RESEARCH BRIEF

Clean Wisconsin Environmental Health Initiative

How do ozone levels impact public health in Wisconsin?

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SUMMARY – Ground-level ozone is a harmful air pollutant that damages the respiratory system, leading to diminished lung capacity, aggravated asthma and other chronic respiratory conditions, and premature mortality. Ground-level ozone is formed when other air pollutants—volatile organic compounds and nitrogen oxides—combine in the presence of heat and sunlight. It is distinct from "good ozone", or the naturally-forming layer of ozone higher up in the stratosphere which protects us from harmful UV radiation from the sun. This brief explains what ozone is, where it comes from, and how it impacts public health in Wisconsin.

Key Takeaways

- Fossil fuel combustion from vehicles and electricity generation are the primary sources of ozone precursors.
- Ozone levels have decreased by 10-15% across most of Wisconsin since the 1990s, due in large part to the effectiveness of the Clean Air Act in reducing air pollution.
- However, about 1/3 of Wisconsin's population lives in areas that do not meet current air quality standards for ozone. This includes Milwaukee and Ozaukee counties, along with portions of Kenosha, Racine, Sheboygan, Washington and Waukesha counties.
- Public health organizations support lowering the current health-based air quality standard of 70 parts per billion (ppb) to 55 or 60 ppb to better protect public health. Thus, the health impact of ozone pollution is underestimated by only considering areas not meeting the current air quality standards.
    - In Wisconsin, 2.5 million residents (44% of the population) live in areas seeing at least one day with ozone concentrations above 70 ppb, and 214,000 residents (4%) live in areas seeing at least five days with ozone concentrations above 70 ppb.
    - In contrast, virtually the entire state sees at least one day above 60 ppb, 4 million (71%) live in areas with at least 5 days above 60 ppb, and 1.8 million (32%) live in areas with at least 10 days above 60 ppb.
- Ozone pollution is estimated to be responsible for 100-400 premature deaths per year in Wisconsin, along with 1,000 hospital and emergency room visits for respiratory issues, 396,000 cases of asthma symptoms, and 240,000 lost school days each year.

  - The public health burden of ozone pollution in Wisconsin is approximately $6 billion per year.

- If a standard of 60 ppb were met, Wisconsin could avoid 32 early deaths, 102 cases of ozone-related respiratory harm, and 186,166 adversely impacted school and workdays each year.
- Limiting climate change to 2.5°C warming by 2050 would have a co-benefit of 135-360 fewer ozone-related premature mortalities per year.

Definitions

- **Nitrogen Oxides (NOx):** Gases produced by burning fossil fuels. They react with VOCs in sunlight to create ozone.
- **Oxidative Damage:** Harm caused to cells when highly reactive single oxygen atoms interfere with normal function and damage genetic material (DNA) and proteins.
- **Parts per Billion (ppb):** A measurement of pollution concentration. For example, 70 ppb means 70 ozone molecules per billion air molecules.
- **Secondary Pollutant:** A harmful substance that forms in the air from chemical reactions between other pollutants, rather than being directly emitted.
- **Volatile Organic Compounds (VOCs):** Chemicals that easily evaporate into the air, often released from gasoline, paints, solvents, and industrial processes. They react with sunlight and other pollutants to form ozone.

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Introduction

What is Ozone?

Ground-level ozone (a gas composed of three oxygen atoms; O_3) is created when volatile organic compounds (VOCs) react with nitrogen oxides (Nox) in the presence of sunlight and warmer temperatures (US EPA 2025a). Since ozone is not directly emitted from pollution sources, it is considered a secondary pollutant. Ground-level ozone formation is weather-dependent, and concentrations are the highest in the summer months, due to the warmer temperatures.

Ground-level ozone ("bad ozone") is distinct from stratospheric ozone, or "good ozone", which helps protect living organisms from harmful UV radiation emitted from the sun via the so-called "ozone layer". The ozone layer is found in the stratosphere (6-30 miles from the Earth's surface) and is naturally-forming. It is formed as UV radiation splits oxygen gas (O_2) into individual oxygen atoms, which then binds with other oxygen gas molecules.

Health concerns associated with ground-level ozone include short-term exposure concerns that can irritate and damage the respiratory system, causing coughing, shortness of breath, and chest pain. Long-term exposure may lead to more serious harms like diminished lung capacity, aggravated asthma and other chronic respiratory conditions, and premature mortality.

Where Does Ozone come from?

Ground-level ozone is created from a chemical reaction between VOCs and nitrogen oxides in the presence of sunlight and warmer temperatures. Both VOCs and nitrogen oxides come from a variety of sources including vehicle exhaust, electricity generation, and a range of industrial and commercial processes. In Wisconsin, approximately 90% of anthropogenic VOC emissions come from vehicle and industrial emissions and 75% of NOx emissions come from vehicles and electricity generation (WI DNR 2024). Typically, the highest levels of ozone occur downwind of urban areas on hotter and sunnier days.

Ozone abundance is also influenced by geographic features that can trap air pollutants in an area, such as a valley. In such areas, ozone and other air pollutants become trapped in the valley as a result of weather inversions. These inversions prevent the air in the valley from dispersing, leading to the build-up of ozone.

Climate Change Exacerbation

As described earlier, ozone formation occurs in the presence of warmer temperatures. Thus, climate change and its associated warming pose a concern for increased ozone pollution (Murazaki and Hess 2006). According to some projections, the high ozone level days, or days that are above the health-based standard, would be more frequent, with an increase of between two and three more unhealthy ozone days by mid-century in Wisconsin (East et al., 2024).

Climate change is also driving more frequent and more intense wildfires in the Western United States and Canada. Smoke from these fires can carry with it ozone precursors (nitrogen oxides), contributing to elevated ozone formation. For example, smoke from the 2023 Canadian wildfires led to record high levels of ozone in the Upper Midwest, including Wisconsin (Cooper et al. 2024).

Human Health Impacts of Ozone Pollution

Ozone molecules are unstable, and the bond with the third oxygen atom can be easily broken. Once ozone is inhaled, the highly reactive single oxygen atoms can interfere with normal cell function. At the cellular level, ozone can induce oxidative damage to cells, genetic material, and the lining fluids of airways, triggering immune and inflammatory responses within and beyond the lungs (Zhang et al 2019).

Ozone exposures are often grouped into short-term and long-term exposures. Short-term exposures to ground level ozone are associated with reduced lung function, lessened airway responsiveness, respiratory sensitivity, coughing, wheezing, and exacerbation of lung disease and infection (US EPA 2025b). Long-term exposure can be associated with all the short-term symptoms, but can additionally lead to new onset asthma cases, respiratory symptoms in children, and potentially premature death. Long-term exposures can also lead to increased rates of respiratory illness, metabolic disorders, nervous system issues, reproductive issues, and increased mortality for cardiovascular and respiratory reasons (US EPA 2025b).

Beyond respiratory effects, additional studies suggest that ambient air pollutants like ozone may also impact the nervous system (Berman et al. 2012) and gut health (Zhang et al. 2019). The research indicates increased ozone exposures can lead to increased corticosteroid levels, leading to fluctuating hormone levels, and causing unwanted stimulation of the automatic nervous system (Berman et al. 2012, Zhang et al. 2019). These emerging findings point to ozone’s widespread health impacts in the body.

A review of susceptibility of different populations to ozone exposure found that older individuals are particularly vulnerable (Bell et al. 2014). Bell et al. also found strong evidence of higher susceptibility among the unemployed or those with lower occupational status. Children, with their still-developing body systems, and those with pre-existing conditions are at higher risk of harm from ozone exposure (EPA 2025c). Additionally, outdoor workers such as migrant farm workers and construction workers are at elevated risk due to workplace exposure during the summer months (EPA 2025c).

Disparities in ozone exposure have not received as much attention as disparities in exposure to other air pollutants. However, one national analysis found that of all criteria air pollutants (the six pollutants for which there are federal air quality standards: carbon monoxide, lead, nitrogen dioxide, ozone, particulate matter, and sulfur dioxide), exposure to ozone had the lowest racial/ethnic disparities (Liu et al. 2021). In Wisconsin specifically, non-white residents were exposed to 1-4% higher ozone concentrations (Liu et al. 2021). Similarly, Kodros et al. (2024) found that ozone had the lowest spatial inequity of all en environment and social risk factors analyzed in Milwaukee County.

Wisconsin-Specific Ozone Impacts

Ground-level Ozone Concentration Patterns and Trends in Wisconsin

Concentrations of air pollutants for regulatory purposes such as compliance with air quality standards are measured by ground-based monitors. Ground-based monitors are limited in their geographic coverage, due both to their initial expense and to the cost of maintaining a network. As such, they are typically sited to capture air pollution in urban areas where there are more pollution sources, with less coverage in rural areas. This leaves large gaps in the data that can be filled with models, and more recently, satellite imaging. For ozone, there are 30 monitoring stations in Wisconsin, many of them in the coastal region of the state, leaving large gaps across the rest of the state, particularly in rural areas (Fig. 1)

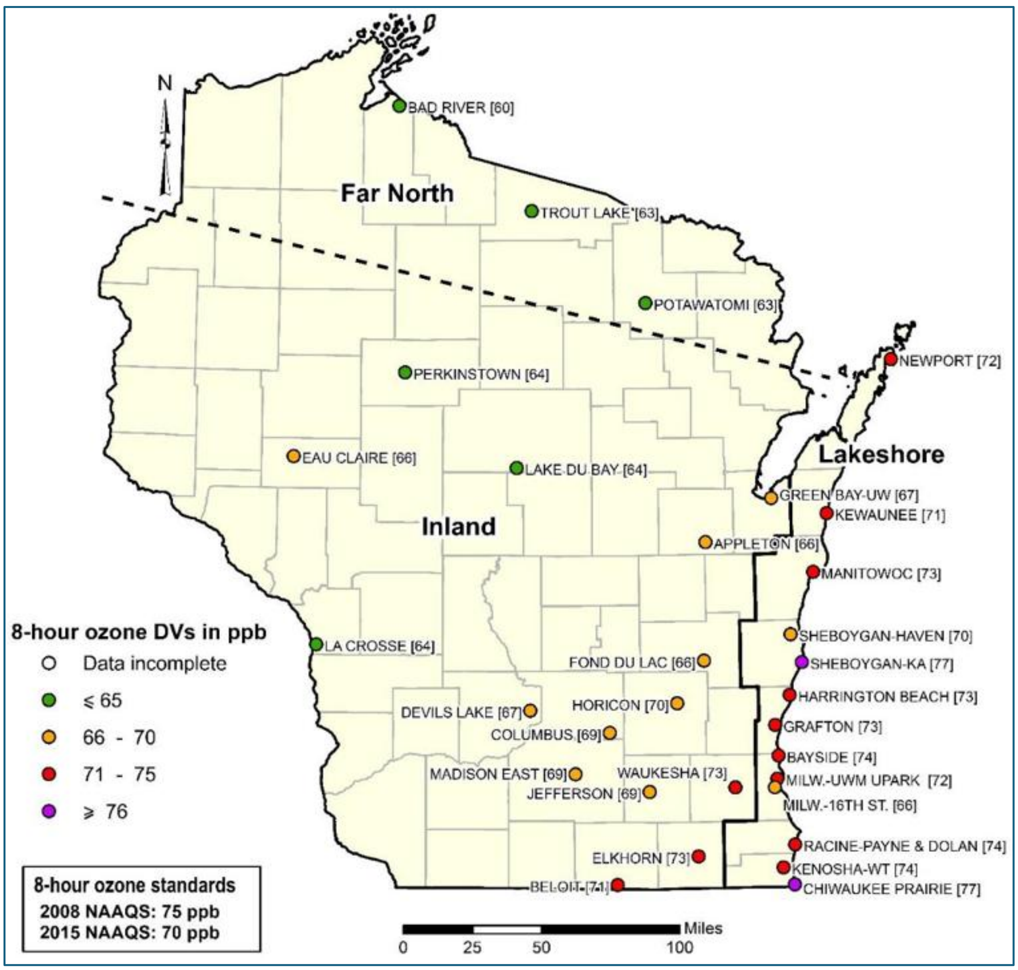

Figure 1. Ozone monitors in Wisconsin's air quality monitoring network. Stations are color coded by 2021-2023 ozone design values (DVs). Design values are the average of the 4th highest 8-hour ozone concentration from the prior three years and are used to determine compliance with the regulatory air quality standard (70 ppb). Higher concentrations are found in the lakeshore region, as a result of ozone temperature and circulation effects fostering a higher concentration of ozone-forming pollutants. Source: Wisconsin DNR 2024.

Data from the monitoring networks shows that, overall, ozone concentrations have declined since 2000 and the highest ozone levels are found along the Lake Michigan shoreline, including some counties that exceed the Clean Air Act health-based standard of 70 ppb (Fig. 2). Milwaukee and Ozaukee counties, along with portions of Kenosha, Racine, Sheboygan, Washington and Waukesha counties, have ozone levels higher than the health-based air quality standards. About 1/3 of Wisconsin's population lives in these areas that do not meet air quality standards for ozone (WI DNR 2022).

These high levels along the lakeshore are due to a unique meteorological phenomenon where ozone is formed over the lake and breezes push the formed ozone to the shoreline (Cleary et al. 2022). This study also shows that Wisconsin precursor emissions contribute a small percentage of the ozone formation, with the remainder coming from other states' precursor emissions (e.g., the Chicago metro area) and natural sources.

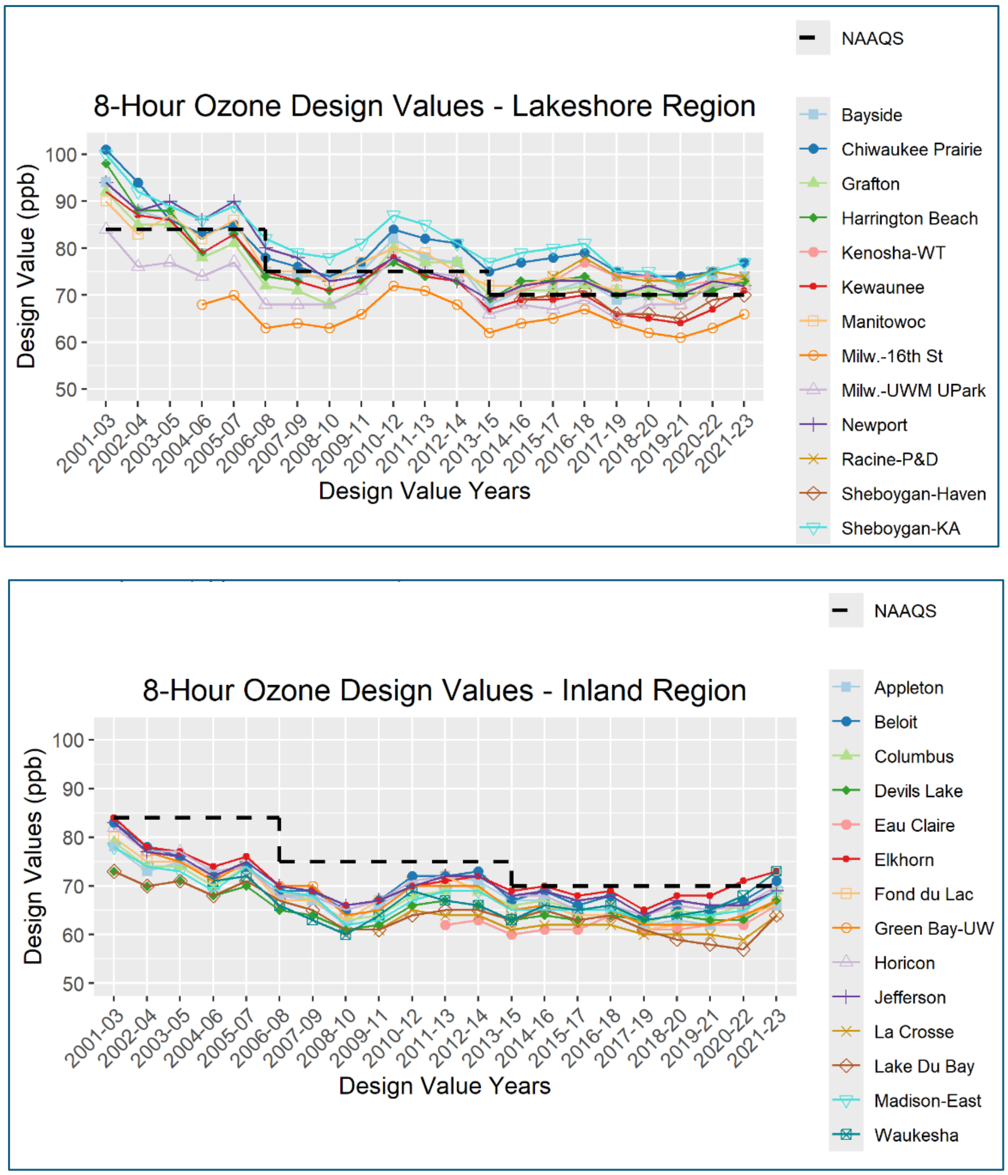

Figure 2. Trends in ozone concentrations over time at Wisconsin ozone monitoring stations, showing a general decline in ozone concentrations since 2001. Concentrations are higher in the lakeshore region, with several counties above the air quality standard (70 ppb; labeled as "NAAQS" and represented as a black dashed line in the figures). Source: Wisconsin DNR 2024.

Air pollution modeling is used to fill in the gaps left by direct monitoring. Air quality models combine meteorological information with emissions and air chemistry and transport models to predict the movement of air pollutants and provide air quality estimates across any geography. However, as with all models, these models are subject to error and bias and have less confidence than direct measurement.

Figure 3 below shows estimated annual average ozone concentrations at the census tract level in Wisconsin from two modeling efforts. The EPA estimate uses the Community Multiscale Air Quality (CMAQ) model to generate predicted ozone concentrations (EPA 2025d). Requia et al. (2020) took an ensemble approach, combining predictions from multiple modeling approaches, including CMAQ, into a single, overall prediction.

These two modeling efforts result in somewhat different patterns of annual average ozone concentrations throughout the state (Figure 3). Both models predict highest ozone concentrations in southeastern Wisconsin, while the Requia et al. model also predicts elevated levels in central and northeastern Wisconsin.

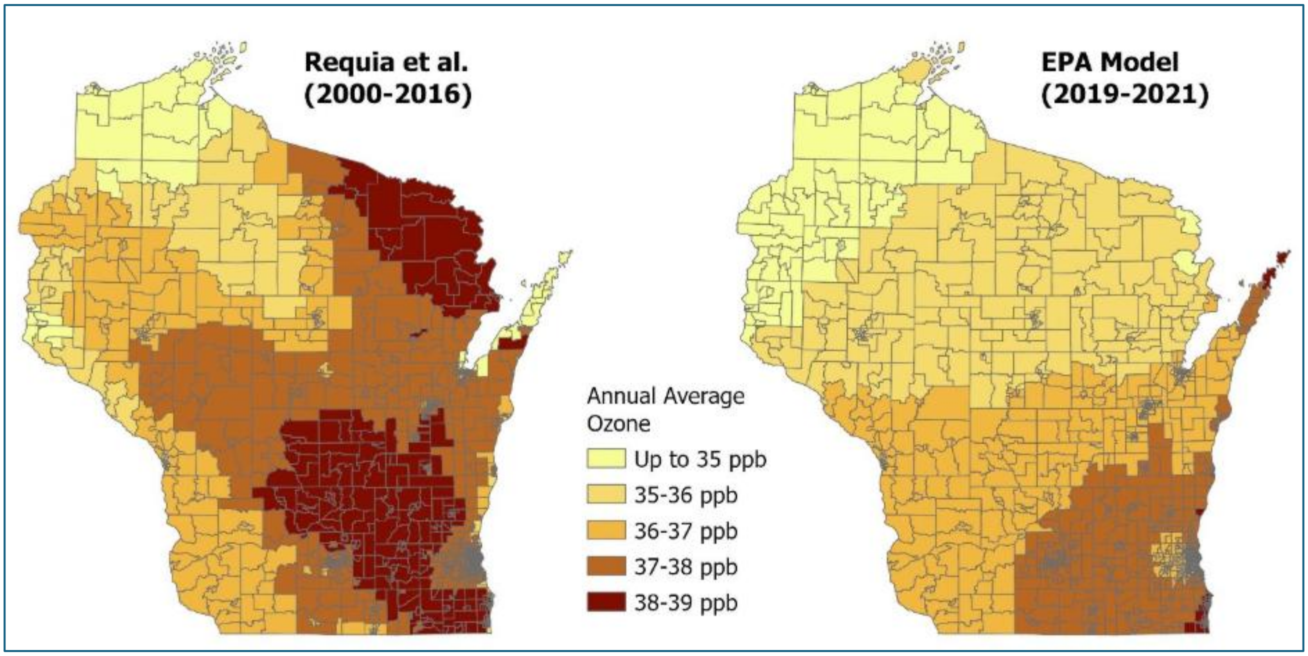

Figure3. Patterns of annual ozone concentrations in Wisconsin as modeled by Requia et al. (2020; representing years 2000- 2016) and the EPA Downscaler model (US EPA 2025d, representing the most recent 3 years of available data, 2019-2021). Both models predict highest ozone concentrations in southeastern Wisconsin, while the Requia et al. model also predicts elevated levels in central and northeastern Wisconsin. Annual average refers to the average daily maximum 8-hour ozone concentration.

Finally, the Center for Air, Climate and Energy Solutions (CACES) developed an ozone concentration model that incorporates land cover and land use data, EPA monitoring station data, and satellite-derived air pollution estimates. The models provide average daily ozone across the warmest months (May-September), when ozone is highest and thus has higher absolute ozone concentrations than the models with annual concentrations. However, the geographic patterns can still be compared. Consistent with the two annual models, the CACES model shows that concentrations are highest in the southeastern part of the state (Figure 4).

All models come with strength and weaknesses, and all are shown since they are the only census-tract ozone estimates in Wisconsin we are aware of, with strongest confidence where both models agree.

The CACES model also shows that ozone concentrations have declined by 10-15% since 1990-1992 levels for most of the state (Figure 5). These reductions can largely be attributed to the success and effectiveness of the Clean Air Act (US EPA 2011; Greenbaum 2018), underscoring the need to defend existing regulations under the act, as well as continue to find ways to further reduce air pollution.

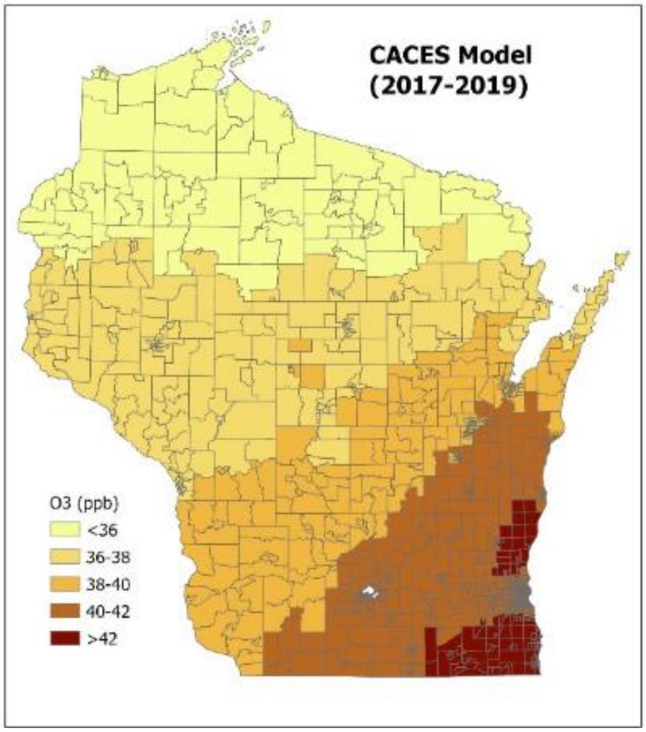

Figure 4. Patterns of 2017-2019 ozone concentrations in Wisconsin from CACES v1 empirical models (Lu et al. 2025). Ozone concentrations reflect the average daily maximum 8-hour ozone concentration from May through September.

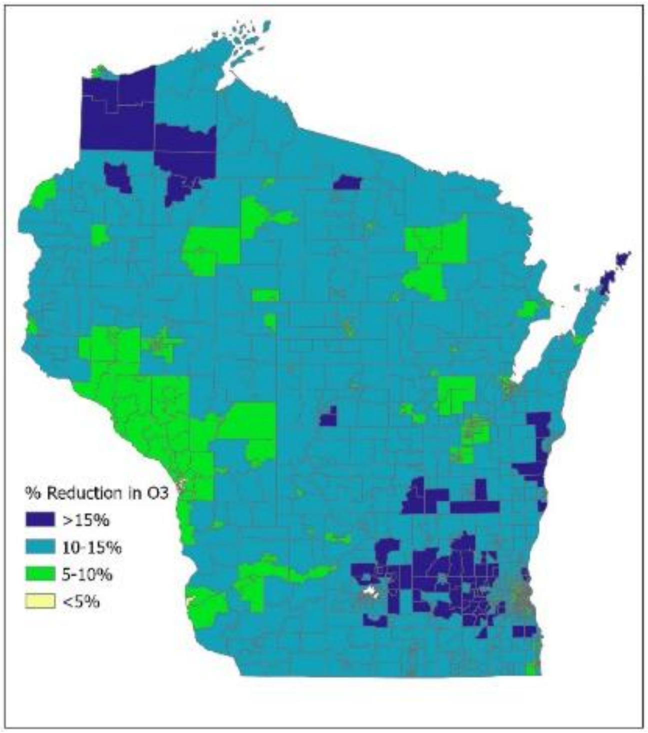

Figure 5. Reductions in May-September daily maximum 8-hour ozone concentration in Wisconsin between 1990-1992 and 2017-2019 from CACES v1 empirical models (Kim et al. 2020; Lu et al. 2025).

Ozone-Related Health Burden in Wisconsin

Monitoring data and model estimates suggest ozone levels in Wisconsin are below the current health-based regulatory standard of 70 ppb for the majority of the state. However, the American Lung Association and numerous other respiratory and public health organizations and scientists have expressed reservations that this level is not protective enough. The EPA's own Clean Air Scientific Advisory Committee (CASAC)[1] recommended a range of 60-70 ppb when the standard was last revised from 75 to 70 ppb in 2015 (American Academy of Pediatrics et al. 2015). During this rulemaking, a group of 15 respiratory health and other public health organizations advocated for a standard of 60 ppb to provide adequate protection (American Academy of Pediatrics et al. 2015).

More recently, when the ozone standard was re-evaluated by the EPA in 2020, again, a coalition of respiratory health and public health groups advocated to lower the standard to 60 ppb (American Lung Association 2020). Then in 2023, six of seven CASAC members recommended that the standard be reduced to 55-60 ppb (CASAC 2023). These concerns come from increasing evidence that there are significant public health risks at ozone concentrations below 70 ppb.

As shown in Figure 6, substantial areas of the state see multiple days with ozone concentrations above 60 ppb every year, indicating that Wisconsin resident health would benefit substantially from meeting more protective ozone quality standards. This shows how the harmful impacts of ozone in Wisconsin are significantly underestimated by only considering areas that exceed 70 ppb (Table 1).

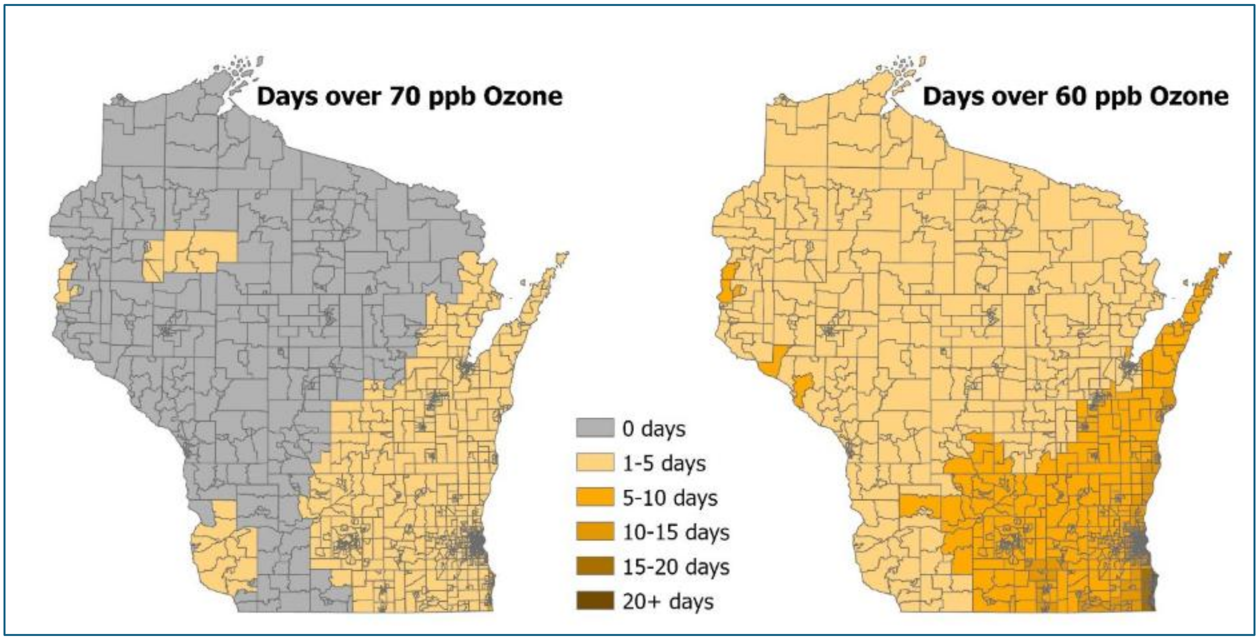

Figure 6. Number of days ozone concentrations exceed the current air quality standard of 70 ppb (left) and 60 ppb (right), the level numerous public health organizations believe is more appropriate to protect against ozone harm.

Table 1. Population in Wisconsin experiencing days where daily maximum 8-hour ozone concentrations are above 70 or 60 parts per billion (ppb), based on 2019-2021 averages. Data obtained from US EPA (2025d).		
Days per year above	**70 ppb**	**60 ppb**
At least one day	2,529,000 (44%)	5,777,000 (>99%)
At least five days	214,000 (4%)	4,092,000 (71%)
At least ten days	0 (0%)	1,829,000 (32%)

Indeed, Cromar et al. (2022) estimates that Wisconsin could avoid 32 early deaths, 102 cases of ozone-related respiratory harm, and 186,166 adversely impacted school and workdays if an ozone standard of 60 ppb were met statewide.

Several studies have reported the health effects associated with ozone pollution in Wisconsin. Zhang et al. (2018) estimated that ozone was responsible for 148 premature deaths annually, based on 2010 air quality data, while Malashock et al. (2022) estimates that ozone causes 90 deaths per year in ten Wisconsin urban areas (Table 2).

Table 2. Premature mortality attributable to ozone exposure in ten Wisconsin cities, as estimated by Malashock et al. (2020). Shown are 2017-2019 average values. Data obtained from Urban Air Quality Explorer (2025).			
City	Maximum 6-month average of the daily 8-hr maximum ozone concentration (ppb) within each city	Annual premature mortality attributable to ozone*	Percent of all premature mortality attributable to ozone
Appleton	41.96	10	5.4
Beloit	43.52	0	6.4
Green Bay	40.27	10	4.5
Janesville	43.30	0	6.2
Kenosha	43.11	10	5.8
La Crosse	42.34	0	5.6
Madison	42.66	10	5.8
Milwaukee	41.36	40	5.1
Oshkosh	41.91	0	5.4
Racine	43.87	10	6.3
*Estimates rounded to the nearest 10 premature mortalities, resulting in 0 for some cities with smaller populations and/or lower ozone concentrations.			

EPA's Co-Benefits Risk Assessment (COBRA) tool estimates that human-related emissions of ozone precursors are responsible for 377 mortalities, along with 1,042 hospital and emergency room visits for respiratory issues, 396,000 cases of asthma symptoms, and 240,000 lost school days each year (US EPA 2025e; Table 3). The total economic burden of all the ozone-related health effects included in the tool totals over $6 billion each year in Wisconsin.

Table 3. Health burden in Wisconsin of ozone from emissions of ozone precursors from all human sources in the United States, as estimated by the US Environmental Protection Agency's Co-Benefits Risk Assessment tool (US EPA 2025e; Web Edition 5.0).

Health Effect	**Cases Per Year**	**Annual Economic Burden**
Mortality	377	$5,440,000,000
Respiratory hospital admissions	42	$750,000
Respiratory emergency room visits	1,000	$1,600,000
Asthma Onset	2,400	$190,000,000
Asthma symptoms	396,000	$154,000
School Loss Days	240,000	$410,000,000
Total		***$6,042,504,000***

Fossil fuel combustion is a major source of harmful air pollutants as well as climate-warming greenhouse gases, and thus climate mitigation efforts have an additional benefit of improving air quality. Some analyses have reported the ozone-related health benefits of addressing climate change through reduced fossil fuel combustion.

Zhang et al (2017) analyzed the potential air quality and health benefits based on the world following the Representative Concentration Pathway 4.5 (RCP4.5) from the Intergovernmental Panel on Climate Change (IPCC). The RCPs were developed by the IPCC to simulate various scenarios with different levels of greenhouse gas emissions. RCP4.5 is regarded as a middle of the road scenario consistent with warming of around 2.5 degrees Celsius. In this study, RCP4.5 is compared with a reference scenario with no climate mitigation policies. According to their study, following the RCP4.5 scenario means Wisconsin would experience 1354 fewer ozone-related deaths in 2050, compared to taking no climate mitigation action.

Shindell et al (2021) analyzed the potential effects of a variety of Shared Socioeconomic Pathways (SSP) and radiative forcing scenarios compared to the current global pathway for the rest of the century. SSPs are more detailed scenarios outlining the socioeconomic environments that would lead to various emissions scenarios. While the SSPs themselves do not have specific greenhouse gas level goals associated with them, there are certain goals that are not compatible with each SSP. Following SSP 2 and RCP4.5, which are middle-of-the-road carbon reduction scenarios, Shindell et al. predict 363 fewer deaths from ozone in Wisconsin annually by 2050 compared to a scenario with little to no new carbon policies and high potential for warming temperatures (SSP3 and RCP7.0). The estimates for mortality reductions are higher than the estimates from Zhang et al. (2017) because Shindell et al. (2021) uses a more recent impact function from the literature that gives higher estimates based on new knowledge regarding the potential harm of ozone exposure.

Recommendations & Conclusions

Individuals can minimize their exposure to ozone by being aware of current ozone levels and, to the extent possible, limit their time outside on high ozone days. The Additional Resources section below includes some links to air quality monitoring options and alerts.

To minimize personal contributions to high-ozone days, limit driving by combining trips or using public transport, refuel your car after sundown, avoid idling, and avoid use of gasoline equipment like lawnmowers.

Important avenues beyond the individual level for addressing ozone pollution and its harms include:

- **Establish stronger national air quality standards for ozone.** There is sufficient evidence of harm from ozone concentrations below the current standard of 70 ppb and that a standard of no more than 60 ppb would be most appropriate to protect public health. This aligns with the Clean Air Scientific Advisory Committee's recommendation to review the current ozone standard so that it reflects current science (CASAC 2023).

- **Reduce emissions from transportation sources via improved vehicle fuel efficiency, increased use of electric vehicles, and fewer vehicle miles traveled.** Vehicle emissions are a major source of ozone precursor emissions. These emissions can be reduced by increasing fuel efficiency, transitioning to electric vehicles, and reducing vehicle traffic through improved public transportation and smart city design.
    - A local example of implementation includes the city of Milwaukee's Climate and Equity Plan. Part of the city's plan is to focus on people-centered transportation and urban design. The main goal of people-centered transportation is to reduce vehicle miles traveled and minimize harmful emissions such as ozone precursors.

- **Support and invest in renewable energy generation**: fossil fuel-based energy generation is another major source of ozone precursor emissions. This is particularly important to realize potential benefits from electric vehicles. Fossil fuel-based energy production is also a primary contributor to global warming, which is expected to increase ground level ozone formation through warmer temperatures. This must be a priority in Wisconsin, as the state's energy grid is still heavily reliant on coal, oil, and methane gas.

- **Defend against regulatory rollbacks and additional EPA & HHS cuts.** In 2025, the EPA cut its staffing by 25-33%, while HHS cut its staffing by 25% (Simmons-Duffin & Martin, 2025). These cuts reduce the agencies' abilities to do their critical work of keeping our air clean and researching how air pollution affects our health (Blum & Sellers 2025). In addition to these staff cuts, the EPA has proposed rolling back pollution-reducing rules such as fuel efficiency standards for new vehicles and no longer considering health costs when setting rules on air pollution. Such rollbacks will increase air pollution and make it easier to repeal limits on certain pollutants, including ozone.

- **Invest in funding and technology to strengthen localized monitoring efforts.** Community-based monitoring programs can help reduce individual exposure to ozone by providing real-time alerts and tracking current ozone levels. Where possible, these efforts can also encourage individuals, employers, and schools to limit outdoor activities on high ozone days.

- **Maintain & strengthen workplace education programs on ozone exposure.** Employers should provide ongoing training and resources to ensure employees understand the health risks of ozone, recognize high-ozone days, and limit outdoor tasks during these periods. Employers should also prioritize the development of workplace safety plans and follow NIOSH regulations.

- **Establish school-level policies to manage exposure on high ozone days.** Utilizing local monitoring efforts, schools should implement policies that help manage student exposure on high ozone days. This includes limiting outdoor activities or providing alternative programs for children who experience asthma or are sensitive to exposure to ozone (ALA, n.d.).

- **Support Serious Nonattainment designation in Southeast Wisconsin.** Areas in Southeastern Wisconsin, including parts of Milwaukee, Waukesha, Ozaukee, Washington, Sheboygan, Racine, and Kenosha counties, are currently designated as Moderate Nonattainment areas due to ozone levels exceeding NAAQS standards. Wisconsin was recently reclassified from Moderate to Serious Nonattainment, however, the reclassification of the nonattainment was stayed by the U.S. Court of in September 2025. Due to the stay, the requirements for moderate nonattainment will continue to be applied (DNR, 2025).
  - Supporting reclassification of Serious Nonattainment in Southeast Wisconsin increases regulation and opportunities to implement strategies and policies that protect public health and reduce ozone levels and exposure for Wisconsinites.

- **Reinstate the Good Neighbor Plan (Interstate Transport Rule)**. Since Wisconsin's ozone problem is largely caused by out-of-state sources, it's critically important to support the Interstate Transport Rule. An effective policy push coming from downwind states may urge the EPA to take action and reduce regional ozone levels and exposure.

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Additional Resources

American Lung Association: **Ozone**

AirNow: **Current particulate matter and ozone air quality levels**

Clean Wisconsin: **Protecting our air**

United States Environmental Protection Agency: **Health effects of ozone pollution**

Wisconsin Department of Health Services: **Outdoor Air Quality and Health**

Wisconsin Department of Natural Resources: **Air Quality Index Map**

Wisconsin Department of Natural Resources: **Air Quality News and Subscriptions: Air Quality Notices**

Love My Air Wisconsin: **Air Quality - Children's Health Alliance of Wisconsin**