6.03%)	501 (4.10%)	9 (0.15%)	9 (0.08%)
Mauritania	76.51	70.13	1,592	2,559	277 (4.89%)	601 (4.32%)	144 (2.53%)	153 (1.10%)
Mexico	14.51	11.93	20,502	26,484	21,559 (2.01%)	37,709 (1.89%)	2,520 (0.23%)	1,815 (0.09%)
Moldova	32.11	17.06	4,026	2,908	1,903 (8.00%)	904 (5.59%)	112 (0.47%)	47 (0.29%)
Mongolia	11.14	8.33	2,690	2,424	966 (8.64%)	2,121 (6.90%)	125 (1.12%)	144 (0.47%)
Morocco	18.25	17.36	6,398	7,034	1,673 (1.69%)	3,723 (1.55%)	418 (0.42%)	435 (0.18%)
Mozambique	5.66	7.33	12,421	12,525	194 (3.86%)	659 (2.41%)	72 (1.44%)	131 (0.48%)
Nepal	29.68	46.09	16,436	22,038	1,033 (4.60%)	2,833 (4.68%)	195 (0.87%)	287 (0.47%)
Netherlands	28.15	16.84	9,581	7,428	33,067 (6.84%)	33,632 (4.41%)	792 (0.16%)	781 (0.10%)
New Zealand	8.49	8.64	730	728	1,988 (2.49%)	2,576 (1.74%)	48 (0.06%)	68 (0.05%)
Nicaragua	6.93	6.98	1,527	1,578	291 (2.32%)	490 (1.82%)	57 (0.45%)	32 (0.12%)
Niger	36.60	38.12	12,446	13,609	559 (7.80%)	583 (3.65%)	301 (4.20%)	220 (1.37%)

Economy	Mean annual ambient $PM_{2.5}$ ($\mu g/m^3$) 1990	Mean annual ambient $PM_{2.5}$ ($\mu g/m^3$) 2013	Total deaths from air pollution 1990	Total deaths from air pollution 2013	Total welfare losses (Million 2011 U.S. dollars, PPP-adjusted; % GDP equivalent) 1990	Total welfare losses (Million 2011 U.S. dollars, PPP-adjusted; % GDP equivalent) 2013	Total forgone labor output (Million 2011 U.S. dollars, PPP-adjusted; % GDP equivalent) 1990	Total forgone labor output (Million 2011 U.S. dollars, PPP-adjusted; % GDP equivalent) 2013
Nigeria	30.97	29.51	77,585	97,248	14,844 (5.12%)	37,609 (3.99%)	3,400 (1.17%)	7,338 (0.78%)
Norway	9.41	6.04	1,456	337	6,349 (3.46%)	1,990 (0.62%)	159 (0.09%)	37 (0.01%)
Oman	27.25	30.35	418	655	1,541 (2.43%)	2,619 (1.73%)	138 (0.22%)	106 (0.07%)
Pakistan	36.55	46.18	103,111	156,191	19,935 (6.06%)	47,713 (5.88%)	4,713 (1.43%)	6,582 (0.81%)
Panama	6.18	6.81	535	524	304 (1.64%)	912 (1.26%)	28 (0.15%)	32 (0.04%)
Papua New Guinea	6.56	5.90	3,753	5,256	335 (5.02%)	822 (4.39%)	30 (0.45%)	51 (0.27%)
Paraguay	8.61	14.13	1,526	3,010	667 (2.62%)	1,909 (3.59%)	92 (0.36%)	168 (0.31%)
Peru	7.84	12.90	8,362	9,374	3,105 (2.70%)	8,723 (2.52%)	537 (0.47%)	329 (0.10%)
Philippines	9.09	8.60	38,676	57,403	10,356 (4.17%)	26,758 (4.31%)	2,171 (0.87%)	2,774 (0.45%)
Poland	30.93	16.98	36,290	23,295	49,555 (12.82%)	61,626 (6.99%)	2,158 (0.56%)	1,362 (0.15%)
Portugal	14.79	9.90	5,492	3,282	13,058 (6.45%)	9,459 (3.51%)	439 (0.22%)	240 (0.09%)
Qatar	34.46	38.36	62	110	.. ..	1,178 (0.42%)	.. ..	44 (0.02%)
Romania	31.15	16.82	24,080	15,880	22,069 (8.51%)	26,658 (7.21%)	1,184 (0.46%)	792 (0.21%)

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	Mean annual ambient $PM_{2.5}$ ($\mu g/m^3$)		Total deaths from air pollution		Total welfare losses (Million 2011 U.S. dollars, PPP-adjusted; % GDP equivalent)		Total forgone labor output (Million 2011 U.S. dollars, PPP-adjusted; % GDP equivalent)	
Economy	**1990**	**2013**	**1990**	**2013**	**1990**	**2013**	**1990**	**2013**
Russian Federation	19.66	14.23	113,744	104,379	260,457 (9.08%)	279,801 (8.28%)	6,808 (0.24%)	8,604 (0.25%)
Rwanda	17.32	17.02	9,734	6,410	405 (6.57%)	534 (3.18%)	138 (2.24%)	117 (0.69%)
Saudi Arabia	49.71	54.12	3,945	6,285	14,625 (2.53%)	30,246 (2.05%)	1,390 (0.24%)	1,792 (0.12%)
Senegal	40.92	41.21	5,941	7,747	634 (4.53%)	1,005 (3.22%)	127 (0.91%)	120 (0.39%)
Serbia	26.46	15.78	5,535	4,627	.. ..	5,029 (5.45%)	.. ..	234 (0.25%)
Sierra Leone	23.69	23.92	5,129	5,284	380 (7.03%)	553 (4.88%)	143 (2.65%)	139 (1.23%)
Singapore	49.80	16.68	1,634	1,601	5,918 (5.66%)	11,153 (2.66%)	186 (0.18%)	298 (0.07%)
Slovak Republic	31.38	15.94	5,173	3,383	.. ..	9,764 (6.98%)	.. ..	173 (0.12%)
Slovenia	25.45	13.62	1,221	847	.. ..	2,557 (4.54%)	.. ..	44 (0.08%)
South Africa	11.68	14.33	20,398	19,802	17,067 (4.68%)	20,656 (3.12%)	3,072 (0.84%)	1,349 (0.20%)
South Sudan	14.96	16.33	7,369	9,966	.. ..	1,115 (5.02%)	.. ..	.. ..
Spain	17.82	11.65	18,484	14,689	50,472 (5.39%)	49,331 (3.39%)	1,550 (0.17%)	1,051 (0.07%)
Sri Lanka	11.45	17.15	11,239	19,693	2,714 (4.34%)	16,336 (7.75%)	567 (0.91%)	1,480 (0.70%)
Sudan	24.43	26.59	21,196	26,785	2,103 (4.65%)	6,824 (4.61%)	879 (1.95%)	690 (0.47%)
Sweden	11.66	7.32	4,220	1,329	14,052 (5.31%)	5,809 (1.39%)	256 (0.10%)	98 (0.02%)

Economy	Mean annual ambient $PM_{2.5}$ (µg/m³) 1990	Mean annual ambient $PM_{2.5}$ (µg/m³) 2013	Total deaths from air pollution 1990	Total deaths from air pollution 2013	Total welfare losses (Million 2011 U.S. dollars, PPP-adjusted; % GDP equivalent) 1990	Total welfare losses (Million 2011 U.S. dollars, PPP-adjusted; % GDP equivalent) 2013	Total forgone labor output (Million 2011 U.S. dollars, PPP-adjusted; % GDP equivalent) 1990	Total forgone labor output (Million 2011 U.S. dollars, PPP-adjusted; % GDP equivalent) 2013
Switzerland	22.92	17.60	3,927	3,016	18,165 (5.80%)	15,910 (3.58%)	606 (0.19%)	357 (0.08%)
Taiwan, China	18.95	19.53	12,915	16,739	24,980 (7.88%)	71,685 (7.26%)	.. ..	.. ..
Tajikistan	20.85	19.62	7,683	5,230	1,829 (9.50%)	779 (3.90%)	212 (1.10%)	64 (0.32%)
Tanzania	7.35	9.16	18,097	25,370	1,456 (4.00%)	3,552 (3.12%)	395 (1.08%)	483 (0.42%)
Thailand	17.24	22.36	31,173	48,819	15,317 (4.07%)	63,369 (6.29%)	1,155 (0.31%)	2,361 (0.23%)
Togo	25.39	25.40	3,597	4,123	261 (5.10%)	292 (3.18%)	133 (2.60%)	111 (1.21%)
Tunisia	19.96	16.35	2,690	3,792	1,093 (2.36%)	3,308 (2.83%)	205 (0.44%)	206 (0.18%)
Turkey	19.88	17.21	33,264	28,881	28,823 (5.00%)	48,625 (3.49%)	3,110 (0.54%)	2,011 (0.14%)
Turkmenistan	44.24	41.68	3,008	3,730	1,943 (6.34%)	4,307 (6.06%)	301 (0.98%)	330 (0.46%)
Uganda	15.09	17.63	15,789	20,658	587 (4.36%)	1,927 (3.16%)	141 (1.05%)	382 (0.63%)
Ukraine	29.24	15.09	62,160	49,078	52,774 (9.69%)	31,631 (8.34%)	1,805 (0.33%)	1,328 (0.35%)
United Arab Emirates	35.68	40.95	394	900	3,741 (1.80%)	5,233 (0.93%)	515 (0.25%)	528 (0.09%)
United Kingdom	19.74	10.81	45,453	19,803	131,836 (8.86%)	76,694 (3.21%)	3,035 (0.20%)	1,569 (0.07%)

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Economy	Mean annual ambient $PM_{2.5}$ ($\mu g/m^3$) 1990	Mean annual ambient $PM_{2.5}$ ($\mu g/m^3$) 2013	Total deaths from air pollution 1990	Total deaths from air pollution 2013	Total welfare losses (Million 2011 U.S. dollars, PPP-adjusted; % GDP equivalent) 1990	Total welfare losses (Million 2011 U.S. dollars, PPP-adjusted; % GDP equivalent) 2013	Total forgone labor output (Million 2011 U.S. dollars, PPP-adjusted; % GDP equivalent) 1990	Total forgone labor output (Million 2011 U.S. dollars, PPP-adjusted; % GDP equivalent) 2013
United States	16.42	10.75	127,240	91,045	490,053 (5.30%)	454,675 (2.80%)	17,942 (0.19%)	18,127 (0.11%)
Uruguay	6.06	6.68	310	358	414 (1.35%)	818 (1.24%)	13 (0.04%)	17 (0.03%)
Uzbekistan	27.27	25.53	17,975	19,085	3,440 (5.53%)	6,662 (4.40%)	534 (0.86%)	562 (0.37%)
Venezuela, RB	10.16	13.43	2,517	5,738	4,563 (1.59%)	12,229 (2.28%)	381 (0.13%)	555 (0.10%)
Vietnam	19.09	25.47	57,774	66,314	4,758 (4.80%)	23,832 (5.18%)	442 (0.45%)	1,557 (0.34%)
West Bank and Gaza	26.64	26.36	577	1,006	.. ..	309 (1.65%)	.. ..	.. ..
Yemen, Rep.	32.50	36.19	10,490	13,442	2,298 (5.66%)	3,229 (3.45%)	.. ..	.. ..
Zambia	9.38	11.78	5,843	8,549	811 (4.29%)	2,027 (3.67%)	205 (1.09%)	315 (0.57%)
Zimbabwe	7.36	9.07	4,776	7,391	734 (2.77%)	699 (2.78%)	196 (0.74%)	138 (0.55%)

Sources: World Bank and IHME.

Note: Estimates of mean annual exposure to ambient $PM_{2.5}$ are generated by combining data from atmospheric chemistry transport models, satellite observations of aerosols in the atmosphere, and ground-level monitoring of particles. Uncertainty in the data on exposure to ambient air pollution is greatest for areas with high concentrations of windblown mineral dust, emissions sources that are highly variable or at too small of scale to be captured by the satellite observations and models, high levels of pollution during wintertime and nighttime when satellite retrievals are limited, or rugged local topography. Total deaths from air pollution represent the combined health impacts of ambient $PM_{2.5}$, household air pollution, and ambient ozone pollution. Given exposure, uncertainty in the estimates of health impacts may arise from the integrated exposure-response functions (IERs) used to describe the health risks associated with exposure to different levels of pollution. The IERs draw from studies of the relative risks of ambient air pollution, second-hard smoking, active smoking, and household air pollution. Total welfare losses are estimated using a value of statistical life (VSL), which is an aggregate measure of people's willingness to pay (WTP) to reduce fatality risks. Country-specific VSLs are derived from empirical studies done in high-income countries, which are then adjusted to account for cross-country differences in per capita income. The absence of WTP studies in many low- and middle-income countries contributes to the uncertainty of the VSL-based estimates of welfare losses, as does a lack of consensus about the elasticity of the VSL with respect to income. Forgone labor output is a measure of lost labor earnings due to premature mortality. The principal sources of uncertainty in the estimates of forgone labor output include assumptions about future rates of income growth and the discount rate; ".." = data not available.


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