AMERICA IS ALL IN

ALL-IN CLIMATE ACTION FOR IMPROVED U.S. AIR QUALITY & HEALTH BENEFITS

Authors: Wei Peng, Xinyuan Huang, Alicia Zhao, Yang Ou, Shannon Kennedy, Gokul Iyer, Haewon McJeon, Ryna Cui, Nate Hultman

KEY FINDINGS

- **An all-of-society approach to achieving U.S. climate goals**—integrating federal policies from Congress and the Executive Branches with actions from states, cities, businesses, and communities—**can realize improved air quality and health benefits across every state and in nearly every county** in the United States.

- Climate-smart implementation of existing policies, including the Inflation Reduction Act and non-federal actions like renewable portfolio standards (RPS) and electric vehicle (EV) sales targets, can **reduce national and state-level premature deaths attributable to air pollution by nearly 3,300 annual deaths in 2030** and can have a cumulative impact of nearly 35,800 fewer deaths from 2024 to 2035 compared to no climate action.

- Building on these current policies, **an all-of-society approach will further reduce national and state-level premature deaths**, with an estimated 5,400 fewer annual deaths in 2030 and a cumulative impact of nearly 63,600 fewer deaths from 2024 to 2035 compared to no climate action.

- **An all-of-society approach will result in improved air quality and health benefits across every state and nearly every county in the United States.** Climate-smart implementation reduce deaths attributable to PM2.5 in 2030 by 10-15% in most states, with large reductions in the Northeast and Midwest regions: West Virginia by 18% and Maryland and Pennsylvania by 15% each.

- **Under an all-of-society approach, nearly every county in America will experience reductions in premature deaths related to PM2.5**—more than 5% in two-thirds of counties and more than 10% in one-third of counties.

- Actions such as **transitioning away from coal power to renewable energy, adopting electric vehicles, and enhancing energy efficiency across all sectors can significantly decrease air pollutants**, leading to substantial health co-benefits across the U.S.

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SUBSTANTIAL HEALTH CO-BENEFITS OF AN AMBITIOUS, ALL-IN U.S. CLIMATE POLICY

The United States has set ambitious climate goals to reduce greenhouse gas (GHG) emissions, including its national climate target of reducing net emissions by 50-52% by 2030 from 2005 levels and a 2050 net-zero emissions goal ("The Long-Term Strategy," 2021). Achieving this goal requires action across all sectors of the economy to slash emissions from all GHGs, including carbon dioxide (CO_2) and methane (CH_4). With the historic passage of the Inflation Reduction Act of 2022 and the Bipartisan Infrastructure Law of 2021, and climate action and leadership from states, cities, businesses, and more, the United States has set a path forward to achieve its 2030 climate target.

Actions to reduce GHG emissions, such as shifting away from fossil fuels and improving energy efficiency, can also yield co-benefits through reduced air pollutants and improved air quality. Although air pollutants in the United States have reduced substantially since the enactment of ambient air quality standards through the Clean Air Act, they remain a public health concern. Today, nearly 36% of the U.S. population—119.6 million people—still live in areas with unhealthy levels of air pollution, with a record number of daily spikes in air pollutants reported under current national standards (American Lung Association, 2023).

Ambient particulate matter (PM2.5) is the largest air pollution-related contributor to premature death globally (Murray et al., 2020; Silva et al., 2013). In the United States, exposure to ambient PM2.5 is associated with 30,000 to 200,000 premature deaths annually, exceeding the number of deaths from murders and car crashes combined (Fann et al., 2012; Jbaily et al., 2022; Murray et al., 2020; Tessum et al., 2021). Ambient PM2.5 can be produced by both primary and secondary sources. Primary PM2.5 is emitted directly, and secondary PM2.5 is formed by precursor emissions of nitrogen oxides (NOx), sulfur dioxide (SO_2), and others. Elevated levels of NOx in the air are also closely linked to asthma and other respiratory conditions (World Health Organization, 2023).

Importantly, poor air quality will have disparate impacts across states, counties, and communities within the United States depending on various factors such as income, population density, ethnicity, etc. (Jbaily et al., 2022; Tessum et al., 2021). As policymakers begin to address these disparities, it will be important to use location-specific strategies to reduce air pollution levels (Wang et al., 2022).

It is well-known that an all-of-society or "all-in" approach, encompassing federal, state, cities, businesses, universities, faith groups, healthcare, and more, is critical to achieving U.S. climate goals (Zhao et al., 2022). But what can such an approach do to reduce emissions from air pollutants and achieve better air quality? In this analysis, we study the impacts of varying levels of climate action on the levels of key air pollutants and associated public health outcomes on a county-by-county basis in the United States.

We assess air quality impacts by pairing an air quality model, InMAP, with an integrated assessment model, Global Change Analysis Model (GCAM-USA). We first model three scenarios using GCAM-USA, which projects economy-wide emissions at the state level. The *Existing Policies* scenario includes existing, on-the-books climate actions, including the IRA and non-federal actions like renewable portfolio standards (RPS) and electric vehicle (EV) sales targets. The *All-In* scenario builds upon this scenario and assumes higher ambition from non-federal and federal actors on top of the *Existing Policies* scenario. Specifically, the *All-In* scenario incorporates the climate-smart application of IRA from climate-leading states, with an all-of-society, accelerated approach to a national climate strategy. Additional policies to achieve the U.S. 2030 climate goal occur across every sector, and action at the state, city, and business levels is critical to solidifying our transition to a clean, healthy, and prosperous future. By layering ambitious actions on top of the *Existing Policies* scenario, this *All-In* scenario shows a pathway for the United States to achieve 52% emissions reductions from 2005 levels by 2030. Finally, the No Climate Action scenario does not include any current federal or non-federal climate policies and serves as a baseline to compare the impacts of the two policy scenarios.

To quantify the impact of these mitigation scenarios on United States air quality, we first downscale the GCAM-USA projected state-level emissions to a finer spatial resolution (12 km by 12 km) using the present-day spatial patterns based on the 2017 National Emissions Inventory (EPA, National Emissions Inventory 2017 Data). We then use a reduced-form air quality model, InMAP (Intervention Model for Air Pollution (Tessum et al., 2017)), to simulate the impacts of emissions on annual average concentrations of PM2.5. We then estimate the annual deaths attributable to PM2.5 at the county level using a well-established methodology for health impact assessment (Anenberg et al., 2012). *Additional details on the methodology to quantify health impacts are available in the Technical Appendix.*

In 2015, we estimated that ~68,300 annual premature deaths were attributable to exposure to ambient particulate matter (PM2.5), which is in line with other studies (Markandya et al., 2018; Murray et al., 2020). In 2030, our No Climate Action scenario—our baseline scenario—projects 3,300 fewer PM2.5-attributable annual deaths compared to 2015 levels due to shifts away from fossil fuels, coal, and efficiency improvements that occur without additional climate policies.

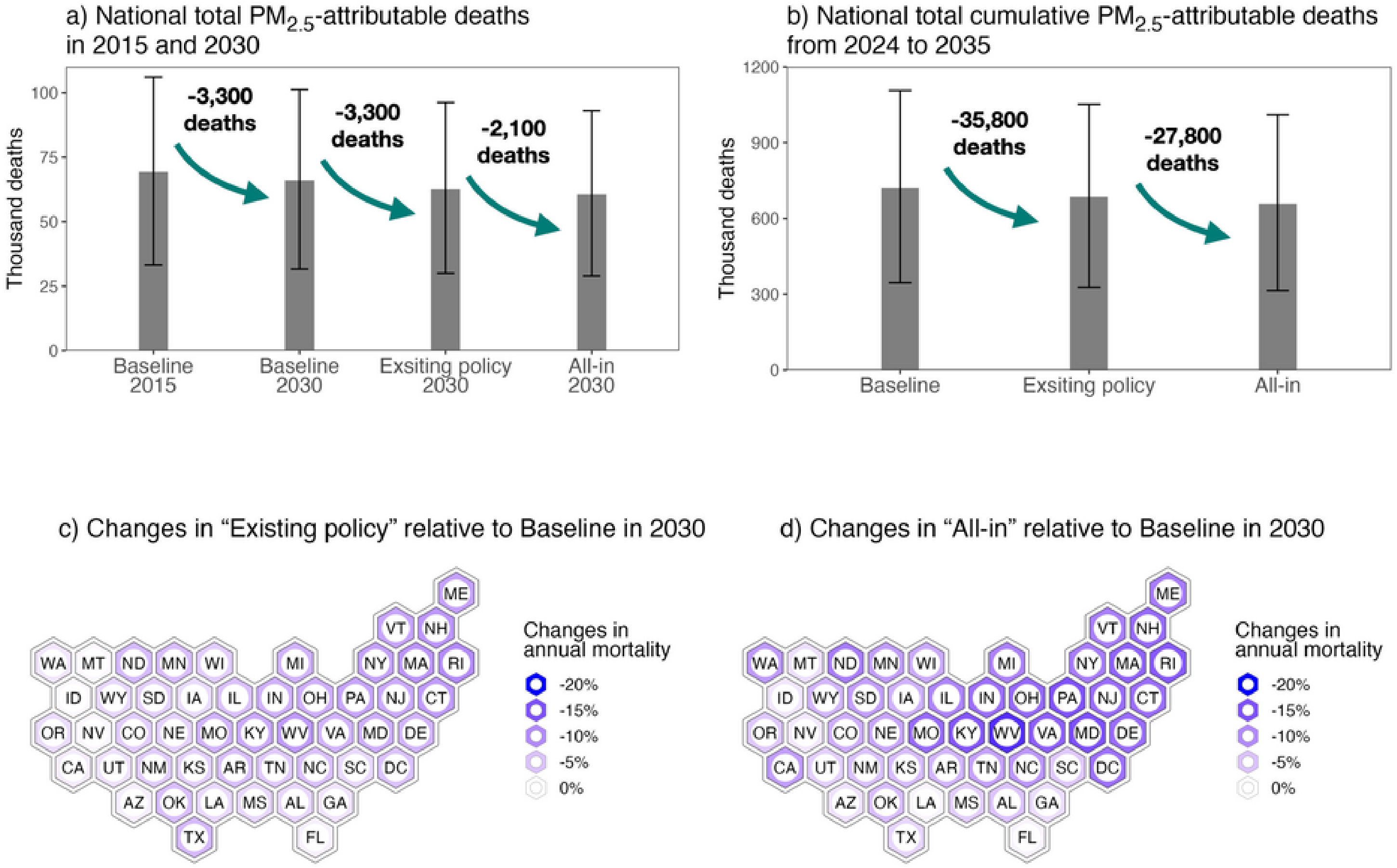


Figure 1. Health benefits from climate policy. Panel a) shows the annual, nationwide deaths attributable to PM2.5 in 2015 and 2030, from the No Climate Action scenario. Panel b) shows the cumulative nationwide deaths from 2024 to 2035. The error bars in Panel a) and b) are based on the 95% confidence interval of the concentration-response relationships used to calculate the premature deaths (CITATION). Panel c) and d) shows the state-level changes in deaths attributable to PM2.5 in 2030 in the two climate policy scenarios relative to No Climate Action. These two panels are based on the central estimates for the deaths attributable to PM2.5.

When climate actions are layered on top of the No Climate Action scenario, we see substantial air quality and health benefits. Under the Existing Policies scenario, we project ~3,300 fewer annual national deaths in 2030 relative to No Climate Action (Figure 1a). Such benefits are spread across the country, with most states experiencing a 5-10% reduction in deaths attributable to PM2.5 (Figure 1c). Under the All-In scenario, we see further reductions of ~2,100 annual national deaths in 2030, resulting in a total of ~5,400 fewer deaths in 2030 relative to No Climate Action. Most states are expected to reduce deaths attributable to PM2.5 by 10-15% relative to No Climate Action. In contrast to Existing Policies, these additional benefits occur in all 50 U.S. states.

The largest percentage reductions are found in the Northeast and Midwest regions: West Virginia leads with a 18% reduction, followed by Maryland and Pennsylvania by 15% each. The largest absolute reductions are found in states with large populations. California reduces ~770 air pollution-related deaths, followed by New York with ~580 fewer deaths and Pennsylvania with ~450 fewer deaths (Figure 1d) compared to the No Climate Action scenario.

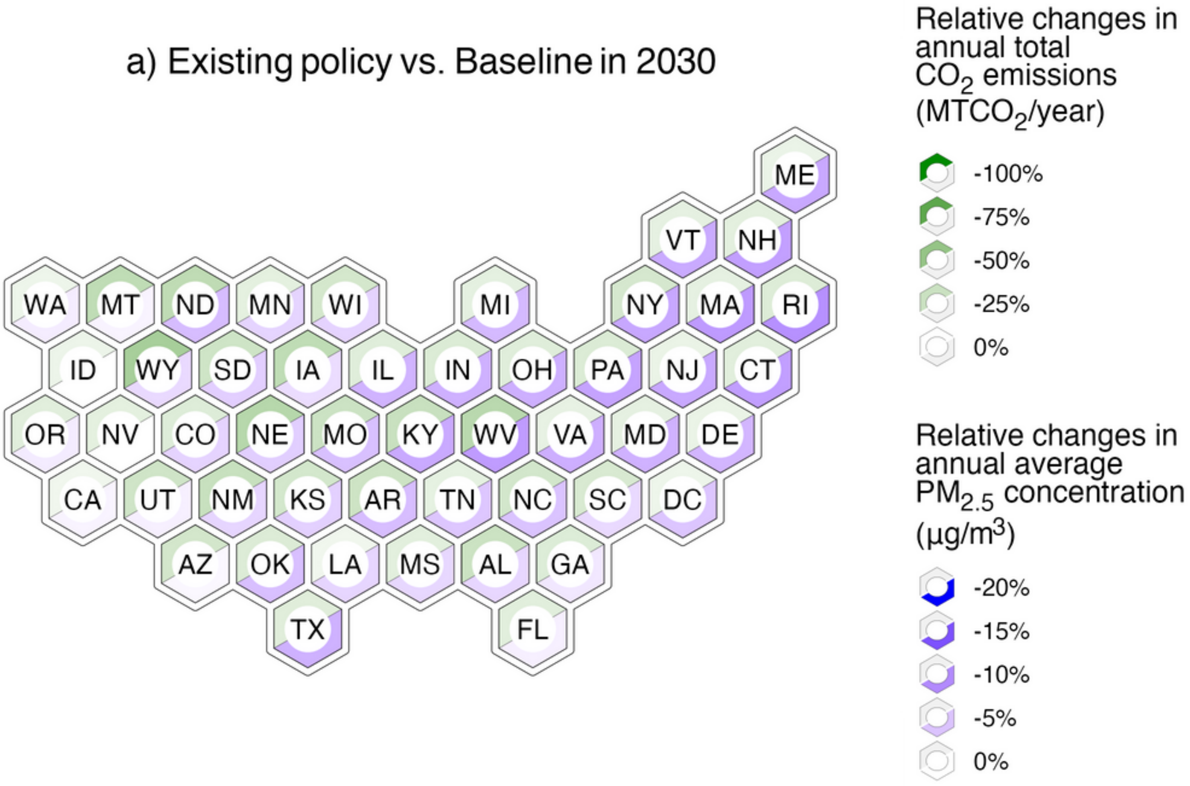
In terms of cumulative benefits, the Existing Policies scenario results in ~35,800 fewer cumulative deaths from 2024 to 2035 relative to the No Climate Action scenario, while the All-In scenario results in ~63,600 fewer cumulative deaths over the same period (Figure 1b).

SUBNATIONAL DISTRIBUTION OF THE CO_2, AIR QUALITY, AND HEALTH IMPACTS

The CO_2, air quality, and health impacts are distributed unevenly across states and counties, and these regional distributions also differ across scenarios. While the absolute changes are generally more pronounced in states with larger economies and populations, the percentage changes show a different pattern.

Under Existing Policies, CO_2 emissions in 2030 decrease by 7-41% across the states, relative to No Climate Action, and annual average concentrations of ambient PM2.5 will decrease by up to 10%. The relationship between CO_2 mitigation and PM2.5 reduction varies across states (Figure 2a). For instance, New York and Wisconsin are expected to lower their CO_2 emissions by roughly 20%. However, PM2.5 concentrations in New York improve by 8%, but Wisconsin only improves by 4%. This state-level variation reflects differences in energy structure across these states. New York sees a shift from traditional biomass to clean energy, which significantly impacts ambient PM2.5 concentrations given the high pollution intensity of biomass. In comparison, Wisconsin primarily sees reductions in coal power, which has a lower pollution intensity than biomass, and therefore realizes lower improvement in PM2.5 concentration.

With additional climate actions under the All-In scenario, we see even greater CO_2 emissions reductions potential across each state. These substantial reductions realize up to 18% lower annual average concentrations of ambient PM2.5 in 2030, relative to No Climate Action (Figure 2b). States with particularly large potential to reduce CO_2 and ambient PM2.5 include West Virginia (68% reduction in CO_2 and 18% in ambient PM2.5), Pennsylvania (37% and 15%), and Maryland (30% and 15%). This suggests a critical opportunity for additional air quality benefits if these states strengthen their actions beyond existing policies.


a) Existing policy vs. Baseline in 2030

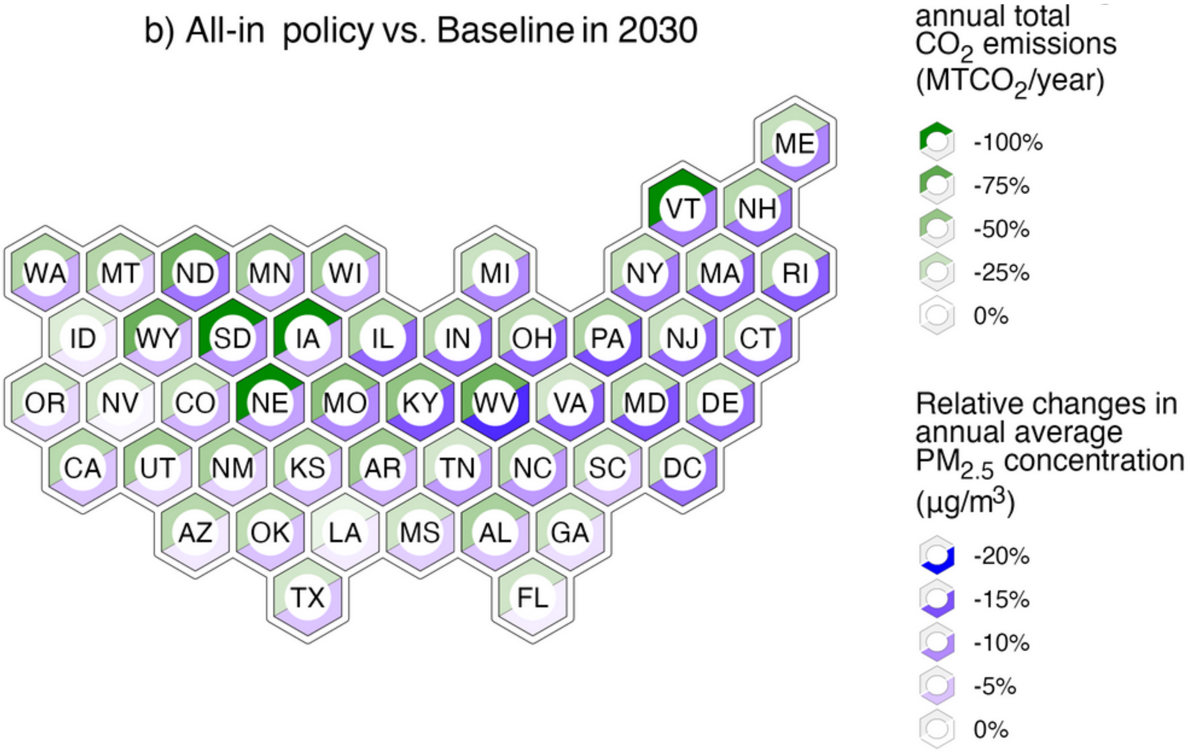

b) All-in policy vs. Baseline in 2030

Figure 2. State-level reductions in CO_2 and ambient PM2.5 concentrations in the Existing Policies and All-In scenarios, relative to No Climate Action, in 2030. The state-level PM2.5 concentrations here are population-weighted values that combine the simulated PM2.5 concentrations at 12 by 12 km resolution and county-level populations.

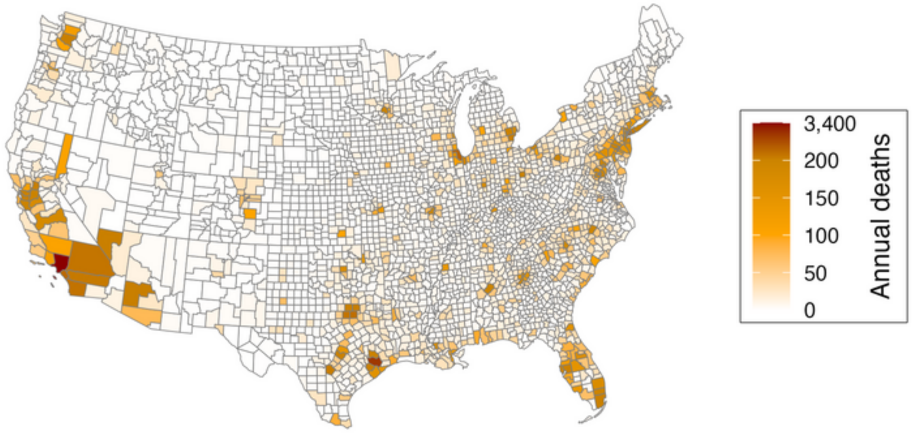
While climate actions contribute to the health impact results, other factors play a role as well. Sociodemographic factors that determine the population size (e.g., growing population) and vulnerability (e.g., aging and improvements in general health conditions) also impact the United State's ability to mitigate the health impacts from air pollution (Yang et al., 2023). In 2015, deaths attributable to PM2.5 were especially high in urban areas due to the co-occurrence of dense population and high pollution (Figure 3a). We expect such geographic patterns to persist because population size remains a key factor in determining health impacts.

Importantly, the health benefits of achieving U.S. climate goals are widely shared across every state in the contiguous U.S. We find significant emissions reductions and health benefits in both urban and rural areas across the United States (Figure 3). Under the Existing Policies scenario, 43% of counties expect deaths attributable to PM2.5 to decrease by more than 5%, relative to No Climate Action (Figure 3b). With additional efforts under the All-In scenario, 67% of counties expect reductions of more than 5%, and 31% of counties expect reductions of more than 10% (Figure 3c).

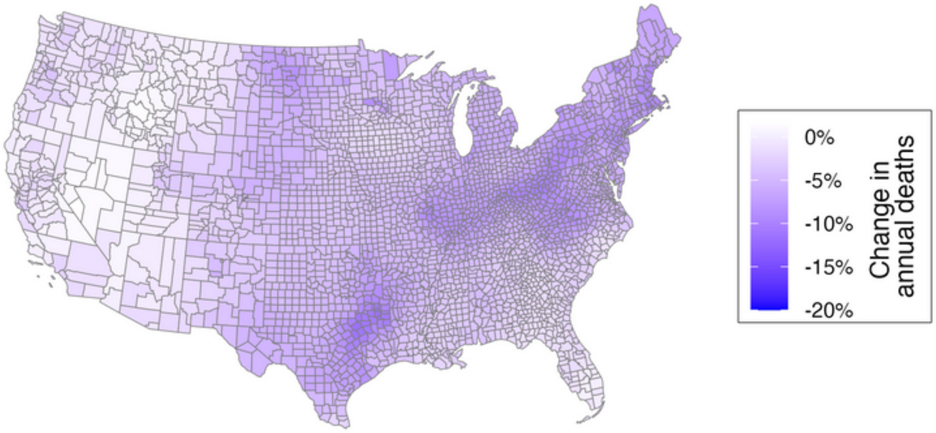
The additional benefits of an enhanced all-of-society approach are particularly large in the Greater Los Angeles area, the San Francisco Bay Area, and the Seattle metropolitan area. This is a combined effect of a large reduction in ambient PM2.5 concentrations led by more stringent climate policies in California and Washington, as well as the high population density in these areas. Significant improvements also occur across the country's largest coal producers and consumers—North Dakota, West Virginia, and Pennsylvania—where coal is assumed to be replaced by a growing clean energy industry.

It is also important to note that high-ambition policies are needed across the entire economy to prevent emissions from leaking into other sectors. Some states that have increased ambition in one sector but not others may see increased PM2.5 emissions under the All-In scenario compared to the Existing Policies scenario.

a) County-level $PM_{2.5}$-attributable deaths, Baseline, 2030



b) County-level $PM_{2.5}$-attributable deaths, Existing policy vs. Baseline, 2030



c) County-level $PM_{2.5}$-attributable deaths, All-in vs. Baseline, 2030

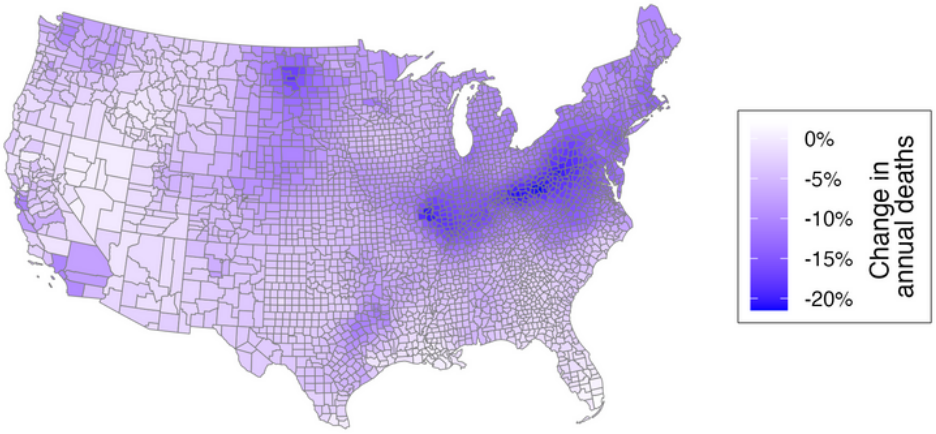


Figure 3. County-level health impacts. Panel a) deaths attributed to PM2.5 in 2030 in the No Climate Action scenario. Panel b) and c) Changes in deaths attributed to PM2.5 in the Existing Policies and All-in scenarios compared to No Climate Action. Here the deaths attributed to PM2.5 are calculated based on the central estimate of the concentration-response relationships (Krewski et al., 2009).

UNPACKING THE UNDERLYING DRIVERS FOR HEALTH CO-BENEFITS TO CLIMATE ACTION

To unpack the underlying drivers that lead to the health results, we conducted a decomposition analysis to estimate the impacts of four individual factors on the aggregate changes in deaths attributable to PM2.5: (a) population growth, (b) population aging, (c) changes in the general health condition measured using the baseline mortality rates that do not consider the effects of changing pollution exposure, and (d) exposure level to ambient PM2.5 (Figure 4). The first three are socio-demographic factors that affect the exposed population's size and vulnerability. At the national level, we find that population growth and aging are key factors increasing the future deaths attributed to PM2.5. Holding the other factors constant, the anticipated population growth and aging from 2015 to 2030 can increase deaths attributed to PM2.5 by 13% and 26%, respectively.

In contrast, improving general health conditions and air quality are key to lowering future deaths attributed to PM2.5. Holding the other factors constant, improving general health conditions can reduce deaths attributed to PM2.5 by 20%. In addition, the decrease in ambient PM2.5 concentration can reduce deaths attributed to PM2.5 by 23% in the No Climate Action scenario, 28% in the Existing Policies scenario, and 31% in the All-In scenario (Figure 4). Given the important role of sociodemographic factors, our finding highlights the importance of substantially lowering the air pollution level to near-zero levels to counteract the effects of sociodemographic trends, such as a growing and aging population, that may make future populations more vulnerable to air pollution exposure.

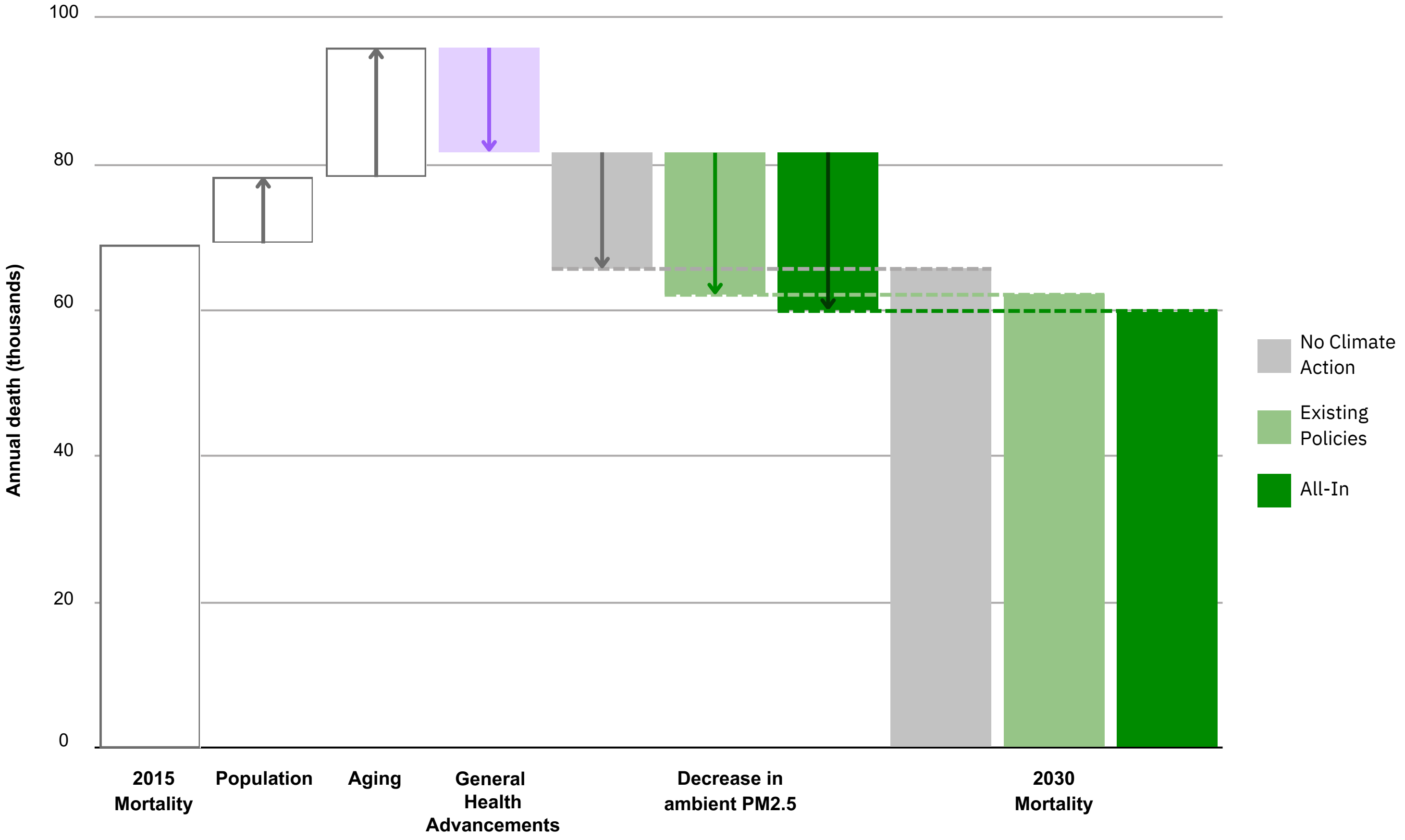


Figure 4. Contribution of population, aging, general health advancements (e.g. improved medicine), and decreases in ambient PM2.5 (per scenario) to the changes in deaths attributed to PM2.5 from 2015 to 2030.

SECTOR-BY-SECTOR IMPACTS ON AIR QUALITY

Different sectors are responsible for emitting different types of air pollutants. For example, the industry sector is a key contributor to SO_2, NOx, and PM2.5 emissions (Figure 5c – 5h), both at present and in 2030. In comparison, the power sector is a major SO_2 and NOx contributor at present, but its importance declines in 2030 due to the transition away from unabated coal and natural gas. The transportation sector is a major contributor to NOx emissions from gasoline combustion, whereas the residential and commercial buildings sector is a major contributor to particulate emissions due to the burning of biomass for heating.

Under both Existing Policies and All-In, we observe large reductions in SO_2, NOx, and PM2.5 emissions, owing to the shift from fossil fuels to renewable energy in the power sector, electrification and more efficient processes in the industrial sector, and more clean energy use in the building sector (from traditional biomass and fossil fuel to electricity). We also observe further NOx reductions in the transport sector in the All-in scenario due to the switch to electric vehicles. The ambition inherent to the climate-smart implementation of All-In policies allows for additional reductions.

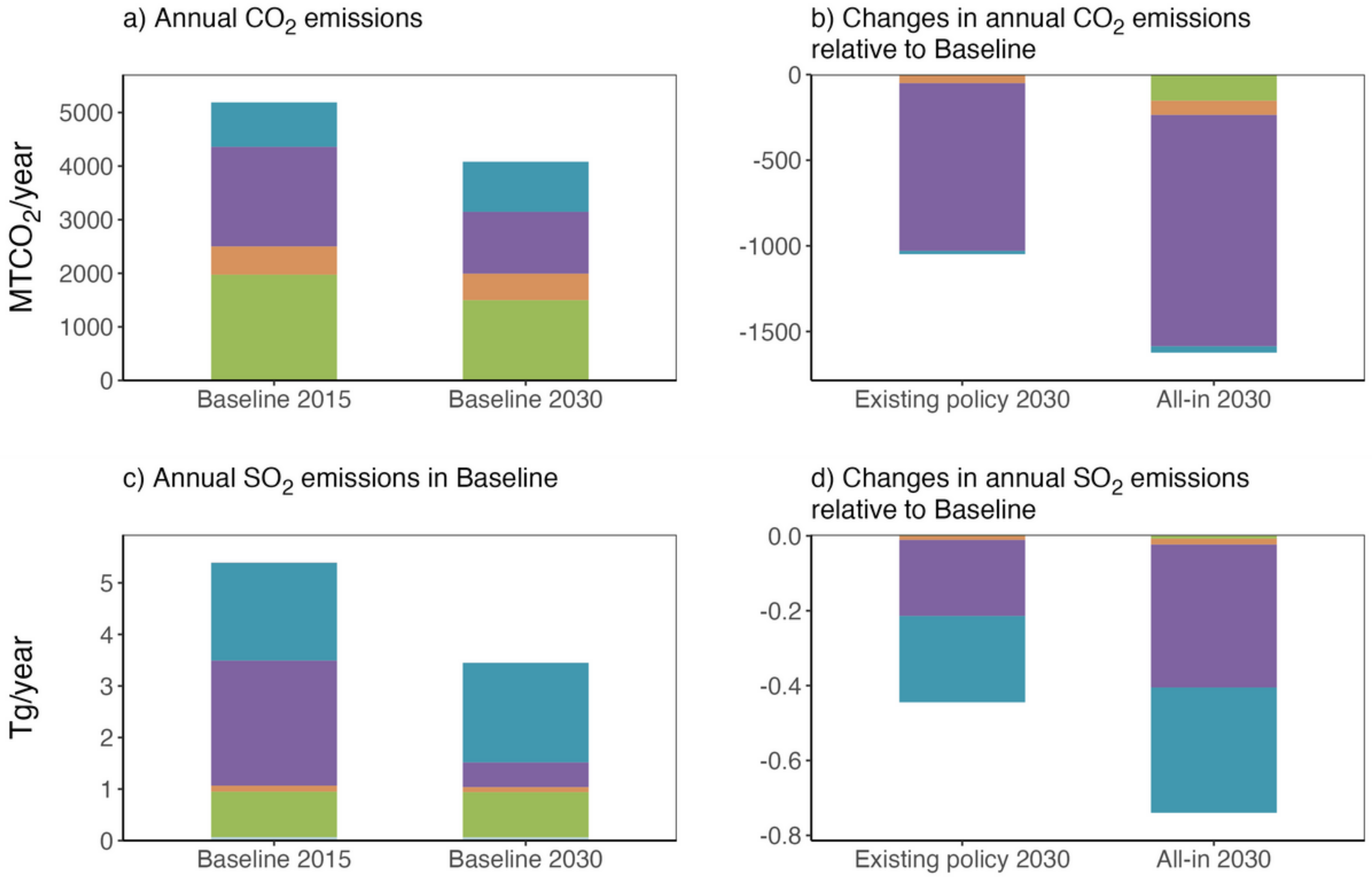


Figure 5. Emissions by sector. Panel a) shows the annual CO_2 emissions in No Climate Action in 2015 and 2030. Panel b) shows the changes in annual CO_2 emissions in the two policy scenarios relative to No Climate Action in 2030. *(Continued on next page).*

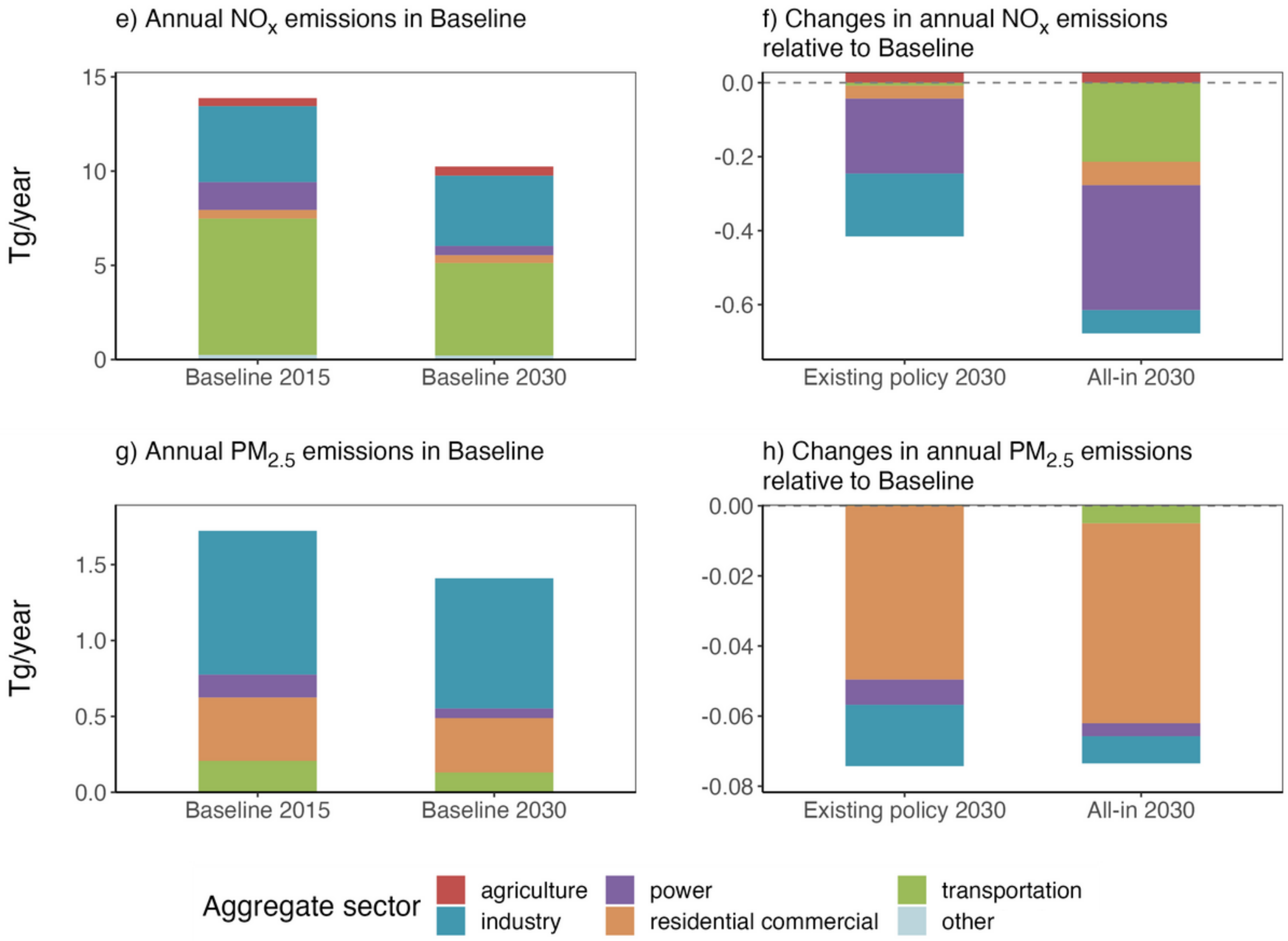


Figure 5. Emissions by sector (continued). Panel c) shows the annual SO_2 emissions in No Climate Action in 2015 and 2030. Panel d) shows the changes in annual SO_2 emissions in the two policy scenarios relative to No Climate Action in 2030. Panel e) shows the annual NOx emissions in No Climate Action in 2015 and 2030. Panel f) shows the changes in annual NOx emissions in the two policy scenarios relative to No Climate Action in 2030. Panel g) shows the annual primary PM2.5 emissions in No Climate Action in 2015 and 2030. Panel h) shows the changes in annual primary PM2.5 emissions in the two policy scenarios relative to No Climate Action in 2030. Here the "Other" emissions consider land use activities projected by the GCAM-USA model. Here we focus primarily on energy-related emissions and do not consider fire emissions that will likely become a major pollution source in the future.

POLICY OPPORTUNITIES

An all-in approach to climate action can achieve greater health benefits in the United States, yet air quality disparities persist. Our analysis demonstrates substantial regional variations in pollution exposure and associated health damages across the country. In addition, the unequal burden of unhealthy air on diverse communities, particularly lower-income and minority populations, underscores the imperative for comprehensive climate action and policy implementation across society (Goforth & Nock, 2022; Picciano et al., 2023).

Due to this unequal burden, targeted policies across all sectors will be critical (Wang et al., 2023). This analysis shows that all counties across the United States benefit from an all-in approach to climate action by 2030. Yet, racial and ethnic minorities in the United States may still face elevated exposure, especially from PM2.5 (Goforth & Nock, 2022; Saha et al., 2022). Industry, construction, light-duty gasoline vehicles, and heavy-duty diesel vehicles are often among the largest sources of this disparity, but this can vary widely by source type and location (Picciano et al., 2023). Because of a legacy of discriminating housing policy and systemic inequity (Lane et al., 2022; Liu & Marshall, 2023), exposure disparities have persisted even with improved air quality across the United States over the past few years (Tessum et al., 2021). Targeting locally important sources for mitigation across all sectors can help counter this persistence. Key actions in critical sectors include:

Improve industrial sector regulations to clean up industrial processes. The industrial sector has been and will continue to be one of the largest contributors to air pollution and health damage. States and cities can promote equity and restorative justice for low-income and disadvantaged communities by requiring manufacturers that exceed a certain emission threshold to submit a cost analysis and timeline for process improvements. States can also set construction targets for using low-carbon materials and, in turn, increase the demand for materials produced by factories and businesses that pollute less (Phelps et al., 2023). Yet, the industrial sector is traditionally harder to abate. Diverse industrial processes require different emission abatement strategies. The substantial impacts of industrial facilities in downwind states also require coordinated efforts across states. Currently, the EPA has the New Source Performance Standards that regulate the emissions of large point sources and the Cross-State Air Pollution Rule that regulates inter-state pollution impacts from power plants. Both policies have the potential to expand their scope and increase the stringency to help mitigate the emissions of industrial sources in the future (US EPA, 2023).

Secure the transition away from coal power to renewable energy sources. This analysis finds that though the power sector is currently a key contributor to SO_2 and NOx, the intensity of these emissions will likely decline by 2030 due to the transition away from coal power. IRA includes significant funding for key tax credits in the power sector, including the Investment Tax Credit (ITC) and Production Tax Credit (PTC), which can accelerate the development and deployment of clean energy and storage technologies to replace coal. Additionally, IRA's Energy Infrastructure Reinvestment provision aids the transition away from fossil fuels, and competitive grants through the Greenhouse Gas Reduction Fund specifically set aside funds for low-income and disadvantaged communities to deploy low and zero-emission technologies. States and local governments can play a role by actively applying for these funds and ensuring that they maximize the uptake of the tax credits (Horowitz et al., 2022); further, they have the jurisdiction to enhance or set their own renewable energy targets (Peng & Ou, 2022) and coal exit policies (Henneman et al., 2023) to support affected communities.

Accelerating the adoption of electric vehicles. Even if powered partially by fossil fuels, electrification of road vehicles brings substantial air quality and health benefits, particularly in reducing PM2.5-attributable mortality. Variable impacts among metropolitan areas underscore the importance of tailored incentives for EV deployment, offering a unique opportunity to enhance public health nationwide (Choma et al., 2020). IRA's Clean Vehicle Tax Credit for new, used, and commercial vehicles—including medium- and heavy-duty vehicles—is vital to electric vehicle (EV) adoption. Furthermore, widespread adoption of California's ambitious zero-emissions vehicle targets and investments in EV charging infrastructure can help accelerate commercial fleet electrification. Under the *All-In* scenario, these policies help drive the 2030 EV market share to 48%, 38%, and 100% for cars, SUVs, freight trucks, and buses.

REFERENCES

Anenberg, S. C., Schwartz, J., Shindell, D., Amann, M., Faluvegi, G., Klimont, Z., Janssens, -Maenhout Greet, Pozzoli, L., Van, D. R., Vignati, E., Emberson, L., Muller, N. Z., West, J. J., Williams, M., Demkine, V., Hicks, W. K., Kuylenstierna, J., Raes, F., & Ramanathan, V. (2012). Global Air Quality and Health Co-benefits of Mitigating Near-Term Climate Change through Methane and Black Carbon Emission Controls. Environmental Health Perspectives, 120(6), 831–839. https://doi.org/10.1289/ehp.1104301

Choma, E. F., Evans, J. S., Hammitt, J. K., Gómez-Ibáñez, J. A., & Spengler, J. D. (2020). Assessing the health impacts of electric vehicles through air pollution in the United States. Environment International, 144, 106015. https://doi.org/10.1016/j.envint.2020.106015

Dedoussi, I. C., Eastham, S. D., Monier, E., & Barrett, S. R. H. (2020). Premature mortality related to United States cross-state air pollution. Nature, 578(7794), Article 7794. https://doi.org/10.1038/s41586-020-1983-8

EPA, National Emissions Inventory 2017 Data. Available at: Https://www.epa.gov/air-emissions-inventories/2017-national-emissions-inventory-nei-data [accessed Oct 31, 2023]. (n.d.).

Fann, N., Lamson, A. D., Anenberg, S. C., Wesson, K., Risley, D., & Hubbell, B. J. (2012). Estimating the National Public Health Burden Associated with Exposure to Ambient PM2.5 and Ozone. Risk Analysis, 32(1), 81–95. https://doi.org/10.1111/j.1539-6924.2011.01630.x

Goforth, T., & Nock, D. (2022). Air pollution disparities and equality assessments of US national decarbonization strategies. Nature Communications, 13(1), Article 1. https://doi.org/10.1038/s41467-022-35098-4

Henneman, L., Choirat, C., Dedoussi, I., Dominici, F., Roberts, J., & Zigler, C. (2023). Mortality risk from United States coal electricity generation. Science, 382(6673), 941–946. https://doi.org/10.1126/science.adf4915

Horowitz, R., Binsted, M., Browning, M., Fawcett, A., Henly, C., Hultman, N., McFarland, J., & McJeon, H. (2022). The energy system transformation needed to achieve the US long-term strategy. Joule, 6(7), 1357–1362. https://doi.org/10.1016/j.joule.2022.06.004

Jbaily, A., Zhou, X., Liu, J., Lee, T.-H., Kamareddine, L., Verguet, S., & Dominici, F. (2022). Air pollution exposure disparities across US population and income groups. Nature, 601(7892), Article 7892. https://doi.org/10.1038/s41586-021-04190-y

Krewski, D., Jerrett, M., Burnett, R. T., Ma, R., Hughes, E., Shi, Y., Turner, M. C., Pope, C. A., Thurston, G., Calle, E. E., Thun, M. J., Beckerman, B., DeLuca, P., Finkelstein, N., Ito, K., Moore, D. K., Newbold, K. B., Ramsay, T., Ross, Z., … Tempalski, B. (2009). Extended follow-up and spatial analysis of the American Cancer Society study linking particulate air pollution and mortality. Research Report (Health Effects Institute), 140, 5–114; discussion 115-136.

Lane, H. M., Morello-Frosch, R., Marshall, J. D., & Apte, J. S. (2022). Historical Redlining Is Associated with Present-Day Air Pollution Disparities in U.S. Cities. Environmental Science & Technology Letters, 9(4), 345–350. https://doi.org/10.1021/acs.estlett.1c01012

Liu, J., & Marshall, J. D. (2023). Spatial Decomposition of Air Pollution Concentrations Highlights Historical Causes for Current Exposure Disparities in the United States. Environmental Science & Technology Letters, 10(3), 280–286. https://doi.org/10.1021/acs.estlett.2c00826

Markandya, A., Sampedro, J., Smith, S. J., Van Dingenen, R., Pizarro-Irizar, C., Arto, I., & González-Eguino, M. (2018). Health co-benefits from air pollution and mitigation costs of the Paris Agreement: A modelling study. The Lancet Planetary Health, 2(3), e126–e133. https://doi.org/10.1016/S2542-5196(18)30029-9

Murray, C. J. L., Aravkin, A. Y., Zheng, P., Abbafati, C., Abbas, K. M., Abbasi-Kangevari, M., Abd-Allah, F., Abdelalim, A., Abdollahi, M., Abdollahpour, I., Abegaz, K. H., Abolhassani, H., Aboyans, V., Abreu, L. G., Abrigo, M. R. M., Abualhasan, A., Abu-Raddad, L. J., Abushouk, A. I., Adabi, M., … Lim, S. S. (2020). Global burden of 87 risk factors in 204 countries and territories, 1990–2019: A systematic analysis for the Global Burden of Disease Study 2019. The Lancet, 396(10258), 1223–1249. https://doi.org/10.1016/S0140-6736(20)30752-2

Peng, W., & Ou, Y. (2022). Integrating air quality and health considerations into power sector decarbonization strategies. Environmental Research Letters, 17(8), 081002. https://doi.org/10.1088/1748-9326/ac8361

Picciano, P., Qiu, M., Eastham, S. D., Yuan, M., Reilly, J., & Selin, N. E. (2023). Air quality related equity implications of U.S. decarbonization policy. Nature Communications, 14(1), Article 1. https://doi.org/10.1038/s41467-023-41131-x

Saha, P. K., Presto, A. A., Hankey, S., Marshall, J. D., & Robinson, A. L. (2022). Racial-ethnic exposure disparities to airborne ultrafine particles in the United States. Environmental Research Letters, 17(10), 104047. https://doi.org/10.1088/1748-9326/ac95af

Silva, R. A., West, J. J., Zhang, Y., Anenberg, S. C., Lamarque, J.-F., Shindell, D. T., Collins, W. J., Dalsoren, S., Faluvegi, G., Folberth, G., Horowitz, L. W., Nagashima, T., Naik, V., Rumbold, S., Skeie, R., Sudo, K., Takemura, T., Bergmann, D., Cameron-Smith, P., … Zeng, G. (2013). Global premature mortality due to anthropogenic outdoor air pollution and the contribution of past climate change. Environmental Research Letters, 8(3), 034005. https://doi.org/10.1088/1748-9326/8/3/034005

Tessum, C. W., Hill, J. D., & Marshall, J. D. (2017). InMAP: A model for air pollution interventions. PLOS ONE, 12(4), e0176131. https://doi.org/10.1371/journal.pone.0176131

Tessum, C. W., Paolella, D. A., Chambliss, S. E., Apte, J. S., Hill, J. D., & Marshall, J. D. (2021). PM2.5 polluters disproportionately and systemically affect people of color in the United States. Science Advances, 7(18), eabf4491. https://doi.org/10.1126/sciadv.abf4491

Wang, Y., Apte, J. S., Hill, J. D., Ivey, C. E., Johnson, D., Min, E., Morello-Frosch, R., Patterson, R., Robinson, A. L., Tessum, C. W., & Marshall, J. D. (2023). Air quality policy should quantify effects on disparities. Science, 381(6655), 272–274. https://doi.org/10.1126/science.adg9931

Wang, Y., Apte, J. S., Hill, J. D., Ivey, C. E., Patterson, R. F., Robinson, A. L., Tessum, C. W., & Marshall, J. D. (2022). Location-specific strategies for eliminating US national racial-ethnic PM2.5 exposure inequality. Proceedings of the National Academy of Sciences, 119(44), e2205548119. https://doi.org/10.1073/pnas.2205548119

World Health Organization. (2023). Types of pollutants. https://www.who.int/teams/environment-climate-change-and-health/air-quality-and-health/health-impacts/types-of-pollutants

Yang, H., Huang, X., Westervelt, D. M., Horowitz, L., & Peng, W. (2023). Socio-demographic factors shaping the future global health burden from air pollution. Nature Sustainability, 6(1), Article 1. https://doi.org/10.1038/s41893-022-00976-8

Zhao, A., S. Kennedy, K. O'Keefe, M. Borrero, K. Clark-Sutton, R. Cui, C. Dahl, G. Deye, J. Feldmann, K. Kennedy, H. McJeon, M. Moravec, D. Nilov, S. Rajpurohit, J. Rosas, C. Squire, and N. Hultman (2022). "An All-In Pathway To 2030: The Beyond 50 Scenario." Center for Global Sustainability, University of Maryland and America Is All In. 16 pp.
Phelps, Bradley, S. Dodds, C. Dahl, S. Edelstein, J. Lewis-Johnson, S., Kennedy. (2023). Policy Briefs: Empowering States for Emission-Free Power: Unleashing IRA's Climate Initiatives. Center for Global Sustainability, University of Maryland.

United States Department of State and the United States Executive Office of the President (2021). The Long-Term Strategy of the United States: Pathways to Net-Zero Greenhouse Gas Emissions by 2050. Washington DC, 61 pp. https://www.whitehouse.gov/wp-content/uploads/2021/10/US-Long-Term-Strategy.pdf

US EPA, OAR. "New Source Performance Standards." US EPA, 25 Nov. 2016, www.epa.gov/stationary-sources-air-pollution/new-source-performance-standards.