U.S. ENVIRONMENTAL PROTECTION AGENCY

OFFICE OF AIR AND RADIATION

Climate Change Adaptation Implementation Plan

OCTOBER 2022

even with the same level of emissions of ozone-forming chemicals.[2] Urban areas experience air temperatures that can be several degrees warmer than surrounding areas, especially during the night. This “urban heat island” effect results from several factors, including reduced ventilation and heat trapping due to the close proximity of tall buildings, heat generated directly from human activities, the heat-absorbing properties of concrete and other urban building materials, and the limited amount of vegetation. Continuing urbanization and increasingly severe heat waves under climate change will further amplify this effect on tropospheric ozone concentrations in the future.[3] Climate change may contribute to lengthening the ozone season[4] (the months of the year when weather conditions, along with pollutants in the air, can result in the formation of elevated levels of ground-level ozone in particular locations around the country). The effects of increased temperatures, a longer ozone season, and higher ozone levels in some areas are leading to increased impacts on residents, particularly on individuals with higher sensitivity to air pollution, and on disadvantaged community members with other risk factors, fewer resources to adapt, and/or higher energy burdens, potentially exacerbating situations of environmental injustice. In addition, these climate effects on ozone levels can result in more areas across the country being at risk of violating the ozone National Ambient Air Quality Standards (NAAQS).

Increases in tropospheric ozone concentrations due to climate change would increase the public health burden from air pollution. The potential impacts on public health include more respiratory illnesses and increased risk of premature deaths.[5] This is a particular concern for sensitive subpopulations which are at greater risk for health effects from exposure to ozone. Recent studies also suggest the risk of mortality increases at higher ozone concentrations and higher temperatures (i.e., a synergistic effect).[6] Furthermore, potential increases in tropospheric ozone due to climate change would lead to more pollution controls being required to attain or maintain ozone NAAQS than would be necessary under the present-day climate.

There are uncertainties associated with the precise timing and location of expected climate impacts on tropospheric ozone. While there is a consensus that ozone air quality levels will increase in some locations—in the absence of additional reductions in ozone precursor emissions—different regional climate models provide varying estimates of the change in ozone from a changing climate by region. Ongoing changes in emissions levels (expected to decline over the next decade) and the significant year-to-year variability in ozone levels we already see from natural variability in weather patterns are additional complicating factors. The state-of-the-science continues to evolve and will serve to inform specific measures to counteract this

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[2] Nolte, C.G., Dolwick, P.D., Fann, N., Horowitz, L.W., Naik, V., Pinder, R.W., Spero, T.L., Winner, D.A., & Ziska, L.H. (2018). Ch. 13: Air quality. In *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II* [Reidmiller, D.R., Avery, C.W., Easterling, D.R., Kunkel, K.E., Lewis, K.L.M., Maycock, T.K., & Stewart, B.C. (eds.)]. U.S. Global Change Research Program, Washington, DC, 512–538. DOI: 10.7930/NCA4.2018.CH13

[3] Doblas-Reyes, F.J., Sörensson, A.A., Almazroui, M., Dosio, A., Gutowski, W.J., Haarsma, R., Hamdi, R., Hewitson, B., Kwon, W.-T., Lamptey, B.L., Maraun, D., Stephenson, T.S., Takayabu, I., Terray, L.., Turner, A., & Zuo, Z. (2021). Ch. 10: Linking global to regional climate change. In *Climate Change: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* [Masson-Delmotte, V., Zhai, P., Pirani, A., Connors, C. Péan, S.L., Berger, S., Caud, N., Chen, Y., Goldfarb, L., Gomis, M.I., Huang, M., Leitzell, K., Lonnoy, E., Matthews, J.B.R., Maycock, T.K., Waterfield, T., Yelekçi, O., Yu, R., & Zhou, B. (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1363–1512. DOI:10.1017/9781009157896.012.

[4] Zhang, Y. & Wang, Y. (2016). Climate-driven surface ozone extreme in the fall. *Proceedings of the National Academy of Sciences,* 113(36), 10025-10030. DOI: 10.1073/pnas.1602563113.

[5] Fann, N., Brennan, T., Dolwick, P., Gamble, J.L., Ilacqua, V., Kolb, L., Nolte, C.G., Spero, T.L., & Ziska, L. (2016). Ch. 3: Air quality impacts. In *The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment.* U.S. Global Change Research Program, Washington, DC, 69–98. http://dx.doi.org/10.7930/J0GQ

[6] U.S. EPA (2020). *Integrated science assessment (ISA) for ozone and related photochemical oxidants*. U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-20/012, sec. 6.1.5.4, 6-12. https://cfpub.epa.gov/ncea/isa/recordisplay.cfm?deid=348522.

vulnerability. EPA will continue to evaluate and improve our regional climate tools to allow for more refined estimates of ozone impacts for specific climate scenarios. Additionally, EPA will continue to monitor and assess trends of ozone air quality. To the extent that it becomes apparent that a changing climate is impeding or will impede attainment of national air quality goals and depending on the specific circumstances, Clean Air Act provisions may require identification of additional control measures at both the State and national levels.

Changes in the frequency and intensity of wildfires, caused by climate change, are affecting particulate matter (PM) levels. With record-breaking wildfire seasons in North America in recent years, there is evidence indicating that climate change is affecting PM levels through changes in the frequency and intensity of wildfires.[7] The Intergovernmental Panel on Climate Change (IPCC) has reported with very high confidence that in North America, disturbances such as wildfires are increasing and are likely to intensify in a warmer future with drier soils and longer growing seasons.[8] Forest fires are increasing in frequency, severity, distribution and duration in the Southeast, the Intermountain West and the West Coast due to climate change. Wildfire smoke can affect air quality and visibility in other areas of the country depending on wind patterns. PM emissions will also be affected by changes in the production of wind-blown dust due to changes in soil moisture.[9] There are technical challenges associated with assessing the specific impacts that climate change will have on PM concentrations. As an example, it is particularly difficult to accurately determine how precipitation and wildfire patterns will evolve in a changing climate. These second-order climate effects have the potential to significantly impact future aerosol air quality. Coupled climate and air quality modeling systems can show significant variation of future impacts on particulate matter by season and by region. As with ozone, this uncertainty will need to be taken into account.

The observed increase in PM resulting from wildfires is also increasing the public health burden in affected areas, which may include sensitive subpopulations at risk for increased health effects from being exposed to PM pollution. Additional situations of environmental injustice may also be exacerbated by PM from wildfires, for example in communities already disproportionately affected by PM from diesel engines or agricultural burning. This potential increase may also complicate state efforts to attain the PM NAAQS and address regional transport of air pollution. Other public health effects that may result from increased exposure to wildfires, and that are of concern to OAR, include those that are physiological, socioeconomic, and psychological in nature. For instance, there are demonstrated linkages to worse mental health due to chronic stress or post-traumatic stress disorder (PTSD). Again, this may affect lower-income individuals to a greater extent if they are unable to afford and/or access the care necessary to address these conditions.

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[7] M.P., Reidmiller, D.R., Avery, C.W., Crimmins, A., Dahlman, L., Easterling, D.R., Gaal, R., Greenhalgh, E., Herring, D., Kunkel, K.E., Lindsey, R., Maycock, T.K., Molar, R., Stewart, B.C., & Vose, R.S. (2018): Frequently asked questions. In *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II* [Reidmiller, D.R., Avery, C.W., Easterling, D.R., Kunkel, K.E., Lewis, K.L.M., Maycock, T.K., & Stewart, B.C. (eds.)]. U.S. Global Change Research Program, Washington, DC, 1508, Figure A5.31. doi: 10.7930/NCA4.2018.AP5.

[8] Seneviratne, S.I., Zhang, X., Adnan, M., Badi, W., Dereczynski, C., Di Luca, A., Ghosh, S., Iskandar, I., Kossin, J., Lewis, S., Otto, F., Pinto, I., Satoh, M., Vicente-Serrano, S.M., Wehner, M., & Zhou, B. (2021). Ch. 11: Weather and climate extreme events in a changing climate. In *Climate Change: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* [Masson-Delmotte, V., Zhai, P., Pirani, A., Connors, S.L., Péan, C., Berger, S., Caud, N., Chen, Y., Goldfarb, L., Gomis, M.I., Huang, M., Leitzell, K., Lonnoy, E., Matthews, J.B.R., Maycock, T.K., Waterfield, T., Yelekçi, O., Yu, R., & Zhou, B. (eds.)]. Cambridge University Press, United Kingdom and New York, USA, 1513–1766. DOI:10.1017/9781009157896.013.

[9] Nolte, C.G., Dolwick, P.D., Fann, N., Horowitz, L.W., Naik, V., Pinder, R.W., Spero, T.L., Winner, D.A., & Ziska, L.H. (2018). Ch. 13: Air quality. In *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II* [Reidmiller, D.R., Avery, C.W., Easterling, D.R., Kunkel, K.E., Lewis, K.L.M., Maycock, T.K., & Stewart, B.C. (eds.)]. U.S. Global Change Research Program, Washington, DC, 512–538. DOI: 10.7930/NCA4.2018.CH13

Likewise, other physiological health effects that result from exposure to wildfires and resultant PM can include low birth weights or pre-term births, which may have lifelong consequences for the overall health of the child.

Climate change may worsen the quality of indoor air. Climate change may worsen existing indoor environmental problems and indoor air quality (IAQ), and it may also introduce new problems as the frequency or severity of adverse outdoor conditions change.[10,11] Ambient air pollution worsened by climate change, including greater levels of fine particulate matter from more frequent or intense wildfires and increased ambient concentrations of tropospheric ozone and aeroallergens, may contribute to reduced indoor air quality by infiltrating into buildings from the outdoors.[12] In some regions, climate change may decrease air exchange rates through infiltration and consequently reduce the amount of outdoor air pollution infiltrating indoors. This may lead to higher concentrations of pollutants generated indoors as their dilution by outdoor air is decreased. However, in warmer climates, infiltration rates may increase during summer months, contributing to greater indoor air pollution levels at peak periods of exposure.[13] Consumer adoption of indoor air pollution prevention and mitigation strategies, including source control, ventilation, the use of filters in mechanical ventilation systems and portable air cleaners, and weatherization practices in tandem with other IAQ strategies, are effective means of reducing indoor air pollutant concentrations and exposure. Future changes in occupant behavior, including time spent indoors and the adoption of indoor air pollution prevention and mitigation strategies, is uncertain. EPA will continue to promote effective IAQ strategies. This may require increased engagement across public and private sectors to understand factors affecting consumer adoption of IAQ strategies and promote increased adoption.

Climate-driven changes in indoor temperature and humidity may also worsen IAQ. High temperature and humidity levels can increase concentrations of some indoor pollutants. Changes in temperature and humidity can affect chemical reaction rates occurring within the air and on surfaces indoors, which contribute to the generation of secondary aerosols. Temperature and humidity indoors also determine the emission rate of certain chemicals from consumer products and building materials, such as volatile organic compounds. Due to climate change, extreme heat and cold events are expected to become more frequent and intense. Extreme heat events contribute to reduced air quality, via temperature- and humidity-driven changes in indoor air chemistry, and ventilation. During an extreme cold event, air pollution accumulates indoors due to reduced ventilation and air exchange. EPA will continue to promote, foster, and communicate research that explores the consequences of climate change on indoor air chemistry, and the significance of these changes for indoor air quality and public health.

Increases in the occurrence and severity of extreme precipitation, hurricanes, and storms, as well as their related flooding, may contribute to increases in indoor dampness and building deterioration. Increased susceptibility of the built environment, due to a breakdown of the

[10] Institute of Medicine (2011). *Climate change, the indoor environment, and health*. The National Academies Press, Washington, DC. https://doi.org/10.17226/13115.
[11] Fann, N., Brennan, T., Dolwick, P., Gamble, J.L., Ilacqua, V., Kolb, L., Nolte, C.G., Spero, T.L., & Ziska, L. (2016). Ch. 3: Air quality impacts. In *The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment.* U.S. Global Change Research Program, Washington, DC, 69–98. http://dx.doi.org/10.7930/J0GQ
[12] Fann, N., Brennan, T., Dolwick, P., Gamble, J.L., Ilacqua, V., Kolb, L., Nolte, C.G., Spero, T.L., & Ziska, L. (2016). Ch. 3: Air quality impacts. In *The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment.* U.S. Global Change Research Program, Washington, DC, 69–98. http://dx.doi.org/10.7930/J0GQ
[13] Ilacqua V., Dawson J., Breen M., Singer S., & Berg A (2017). Effects of climate change on residential infiltration and air pollution exposure. *J Expo Sci Environ Epidemiol*, 27(1), 16-23. DOI: 10.1038/jes.2015.38.

protective building envelope, and indoor dampness, in turn may increase occupants' exposure to harmful biological contaminants (e.g., mold, bacteria, dust mites, viruses), chemical emissions from building materials, as well as outdoor environmental pollutants that have infiltrated indoors.[14,15,16] Warmer average temperatures may also affect the emergence, evolution and geographic ranges of pests, infectious agents, and disease vectors. This may also lead to shifting patterns of indoor exposure to pesticides as occupants and building owners respond to new infestations. Increased stress on the building envelope from temperature shifts and more extreme weather events may decrease the capability of homes and buildings to protect occupants from shifts in the numbers or types of organisms in a given area. In addition, increased outdoor temperatures and extreme weather may lead rodents and other pests into the indoor environment, leading to potential increases in pesticide use. Exposures to pests, other biological pollutants, and pesticides used to respond to infestations, can contribute to illness and disease, including allergy and asthma exacerbation.[17] This may require increased engagement across public and private sectors to promote IAQ strategies and building resilience to reduce exposure to biological contaminants and pests. More research on the relationships between climate change and exposure to biological contaminants and pest infestation is needed. EPA may need to increase its intra- and inter-agency interactions, to update its guidance and messaging regarding prevention and adaptation strategies by occupants, as well as to ensure climate projections are accounted for in comprehensive allergy and asthma intervention programs.

Extreme weather and temperature events also correspond to a greater probability of electricity and infrastructure failures, which in turn affect the use of air conditioning and filtration systems that can mitigate IAQ issues.[18] Power outages lead to more frequent use of portable generators. Carbon monoxide poisoning from improper use of portable generators results in hundreds of deaths and thousands of illnesses each year. EPA will continue to develop guidance for communities on protecting IAQ before, during, and following climate-driven extreme disasters and emergencies, including safeguarding the health of building occupants from carbon monoxide following power outages. Furthermore, in homes where increased wood burning for residential heating is occurring—which may result from power disruptions, uncertain fuel prices, and potential increased use of wood as a renewable fuel[19,20,21]—exposure to indoor PM and air toxics could be

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[14] Institute of Medicine (2011). *Climate change, the indoor environment, and health*. The National Academies Press, Washington, DC. https://doi.org/10.17226/13115.
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[18] Fann, N., Brennan, T., Dolwick, P., Gamble, J.L., Ilacqua, V., Kolb, L., Nolte, C.G., Spero, T.L., & Ziska, L. (2016). Ch. 3: Air Quality Impacts. In *The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment.* U.S. Global Change Research Program, Washington, DC, 69–98. http://dx.doi.org/10.7930/J0GQ
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[20] Gowda, P., Steiner, J.L., Olson, C., Boggess, M., Farrigan, T., & Grusak, M.A. (2018). Ch. 10: Agriculture and rural communities. In *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II* [Reidmiller, D.R., Avery, C.W., Easterling, D.R., Kunkel, K.E., Lewis, K.L.M., Maycock, T.K., & Stewart, B.C. (eds.)]. U.S. Global Change Research Program, Washington, DC, 391–437. DOI: 10.7930/NCA4.2018.CH10.
[21] M.P., Reidmiller, D.R., Avery, C.W., Crimmins, A., Dahlman, L., Easterling, D.R., Gaal, R., Greenhalgh, E., Herring, D., Kunkel, K.E., Lindsey, R., Maycock, T.K., Molar, R., Stewart, B.C., & Vose, R.S. (2018): Frequently asked questions. In *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II* [Reidmiller, D.R., Avery, C.W.,

increased. With increased storms and flooding, the availability of biomass fuels for cooking in developing nations may be affected. More research is required to better understand the influence that climate change has on the availability of biomass fuels and cooking behaviors in low- income countries.

Individuals may adapt or weatherize buildings to improve their resilience and reduce energy consumption and the use of fossil fuels in a changing climate. Such efforts, without appropriate strategies to ensure proper building modifications, could lead to a reduction in ventilation and an increase in indoor environmental pollutants unless measures are taken to preserve or improve IAQ. With respect to weatherization-related increases in radon and its decay products, EPA may need to update its voluntary guidance or increase its work with other federal and industry partners to ensure that weatherization of new and existing homes and buildings is carried out with radon-resistant features or modified to ensure that effective radon-mitigation systems are in place. EPA has developed practical guidance for improving or maintaining indoor environmental quality during home energy upgrades or remodeling in single-family homes and schools. EPA's guidance and protocols may need to be revised to consider state and local climate change projections. In addition, these programs may need to increase partnerships with other Federal agencies to address training needs and workforce development for building owners, managers, and others, as well as develop mechanisms to assess the effectiveness of weatherization and remodeling techniques as they relate to indoor environmental quality.

Increases in air pollution exposure indoors due to climate change may increase the public health burden from air pollution. More research is needed to understand the potential impacts on public health of worsened IAQ from climate change, including on respiratory illnesses and increased risk of premature deaths. Uncertainties remain regarding the relationship between outdoor-indoor atmospheric chemistry, changes in the composition of indoor air pollution under a changing climate, and associated changes in exposure and risk of health impacts. Moreover, information is needed on how climate-driven changes in IAQ may affect certain populations that are inherently more vulnerable to weather and climate impacts, such as overburdened communities that already have a disproportionate share of pollution burdens.

Climate change is contributing to the increasing frequency and severity of wildfires and extreme weather events and may affect the Agency's capacity to reliably monitor, assess, and implement certain Agency programs. As the climate changes, rising temperatures, persistent annual decreases in snowpack, increased drought, and changes in land use, have led to greater and more severe wildfire activity, especially in the western U.S. Climate change has also led to record breaking temperature extremes and heavy precipitation events, and the increased frequency of regional droughts, flooding, and heat waves. In the coming years, heavier precipitation, stronger hurricanes, and an increase in conditions favorable to severe thunderstorms are anticipated.[22]

Easterling, D.R., Kunkel, K.E., Lewis, K.L.M., Maycock, T.K., & Stewart, B.C. (eds.)]. U.S. Global Change Research Program, Washington, DC, 1493, Figure A5.24. DOI: 10.7930/NCA4.2018.AP5.

[22] Seneviratne, S.I., Zhang, X., Adnan, M., Badi, W., Dereczynski, C., Di Luca, A., Ghosh, S., Iskandar, I., Kossin, J., Lewis, S., Otto, F., Pinto, I., Satoh, M., Vicente-Serrano, S.M., Wehner, M., & Zhou, B. (2021). Ch. 11: Weather and climate extreme events in a changing climate. In *Climate Change: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* [Masson-Delmotte, V., Zhai, P., Pirani, A., Connors, S.L., Péan, C., Berger, S., Caud, N., Chen, Y., Goldfarb, L., Gomis, M.I., Huang, M., Leitzell, K., Lonnoy, E., Matthews, J.B.R., Maycock, T.K., Waterfield, T., Yelekçi, O., Yu, R., & Zhou, B. (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1513–1766. DOI:10.1017/9781009157896.013.

Future climate change and extreme weather events increasingly pose a risk to our nation's energy and transportation systems, threatening more frequent and longer-lasting power outages, fuel shortages, service disruptions, and infrastructure damage, with cascading impacts on other critical sectors.[23]

Specific potential vulnerabilities related to an increase in the frequency and severity of wildfires and extreme weather events may include:

- The increasing frequency of wildfires and extreme weather events, including severe winds and lightning, could damage EPA's long-term environmental monitoring assets, particularly in the western U.S. and coastal areas, respectively. The Agency has already experienced such damage to equipment at sites in the Clean Air Status and Trends Network (CASTNET) and the National Atmospheric Deposition Program (NADP). Damage to monitoring equipment could impact the agency's ability to accurately characterize situations of environmental injustice, among other priorities.
- More frequent and intense weather events could impact OAR's disaster response planning efforts, requiring consideration of more frequent events and more complex responses.
- The prospect of future power outages could lead to increased use and sales of wood burning appliances, resulting in more high PM pollution days in some areas.
- Extreme weather events could damage infrastructure funded through OAR programs and may reduce the effectiveness of OAR's partnership programs to reduce air pollution from mobile sources, including in overburdened communities such as those near ports and roadways.

Climate change may alter the effects and priorities of EPA's regulatory and partnership programs to help restore the stratospheric ozone layer. The interactions between the changing climate and stratospheric ozone layer are complex. Climate change affects the ozone layer through changes in chemical transport, atmospheric composition, and temperature. In turn, changes in stratospheric ozone can have implications for the weather and climate of the troposphere. Stratospheric ozone depletion and increases in global tropospheric ozone that have occurred in recent decades have made differing contributions to climate change. Additionally, climate change may exacerbate the health effects of ozone layer damage at some latitudes and mitigate them at others.[24] Ozone depletion and climate change are also linked because both ozone depleting substances and their principal substitutes are significant greenhouse gases. While the science continues to evolve, potential climate change impacts are included in the planning and implementation of the Agency's programs to protect stratospheric ozone.

Specific potential vulnerabilities of EPA stratospheric ozone programs to climate change include:

- Different ozone depleting substances (ODS) have different atmospheric lifetimes and patterns of transport in the atmosphere. If climate change increases the heterogeneity of

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[23] USGCRP (2017): Summary findings. In *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II* [Reidmiller, D.R., Avery, C.W., Easterling, D.R., Kunkel, K.E., Lewis, K.L.M., Maycock, T.K., & Stewart, B.C. (eds.)]. U.S. Global Change Research Program, Washington, DC, 34. https://nca2018.globalchange.gov/downloads/NCA4_Ch01_Summary-Findings.pdf

[24] World Meteorological Organization (2018). *Scientific assessment of ozone depletion*. Global Ozone Research and Monitoring Project. Geneva, Switzerland, Report No. 58, 588. https://ozone.unep.org/sites/default/files/2019-05/SAP-2018-Assessment-report.pdf.

processes that influence ozone destruction and production, increased regional disparities may need to be taken into account when implementing programmatic priorities.

- Climate change may lead to increased use of cooling devices in commercial, residential, and transportation applications as well as increased use of insulation foams containing ODS or their substitutes. Such a shift in demand might impact how EPA plans and operates its programs concerned with the ODS that are used to produce and operate these devices and materials. A shift in demand for ODS may also increase imports of ODS, which could affect EPA's oversight of such imports.
- EPA's Significant New Alternatives Policy (SNAP) program evaluates and regulates substitutes for ODS, seeking a constantly improving suite of chemicals for protection of the environment. Evaluation of substitutes can depend on factors influenced by climate change, for example the effectiveness of various refrigerants varying with ambient temperature. A changing climate may influence priority setting and operation of SNAP in relation to the suitability of substitutes.

The combined effects of climate change and multi-pollutant deposition loadings and ozone concentrations could have consequences for ecosystem services and the effectiveness of ecosystem protection from Agency emissions reduction programs. Scientific understanding related to ways that climate change interacts with sulfur, nitrogen, and mercury deposition, the global carbon cycle, and impacts to ecosystems is growing. Climate warming and changes in precipitation can affect the spatial distribution of atmospheric deposition, the relative contributions of wet and dry deposition, biogeochemical cycling processes, and ecosystem responses to pollutant exposures. This has implications for key environmental concerns, such as acidification, eutrophication, and contaminant bioaccumulation. [25,26] Consistent, long-term monitoring is important for assessing the long-term effects of climate change on air quality, atmospheric deposition, and effects on ecosystems.

EPA's Acid Rain Program under Title IV of the Clean Air Act Amendments of 1990 was specifically designed to protect sensitive ecosystems from acidic deposition. For more than three decades, this program and the agency power sector emissions reduction programs which followed have dramatically reduced SO_2 and NO_x emissions across the country, most notably in the Eastern U.S. where the largest sources reside. These reductions have led to significant improvements to air quality, declines in acidic deposition, and improvements in the health of aquatic ecosystems in New England, the Adirondacks, and the Catskills mountains.[27] However, as the climate changes, it is unclear whether improvements in ecosystem health will continue as emissions decline or whether ecosystem recovery will stop or reverse. For example, Greaver et al. (2016) notes that increased temperature and precipitation generally will be likely to enhance inputs of buffering agents from weathering and deposition, but also increase inputs of acidifying agents

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[25] USGCRP (2017): *Climate Science Special Report: Fourth National Climate Assessment, Volume I* [Wuebbles, D.J., D.W. Fahey, K.A. Hibbard, D.J. Dokken, B.C. Stewart, and T.K. Maycock (eds.)]. U.S. Global Change Research Program, Washington, DC, 470. DOI: 10.7930/J0J964J6.
[26] IPCC (2019). *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate* [Pörtner, H.-O., Roberts, D.C., Masson-Delmotte, V., Zhai, P., Tignor, M., Poloczanska, E., Mintenbeck, K., Alegría, A., Nicolai, M., Okem, A., Petzold, J., Rama, B., & Weyer, N.M. (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, 755. https://doi.org/10.1017/9781009157964.
[27] LaCount, M.D., Haeuber, R.A., Macy, T.R., & Murray, B.A. (2021). Reducing power sector emissions under the 1990 Clean Air Act Amendments: A retrospective on 30 years of program development and implementation. *Atmospheric Environment,* 245, 118012. https://doi.org/10.1016/j.atmosenv.2020.118012.

from deposition and enhanced nitrogen cycling.[28] Also, increased temperature and droughts may lead surface waters to increase eutrophication impacts, particularly, for waterbodies recovering from acidification. How these opposing processes will respond to a change in climate remains uncertain.

EPA's recent regulations continue to reduce NOx emissions, an important precursor to ground level ozone, and help protect forest ecosystems from ozone damage. However, change in future climate conditions (e.g., higher temperatures) may offset these ecological benefits as forests negatively respond directly to climate change and potentially higher ozone concentrations occuring due to warmer weather.[29] The stresses on plant growth and productivity from increasing ozone concentrations combined with an increasing frequency of droughts could negatively affect the carbon sequestration capacity of forests. In addition, an increasing frequency of wildfires combined with increasing levels of methane globally may result in higher background ozone concentrations in the near future,[30] which also has implications for forest ecosystem protection.

Conclusion

This is an initial assessment of the potential vulnerabilities EPA's Office of Air and Radiation may face due to a changing climate. It provides a foundation on which to examine OAR's programs and is meant to provide flexibility so that emerging scientific understanding may continue to be incorporated over time.

[28] Greaver, T., Clark, C., Compton, J. et al. (2016). Key ecological responses to nitrogen are altered by climate change. *Nature Climate Change*, 6, 836–843. https://doi.org/10.1038/nclimate3088.
[29] Wells, B., Dolwick, P., Eder, B., et al (2021). Improved estimation of trends in U.S. ozone concentrations adjusted for interannual variability in meteorological conditions. *Atmospheric Environment*, 248, 118234. https://doi.org/10.1016/j.atmosenv.2021.118234.
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OAR Programmatic Vulnerability Summary Table

Goals [a]	CLIMATE CHANGE IMPACTS [b]		EPA PROGRAMMATIC IMPACTS [c]		
	Climate Change Impact [d]	**Likelihood of Impact [e]**	**Focus of Associated EPA Program**	**Likelihood EPA Program will be Affected [f]**	**Example of Risks if Program were Impacted**
Goal 1: Climate Crisis, Goal 2: Environmental Justice, Goal 3: Enforcement & Compliance, Goal 4: Clean and Healthy Air	• Increased tropospheric ozone pollution in certain regions	Likely[1]	• Protecting public health and the environment by setting National Ambient Air Quality Standards (NAAQS) and implementing programs to help meet the standards	High	• Could become more difficult to attain NAAQS for ozone in many areas with existing ozone problems
	• Increased frequency and intensity of wildfires	Very Likely[2]	• Protecting public health and the environment by setting National Ambient Air Quality Standards (NAAQS) and implementing programs to help meet the standards • Promote non-regulatory guidance for reducing indoor exposure to wildfire smoke	High	• Could continue to complicate Agency efforts to protect public health and the environment from risks posed by particulate matter (PM) pollution in areas affectedby more frequent wildfires
	• Increasing extreme temperatures • Increasing heavy precipitation events	Very Likely[3] and Likely[3]	• Protect public health by promoting healthy indoor environments through non-regulatory programs and guidance • Mitigating health, air quality, and energy use impacts of urban heat islands through outreach and technical assistance to local governments	Medium	• Could increase public health risks, including risksfor the young, the elderly, the chronically ill, and socioeconomically disadvantaged populations • Could reduce air quality and increase heat-related illnesses and deaths in urban areas
	• Effects on the stratospheric ozone layer	Likely[4]	• Restoring the stratospheric ozone layer • Preventing UV-related disease • Providing a smooth transition to safer alternatives	High	• Unable to restore ozone concentrations to benchmark levels as quickly at some latitudes
	• Effects on response of ecosystems to atmospheric deposition of sulfur, nitrogen, and mercury	Likely[5,6,7]	• Ecosystem protections from Agency emissions reduction programs	Low	• Based on growing research, could have consequences for the effectiveness of ecosystem protections under those programs
	• Increased frequency and severity of severe weather events	Very Likely[8]	• Monitoring and assessing the benefits and effectiveness of Agency emissions reduction programs • Agency disaster planning, preparedness, and response	Medium	• Could decrease the amount and/or quality of data collected by the Agency • Could impact the Agency's ability to accurately characterize situations of environmental injustice, among other priorities

Footnotes for OAR Programmatic Vulnerability Summary Table

[a] This table summarizes vulnerabilities by goals in EPA's FY 2022–2026 Strategic Plan. OAR's program vulnerabilities fall under Goal 1: Tackle the Climate Crisis, Goal 2: Take Decisive Action to Advance Environmental Justice and Civil Rights, Goal 3: Enforce Environmental Laws and Ensure Compliance, and Goal 4: Ensure Clean and Healthy Air for All Communities.

[b] Climate Change Impacts are based upon peer-reviewed scientific literature.

[c] Programmatic Impacts are based upon EPA best professional judgment at this time.

[d] Impacts can vary by season and location.

[e] In general, the sources cited in this section use Intergovernmental Panel on Climate Change (IPCC) likelihood of outcome terminology where the term 'very likely' means 90-100% probability and the term 'likely' means 66-100% probability. For some impacts in the table, additional discussion on the likelihood term is provided in the associated footnote.

[f] **High** assumes the program will be affected by the impact; **Medium** assumes the program could be affected under some conditions by the impact; **Low** assumes that there is a potential for the program to be impacted or uncertainty currently exists as to the potential nature and extent of the impact. This assessment is based on best professional judgment within EPA at this time. Please note, this column does not reflect several important considerations. For example, it does not distinguish timeframes (current, near-term, long-term). It does not account for regional and local variations. And it does not reflect the priority of actions the agency may undertake now or in the future.

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III. Priority Actions

Introduction

EPA's Office of Air and Radiation (OAR) works to fulfill a number of strategic goals in *EPA's 2022–2026 Strategic Plan*. These include Goal 1: Tackle the Climate Crisis, Goal 2: Take Decisive Action to Advance Environmental Justice and Civil Rights, Goal 3: Enforce Environmental Laws and Ensure Compliance, and Goal 4: Ensure Clean and Healthy Air for All Communities. In doing so, OAR implements programs including those that address outdoor and indoor air quality, climate change, stratospheric ozone, and atmospheric deposition. OAR works closely with EPA's Program and Regional Offices and other federal agencies to implement many of the programs and fosters collaborative partnerships with the business community when implementing certain programs. OAR also collaborates closely with researchers and modelers to better understand, characterize, and project the potential impacts of climate change on outdoor and indoor air quality and other environmental and public health endpoints that are the focus of OAR programs. Furthermore, OAR works with an extensive set of stakeholders from states and local communities, Tribal nations, and various business, environmental, and health organizations to effectively reach the public. Many of these efforts provide opportunities to factor in the impacts of climate change as well as advance our understanding of how vulnerable populations—including low-income communities, communities of color, Tribes,[31] and Indigenous people—are disproportionately affected.

OAR will continue to exercise its authorities under the Clean Air Act, including new investments under the Inflation Reduction Act, to reduce greenhouse gases (mitigation), the primary pollutants that cause climate change. This Implementation Plan, however, is designed to address adaptation of OAR's programs in response to climate change and, specifically, to consider how OAR's programs will continue to strive to protect public health and the environment given a changing climate. Furthermore, climate change will have inherently unequal impacts on people and communities, who will have varying adaptive capacities and resilience. As a result, OAR will need to consider these inequitable climate impacts as it identifies ways to continue, improve upon, and extend the reach of its programs to all communities. This Implementation Plan also considers when and how analytical tools can be adapted to better reflect a changing climate. As part of this process, OAR will continue to review our standard operating procedures and identify, where appropriate, opportunities for integration of climate adaptation considerations. In addition, OAR will take steps to ensure the outcomes of infrastructure investments using Infrastructure Investment and Jobs Act (IIJA, or Bipartisan Infrastructure Law [BIL]) funds are resilient to the impacts of climate change. OAR will explore opportunities to integrate climate change considerations into its financial assistance programs in order to expand support for projects that increase climate resilience while delivering co-benefits for public health, the mitigation of greenhouse gases, and the reduction of other pollution. OAR will also provide technical assistance to recipients of BIL funds to help them make climate smart infrastructure investments.

[31] In this Implementation Plan, the term "Tribe" and "Tribal nation" is referring to federally recognized Indian Tribes. Federally recognized Indian Tribes are those Tribes that have met criteria established by the Department of the Interior or are designated by law as eligible to receive federal benefits, federal services, and federal protections. The special relationship federally recognized Tribes have with the United States is known as the government-to-government relationship.

OAR derived its priority actions from the vulnerabilities identified in the vulnerability assessment of this implementation plan (p. 6-18) and in the Agency's *2021 Climate Adaptation Action Plan*. In determining these priority actions, OAR considered the following:

- Strength of the science
- Extent of the threat to the program
- Complexity in implementation
- Feasibility of integrating climate change adaptation into a particular program
- Legal authorities

There are five priority actions that represent different types of efforts OAR intends to implement annually in 2022–2026. The five priority actions will be supported by a series of sub-actions that represent achievable activities in 2022 and 2023. These sub-actions range from relatively straightforward incorporations of adaptation into ongoing programs to activities that will require multiple steps before implementation. For example, before recalibrating any regulatory or program models, OAR would follow all existing Clean Air Act procedures for public engagement and initiate a process for a transparent and methodological approach to incorporate climate change adaptation. While OAR is committed to accomplishing the following priority actions and sub-actions, successful implementation will depend on availability of appropriate resources (i.e., staff and funding). This list reflects the Office's best current understanding and is designed to be updated every few years to reflect new activities as the science and knowledge about vulnerabilities and adaptation issues evolves.

OAR Priority Actions

Priority Action 1.0: Planning and Implementation

This action is designed to strengthen climate change adaptation across OAR through planning, evaluation, and coordination across OAR offices and programs. OAR implements a wide range of programs that address air quality, climate change, stratospheric ozone, atmospheric deposition, and indoor air. As a result, climate change will affect OAR's programs and mission. To address these vulnerabilities, the following sub-actions are activities that will better integrate climate change adaptation into OAR's work and help meet its goal to build more resilient and climate-responsive programs.

1.1 Develop Climate Adaptation Implementation Plan.

1.2 Coordinate OAR web areas with Climate Adaptation microsite and link to adaptation information, resources, tools, etc., as appropriate.

Co-benefits associated with these sub-actions include support for EPA's strategic objective to accelerate resilience and adaptation to climate change impacts through the development of implementation plans as well as communications of EPA-mission essential priorities and programs including mitigation of greenhouse gas emissions (GHGs) and other pollution, air quality, public health, and environmental justice.

Priority Action 2.0: Outreach and Education

This action encourages work within EPA and with external stakeholders, as necessary, to review and revise information for citizens, especially at-risk populations, on the impact of climate change and associated events on ambient and indoor air quality, including ozone and particulate matter (PM) health impacts. Climate change is likely to increase tropospheric ozone pollution and affect levels of particulate matter through changes in the frequency or intensity of wildfires. As a result, climate change may worsen existing indoor environmental problems and indoor air quality and may also introduce new problems as the frequency of outdoor conditions change. These impacts can disproportionately impact vulnerable and disadvantaged populations and lifestages. To address these vulnerabilities, the following sub-actions are activities that will provide the most current information to the public on air quality conditions, public health, and adaptation planning.

2.1 Incorporate adaptation considerations into OTAQ's partnership programs through outreach and education to stakeholders. As adaptation planning and implementation is an established priority for some stakeholders, OTAQ will connect for them ways that this priority can be addressed that will also accomplish our program objectives, including climate mitigation benefits.

2.2 Address the public health impacts from wildfire smoke, which impacts millions of people each year, by communicating trusted information about air quality conditions and health impacts and manage how fire emissions (wildfire and prescribed fire) are considered in the broader context of the nation's air quality programs.

2.3 Develop and/or update existing indoor air guidance on climate change adaptation strategies to further equip stakeholders to build adaptive capacity in communities.

Co-benefits associated with these sub-actions include providing resources to vulnerable, at-risk populations on air quality conditions, indoor air guidance, and public health as well as resources to support state and community actions such as the Smoke Ready Communities and Air Quality Flag Programs.

Priority Action 3.0: Technical Assistance and Adaptive Capacity

This action is to strengthen resilience and adaptive capacity of federal, state, local, and tribal stakeholders to climate change impacts on ambient and indoor air quality, through enhanced technical assistance and training. Climate change is likely to worsen the quality of ambient and indoor air due to increases in tropospheric ozone pollution and increasing levels of particulate matter from changes in frequency or intensity of wildfires with vulnerable populations experiencing disproportionate impacts. Climate change may also increase the frequency and severity of extreme weather events thereby affecting the capacity to reliably monitor and assess the effectiveness of OAR’s programs. To address these vulnerabilities, the following sub-actions are activities that will provide technical assistance and guidance on adaptation strategies to address ambient and indoor air quality and extreme weather events.

3.1 Collaborate with internal and external stakeholders to improve building and infrastructure resilience to the impacts of climate through improved building codes and practices, and enhanced adoption of design, construction, and maintenance practices.

3.2 Provide training and technical assistance on climate change adaptation strategies to mitigate impacts on indoor air quality with the aim of building adaptive capacity in communities.

3.3 Enhance the Exceptional Events Submission and Tracking System (EETS) and develop wildfire-related implementation tools.

3.4 Promote participation in the $PM_{2.5}$ & Ozone Advance program as proactive approach to integrating actions to improve air quality and address climate change.

3.5 Protect infrastructure funded through the Diesel Emissions Reduction Act (DERA) (such as shore power installations and new dray truck fleets) from severe weather impacts by developing guidance to grant recipients and request for applications (RFA) scoring that gives an appropriate amount of priority for applications that describe steps that will ensure infrastructure enabling grant-eligible clean technologies will be resilient to the effects of climate change. Apply knowledge gained from DERA to include adaptation considerations in future grants (i.e., BIL Clean School Bus grant program).

3.6 Develop feasibility assessment describing how climate measures and associated impacts can be integrated into NAAQS attainment planning.

Co-benefits associated with these sub-actions include supporting EPA priorities on protecting public health, mitigation of GHGs and other pollution, and environmental justice. Support is provided through technical assistance and training on adaptation strategies to address air quality conditions, extreme weather events, and to help local governments mitigate urban heat islands such as in the Heat Island Reduction Program.

Priority Action 4.0: Research and Integration

This action promotes, fosters, and integrates research and improved data collection, internally and externally, on climate change adaptation and related effects on OAR programs. Knowledge and understanding of effects to air quality from climate change is always growing resulting in challenges with data collection, modeling, and analysis of future trends and impacts. Furthermore, climate change can affect data collection processes on OAR programs such as Clear Air Status and Trends Network (CASTNET) monitoring sites, which are vulnerable to extreme weather events (e.g., hurricanes, wildfires, etc.). To address these vulnerabilities, the following sub-actions are activities focused on advancing climate change research in OAR and integrating climate change adaptation into OAR research and program monitoring.

4.1 Incorporate adaptation scenarios and costs into more climate change impact and risk analyses and economic modeling, where appropriate.

4.2 Promote research and collaboration, including within the environmental research community, to improve the understanding of the relationship between climate change, indoor air quality, and human health.

4.3 Assess combined health effects of extreme heat and air pollution.

4.4 Capital investment to build monitoring resiliency into the existing CASTNET infrastructure, enabling the Agency to enhance climate monitoring capacity to better assess public health (e.g., duration/intensity of pollen season) and environmental impacts across the US.

4.5 Collaborate with the environmental research community and long-term monitoring community on climate change interactions with atmospheric deposition of pollutants and impacts to natural and managed ecosystems.

Co-benefits associated with these sub-actions include data collection, modeling, and analysis that will better capture impacts of climate change and adaptation on atmospheric deposition and ecosystems, air quality and public health, and disproportionate impacts on vulnerable populations. One of the added benefits of building monitoring resiliency into long-term air quality and deposition monitoring programs such as CASTNET is the enhanced collaboration with Tribes, including opportunities that expand tribal monitoring capacity. At present, CASTNET has 7 tribal partners: Cherokee Nation, Santee Sioux Nation, Alabama-Coushatta Tribe, Red Lake Band of Chippewa Indians, Kickapoo Tribe, Nez Perce Tribe, and the Confederated Tribes of the Umatilla Indian Reservation.

Priority Action 5.0: Modeling and Analysis

This action advances climate change science through modeling and analysis activities. Climate change is likely to have wide-ranging impacts on OAR program areas including stratospheric ozone protection, ambient and indoor air quality, long-term monitoring activities, and ecosystem protection from multi-pollutant deposition. To address these vulnerabilities, the following sub-actions are activities that will improve understanding of climate change impacts through modeling and analysis activities, which can inform climate change adaptation strategies.

5.1 Develop indoor air chemistry modeling capabilities to inform research of the sensitivity of indoor air chemistry to changes in ambient temperature and humidity, occupant behaviors, and indoor air quality interventions.

5.2 Continue to utilize, refine, and further develop a meteorological adjustment procedure to assess the impact of long-term changes in meteorological conditions on trends in surface ozone levels.

5.3 Update internal multi-pollutant screening tool (NEXUS) with new climate vulnerability analysis and risk indicators (e.g., flood, fire, sea level rise, heat, disease) to more fully inform a holistic understanding of population risk exposure. NEXUS is being developed as an advanced multi-pollutant internal screening tool to identify geographic areas where health risks related to ozone, $PM_{2.5}$, and air toxics overlap.

5.4 Integrate climate change impacts into the electric power sector projections.

Co-benefits associated with these sub-actions include supporting EPA priorities on mitigation of GHGs and other pollution and protecting public health through modeling and analysis activities that advance understanding of climate change science, impacts on air quality and public health, and impacts on electric power sector.

Partnerships with Tribes

Under the U.S. Constitution, treaties with tribal nations are part of the supreme law of the land, establishing unique sets of rights, benefits and conditions for the treaty-making tribes who were forced to cede millions of acres of their homelands to the United States, in return for recognition of property rights in land and resources as well as federal protections. Tribal treaty rights have the same legal force and effect as federal statutes, and they should be integrated into and given the fullest consideration throughout EPA's collective work. Reserved rights are the rights tribes retain that were not expressly granted to the United States by tribes in treaties. Treaty and reserved rights, including but not limited to the rights to hunt, fish and gather, may be found both on and off-reservation lands. Agencies should consider treaty and reserved rights in developing and implementing climate adaption plans in order to protect these rights and ensure the Agencies meet their legal and statutory obligations and other mission priorities as we work to combat the climate crisis.

In September 2021, EPA joined 16 other federal agencies in signing a Memorandum of Understanding (MOU) that committed those parties to identifying and protecting tribal treaty rights early in the decision-making and regulatory processes. Accordingly, EPA will consider and protect treaty and reserved rights in developing and implementing climate adaptation plans through strengthened consultation, additional staff training and annual reporting requirements.

EPA values its unique government-to-government relationship with Indian tribes in planning and decision making. Supporting the development of adaptive capacity among tribes is a priority for the EPA. Tribes are particularly vulnerable to the impacts of climate change due to the integral nature of the environment within their traditional lifeways and culture. They have also been limited to living on marginal land that will be less resilient to climate impacts. OAR is committed to supporting adaptation actions that help to promote sustainability and reduce the impacts of climate change on tribes in the U.S.

EPA hosted a listening session with Tribes on the Agency's *Climate Change Adaptation Action Plan* in October 2021. Tribes identified unique tribal needs and circumstances as well as some of the most pressing issues they are facing including erosion, temperature change, drought, and various changes in access to and quality of water. Tribes recommended a number of strategies to address these issues, including improving access to data and information; supporting research to better track the effects of climate change and to protect and preserve important species; developing community-level education and awareness materials; and providing financial and technical support. EPA will host an engagement process with Tribes on the draft program and regional climate adaptation implementation plans later this year.

The *EPA's FY 2022–2026 Strategic Plan* outlines cooperation and collaboration priorities with Tribes on climate change and air quality in Goal 1: Tackle the Climate Crisis and Goal 4: Ensure Clean and Healthy Air for All Communities. Goal 1 broadly entails cutting pollution that causes climate change and increasing the adaptive capacity of Tribes, states, territories, and communities. A key objective of this goal is to deliver targeted assistance to increase the resilience of Tribes, states, territories, and communities to the impacts of climate change (Objective 1.2). Specifically, through consultation and partnership, the Agency will assist federally recognized Tribes to take action to anticipate, prepare for, adapt to, or recover from the impacts of climate change. Goal 4 centers on protecting human health and the environment from the harmful effects of air pollution. A primary objective of this goal is to limit unnecessary radiation exposure and achieve healthier indoor air quality, especially for vulnerable populations (Objective 4.2). Specifically, EPA will provide technical assistance and other support to Tribes through the Tribal Air Monitoring Support (TAMS) Center and tools to build local expertise and indoor air quality capacity among Tribal air quality professionals to help reduce exposure to harmful indoor air pollutants, including through radon testing and mitigation technologies.

OAR's adaptation efforts can benefit from the expertise our tribal partners choose to share, including insights drawn from their Traditional Ecological Knowledge (TEK). TEK is a valuable body of knowledge in understanding the current and future impacts of climate change and has been used by tribes for millennia as a tool to adapt to changing surroundings. Consistent with the principles in the 1984 *EPA Policy for the Administration of Environmental Programs on Indian Reservations* and EPA's *Policy on Consultation and Coordination with Indian Tribes*, EPA will strive to better understand TEK as a complementary resource that can inform planning and decision-making.

OAR will utilize existing (and new) networks, partnerships, and sources of funding and training/technical to collaborate with tribes on climate change issues. These collaborations and resources include American Indian Air Quality Training Program, Regional Tribal Operations Committees, the National Tribal Air Association, the Institute for Tribal Environmental Professionals, the Tribal Air Monitoring Support Center, the Bureau of Indian Affairs Tribal Resilience Program, and the Indian General Assistance Program. Additionally, efforts will be made to coordinate with other Regional and Program Offices in EPA, since climate change has many impacts that transcend media and regional boundaries. Transparency and information-sharing will be essential to better leverage activities already taking place within EPA Offices and tribal governments.

Vulnerable Populations and Places

Certain individuals and communities—such as communities of color, children, the elderly, those with low income, persons with underlying medical conditions and disabilities, those with limited access to information, Tribal communities, and Indigenous people—can be especially vulnerable to the impacts of a changing climate. As climate change exacerbates existing pollution problems and environmental stressors, overburdened and underserved communities and individuals are particularly vulnerable to these impacts. Also, certain geographic locations and communities are particularly vulnerable, such as those located in low-lying coastal areas or living in isolated or segregated areas.

The *EPA's FY 2022–2026 Strategic Plan* prioritizes consideration of climate change, air quality, and environmental justice in Goal 1: Tackle the Climate Crisis and Goal 4: Ensure Clean and Healthy Air for All Communities. Similar to the strategies with Tribes mentioned above (p. 24-26), a key objective of Goal 1 is to deliver targeted assistance to increase the resilience of Tribes, states, territories, and communities to the impacts of climate change (Objective 1.2). Specifically, the Agency will provide assistance to states, territories, local governments, and communities with environmental justice concerns to take action to anticipate, prepare for, adapt to, or recover from the impacts of climate change. In the case of Goal 4, a key objective is to limit unnecessary radiation exposure and achieve healthier indoor air quality, especially for vulnerable populations (Objective 4.2). Notably, the Agency will work to reduce exposures to radon through home testing and mitigation, promote in-home asthma management, improve air quality in homes and schools, and build capacity for Tribes and communities with environmental justice concerns to comprehensively address indoor air risks. EPA will also continue to provide State Indoor Radon Grant funding, and technical assistance to Tribes and states, with a focus on increasing access to testing and mitigation in underserved communities.

While actions to reduce greenhouse gas emissions remain a top priority, OAR also recognizes the importance of implementing adaptation strategies to minimize the impacts from climate change that people and communities are already experiencing as well as those that will occur. One of the principles guiding EPA's efforts to integrate climate adaptation into its programs, policies, and rules calls for its adaptation plans to prioritize helping people, places, and infrastructure that are most vulnerable to climate impacts and that the plans are to be designed and implemented with the meaningful involvement from all parts of society.

OAR currently integrates Tribal and environmental justice considerations into a number its programs. For example, in its non-regulatory indoor air program, consistent with Priority Action 2.4 above (p. 21), OAR will increase its work with partners and regional staff to revise and update guidance so that it further addresses the adaptive capacity among disproportionately impacted populations. OAR also released a new analysis, *Climate Change and Social Vulnerability in the United States: A Focus on Six Impact Sectors*, which shows that the highest impacts of climate change fall disproportionately upon socially vulnerable individuals and communities. In keeping with Priority Action 4.1 above (p. 23), OAR will continue to look for opportunities to integrate adaptation and environmental justice considerations in its climate change impacts and risk analysis research. Another example is that OAR currently collaborates with 7 Tribes to monitor air quality and atmospheric deposition as part of the Clean Air Status and Trends Network (CASTNET). OAR will continue to seek opportunities to create new Tribal partnerships and provide technical monitoring assistance to Tribes through CASTNET. OAR's Burn Wise Program is developing targeted outreach and educational tools (e.g., Simple & Inexpensive Options for Storing Firewood video), based on feedback from low-income and Tribal communities, to reduce residential wood smoke emissions (e.g., PM, air toxics, methane, and black carbon) indoors and out. Burn Wise will continue to partner with Tribes and environmental justice communities and focus efforts to provide and promote sharing of appropriate and effective outreach tools. Lastly, OAR's Heat Island Reduction Program has developed communications and technical materials to raise awareness of and share solutions related to the disproportionate health impacts of extreme heat on underserved communities. OAR will continue to develop and enhance its materials on extreme heat inequities.

Conclusion

Climate change will continue to have significant impacts on the health and well-being of Americans and the environment, with the greatest impacts falling disproportionately on historically underserved and overburdened communities. This Implementation Plan identifies key programmatic vulnerabilities (p. 6-18) and the priority actions (p. 19-35) that will be taken to address those vulnerabilities over time. As the work called for in this Implementation Plan is conducted, where appropriate and technically possible, the communities and demographic groups most vulnerable to the impacts of climate change will be identified. Efforts will be made to share information and coordinate with other Regional and Program Offices in EPA, to leverage and enhance climate change and environmental justice activities that are already taking place. The Agency will work in partnership with these communities to increase their adaptive capacity and resilience to climate change impacts learning from experiences with past extreme weather events (e.g., hurricanes, droughts, tornados, etc.) and subsequent recovery efforts.

OAR Priority Actions Summary Table

	Priority Action Statement	Performance Metric	Lead Office	Start/End Date	Agency-Wide Priority	Resources
1.0	**<u>Planning and Implementation</u>:** Strengthen climate change adaptation across OAR through planning, evaluation, and coordination across OAR offices and programs.	Accomplish 100% of the sub-actions below in FY22 and FY23	OAR	FY22/Ongoing	**Priority 1**: Integrate climate adaptation into EPA programs, policies, rulemaking processes, and enforcement activities.	-
1.1	Develop Climate Adaptation Implementation Plan.	Completed Plan submitted to OP (i.e., 1 plan for FY22)	OAP	FY22	**Priority 1**: Integrate climate adaptation into EPA programs, policies, rulemaking processes, and enforcement activities.	Yes
1.2	Coordinate OAR web areas with Climate Adaptation microsite and link to adaptation information, resources, tools, etc. as appropriate.	Update EPA Climate Change website every year (or as needed) to include links to adaptation content from across EPA (i.e., 1 update per year)	OAP	FY22/Ongoing	**Priority 1**: Integrate climate adaptation into EPA programs, policies, rulemaking processes, and enforcement activities.	Yes
2.0	**<u>Outreach and Education</u>**: Work within EPA and with external stakeholders, as necessary, to review and revise information for citizens, especially at-risk populations, on the impact of climate change and associated events on ambient and indoor air quality, including ozone and particulate matter (PM) health impacts.	Accomplish 67% of the sub-actions below in FY22; 67% in FY23	OAR	FY22/Ongoing	**Priority 1**: Integrate climate adaptation into EPA programs, policies, rulemaking processes, and enforcement activities.	-
2.1	Incorporate adaptation considerations into OTAQ's partnership programs through outreach and education to stakeholders. As adaptation planning and implementation is an established priority for some stakeholders, OTAQ will connect for them ways that this priority can be addressed that will also accomplish our program objectives, including climate mitigation benefits.	Include adaptation information in one stakeholder document, presentation, or other outreach communications per year	OTAQ	FY22/Ongoing	**Priority 1**: Integrate climate adaptation into EPA programs, policies, rulemaking processes, and enforcement activities.	Additional resources needed to implement this sub-action.

	Priority Action Statement	Performance Metric	Lead Office	Start/End Date	Agency-Wide Priority	Resources
2.2	Address the public health impacts from wildfire smoke, which impacts millions of people each year, by communicating trusted information about air quality conditions and health impacts and manage how fire emissions (wildfire and prescribed fire) are considered in the broader context of the nation's air quality programs.	Develop, enhance, and deploy tools and resources to support community wildfire smoke preparedness and response (i.e., aim to develop 2 published resources per year)	OAQPS	FY22/Ongoing	**Priority 1**: Integrate climate adaptation into EPA programs, policies, rulemaking processes, and enforcement activities.	Additional resources needed to implement this sub-action.
2.3	Develop and/or update existing indoor air guidance on climate change adaptation strategies to further equip stakeholders to build adaptive capacity in communities.	Update 1-3 existing guidance and/or communication materials per year	ORIA	FY22/Ongoing	**Priority 1**: Integrate climate adaptation into EPA programs, policies, rulemaking processes, and enforcement activities.	Additional resources needed to implement this sub-action.
3.0	**<u>Technical Assistance and Adaptive Capacity</u>:** Strengthen resilience and adaptive capacity of federal, state, local, and tribal stakeholders to climate change impacts on ambient and indoor air quality, through enhanced technical assistance and training.	Accomplish 67% of the sub-actions below in FY22; 75% in FY23	OAR	FY22/Ongoing	**Priority 1**: Integrate climate adaptation into EPA programs, policies, rulemaking processes, and enforcement activities. **Priority 2**: Consult and partner with states, tribes, territories, local governments, environmental justice organizations, community groups, businesses, and other federal agencies to strengthen adaptive capacity and increase the resilience of the nation, with a particular focus on advancing environmental justice.	-

	Priority Action Statement	Performance Metric	Lead Office	Start/End Date	Agency-Wide Priority	Resources
3.1	Collaborate with internal and external stakeholders to improve building and infrastructure resilience to the impacts of climate through improved building codes and practices, and enhanced adoption of design, construction, and maintenance practices.	Host 1-3 meetings with internal or external stakeholders per year	ORIA	FY22/Ongoing	**Priority 1**: Integrate climate adaptation into EPA programs, policies, rulemaking processes, and enforcement activities. **Priority 2**: Consult and partner with states, tribes, territories, local governments, environmental justice organizations, community groups, businesses, and other federal agencies to strengthen adaptive capacity and increase the resilience of the nation, with a particular focus on advancing environmental justice.	Additional resources needed to implement this sub-action.
3.2	Provide training and technical assistance on climate change adaptation strategies to mitigate impacts on indoor air quality with the aim of building adaptive capacity in communities.	Provide technical assistance as 1-3 trainings and/or webinars per year	ORIA	FY22/Ongoing	**Priority 1**: Integrate climate adaptation into EPA programs, policies, rulemaking processes, and enforcement activities. **Priority 2**: Consult and partner with states, tribes, territories, local governments, environmental justice organizations, community groups, businesses, and other federal agencies to strengthen adaptive capacity and increase the resilience of the nation, with a particular focus on advancing environmental justice.	Additional resources needed to implement this sub-action.
3.3	Enhance the Exceptional Events Submission and Tracking System (EETS) and develop wildfire-related implementation tools.	Develop and implement enhancements to the EETS (i.e., develop 3 requirements for enhancements in FY22; implement these 3 enhancements in FY23); work with S/L/Ts to increase EE demonstrations in FY22 and FY23	OAQPS	FY22/Ongoing	**Priority 1**: Integrate climate adaptation into EPA programs, policies, rulemaking processes, and enforcement activities. **Priority 2**: Consult and partner with states, tribes, territories, local governments, environmental justice organizations, community groups, businesses, and other federal agencies to strengthen adaptive capacity and increase the	Resources required to implement this sub-action.

	Priority Action Statement	Performance Metric	Lead Office	Start/End Date	Agency-Wide Priority	Resources
					resilience of the nation, with a particular focus on advancing environmental justice.	
3.4	Promote participation in the $PM_{2.5}$ & Ozone Advance program as proactive approach to integrating actions to improve air quality and address climate change.	Provide information and collaboration opportunities through monthly webinars, newsletters, website, networking, and partner meetings twice per year. (Goal is to attract new areas to the program and support greater integration of climate/air quality-related programs/benefits in plans submitted by Advance areas.)	OAQPS	FY22/Ongoing	**Priority 1**: Integrate climate adaptation into EPA programs, policies, rulemaking processes, and enforcement activities. **Priority 2**: Consult and partner with states, tribes, territories, local governments, environmental justice organizations, community groups, businesses, and other federal agencies to strengthen adaptive capacity and increase the resilience of the nation, with a particular focus on advancing environmental justice.	Additional resources needed to implement this sub-action.
3.5	Protect infrastructure funded through DERA (such as shore power installations and new dray truck fleets) from severe weather impacts by developing guidance to grant recipients and RFA scoring that gives an appropriate amount of priority for applications that describe steps that will ensure infrastructure enabling grant-eligible clean technologies will be resilient to the effects of climate change. Apply knowledge gained from DERA to include adaptation considerations in future grants (i.e., BIL Clean School Bus grant program).	Incorporate appropriate adaptation information in DERA RFA and guidance documents	OTAQ	FY22/Ongoing	**Priority 1**: Integrate climate adaptation into EPA programs, policies, rulemaking processes, and enforcement activities. **Priority 2**: Consult and partner with states, tribes, territories, local governments, environmental justice organizations, community groups, businesses, and other federal agencies to strengthen adaptive capacity and increase the resilience of the nation, with a particular focus on advancing environmental justice.	Additional resources needed to implement this sub-action.

	Priority Action Statement	Performance Metric	Lead Office	Start/End Date	Agency-Wide Priority	Resources
3.6	Develop feasibility assessment describing how climate measures and associated impacts can be integrated into NAAQS attainment planning.	Develop a feasibility assessment of potential options to integrate climate adaptation into NAAQS attainment planning (i.e., develop feasibility assessment in FY23)	OAQPS	FY23/Ongoing	**Priority 1**: Integrate climate adaptation into EPA programs, policies, rulemaking processes, and enforcement activities. **Priority 2**: Consult and partner with states, tribes, territories, local governments, environmental justice organizations, community groups, businesses, and other federal agencies to strengthen adaptive capacity and increase the resilience of the nation, with a particular focus on advancing environmental justice.	Additional resources needed to implement this sub-action.
4.0	**Research and Integration:** Promote, foster, and integrate research and improved data collection, internally and externally, on climate change adaptation and related effects on OAR programs.	Accomplish 80% of the sub-actions below in FY22 and FY23	OAR	FY22/Ongoing	**Priority 5**: Identify and address climate adaptation science needs.	-
4.1	Incorporate adaptation scenarios into more climate change impact and risk analyses, where appropriate.	Present research to internal and external audiences through briefings and webinars (i.e., give 2-3 briefings/webinars per year)	OAP	FY22/Ongoing	**Priority 5**: Identify and address climate adaptation science needs.	Additional resources needed to implement this sub-action.
4.2	Promote research and collaboration with the environmental research community to improve the understanding of the relationship between climate change, indoor air quality, and human health.	Facilitate 1-3 technical webinars per year	ORIA	FY22/Ongoing	**Priority 5**: Identify and address climate adaptation science needs.	Additional resources needed to implement this sub-action.
4.3	Assess combined health effects of extreme heat and air pollution.	Publish results in peer-reviewed scientific journal, include in health effects and benefits assessment tools, conduct QA and develop documentation (i.e., develop 1 assessment in	OAQPS	FY22/FY24	**Priority 5**: Identify and address climate adaptation science needs.	Yes

	Priority Action Statement	Performance Metric	Lead Office	Start/End Date	Agency-Wide Priority	Resources
		FY22; prepare paper for submission to journal in FY23)				
4.4	Capital investment to build monitoring resiliency into the existing CASTNET infrastructure, enabling the Agency to enhance climate monitoring capacity to better assess public health (e.g., duration/intensity of pollen season) and environmental impacts across the US.	Capital improvements to modernize monitoring sites to better meet the needs of air quality managers, researchers, and the public (i.e., identify and develop a prioritized list of CASTNET monitoring sites in need of infrastructure upgrades in FY22; develop a network modernization plan in FY23	OAP	FY22/Ongoing	**Priority 5**: Identify and address climate adaptation science needs.	Resources required to implement this sub-action.
4.5	Collaborate with the environmental research community and long-term monitoring community on climate change interactions with atmospheric deposition of pollutants and impacts to natural and managed ecosystems.	Meet twice yearly with the scientific community at NADP meetings (i.e., facilitate expert participation to present latest findings at the annual NADP science symposium and the Critical Loads Science Committee (CLAD) meeting in FY22 and repeated in FY23)	OAP	FY22/Ongoing	**Priority 5**: Identify and address climate adaptation science needs.	Yes
5.0	**Modeling and Analysis: Advance climate change science through modeling and analysis activities.**	Accomplish 50% of the sub-actions below in FY22; 75% in FY23	OAR	FY22/Ongoing	**Priority 5**: Identify and address climate adaptation science needs.	-
5.1	Develop indoor air chemistry modeling capabilities to inform research of the sensitivity of indoor air chemistry to changes in ambient temperature and humidity, occupant behaviors, and indoor air quality interventions.	Develop draft residential air infiltration model	ORIA	FY23/Ongoing	**Priority 5**: Identify and address climate adaptation science needs.	Additional resources needed to implement this sub-action.

	Priority Action Statement	Performance Metric	Lead Office	Start/End Date	Agency-Wide Priority	Resources
5.2	Continue to utilize, refine, and further develop a meteorological adjustment procedure to assess the impact of long-term changes in meteorological conditions on trends in surface ozone levels.	Publish results in a peer-reviewed scientific journal (i.e., prepare 1 paper for submission in FY23; publish paper in FY24)	OAQPS	FY22/Ongoing	**Priority 5**: Identify and address climate adaptation science needs.	Additional resources needed to implement this sub-action.
5.3	Update internal multi-pollutant screening tool (NEXUS) with new climate vulnerability analysis and risk indicators (e.g., flood, fire, sea level rise, heat, disease) to more fully inform a holistic understanding of population risk exposure. NEXUS is being developed as an advanced multi-pollutant internal screening tool to identify geographic areas where health risks related to ozone, $PM_{2.5}$, and air toxics overlap.	Develop and integrate new data layers and tool capabilities relevant to climate adaptation (i.e., develop a list of new data layers and tool capabilities in FY22; integrate 1 new data layer in FY23)	OAQPS	FY22/Ongoing	**Priority 5**: Identify and address climate adaptation science needs.	Additional resources needed to implement this sub-action.
5.4	Integrate climate change impacts into power sector projections.	Publish results in peer-reviewed journals (i.e., prepare papers for submission in FY22; publish paper and post results to Power Sector Modeling web page in FY23)	OAP	FY22/Ongoing	**Priority 5**: Identify and address climate adaptation science needs.	Additional resources needed to implement this sub-action.

IV. Climate Adaptation Training Plan for Enhancing Staff Knowledge

Introduction

Consistent with *EPA's 2022–2026 Strategic Plan*, Goal 1: Tackle the Climate Crisis, OAR will provide training to enhance staff, management and partner awareness and knowledge of relevant climate change impacts and climate adaptation approaches to build resilience. This will ensure strong communication, coordination, and consistency of information shared across EPA air program offices, regional offices, and stakeholders. Training for staff will be focused on both raising awareness of the elements of climate change in general, as well as how climate change is likely to impact our mission and specific topics critical to OAR's work.

Training Plan and Timeline

OAR will have two components to its training plan. The first component will be administering a climate adaptation training produced by the Office of Policy. This training will provide foundational information on climate adaptation. The second component will be developing and administering an OAR-specific climate adaptation training. This training will provide information on the climate impacts affecting mission topics essential to OAR's programs and activities and what OAR is doing to integrate adaptation into its work. Topics included will reflect priorities across OAR offices (e.g., indoor air, transportation system, urban heat islands, wildfires, etc.) and how staff and regions can think about adaptation and air activities.

Topic	Format	Lead Office	Dates Available
Climate Adaptation 101	**Online Module**	**Office of Policy**	**Spring/Summer 2023**
OAR Climate Adaptation Overview	**Presentation w/Q&A**	**Office of Air and Radiation**	**February 2023 April 2023 June 2023**

The OAR Climate Adaptation 101 training will be in a presentation format with a question-and-answer portion. It will be offered on three different occasions in FY23. This will give OAR staff, management, and partners ample opportunities to attend one of the trainings. The slides will be made available and include links to relevant resources and materials on the topics discussed and on OAR programs and activities. The training will also be recorded and made available on EPA's website.

Measurements and Progress

Measurement and evaluation of progress is an important part of this training plan as it facilitates better understanding of OAR staff's adaptation awareness and engagement. OAR will evaluate staff's participation level in this training plan using the following metrics:

- Fundamentals of Climate Adaptation
  - The # of staff that complete the online modules

- OAR Climate Adaptation 101
    - The # of attendees at each scheduled training
    - The # of times the recorded training is accessed online

OAR will continue to encourage staff engagement and awareness of adaptation by updating its training, as appropriate, to reflect the latest climate impacts and adaptation information.

V. Climate Science Needs

Introduction

OAR has identified office-specific needs to assess climate impacts and build resilience. The Office leveraged the science needs OAR offices identified for the ORD Climate Workshop in October 2021 as well as identified new and emerging areas of interest. The needs outlined below are important areas for OAR moving forward especially in terms of the programmatic vulnerabilities and priority actions identified in this Implementation Plan.

This information will be provided to ORD to help it identify and address science needs relevant to multiple Programs and Regions.

Office of Atmospheric Programs

How does climate change impact air quality and health, especially on vulnerable populations?

This includes research that leads to continued quantification of expected climate impacts on air quality and human health. This research would be used to inform key climate policy reports and support rationale for GHG regulations under the Clean Air Act. The form of the research could be data, peer-reviewed reports and journal articles. In addition, the research could take the form of an assessment (building on the 2009 Assessment of the Impacts of Global Change on Regional U.S. Air Quality: A Synthesis of Climate Change Impacts on Ground-Level Ozone). This assessment could include both updates on the impacts of climate change on ozone and a first assessment of the impacts of climate change on particulates but could also extend to other air quality impacts as appropriate (e.g., dust, aeroallergens). Such a product would also be useful for information adaptation planning and air quality management within OAR. The research is needed in the next 1-3 years.

Vulnerability Linkages: Wildfire, air quality, extremes, health

What are the benefits of climate mitigation? How are climate risks avoided or reduced as a result of adaptation?

Research on climate change impacts across multiple future scenarios would inform quantification and valuation of potential benefits of greenhouse gas mitigation, including how adaptation may avoid or reduce climate risks. Translating the physical impacts of climate change into monetized estimates of their effects on economic and human systems continues to be an important research gap. In particular, there is a need for research to improve damage functions (for use in integrated assessment models) for specific categories such as storms, flooding, agricultural impacts, and heat. The research would contribute to improving our understanding and ability to model the economic consequences of the impacts of climate change and inform broader policy analysis frameworks (e.g., Framework for Evaluating Damages and Impacts (FrEDI), the social cost of GHGs) for estimating benefits of GHG mitigation and adaptation policies.

Vulnerability Linkages: Wildfire, air quality, extremes, health

How does climate change interact with sulfur, nitrogen, and mercury deposition, ozone concentrations, and the global carbon cycle to impact to ecosystems?

This includes research that leads to improvements in total atmospheric deposition estimates and the scientific understanding of air-surface exchange processes, nutrient cycling, assessment of critical loads and impacts to ecosystems. Much of the research is underway and would be used to improve total deposition data used in program evaluation and regulatory assessment, reduce uncertainties in deposition budgets, and improve ecological and critical loads determination and assessments. A priority research need is the continued development of low-cost deposition measurements that can be used to support the Community Multiscale Air Quality Modeling System (CMAQ) model development and evaluation and generate greater confidence in measurement-model fusion data products. In addition, continued long-term flux measurements and improved modeling of air surface exchange processes will lead to improved understanding of how changes in air quality and climate impact air surface exchange processes and nutrient cycling. Specific to critical loads, OAR supports improved critical load models, including efforts to decrease uncertainty and account for the effect of climate change in the estimates. This will improve understanding of how changes in air quality and climate change will impact ecosystems and biota. Research is also needed to improve understanding of the complex interactions among nitrogen deposition, climate change, and ecological impacts on biodiversity and carbon storage in terrestrial and aquatic ecosystems. Continued development of eutrophication and nitrogen enrichment critical loads for various ecosystems is needed.

In 1–3 years, CMAQ deposition modeling should incorporate scientific data from field research and experimentation to refine algorithms to meet gross deposition estimates (i.e., top down) and process-level deposition estimates (i.e., bottom up). Improved access to critical load and supporting data and the integration of critical loads across ecosystems and land units are also needed in this time frame. Longer-term, in 3–8 years, OAR needs a 15-year time series of modeled gridded deposition data over the conterminous U.S. using stable emissions, algorithms, and meteorological inputs to allow evaluation of trends over time. This dataset will be incorporated into the TDep Measurement Model Fusion Product.

Vulnerability Linkages: ecosystem protection, air quality

What measurements can be made at existing monitoring sites to improve the GHG inventory to help reduce uncertainties in the inventory or source contributions?

Ground-based monitors at select locations (source impacted and background sites) can be used to verify remote sensing/satellite measurements. Improvements to the inventory and reduced uncertainty in the magnitude of GHG emissions would be used for regulatory development and longer-term climate assessments. This research would also be used to inform key climate policy reports and support rationale for GHG regulations under the Clean Air Act. Research would focus on lower cost, network-ready monitors that can help address this climate vulnerability over the next 3-5 years.

Vulnerability Linkages: air quality, human health

Office of Air Quality Planning and Standards

As climate change increases wildfire season length and severity, what actions can populations take to minimize both short-term and long-term health risks of wildfire smoke?

Wildfire smoke is increasingly affecting the American population due to on-going climate change and other factors. The science suggests that this increasing trend in smoke impacts across the United States will continue as climate change continues. The increasing prevalence of smoke poses significant health risks to the U.S. population, although these risks can be mitigated by adaptation actions at the community and individual levels. There are several research questions embedded in the larger issue of how to most effectively minimize the health risks of wildfire smoke. Do the health effects from exposure to wildfire smoke differ from traditional air pollution events? What are the long-term health effects of exposures to repeated fire/smoke events (e.g., over multiple seasons)? Are there differential health impacts of smoke depending on the nature of the fire itself? What should be the balance between managing healthy outdoor activities such as hiking or running while accounting for periodic smoke impacts. Can we quantify the effectiveness of specific actions to reduce exposures to wildfire smoke during smoke events? This research is already underway, and its continuation will be used for subsequent improvements in EPA public communication about health-related smoke adaptation measures (including in *Wildfire Smoke: A Guide for Public Health Officials*).

Vulnerability Linkages: Wildfires, PM/Wildfires, Tropospheric Ozone, Indoor Air

What are the air quality, health, and climate impacts from residential wood combustion (RWC)?

As the U.S. may be more vulnerable to extreme cold weather events, and prolonged winters which can cause infrastructure issues (e.g., power outages), there may be increased use of wood for heating, resulting in poorer air quality both outdoors and indoors, as well as leading to emissions that would exacerbate the extreme events. These impacts may particularly influence rural and tribal areas raising environmental justice concerns. Residential wood combustion emits PM, hazardous air pollutants (e.g., benzene, formaldehyde) and other pollutants that contribute to nonattainment and poor indoor air quality. This sector also emits short lived climate forcing pollutants such as methane, black and brown carbon. In addition, there have been some studies indicating the potential for RWC to contribute to secondary organic aerosols (SOA). In-situ test methods and data from these test methods are needed to characterize their emissions across multiple pollutants (including hazardous air pollutants that have risk associated with them) and to quantify the impacts of various appliances, wood species and moisture and operating parameters on emissions to support regulatory and voluntary program development. These data also need to be correlated with compliance test methods. Furthermore, these data need to be used in photochemical and source apportionment modeling along with enhanced ambient data such as will be available from the Atmospheric Science and Chemistry mEasurement NeTwork (ASCENT) to ascertain the impacts of RWC emissions on PM, secondary organic aerosols and other pollutants in ambient air. The research is needed immediately.

Vulnerability Linkages: Climate change may increase the frequency and severity of wildfires and extreme weather events and may affect the Agency’s capacity to reliably monitor, assess, and implement certain Agency programs, and climate change may worsen the quality of indoor air.

How can we improve $PM_{2.5}$ speciation profiles in SPECIATE, with a focus on organic and elemental carbon (OC/EC)?

Discordance between model output of OC and EC and ambient measurements could mean speciation profiles and OC and EC fractions need updating for sectors in question. Resolving this discordance will require testing to show how BC fractions compare with EC fractions for sources where there are expected to be differences (diesels, biomass burning). Research on this issue is needed both in the short- and longer-term time frame, and there are a number of related sub-questions that require further investigation to improve these speciation profiles. For example:

- How well do current speciated inventories generate model results that reflect observations?
- How do ambient measurements of OC and EC compare with model predicted values of OC and EC?
- What source profiles most need improvement for current inventories to better reflect observations?
- What is the magnitude of carbon fractions of $PM_{2.5}$ in present observations, and what is the estimated magnitude of carbon fractions of $PM_{2.5}$ in future ambient concentrations?
- How well can carbon fractions of $PM_{2.5}$ be controlled through policies to control PM?
- Are these reductions reflected in the speciated OC/EC profiles in SPECIATE? If not, these profiles should be evaluated and updated as needed.

Vulnerability Linkages: Air Quality, Fine Particulate Matter

Office of Transportation and Air Quality

What are the impacts of climate change on a changing transportation system and what are the opportunities for building resilience?

Zero Emission Vehicles (ZEVs) are considered to be an important component of necessary climate change mitigation efforts in the transportation sector. As ZEVs become more prevalent, an emerging research need is to better understand the benefits and vulnerabilities of ZEVs and their associated infrastructure in the face of climate impacts such as extreme weather events. This includes light duty vehicles, but also extends to other transportation subsectors, including medium duty/heavy duty trucks and buses, and nonroad applications including at marine ports. For example:

- ZEVs will increase the demand on the electrical grid. At the same time, extreme weather and temperature events can impact grid stability and lead to electrical and infrastructure failure. Battery electric vehicles have potential climate adaptation co-benefits because their batteries store electricity when not in service, and can act as distributed power storage – i.e., as part of the grid itself. With vehicle-to-grid (V2G) technologies, electricity can flow back to the grid and buffer differences in supply and demand. Similarly, vehicle-to-building (V2B) technologies could serve as a backup source of energy for other purposes, such as residential cooling in a heat wave. More research is needed on the potential of V2G/V2B technologies to contribute to grid stability and resilience in the face of climate change.
- There is particular interest in the benefits and impacts of the transition to ZEVs and build out of charging infrastructure in communities that are historically underserved, and that experience disproportionate impacts from transportation and climate change.

This research could be used to strengthen EPA assistance and partnerships programs, improve guidance and information provided to stakeholders, and could inform programmatic analysis, and climate and energy models. The form of research needed is modeling and analysis**.** This research is needed in the next 1-3 years.

*Vulnerability Linkages***:** Increased frequency, and severity of extreme weather events.

Office of Radiation and Indoor Air

How can indoor air pollution exposures and their attributable health burdens be reduced with indoor air quality interventions?

Climate change may worsen existing indoor environmental problems and indoor air quality (IAQ), and it may also introduce new problems as the frequency or severity of adverse outdoor conditions change. This includes potential increases in indoor concentrations and exposure to particulate matter (PM). Additionally, climate-driven increases in the occurrence and severity of extreme precipitation, hurricanes, and storms, as well as their related flooding, may contribute to increases in building damage, deterioration, and dampness, which may affect existing IAQ interventions in buildings, such as weatherization and radon mitigation systems, as well as increase the prevalence of mold indoors. Understanding how to reduce indoor air pollution exposures and taking action to reduce those exposures will reduce public health burdens attributable to indoor contaminants, including those driven by climate change. Research needs include:

Exposure Mitigation

- *Reducing exposure to radon* - Evaluate alternatives to sub-slab depressurization radon mitigation techniques that can reduce residential radon risks reliably for low income and tribal communities. Climate change may induce shifts in indoor radon concentrations in ways that are difficult to predict, and efforts to increase energy efficiency may inadvertently lead to increased radon exposures.
- *Mitigation of exposure disparities from indoor pollutants particularly Indoor PM* - Investigate how human PM exposure disparities are related to indoor conditions and indoor activities (e.g., cooking, cleaning) and how to mitigate them. Climate mitigation strategies have the potential to modify these exposures. For example, tightening building envelopes could lead to increases in some exposures and reductions in other exposures.

Health Effects and Exposure

- *Health benefits of reducing indoor exposure to $PM_{2.5}$ with filtration/air cleaners* **-** Evaluate health benefits of using HVAC filtration/ air cleaners to reduce indoor exposures to $PM_{2.5}$, including PM from wildfires (e.g., cardiovascular, respiratory, maternal & birth outcomes, neurological) with a focus on reducing exposure disparities. Wildfires and exposure to PM indoors are expected to increase with climate change.

Vulnerability Linkages: Climate Change and Indoor Air Quality

How can low-cost sensors guide consumer indoor air quality action?

Climate change can contribute to increases in indoor air pollution by reducing outdoor air infiltration rates into buildings, thus reducing the entry of outdoor air into buildings This can result in increases in levels of indoor generated pollutants (since they are not diluted with outdoor air).

Low-cost air sensor technologies can provide consumers with information on levels of air pollutants indoors. More frequent use of low-cost monitoring indoors is being used during and after some climate driven events such as wildfires to assess the air inside and outside of buildings; however, there are many different devices, with varying accuracy and reliability. More information is needed on how these technologies can aid building occupants and communities to monitor and mitigate indoor air exposures and improve their ability to recognize and effectively respond to worsening conditions indoors resulting from wildfires and other climate related events. Research needs include:

- *Evaluate new lower cost air sensors for consumer use indoors to help guide use* **-** Including short and long-term use, detection of multiple indoor contaminants and biological contaminants, particularly in residential environments.
- *Inform decision making during wildfire smoke events* - Evaluate sensors for use indoors and outdoors for decision making during wildfire smoke events in buildings such as schools, offices, gyms, and other (semi-) public spaces.

Vulnerability Linkages: Climate Change and Indoor Air Quality