CAPHE
PUBLIC HEALTH ACTION PLANNING
RESOURCE MANUAL
2016

SUPPORT FOR COMMUNITY ACTION TO PROMOTE HEALTHY ENVIRONMENTS (CAPHE) IS PROVIDED BY THE NATIONAL INSTITUTE OF ENVIRONMENTAL HEALTH SCIENCES, GRANT NUMBER RO1ES022616, AND THE ERB FAMILY FOUNDATION. CAPHE MEMBERSHIP IS MADE UP OF THE FOLLOWING PARTNERSHIPS AND PARTNER ORGANIZATIONS:

1 COMMUNITY ACTION TO PROMOTE HELATHY ENVIRONMENTS (CAPHE) GOALS AND OBJECTIVES

Community Action to Promote Healthy Environments (CAPHE) is a partnership of community-based organizations, academic researchers, and public health and environmental health practitioners based in governmental organizations. Our overarching goal is to work collaboratively to develop and implement a scientifically-informed public health action plan designed to reduce exposure to air pollutants and mitigate adverse health effects in Detroit, with a particular focus on vulnerable populations.

Toward this end, our specific objectives are to:

1) Strengthen, support and enhance our individual and collective capacity to work together to conduct research and communicate effectively about the science of air pollution and its effects on human health, and for all partners to be actively engaged in all aspects of the research and its translation into action;

2) Identify important sources of air pollution associated with adverse health outcomes among Detroit residents;

3) Examine and evaluate strategies to mitigate these adverse health outcomes;

4) Use the information above to develop a multilevel, integrated and scientifically-informed public health action plan that includes recommendations designed to reduce air pollutant exposures and mitigate advese health effects;

5) Develop and implement campaigns, interventions and policies to promote recommendations in the public health action plan, in order to reduce pollutant exposure and mitigate adverse health effects. Efforts will be undertaken collaboratively by community, practice and academic partners, and will be designed to engage community residents, planners, community and business leaders, as well as public health and other local decision makers.

Evaluate the effectiveness and impact of these activities, which aim to improve health outcomes and quality of life in communities disproportionately at risk for adverse health effects linked to air pollution.

2 BACKGROUND AND CONTEXT

2.1 Overview of air pollution and health in Detroit

People living and working in Detroit are exposed to elevated levels of ambient air pollutants. Air pollutants of concern include, but are not limited to, particulate matter (PM), diesel exhaust,[1, 2] volatile organic compounds (VOCs),[1,2,3,4] sulfur dioxide (SO_2), nitrogen oxides (NO_x), ozone (O_3), and several toxics (such as manganese). Exposures to these and other pollutants and the associated health effects have long been a concern among Detroit residents, who disproportionately experience many adverse health effects. Air pollution continues to be identified as one of the top public health priorities by Detroit community members and community-based organizations.[5, 6]

The adverse impacts of air pollutant exposure on health over the life course are well established.[7, 8] Air pollutants have been demonstrated to affect asthma,[9, 10] cardiovascular risk,[11, 12] and birth outcomes.[13] These adverse health effects can occur at concentrations below the current U.S. National Ambient Air Quality Standards (NAAQS). There is strong evidence that environmental pollutants make a large contribution to adverse health outcomes in urban areas such as Detroit, where a large and vulnerable population experiences high exposures.[14] Pollutant exposures have been associated with elevated cardiovascular risk,[11] asthma exacerbation,[9, 10] and adverse birth outcomes[9] among Detroit residents.

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[1] Du L, Batterman SB, Parker E, et al. 2011.Particle concentrations and effectiveness of free-standing air filters in bedrooms of children with asthma in Detroit, Michigan. Build Environ 46(11):2303-2313. PMCID: PMC3161201

[2] Keeler GJ, Dvonch JT, Yip F, et al. 2002. Assessment of personal and community-level exposures to particulate matter among children with asthma in Detroit, Michigan, as part of Community Action Against Asthma (CAAA). Environ Health Perspect. 110(suppl 2):173-181

[3] Batterman S, Chin JY, Jia C, et al. 2012. Sources, concentrations, and risks of naphthalene in indoor and outdoor air. Indoor Air 22(4):266-78.

[4] Jia C, Batterman SB, Godwin C. 2008. VOCs in industrial, urban and suburban neighborhoods: Part 2: Factors affecting indoor and outdoor concentrations. Atmospheric Environment 42(9):2101-2116.

[5] Detroit Works Project. 2012. Strategic Action Plan. Available: http://detroitfuturecity.com/framework/ [accessed 10 May 2016]

[6] Southwest Detroit Environmental Vision. 2013. SW Detroit Environmental Vision Care Project Action Plan. http://www.sdevweb.org/healthybusinesses.htm

[7] Pope CA. 2007. 3rd. Mortality effects of longer term exposures to fine particulate air pollution: Review of recent epidemiological evidence. Inhal Toxicol. 19 Suppl 1:33-38.

[8] U.S. Census Bureau. 2010. 2010 Census, Detroit City Quickfacts. Available: http://quickfacts.census.gov/qfd/states/26/2622000.html [accessed 10 May 2016]

[9] Li S, Batterman S, Wasilevich E, Elasaad H, Wahl R, Mukherjee B. 2011. Asthma exacerbation and proximity of residence to major roads: A population-based matched case-control study among the pediatric Medicaid population in Detroit, Michigan. Environ Health 10:34. PMCID: PMC3224543

[10] Li S, Batterman S, Wasilevich E, et al. 2011. Association of daily asthma emergency department visits and hospital admissions with ambient air pollutants among the pediatric Medicaid population in Detroit: time-series and time-stratified case-crossover analyses with threshold effects. Environ Res 111(8):1137-1147. PMID: 21764049

[11] Milando C, Huang L, Batterman S. 2016. Trends in PM2.5 emissions, concentrations and apportionments in Detroit and Chicago. Atmos Environ 129:197-209.

[12] Peters A, Dockery DW, Muller JE, Mittleman MA. 2012. Increased particulate air pollution and the triggering of myocardial infarction. Circulation 103(3):2810-2815.

[13] Le HQ, Batterman SA, Wirth JJ, et al. 2012. Air pollutant exposure and preterm and term small-for-gestational-age births in Detroit, Michigan: Long-term trends and associations. Environ Int 44:7-17. PMID: 223141

[14] Giles LV, Barn P, Kunzli N, et al. 2011. From good intentions to proven interventions: Effectiveness of actions to reduce the health impacts of air pollution. Environ Health Perspect 2011;119(1):29-36. PMCID: PMC301849

Air pollutants typically occur as mixtures, and these mixtures vary at different points in time and across areas. As a result, it can be challenging to identify and quantify the specific pathways through which pollutants affect respiratory (lung), cardiovascular (heart and circulatory system), neurological, and other health outcomes. Section 4 of this manual describes air quality monitoring and exposures in Detroit and describes, for key pollutants, attainment with the NAAQS, the monitoring network for that pollutant, and concentration trends. Monitoring and exposures of $PM_{2.5}$, O_3 and SO_2 are emphasized, given the importance of these pollutants in the Detroit area.

Because exposures vary across places, it is important to identify where there are vulnerable populations who are being exposed. Important factors linked to vulnerability of individuals and populations include age (young, old), race and ethnicity (African American and Hispanic), income, and pre-existing cardiovascular (heart) or pulmonary (lung) disease. Protecting vulnerable populations from exposure to air pollutants is particularly important because their health is more strongly affected. Issues of vulnerability and susceptibility are detailed in Section 3 of this manual.

In addition to the amount of pollutants emitted, exposure is affected by how close point (stationary) and mobile (cars, trucks) emission sources are to homes, schools, playgrounds and other frequented locations, and the number of people living or going to school or work in an area affects how many people are exposed.[9, 15] However, emissions from many sources, including those with elevated stacks and those that form secondary pollutants, can affect a broad region, and sometimes the area most affected can be several or many miles distant from sources. Section 5 of this manual describes emission sources, including point, mobile and area sources, the spatial patterns or dispersion of pollutants result from major sources factoring in effects of meteorology, and estimates the health impacts from $PM_{2.5}$, O_3, and NO_x exposures.

2.2 Important sources of ambient air pollutants in Detroit

Exposure to ambient air pollutants results from emissions at both stationary and mobile sources. The concentrations that result from these emissions are influenced by weather and climate conditions, including wind patterns that carry and disperse pollutants from sources to neighborhoods, cities and other regions.[16, 17] Source apportionment studies provide estimates of sources contributing to air pollutants. One study that used data from southwest and eastside Detroit indicated that 60% of ambient particulate matter ($PM_{2.5}$) is attributable to secondary sulfate/coal combustion sources (for example, coal fired power plants), and 30% to vehicular sources (e.g., cars, trucks).[18] A more recent study in Detroit found that while Wayne county-wide data suggest emissions from point sources are decreasing, emissions from on-road mobile sources are constant.[11] Thus, while concentrations of $PM_{2.5}$ have declined over the past two decades, the fraction of $PM_{2.5}$ due to emissions from vehicles and some other local emission sources has increased.[11] Section 4 of this manual provides a more recent update, showing that trends of $PM_{2.5}$ are not decreasing. These and other studies in North America, Europe and Asia show that in urban areas, cars, trucks and other vehicles are one of the

[15] Rioux CL, Tucker KL, Mwamburi M, Gute DM, Cohen SA, Brugge D. Residential traffic exposure, pulse pressure, and C-reactive protein: Consistency and contrast among exposure characterization methods. Environ Health Perspect 118(6):803-811. PMCID: PMC2898857

[16] Health Effects Institute. 2010. Traffic-related air pollution: A Critical review of the literature on emissions, exposure, and health effect. Boston, MA. Available: http://pubs.healtheffects.org/view.php?id=334 [accessed 10 May 2016]

[17] Turner JR. 2008. A Conceptual Model for Ambient Fine Particulate Matter Over Southeast Michigan: High Concentration Days: Southeast Council of Governments.

[18] Hammond DM, Dvonch JT, Keeler GJ, et al. 2008. Sources of ambient fine particulate matter at two community sites in Detroit, Michigan. Atmos Environ 42:720-732.

dominant sources of air pollutants such as PM, diesel exhaust PM, VOCs, carbon monoxide (CO), nitrogen oxides (NO_x), and ozone (O_3) precursors.

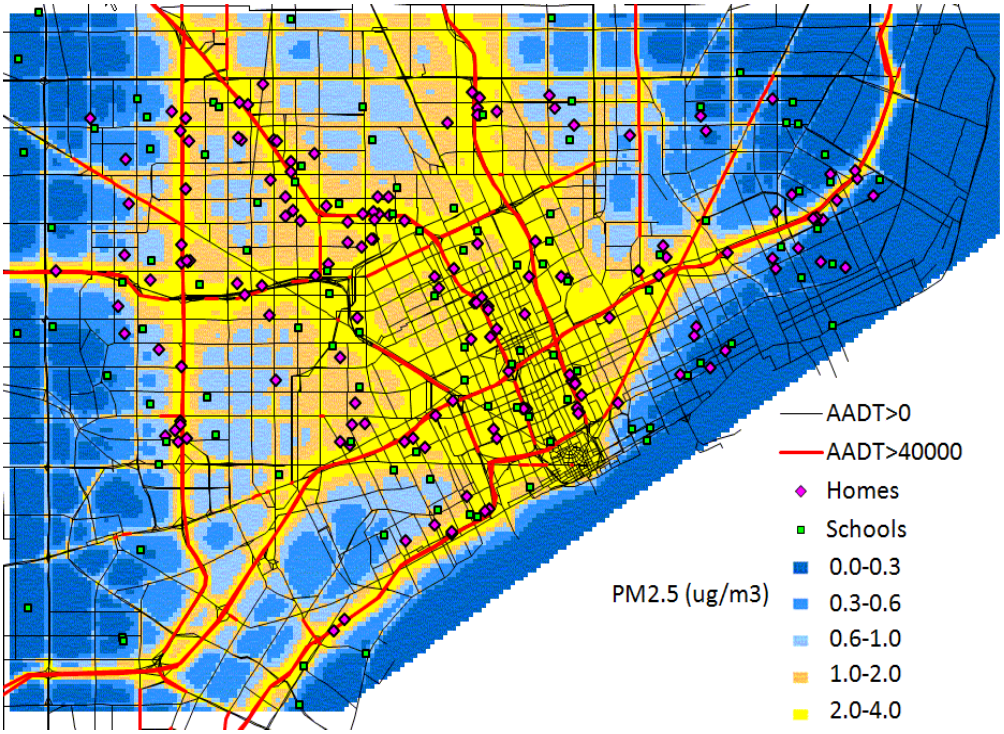

Figure 1-1 is a map showing annual average (2010) $PM_{2.5}$ concentrations attributable to vehicular sources in Detroit, showing sharp spatial gradients characteristic of these emissions, and the locations of study participant homes and schools in one of our CBPR-based epidemiological studies.[19] Section 5 of this resource manual describe emission sources in depth.

Fig 1-1: Annual average $PM_{2.5}$ concentrations from traffic in Detroit/Wayne Co. Based on EPA MOVES/ AERMOD models, 9701 road links, 2010 meteorology. Figure also shows homes and schools in an ongoing CAAA study. Derived from Batterman et al., 2014. [20]

As an older industrial city, Detroit has many homes and schools very close to highways. For example, 80 public schools are within 150 meters (about 500 feet) of large highways, many with high proportions of heavy diesel vehicles.[21] The proximity of many homes and schools to freeways can increase residents' and students' exposure to air pollutants from traffic, including $PM_{2.5}$ and diesel exhaust.[16, 22]

[19] Vette A, Burke J, Norris G, et al. 2012. The near-road exposures and effects of urban air pollutants study (NEXUS): Study design and methods. Sci Total Environ

[20] Batterman S, Ganguly R, Isakoff V, Burke J, Arunachalam S, Snyder M, et al. 2014. Dispersion Modeling of Traffic-Related Air Pollutants: Exposure and Health Effects among Children with Asthma in Detroit, Michigan. Transportation Research Record (TRR), Journal of the Transportation Research Board, No. 2452, 105–113.

[21] Wu YC, Batterman SA. 2006. Proximity of schools in Detroit, Michigan to automobile and truck traffic. J Expo Sci Environ Epidemiol 16(5):457-470.

[22] Cho SH, Tong H, McGee JK, Baldauf RW, Krantz QT, Gilmour MI. 2009. Comparative toxicity of size-fractionated airborne particulate matter collected at different distances from an urban highway. Environ Health Perspect 117(11):1682-1689. PMCID: PMC2801189

Detroit is also notable for its many large industrial sources of air pollutants. These include coal-fired power plants, coke, steel, and cement facilities, petroleum refineries, and incinerators, among others. There are also large neighborhoods adjacent to many of the large industrial facilities. Several of these facilities are large emitters of sulfur dioxide (SO_2) and other pollutants, and portions of the Detroit area are currently classified as a SO_2 NAAQS non-attainment area, that is, an area that does not meet the heath-based federal air pollution standard for this pollutant. Fig 1-2 shows that high SO_2 concentrations span much of the Detroit region, largely due to emissions from coal-fired power plants, steel industry, and other SO_2 emission sources. Ambient monitoring, emissions and health impacts related to SO_2 exposure (and other pollutants) are discussed in Sections 4 and 5 of this manual.

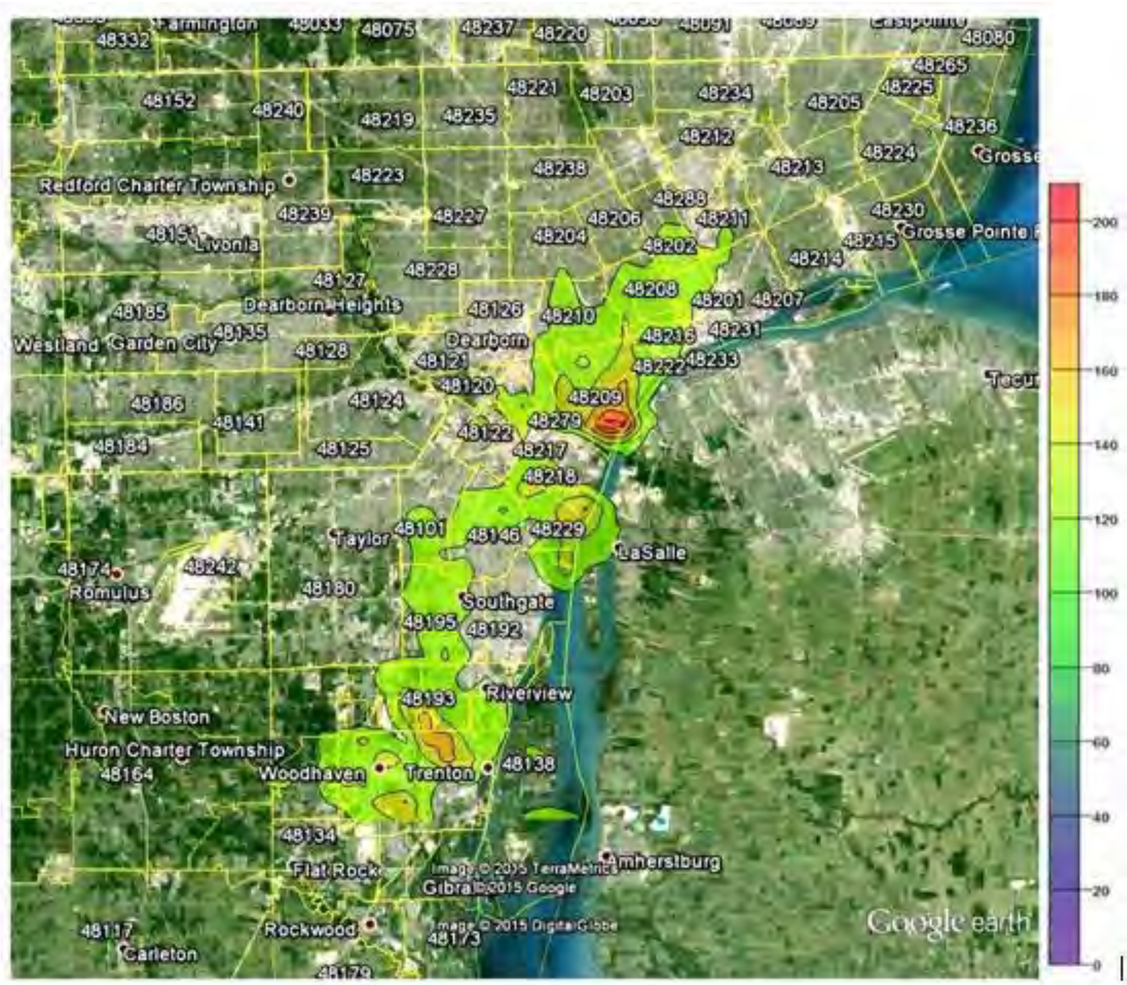

Figure 1-2. Predicted SO_2 concentrations ($\mu g/m^3$) across the Detroit region. Shows 4th highest daily 1-hr concentration predicted from major Detroit area. Based on AERMOD, 2012 meteorology, 1000 m grid, and no background. (157 $\mu g/m^3$ is equal to 75 ppb, the current 1-hr NAAQS concentration. Concentration scale at right.

Considering pollutants other than SO_2 and $PM_{2.5}$, Detroit (like many other urban areas) is very close to exceeding the health-based ozone (O_3) NAAQS that was promulgated by US EPA in late 2015; this might require significant reductions in precursor NO_x and VOC emissions to attain the new and lower O_3 standard. From a regulatory and political perspective, non-attainment status greatly increases both the awareness and attention given to air pollution problems. O_3 and other pollutants are discussed in Sections 4 and 5.

2.3 Mitigating air pollutant exposure

There are many approaches or interventions that can be used to mitigate air pollutant exposure, reduce adverse health effects, and improve public health.[14, 23] Public health actions informed by scientific evidence can make substantial contributions to public health. Potential interventions include, for example, "traditional" end-of-pipe emission controls, air filters installed in homes and schools to reduce particulate matter exposure, and the

[23] U.S. EPA. 2011. School Siting Guidelines. Atlanta, GA: EPA; Report No.: EPA-100-K-11-004. http://www.epa.gov/schools/siting/

use of barriers, buffers and "green spaces" adjacent to roadways and other pollution sources (e.g., industry) that can reduce noise and the concentration of air pollutants that reach people.[24, 25,26]

A wide range of mitigation measures is evaluated in Section 9 of this manual. This includes a considerable amount of new information and research evaluating the effectiveness and applicability of these measures to improving health in the Detroit area.

2.4 CAPHE goals and partnerships

Community Action to Promote Healthy Environment's (CAPHE's) goal is to develop a public health action plan that includes multiple strategies that will improve air quality and health in Detroit.

CAPHE builds on, and substantially extends, over 15 years of community-based participatory research (CBPR) partnerships, involving collaboration between community-based organizations working on environmental health issues in Detroit, academic researchers with expertise in the health effects of air pollutants, land use, climate change, and community health promotion, and public health and environmental health practitioners based in government institutions.

Three long-standing CBPR partnerships serve as the foundation for CAPHE; the Detroit Community-Academic Research Center, Community Action Against Asthma, and the Healthy Environments Partnership.

The **Detroit Community-Academic Research Center (Detroit-URC)** a CBPR partnership established in 1995, involves collaboration among eight community-based organizations (Community Health and Social Services Center, CHASS; Communities In Schools; the Detroit Hispanic Development Corporation (DHDC); Detroiters Working for Environmental Justice (DWEJ); Friends of Parkside (FOP); Latino Family Services (LFS); Neighborhood Service Organization (NSO); Eastside Community Network (ECN), the Institute for Population Health, Detroit Health Department, Henry Ford Health System, and the University of Michigan Schools of Public Health, Nursing and Social Work. These organizations comprise the URC Board, which oversees all URC activities, including adherence to its CBPR principles and the development of new, affiliated partnerships.[27] The URC's mission is to foster and support community-based participatory research efforts to examine and address social and physical environmental determinants of health aimed at eliminating health inequities. Its policy-advocacy goals are to: (1) enhance capacity at the organization, local, state and national levels to impact policy change; and (2) translate research findings to promote policy change. Since 2008, the URC has worked to enhance knowledge and skills of community members to engage in the policy advocacy process.[28]

Community Action Against Asthma (CAAA) began in 1998 as part of an NIEHS/EPA funded Children's Center initiative. CAAA uses a CBPR approach to conduct epidemiological and intervention research investigating the influence of environmental factors on childhood asthma. It engages six CBO partners, including the DHDC, DWEJ,

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[24] Baldauf R, Thoma E, Hays M, et al. 2008. Traffic and meteorological impacts on near-road air quality: Summary of methods and trends from the Raleigh Near-Road Study. J Air Waste Manag Assoc 58(7):865-878. PMID: 18672711

[25] Bowker GE, Baldauf RW, Isakov V, Khlystov A, Petersen W. 2007. Modeling the effects of sound barriers and vegetation on the transport and dispersion of air pollutants from roadways. Atmos Environ 41:8128-8139.

[26] The Marathon Oil Refinery, located on Detroit's Southwest side, recently purchased several hundred homes around it so it could expand; this forms a type of buffer. As a result, hundreds of nearby households moved away. However, buffers have much broader applicability.

[27] Israel BA, Lichtenstein R, Lantz P, et al. 2001. The Detroit Community-Academic Urban Research Center: Development, implementation and evaluation. J Public Health Manag Pract 7(5):1-19.

[28] Israel BA, Coombe CM, Cheezum RR, et al. 2010. Community-based participatory research: A capacity building approach for policy advocacy aimed at eliminating health disparities. Am J Public Health 2010;100(11):2094-2102. PMID: 20864728

Southwest Detroit Environmental Vision, LFS, FOP, WCDC and CHASS. Its Steering Committee oversees all phases of the research process.[29] Since its inception, CAAA has received 4 R01s from NIEHS and an EPA STAR grant. CAAA has conducted an intervention study investigated the efficacy of air filters in reducing PM levels and improving respiratory health among children with asthma, an exposure and health effects study investigating effects of residence and school proximity to major highways and exposure to diesel PM on the health status of children with asthma,[30] and an epidemiologic study evaluating interactions between traffic exposures and viral respiratory infections, and asthma. CAAA has reported, for example: elevated levels of PM and effects of filters on indoor air quality[1, 3, 31, 32], elevated indoor levels of VOCs[3, 33, 34], relationships between PM exposure and children's asthma symptoms and unscheduled medical visits,[35] areas within the city where high concentrations of African American and Hispanic residents experience reduction in lung function with exposure to PM[33], and advanced exposure modeling techniques.[19] For a summary of CAAA's research, see Appendix TBD.

The **Healthy Environments Partnership**, established in 2000 with funding from NIEHS, is a CBPR partnership with a focus on cardiovascular health in Detroit neighborhoods.[36] HEP conducts etiological research linking aspects of the physical, built and social environments to cardiovascular health, and develops, implements and evaluates interventions to address those conditions toward the end of reducing racial/ethnic and socioeconomic inequities in cardiovascular disease (CVD). Since HEP's inception, the partnership has examined environmental

[29] Parker EA, Israel BA, Brakefield-Caldwell W, et al. Community Action Against Asthma: Examining the partnership process of a community-based participatory research project. J Gen Intern Med 18(7):558-567.

[30] Li S, Mukherjee B, Batterman S. 2012. Point source modeling of matched case-control data with multiple disease subtypes. Stat Med 31(28):3617-3637. PMID: 22826092

[31] Du L, Batterman S, Godwin C, et al. 2012. Air change rates and interzonal flows in residences, and the need for multi-zone models for exposure and health analyses. Int J Environ Res Public Health 9(12):4639-61.

[32] Batterman S, Du L, Mentz G, et al. 2012. Particulate matter concentrations in residences: an intervention study evaluating stand-alone filters and air conditioners. Indoor Air 22(3):235-252. PMID: 22145709

[33] Chin JY, Godwin C, Jia C, et al. 2012. Concentrations and risks of p-dichlorobenzene in indoor and outdoor air. Indoor Air 23(1):40-9. PMCID: PMC3501547

[34] Jia C, Batterman SA, Relyea GE. 2012. Variability of indoor and outdoor VOC measurements: an analysis using variance components. Environ Pollut 169:152-159. PMID: 21995872

[35] Lewis TC, Robins TG, Dvonch JT, et al. 2005. Air pollution associated changes in lung function among asthmatic children in Detroit. Environ Health Perspect 113(8):1068-1075.

[36] Schulz AJ, Kannan S, Dvonch JT, et al. 2005. Social and physical environments and disparities in risk for cardiovascular disease: The Healthy Environments Partnership conceptual model. Environ Health Perspect 113(12):1817-1825

conditions and CVD risk factors.[37, 38, 39, 40, 41, 42] Research conducted has demonstrated effects of $PM_{2.5}$ on blood pressure, particularly for residents of neighborhoods proximate to air pollutant sources.[43] These effects are exacerbated for residents who are obese[44] and for those who report high levels of stress.[45] HEP has also conducted an extensive community assessment and participatory action planning process,[46] which included dissemination of findings to policy makers, in order to develop multilevel interventions to reduce inequities in CVD, which are currently being implemented and evaluated. In keeping with HEP's CBPR approach, four CBOs (Friends of Parkside (FOP), Detroit Hispanic Development Corporation (DHDC), Eastside Community Network (ECN) and Chandler Park Conservancy (CPC)), Detroit Health Department, Henry Ford Health System, and the University of Michigan School of Public Health are members of the HEP Steering Committee, which guides all phases of this work. For a summary of HEP's research, see www.hepdetroit.org, and for a summary of HEP's research related to air quality and health, see Appendix TBD.

Representatives from each of the above partnerships are involved with CAPHE, as well as additional groups and organizations whose work is relevant to air pollution and health in Detroit.

2.5 CAPHE Core Team

Members of the CAPHE Core Team include:

The **Detroit Hispanic Development Corporation (DHDC),** a non-profit organization in Southwest Detroit, rooted in the vibrant culture of Detroit's Latino community. DHDC's mission is to make a difference by creating life-changing opportunities. DHDC serves over 5,000 youth and adults annually. Programs include adult education services that reach out to non-traditional students, youth services that are recognized as some of the best in the city of Detroit, and family services that emphasize the importance of healthy family communication and parent leadership. DHDC also leads a "Colectivo" of Latino-led groups in organizing efforts designed to strengthen the Detroit Latino community's voice and increase their participation in democratic processes, while

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[37] Schulz AJ, House JS, Israel BA, et al. 2008. Relational pathways between socioeconomic position and cardiovascular risk in a multiethnic urban sample: Complexities and their implications for improving health in economically disadvantaged populations. J Epidemiol Community Health 62(7):638-646. PMCID: PMC2668209

38 Zenk S, Schulz AJ, Hollis-Neely T, et al. 2005. Fruit and vegetable intake in African Americans: Income and store characteristics. Am J Prev Med 29(1):1-9.

[39] Zenk S, Schulz AJ, House JS, Benjamin A, Kannan S. 2005. Application of CBPR in the design of an observational tool: The Neighborhood Observational Checklist. In: Israel BA, Eng E, Schulz AJ, Parker E, eds. Methods in Community-Based Participatory Research for Health. San Francisco, CA: Jossey-Bass p. 167-187.

[40] Zenk S, Schulz AJ, Israel BA, James SA, Bao S, Wilson ML. 2005. Neighborhood racial composition, neighborhood poverty, and supermarket accessibility in metropolitan Detroit. Am J Public Health 95(4):660-667.

[41] Zenk SN, Schulz AJ, Israel BA, House JS, Benjamin A, Kannan S. 2005. Use of community-based participatory research to assess environmental determinants of health: Challenges, facilitators, and implications for universities. Metropolitan Universities Journal 16(1):107-125.

[42] Schulz AJ, Mentz G, Lachance L, Johnson J, Gaines C, Israel BA. 2012. Associations between socioeconomic status and allostatic load: Effects of neighborhood poverty and tests of mediating pathways. Am J Public Health 102(9):1706-14. PMCID: PMC3416053

[43] Dvonch JT, Kannan S, Schulz AJ, et al. 2009. Acute effects of ambient particulate matter on blood pressure: Differential effects across urban communities. Hypertension 53(5):853-859. PMID:19273743

[44] Kannan S, Dvonch JT, Schulz AJ, et al. 2010. Exposure to fine particulate matter and acute effects on blood pressure: effect modification by measures of obesity and location. J Epidemiol Community Health 64(1):68-74. PMID:19833604

[45] Hicken MT, Dvonch, JT, Schulz AJ, Mentz G, Max P. 2014. Fine particulate matter air pollution and blood pressure: The modifying role of psychosocial stress. Environmental Research. 133:195-203. PMID: 24968081. PMCID: PMC4137402

[46] Schulz AJ, Israel BA, Coombe CM, et al. 2011. A community-based participatory planning process and multilevel intervention design: Toward eliminating cardiovascular health inequities. Health Promot Pract 12(6):900-912. PMCID: PMC3212629

building their capacity as agents of change and self-determination in their own families, schools and communities.

Detroiters Working for Environmental Justice (DWEJ) champions local and national collaboration to advance environmental justice and sustainable redevelopment. They foster clean, healthy and safe communities through innovative policy, education and workforce initiatives. DWEJ envisions Detroit as the global model of a vibrant urban center where all thrive in environmental, economic and social health. DWEJ provides leadership and coordination for the Detroit Environmental Agenda, a far reaching plan to promote environmental justice throughout the city, and encompassing air, water, tree canopy, recycling, sewerage and other environmental issues in the city.

Southwest Detroit Environmental Vision (SDEV), is a 501(c)(3) nonprofit organization whose mission is to improve the environment and strengthen the economy of Southwest Detroit. They work together with residents, community organizations, government agencies, schools, businesses and industry to combat environmental issues, including: indoor and outdoor air quality, blight (illegal dumping, graffiti, abandoned homes), and incompatible land use. SDEV is funded through memberships, individual and corporate donations, and grants. SDEV's work would not be possible without the dedication of our community volunteers.

The **University of Michigan School of Public Health (UM SPH),** whose mission is to create and disseminate knowledge with the aim of preventing disease and promoting the health of populations worldwide. The UM SPH is especially concerned with health equity and thus has a special focus on populations who disproportionately experience excess exposures that are harmful to health, including exposures in the physical environment (e.g., air pollutants) and social and economic environments (e.g., isolation, poverty). Faculty from the Departments of Environmental Health Sciences and Health Behavior and Health Education are actively involved with CAPHE, and bring expertise in air pollution and mitigation strategies, social and economic factors that are associated with health equity, community-based participatory research, and translation of research into action to promote health and health equity.

2.6 CAPHE Steering Committee

Members of the CAPHE Steering Committee include the above mentioned Core Team Members, and additional representatives from:

Detroit Future City (DFC), the home-base of the DFC Strategic Framework, which was formed in 2013 after three years of solid work, drawing on the best local and national talent as well as the insights of tens of thousands of Detroiters. The DFC Strategic Framework is a highly detailed long term guide for decision–making by all of the stakeholders in the City. Through the support of the Kresge Foundation, Detroit Economic Growth Corporation, W. K. Kellogg Foundation, John S. and James L. Knight Foundation and working in collaboration with the City of Detroit, the DFC Strategic Framework is guiding planning in Detroit.

Green Door Initiative (GDI), a non-profit 501(c) 3, environmental organization that works to ensure that every person is environmentally literate capable of practicing and promoting sustainability as a life style. GDI has several programs including environmental education and awareness, land use development, "Youths Speak Green" youth development program, climate change and environmental restoration, and development of a green workforce in Detroit.

Michigan Department of Environmental Quality (DEQ), the state agency that ensures that Michigan's air remains clean by regulating sources of air pollutants to minimize adverse impact on human health and the environment. Goals are to meet and maintain air quality standards, limit emissions of hazardous and toxic pollutants, and inform the public about current air conditions.

The **Sierra Club's** Detroit-based Environmental Justice Office, which is part of the nation's oldest, largest and most influential grassroots environmental organization. The Sierra Clubs Environmental Justice efforts in Detroit include a strong focus on communities disproportionately affected by environmental exposures, with advocacy to change policies to promote environmental justice.

The Taubman College of Architecture and Urban Planning, a school at the University of Michigan, that strives to improve the environmental quality, economic potential, and social equity of places: neighborhoods, towns, cities, metropolitan areas, and larger regions. The college seeks to shape place-based policy and design for social equity and sustainability, regional solutions to metropolitan problems, just and effective remedies for urban decline, and the creation of human settlements that offer alternatives to environmentally consumptive land-development patterns.

The **University of Michigan's Medical School,** which has more than 160 years of service to the University, State of Michigan, and the world. They have known how to put patients first, when to push the boundaries of science and medicine, how to design successful curricula, and how to reward our faculty, students and staff for their everyday excellence.

Wayne State University Law School – Transnational Environmental Law Clinic: Wayne State University Law has partnered with the University of Windsor Law School to create North America's first Transnational Environmental Law Clinic. The clinic teaches students the skills and strategies needed to affect environmental policy in all three branches of state and federal government. During classroom sessions, students learn about current environmental policy challenges and opportunities and explore these issues from multiple perspectives. In the clinical component, students participate in the lawmaking process by preparing policy papers and formal legislative testimony, commenting on rulemaking and permit decisions, and engaging in judicial review and enforcement litigation.

CAPHE PHAP-RM

3. AIR QUALITY, HEALTH AND ENVIRONMENTAL JUSTICE

2016

This work is made possible by National Institute of Health and Environmental Sciences, RO1ES022616, and the Fred A. and Barbara M. Erb Family Foundation. Additional support was provided by the Michigan Center on Lifestage Environmental Exposures and Disease (M-LEEaD), #P30ES017885.

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3. AIR QUALITY, HEALTH, AND ENVIRONMENTAL JUSTICE

3.1 Environmental justice and cumulative risk

Environmental Justice (EJ) is social movement that works toward the fair or equitable distribution of environmental burdens and benefits. Advocates working toward environmental justice have long argued that environmental risk assessments that examine the health risks associated with a single environmental exposure (e.g. a single air pollutant, at a single point in time) provide only a partial assessment of risk or burden.[1] Individuals and communities are exposed to more than one air pollutant (e.g., mixtures of chemicals in air) and at more than one time (e.g., exposures occur throughout life). In addition to pollution, people and communities are also exposed to life conditions that can affect health, for example, poverty, or stressful work conditions, and there is a strong body of evidence documenting excess exposure to environmental burdens in communities that also experience other adverse conditions such as poverty and poor quality schools.[2,3,4] Furthermore, there is increasing evidence that the effects of those exposures may vary, with some individuals or communities experiencing more adverse health effects at any given level of exposure (e.g., people with asthma are more likely to have a more negative reaction to ozone exposure than those without asthma).[5,6,7,8] This is sometimes referred to as "susceptibility." Assessing the combinations of exposures to pollutants, susceptibility to their adverse effects, and their combined implications for health, is central to efforts to promote environmental justice and health equity.

Over the past decade, the Environmental Protection Agency (EPA) has worked with environmental advocates to create a framework for assessing the combined effects of multiple exposures and vulnerabilities. In 2003 the EPA created the *Framework for Cumulative Risk Assessment*[9], offering guidelines for assessing the cumulative

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[1] NEJC (National Environmental Justice Council). 2004. Ensuring Risk Reduction in Communities with Multiple Stressors: Environmental Justice and Cumulative Risks/Impacts. https://www3.epa.gov/environmentaljustice/resources/publications/nejac/nejac-cum-risk-rpt-122104.pdf [accessed 23 March 2016].

[2] Morello-Frosch R, Lopez R. 2006. The riskscape and the color line: examining the role of segregation in environmental health disparities. Environ Res. 102(2):181-96.

[3] Mohai P, Lantz PM, Morenoff J, House JS, Mero RP. 2009. Racial and socioeconomic disparities in residential proximity to polluting industrial facilities: evidence from the Americans' Changing Lives Study. Am J Public Health 99(S3):S649-56.

[4] Sadd JL, Pastor M, Morello-Frosch R, Scoggins J, Jesdale B. 2011. Playing it safe: Assessing cumulative impact and social vulnerability through an environmental justice screening method in the south coast air basin, California. Int J Environ Res Public Health 8(5):1441-59.

[5] Bell ML, Zanobetti A, Dominici F. 2013. Evidence on vulnerability and susceptibility to health risks associated with short-term exposure to particulate matter: a systematic review and meta-analysis. Am J Epidemiol 178(6):865-876.

[6] Kelishadi R, Poursafa P. 2010. Air pollution and non-respiratory health hazards for children. Arch Med Sci. 6(4):483-95.

[7] Sacks JD, Stanek LW, Luben TJ, Johns DO, Buckley BJ, Brown JS, Ross M. 2011. Particulate matter-induced health effects: who is susceptible? Environ Health Perspect 119(4):446.

[8] Solomon GM, Morello-Frosch R, Zeise L, Faust J. 2016. Cumulative Environmental Impacts: Science and Policy to Protect Communities. Annual Review of Public Health 37:83-96. Available: http://www.annualreviews.org.proxy.lib.umich.edu/doi/full/10.1146/annurev-publhealth-032315-021807. Published [6 Jan 2016].

[9] EPA (Environmental Protection Agency). 2003. Framework for Cumulative Risk Assessment. Available: https://www.epa.gov/sites/production/files/2014-11/documents/frmwrk_cum_risk_assmnt.pdf [accessed 23 March 2016].

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(or combined) risks associated with multiple exposures and vulnerabilities.[10] The National Environmental Justice Action Council (NEJAC)[11] reviewed EPA's *Framework* and recommended including social and cultural as well as economic indicators into the assessment process. Building on this work, in 2007 the EPA released *Concepts, Methods, and Data Sources for Cumulative Health Risk Assessment of Multiple Chemicals, Exposures and Effects: A Resource Document*[12]. Since that time, the EPA has developed specific plans for deepening the commitment of the Agency to environmental justice issues, and for assessment of progress in this regarding, most recently articulated in the EPA's EJ 2020 Action Agenda.[13]

Below, we summarize and define several key concepts that have emerged from the Environmental Justice Movement and the efforts of members of the scientific community to develop metrics that capture the combined risks or impacts experienced by communities.

Cumulative Risk: Cumulative risk refers to the combined risks from multiple exposures to multiple agents or stressors. [14] [15] Agents or stressors are variously defined, and can include physical stressors (e.g., malnutrition, noise), chemical (e.g., exposure to nitrous oxides), biological (e.g., illness, injury), economic (e.g. poverty) or psychosocial stressors (e.g., chronic concerns about safety). Chemical exposures can occur via multiple pathways, e.g., you may be exposed to lead in air, water, food and dust.

For example, an elderly person with a limited income who lives near a freeway and does not have access to health care may be exposed to multiple agents or stressors that contribute to health risks. These include exposure to near-road air pollutants, road or traffic noise, psychosocial stress due to financial concerns, and unmet medical needs due to limited access to health care.

Cumulative risk assessment attempts to predict how these multiple stressors combine to affect health, by attempting to quantify the combined risks to health that would occur as a result of exposure to these multiple agents or stressors. Cumulative risk assessments generally focus on these combined risks in a *population*, rather than in a particular individual. Thus, they might estimate the cumulative risks in a community with a greater

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[10] Sexton, Ken. 2012. Cumulative Risk Assessment: An overview of methodological approaches for evaluating combined health effects from exposure to multiple environmental stressors. International Journal of Environmental Research and Public Health. 9, pp. 370-390.

[11] NEJC (National Environmental Justice Council). 2004. Ensuring Risk Reduction in Communities with Multiple Stressors: Environmental Justice and Cumulative Risks/Impacts.
https://www3.epa.gov/environmentaljustice/resources/publications/nejac/nejac-cum-risk-rpt-122104.pdf [accessed 23 March 2016].

[12] EPA (Environmental Protection Agency). 2007. Concepts, Methods, and Data Sources for Cumulative Health Risk Assessment of Multiple Chemicals, Exposures and Effects: A Resource Document.

https://cfpub.epa.gov/ncea/risk/recordisplay.cfm?deid=190187 [accessed 23 March 2016].

[13] Draft EJ 2020 Action Agenda: Environmental Justice Strategic Plan 2016-2020. https://www.epa.gov/sites/production/files/2016-05/documents/052216_ej_2020_strategic_plan_final_0.pdf. Accessed August 7, 2016.

[14] Another relevant term is **Cumulative Exposure.** The EPA defines cumulative exposure as the combined exposure to a substance over a period of time, for example, over a lifetime. For example, the total amount of radiation that a person is exposed to over a lifetime from multiple sources (e.g. airport x-ray machines, dental x-rays) (EPA 2003). Generally, this definition of cumulative exposure addresses exposure to chemical stressors and only one specific type of vulnerability, that of differential exposure. Specifically, differential exposure to both point and mobile sources throughout an individual's lifetime.

[15] **Cumulative Impact** - This term refers to the combined public health or environmental effects from the combined emissions or discharges in a geographic area. This would include pollution from all sources, whether routinely or accidentally released. An assessment of impacts takes into account population vulnerability (e.g., existing health conditions, poverty) which may increase the adverse effects of exposures on health (California EPA, p. v). Cumulative impacts can result from emissions that are individually small, but which when combined with other emissions or combined over a period of time, can be significant collectively.

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proportion of people above the age of 65, with multiple freeways located in or near the community, and with high rate of poverty.

Assessing these combined risks and comparing them to, for example, population risks in a community with fewer residents who live near to roadways with heavy traffic, and with greater economic resources, allows comparison of the differences in the level of combined risk in the two communities. Such comparisons offer an opportunity to assess the extent to which there may be environmental inequalities or injustices.

The EPA's 2007 *Cumulative Health Risk Assessment*[16] identifies three key 'initiating factors' that would indicate that a cumulative risk assessment is necessary. These include:

- Multiple pollutant sources or releases;
- Elevated concentrations that are apparent from environmental monitoring or biomonitoring of chemicals;
- Increased population illness in a community.

Note that the EPA definition above uses more traditional risk assessment language, which tends to focus on population exposures to chemical, physical and biological (illness) stressors. Recommendations from NEJAC (2004) suggested that cumulative risk assessment should explicitly recognize both population **exposures (stressors)** and **vulnerability** factors. These terms are defined below.

Stressors*:* Stressors are exposures that can cause adverse effects for people or the environment. Since our emphasis is on health, we focus on adverse health effects in human populations. As noted above, stressors can include physical (e.g., malnutrition, noise), chemical (e.g., exposure to nitrogen oxides), biological (e.g., illness, injury), economic (e.g. poverty) or psychosocial (e.g., chronic concerns about safety) exposures). They can also involve the absence of a necessity, such as lack of access to health care, nutritious foods, clear air or water.

Many risk assessments only examine a single stressor. The United States Environmental Protection Agency (EPA) attempts to understand the combined effects of multiple exposures, and has expanded efforts to include multiple factors. They sometimes refer to these as chemical (e.g., nitrous oxides) and non-chemical (e.g., poverty) exposures. This has expanded the range of factors (stressors) that can be included in assessing community risk and community health.[17]

Community risk can be heightened due to higher levels of ***exposure*** to a single chemical, to multiple chemicals, and to non-chemical exposures. Some of these factors can also increase ***vulnerability*** to the adverse effects of those exposures (see below).

Vulnerability: Vulnerability recognizes that some communities (or individuals) experience more adverse effects from environmental exposures than others. These may result from: 1) higher levels of exposure; 2) increased susceptibility or sensitivity (that is, a stronger adverse effect at any given level of exposures); 3) fewer resources

[16] EPA (Environmental Protection Agency). 2007. Concepts, Methods, and Data Sources for Cumulative Health Risk Assessment of Multiple Chemicals, Exposures and Effects: A Resource Document.

https://cfpub.epa.gov/ncea/risk/recordisplay.cfm?deid=190187 [accessed 23 March 2016], p. xxv.

[17] NEJC (National Environmental Justice Council). 2004. Ensuring Risk Reduction in Communities with Multiple Stressors: Environmental Justice and Cumulative Risks/Impacts. https://www3.epa.gov/environmentaljustice/resources/publications/nejac/nejac-cum-risk-rpt-122104.pdf [accessed 23 March 2016], p. 22.

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with which to respond to the exposures; and 4) reduced ability to recover from the exposure.[18] These four categories of vulnerability recognize both chemical and non-chemical stressors.

In subsequent years, the National Environmental Justice Action Council (NEJAC) has continued to provide substantive input into EPA's plans for addressing environmental justice, including recommendations on the EPA's EJ 2014 Action Agenda[19] that were subsequently incorporated and reflected in the 2020 Action Agenda.[20] These recommendations recognize that environmental burdens and benefits are inequitably distributed across geographic communities, reflecting process of race-based residential segregation and their implications for socioeconomic opportunity. These variations ultimately contribute to racial, ethnic, and socioeconomic inequities in health outcomes.

3.2 Health effects of air pollutants

There is substantial evidence for adverse health effects of exposure to multiple air pollutants. Health effects associated with seven common air pollutants are briefly summarized in Table 3-1, and discussed in greater detail in Section 5.5 of this manual.

[18] EPA (Environmental Protection Agency). 2003. Framework for Cumulative Risk Assessment. Available: https://www.epa.gov/sites/production/files/2014-11/documents/frmwrk_cum_risk_assmnt.pdf [accessed 23 March 2016], pp. 39-41.

[19] National Environmemtal Justice Action Council (NEJAC) comments on EPAs 2014 EJ Action Agenda, https://www.epa.gov/sites/production/files/2015-02/documents/plan-ej-2014-comments-0511.pdf. Accessed August 8, 2016.

[20] Draft EJ 2020 Action Agenda: Environmental Justice Strategic Plan 2016-2020. https://www.epa.gov/sites/production/files/2016-05/documents/052216_ej_2020_strategic_plan_final_0.pdf. Accessed August 7, 2016.

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Table 3-1. Health effects for the six criteria pollutants (ozone, lead, nitrogen oxide, particulate matter, carbon monoxide, sulfur dioxide) and diesel. Drawn from the EPA's Integrated Science Assessments.

	Ozone	Lead	NO_x	$PM_{2.5}$	CO	SO_2	Diesel
Respiratory Effects							
Lung diseases (COPD, chronic bronchitis, emphysema, and/or cancer)	X		X			X	X
Asthma incidences, attacks, hospitalizations, and aggravations	X			X			X
Aggravation of bronchitis	X						X
Impaired lung growth				X			X
Decreased lung function			X	X			
Difficulty breathing	X			X	X	X	
Lung irritation (airway hyper responsiveness and inflammation)			X	X		X	X
Lung related emergency visits	X		X				
Irritation of the nose and throat; coughing	X			X		X	X
Cardiovascular Effects							
Coronary heart disease		X					
Heart attacks				X			X
Hypertension or increases in blood pressure		X		X			X
Reduce oxygen carrying capacity of the blood		X			X		
Aggravation of existing heart disease					X	X	
Reproductive Effects							
Decreased fertility (men and women)		X				X	
Birth Outcomes & Childhood Development							
Adverse birth outcomes (premature birth, low birth weight, or miscarriage)	X	X	X	X	X		
Brain damage and other birth defects	X	X					
Behavioral and emotional problems		X					
Cognitive impairments		X			X		
Other							
Cancer		X		X			
Increased risk of premature death	X	X	X	X	X	X	X
Fever, convulsions, dizziness						X	
Headaches, nausea, vomiting		X			X	X	
Inhibition of thyroid functions						X	
Kidney damage		X					X
Loss of Smell						X	
Visual impairment					X		
Cognitive decrements in adults		X			X		
Immune system impairments		X					

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3.3 Factors associated with increased susceptibility to adverse health effects

As noted above, there is also substantial evidence that some subgroups of the population experience more adverse effects when exposed to air pollutants. That is, they are more "susceptible" to adverse health effects at any given level of exposure. Table 3-2 shows the evidence base to date regarding the characteristics or conditions that may results in more adverse health effects of exposure to specific air pollutants. The information in this table is extracted from the EPA's most current Integrated Science Assessments at the time of this writing.

Table 3-2. Factors associated with increased susceptibility to adverse health effects. Based on the EPA's Integrated Science Assessments identify potential risk factors for the six criteria pollutants (ozone, lead, nitrogen oxide, particulate matter, carbon monoxide, sulfur dioxide).

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	CRITERIA POLLUTANTS					
Potential Risk Factors	**Ozone[1]**	**Lead[2]**	**NO_2[3]**	**PM[4]**	**CO[5]**	**SO_2[6]**
Example risk factor	Level of Evidence (section in PHAP)					
			Genetic			
Genetic Factors	Adequate (8.1)[7]	Suggestive (5.3.3)	Inadequate (4.3.4, 4.3.5)	Suggestive (8.1.5)		Inadequate (4.2.2)
			Behavioral			
Diet /Nutrition	Adequate (8.4.1)	Adequate (5.3.10)		Suggestive	Diet /Nutrition	Adequate (8.4.1)
Exercise			Inadequate (4.3.5)		Inadequate (5.7.5)	Suggestive (4.2.5)
Alcohol Consumption		Inadequate (5.3.9)				
Smoking Status	Inadequate (8.4.3)	Inadequate (5.3.5)				
Outdoor Workers	Adequate (8.4.4)		Inadequate (4.3.5)			Adequate (4.2.5)
			Existing Health Conditions			
Obesity , BMI	Suggestive (8.4.2)	Inadequate (5.3.8)	Suggestive (4.3.5)	Inadequate (8.1.6.4)		Suggestive (4.2.4)
Chronic Obstructive Pulmonary Disease (COPD)	Inadequate (8.2.3)		Inadequate (4.3.5)	Suggestive (8.1.6.2)	Suggestive (5.7.1.2)	
Influenza/Infection	Inadequate (8.2.1)					
Anemia					Inadequate (5.7.1.4)	
Cardiovascular Disease (CVD)	Inadequate (8.2.4)		Suggestive (4.3.1.2)	Suggestive (8.1.6.1)	Suggestive (5.7.1.1)	Inadequate (4.2.1.2)
Respiratory Contributions to Cardiovascular Disease				Inadequate (8.1.6.3)		
Respiratory Illness			Suggestive (4.3.1, 4.3.5)	Suggestive (8.1.6.2)		Adequate (4.2.1.1)
Hyperthyroidism	Inadequate (8.2.6)					
Diabetes	Inadequate (8.2.5)	Inadequate (5.3.4.2)	Suggestive (4.3.5)	Inadequate (8.1.6.4)	Suggestive (5.7.1.3)	Suggestive (4.2.4)

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Potential Risk Factors Continued	Ozone	Lead	NO_2	PM	CO	SO_2
Pre-Existing Disease*	Suggestive[8] (8.2)	Suggestive[9] (5.3.4)	Suggestive[10] (4.3.1)	Suggestive[11] (8.1.6)	Suggestive[12] (5.7.1, 5.7.7)	Adequate[13] (4.2.1, 4.2.1.1)
Age Related						
Children	Adequate (8.3.1.1)	Adequate (5.2.1, 5.3.1)	Adequate (4.3.2)	Suggestive (8.1.1.2)		Suggestive (4.2.3, 4.2.5)
Older Adults	Adequate (8.3.1.2)	Suggestive (5.2.1, 5.3.1)	Suggestive (4.3.2)	Suggestive (8.1.1.1)	Suggestive (5.7.2.1)	Suggestive (4.2.3)
Pregnant Women and Infants						
Maternal Self-Esteem		Inadequate (5.3.12)				
Pregnancy and Developmental Effects			Suggestive (4.3.5)	*Inadequate (8.1.2)*	Suggestive (5.7.2.2)	Suggestive (4.2.4)
Demographic Characteristics						
Sex	Suggestive (8.3.2)	Suggestive (5.2.2, 5.3.2)	Inadequate (4.3.3, 4.3.5)	Evidence of no effect (8.1.3)	Inadequate (5.7.3)	
SES	Suggestive (8.3.3)	Suggestive (5.2.4, 5.3.6)	Inadequate (4.3.5)	Adequate (8.1.7)		Suggestive (4.2.5)
Race/ethnicity	Inadequate (8.4.3)	Adequate (5.2.3, 5.3.7)	Inadequate (4.3.5)	Inadequate (8.1.4)		
Educational Attainment			Inadequate (4.3.5)	Suggestive(8.1.7)		
Housing, residential, living conditions						
Air Conditioning Use (8.4.5)	Inadequate (8.4.5)		Inadequate (4.3.5)			Suggestive (4.2.5)
Proximity to Source		Adequate (5.2.5)	Inadequate (4.3.5)		Suggestive (5.7.6)	Suggestive (4.2.6)
Residential Factors		Adequate [14](5.2.6)	Inadequate [15] (4.3.5)	Suggestive[16] (8.1.7)		Suggestive[17] (4.2.5)
Altitude					Suggestive (5.7.4)	
Other, miscellaneous						
Stress		Suggestive (5.3.11)				
Cognitive Reserve*		Inadequate (5.3.13)				
Other metals		Suggestive (5.3.14)				

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[1] All information for Ozone is taken from the 2013 Integrated Science Assessment. Available: https://www.epa.gov/isa/integrated-science-assessment-isa-ozone [accessed 2-2-16]

[2] All information for Lead is taken from the 2013 Integrated Science Assessment. Available: All information for Ozone is taken from the 2013 Integrated Science Assessment. Available: https://www.epa.gov/isa/integrated-science-assessment-isa-ozone [accessed 2-2-16]

[3] All information for Nitrogen Dioxide is taken from the 2013 Integrated Science Assessment. Available: https://www.epa.gov/isa/integrated-science-assessment-isa-nitrogen-dioxide-health-criteria [accessed 2-2-16]

[4] All information for Particulate Matter is taken from the 2013 Integrated Science Assessment. https://www.epa.gov/isa/integrated-science-assessment-isa-particulate-matter Available: [accessed 2-2-16]

[5] All information for Carbon Monoxide is taken from the 2013 Integrated Science Assessment. Available: https://www.epa.gov/isa/integrated-science-assessment-isa-carbon-monoxide [accessed 2-2-16]

[6] All information for Sulfur Dioxide is taken from the 2013 Integrated Science Assessment. Available: https://www.epa.gov/isa/integrated-science-assessment-isa-sulfur-dioxide-health-criteria [accessed 2-2-16]

[7] The numbers associated with each factor reference the chapter of the specific ISA, where the information can be found. For example, if you want more information about genetic factors and ozone, see chapter 8.1.

[8] There is adequate evidence from epidemiologic, controlled human exposure, and toxicological studies that asthma is a risk factor for ozone related health effects.

[9] Overall, studies of lead related health effects related to pre-existing conditions have some evidence of a potential increased risk of lead related health effects. The evidence is consistent for lead related renal effects and hypertension, but is limited for other preexisting conditions.

[10] There is suggestive evidence that preexisting asthma, cardiovascular related conditions, diabetes, hypertension, and coronary artery disease may lead to heightened susceptibility to the effects of NO2 exposure.

[11] Epidemiological evidence suggests that individuals with respiratory illness, cardiovascular disease, and diabetes are more susceptible to the effect of PM exposure.

[12] Evidence from controlled human exposure and epidemiological studies provides coherence and biological plausibility for the association between CO exposure and cardiovascular morbidity in individuals with CAD, particularly those with IHD. Additionally, limited evidence suggests that individuals COPD, diabetes, and/or anemia may be more susceptible to health effects due to ambient CO exposure, with less available evidence for anemia. Finally, evidence indicates that individuals ingesting medications and other substances that enhance endogenous or metabolic CO production may be more susceptible to increased health effects due to additional exposure to ambient CO.

[13] There is substantial evidence that individuals with preexisting respiratory diseases, particularly asthma, are more susceptible to respiratory health effects, though not mortality, from S02 exposures than the general public.

[14] Numerous studies show an inverse association between blood Pb and residence in homes being built after 1950. Renovation activities on older homes have been shown to produce excess Pb dust concentrations.

[15] It was briefly stated that geographic location (west versus east) may be a potential risk factor for NOx; however, this requires further research.

[16] Residential factors, in relation to SES, may predict susceptibility to PM as one study found that the neighborhoods with the lowest SES characteristics had the largest health effects from exposure to PM.

[17] The EPA ISA only generally states, "Other factors that may potentially increase vulnerability to SO2 are residential or geographic location. However, residential location is not as strong of a predictor of exposure vulnerability for SO2 as for traffic-related pollutants, because meteorological conditions have a greater impact on pollutant plume direction from primary point sources such as coal-fired power plants."

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4. AIR QUALITY, EXPOSURE & MONITORING

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Tables

Figures

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4 AIR QUALITY EXPOSURE AND MONITORING

This chapter provides an introduction to air quality monitoring and exposure. The following sections describe, for each major pollutants, NAAQS compliance, the monitoring network for that pollutant, and concentration trends based on monitoring data in the Detroit area, and apportionments (for $PM_{2.5}$). Monitoring and exposures of $PM_{2.5}$, O_3 and SO_2 are emphasized, given the importance of these pollutants in the Detroit area.

4.1 Exposures to air pollution and contributing sources

Direct and indirect air pollution exposure. Air pollution exposure can occur directly by breathing pollutants in outdoor air, indoor air, and vehicle cabins. In addition, so-called "indirect" air pollution exposure can occur by ingesting food, water and other materials (e.g., dust) that has been contaminated with air pollutants, and by drinking mother's milk if the mother is exposed to air pollutants. Indirect exposure is important for certain pollutants, e.g., persistent pollutants like lead and other metals, flame retardant chemicals, PCBs, mercury, and DDT.

This resource manual focuses on exposure via the "direct" inhalation exposure pathway. Inhalation exposures depend on the concentration of air pollutants present in each location where spent by an individual, the breathing rate, and the duration in that location. The most important locations, based on the amount of time spent, are generally homes, schools, workplaces, outdoors (often near homes), and in vehicle cabins (car and bus).

Indoor exposure. Exposure from pollutants emitted by industry, vehicles, construction equipment, and other outdoor sources can elevate concentrations in outdoor air. In addition, because pollutants enter buildings and vehicle cabins, indoor and cabin air quality can be affected. For pollutants like O_3 and some PM, indoor concentrations can be lower than outdoor concentrations because these pollutants are unstable or filtered out; for other pollutants, like SO_2, CO, and NO_x, indoor and outdoor levels may be similar since these pollutants are relatively stable gases that are not removed by filters.

Indoor environments and vehicle cabins can contain many pollutant sources, and emissions from indoor sources can seriously degrade air quality and cause levels of some pollutants to exceed outdoor levels. This *Resource Manual* focuses on outdoor sources, but it is important to remove, restrict or ventilate to control indoor pollution sources. Important indoor sources can include cigarette smoke, dust from lead paint, radon gas emanating from subsurface soils, mold on damp or wet surfaces, formaldehyde gas from some carpeting and wood products, scented items (air fresheners, deodorizers, incense, mothballs, etc.,) pesticides, and solvents and fumes (from paint, hair spray, varnish, aerosol sprays, gasoline), among others. Improperly constructed or operating vents, chimneys, heaters, fireplaces, and furnaces can cause very serious air pollutant exposure and possibly death by carbon monoxide poisoning.

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4.2 Air quality monitoring

Monitoring data provides key information regarding current air quality and compliance with air quality standards,[1] including both the primary health protective NAAQS and the secondary welfare protective NAAQS.[2]

In addition, monitoring data can show historical trends indicating whether air quality is changing, as well as information identifying the sources that cause or contribute to air pollution. Monitoring data also are used to quantify health risks, conduct epidemiological studies, and determine whether emission reductions or other actions are needed. The importance of ambient air monitoring data should not be understated. In Michigan, the state's ambient air quality monitoring network and the collected data are described by the MDEQ each year, and this *Resource Manual* draws heavily from the annual Air Monitoring Network Review[3] and the annual Air Quality Monitoring Reports[4] that are published annually.

Monitors are operated and sited to provide different types of information. This includes sites that are selected to: (1) represent population exposure ("population" sites); (2) quantify impacts of major industrial sources ("hotspot" or "source-oriented" sites); (3) quantify impacts of vehicle traffic ("near-road" sites); (4) provide upwind or background concentrations for pollutants that are transported into the area ("background" or "transport-oriented" sites); (5) provide trend or data comparable to national-level assessments; and (6) inform special studies typically lasting from months to years ("research" sites). Many sites have been operated for many years, but the network evolves over time to address EPA rules and meet other demands. The equipment at MDEQ and other monitoring sites varies from location to location, e.g., sites can monitor from one to potentially dozens of pollutants. Most sites have some meteorological instrument, e.g., wind direction and wind speed sensors. The annual costs to equip and maintain a MDEQ or industry monitoring site can range from roughly $75,000 to $250,000, depending on what is measured, the frequency of measurements, and other factors. US EPA provides support for some monitoring operations.

<u>MDEQ monitoring.</u> Many aspects of air quality monitoring, including the number of sites, equipment and procedures, operated by Michigan and other states must meet US EPA guidelines. The monitoring approaches used to determine compliance with air quality standards must be designated meet US EPA rules that designate instrumentation as a Federal Reference Method (FRM) or equivalent. EPA guidelines and rules also specify the minimum number of monitoring sites in an urban region like Detroit, which depend multiple factors including the population size, emissions of certain pollutants (e.g., SO_2), size of roads (e.g., for NO_x), and the recent record of pollutant levels (e.g., $PM_{2.5}$ and O_3). State and federal agencies do not routinely monitor indoor air pollution.

<u>Industry monitoring.</u> Some regions also have high quality fixed site monitoring networks operated by industry and sometimes by industry associations. These vary from single monitors to complex networks. These networks can be either voluntary, or required as part of an air quality permit or court decision. In Michigan, some large

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[1] NAAQS Status is shown by county by US EAA at https://www3.epa.gov/airquality/greenbk/anayo_mi.html.

[2] Primary standards provide public health protection, including protecting the health of "sensitive" populations such as asthmatics, children, and the elderly. Secondary standards provide public welfare protection, including protection against decreased visibility and damage to animals, crops, vegetation, and buildings.

[3] Michigan Department of Environmental Quality Air Quality Division. 2015. 2016 Air Monitoring Network Review. Available: http://www.michigan.gov/documents/deq/deq-aqd-toxics-2016_Air_Mon_Network_Review_489490_7.pdf [accessed 2 May 2016]

[4] Michigan Department of Environmental Quality Air Quality Division. 2015. 2014 Air Quality Monitoring Report. Available: http://www.michigan.gov/documents/deq/deq-aqd-amu-2014_Annual_Air_Quality_Report_492732_7.pdf [accessed 2 May 2016]

This work is made possible by National Institute of Health and Environmental Sciences, RO1ES022616, and the Fred A. and Barbara M. Erb Family Foundation. Additional support was provided by the Michigan Center on Lifestage Environmental Exposures and Disease (M-LEEaD), #P30ES017885.

landfills and other facilities operate monitoring sites to confirm that dust and other emissions are not excessive. In Detroit, Marathon initiated a monitoring network consisting of four sites measuring SO_2 around the facility. Given the intensity of industry and the magnitude of emissions in southwest Detroit, the lack of monitoring by industry is surprising. For some pollutants, additional sites and measurements of additional pollutants can provide significant information

Low cost monitoring. In recent years, there is considerable interest in using low cost monitors, including those operated by community organizations. This information can be useful, but the quality of the data provided by low cost monitoring approaches can be variable, and these measurements cannot be used to determine compliance or violation of a standard in any "official" capacity.

Additional information regarding monitoring network is described in the sections for each pollutant that follow.

4.3 Ozone

4.3.1 NAAQS Status

The Detroit area (Wayne County) has previously been in non-attainment for O_3: from 1992-1994 under the 1979 1-hr O_3 NAAQS, and from 2004-2008 for the 1997 8-hr O_3 NAAQS. From 2009 to the 2015, all monitors in Southeast Michigan met the O_3 standard, and currently, the area is considered in attainment. However, on October 1, 2015, US EPA established a new health-protective ozone NAAQS of 0.070 ppm (lowering it from 0.075 ppm), measured as the annual 4th highest 8-hr daily maximum averaged over 3 years. O_3 levels in the Detroit area are fluctuating around this level.

MDEQ is currently collecting O_3 data to determine whether the attainment status for Wayne County needs to be changed from attainment to non-attainment, and a recommendation to USEPA is expected in October, 2016. If the area is designated as non-attainment by US EPA, an enforceable air pollution abatement plan must be developed by the MDEQ to bring the area back into attainment.[5] These plans typically involve reductions in emissions of NO_x and VOCs using additional source controls, depending on whether O_3 is NO_x or VOC limited, as and anticipating further reductions in vehicle fleet emissions due to turnover of old vehicles. They may also involve transportation control measures, vehicle inspection programs, restrictions on summer activities emitting VOCs (and possibly NO_x) such as paving bans, and consumer sales of VOC emitting products, such as barbeque lighting fluid.

4.3.2 Monitoring

Ozone (O_3) is monitored at two sites in Detroit, and at six sites in SE Michigan, shown in Figure 4-1. This number of sites is considered adequate because ozone concentrations tend to be fairly similar across an urban region. In southeast Michigan, the New Haven site, generally downwind of Detroit, has had the highest O_3 concentrations downwind from Detroit, however, in 2009, the highest levels occurred at the Detroit-E 7 Mile site. More recent data (2012-2014) show that Detroit-E 7 Mile, New Haven and Port Huron sites have similar three-year averages. MDEQ suggests that the location of the maximum O_3 concentration has moved about 19 miles closer to the urban center city area, possibly due to changes in the amount, type and location of ozone

[5] MDEQ and DTE Electric Company. 2016. Trenton Channel Power Plant, Proposed permit 227-15 and 125-11C, March 9, 2016.

precursor emissions. EPA has indicated that Warren may be becoming the site with the highest O_3 concentration.

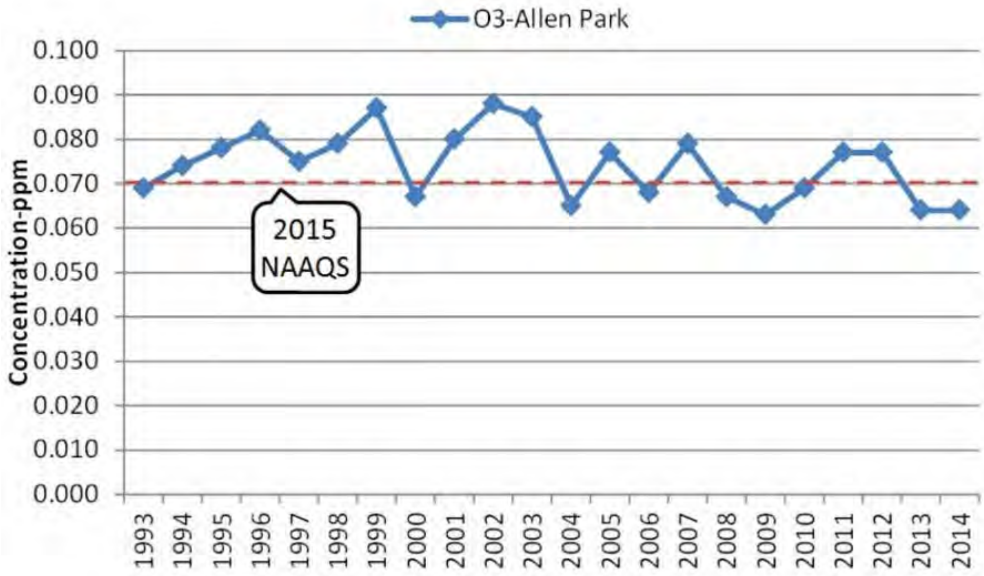
Figure 4-1. Location of ozone monitoring sites in Michigan. From MDEQ. http://www.michigan.gov/documents/deq/deq-aqd-toxics-2016_Air_Mon_Network_Review_489490_7.pdf

4.3.3 Trends

Long-term O_3 trends are shown in Figure 4-2 for the Allen Park site, which now has the highest O_3 levels in Detroit. While some decrease in O_3 levels has been seen in Detroit since 2002, current levels are fluctuating around the new NAAQS. Other areas in Michigan have shown greater decreases.

This work is made possible by National Institute of Health and Environmental Sciences, RO1ES022616, and the Fred A. and Barbara M. Erb Family Foundation. Additional support was provided by the Michigan Center on Lifestage Environmental Exposures and Disease (M-LEEaD), #P30ES017885.

Figure 4-2. Trends in the 4th highest 8-hr concentration monitored at Allen Park. From MDEQ, 2016.[6]



[6] From p. 5, MDEQ, DTE Electric Company, Trenton Channel Power Plant, Proposed permit 227-15 and 125-11C, March 9, 2016

This work is made possible by National Institute of Health and Environmental Sciences, RO1ES022616, and the Fred A. and Barbara M. Erb Family Foundation. Additional support was provided by the Michigan Center on Lifestage Environmental Exposures and Disease (M-LEEaD), #P30ES017885.

4.4 Particulate Matter

4.4.1 NAAQS status

Detroit (Wayne County) had previously been in non-attainment with the $PM_{2.5}$ NAAQS: from 2005 to 2012 for the 1997 $PM_{2.5}$ NAAQS; and from 2009 to 2012 for the 2006 NAAQS. Earlier, Wayne County had been in non-compliance from 1992 to 1995 with the PM10 NAAQS. The January 15, 2013 revision to the PM NAAQS lowered the $PM_{2.5}$ annual average concentration from 15.0 µg/m^3 to 12.0 µg/m^3, the 24-hr NAAQS remained at 35 µg/m^3 and is measured as a 98th percentile concentration averaged over 3 years. All sites in Michigan currently meet the $PM_{2.5}$ NAAQS.

4.4.2 Monitoring

Airborne particulate matter (PM) is measured in many ways, the most common of which are:

- Particles less than 2.5 um in diameter, called $PM_{2.5}$. The current health-based NAAQS uses $PM_{2.5}$,which is the emphasis of this report
- Particles less than 10 um in diameter, called PM_{10}. Prior to 1997, the NAAQS used PM_{10}.
- Particles measured as "total suspended particulate (TSP). Prior to 1986, the NAAQS used TSP. These measurements are especially useful for understanding dust fall, including dust fall containing toxic metals and other pollutants.

As for the other pollutants, compliance with the $PM_{2.5}$ NAAQS is based on monitoring data, and US EPA specifies the number and types of monitoring sites required. Locations of $PM_{2.5}$ monitoring sites are shown in Figure 4-3. Currently, monitors with the highest annual average concentration are the Detroit–SWHS (10.7 µg/m^3) and Dearborn (11.6 µg/m^3) sites ("design" values shown); the Dearborn site also has the highest design value (26 µg/m^3) for the 24-hr average value.

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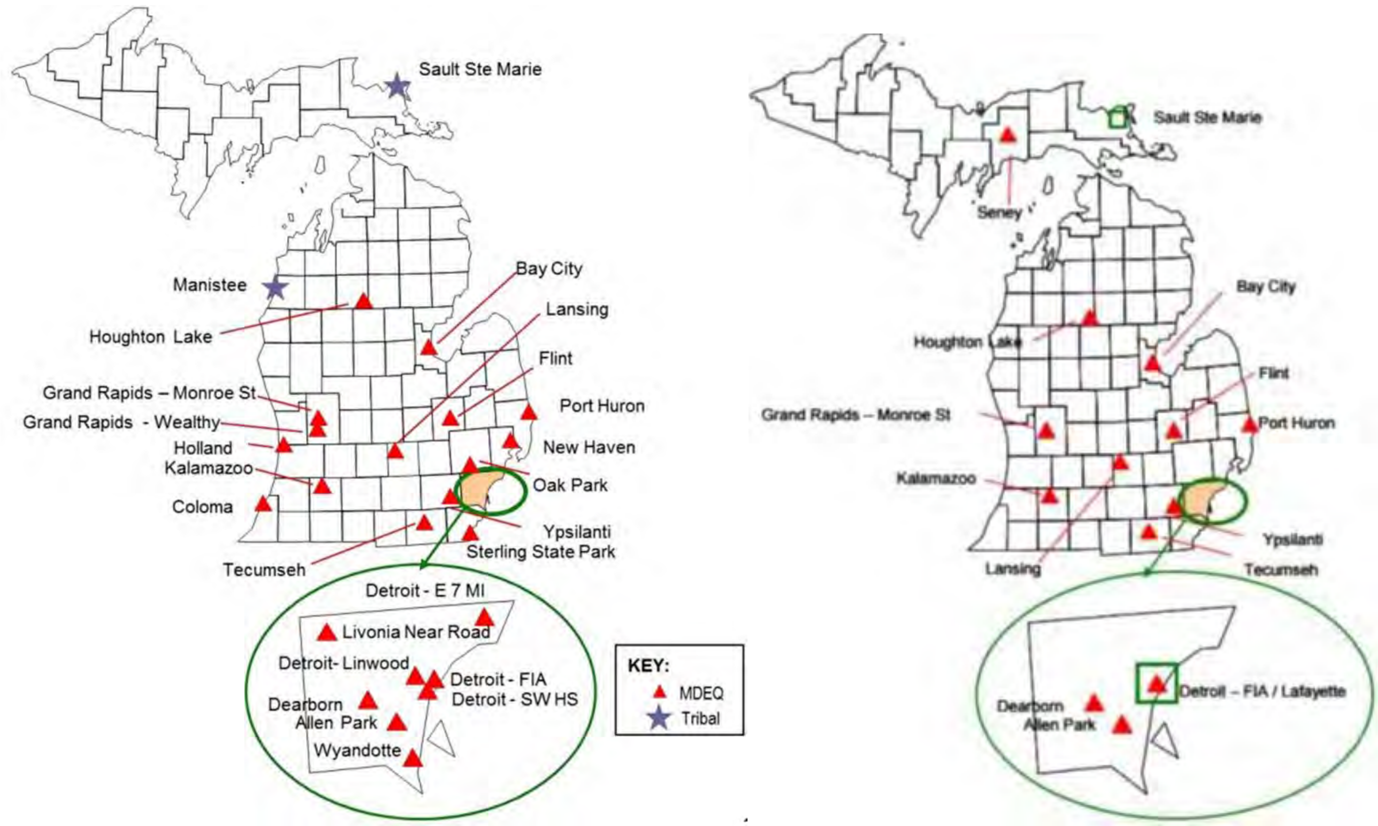
Figure 4-3. Location of $PM_{2.5}$ monitoring sites in Michigan. Left panel shows sites collecting 24-hr samples (FRM monitors). Right panel shows sites collecting continuous (1-hr) samples.[7]



4.4.3 Source apportionments

$PM_{2.5}$ arises from many sources. Secondary PM, largely due to regional or "background" component that drifts from areas distant to Detroit (e.g., Ohio River Valley), is substantial and constitutes roughly 50 to 60% of $PM_{2.5}$ overall (including secondary sulfur and nitrogen compounds). In addition, many local sources emit $PM_{2.5}$, including the point, mobile and area sources discussed in Section 5. These "local" sources can be affected by mitigation strategies such as source control and buffers; these strategies will not greatly alter background levels.

The fraction of PM attributable to different sources can be estimated using source inventories, monitoring data, dispersion modeling, and receptor modeling. A recent analysis[8] of long term $PM_{2.5}$ records at Allen Park using receptor modeling (positive matrix factorization of monitored PM and its composition at this site) provided the following overall apportionment for Detroit (a parallel analysis at a Chicago site was similar): sulfate formed 32 - 33% of $PM_{2.5}$; vehicles contributed 21 - 22%; nitrate constituted 21%; and biomass was 7 - 9%. These four sources represented over 80% of $PM_{2.5}$ concentrations. Crustal (e.g., wind-blown dust) (4 - 8% of $PM_{2.5}$), several

[7] Michigan Department of Environmental Quality Air Quality Division. 2015. 2016 Air Monitoring Network Review. Available: http://www.michigan.gov/documents/deq/deq-aqd-toxics-2016_Air_Mon_Network_Review_489490_7.pdf [accessed 2 May 2016]

[8] Milando C, Huang L, Batterman S. 2016. Trends in PM2.5 emissions, concentrations and apportionments in Detroit and Chicago. Atmospheric Environment: 129, 197-209.

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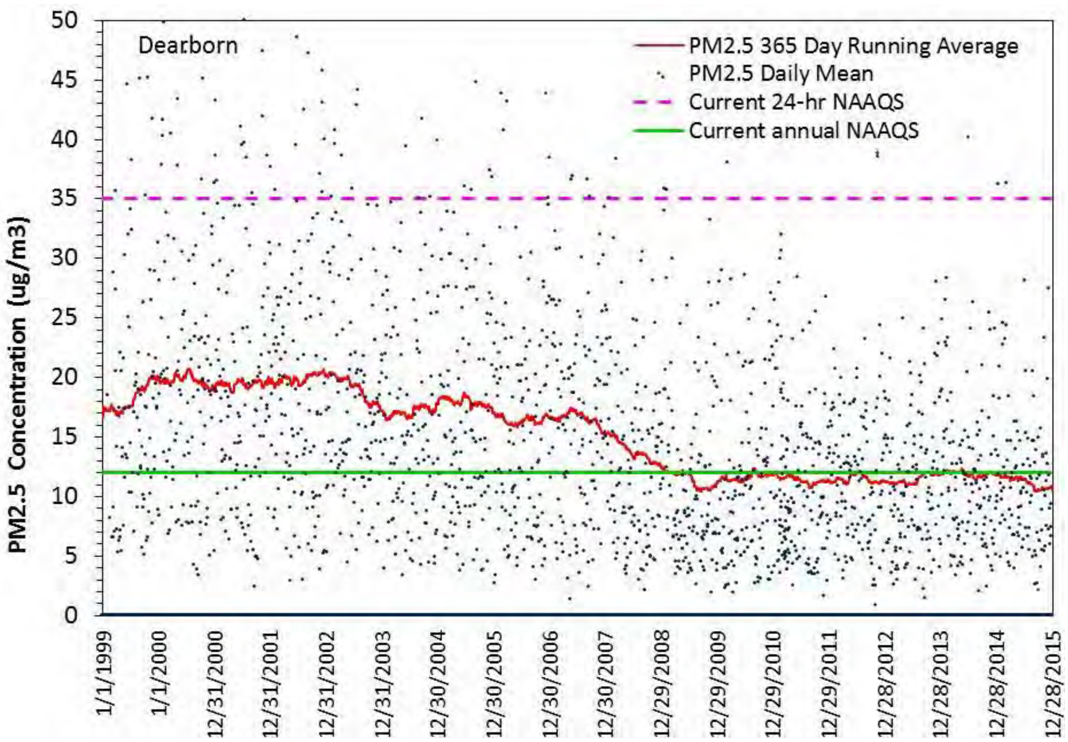
metals (4 - 11%) and Cl/NaCl (2 - 5%) represented the remainder of $PM_{2.5}$. These results were supported by the emissions inventory and the similarity of the secondary contributions (e.g., sulfate and nitrate).

The next section of this Resource Manual uses monitoring data in an approach to separate local and background components of $PM_{2.5}$ in Detroit.

4.4.4 Trends

$PM_{2.5}$ concentrations at many Michigan monitoring sites have shown a general downward trend since 1995. For example, $PM_{2.5}$ levels at Allen Park have decreased by about 5% per year from 2001 to 2015; as mentioned, this was largely driven by decreases in ammonia, nitrate, sulfate and organic carbon.[9] However, results differ from site-to-site, and trends are less apparent in more recent years and at industrial sites like Dearborn. Figure 4-7 displays the 17-year record of $PM_{2.5}$ measurements at the Dearborn site, which used every 3rd day measurements for much of the record, and which currently records some of the highest $PM_{2.5}$ Levels in Detroit. The 365-day running average shows a large decrease from 2006 to 2009; the frequency of very high 1 hour concentrations also fall.

Figure 4-4. 17 year record of the 24-hr daily $PM_{2.5}$ concentration at Southwestern High School. Plot does not show several measurements above 50 µg/m^3 (highest was 71.5 µg/m^3). Running annual average, current 24-hr and current annual average NAAQS are also shown.



[9] Milando C, Huang L, Batterman S. 2016. Trends in PM2.5 emissions, concentrations and apportionments in Detroit and Chicago. Atmospheric Environment: 129, 197-209.

This work is made possible by National Institute of Health and Environmental Sciences, RO1ES022616, and the Fred A. and Barbara M. Erb Family Foundation. Additional support was provided by the Michigan Center on Lifestage Environmental Exposures and Disease (M-LEEaD), #P30ES017885.

To examine recent trends more comprehensively, we used 2009 to 2015 $PM_{2.5}$ data from 12 area monitoring sites around Detroit (each using high quality and comparable Federal Reference Methods), and attempted to separate "background" and "local" sources of $PM_{2.5}$. This analysis shows that $PM_{2.5}$ levels have not changed significantly in the Detroit area over this period, with annual average concentrations averaging 9.9 ±5.8 $\mu g/m^3$ across the 12 sites (the NAAQS is 12 $\mu g/m^3$), and peak 24-hr daily concentrations have remained near or above the NAAQS (35 $\mu g/m^3$). As noted earlier, the area attains the $PM_{2.5}$ NAAQS. Figure 4-5 summaries these data and shows three panels that separate total, background and local contributions.

The top panel of Figure 4-5 shows recent trends in the Detroit area; the green line shows that the long-term average concentration has remained stable. The red dots show the daily 24-hr maximum across the 12 sites. During this period, there were 909 days of valid observations (defined with at least 6 monitors providing values), of which 20 days exceeded 30 $\mu g/m^3$, 12 exceeded 35 $\mu g/m^3$ (the current NAAQS), and 4 exceeded 40 $\mu g/m^3$.

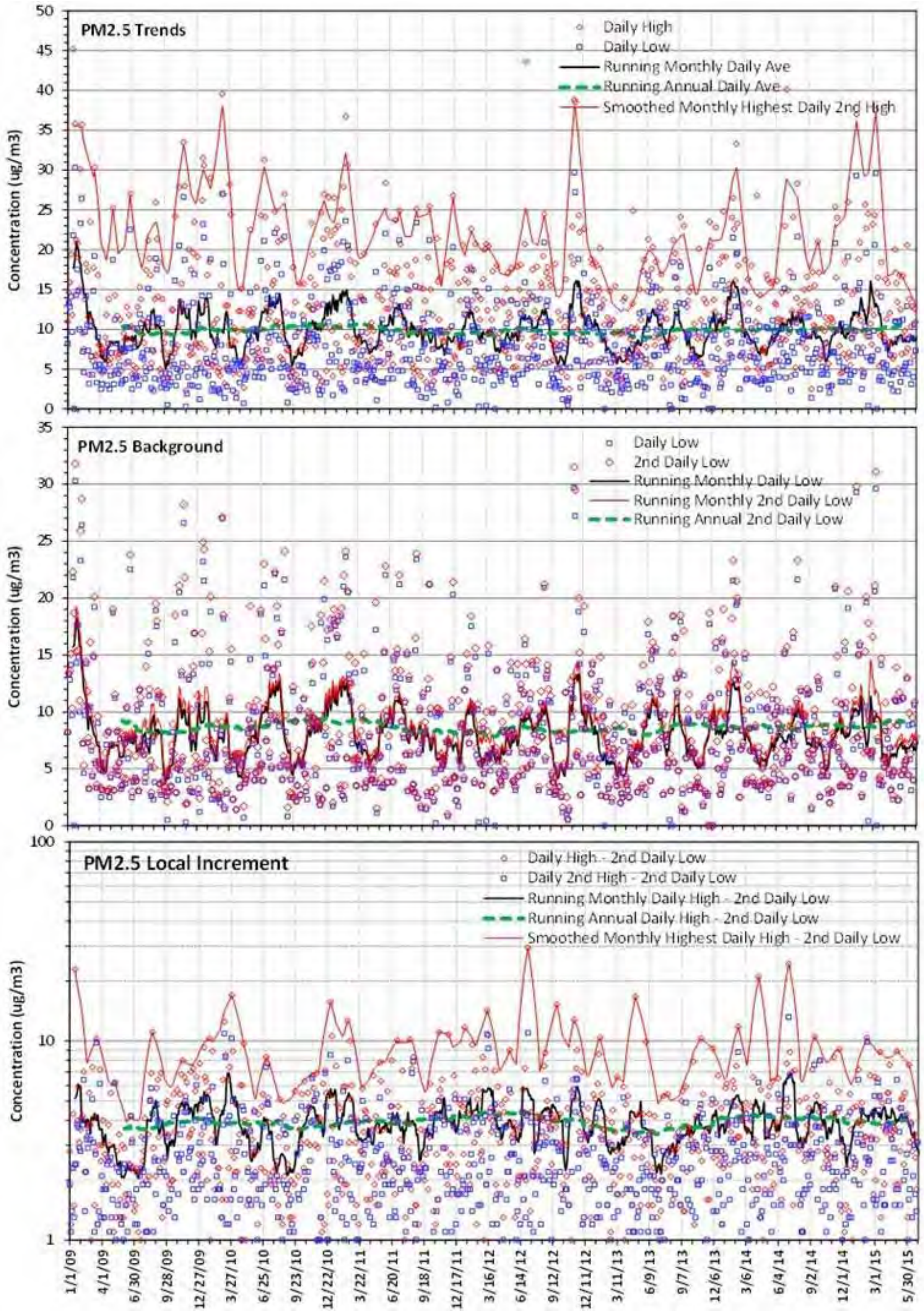
The center panel of Figure 4-5 shows estimates of "background" concentrations, defined as the lowest or second lowest observation in the network when at least 6 sites reported valid data. While there are significant fluctuations, the long term average (green line) is relatively flat, indicating little change over the 5-year period. The lowest and 2nd lowest averaged 8.0 ± 5.2 and 8.8 ± 5.5 $\mu g/m^3$, respectively.

The lower panel of Figure 4-5 shows estimates of the "local" increment, defined as the maximum 24-hr daily concentration minus the 2nd lowest 24-hr daily concentrations, again when at least 6 sites reported valid data. The 2nd lowest is used, rather than the lowest, to be more robust in the case of monitoring anomalies. This plot, using a log scale, also shows no consistent trend, with the average local increment being 3.9 ± 2.8 $\mu g/m^3$. These results suggest that at the most impacted sites (e.g., Dearborn), local sources contribute about 30% of the $PM_{2.5}$. This result is somewhat lower than suggested by receptor modeling, discussed above, probably because the lowest or 2nd lowest observation includes contributions from local sources.

Overall, this analysis shows that both long term (e.g., annual) and short-term peak (e.g., 24-hr) average levels of $PM_{2.5}$ in Detroit have changed little over the past 6 years.

This work is made possible by National Institute of Health and Environmental Sciences, RO1ES022616, and the Fred A. and Barbara M. Erb Family Foundation. Additional support was provided by the Michigan Center on Lifestage Environmental Exposures and Disease (M-LEEaD), #P30ES017885.

Figure 4-5. Trends of $PM_{2.5}$ at Detroit area monitoring sites. 2009 to 2012 data at FRM sites.



This work is made possible by National Institute of Health and Environmental Sciences, RO1ES022616, and the Fred A. and Barbara M. Erb Family Foundation. Additional support was provided by the Michigan Center on Lifestage Environmental Exposures and Disease (M-LEEaD), #P30ES017885.

4.5 SO_2

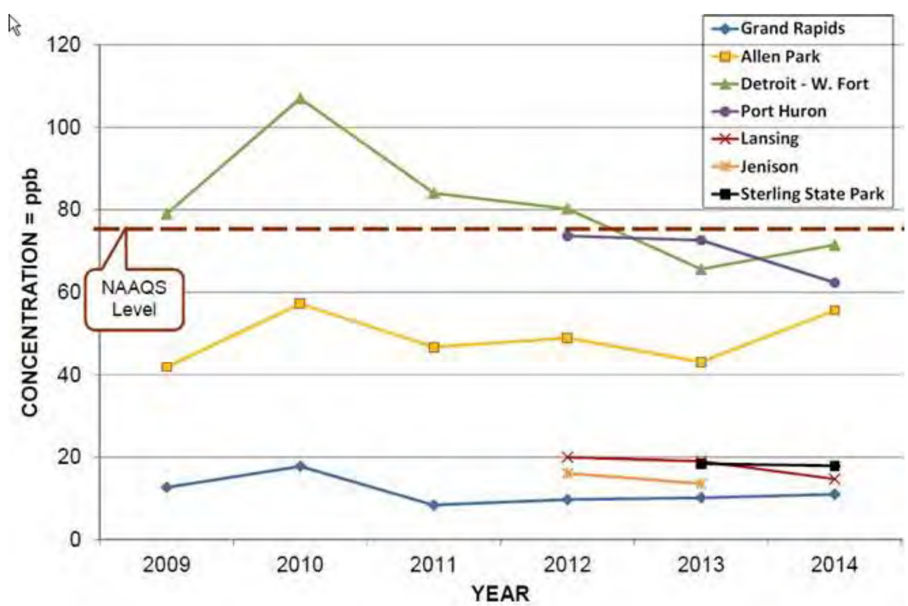
4.5.1 NAAQS Status

SO_2 levels have fallen from very high levels seen in the 1980s, as discussed later. Still, prior to 2010, Wayne County had always been in attainment with the SO_2 NAAQS prevailing at the time.

On June 2, 2010, the EPA revised the health protective SO_2 NAAQS by changing from 24-hour and annual average concentration standards to a 1-hour, 99th percentile measurement averaged over 3 years, set at 75 ppb. Based on air monitoring data, the SO_2 NAAQS was not met in Wayne County. Because MDEQ has not completed an air pollution abatement plan, a portion of Wayne County was designated as non-attainment for SO_2 from 2013 to the present. This region was defined by MDEQ as a corridor that runs from the southern border with Monroe County, along I-75, M-39, M-94 and US-12 and extending east to the Detroit River. Several major SO_2 sources are located in this corridor.[10] A proposed State Implementation Plan (SIP) for SO_2 was released by MDEQ in August, 2015.[11] SIPs are designed to bring areas into compliance with the NAAQS.

Air quality monitoring data are used to determine NAAQS status for SO_2 (and other pollutants). Trends of concentration statistics that follow the NAAQS definition for the past 5 years are shown in Figure 4-6.

Figure 4-6. SO_2 levels in Michigan from 2009-2014 showing 1-hour 99th percentile concentration commensurate with the NAAQS. From MDEQ.[12]



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[10] Michigan Department of Environmental Quality. 2016. Public Participation Documents for DTE Electric Company Trenton Channel Power Plant, March 9, 2016. Available: http://www.deq.state.mi.us/aps/downloads/permits/PubNotice/227-15/227-15and125-11CFactSheet.pdf [accessed 2 May 2016]

[11] Michigan Department of Environmental Quality. 2015 Proposed Sulfur Dioxide One-Hour National Ambient Air Quality Standard State Implementation Plan, August 20, 2015.Available: http://www.deq.state.mi.us/aps/downloads/SIP/SO2SIP.pdf [accessed 2 May 2016]

[12] Michigan Department of Environmental Quality Air Quality Division. 2015. 2016 Air Monitoring Network Review. Available: http://www.michigan.gov/documents/deq/deq-aqd-toxics-2016_Air_Mon_Network_Review_489490_7.pdf [accessed 2 May 2016]

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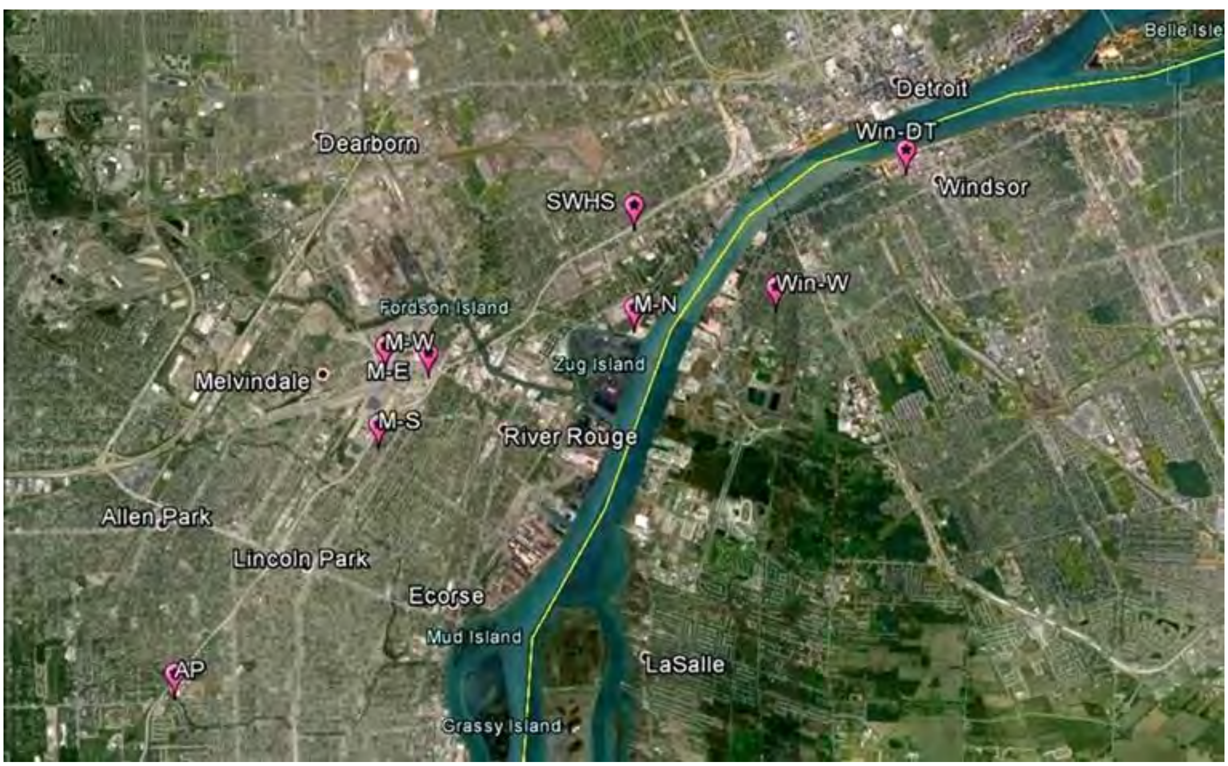
As discussed later, the spatial coverage of SO_2 monitoring in Detroit is sparse and likely misses a number of SO_2 hotspots. (Our analysis below adds the Marathon and Canadian sites to what has been discussed by MDEQ.) In particular, our dispersion modeling suggests that a larger region may not be in attainment, however, there are few monitoring sites that can confirm dispersion modeling results.

4.5.2 Monitoring sites

SO_2 has been monitored at Detroit area locations using EPA-approved methods since 1971, initially by the Wayne County Air Quality Management Division, and then by the MDEQ after 2002. Since 2009, SO_2 has been continuously monitored at 3 locations in Michigan (Southwestern High School on Fort Street in Detroit, Allen Park in Detroit, and in Grand Rapids). Other sites in the region include Port Huron, Sterling State Park (in Monroe County, and West Olive near Lake Michigan.

For portions of the 2009-2015 period evaluated here, SO_2 has been monitored at 9 additional locations in the Detroit area. These include 4 locations surrounding the Marathon Refinery (designated as Marathon North, West, East and South) that started on Jan. 1, 2012. In addition, SO_2 is monitored using EPA-type instrumentation at two sites in Windsor, Canada, designated as Windsor Downtown (DT) and Windsor West (W). SO_2 is monitored continuously and reported as a 1-hr average on the EPA and Canadian sites, commensurate with the current form of the National Ambient Air Quality Standard (NAAQS), which is currently 75 ppb calculated as the 3-year average of the annual 99th percentile 1-hr concentration. The locations of the 8 Detroit area monitoring sites are shown in Figure 4-7. The Windsor downtown site is essentially just across the Detroit River from downtown Detroit.

Figure 4-7. Locations of current SO_2 monitoring sites in the Detroit area. SWHS is Southwestern High School, AP is Allen Park, M is Marathon (North, East, West, South), Win-DT is Windsor Downtown, Win-W is Windsor West. Uses Google maps.



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The number of sites in the Detroit area does not necessarily reflect the complexity of spatial pattern of SO_2 concentrations. Based on modeling, the maximum 1-hr SO_2 concentrations occur near but not exactly at the location of the Southwestern High School monitor. There are also localized "hotspots" that may occur closer to large SO_2 emission sources with poor dispersion (i.e., low stacks), such as Carmeuse Lime, US Steel and AK Steel. (Figure 4-11, discussed later, provides a map showing predicted locations of maximum impact.)

4.5.3 Trends

Data summary

Hourly SO_2 data from 1980 through the present were obtained from the EPA and Canadian web sites and collated. Missing data was ignored. Because the NAAQS focuses on 1-hr peak concentrations, our analysis also emphasizes this statistic. The daily 1-hr high was calculated for each day if any SO_2 data were present on that day. (Results did not change in any noticeable way if 75% or more of the hourly observations were required on each day to calculate the daily 1-hr high.)

During the 2009-2015 period, the single highest 1-hr concentrations at the eight sites reached 500 ppb at the Marathon N site and 160 ppb at the SWHS site. During this period, the maximum 1-hr concentration exceeded or reached the NAAQS concentration of 75 ppb at all sites, though this does not constitute violation of the NAAQS since the NAAQS is determined using a 3-year running average of the 99^{th} percentile daily 1-hr concentration. Higher 1-hr concentrations have been measured prior to 2009, e.g., concentrations at the SWHS site reached 172 ppb in 1999, 224 ppb in 2001, and 832 ppb in 2002; concentrations at the Allen Park site reached 99 ppb in 2008.

A summary of available data at the 8 Detroit area monitors is shown in Table 4-1.

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Table 4-1. Summary of highest 1-hr daily SO_2 concentrations at the Detroit area monitoring sites (ppb). SWHS is Southwestern High School, AP=Allen Park, M is Marathon (North, East, West, South), Win-DT is Windsor downtown, Win-W is Windsor west. Covers 2009 to 2015 (2015 is incomplete; 2015 data for Canada is not available.)

Statistic	SWHS	AP	M-N	M-W	M-E	M-S	Wind-DT	Wind-W
No. Obs.	2326	2335	1328	1328	1332	1324	2185	2149
Mean	13.1	6.8	7.2	6.5	7.5	7.7	12.2	12.2
SD	18.7	10.0	16.1	8.9	9.2	10.9	11.3	11.3
Minimum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.2
10th Percentile	0.7	0.4	1.0	1.0	1.0	0.0	1.7	1.0
25th Percentile	1.7	0.9	2.0	1.0	2.0	1.0	3.8	3.0
50th Percentile	4.5	2.5	4.0	3.0	4.0	3.0	9.0	9.0
75th Percentile	16.5	8.4	8.0	8.0	9.0	10.0	18.0	18.0
90th Percentile	40.0	19.2	16.0	17.0	18.0	21.0	28.0	27.7
95th Percentile	54.4	27.2	24.0	24.0	24.0	27.0	34.0	34.5
Maximum	160.0	87.8	500.0	88.0	108.0	107.0	82.0	75.0

Temporal trends

First, we show the 35 year record of the highest 1-hr daily concentrations measured at Southwestern High School in Figure 4-7. This site has the longest complete record in Detroit, and some of the highest SO_2 concentrations. The red line shows a 365 day running 99th percentile trend. This plot is designed to show how peak levels have been changing. It is largely comparable to the NAAQS statistic, except that the NAAQS uses a calendar year period. However, the current NAAQS would not apply prior to 2010. If it had, Detroit – and most other areas with large coal-fired facilities – would be in "severe" non-attainment. Figure 4-7 shows that peak levels have declined considerably from the 1980s and mid-2000s, although highest 1-hr daily levels at this site still approach or exceed the current NAAQS in recent years.

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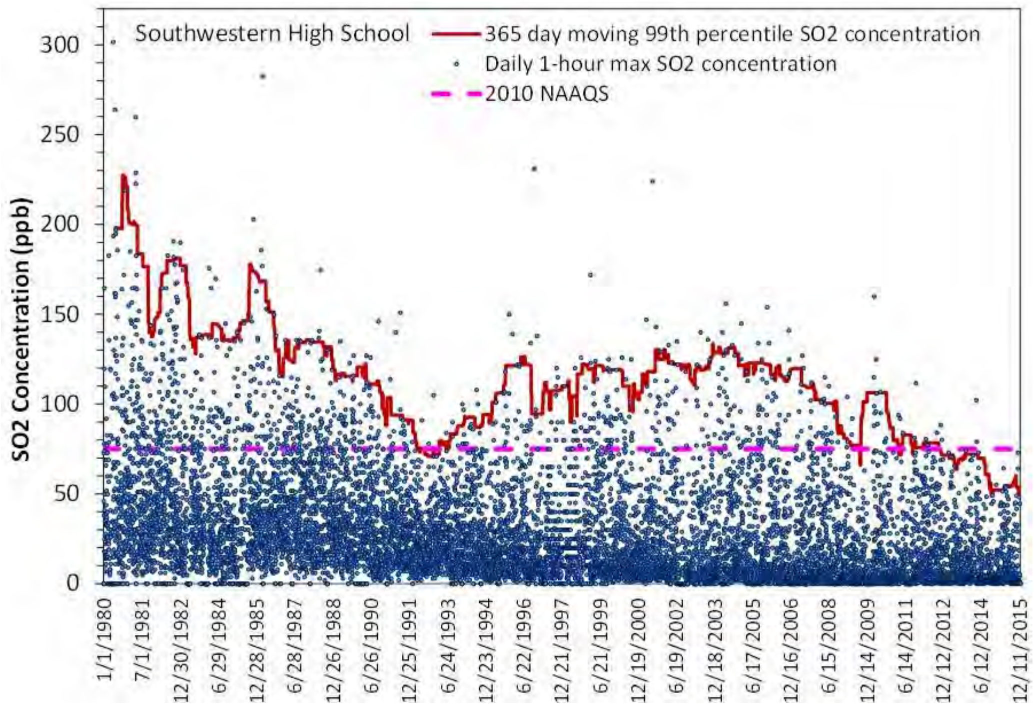
Figure 4-8. 35 year record of the highest 1-hr daily SO_2 concentrations at Southwestern High School and the current NAAQS. Plot does not show measurement of 832 ppb on 9/16/2002.



A second plot of trends is shown in Figure 4-9 again using the daily 1-hr high, but with more recent data at the 8 Detroit area sites (Southwestern High School, Allen Park, the group of monitors surrounding Marathon, and the two Windsor sites). For the four Marathon sites, the analyses uses the daily 1-hr high across the four sites. For the two Windsor sites, the analysis uses the daily 1-hr maximum across the two sites. Analysis of 1-hr data is somewhat complex as these concentrations are highly variable. To observe trends that are potentially more relevant to health effects, e.g., exacerbation of asthma, the following variable are plotted:

- Daily 1-hr high concentrations (shown as individual points).
- Smoothed running weekly daily 1-hr high concentration (shown as the red line). This is calculated as the highest 1-hr daily concentration over the week, with two iterations of a smoother, each using a weekly running average. This shows the trend of 1-hr high concentrations at the site.
- Smoothed running weekly average of the daily 1-hr high concentration. This takes the average 1-hr concentration over the week at the site, and applies two iterations of the same smoother described above. This shows average peak levels over the week. This statistic is of secondary interest.
- Running seasonal daily 1-hr average. This takes the 90-day average of the daily 1-hr high concentrations. It mainly shows long term (seasonal) trends.

This analysis is designed to indicate trends of peak concentrations that are relevant to health impacts from SO_2 (not NAAQS compliance). Because a log scale is used, small excursions at the top of the plot can be meaningful.

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The following are some key results of the trend analysis:

- The highest monitored concentrations occurred at Marathon in 2012 when a concentration of 500 ppb was noted for a single hour. With this exception, the highest concentrations occurred at the Southwest High School in 2010 when a 1-hr concentration reached 160 ppb, and three daily 1-hr concentrations exceeded 100 ppb.
- No strong long-term (across years) trends are apparent. This applies to both the peak and average 1-hr concentrations. Towards the end of the available record (fall 2015 onward), a small decrease is apparent, but this could also just reflect the variability in the data.
- Seasonal effects are shown at the Allen Park monitoring site, with higher concentrations in summer, likely due to prevailing wind directions in the direction of sources. Seasonal averages at the Canadian sites also show seasonal effects, though less strong that those at Allen Park. The other sites do not show seasonal trends.

Figure 4-9. Trends of daily 1-hr SO_2 concentrations at Detroit area monitors. Panel 1: Southwestern High School; Panel 2: Allen Park; Panel 3: Maximum of 4 Marathon Refinery Sites; Panel 4: Maximum of 2 Windsor Sites.

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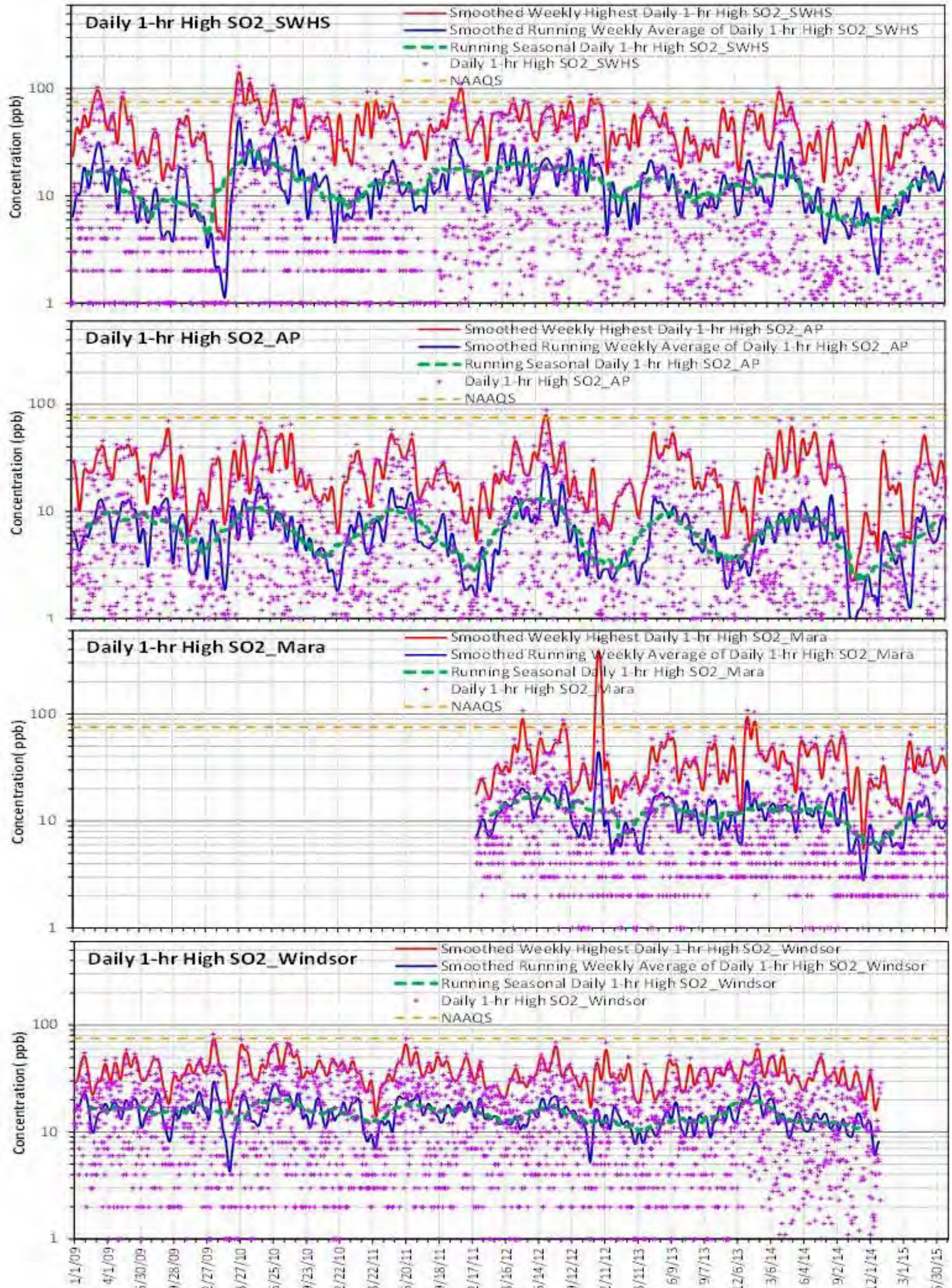

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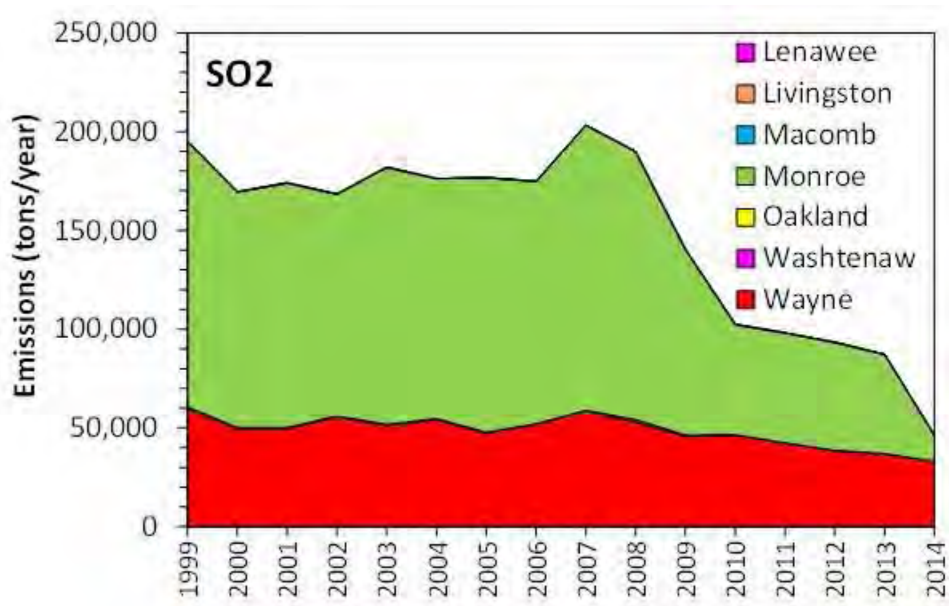
The lack of large trends in recent 1-hr concentrations is noteworthy given the gradual decrease in reported SO_2 emissions in Wayne County over 2010 to 2014 and earlier (shown in Figure 4-10), and the larger decrease in Monroe County emissions from 2013 to 2014. Examination of daily 24-hr average concentrations, rather than daily 1-hr high concentrations shows comparable results, i.e., no strong long-term trends (plots not shown). This suggests that the smaller sources in Detroit, rather than the larger sources that are responsible for the bulk of SO_2 emissions, produce the "hotspots" recorded by the Detroit monitors.

By comparison, the only other SO_2 monitor with long term records located in Michigan (in Grand Rapids), shows a long-term trend of decreasing SO_2 concentrations over this period, although concentrations are much lower (rarely exceeding 10 ppb, as compared to 100 ppb in Detroit).

Figure 4-10. Trends of SO_2 emissions from point sources from 1999 to 2014 by county. Based on MAERS data.



4.5.4 Spatial patterns

Most SO_2 is emitted by a relatively small number of large point sources, and the areas affected by SO_2 tend to reflect local source influences. Areas with the highest concentrations are called "hotspots."

SO_2 "hotspots" are depicted in Figure 4-11, which shows the 4th highest 1-hr daily concentration predicted using MDEQ and EPA approved models (AERMOD), emission parameters used by MDEQ, and 2012 meteorology. The figure shows predicted concentrations over a larger area than the modeling performed by MDEQ in the 2015 proposed SO_2 SIP. The areas potentially impacted by SO_2 clearly extends beyond the SIP non-attainment zone.

As noted earlier, the SO_2 monitoring network in Detroit includes only two sites with long term records (Southwestern High School and Allen Park). This report utilizes all available SO_2 data, and incorporates data from 6 additional sites (locations shown earlier in Figure 4-7). Even with these 8 sites, the existing monitoring network does not provide adequate spatial coverage of SO_2 concentrations. In particular, existing monitoring

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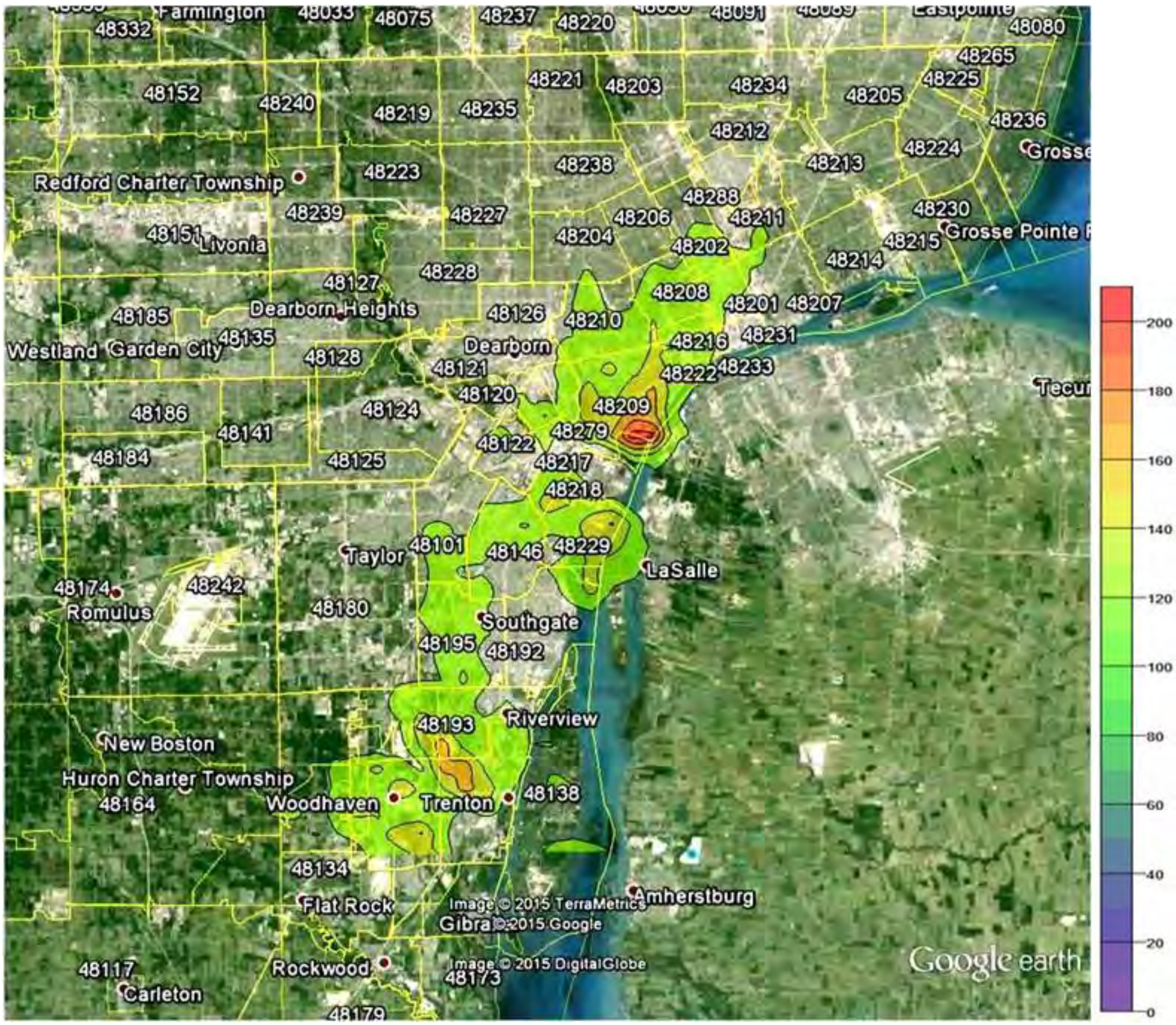
sites are not at the hotspot locations with the highest predicted SO_2 concentration. The Southwestern High School monitor site is closest to the predicted hotspot, but depending on the modeling assumptions, the predicted hotspot can be closer to or further from major sources, and the resulting concentrations can vary substantially.

Figure 4-11. Predicted SO_2 concentrations (μg/m3) across the Detroit region. Shows 4th highest daily 1-hr concentration predicted from major Detroit area sources, including DTE-Trenton, DTE-River Rouge, DTE-Monroe Facilities, and US Steel. Based on AERMOD, 2012 meteorology, 1000 m grid, and no background. (157 μg/m3 is the equivalent of 75 ppb, the current 1-hr NAAQS concentration.



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4.6 Nitrogen oxides

4.6.1 NAAQS status

EPA has set both primary and secondary standards for NO_2 at 0.053 parts per million (53 ppb), averaged annually, and also established an additional 1-hour primary standard at 100 ppb. Since 1978 no areas in Michigan have exceeded the annual NO_2 NAAQS. In addition, no monitoring site has exceeded the 1-hour standard. However, if the region becomes non-attainment for O_3 (see Section 4.3), there will be considerable attention to NO_x emissions and monitoring.

4.6.2 Monitoring

Monitoring for nitrogen oxides (NO_x) by MDEQ using EPA-approved methods provides essentially simultaneous and hourly measurements of nitrogen dioxide (NO_2) and nitric oxide (NO). Most sources emit primarily NO, which is quickly oxidized in the atmosphere into NO_2. The NAAQS health-based limits use NO_2.

Monitoring of NO_x and NO_x trends are important due to the potential for health effects from NO_2 (and NO) exposure directly, but also for two other important reasons: (1) NO and NO_2 can react with volatile organic compounds (VOCs) in the presence of sunlight to produce ground-level ozone (O_3), a widespread and important pollutant affecting health in Detroit and numerous other urban and rural areas. (2) NO_x can form nitrate aerosols that contribute to “secondary” $PM_{2.5}$.

Overall, NO_2 concentrations are decreasing across Michigan. The percent reduction in annual mean NO_2, for the period 2002 to 2011 recorded at Detroit was 33 percent.

Trends suggested by analyses of data in Detroit and elsewhere suggest that the relative contribution of nitrogen-associated secondary PM fraction of total $PM_{2.5}$ is increasing, a result of decreases concentrations of sulfate aerosol and potentially growing importance of other secondary aerosols, including those formed from NO_x emissions.[30] Major emission sources of NO_x include motor vehicle exhaust, electric utilities and industrial boilers.

4.7 Carbon Monoxide

4.7.1 NAAQS Status

At present, all Michigan areas are designated in attainment of the 1-hour and 8-hour standards. There have been no exceedances of the 1-hour and 8-hour CO NAAQS since 1991. The 1-hr standard of 35 ppm has not changed since 1971; the 8-hr standard is 9 ppm. Monitored levels fall well below the NAAQS, e.g., levels have been below 5 ppm at the four Detroit area sites since 2002.

4.7.2 Monitoring

CO is monitored at four sites in Detroit. Two are near-road sites, within 50 m (Livonia, and Eliza Howell #1); the two others are within 200 m (Allen Park, Eliza Howell #2).

Vehicle emissions are typically the largest emitter of CO, and CO ”hotspots” can occur near major roads and intersections.

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4.8 Toxics

A variety of monitoring sites measure air toxics, including metals and organic compounds. The number of sites measuring toxics is limited, in large part due to the cost of monitoring.

Air toxics represent a large and diverse group of substances, including compounds that are persistent, bioaccumulative and toxic (PBT). There are no health-protective standards, but typically a risk-based approach is used; MDEQ uses short- and long-term screening levels and health benchmark levels that focus on the direct inhalation pathway. While data are collected, there has been few comprehensive analyses of toxics data. On an intermittent basis, several special studies have been conducted that increased monitoring and analysis of toxics, the most recent being the Detroit Area Toxics Imitative in 2005-6. More recently, MDEQ notes that formaldehyde levels in southeast Michigan are very heterogeneous, and that historical concentrations at River Rouge are elevated. [13]

Metals

Currently, metals are measured at the following sites:

- Manganese, arsenic, cadmium and nickel (Mn, As, Cd, and Ni) are measured on TSP (total suspended particulate) samples at 5 area sites (Southwestern HS, Dearborn, Delray/Jefferson, River Rouge, and Allen Park). These samples are collected every 6 or 12 days.
- Lead (Pb) is measured on TSP samples at 2 sites (Allen Park and Dearborn)
- Other metals on TSP samples: Dearborn also measures a large suite of additional metals (beryllium, vanadium, chromium, manganese, nickel, cobalt, copper, zinc, arsenic, molybdenum, cadmium, barium, lead, and iron)
- Many metals are measured on $PM_{2.5}$ samples at three sites (Dearborn, Allen Park, and Fort Street). These samples are collected every 6 days (every 3 at Allen Park).

The spatial coverage of the metals network is limited vis-à-vis the potentially large emission from the steel, coke and other industries in southwest Detroit.

Organics

Two site currently measure organic species

- Fort Street measures VOCs and carbonyls (formaldehyde and acetaldehyde) every 12 days
- Dearborn measures VOCs, carbonyls and PAHs, as well as EC and OC, every 6 days.

In addition, Dearborn and Allen Park use aethalometers to measure carbon black, and indicator of soot and diesel exhaust.

[13] 2016 Air Monitoring Network Review, Michigan Department of Environmental Quality Air Quality Division. June 29, 2015, http://www.michigan.gov/documents/deq/deq-aqd-toxics-2016_Air_Mon_Network_Review_489490_7.pdf

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5. AIR POLLUTANT SOURCES, EXPOSURES & HEALTH IMPACTS

2016

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Tables

Figures

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5. AIR POLLUTANTS SOURCES, EXPOSURES AND HEALTH IMPACTS

5.1 Source types and data sources

5.1.1 Source and pollutant types

Data describing emissions are contained in "emissions inventories." These inventories use several classifications of sources and pollutants. There is a degree of overlap among these categories.

Source types

Point sources range in size from very large industrial facilities with tall smoke stacks, such as major power plants (Figure 5-1), to small or modestly-sized industries with small stacks, e.g., small factories or paint shops. An industrial facility, that is, an entity under single control, may have one to several dozens of point sources, e.g., the Ford Dearborn Assembly plant has many dozens of small facilities that are small point sources of pollutants. Typically, a relatively small number of sources and facilities accounts for the bulk of point source emissions.

Figure 5-1. Arial photo of the Trenton Channel power plant, which can burn coal, natural gas, fuel oil and residual paint solids, is an example of a major point source in southwest Detroit. Each stack is over 560 feet tall. Photo from Google Maps.

In this report, a facility is an entity under single control that may have one to several dozens of point sources (e.g., stacks). Facility-level emissions sum emissions across the various stacks. Facilities also may be associated with non-point emissions (fugitive, area and mobile emissions).

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Mobile sources include on-road vehicles (cars and trucks driven on roads), off-road or non-road sources (locomotives, aircraft, marine, off-road vehicles), and non-road equipment (such as lawn and garden equipment).

On-road emissions include exhaust emissions (e.g., diesel exhaust), brake wear, tire wear, and running losses (e.g., evaporation of fuel). On-road vehicles also cause emissions of windblown dust (silt) and pavement wear; this is sometimes considered as an area source (see below).

Area sources are defined by US EPA as stationary source of air pollutants that are not "major" sources. These consist of smaller facilities that release emit than 10 tons per year of a single air pollutant or less than 25 tons per year of a combination of pollutants. In addition to smaller factories and point sources, area sources include many types of sources, including, for example, entrained dust (from waste piles, roads, etc.), natural sources (pollen), residential fuel combustion, construction, and forest fires. Though emissions from individual area sources can be relatively small, collectively their impact can be considerable, particularly where large numbers of sources are located in or near heavily populated areas.[1]

Pollutant types

Criteria or conventional pollutants include NO_x, PM (including $PM_{2.5}$, PM_{10}, and others), CO, O_3, and VOCs. O_3 is not included in emissions inventories as it is a secondary pollutant formed from precursors NO_x and VOCs.

Toxic pollutants are pollutants that are not criteria pollutants and that may pose health or environmental risks. These include many metals, specific VOCs, semivolatile compounds, and mixtures such as diesel exhaust.

Greenhouse gas (GHG) pollutants include some conventional and criteria pollutants, as well as CO_2, N_2O, CH_4 and others. Emissions of GHGs are not discussed in this report.

Emission inventories provide estimates of only "primary" emissions. Primary emissions can form "secondary" pollutants, e.g., emissions of gases form a significant amount of secondary $PM_{2.5}$ (e.g., organic aerosols and ammonium sulfate particles). This information is not indicated by emission inventory data.

5.1.2 Data sources

Information regarding emissions from point sources was obtained from multiple sources, outlined in Table 5-1. This report discusses MAERS, TRI and NEI sources in depth; other sources are used to revise, confirm and supplement the data and to allow dispersion modeling and the quantitative health impact analyses. Other sources of data include permit to install (PTI) applications and state implementation plans (SIPs). These databases are not harmonized, and differences in emissions and other data can be large. Section 5.2.4 discusses discrepancies in the $PM_{2.5}$ point source emissions inventories, an important issue in the health impact analyses given the significance of this pollutant.

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Table 5-1. Datasets used for emission data and modeling analyses.

Dataset (Abbreviation)	Approach	Parameters and Pollutants	Years
National Emission Inventory (NEI)	EPA takes state level data from inventories and does adjustments using emission factors and other means, public access.	Stack parameters and locations. Stack level annual average emissions of conventional air pollutants (CAP) and hazardous air pollutants (HAP).	Every 3 years (2002, 2005, 2008, 2011)
Michigan Air Reporting System (MAERS)	Derived by MDEQ for emissions data at the facility level, public access.	Facility level annual average emissions of conventional pollutants: CO, NH_3, NMOC, NO_x, Pb, $PM_{2.5}$, PM_{10}, PM, SO_2, TNMOC, TOC, VOC	Annual (1999 to 2014)
Toxic Release Inventory (TRI) System	Self-reported data by industry using variety of approaches (judgment, emission factors, and measurements.	Facility level annual discharges/emissions, to air, water, off-site transfers. Nearly 600 toxics and some conventional pollutants	Annual (1999 to 2014)
MDEQ Emissions (FOIA)	Compiled by MDEQ from industry data and MDEQ calculations	Facility emissions of all CAPs and HAPs	1998 to 2008
MDEQ Stack Parameters (MDEQ-STACK) (FOIA)	Compiled by MDEQ from industry data	Stack parameters and locations	2009 to 2013
Stack Parameters (FOIA-STACK)	Compiled by MDEQ from industry data	Stack parameters and locations	1998 to 2008
Permit to Install (PTI) applications for specific sources	Compiled by MDEQ with input from industry	Allowable emission data and some stack parameters	When PTI is filed
State Implementation Plans (SIPs)	Compiled by MDEQ with input from industry	Allowable emission data and some stack parameters	When air quality non-attainment

FOIA: Freedom of Information Act

MDEQ: Michigan Department of Environmental Quality

The Michigan Air Emission Reporting System (MAERS) provides a record of estimated "actual" emissions in Michigan at the "stack" level for conventional pollutants, e.g., $PM_{2.5}$, PM_{10}, NO_x, SO_2, lead, CO, VOCs, and several other pollutants (e.g., ammonia). This public access reporting system is maintained by MDEQ and report actual emissions on an annual basis. This inventory is not necessarily used for compliance purposes, although it is often cited in permits and SIPs. It provides an indication of discharges to air for point sources. As indicated below, not all information is consistent, and trends in MAERS and the other emissions inventories must be interpreted cautiously.

5.2 Point sources

5.2.1 Conventional pollutants

This section discusses emission of conventional pollutants, drawing heavily on the Michigan Air Emissions Reporting System (MAERS). All data reported in MAERS (1999 to 2014) is considered. Most analyses use the most recent 5 year period available (2010 to 2014). Stack-level data reported in MAERS was consolidated to the facility level.

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In the 7 county SE Michigan area (Lenawee, Livingston, Macomb, Monroe, Oakland, Washtenaw, and Wayne Counties) and over the 1999-2014 period, MAERS included a total of 871 facilities. A large number of these facilities no longer report emissions in MAERS, primarily due to the shuttering of many industrial, manufacturing, and commercial facilities over the past decade or more. A smaller number of facilities report emissions in the 2010-2014 period, as shown in Table 5-2. Some facilities are relative small emitters, thus, the table shows facilities reporting both any emissions as well as emissions over 1 ton/yr. The table includes facilities reporting emissions for at least one year in the 2010-2014 period; some of these may have been shuttered since 2010 as well.

Table 5-2. Summary of number of facilities by county listing emissions in the 2010-2014 period in MAERS.

Type	County	NOx	SO2	PM2.5	PM10	VOC	CO
Number of Facilities Reporting Emissions Over 1 tons/yr							
	Wayne	88	24	38	70	109	83
	Washtenaw	26	4	7	12	20	23
	Oakland	56	12	16	32	61	46
	Monroe	14	4	5	19	8	13
	Macomb	43	5	13	29	60	38
	Livingston	8	0	1	4	11	5
	Lenawee	9	3	2	9	10	10
	Total	244	52	82	175	279	218
Number of Facilities Reporting Any Emissions							
	Wayne	125	125	115	143	157	117
	Washtenaw	28	28	28	29	31	28
	Oakland	68	70	66	84	101	63
	Monroe	16	16	14	21	16	15
	Macomb	51	49	49	58	67	49
	Livingston	8	9	8	13	14	8
	Lenawee	13	13	10	16	16	11
	Total	309	310	290	364	402	291

Table 5-3 uses 1999 to 2014 MAERS data to show how a few dozen facilities account for the bulk of NO_x, SO_2 and $PM_{2.5}$ point source emissions. For example, for SO_2, 5 facilities account for 95% of emissions in the 7-county area. These larger facilities can cause a large "footprint" in which concentrations and exposures are elevated, and thus the large facilities warrant special attention. However, smaller point sources can also be important if emissions are released near ground level and near populated areas.

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Table 5-3. Summary of emissions at the facility level in the 7 county southeast Michigan area from MAERS. Shows total long-term average emissions (1999-2014 average), the number of facilities that account for 85, 90, 95 and 99% of emissions, the number of sources with emissions, and the total number of facilities.

	NOx	SO2	PM2.5	PM10	VOC	CO	CO	Lead
Total Emissions (tons/year)	62398	148647	1523	5980	14994	264	42116.2	7.3
No. Facilities to get 85%	12	3	21	38	86	12	18	9
No. Facilities to get 90%	21	4	40	67	128	20	29	12
No. Facilities to get 95%	49	5	75	126	210	37	62	18
No. Facilities to get 99%	158	12	177	249	383	100	160	34
Source with Emissions	548	527	423	423	618	768	508	234
Total Number of Facilities	871	871	871	871	871	871	871	871

5.2.2 Trends in point source emissions of conventional pollutants

Figure 5-2 shows trends at the county level for eight pollutants. With the exception of CO, emissions have been declining over the 1999 to 2014 period. This figure also shows that for most pollutants, point sources located in Monroe and Wayne counties account for most of point source emissions in southeast Michigan. Further data on this is presented later in Section 5.5 and Table 5-10 in particular.

Trends based on emission data must be interpreted cautiously. In particular, there is considerable uncertainty in PM emissions, mobile emissions, and other nonpoint emissions (area sources).[2] This arises due to the changing methodologies used to estimate emissions, changes in which sources and pollutants are included, and changes in associated data (emission factors, activity estimates, etc.). For example, for mobile sources, important uncertainties include the availability and accuracy of the data providing on-road and off-road gasoline and diesel fuel consumption, the age and composition of the fleet, and the emission factors. Emission trends for CO, SO_2, and possibly NO_x and lead (Pb) should be more reliable than PM.

[2] Milando, C, L Huang, S Batterman. 2016. Trends in PM2.5 emissions, concentrations and apportionments in Detroit and Chicago, *Atmospheric Environment*, 129, 197-209..

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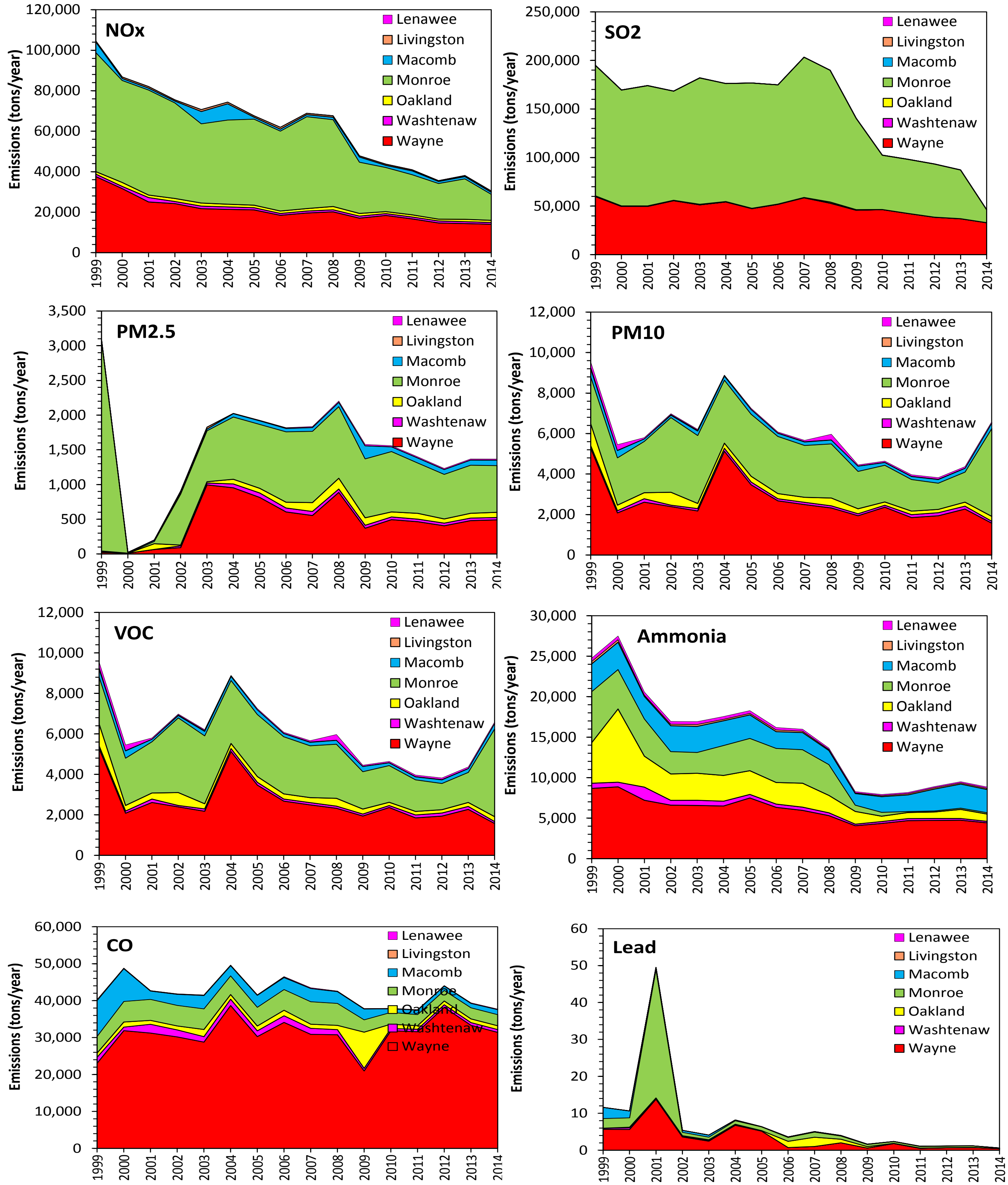
Figure 5-2. Trends of emissions of conventional pollutants from point sources from 1999 to 2014 by county. Based on MAERS data. Trends for $PM_{2.5}$ and PM_{10} are suspect due to methodological issues.



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Emission data for 2010-2014 at the facility level[3] are summarized in Table 5-4. This table lists sources in rough order of emissions for six pollutants (sorted by summing the weighted sum of the six pollutants, using weights that give a similar weight to each pollutant). For each facility, the current representative annual average emissions was estimated. This value was designed to be robust, account for year-to-year variation, and reflect the best estimate of current emissions. The year-to-year variation in reported emissions can be significant, e.g., high or low emission rates may represent ramp-up of production, temporary repairs or other anomalies, or permanent shut-downs. For pollutants other than $PM_{2.5}$, the representative emission estimate was calculated using 2010 to 2014 MAERS data, and the 5-year average if year-to-year variation was small. If the variation was high, the very high or low observations were removed. If the more recent years (2013, 2014) showed significant variation from earlier years, then more recent years were weighted more heavily. For $PM_{2.5}$, due to large discrepancies in the emission data (see Section 5.2.4), a consolidated inventory was developed that incorporated MAERS, NEI, emission factors, and other data; some of revised $PM_{2.5}$ estimates in the consolidated inventory considerably exceeded MAERS figures.

The locations of these sources are shown in maps included in the area-specific sections of this manual.

Table 5-4 also estimates recent emission trends, using the five year period. Trends were calculated if 5 years of data is available for the 2010-2014 period and if a straight-line regression explains at least 50% of the v variance (R^2>0.5). Trends exceeding 15% are noteworthy; small changes are not likely to be meaningful. Increases in the table are shown in pink, and decreases in blue.

Most facilities do not show significant trends over the 5-year period, although a number of facilities have slightly reduced emissions over this period. NO_x shows the most variation, and of the top 100 sources, 21% show reductions that exceed 10% per year for the five year period; only 1 facility increased NO_x emissions by over 10% per year (Eagle Valley Recycle & Disposal Facility in Orion Township increased by about 21% per year.) For $PM_{2.5}$, two facilities in the top 100 increased emissions by more than 10% per year (City of Wyandotte Municipal Power Plant by 61% per year, and Marathon Ashland Petroleum LLC by 97% per year).

Again, as discussed later (Section 5.2.4), PM data in MAERS may not be accurate, and thus PM data in Table 5-4 and elsewhere should be interpreted cautiously.

[3] Facility information is aggregated using the facility's state source number (SRN) assigned by MDEQ.

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Table 5-4A. Point source emissions (tons/yr) of conventional pollutants in the SE Michigan area. Trends from MAERS. Shows 5-year average emissions (filtered to exclude some variations, see text), and rate of change over 5 year period (see text). Note indicates type of variation. 1= one or two low values excluded; 2=one or two high values excluded; 3=based on last two years of data.

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			NOx			SO2			PM2.5			PM10			VOC			CO		
Order	Facility Information	City	5 Year Filtered Ave	Note	Annual Change (%/yr)	5 Year Filtered Ave	Note	Annual Change (%/yr)	5 Year Filtered Ave	Note	Annual Change (%/yr)	5 Year Filtered Ave	Note	Annual Change (%/yr)	5 Year Filtered Ave	Note	Annual Change (%/yr)	5 Year Filtered Ave	Note	Annual Change (%/yr)
1	DETROIT EDISON - MONROE POWER PLANT	MONROE	13,818		-12	47,402	(1)	-22	63.9	(1)		2,999.6	(3)		0.5	(1)	31	2,111		-3
2	ROUGE STEEL COMPANY	DEARBORN	567		-8	700			64.8			356.1			49.7		13	14,844		-8
3	J. R. WHITING PLANT	ERIE	2,274			6,132			366.3			851.2			0.2	(1)		243		
4	NATIONAL STEEL CORPORATION GREAT LAKES	ECORSE	1,522		-15	3,245	(1)	-28	97.7			270.9		-20	54.2	(1)	-42	12,393		
5	TRENTON CHANNEL POWER PLANT	TRENTON	4,409		-12	20,824		-9	22.2			646.3	(3)		1.1	(1)	24	473		3
6	GUARDIAN INDUSTRIES CORP FLOAT GLASS MA	CARLETON	2,061			569			293.3		-4	310.6		-4	59.6			15		
7	DETROIT EDISON RIVER ROUGE POWER PLANT	RIVER ROUGE	3,416			10,443		-10	6.4	(1)		25.1	(1)		3.6		18	380		-6
8	MARATHON ASHLAND PETROLEUM LLC	DETROIT	408			163		24	94.6	(3)	43	94.5			558.9		-10	128		
9	DAIMLERCHRYSLER AG, WARREN TRUCK ASSEI	WARREN	104			1		7	5.5			8.2		18	1,240.4		19	76		9
10	EES COKE BATTERY LLC	RIVER ROUGE	1,193	(1)		2,050	(1)		18.9	(1)		433.5	(3)		200.0	(3)		370	(1)	
11	DEARBORN INDUSTRIAL GENERATION, L.L.C.	DEARBORN	391			622		19	55.8		-9	57.4		-10	3.8		-8	96	(1)	-42
12	FORD MOTOR CO. - ROUGE COMPLEX (ASMBLY	DEARBORN	53			0		2	8.0			18.2		-12	722.2			17		-19
13	JEFFERSON NORTH ASSEMBLY PLANT, DAIMLE	DETROIT	59			0			2.7	(1)	-68	24.3	(1)		587.6	(1)	21	19	(1)	-34
14	RESEARCH & ENGINEERING CENTER	DEARBORN	86			5			5.7			6.0			62.4			1,458		
15	STERLING HEIGHTS ASSEMBLY PLANT, DAIMLE	STERLING HTS	58			0		9	9.8	(1)	35	8.0		29	447.5		7	56		8
16	FORD MOTOR CO. - WAYNE COMPLEX-STMP &.	WAYNE	61			2		-14	3.4			6.0	(1)		412.6			14		-5
17	AUTOALLIANCE INTERNATIONAL, INC.	FLAT ROCK	52		6	0		7	4.4		5	18.4	(1)	38	394.2			10		6
18	GREATER DETROIT RESOURCE RECOVERY FA(	DETROIT	1,162		-13	141			0.2			22.1	(1)	26	6.4	(1)		283		
19	MARBLEHEAD LIME COMPANY - RIVER ROUGE	RIVER ROUGE	553		7	640		15	5.0		7	67.4		9	0.0			72		7
20	GENERAL MOTORS CORPORATION DETROIT -	DETROIT	186	(1)	-13	302			5.1	(1)	-14	5.7	(1)	-25	233.0			74		-12
21	WOODLAND MEADOWS RDF	WAYNE	32			12		4	13.4			69.7			9.4		8	155		
22	NORTH STAR STEEL COMPANY-MICHIGAN DIVIS	MONROE	154			23			2.3	(3)		31.3			30.7			546		
23	PINE TREE ACRES, INC.	LENOX	76			38	(1)	-30	7.7			56.4	(1)	27	24.0	(1)	38	368	(1)	29
24	THE UNIVERSITY OF MICHIGAN	ANN ARBOR	318		4	10	(3)		13.7		5	14.7		5	12.8		2	173		
25	AUTOMATIC TRANSMISSION NEW PRODUCT CE	LIVONIA	49		6	1	(1)	-47	3.3			3.6			24.0			674		
26	CITY OF WYANDOTTE MUNICIPAL POWER PLAN	WYANDOTTE	237	(1)	-50	138	(2)	-34	8.1	(3)	25	12.3			4.1	(3)	63	87	(2)	-34
27	DAIMLERCHRYSLER TECHNOLOGY CENTER	AUBURN HILLS	147			9			10.3			13.0			30.8	(1)		280	(1)	15
28	ARBOR HILLS LANDFILL	NORTHVILLE	99		-5	17	(1)		0.9	(1)		83.0	(1)		9.0	(1)	-25	122		
29	CARLETON FARMS LANDFILL	NEW BOSTON	113		-8	20			0.0	(1)		28.6	(1)		14.5			357		
30	GENERAL MOTORS PONTIAC SITE OPERATION	PONTIAC	134		-5	7		-12	7.0		-13	7.8		-9	7.9	(2)	-49	86		
31	VISTEON CORPORATION STERLING PLANT	STERLING HTS	58			0		4	10.5		14	12.3			32.5			6		14
32	Green Plains Holdings II LLC	RIGA	69			1		-2	9.8		-3	17.8			19.3			14		-2
33	EAGLE VALLEY RECYCLE & DISPOSAL FACILITY	ORION TWP	45	(1)	21	5		8	5.2		-5	29.0	(1)	18	5.4	(1)	25	158	(1)	20
34	ROMEO GAS PROCESSING PLANT	ROMEO	69	(1)		0			5.3			5.3			30.5		-23	88	(1)	
35	ROUSH INDUSTRIES	LIVONIA	53		-12	1	(2)	-28	3.2	(1)	-27	1.6	(2)	-25	27.6	(3)		712	(3)	
36	GENERAL MOTORS CORPORATION - ORION AS	LAKE ORION	58			5	(1)		2.7			10.9	(3)	38	125.2	(1)	27	22		
37	SUMPTER ENERGY ASSOCIATES	LENOX TWP	121			42		8	0.0			8.0			20.3			222		
38	DETROIT WASTEWATER TREATMENT PLANT	DETROIT	281			56			0.1	(3)		4.7			56.1			2	(1)	
39	FORD MOTOR COMPANY - ROMEO ENGINE PLA	ROMEO	11			0		-10	7.0			8.0			42.0		-12	3	(1)	-59
40	FORD MOTOR COMPANY - LIVONIA TRANSMISS	LIVONIA	30			0			8.2			8.2			26.6	(1)		7		
41	HOWELL COMPRESSOR STATION	HOWELL	488			0			0.0			0.0			8.2			15		
42	SAUK TRAIL HILLS DEVELOPMENT, INC.	CANTON TWP	21	(1)		14	(1)		0.8	(1)	-59	24.6			1.6	(1)	-61	42	(1)	
43	FREEDOM COMPRESSOR STATION	MANCHESTER	252			0		8	3.8			3.9			9.7			31		
44	EAGLE INDUSTRIES INC	WIXOM	0			0			0.0			0.0			110.5		12	0		
45	ST. MARYS CEMENT, INC. (U.S.)	DETROIT	5			0			0.0			42.6			0.0			4		
46	SOLUTIA INC.	TRENTON	0			0			0.0			1.5			105.8			0		
47	RIVERVIEW LAND PRESERVE	RIVERVIEW	51	(1)		79	(1)	36	2.1	(3)		20.0		-13	3.9			76	(1)	
48	RAY COMPRESSOR STATION	ARMADA	73			0			1.9	(2)	-25	1.9	(2)	-25	15.4			62		
49	OAKLAND HEIGHTS DEVELOPMENT, INC.	AUBURN HILLS	16		-10	3		-11	4.5		-10	20.1	(1)	28	0.6			26		-10
50	GEORGIA PACIFIC CORP	MILAN	3			0			6.5		-6	13.0		-7	1.5		10	2		

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Table 5-4B. Point source emissions of conventional pollutants (tons/yr) in the SE Michigan area. (continued).

			NOx			SO2			PM2.5			PM10			VOC			CO		
Order	Facility Information	City	5 Year Filtered Ave	Note	Annual Change (%/yr)	5 Year Filtered Ave	Note	Annual Change (%/yr)	5 Year Filtered Ave	Note	Annual Change (%/yr)	5 Year Filtered Ave	Note	Annual Change (%/yr)	5 Year Filtered Ave	Note	Annual Change (%/yr)	5 Year Filtered Ave	Note	Annual Change (%/yr)
51	Shelby Foam Systems, a Division of Magna Seating	SHELBY TWP	0			0			0.0			0.0			99.0			0		
52	WESTPORT LD, INC.	PLYMOUTH TWI	206	(3)		14	(3)		29.0	(3)		29.0	(3)		0.0	(3)		46	(3)	
53	WOODBRIDGE FOAM CORPORATION	ROMULUS	0			0			0.0			0.0			97.2			0		
54	GM TECHNICAL CENTER	WARREN	76			1		9	3.0			5.0			13.3			61		4
55	AJAX MATERIALS CORP	ROMULUS	6			1			3.3			17.2			7.1			29		
56	FORD MOTOR COMPANY-ELM STREET BOILER	DEARBORN	92			0			4.8			4.8			3.5			26		
57	BEACON HEATING PLANT	DETROIT	96	(1)	-30	0	(1)		4.6	(1)		4.6	(1)		3.7	(1)		48	(1)	
58	CONCEPP TECHNOLOGIES	WYANDOTTE	0			0			0.0			2.6			80.7			0		
59	ANGELOS CRUSHED CONCRETE INC	WARREN	5			1			2.8			15.6			6.0			24		
60	WARREN WASTE WATER TREATMENT PLANT	WARREN	17			2			0.5			0.9			39.6			84		
61	SYLVANIA CO LTD PARTNERSHIP	BERLIN TWP	0			0			0.0			31.8		21	0.0			0		
62	Heat Treating Services Corp of America - Plant 1	PONTIAC	6		27	0		27	0.5	(1)		0.5	(1)		17.5	(3)	55	5		27
63	JOHNSON MATTHEY VEHICLE TESTING & DEVE	TAYLOR	3			6		-8	6.0		-8	6.0		-8	1.6			6		
64	FLAT ROCK METAL, INC.	FLAT ROCK	4		10	0		10	4.6		9	4.6		9	17.7		16	3		10
65	WALSH-HIGGINS IRS COMPUTER CTR	DETROIT	0	(1)	-99	0	(1)		0.0	(1)		0.0	(1)	-99	0.0			0	(1)	-99
66	VISTEON CORPORATION MILAN PLANT	MILAN	0	(1)		0	(1)		0.0	(1)		0.0	(1)		0.0	(1)		0	(1)	
67	VIENNA JUNCTION LANDFILL	ERIE	5			0			0.1	(1)		23.5			0.3			17		
68	VENTRA FOWLERVILLE LLC	FOWLERVILLE	4		4	0		4	0.3		4	0.3		4	67.4		16	3		4
69	U S SILICA COMPANY-ROCKWOOD PLANT	ROCKWOOD	5	(1)	20	0	(1)	20	4.6			9.4			0.3	(1)	20	4	(1)	20
70	EDW C LEVY CO PLANT 1	DETROIT	0			0			0.0			12.2	(1)	-44	0.0			0		
71	DETROIT DIESEL CORPORATION	DETROIT	55	(1)	-31	7		-9	2.0		-10	3.0		-8	13.6			32		-8
72	BP - RIVER ROUGE TERMINAL	RIVER ROUGE	0	(3)		0	(3)		0.0	(3)		0.0	(3)		71.2			0	(3)	
73	DAIMLERCHRYSLER TRENTON ENGINE PLANT	TRENTON	19		-3	0	(1)		1.0		-12	7.4		-1	15.0	(1)	40	107	(1)	35
74	DU PONT MT. CLEMENS PLANT	MOUNT CLEMEI	5		20	0	(3)	34	0.4		18	0.6		22	62.7		3	4		18
75	VECTOR PIPELINE LP	HIGHLAND	35		-7	1		-5	4.3		-5	4.3		-5	1.4		-5	15		-10
76	ROMEO RIM, INC.	ROMEO	0			0			0.0			0.0			68.4			0		
77	MARATHON PIPE LINE COMPNAY	WOODHAVEN	0	(1)		0			0.0			0.0			66.9		3	1	(1)	
78	VECTOR PIPELINE L.P.	WASHINGTON	41	(1)	-26	2	(1)		4.0			4.0			1.3			4	(1)	-77
79	WAYNE STATE UNIVERSITY	DETROIT	37		-4	1		14	3.0		-7	3.9			2.2		-6	32		-7
80	VISTEON CORPORATION SALINE PLANT	SALINE	13			0			1.0		7	1.0			44.4			5		
81	WILLIAM BEAUMONT HOSPITAL	ROYAL OAK	38	(1)		0		5	2.5			2.9			2.5	(1)		29	(1)	
82	EASTERN MICHIGAN UNIVERSITY	YPSILANTI	81			1			2.0			2.6			1.2			25		
83	EQ-SITE #2	BELLEVILLE	35	(1)		1			0.0	(1)		9.2			1.2			21		-11
84	DARLING INTERNATIONAL	MELVINDALE	4			1		-14	4.4		-14	3.1	(3)	61	3.2		-14	4		
85	HENKEL SURFACE TECHNOLOGIES	WARREN	1		7	0		8	3.9			3.9			2.8			1		7
86	HEAT TREATING SERVICES CORP	PONTIAC	10			0			3.6		15	3.6		15	1.0		9	8		
87	MICHIGAN AGRICULTURAL COMMODITIES	BLISSFIELD	1	(1)		0	(1)		2.1		2	12.2		2	0.0	(1)		0		
88	MAGNI INDUSTRIES INC	DETROIT	0			0			0.0			6.3		6	34.4		5	0		
89	X-CEL INDUSTRIES INC	SOUTHFIELD	0			0			0.0			0.0			49.6		13	0		
90	GENERAL MOTORS CORP. - MILFORD PROVING	MILFORD	37			1			1.9			2.8			12.6	(3)		23		2
91	FEDERAL-MOGUL TECHNICAL CENTER	PLYMOUTH	16			1			1.3			1.3			1.1			80		5
92	BASF CORPORATION	WYANDOTTE	5			0	(2)	-22	0.0			11.9			16.2			2	(1)	25
93	Global Engine Manufacturing Alliance (GEMA)	DUNDEE	6	(1)		0	(1)		0.1			7.3		11	5.8			71	(1)	
94	Umicore Autocat USA Inc.	AUBURN HILLS	3		-10	1		-7	1.2		-7	1.2		-7	1.0			25	(1)	-72
95	SILBOND CORPORATION	WESTON	3			0			0.1		3	0.1		3	43.1		4	2		3
96	PARKEDALE PHARMACEUTICALS, INC.	ROCHESTER	99		1	1			1.0			1.0			6.5			12		
97	FITZGERALD FINISHING COMPANY	DETROIT	6		10	0		10	0.4		10	0.4		10	36.7		20	5		10
98	ANGELOS CRUSHED CONCRETE INC	ROCHESTER HL	3			0			1.6			8.3			3.4			14		
99	CURTIS METAL FINISHING CO	STERLING HTS	9		4	0		7	0.7		4	0.9		6	32.3			4		
100	LOTUS ENGINEERING, INCORPORATED	ANN ARBOR	7	(2)		0	(1)		0.5	(1)		0.5	(1)		6.8	(3)		124	(1)	

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5.2.3 Toxic pollutants

Releases of toxic pollutants are reported in the Toxic Release Inventory (TRI) database, which contains industry-reported estimate of annual emissions and other data for approximately 594 chemicals and 31 chemical groups. This inventory is separate from MAERS and is not used for most compliance or other regulatory purposes. TRI provides an indication of discharges to air, water, land and off-site transfers. Not all information is consistent, and chemicals and sources have been added over the years, and thus trends must be interpreted cautiously.

Table 5-5 summarizes air emissions in Wayne County by chemical group from 2010 to 2014. Table 5-6 provides a summary by pollutant. Table 5-7 lists of emissions by facility and pollutant category. The ranking of sources in this table was based on the tonnage released as averaged over 2010-2014, which provides only a crude measure of toxicity. The tables include sources releasing more than a few pounds/year of the TRI chemicals over the 2010-2014 period. All source reporting emissions (of at least a few pounds) for this period were included in the table. A number of sources may have been shuttered by the time of this report.

Over the 2010-2014 period, 133 facilities reported toxic emissions in Wayne County in the TRI database. Of these, about 90 facilities had emissions exceeding a few pounds per year. The remainder reported very low emission rates. Of the nearly 600 chemicals listed in the TRI, facilities reported about 90 chemicals in amounts that exceeded 100 lbs/yr. In comparison, MAERS includes a larger number of facilities in Wayne County (about 160 in the study period) that report emissions of conventional pollutants.

Table 5-6 shows that over the 5-year period, releases of acids decreased by about 23% per year. Most of the acids are hydrochloric acid aerosols, and most were released by the DTE Trenton Channel Power Plant, the DTE River Rouge Power Plant, and the Dept. of Municipal Services Power Plant. Emissions of nitrogen compounds increased by about 11% per year; most of these emissions were ammonia, and most arose from US Steel Corp Great Lakes Works, Marathon Petroleum Co LP - Michigan Refining Div., and the EES Coke Battery LLC.

Table 5-5. Summary of TRI emissions (lbs/year) in Wayne County by compound class for 2010 through 2014 from TRI. Shows number of facilities emitting more than 100 lbs/year, 5-year average, and rate of change over 5 year period (see text).

Pollutant	No. Facilities	Emissions by Year (lbs/year)						Trend
Group	>100 lbs/yr	2010	2011	2012	2013	2014	Average	(%/yr)
Acids	24	3,118,877	3,116,265	2,291,049	1,116,278	1,557,573	2,240,050	-22.9
Volatile Organic	146	1,667,892	1,606,954	1,816,728	1,510,531	1,270,963	1,578,108	-
Metals and Metal Compounds	49	89,120	118,454	107,459	84,790	74,299	94,909	-
Nitrogen Componds	18	92,168	100,807	96,265	143,111	136,347	113,740	11.5
Sulfur Compounds	2	28	35	42,298	41,801	38,904	41,001	-
Other	20	406,223	451,495	406,919	487,002	400,923	430,959	-
Total	222	5,374,308	5,394,010	4,760,717	3,383,512	3,479,008	4,498,767	-12.9

Notes: Acids include: Hydrochloric, Sulfuric acid, Nitric acid, Acrylic acid, Formic acid

Nitrogen compounds include: Ammonia (includes Hydrogen cyanide, Nitrate compounds, Sodium nitrite, Diethanolamine, Dimethylamine, and Cyanide compounds

Sulfur compounds include: Hydrogen sulfide, Carbon disulfide

Other includes: Certain glycol ethers, Hydrogen fluoride, Vinyl acetate, Chlorine, Hydroquinone

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Table 5-6A. Emissions of toxics in Wayne County by pollutant and year from TRI. Ranked by tonnage of emissions. Shows number of facilities emitting more than 100 lbs/year, 5-year average, and rate of change over 5 year period (see text).

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Rank by lbs/yr	Pollutant Type	No. Facilities >100 lbs/yr	Emissions by Year (lbs/year) 2010	2011	2012	2013	2014	Average	Trend (%/yr)
1	Hydrochloric acid (acid aerosols ir	13	2,867,653	2,840,441	2,047,655	916,106	1,335,314	2,001,434	-24.9
2	Xylene (mixed isomers)	14	293,572	318,706	481,317	334,919	270,829	339,869	-
3	1,2,4-Trimethylbenzene	10	281,403	291,279	369,514	306,145	228,656	295,399	-
4	Certain glycol ethers	13	269,751	299,650	275,625	310,384	293,523	289,787	-
5	Sulfuric acid (acid aerosols includ	3	246,895	270,759	238,639	193,734	212,071	232,420	-6.3
6	n-Butyl alcohol	9	283,263	205,759	249,821	235,750	166,008	228,120	-9.0
7	Hydrogen fluoride	4	118,187	135,493	114,327	160,209	87,259	123,095	-
8	Benzene	7	134,847	135,993	100,412	104,966	121,998	119,643	-
9	Ethylene	3	135,434	113,385	89,377	98,953	106,513	108,732	-
10	Methanol	13	97,379	115,178	130,086	67,089	70,084	95,963	-
11	Toluene	16	84,301	90,604	77,831	77,863	79,702	82,060	-
12	Ammonia (includes anhydrous ar	5	86,160	64,978	63,955	100,465	81,491	79,410	-
13	Zinc compounds	10	67,454	96,942	87,756	60,832	53,979	73,392	-
14	Ethylbenzene	7	50,696	54,687	91,437	58,330	47,462	60,522	-
15	Propylene (Propene)	2	96,731	58,163	23,877	45,128	47,190	54,218	-
16	Methyl isobutyl ketone	5	46,968	35,608	31,390	70,049	36,708	44,145	-
17	n-Hexane	8	49,357	54,904	40,102	30,735	17,481	38,516	-22.8
18	Hydrogen sulfide	2	-	-	42,262	41,773	38,874	40,970	-
19	Hydrogen cyanide	1	900	30,001	26,473	30,603	31,624	23,920	25.9
20	Vinyl acetate	1	16,977	15,651	16,195	15,649	19,377	16,770	-
21	Cyclohexane	2	17,519	16,175	17,823	8,890	12,003	14,482	-12.6
22	Acetaldehyde	1	11,587	12,324	13,452	11,044	11,815	12,044	-
23	Naphthalene	5	8,399	9,212	25,179	9,540	5,323	11,530	-
24	Formaldehyde	3	6,414	7,485	20,384	11,402	9,833	11,104	-
25	Chloromethane (Methyl chloride)	1	-	14,807	10,804	10,647	10,626	11,721	-
26	Dichloromethane (Methylene chlor	3	23,235	15,995	3,523	2,749	750	9,250	-62.9
27	N-Methyl-2-pyrrolidone	4	9,875	24,620	3,479	3,238	3,462	8,935	-
28	Butyraldehyde	1	9,221	10,337	8,515	8,255	8,009	8,867	-5.1
29	Nitric acid	5	3,829	4,535	4,470	5,408	9,749	5,598	22.7
30	Nitrate compounds (water dissoci	3	78	343	760	7,606	18,632	5,484	80.9
31	Manganese compounds	8	4,486	4,622	6,190	5,495	4,669	5,093	-
32	Styrene	2	2,438	4,694	4,110	6,848	6,867	4,991	22.1
33	Sodium nitrite	4	4,426	4,575	4,613	3,827	4,055	4,299	-
34	Phenol	4	11,389	1,851	1,734	1,823	2,486	3,857	-
35	Barium compounds (except for ba	3	4,285	3,417	2,668	4,152	2,042	3,313	-
36	Cumene	2	1,560	3,214	9,789	53	1,141	3,151	-
37	Trichlorofluoromethane (CFC-11)	1	2,174	1,994	2,810	2,208	3,463	2,530	11.0
38	1,3-Butadiene	1	1,992	3,820	333	2,387	2,171	2,141	-
39	Methyl methacrylate	1	1,650	1,550	1,450	2,710	1,447	1,761	-
40	Aluminum (fume or dust)	1	1,608	1,624	1,824	1,740	1,740	1,707	-
41	Propylene oxide	1	1,000	1,000	5,050	542	588	1,636	-
42	Diisocyanates (includes 20 specif	1	1,042	1,679	1,067	1,422	1,497	1,342	-
43	Lead compounds	4	1,134	1,408	1,404	1,499	910	1,271	-
44	Nickel	2	1,820	1,529	242	283	261	827	-52.8
45	Copper compounds (this category	3	717	708	750	762	917	771	5.9

continued

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Table 5-6B. Emissions of toxics in Wayne County by pollutant and year from TRI. Continued.

Rank by lbs/yr	Pollutant Type	No. Facilities >100 lbs/yr	Emissions by Year (lbs/year) 2010	2011	2012	2013	2014	Average	Trend (%/yr)
46	Chlorine	1	750	701	772	760	764	749	-
47	Chromium compounds (except fo	3	609	591	1,099	448	646	679	-
48	Ethylene glycol	3	879	824	355	484	438	596	-20.5
49	Ethylene oxide	1	500	500	1,350	79	175	521	-
50	Zinc (fume or dust)	1	500	500	500	507	507	503	0.4
51	Copper	4	509	74	12	945	953	499	-
52	Acrylic acid	2	500	500	255	775	439	494	-
53	Ethyl acrylate	1	500	500	500	590	310	480	-
54	Acrylonitrile	1	500	500	500	336	403	448	-8.0
55	Mercury compounds	2	392	450	514	432	414	440	-
56	Nickel compounds	3	473	526	541	328	296	433	-12.7
57	Manganese	1	1,468	155	157	165	149	419	-62.8
58	Butyl acrylate	1	500	500	500	367	202	414	-17.6
59	Diethanolamine	3	397	703	277	298	375	410	-
60	Polycyclic aromatic compounds (i	1	484	512	435	426	180	407	-17.1
61	Vanadium compounds	1	412	395	293	306	249	331	-12.5
62	tert-Butyl alcohol	1	500	500	500	71	82	331	-38.3
63	Phthalic anhydride	1	1,000	500	-	-	-	750	-
64	Phenanthrene	1	651	672	1	1	161	297	-55.6
65	sec-Butyl alcohol	1	255	255	503	175	173	272	-
66	4,4'-Isopropylidenediphenol	2	-	-	-	615	661	638	-
67	Arsenic compounds	1	446	459	124	117	98	249	-41.7
68	Toluene diisocyanate (mixed isom	1	292	341	342	34	165	235	-
69	Selenium compounds	1	529	545	3	3	3	217	-73.6
70	Dimethylamine	1	197	197	177	187	167	185	-3.8
71	Chromium	1	-	-	263	265	104	211	-
72	Antimony compounds	1	271	271	24	23	20	122	-61.5
73	Hydroquinone	1	559	-	-	-	-	559	-
74	Lead (when lead is contained in st	0	135	93	49	51	97	85	-
75	Formic acid	1	-	30	30	255	-	105	-
76	Methyl tert-butyl ether	1	59	25	65	58	107	63	-
77	Chloroform	1	-	250	-	-	-	250	-
78	Barium	0	42	42	34	36	24	36	-11.8
79	Cyanide compounds	1	10	10	10	125	3	32	-
80	Carbon disulfide	0	28	35	36	28	30	31	-
81	Anthracene	1	139				-	35	-
82	Tetrachloroethylene (Perchloroeth	0	16	16	22	10	15	16	-
83	m-Xylene	0	-	69	-	-	-	69	-
84	p-Xylene	0	-	69	-	-	-	69	-
85	3-Iodo-2-propynyl butylcarbamate	0	58	-	-	-	-	58	-
86	Molybdenum trioxide	0	-	-	18	23	-	21	-
87	Benzo(g,h,i)perylene	0	7	4	5	13	5	7	-
88	Dibenzofuran	0	25	4	4	1	-	9	-
89	Di(2-ethylhexyl) phthalate (DEHP)	0	10	2	-	13	4	7	-
90	Polychlorinated biphenyls (PCBs)	0	4	8	5	8	2	5	-

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Table 5-7A. Emissions of toxics (lbs/year) by facility in Wayne County by pollutant type. Average over 2010-2014. Categories are defined in Table 4. Ranked by total TRI emissions.

Facility Rank, Name and Address				TRI Emissions by Chemical Class (lbs/year)					
Rank	FACILITY_NAME	STREET_ADDRESS	CITY_NAME	Acids	Volatile Organic Compounds	Metals and Metal Compounds	Nitrogen Componds	Sulfur Compounds	Other
1	DTE ELECTRIC CO - TRENTON CHANNEL POWER PLANT	4695 W JEFFERSON AVE	TRENTON	699,000	64	581	0	0	65,200
2	DTE ELECTRIC COMPANY- RIVER ROUGE POWER PLANT	1 BELANGER PARK DR	RIVER ROUGE	268,400	51	186	0	0	57,600
3	DEPARTMENT OF MUNICIPAL SERVICES-POWER PLANT	2555 VAN ALSTYNE	WYANDOTTE	81,001	0	62	0	0	0
4	FORD MOTOR CO DEARBORN TRUCK PLANT	3001 MILLER RD	DEARBORN	72	37,269	24	124	0	135,526
5	GENERAL MOTORS GM VA DETROIT-HAMTRAMCK ASSEI	2500 E GENERAL MOTORS	DETROIT	52,600	17,381	362	0	0	3,397
6	SOUTHWIN - LIVONIA PLANT	11800 SEARS DR	LIVONIA	0	12,885	0	0	0	0
7	CARMEUSE LIME INC RIVER ROUGE FACILITY	25 MARION AVE	RIVER ROUGE	51,185	153	2	0	0	0
8	EES COKE BATTERY LLC	1400 ZUG ISLAND	RIVER ROUGE	41,754	13,500	24	14,246	15,740	0
9	FCA US JEFFERSON NORTH ASSEMBLY PLANT	2101 CONNOR AVE	DETROIT	15	8,933	236	3	0	89,580
10	SOLUTIA INC	5100 W JEFFERSON AVE	TRENTON	0	10,456	0	0	0	16,770
11	MARATHON PETROLEUM CO LP - MICHIGAN REFINING DI	1300 S FORT ST HES DEP	DETROIT	9,759	12,763	101	15,484	7,513	21
12	US STEEL CORP GREAT LAKES WORKS	1 QUALITY DR	ECORSE	1,342	33,537	4,075	13,214	0	0
13	FORD MOTOR CO MICHIGAN ASSEMBLY PLANT	38303 MICHIGAN AVE	WAYNE	0	14,890	24	0	0	11,522
14	FLAT ROCK ASSEMBLY PLANT	1 INTERNATIONAL DR	FLAT ROCK	10	10,592	33	2	0	11,978
15	DETROIT TUBULAR RIVET	1213 GROVE	WYANDOTTE	0	12,484	0	0	0	0
16	FORD MOTOR COMPANY-WAYNE ASSEMBLY	37625 MICHIGAN AVE	WAYNE	0	7,288	5	0	0	5,563
17	FITZGERALD FINISHING LLC	17450 FILER AVE	DETROIT	3,064	9,433	0	0	0	0
18	AK STEEL DEARBORN WORKS	4001 MILLER RD	DEARBORN	15,448	67	4,375	0	0	0
19	RED SPOT PAINT & VARNISH CO INC	550 S EDWIN ST	WESTLAND	0	1,473	0	0	0	3,908
20	AJAX METAL PROCESSING INC	4651 BELLEVUE AVE	DETROIT	268	7,376	0	0	0	13,595
21	FINTEX LLC	8900 INKSTER RD	ROMULUS	0	7,168	0	0	0	0
22	NEW BOSTON RTM INC	19155 SHOOK RD	NEW BOSTON	0	2,767	0	0	0	0
23	APPLIED PROCESS INC	12238 NEWBURGH RD	LIVONIA	0	0	0	3,447	0	0
24	3M CO-DETROIT	11900 E 8 MILE RD	DETROIT	0	1,583	0	0	0	0
25	DETROIT DIESEL CORP REDFORD FACILITY	13400 OUTER DR W	DETROIT	0	384	0	0	0	12,630
26	CADON PLATING CO	3715 11TH ST	WYANDOTTE	11	0	0	0	0	6,162
27	DOUBLE EAGLE STEEL COATING CO	3000 MILLER RD	DEARBORN	4,480	0	2	0	0	0
28	MAGNI INDUSTRIES INC	2771 HAMMOND	DETROIT	0	1,994	719	0	0	0
29	DIFCO LABORATORIES INC	920 HENRY ST	DETROIT	0	1,227	0	0	0	0
30	EQ DETROIT INC	1923 FREDERICK	DETROIT	1,319	1,220	3	1,650	0	1,691
31	MARATHON PIPE LINE LLC WOODHAVEN TERMINAL	24400 ALLEN RD	WOODHAVEN	0	893	0	0	0	0
32	ASH STEVENS INC	18655 KRAUSE ST	RIVERVIEW	0	800	0	0	0	0
33	DURCON INC	8464 RONDA DR	CANTON	0	750	0	0	0	0
34	FRITZ PRODUCTS	255 MARION	RIVER ROUGE	14,813	0	0	0	0	721
35	BASF CORP	1609 BIDDLE AVE	WYANDOTTE	445	730	25	1,997	0	8
36	MCGEAN-ROHCO INC	38521 SCHOOLCRAFT AVE	LIVONIA	39	1,873	0	13	0	0
37	V&S DETROIT GALVANIZING LLC	12600 ARNOLD ST	REDFORD	0	0	600	0	0	0
38	AIR PRODUCTS & CHEMICALS INC/DETROIT HYDROGEN I	1025 OAKWOOD BLVD	DETROIT	0	55	0	3,078	0	0
39	CYGNET AUTOMATED CLEANING LLC	45889 MAST ST	PLYMOUTH	0	410	0	0	0	0
40	Z TECHNOLOGIES CORP	26500 CAPITOL AVE	REDFORD	0	416	0	15	0	25
41	ALCO PRODUCTS LLC	580 ST JEAN ST	DETROIT	0	328	0	0	0	0
42	TOWER AUTOMOTIVE PLYMOUTH	43955 PLYMOUTH OAKS BI	PLYMOUTH	0	0	311	0	0	0
43	MARATHON PETROLEUM CO - ROMULUS MI TERMINAL	28001 CITRON DR	ROMULUS	0	376	0	0	0	0
44	INTERNATIONAL PRECAST SOLUTIONS LLC	60 HALTINER AVE	RIVER ROUGE	284	0	0	0	0	0
45	BP PRODUCTS NA INC RIVER ROUGE TERMINAL	205 MARION ST	RIVER ROUGE	0	361	0	0	0	0

continued

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Table 5-7B. Emissions of toxics (lbs/year) by facility in Wayne County by pollutant type. Continued.

Facility Rank, Name and Address				TRI Emissions by Chemical Class (lbs/year)					
Rank	FACILITY_NAME	STREET_ADDRESS	CITY_NAME	Acids	Volatile Organic Compounds	Metals and Metal Compounds	Nitrogen Componds	Sulfur Compounds	Other
46	ARCO ALLOYS CORP	1891 TROMBLY	DETROIT	0	0	250	0	0	0
47	CUL-MAC INDUSTRIES INC	3720 S VENOY RD	WAYNE	0	500	0	0	0	0
48	WOODBRIDGE CORP	15573 OAKWOOD DR	ROMULUS	0	176	0	261	0	0
49	HOUGHTON INTERNATIONAL INC	9100 FREELAND AVE	DETROIT	0	0	0	0	0	1,073
50	FAURECIA EMISSIONS CONTROL TECHNOLOGIES	24850 NORTHLINE RD	TAYLOR	0	0	207	0	0	0
51	PARK METALLURGICAL CORP	8074 MILITARY AVE	DETROIT	0	0	24	533	0	0
52	EQ RESOURCE RECOVERY INC	36345 VAN BORN RD	ROMULUS	0	191	0	0	0	0
53	UNIVAR USA INC ROMULUS BRANCH	13395 HURON RIVER DR	ROMULUS	0	166	0	0	0	65
54	CHEMETALL US INC	13177 HURON RIVER DR	ROMULUS	250	4	55	189	0	127
55	EDW C LEVY CO - PLANT 3	100 WESTFIELD	ECORSE	0	0	127	0	0	0
56	POLYCHEMIE INC	38070 VAN BORN RD	WAYNE	0	135	0	185	0	0
57	EDW C LEVY CO - PLANT 6	13800 MELLON	DETROIT	0	0	109	0	0	0
58	INLAND WATERS POLLUTION CONTROL DETROIT FACILIT	4086 MICHIGAN AVE	DETROIT	0	89	0	0	0	0
59	AMERICAN JETWAY CORP	34136 MYRTLE	WAYNE	0	76	0	0	0	103
60	EFTEC NORTH AMERICAS LLC	20219 NORTHLINE RD	TAYLOR	0	1	127	0	0	0
61	ALPHA RESINS LLC	17350 RYAN RD	DETROIT	0	49	0	0	0	20
62	MT ELLIOTT TOOL & DIE MANUFACTURING	3675 E OUTER DR	DETROIT	0	0	46	0	0	0
63	FORD MOTOR CO - LIVONIA TRANSMISSION PLANT	36200 PLYMOUTH RD	LIVONIA	0	0	63	0	0	0
64	WINDSOR MACHINE & STAMPING (US) LTD	26655 NORTHLINE RD	TAYLOR	0	0	2	83	0	0
65	FORD MOTOR CO WOODHAVEN STAMPING PLANT	20900 W RD	WOODHAVEN	0	0	39	0	0	0
66	PVS NOLWOOD CHEMICALS INC	9000 HUBBELL AVE	DETROIT	163	8	10	8	0	29
67	SUPERIOR MATERIALS 32	8911 W JEFFERSON	DETROIT	0	56	0	0	0	0
68	PVS TECHNOLOGIES INC	10825 HARPER AVE	DETROIT	0	0	0	0	0	28
69	DETROIT AXLE PLANT	6700 LYNCH RD	DETROIT	0	0	7	0	0	0
70	PLASTOMER CORP	37819 SCHOOLCRAFT RD	LIVONIA	0	24	0	0	0	0
71	FORD MOTOR CO DEARBORN ENGINE PLANT	3001 MILLER RD	DEARBORN	0	22	16	8	0	0
72	ST MARY'S CEMENT INC	9333 DEARBORN ST	DETROIT	0	0	17	0	0	0
73	FORD MOTOR CO DEARBORN TOOL & DIE PLANT	3001 MILLER RD	DEARBORN	0	20	0	0	0	12
74	FORD MOTOR CO DEARBORN STAMPING PLANT	3001 MILLER RD	DEARBORN	0	7	14	0	0	0
75	WAYNE DISPOSAL INC	49350 N I-94 SERVICE DR	BELLEVILLE	125	15	2	49	0	64
76	FORD MOTOR CO DEARBORN DIVERSIFIED MANUFACTU	3001 MILLER RD	DEARBORN	3	18	10	0	0	7
77	FORD MOTOR CO WAYNE INTEGRAL STAMPING	37500 VAN BORN	WAYNE	0	19	3	0	0	15
78	KREHER WIRE PROCESSING	34822 GODDARD RD	ROMULUS	8	8	0	0	0	0
79	NORTHFIELD	36506 SIBLEY RD	NEW BOSTON	0	12	0	0	0	0
80	CONCEPP TECHNOLOGIES INC	1609 BIDDLE AVE (PART O	WYANDOTTE	10	0	0	4	0	0
81	DYNAMIC SURFACE TECHNOLOGIES INT INC	7784 RONDA DR	CANTON	0	0	0	7	0	0
82	FORD MOTOR CO WOODHAVEN FORGING PLANT	24189 ALLEN RD	WOODHAVEN	0	0	6	0	0	0
83	UNISTRUT INTERNATIONAL CORP	4205 ELIZABETH ST	WAYNE	0	0	3	0	0	0
84	DCI AEROTECH	7515 LYNDON	DETROIT	0	0	0	7	0	0
85	MICHIGAN DAIRY	29601 INDUSTRIAL RD	LIVONIA	7	0	0	0	0	0
86	BORGWARNER POWDERED METALS INC	32059 SCHOOLCRAFT	LIVONIA	0	0	3	0	0	0
87	SAFETY-KLEEN SYSTEMS ROMULUS (ROM)	10480 HARRISON RD	ROMULUS	0	5	0	0	0	0
88	CADILLAC OIL CO	13650 HELEN	DETROIT	0	3	0	2	0	0
89	CANTON MANUFACTURING CORP	7295 HAGGERTY RD	CANTON	0	0	2	0	0	0
90	POOF-SLINKY INC	45605 HELM ST	PLYMOUTH	0	2	0	0	0	0

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5.2.4 Emission data accuracy

While often technically feasible, very few facilities actually use continuous measurements of emissions. Only the large coal fired power plants have continuous emission monitoring systems (CEMS) for NO_x, CO, and SO_2 and opacity, a surrogate for PM. In most cases, emissions are estimated using a variety of means, e.g., emission factor calculations or fuel sulfur content.

In general, for NO_x and SO_2, emission estimates appear reliable, as seen by agreement between facility emissions listed in MAERS, the FOIA request data, and NEI emissions for the NEI years.

For PM, emission estimates have considerable uncertainty, and much of the data reported are not believed to be accurate. Several issues limit comparisons and potentially represent large discrepancies among PM emission estimates. For example, in many cases MAERS shows that filterable $PM_{2.5}$ emissions exceed primary $PM_{2.5}$ emissions, anomaly because, by definition, primary $PM_{2.5}$ is the sum of filterable $PM_{2.5}$ and condensable PM. As noted, PM emissions at the stack or facility level are rarely measured. The large coal-fired power plants do measure opacity, which is related to PM emissions, but these data are not typically used to estimate PM emissions (but rather are used to verify operation of the emission control systems.)

As an example of discrepancies, Table 5-8 assembles PM estimates for the recent Permit to Install application filed by MDEQ and DTE in March, 2016 for the Trenton Channel Power Plant, a large coal-fired facility with significant emissions of PM, NO_x and SO_2. Considering only Boiler 9A at this facility, and using the most recent test of PM emissions identified at this facility (12/12/2002) and the 2-year average heat rate, PM emissions are an estimated 356.9 tons/year: this represents an average "actual" emission rate. By comparison, MAERS give only 15 tons/year, and the NEI 2011 gives 210 tons/year. The estimate of 356.9 tons/year may be most accurate, but again, there are few measurements available, and thus uncertainty is considerable.

Emission data reported in Table 5-3 earlier in this report used a series of checks to provide "best" estimates; these estimates incorporated the data sources listed in Table 5-1, and they utilized a number of quality checks and revisions.

Emissions inventory data discussed later for mobile and non-point sources (Sections 5.3 and 5.4) also have large uncertainties; these are very difficult to quantify. No formal analysis of the uncertainty of these data has been performed.

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Table 5-8. PM emission estimates for the Trenton Channel power plant showing variation among estimates and emissions inventories.

Type	Factor	Unit	Basis	Unit	Annual Average		notes 1, 2
Maximum	0.0248	lb / MMBTU	Compliance test on 7/19/12, filterable + condensible	Boiler 9A	492.1	PM ton/yr	note 1
	0.0300	lb / MMBTU	from above with MATS	Boiler 9A	595.2	PM ton/yr	note 1
	0.0270	lb PM/1000 lbs	Compliance plan on 12/12/02	Boiler 9A	769.6	PM ton/yr	note 8
	0.0314	lb / MMBTU	Compliance test on 7/19/12, scaled	Boilers 16-19	415.9	PM ton/yr	notes 1, 2
125-11C							
Permit Limi	0.15	lbs PM per 1000 lbs exhaust gas using test protocol		Boiler 9A	42.8	PM ton/yr	note 3
"Actuals"	MAERS average 2010-2014			Boiler 9A	15.0	PM ton/yr	note 2
	MAERS average 2010-2014			Boilers 16-19	7.2	PM ton/yr	note 2
	National Emission Inventoryfor 2008			Boilers 9A, 16-19	749.7	PM ton/yr	note 4
	National Emission Inventoryfor 2011			Boilers 9A, 16-19	210.6	PM ton/yr	note 4
	Permit 125-11C, "Creditable Decreases due to shutdown of high side boilers			Boilers 16-19	158.6	PM ton/yr	note 5
	Compliance test, scaled, with estimated 5 year average heat rate			Boilers 16-19	158.0	PM ton/yr	note 6
	Compliance test (7/19/12) and 2 year average heat rate			Boiler 9A	356.9	PM ton/yr	note 7

note 1: Based on Rated Heat Capacity - Boiler 9A of 4,530 MMBTU/hr, Boilers 16-19 of 3,012 MMBTU/hr collectively. Emission factor from RTP Environmental Associates Inc., Air Pollution Control Permit to Install Application, MATS Compliance, Trenton Channel Power Plant, Oct. 27, 2014

note 2: Scaled up emission factor by PM ratio in permit 11-125 for boilers 16-19 compared to boiler 9A

note 3: Volumetric flow based on eq. 8 in MDEQ 2004, Calculating Air Emissions for the Michigan Air Emissions Reporting System (volumetric flow of 6,507,682 lb/hr sat air for Boiler 9A and 4,341,764 lb/hr sat air for Boilers 16-19, collectively) and bitum coal, saturated air density of 0.07344 lb/cf, and 99% removal by the electrostatic precipitator.

note 4: Combines all boilers at facility

note 5: Based on 125-11C Public Participation Document, Table 2, Net emission changes.

note 6: Uses scaled emission factor (note 2) with estimated heat rate, based on scaling (note 7) using average of 2010-2014 SO_2 emissions at Boiler 9A and Boilers 16-19, and assuming same coal source.

note 7: Uses compliance test (note 1) and average heat rate in DTE Trenton Channel MATS assessment of 28,781,800 BTU/yr.

note 8: Uses compliance test for EP plan and maximum volumetric flow in note 3

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5.3 Mobile sources – on road

This section examines mobile on-road emissions, which result from cars and trucks driven on roads, and considers exhaust emissions, brake wear, tire wear, and running losses (e.g., evaporation of fuel). Entrained dust and other emissions are discussed in Section 5.4.

On road emissions from NEI are summarized by county in Table 5-9. These emissions result from all types of vehicles traveling on roads, e.g., motorcycles, passenger cars, light duty trucks, buses, medium duty trucks, and heavy duty diesel vehicles. On-road emissions represent over half of total emissions (considering point and area sources) of CO and NO_x (Table 5-9). They represent 27% of VOC emissions, 15% of $PM_{2.5}$ emissions, but only 0.4% of SO_2 emissions. SO_2 emissions will decline further in 2016 with the implementation of the Tier 3 fuel standards that will reduce fuel sulfur content to 10 ppm.

Table 5-9. On-road mobile source emission estimates by county. From NEI 2011. % of total emissions shows fraction of total emission in the NEI inventory for the 7-county area.

	Emissions (tons/year)								
Pollutant	Lenawee	Livingston	Macomb	Monroe	Oakland	Washtenaw	Wayne	Total	% of Total Emissions
PM2.5	109	150	458	128	875	259	1,098	3,077	14.6
PM10	164	279	839	239	1,615	481	2,035	5,651	8.3
SO2	9	21	64	18	124	37	156	430	0.4
CO	12,844	18,001	61,955	15,087	107,527	29,608	129,647	374,668	56.5
Nox	2,659	4,062	12,634	3,476	23,694	6,956	29,767	83,248	50.1
VOC	1,493	1,819	6,665	1,514	11,095	2,953	13,193	38,732	26.7

Diesel emissions

Most on-road $PM_{2.5}$ emissions arise from diesel vehicles, and heavy duty diesel vehicles in particular. Diesel exhaust emissions of $PM_{2.5}$ are of considerable interest given its toxicity. Based on NEI 2011 data, across the 7-county area, on-road diesel emission of $PM_{2.5}$ total 2,074 tons/year; $PM_{2.5}$ emissions from gasoline-powered vehicles, which are much more numerous, represent about half as much $PM_{2.5}$ (1,002 tons/yr in the 7 counties). Most on-road $PM_{2.5}$ emissions in the 7-county area arise in Wayne and Oakland Counties (Table 5-11).

As described in the next section, on-road vehicles cause additional $PM_{2.5}$ emissions that include windblown dust (silt) on roads, and pavement wear. These emissions total 2,432 tons/year, comparable to the diesel-related fraction of on-road exhaust emissions. (Most of the PM emissions from wind-blown dust are actually PM_{10}, but $PM_{2.5}$ is estimated to constitute about one-third of the total.)

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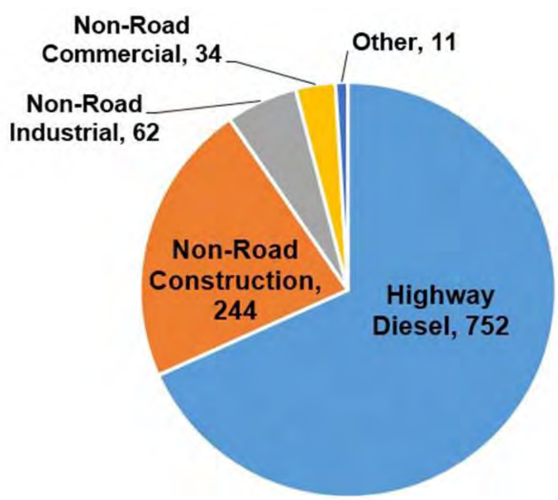
An apportionment of diesel-related emissions for Wayne County is shown in Figure 5-3. (Additional detail is provided in Table 5-11 for each county). On-road emissions of diesel exhaust emissions total 725 tons/yr, compared to 1,098 tons per year for all on-road emissions in the county. Off-road diesel equipment and vehicles contributes an additional 401 tons/yr. As further described in the next section, on-road vehicles cause additional emissions of windblown dust (silt) on roads, and pavement wear. In Wayne County, vehicle-associated emissions of $PM_{2.5}$ as dust, silt and road wear are estimated to be 573 tons/yr. However, these emissions are highly uncertain, as they depend on many variable factors, such as road condition, silt loading, and weather.

Emission estimates were also derived using our Detroit on-road link-based (by road) emissions inventory, which covered about 33% of Wayne County by area and 2,205 km compared to 4,134 km of roads in Wayne County (freeways, arterials, and collectors, not minor roads). In the inventory, $PM_{2.5}$ totaled 472 tons/year, representing about half of that shown in Table 5-9. Most of these emissions were due to heavy-duty diesel trucks, and most occurred on the largest roads. For Detroit, our detailed emission inventory indicates that $PM_{2.5}$ emissions occur primarily on freeways (43% of total $PM_{2.5}$ exhaust emissions), other principal arterials (31%), and the balance on smaller arterials, collectors and minor roads. This emphasizes the importance of major roads, especially major roads with extensive truck traffic, for $PM_{2.5}$ emissions.

Figure 5-3. Apportionment of diesel-related emissions in Wayne County. Tons per year shown. Highway diesel includes exhaust (725 ton/yr), brake wear (22 ton/yr), and tire wear (5 ton/yr). Derived from NEI 2011.



5.4 Area and non-road mobile sources

This section summarizes other pollution sources, called “non-point” and “area” sources, e.g., emissions occurring at smaller facilities. Area sources also include entrained dust (from waste piles, roads, etc.), natural sources (pollen), residential fuel combustion, construction, and forest fires.

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Table 5-10 summarizes emissions estimates from area sources and non-road mobile sources at the county level for CO, PM_{10}, $PM_{2.5}$, SO_2, NO_x, and VOCs, data derived from the NEI 2011. This national level database estimates emissions using many data types and sources, e.g., activity (e.g., extent of unpaved surfaces), emission factors, meteorology (precipitation), and population (density, city size). Emissions from on-road and point sources, discussed in previous sections, are also shown in the table (with a blue background).

Some key results for the pollutants emphasized in this Resource Manual are noted below.

- $PM_{2.5}$. As noted earlier, the most important sources of $PM_{2.5}$ are related to non-road mobile sources (1,182 tons/yr in Wayne County). These include large contributions from off-road vehicles, vehicles on paved roads, and emissions from unpaved roads. As noted above, vehicles also have sizable on-road emissions, particularly diesel exhaust from heavy duty vehicles.

  Unpaved roads can emit significant amounts of $PM_{2.5}$, especially in rural counties, e.g., Monroe county emissions from unpaved roads is several times larger than that from paved roads. These emissions in Wayne Country are small, however. Most of these emissions are PM_{10}, but a sizable fraction is $PM_{2.5}$.

- SO_2. Emissions are small compared to point sources (commercial, industrial and residential sources totaled only 1,101 tons/yr).

- CO. Most CO emissions come from mobile sources, particularly off-highway gasoline vehicles (e.g., construction equipment).

- VOCs. Area source emissions of VOCs are large collectively, in part due to releases from fuel distribution and storage losses.

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Table 5-10A. Annual emission estimates (tons/year) from area, point and mobile sources by county. From NEI, 2011.

Pollutant	Source Group	Lenawee	Livingston	Macomb	Monroe	Oakland	Washtenaw	Wayne	Grand Total
PM2.5	**Total**	**2,271**	**1,428**	**2,565**	**2,751**	**4,210**	**2,776**	**5,131**	**21,133**
	Industrial Processes	33	87	282	57	724	152	489	1,823
	Miscellaneous Area Sources	993	116	130	599	39	293	27	2,197
	Mobile Sources	519	651	551	589	1,155	672	689	4,825
	Stationary Source Fuel Combustion	412	159	735	202	772	1,136	725	4,142
	Waste Disposal, Treatment, and Recovery	96	153	0	106	0	0	0	355
	Non-road mobile	72	95	269	97	491	199	493	1,715
	On-road	109	150	458	128	875	259	1,098	3,077
	Point	37	17	140	975	154	67	1,610	2,999
PM10	**Total**	**10,241**	**7,348**	**6,740**	**10,438**	**14,181**	**9,060**	**10,085**	**68,094**
	Industrial Processes	128	528	830	248	3,734	462	836	6,765
	Miscellaneous Area Sources	4,966	581	648	2,994	194	1,464	132	10,979
	Mobile Sources	4,317	5,505	3,223	4,788	7,114	5,151	3,241	33,340
	Stationary Source Fuel Combustion	415	162	754	207	817	1,145	770	4,271
	Waste Disposal, Treatment, and Recovery	106	175	0	117	0	0	0	398
	Non-road mobile	75	100	282	101	516	208	515	1,797
	On-road	164	279	839	239	1,615	481	2,035	5,651
	Point	70	19	165	1,744	190	149	2,557	4,893
SO2	**Total**	**66**	**68**	**349**	**55,706**	**532**	**188**	**43,266**	**100,176**
	Industrial Processes	2	0	0	0	0	0	0	2
	Miscellaneous Area Sources	0	0	0	0	1	0	1	2
	Mobile Sources	1	1	1	9	2	1	131	145
	Stationary Source Fuel Combustion	34	38	178	49	344	96	363	1,101
	Waste Disposal, Treatment, and Recovery	3	3	0	3	0	0	0	9
	Non-road mobile	2	3	11	3	16	6	20	61
	On-road	9	21	64	18	124	37	156	430
	Point	15	1	95	55,623	46	48	42,596	98,424
CO	**Total**	**21,584**	**29,862**	**106,479**	**30,844**	**181,357**	**54,569**	**238,788**	**663,483**
	Industrial Processes	28	37	98	15	176	57	194	604
	Miscellaneous Area Sources	0	0	0	0	0	0	0	0
	Mobile Sources	20	12	14	84	23	10	107	270
	Natural Sources	943	741	501	718	876	879	642	5,300
	Stationary Source Fuel Combustion	2,835	1,219	5,807	1,587	6,346	8,098	6,347	32,238
	Waste Disposal, Treatment, and Recovery	297	752	9	327	5	0	27	1,416
	Non-road mobile	4,485	8,841	36,948	9,829	65,021	15,073	65,491	205,688
	On-road	12,844	18,001	61,955	15,087	107,527	29,608	129,647	374,668
	Point	132	259	1,147	3,198	1,382	845	36,335	43,298

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Table 5-10B. Annual emission estimates (tons/year) from area sources by county. Continued

Pollutant	Source Group	Lenawee	Livingston	Macomb	Monroe	Oakland	Washtenaw	Wayne	Grand Total
Nox	**Total**	**4,436**	**6,409**	**20,831**	**25,987**	**34,626**	**11,614**	**62,411**	**166,314**
	Industrial Processes	13	16	5	1	11	5	4	54
	Miscellaneous Area Sources	0	1	3	0	4	1	7	16
	Mobile Sources	137	93	106	589	166	70	872	2,033
	Natural Sources	392	186	145	305	151	261	167	1,607
	Stationary Source Fuel Combustion	300	495	2,528	412	4,202	1,136	5,087	14,159
	Waste Disposal, Treatment, and Recovery	19	34	3	26	0	0	170	253
	Non-road mobile	776	996	3,670	1,182	5,334	2,259	6,847	21,064
	On-road	2,659	4,062	12,634	3,476	23,694	6,956	29,767	83,248
	Point	139	526	1,738	19,996	1,066	925	19,489	43,879
VOC	**Total**	**8,528**	**9,982**	**22,618**	**9,161**	**35,352**	**14,804**	**44,727**	**145,174**
	Industrial Processes	331	168	59	10	139	53	120	881
	Miscellaneous Area Sources	0	0	0	0	0	0	0	0
	Mobile Sources	7	4	5	30	8	3	39	96
	Natural Sources	3,829	4,363	2,304	3,188	5,431	4,661	3,356	27,132
	Solvent Utilization	1,201	1,337	5,819	1,704	8,023	2,629	12,310	33,024
	Stationary Source Fuel Combustion	479	194	928	238	840	1,390	824	4,893
	Storage and Transport	270	503	1,686	545	2,564	1,030	3,962	10,560
	Waste Disposal, Treatment, and Recovery	31	64	45	60	62	9	363	633
	Non-road mobile	738	1,354	2,993	1,442	6,342	1,756	5,016	19,639
	On-road	1,493	1,819	6,665	1,514	11,095	2,953	13,193	38,732
	Point	149	176	2,114	432	848	319	5,544	9,582

Because of its importance, some additional details are provided for $PM_{2.5}$ emissions in Table 5-11. This excludes point and on-road mobile sources.

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Table 5-11. $PM_{2.5}$ emission estimates (tons/year) from non-point, point and mobile sources by county. From NEI, 2011.

Source and Sub-Group	Lenawee	Livingston	Macomb	Monroe	Oakland	Washtenaw	Wayne	Grand Total
Total	2,271	1,428	2,565	2,751	4,210	2,776	5,131	21,133
Non-point	2,053	1,166	1,698	1,552	2,690	2,252	1,930	13,342
Industrial Processes	33	87	282	57	724	152	489	1,823
Construction: SIC 15 - 17	8	46	57	7	307	31	17	473
Food and Kindred Products: SIC 20	22	37	222	31	386	117	450	1,265
Mining and Quarrying: SIC 14	3	3	3	18	31	3	22	83
Oil and Gas Exploration and Production	0	1	0	0	0	0	0	2
Miscellaneous Area Sources	993	116	130	599	39	293	27	2,197
Agriculture Production - Crops	993	116	129	599	39	293	26	2,196
Agriculture Production - Crops - as nonpoint	0	0	0	0		0	0	0
Other Combustion	0	0	0		0	0	0	1
Mobile Sources	519	651	551	589	1,155	672	689	4,825
Marine Vessels, Commercial			0	0			7	7
Paved Roads	144	171	379	162	739	264	573	2,432
Railroad Equipment	4	3	3	18	5	2	19	54
Unpaved Roads	370	478	169	408	412	406	91	2,332
Stationary Source Fuel Combustion	412	159	735	202	772	1,136	725	4,142
Commercial/Institutional	8	14	79	11	208	46	202	567
Industrial	1	1	5	1	6	1	8	22
Residential	404	144	651	191	559	1,088	515	3,553
Waste Disposal, Treatment, and Recovery	96	153		106				355
Open Burning	96	153		106				355
Non-road mobile	72	95	269	97	491	199	493	1,715
CNG	0	0	1	0	1	0	1	3
LPG	1	1	8	1	9	2	12	35
Off-highway Vehicle Diesel	54	60	176	63	292	145	348	1,137
Off-highway Vehicle Gasoline, 2-Stroke	12	22	61	23	135	38	94	386
Off-highway Vehicle Gasoline, 4-Stroke	2	4	14	3	31	7	25	85
Pleasure Craft	3	8	9	6	22	6	13	68
Railroad Equipment	0	0	0	0	0	0	0	1
On-road	109	150	458	128	875	259	1,098	3,077
Highway Vehicles - Compressed Natural Gas (CNG)	0	0		0	0	0	0	1
Highway Vehicles - Diesel	79	100	300	87	584	175	748	2,074
Highway Vehicles - Gasoline	30	50	158	41	290	83	349	1,002
Point	37	17	140	975	154	67	1,610	2,999
External Combustion		0	6	0	1	3	18	28
External Combustion Boilers	5	0	15	528	17	23	246	834
Industrial Processes	27	12	59	436	74	11	904	1,523
Internal Combustion Engines	4	1	34	6	43	27	260	374
Mobile Sources	1	3	2	3	8	3	85	105
Petroleum and Solvent Evaporation	0		12	0	0		52	64
Waste Disposal	0		13	1	12	0	46	72

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5.5 Exposure and health impacts

5.5.1 Approach

This section estimates the human health impacts that potentially result from exposure of SO_2, NO_x, and $PM_{2.5}$ emitted by the major point sources in and near Detroit, MI., as well as impacts from primary $PM_{2.5}$ emissions from on-road vehicles. For point sources, health impacts are estimated separately for the 16 industrial facilities with the highest emissions of SO_2, NO_x, and $PM_{2.5}$, as well as for all point sources in the area.

Health outcomes depend on the pollutant and age of individual considered. We consider both children and adults, and consider the following types of health effects:

- Mortality including all-cause mortality, lung cancer, and ischemic heart disease (IHD);
- Hospitalizations for chronic obstructive pulmonary disease (COPD), pneumonia, cardiovascular disease (CVD), non-fatal heart attacks, and emergency department (ED) visits for asthma;
- Asthma exacerbations due to cough, shortness of breath and wheeze, and other symptoms; and
- Restricted activity days and work loss days due to respiratory or other symptoms.

We also consider summary measures that consolidate and summarize these impacts, specifically, monetized health impacts (using dollar figures with valuations used by US EPA); and disability-adjusted life years (DALY), which account for the severity and duration of impacts. DALYs estimate the number of years of healthy life that are lost each year due to pollutant exposure.

Exposures and health impacts for Detroit and downriver communities are estimated using a system of models and algorithms called FRESH-EST.[4] This system integrates: (1) estimates of current emissions (see Section 5.2.2); (2) facility-specific stack parameters; (3) the AERMOD dispersion model; (4) hourly meteorology for 2012; rasterization and other spatial interpolation techniques to estimate concentrations at the Census block level; (5) population and demographic data at the Census block or other level, as available;[5] (6) disease incidence data

[4] Framework for Rapid Emission Scenario and Health Impact Estimation

[5] Population data from the American Community Survey at the block level were stratified based on the age distribution of the block group to which the block belongs. US Census Bureau, 2015. TIGER/Line® with Selected Demographic and Economic Data [WWW Document]. URL http://www.census.gov/geo/maps-data/data/tiger-data.html (accessed 7.2.15); US Census Bureau. American Community Survey 5-year Estimates. URL https://www.census.gov/programs-surveys/acs/ [accessed 2-16-16].

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at the ZIP code or county level, as available;[6] and (7) health impact functions and parameters for health outcomes relevant to air pollutants.[7]

For mobile source impacts, annual average concentrations of $PM_{2.5}$ were predicted at over 27,000 receptors using a 150 m grid, the RLINE dispersion model, a link-based emission inventory consisting of 8700 links, and hourly meteorology, and methods described by Batterman et al. 2014.[8] The modeled network includes Detroit and some nearby areas, and includes 883,638 persons based on the 2010 census. Receptor concentrations were interpolated to a 25 m raster in ArcGIS using inverse distance weighting (IDW power of 2 with the 12 nearest neighbors), loaded into ArcGIS, and the zonal statistics tool calculated the average concentrations of raster grid cells that overlapped the block polygons. Results are similar to methods in FRESH-EST. Most but not all of the FRESH-EST blocks are covered by the receptor grid (e.g., portions of the downriver section are excluded). Concentrations were predicted 18,944 blocks, representing 87% of the original study area population. $PM_{2.5}$ concentrations in excluded portions are assumed to be 0. For mortality estimates, health impact functions use the annual average concentration at the block level. For morbidities, the annual average is substituted for the daily average. This does not significantly alter results because the health impact functions are nearly linear over the concentration range considered.

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[6] Mortality rates use ZIP code level data and reported deaths for 2009-2013. Asthma hospitalization and ED visits use ZIP code level data for Detroit and county level data outside of Detroit; asthma exacerbation rates use Detroit data (Batterman et al. in prep). Rates of COPD, CVD and pneumonia hospitalizations are available at the county level. Area-specific rates of non-fatal heart attacks, MRAD and work loss days are unavailable, so nationally representative rates are used. See: DeGuire, P., Cao, B., Wisnieski, L., Strane, D., Wahl, R., Lyon-Callo, S., Garcia, E., 2016. Detroit: The current status of the asthma burden. Michigan Department of Health and Human Services; Michigan Department of Health and Human Services [MDHHS], 2016. Michigan Asthma Surveillance, Data and Reports [WWW Document]. URL http://www.michigan.gov/mdhhs/0,5885,7-339-71550_5104_5279-213824--,00.html (accessed 2.8.16); Michigan Department of Health and Human Services [MDHHS], 2014. Hospitalizations by Selected Diagnosis [WWW Document]. URL http://www.mdch.state.mi.us/pha/osr/CHI/hospdx/frame.html (accessed 2.8.16); National Hospital Discharge Survey [NHDS], 2007. Number and rate of discharges by first-listed diagnostic categories [WWW Document]. Data Highlights- Selected Tables. URL http://www.cdc.gov/nchs/nhds/nhds_tables.htm#number (accessed 11.24.14); US Environmental Protection Agency [US EPA], 2015. BenMAP User's Manual Appendicies. Research Triangle Park, NC.

[7] For $PM_{2.5,}$ the health impact assessment uses the same health impact functions as a previous case study of $PM_{2.5}$ health impacts in Wayne County, MI. See Martenies, S.E., Wilkins, D., Batterman, S.A., 2015. Health impact metrics for air pollution management strategies. Environment International 85, 84–95. For SO_2 and NO_x health impact functions, concentration response coefficients are drawn from epidemiological studies. See: Yang, Q., Chen, Y., Krewski, D., Burnett, R.T., Shi, Y., McGrail, K.M., 2005. Effect of short-term exposure to low levels of gaseous pollutants on chronic obstructive pulmonary disease hospitalizations. Environ. Res. 99, 99–105. doi:10.1016/j.envres.2004.09.01; Li, S., Batterman, S., Wasilevich, E., Elasaad, H., Wahl, R., Mukherjee, B., 2011. Asthma exacerbation and proximity of residence to major roads: a population-based matched case-control study among the pediatric Medicaid population in Detroit, Michigan. Environ Health 10, 34; Schildcrout, J.S., Sheppard, L., Lumley, T., Slaughter, J.C., Koenig, J.Q., Shapiro, G.G., 2006. Ambient Air Pollution and Asthma Exacerbations in Children: An Eight-City Analysis. Am. J. Epidemiol. 164, 505–517; Linn, W.S., Szlachcic, Y., Gong, H., Kinney, P.L., Berhane, K.T., 2000. Air pollution and daily hospital admissions in metropolitan Los Angeles. Environ Health Perspect 108, 427–434

[8] Batterman, S., R Ganguly, V Isakoff, J Burke, S Arunachalam, M Snyder, T Robins, T Lewis. 2014. Dispersion Modeling of Traffic-Related Air Pollutants: Exposure and Health Effects among Children with Asthma in Detroit, Michigan. Transportation Research Record (TRR), *Journal of the Transportation Research Board*, No. 2452, 105–113.

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5.5.2 Health impacts from point source emissions

Table 5-12 summarizes the results of the quantitative health impact evaluation for major point sources in the Detroit area. Current emissions of NO_x, SO_2, and $PM_{2.5}$ from point sources incur a total of 971 DALYs per year and $550 million per year in monetized health impacts. Of these impacts, 398 DALYs and $223 million in monetized health impacts are attributed to emissions at the largest 16 facilities alone.

Considering health impacts from all point sources and the three pollutants, emissions and exposures of $PM_{2.5}$ tend to cause the greatest impact.

- Exposure to $PM_{2.5}$ causes all of the mortality (including all-cause, IHD, lung cancer, and infant). In addition, $PM_{2.5}$ causes most of the hospitalizations, including all hospitalizations for asthma, CVD, pneumonia, and non-fatal heart attacks. For asthma exacerbations, $PM_{2.5}$ causes all ED visits for asthma, and all cases of shortness of breath, minor restricted activity days, and work loss day. For the summary measures, $PM_{2.5}$ causes 98.4% of the total DALYs and 99.3% of the monetized impact.
- Exposure to NO_x causes 32% of hospitalizations for asthma, 38% of ED visits for asthma, 54% of hospitalizations for COPD, and 57% of asthma aggravations with one or more symptoms.
- Exposure to SO_2 causes 39% of the hospitalizations for asthma, 47% of ED visits for asthma, 100% of ED visits for asthma using the Detroit-based epidemiology study, and 45% of hospitalizations for COPD.

The results shown in Table 5-12 and percentages discussed above depend on the concentration-response function and the literature. They consider only the health effects that well supported by literature.

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Table 5-12. Summary of health impacts (per year) associated with SO_2, $PM_{2.5}$ and NO_x emissions and exposure from point sources in Detroit.

Health Outcome or Metric (age)	DTE Monroe	DTE Trenton Channel	DTE River Rouge	JR Whiting Co.	US Steel	EES Coke	AK Steel	Carmeuse Lime	Dearborn Industrial Generation	Guardian Industries	GM Hamtramck	Marathon Petroleum	Greater Detroit Resource Recovery	Carleton Farms Landfill	Daimler Chrysler Technology	A123 Systems	Other Point Sources	**Total Point Sources**
Mortality (number of cases)																		
All Cause (>29)	0.1	0.2	0.0	0.4	3.7	0.4	2.2	0.2	0.6	1.1	0.1	0.5	0.1	0.6	0.2	1.1	19.1	**28.6**
IHD (>29)	0.1	0.2	0.0	0.4	3.1	0.4	1.8	0.2	0.5	0.9	0.0	0.4	0.1	0.5	0.2	0.9	15.4	**23.4**
Lung Cancer (>29)	0.0	0.0	0.0	0.1	0.6	0.1	0.3	0.0	0.1	0.2	0.0	0.1	0.0	0.1	0.0	0.2	2.9	**4.3**
Infant (0-1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	**0.3**
Hospitalizations (number of cases/events)																		
Asthma (0-64)	1.7	1.0	1.1	0.4	2.6	1.0	0.9	0.8	0.6	0.5	0.2	0.4	0.6	0.2	0.1	0.2	6.1	**17.9**
COPD (>64)	10.6	6.4	6.8	2.2	12.4	5.9	3.2	5.0	3.3	2.4	1.4	2.1	4.2	1.1	0.5	0.0	20.7	**86.7**
CVD (>64)	0.0	0.0	0.0	0.1	0.8	0.1	0.5	0.1	0.1	0.3	0.0	0.1	0.0	0.1	0.1	0.3	4.4	**6.6**
Pneumonia (>64)	0.0	0.0	0.0	0.0	0.4	0.0	0.2	0.0	0.1	0.1	0.0	0.0	0.0	0.1	0.0	0.1	2.1	**3.1**
Non-fatal heart attack (>17)	0.0	0.0	0.0	0.0	0.2	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1	1.2	**1.7**
ED visit for asthma (0-17)	20.6	11.8	13.2	4.6	26.3	11.0	8.3	8.8	7.2	4.5	2.7	3.9	6.8	2.1	1.0	1.1	49.7	**179.6**
ED visit for asthma-Detroit CR (0-17)	18.8	12.1	12.0	3.7	19.4	8.1	5.7	5.7	6.3	0.9	2.0	1.8	0.9	0.3	0.1	0.0	2.0	**99.9**
Asthma exacerbations and restricted days (number of cases, days)																		
Cough (6-14)	31	78	6	175	1,521	170	932	96	247	429	21	188	49	233	93	453	7,875	**11,818**
Shortness of breath (6-14)	3	8	1	17	149	17	91	9	24	42	2	18	5	23	9	44	779	**1,165**
Wheeze (6-14)	2	6	0	14	117	13	72	7	19	33	2	14	4	18	7	35	613	**917**
One or more symptoms (6-14)	1,496	873	973	312	1,781	855	468	754	497	332	203	311	654	149	78	0	3,320	**12,847**
One or more symptoms - Det CR (6-14)	4,375	2,842	2,816	861	4,655	1,945	1,374	1,401	1,538	219	452	447	208	67	13	0	654	**23,868**
Minor restricted activity day (18-64)	51	129	10	287	2,474	281	1,445	155	383	712	35	305	81	389	150	750	12,833	**19,181**
Work loss day (18-64)	9	22	2	50	428	49	250	27	66	123	6	53	14	67	26	130	2,229	**3,327**
Summary measures																		
Total DALYs (years)	4.4	7.6	1.7	15.0	127.6	15.4	73.4	8.8	19.9	36.3	2.1	16.0	5.1	19.6	7.9	37.0	573.7	**971.4**
Monetized Impact (2010 $millions)	2.0	4.1	0.6	8.5	71.3	8.4	41.7	4.7	11.1	21.0	1.1	9.0	2.6	11.3	4.4	21.6	327.0	**550.5**

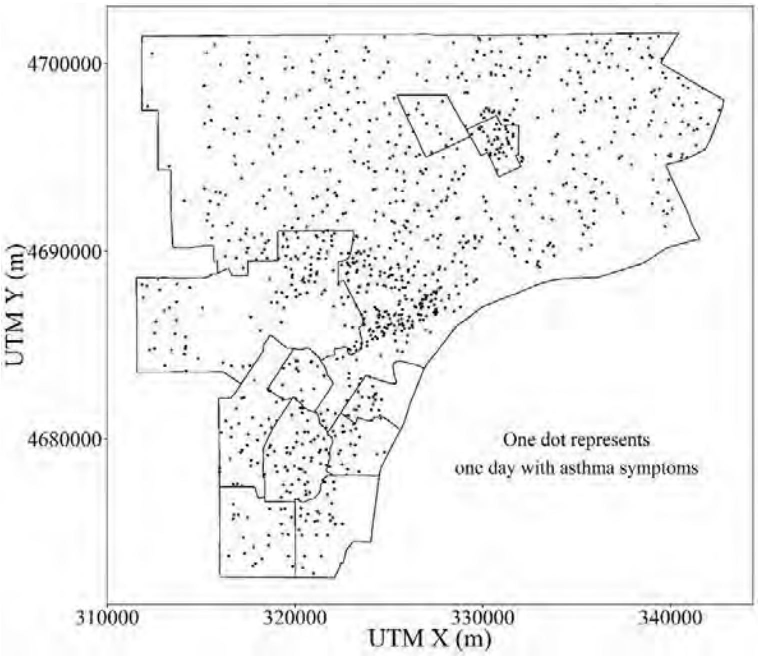
5.5.3 Areas affected from point source emissions

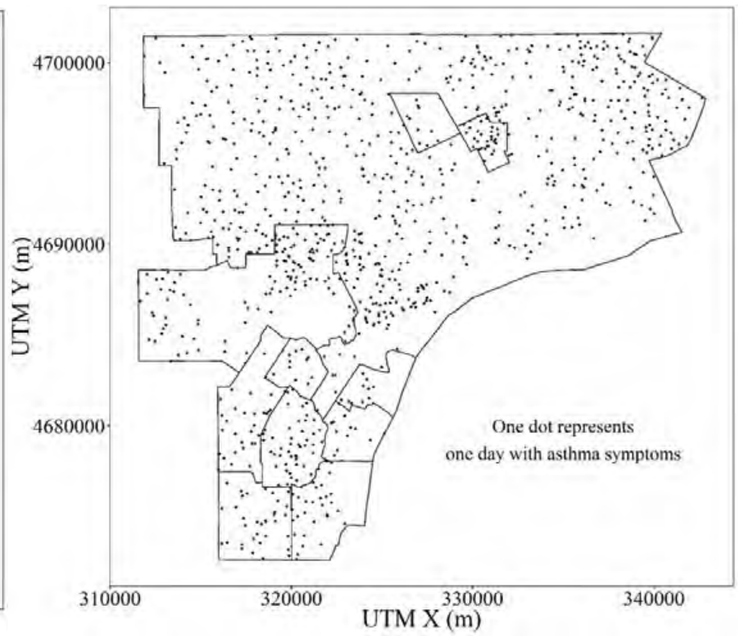
This section includes a large number of maps to show those areas that are affected by point source emissions. First, some results for SO_2 are shown in Figure 5-4 (left panel), which depicts the number of SO_2 attributable asthma exacerbations attributable to current emissions from US Steel, which is located within the study area in close proximity to populated areas. While impacts extend across the study area, clusters of exacerbations are expected to occur in southwest Detroit and the area near Hamtramck. The right panel of Figure 5-4 shows

This work is made possible by National Institute of Health and Environmental Sciences, RO1ES022616, and the Fred A. and Barbara M. Erb Family Foundation. Additional support was provided by the Michigan Center on Lifestage Environmental Exposures and Disease (M-LEEaD), #P30ES017885.

results for DTE Monroe, which is outside of the study area. This map is much more uniform since this source is distant from the study area, the facility has tall stacks, and emissions are well dispersed by the time they reach the population. Each of the two maps represent over 1000 asthma exacerbations each year. These two facilities represent 37% of all of the SO_2-attributable asthma exacerbations from point source emissions.

Figure 5-4. Maps showing days per years of asthma aggravations (at least 1 symptom) for SO_2 emissions from US Steel (left panel) and DTE Monroe (right panel).





A total of 72 additional maps are shown in three sets:

- The left panels (red maps) of Figures 5-5A show the highest daily 24-hr daily $PM_{2.5}$ concentrations across the Detroit area for the top 12 emitting sources. Figures 5-6A – L (left panels) show comparable information for SO_2. Figures 5-7A – L (left panels) shows comparable information for NO_x. These maps indicate areas that may receive high concentrations of pollutants. This measure is relevant to acute (short-term) exposures that can cause, for example, asthma exacerbations. Note that the scales on these figures change, depending on the concentrations predicted.
- The right panel (blue maps) of Figures 5-5 to 5-7 indicate the pollution-attributable risk of asthma exacerbations, defined as an individual having a day with one or more symptoms such as cough, wheeze, and shortness of breath. Again, separate maps are provided for SO_2, NO_x and $PM_{2.5}$, and for emissions at largest 12 sources of each of these pollutants in the Detroit area. Asthma exacerbations are shown because these impacts are common, caused by all three pollutants, and occur among children, an important subpopulation, as well as adults. Scales on these figures change, depending on the risk level.

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The maps are ordered based on the total tonnage of pollutant emitted. They show a number of features:

- Each source affects different areas.
- Many sources affect much of the Detroit area. A notable exception is Carmeuse Lime, which causes a local SO_2 "hotspot" due to its relatively short stack height. MDEQ has negotiated with this facility a State Implementation Plan that will raise the height of the stack to increase pollutant dispersion.
- Areas affected can be distant from the source and often span the different sections of Detroit and communities outside Detroit. Thus, for point sources, proximity is not necessary a good measure of impact.
- Spatial patterns of areas potentially affected by pollutants are complex. Dispersion of pollutants depends on many parameters, including stack height and other facility characteristics, as well as local meteorology. In addition, the spatial pattern of health impacts depends on population density, population demographics (e.g., fraction children), and health status (e.g., asthma incidence).
- The spatial patterns of other short-term health impacts attributable to point source emissions, e.g., CVD due to exposure from a particular source, is likely to be similar to that shown for asthma. However, health impacts associated with chronic exposure, e.g., cancer, will differ.

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Figure 5-5A. JR Whiting Co. Left panel shows PM2.5 concentrations (ug/m3); right panel shows risk of asthma symptoms from PM2.5 exposure.

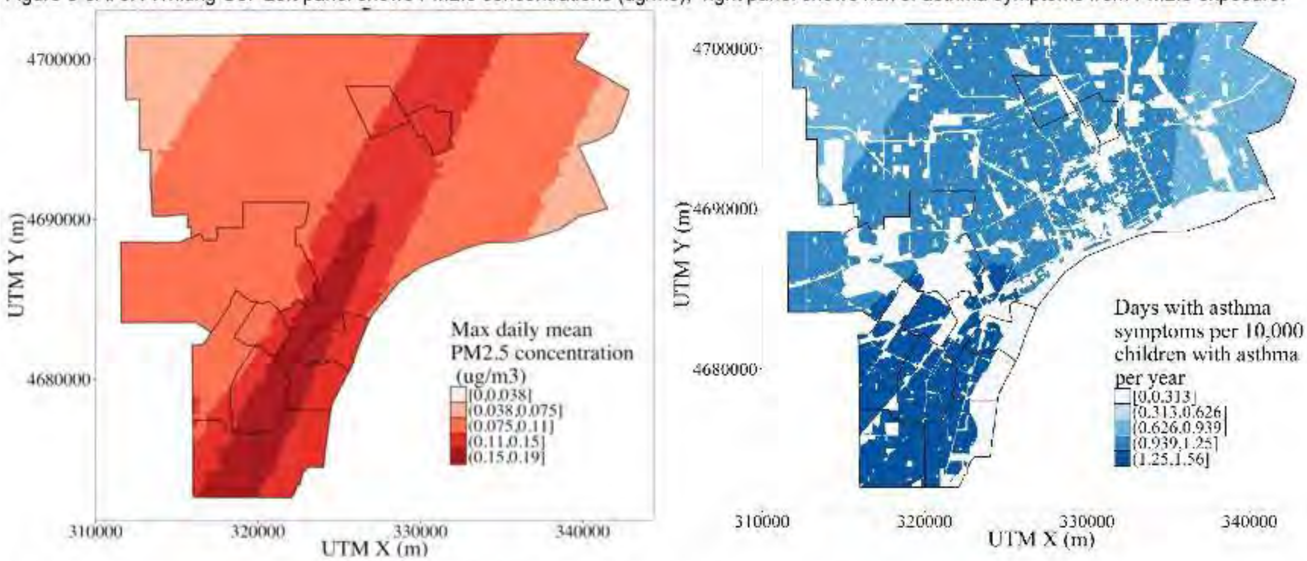


Figure 5-5B. Guardian Industries Left panel shows PM2.5 concentrations (ug/m3); right panel shows risk of asthma symptoms from PM2.5 exposure.

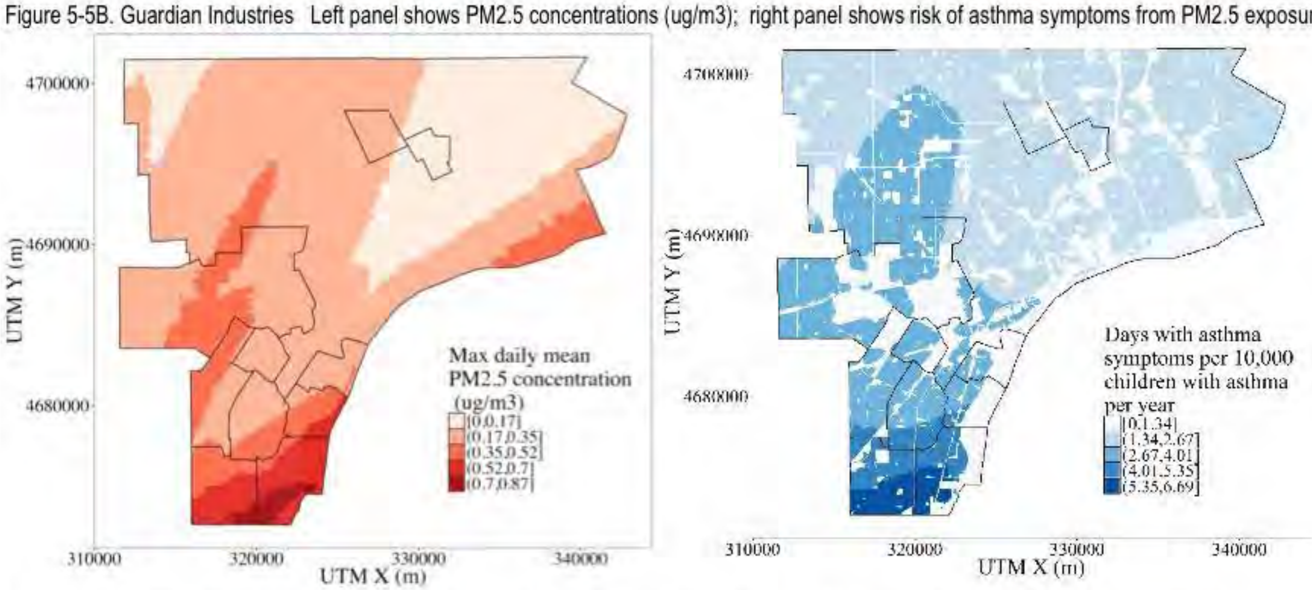


Figure 5-5C. US Steel Left panel shows PM2.5 concentrations (ug/m3); right panel shows risk of asthma symptoms from PM2.5 exposure.

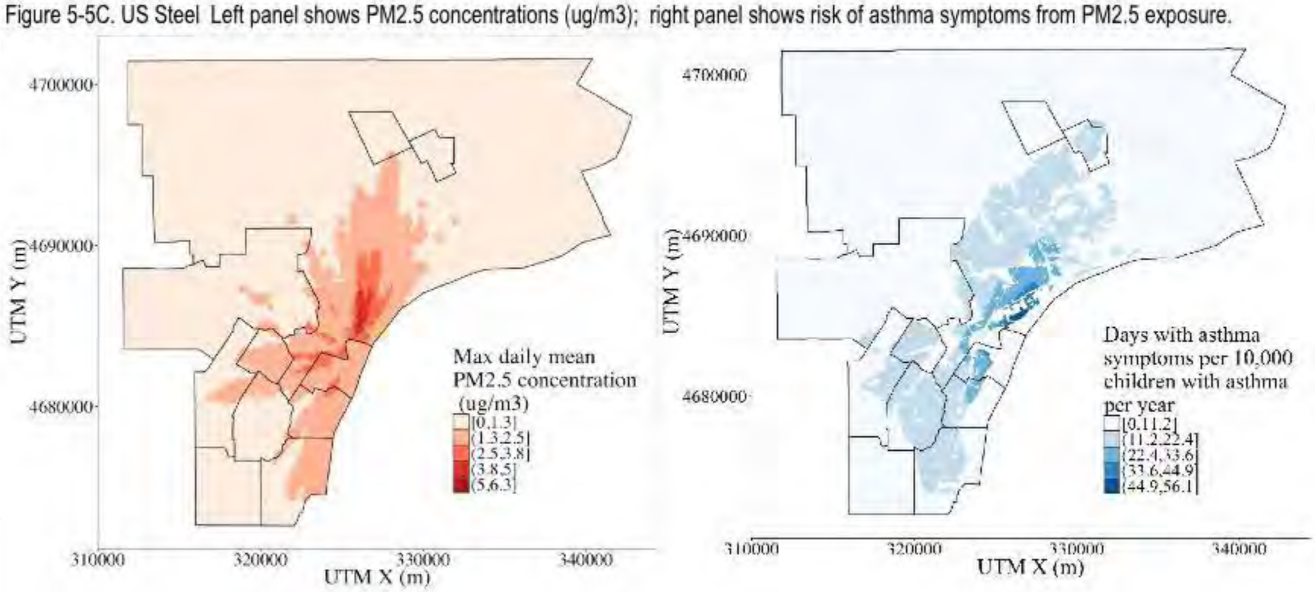


Figure 5-5D. Trenton Channel Left panel shows PM2.5 concentrations (ug/m3); right panel shows risk of asthma symptoms from PM2.5 exposure.

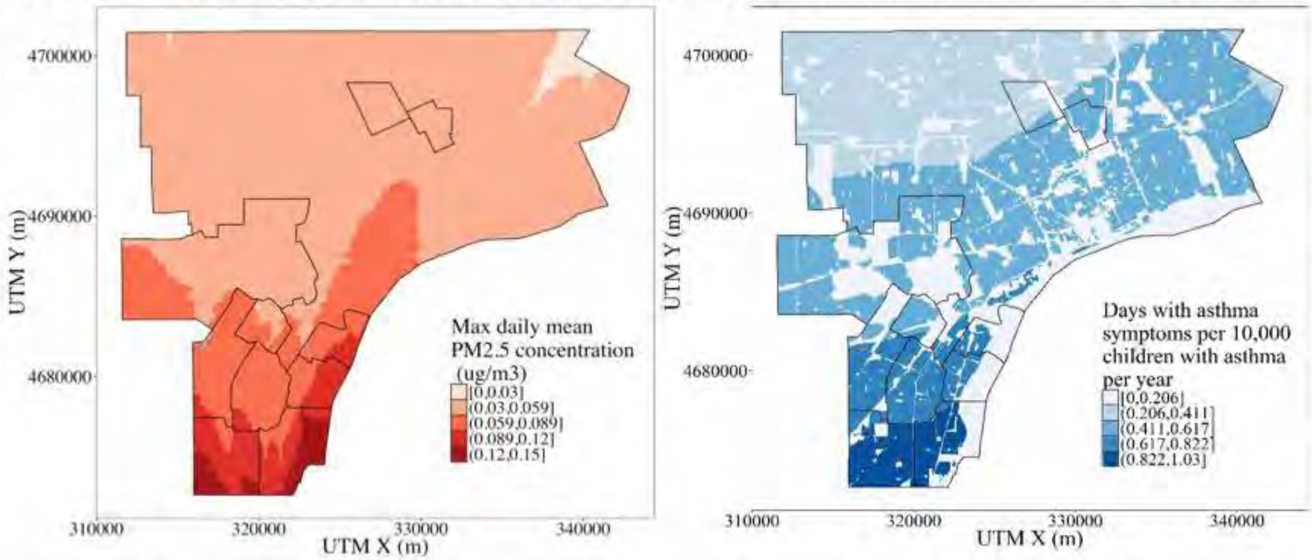


Figure 5-5E. AK Steel Left panel shows PM2.5 concentrations (ug/m3); right panel shows risk of asthma symptoms from PM2.5 exposure.

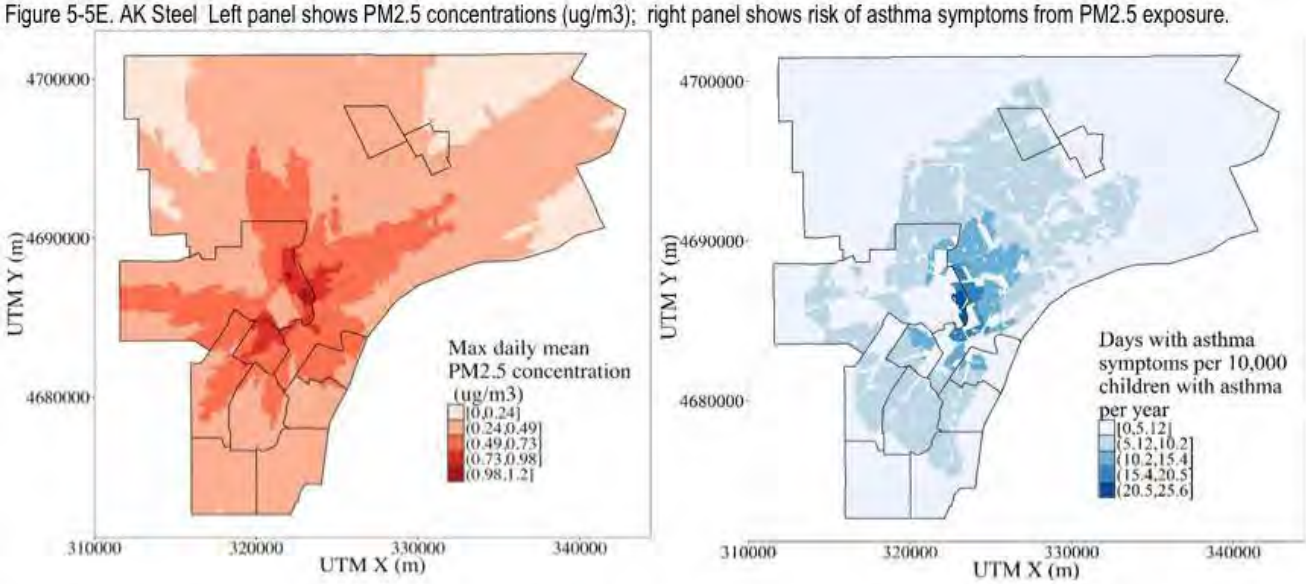


Figure 5-5F. EES Coke Left panel shows PM2.5 concentrations (ug/m3); right panel shows risk of asthma symptoms from PM2.5 exposure.

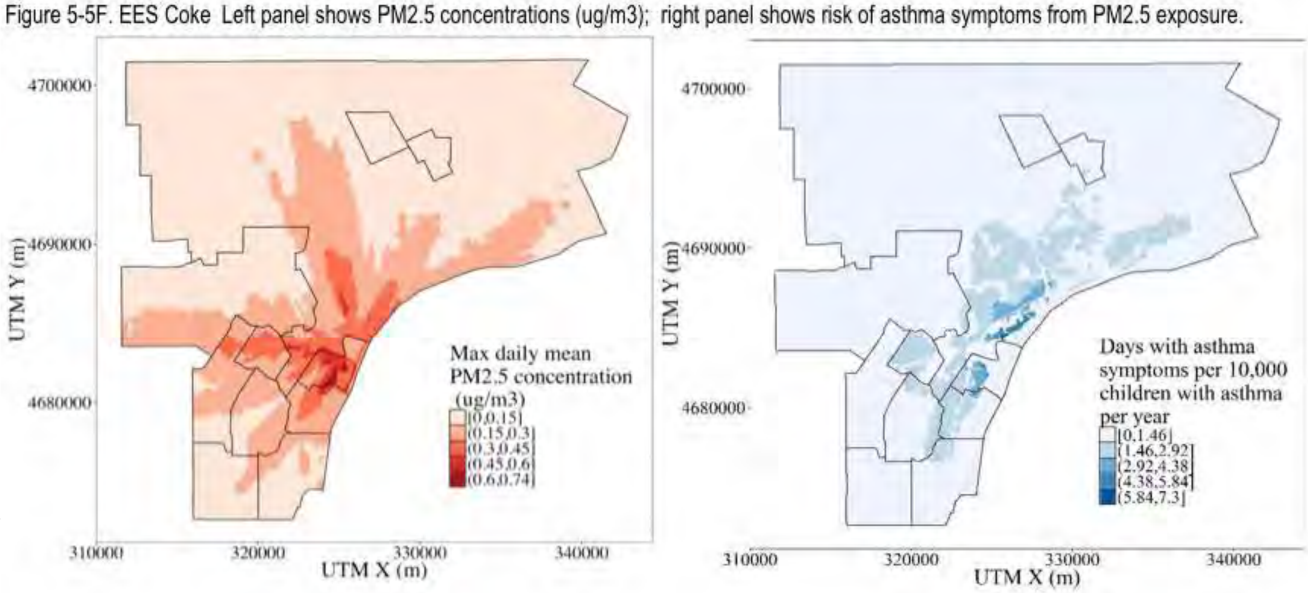


Figure 5-5G. DTE Monroe Left panel shows PM2.5 concentrations (ug/m3); right panel shows risk of asthma symptoms from PM2.5 exposure.

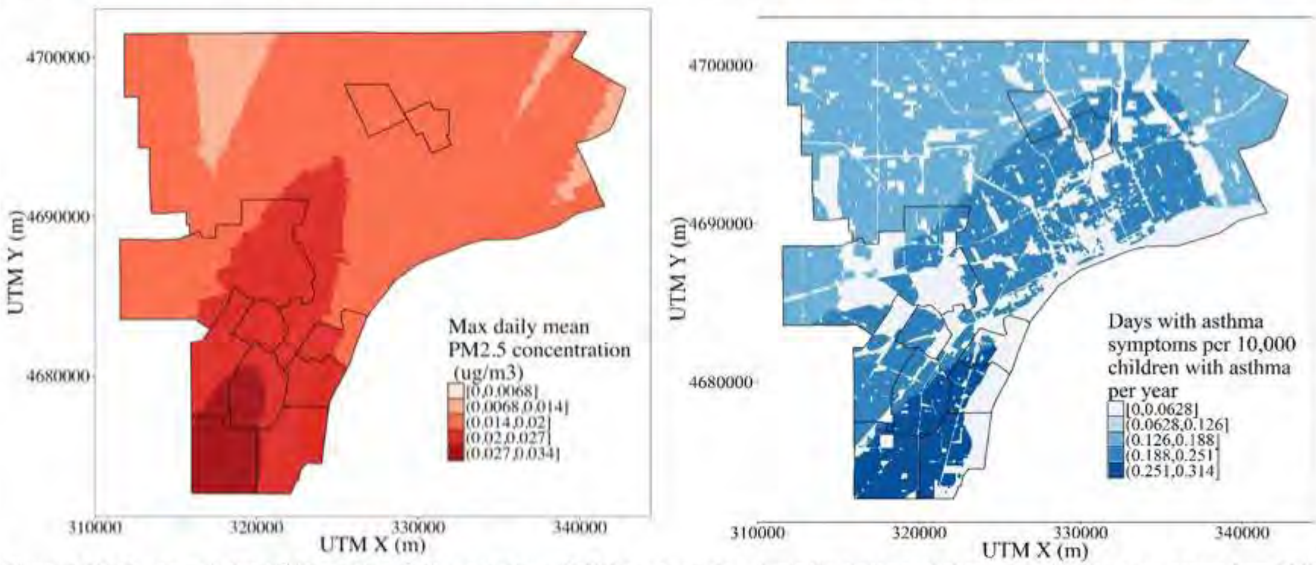


Figure 5-5H. Dearborn Industrial Generation Left panel shows PM2.5 concentrations (ug/m3); right panel shows risk of asthma symptoms from PM2.5 exposure.

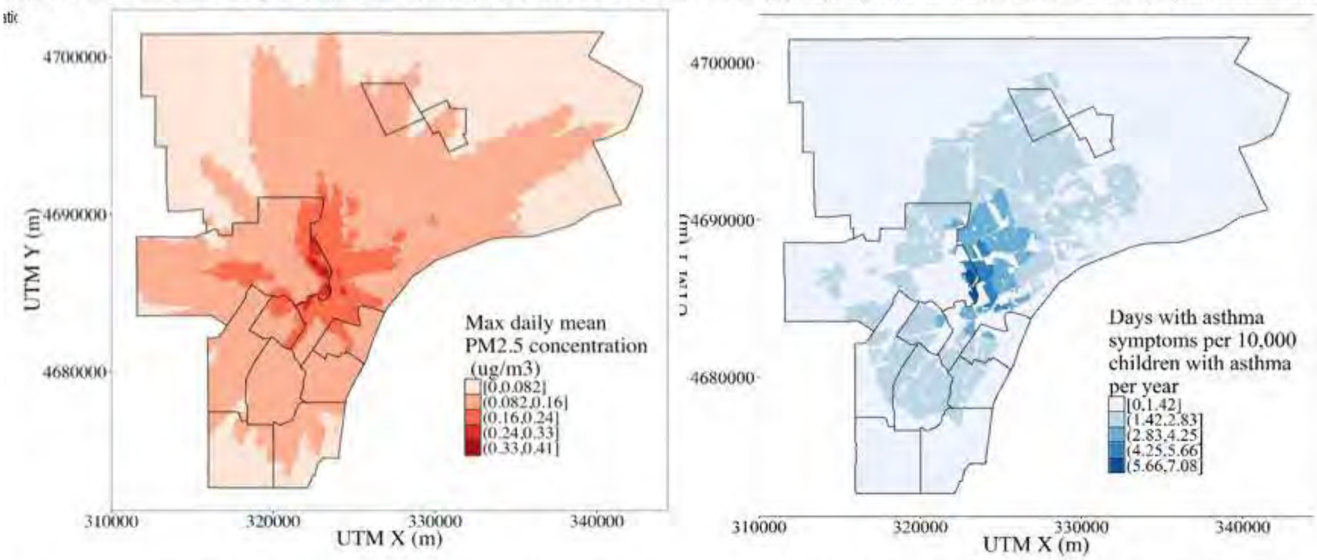


Figure 5-5I. Marathon Left panel shows PM2.5 concentrations (ug/m3); right panel shows risk of asthma symptoms from PM2.5 exposure.

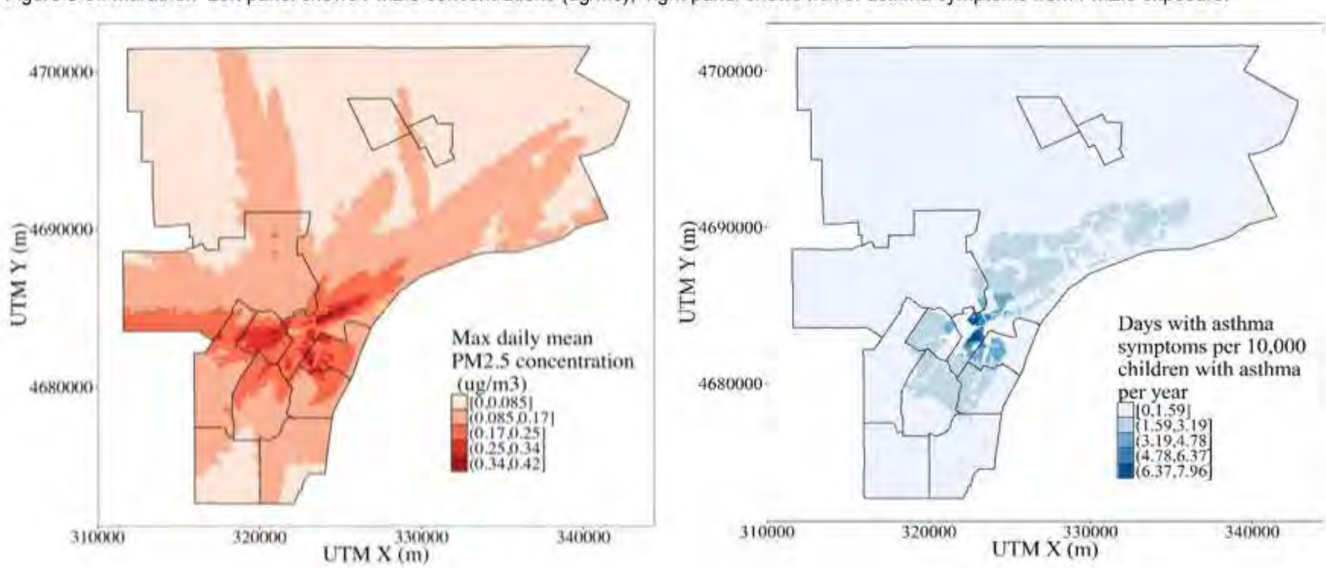


Figure 5-5J. A123 Systems Left panel shows PM2.5 concentrations (ug/m3); right panel shows risk of asthma symptoms from PM2.5 exposure.

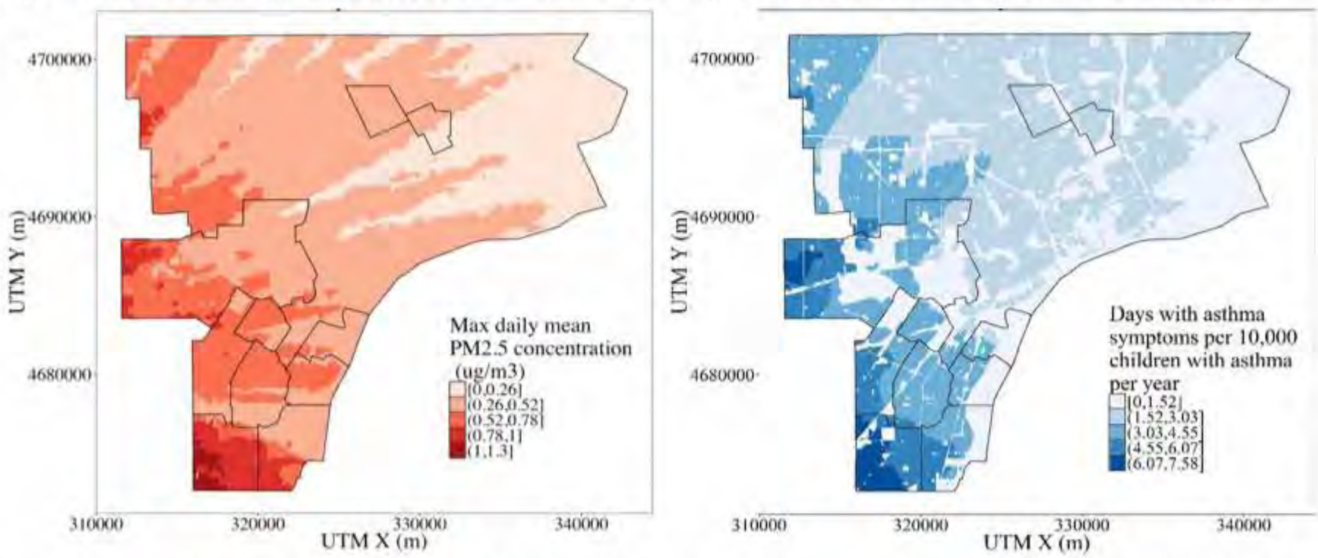


Figure 5-5K. Carleton Farms Landfill Left panel shows PM2.5 concentrations (ug/m3); right panel shows risk of asthma symptoms from PM2.5 exposure.

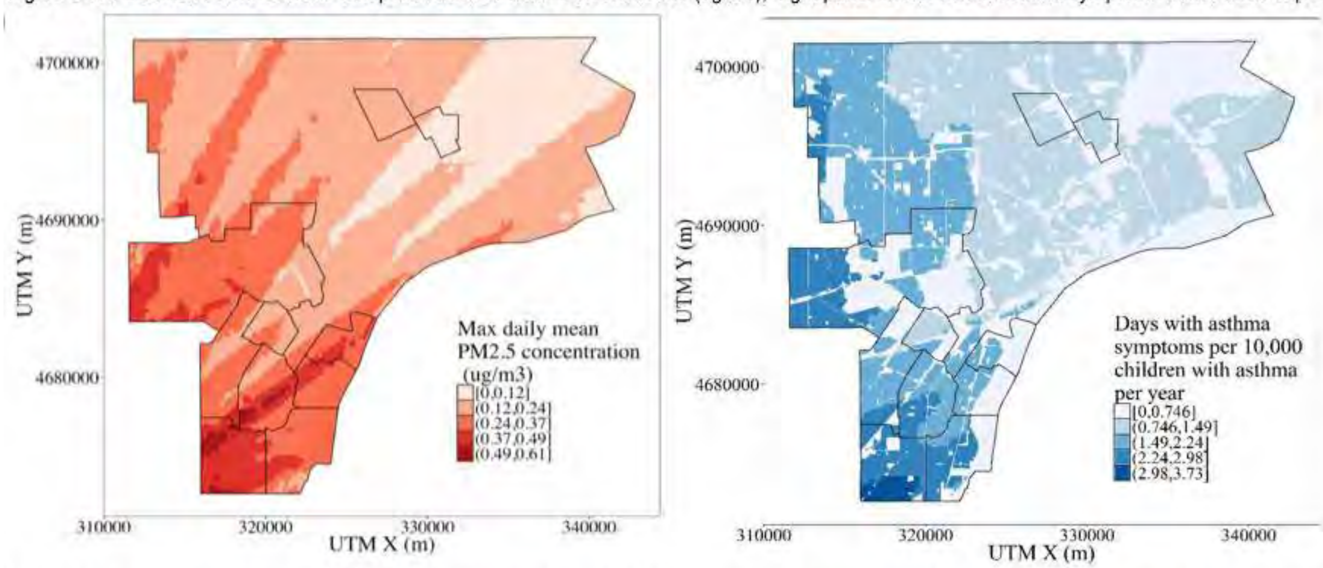


Figure 5-5L. Daimler Chrysler Technology Center Left panel shows PM2.5 concentrations (ug/m3); right panel shows risk of asthma symptoms from PM2.5 exposure.

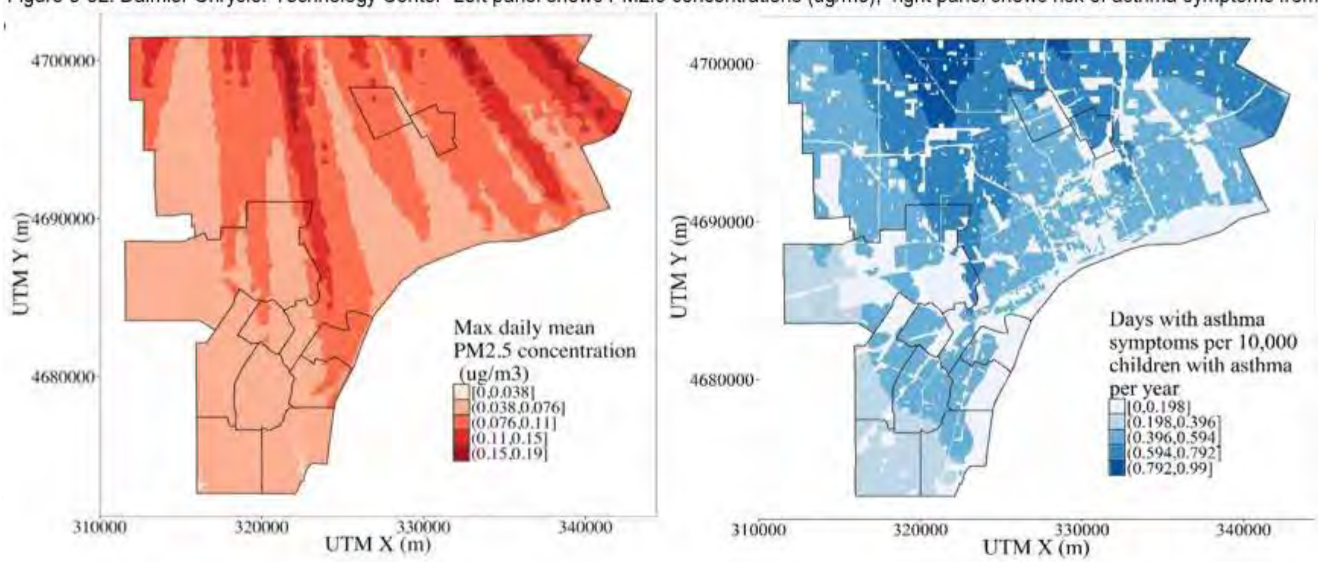


Figure 5-6A. DTE Monroe Left panel shows SO2 concentrations (ppb); right panel shows risk of asthma symptoms from SO2 exposure.

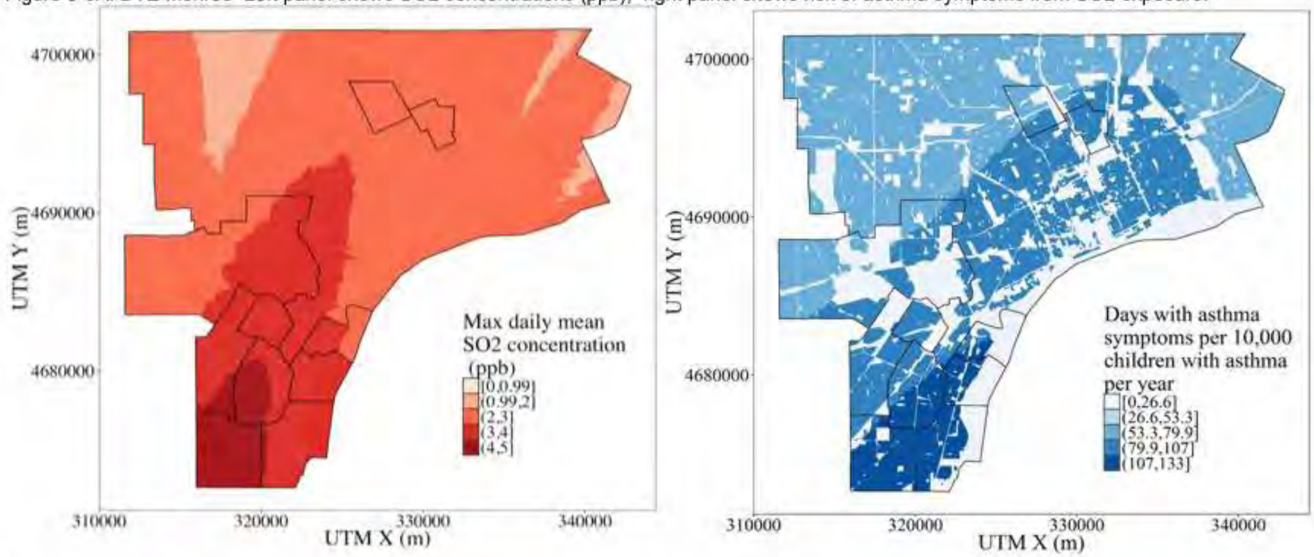


Figure 5-6B. DTE Trenton Channel Left panel shows SO2 concentrations (ppb); right panel shows risk of asthma symptoms from SO2 exposure.

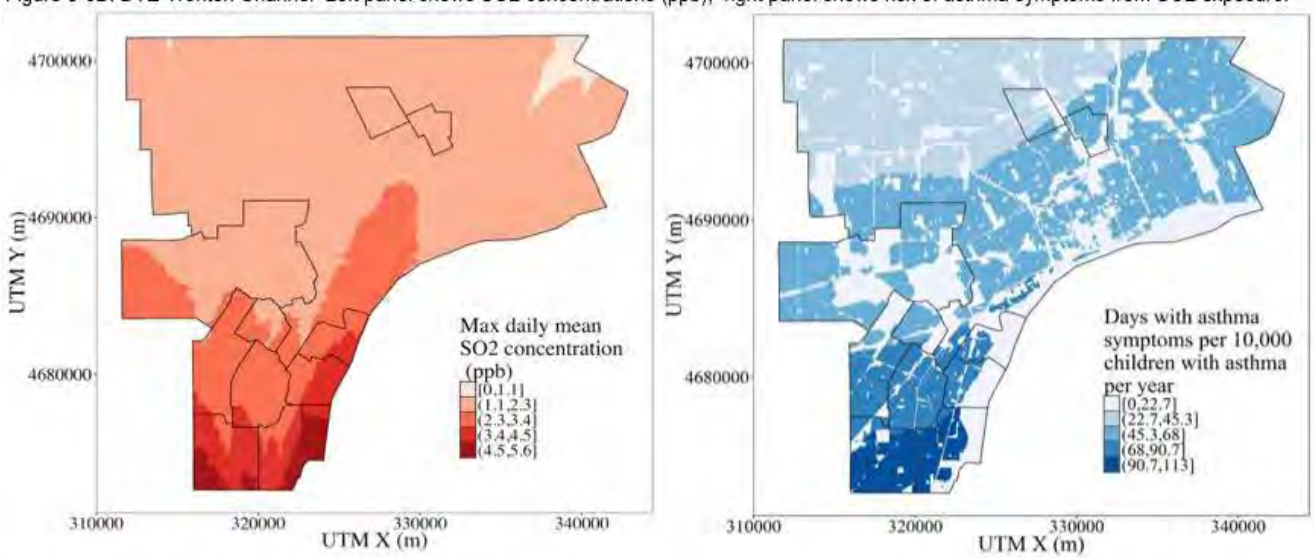


Figure 5-6C. DTE River Rouge Left panel shows SO2 concentrations (ppb); right panel shows risk of asthma symptoms from SO2 exposure.

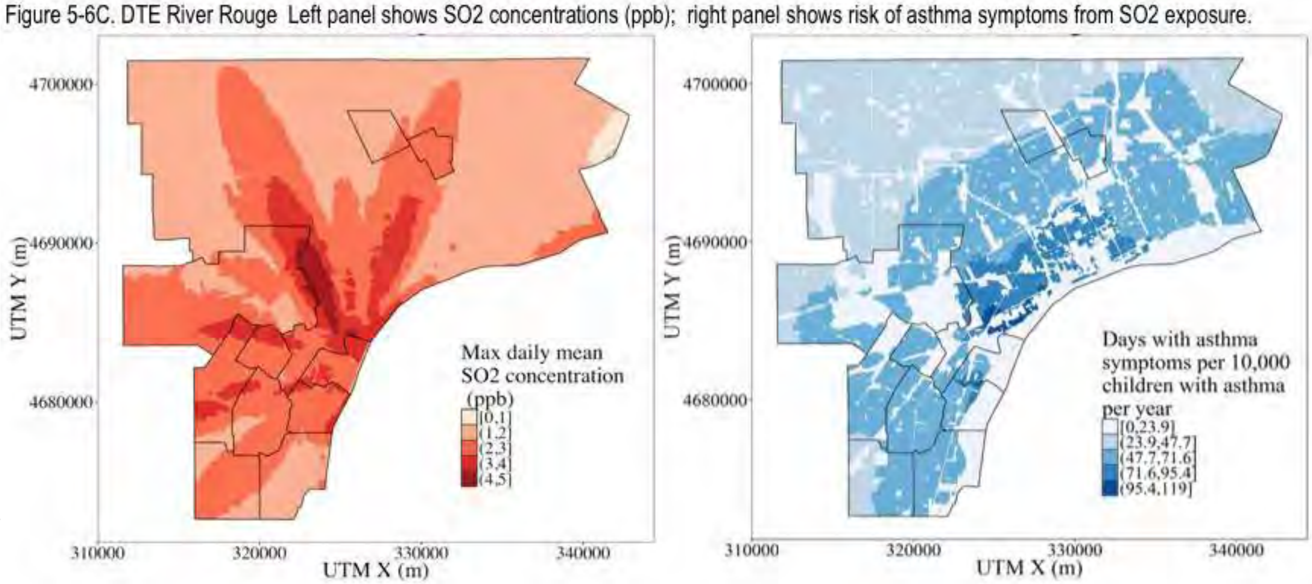


Figure 5-6D. Left panel shows SO2 concentrations (ppb); right panel shows risk of asthma symptoms from SO2 exposure.

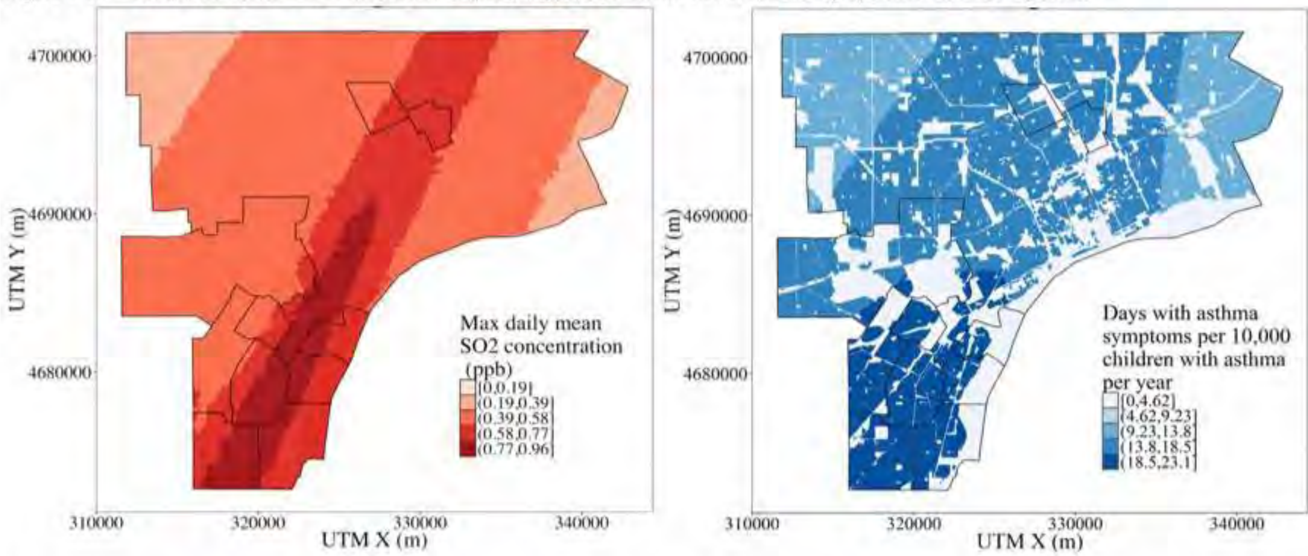


Figure 5-6E. US Steel Left panel shows SO2 concentrations (ppb); right panel shows risk of asthma symptoms from SO2 exposure.

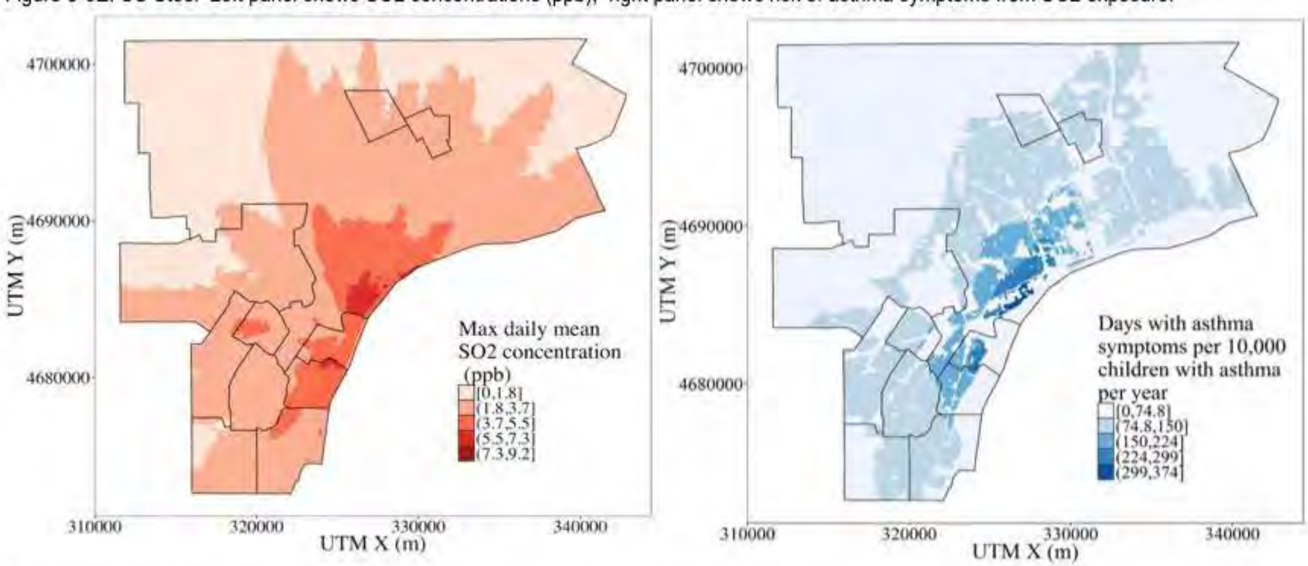


Figure 5-6F. EES Coke Left panel shows SO2 concentrations (ppb); right panel shows risk of asthma symptoms from SO2 exposure.

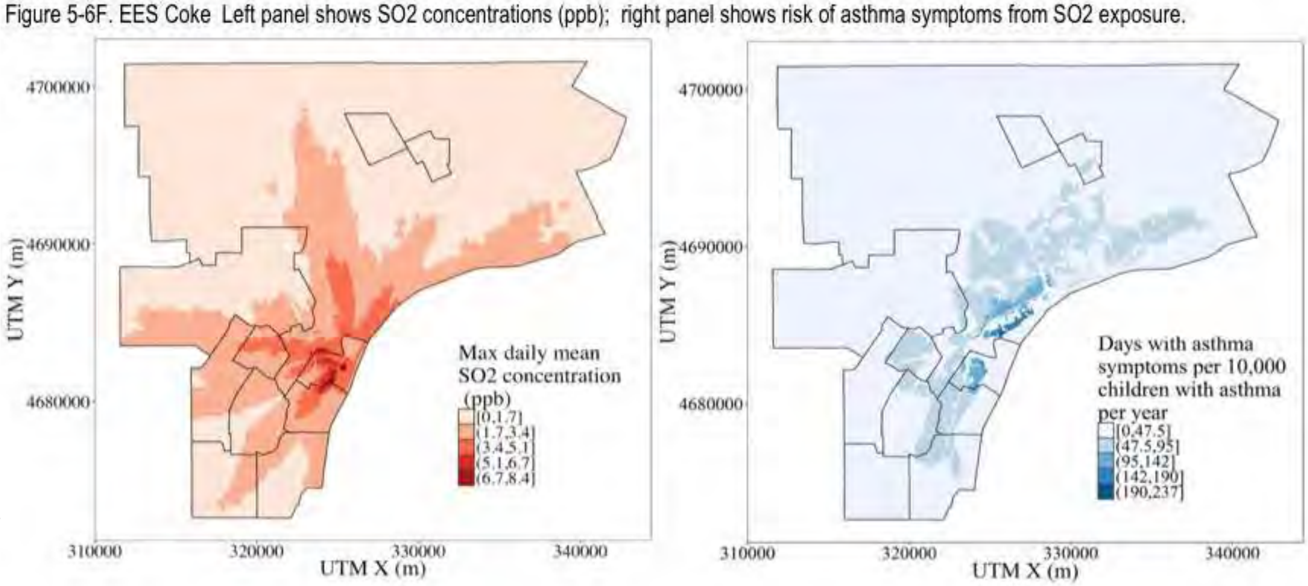


Figure 5-6G. AK Steel Left panel shows SO2 concentrations (ppb); right panel shows risk of asthma symptoms from SO2 exposure.

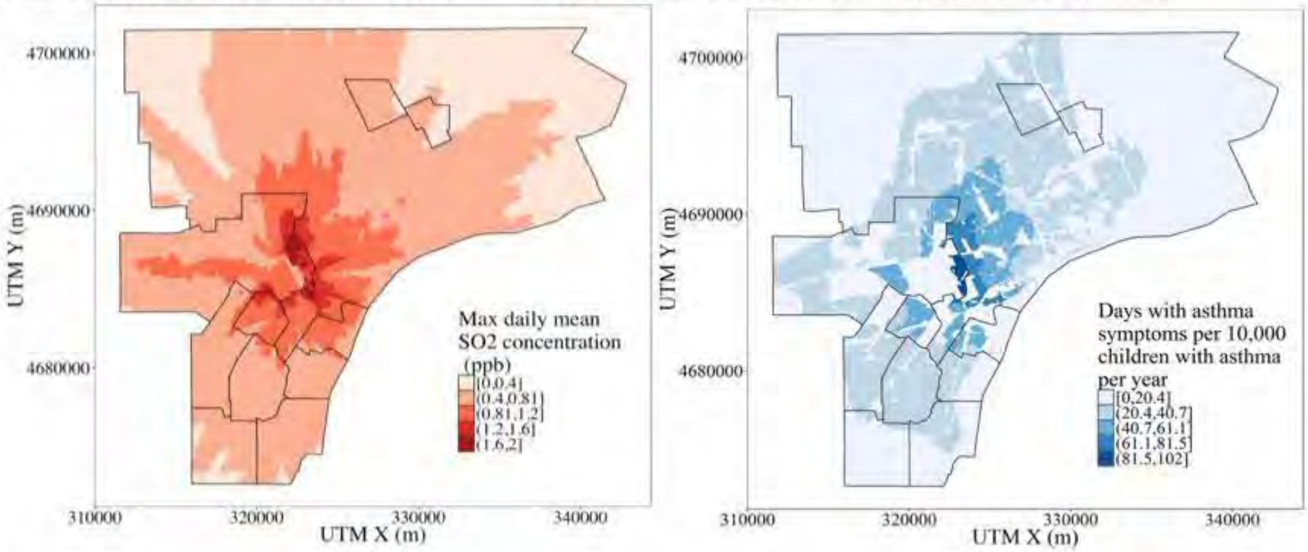


Figure 5-6H. Carmeuse Lime Left panel shows SO2 concentrations (ppb); right panel shows risk of asthma symptoms from SO2 exposure.

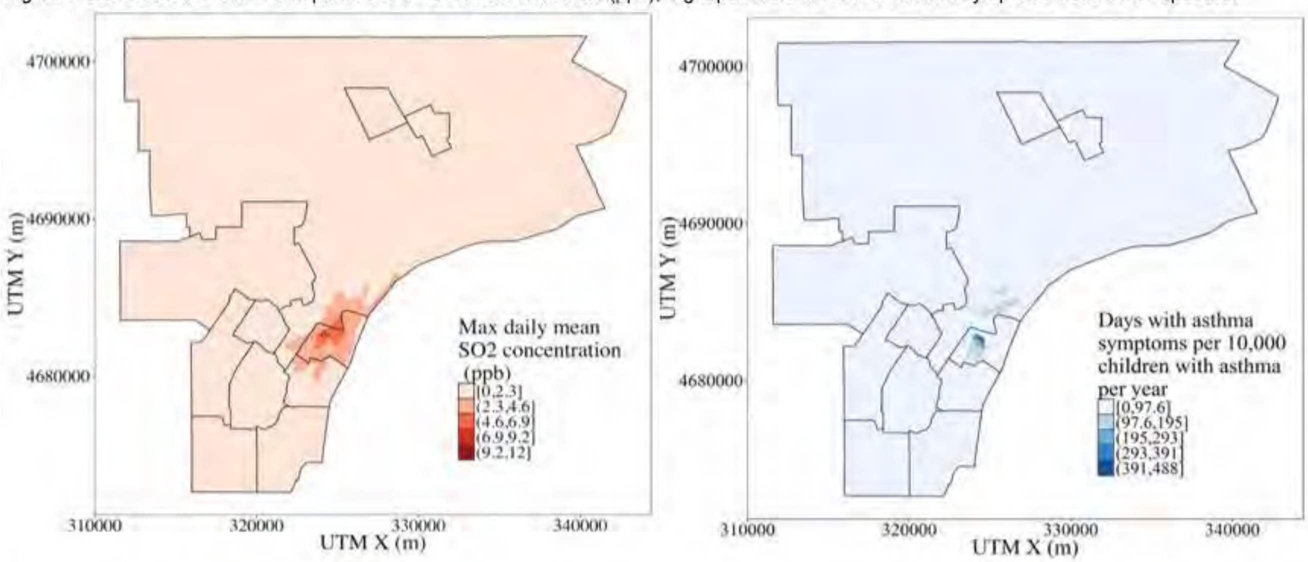


Figure 5-6I. Dearborn Industral Generation Left panel shows SO2 concentrations (ppb); right panel shows risk of asthma symptoms from SO2 exposure.

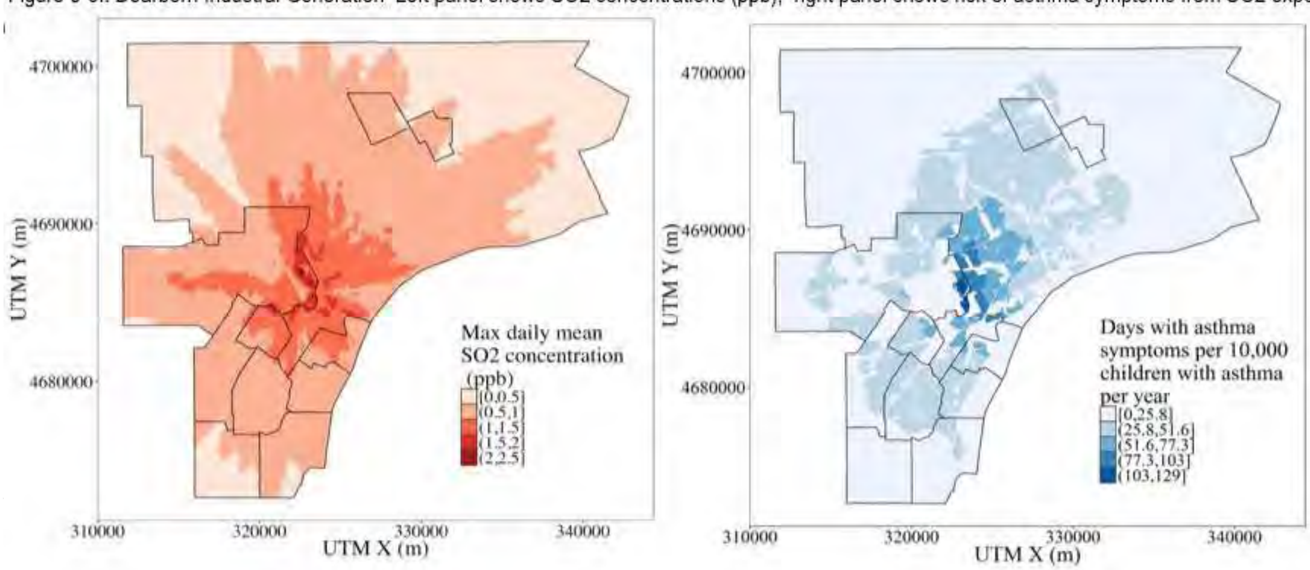


Figure 5-6J. Guardian Industries Left panel shows SO2 concentrations (ppb); right panel shows risk of asthma symptoms from SO2 exposure.

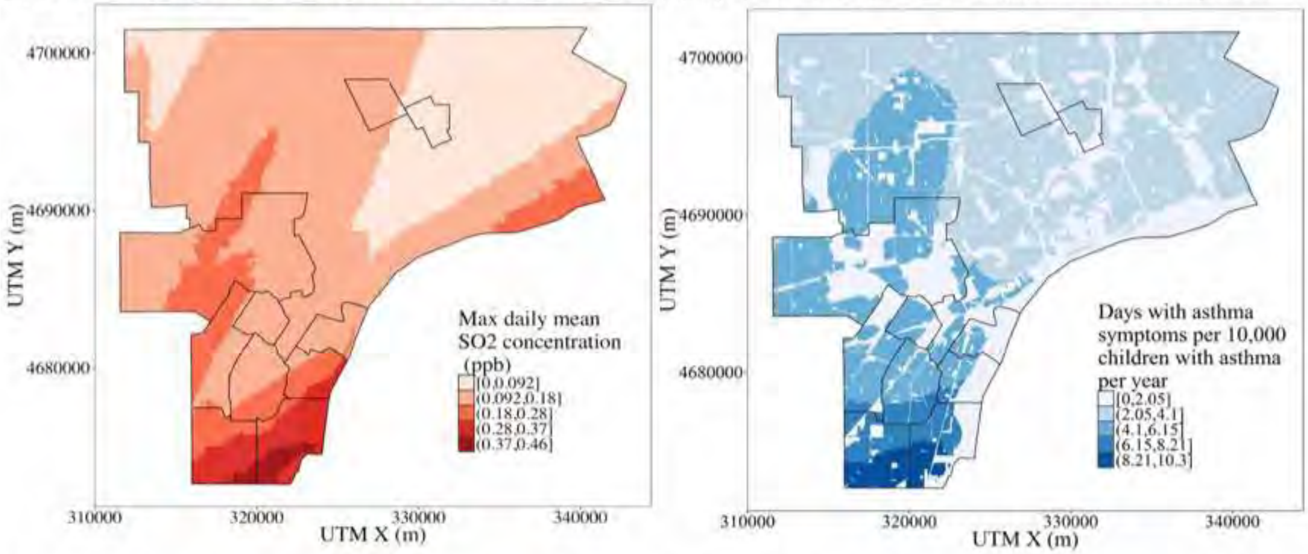


Figure 5-6K. General Motors Hamtramck Left panel shows SO2 concentrations (ppb); right panel shows risk of asthma symptoms from SO2 exposure.

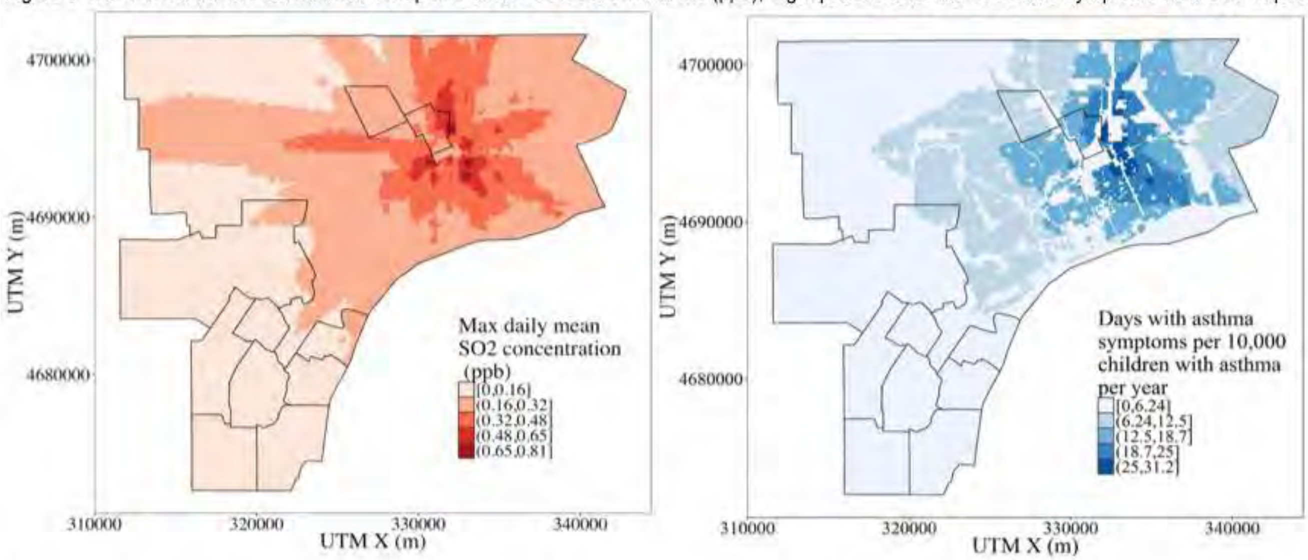


Figure 5-6L. Marathon Left panel shows SO2 concentrations (ppb); right panel shows risk of asthma symptoms from SO2 exposure.

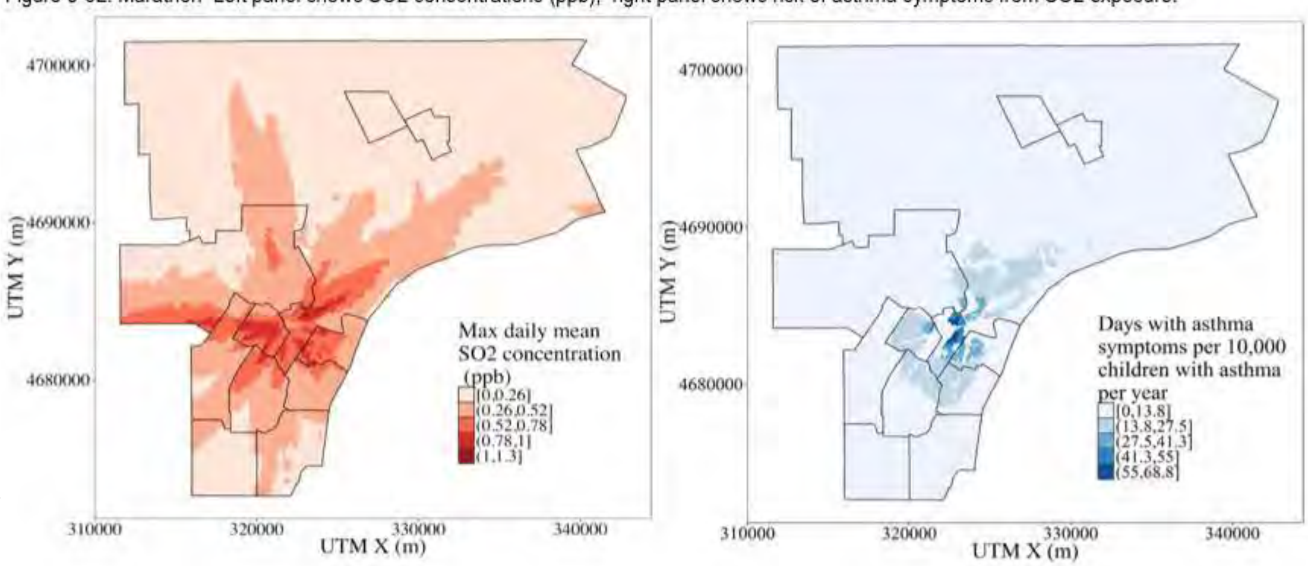


Figure 5-7A. DTE Monroe Left panel shows NOx concentrations (ppb); right panel shows risk of asthma symptoms from NOx exposure.

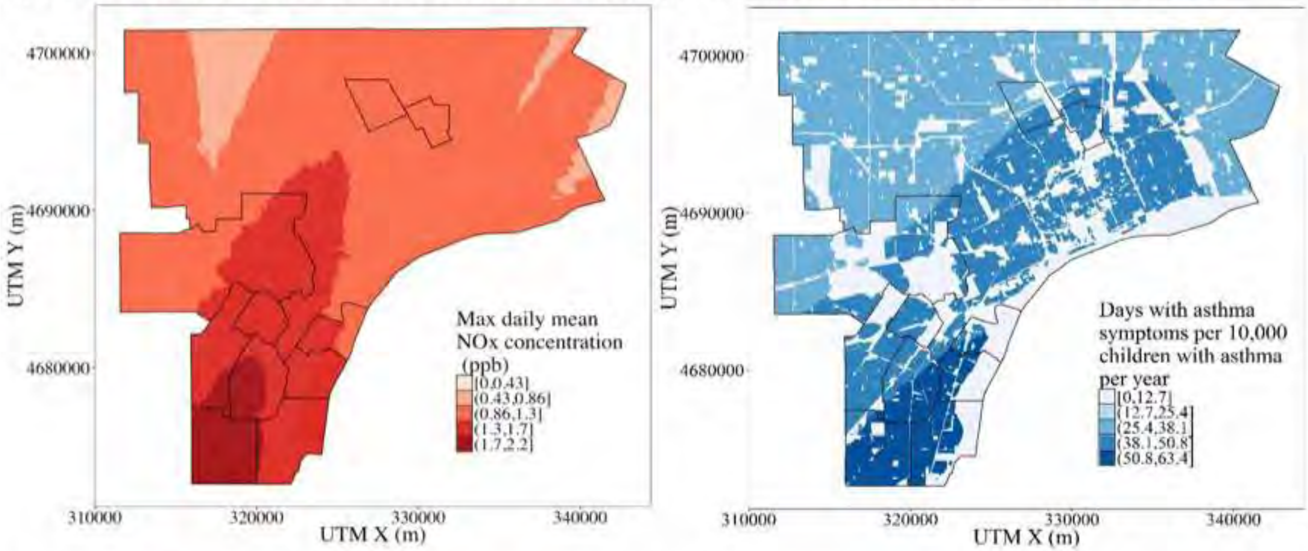


Figure 5-7B. DTE Trenton Channel Left panel shows NOx concentrations (ppb); right panel shows risk of asthma symptoms from NOx exposure.

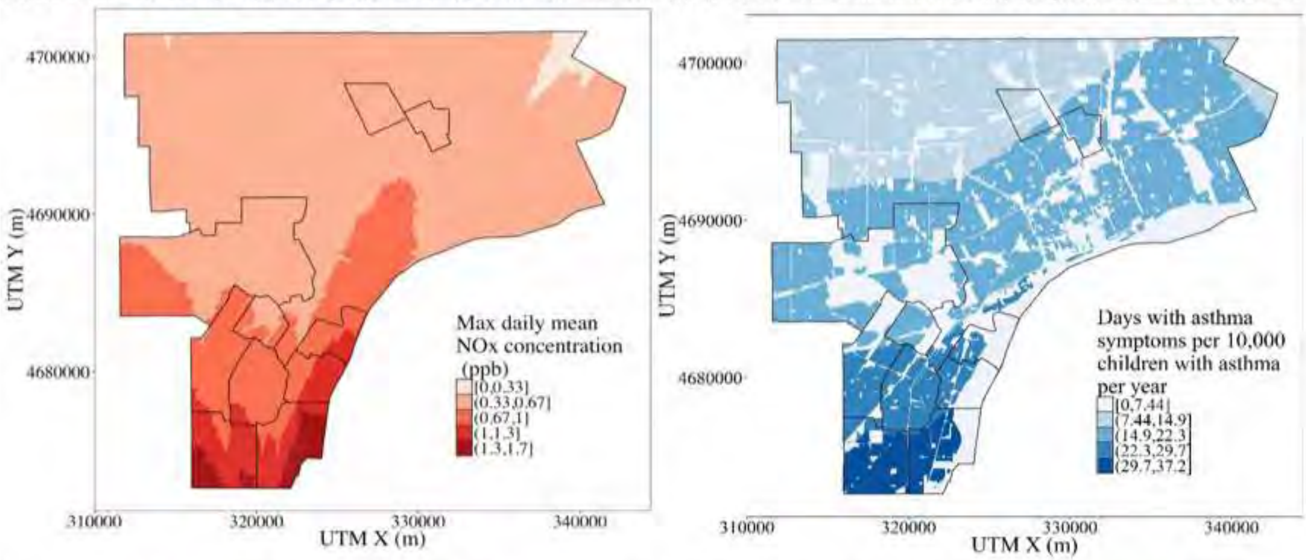


Figure 5-7C. DTE River Rouge Left panel shows NOx concentrations (ppb); right panel shows risk of asthma symptoms from NOx exposure.

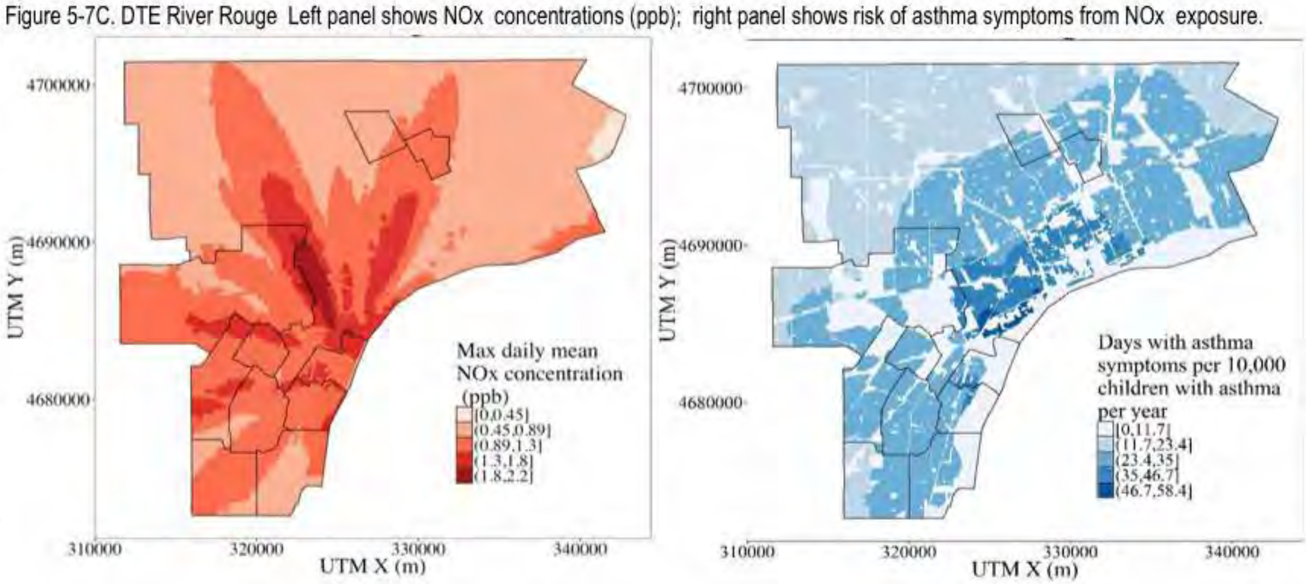


Figure 5-7D. JR Whiting Co. Left panel shows NOx concentrations (ppb); right panel shows risk of asthma symptoms from NOx exposure.

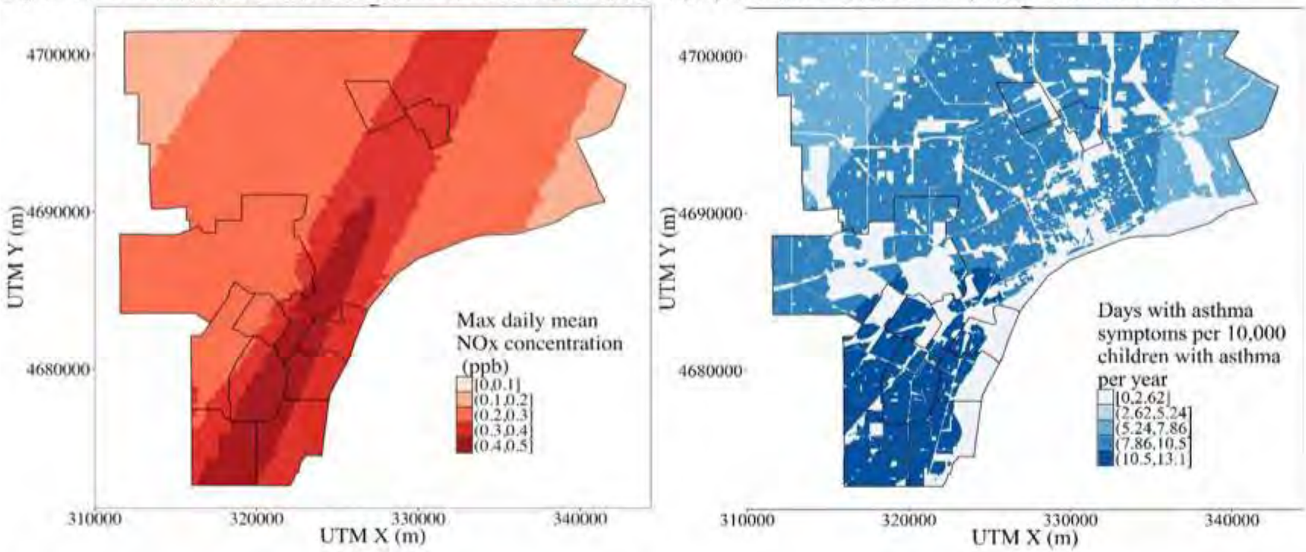


Figure 5-7E. Guardian Industries Left panel shows NOx concentrations (ppb); right panel shows risk of asthma symptoms from NOx exposure.

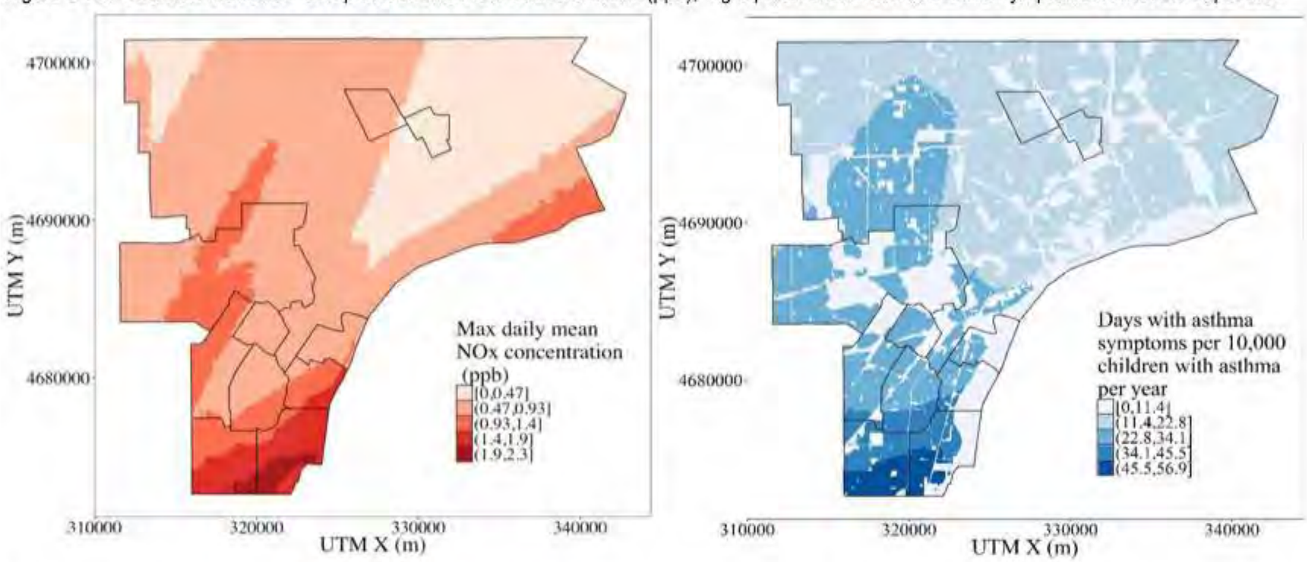


Figure 5-7F. US Steel Left panel shows NOx concentrations (ppb); right panel shows risk of asthma symptoms from NOx exposure.

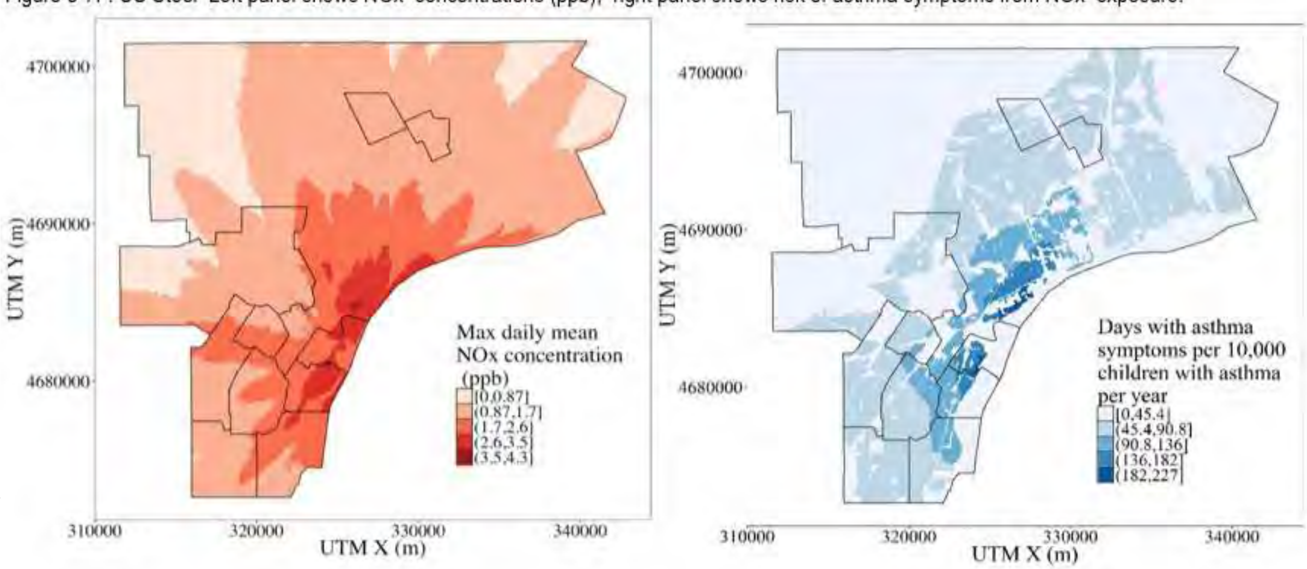


Figure 5-7G. EES Coke Left panel shows NOx concentrations (ppb); right panel shows risk of asthma symptoms from NOx exposure.

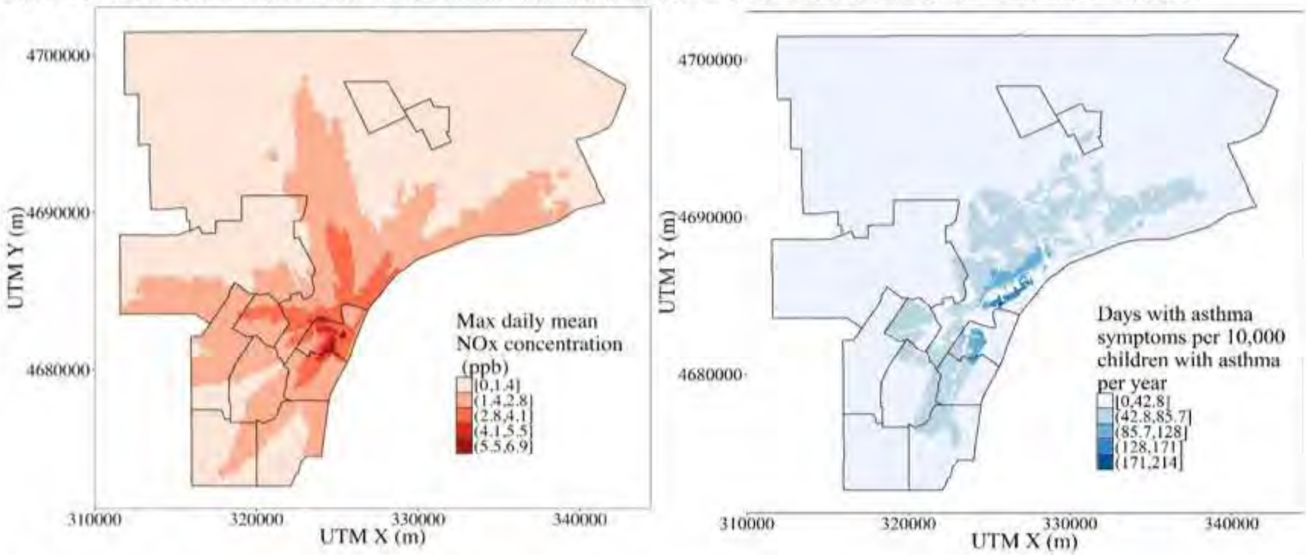


Figure 5-7H. Greater Detroit Resource Recovery Left panel shows NOx concentrations (ppb); right panel shows risk of asthma symptoms from NOx exposure.

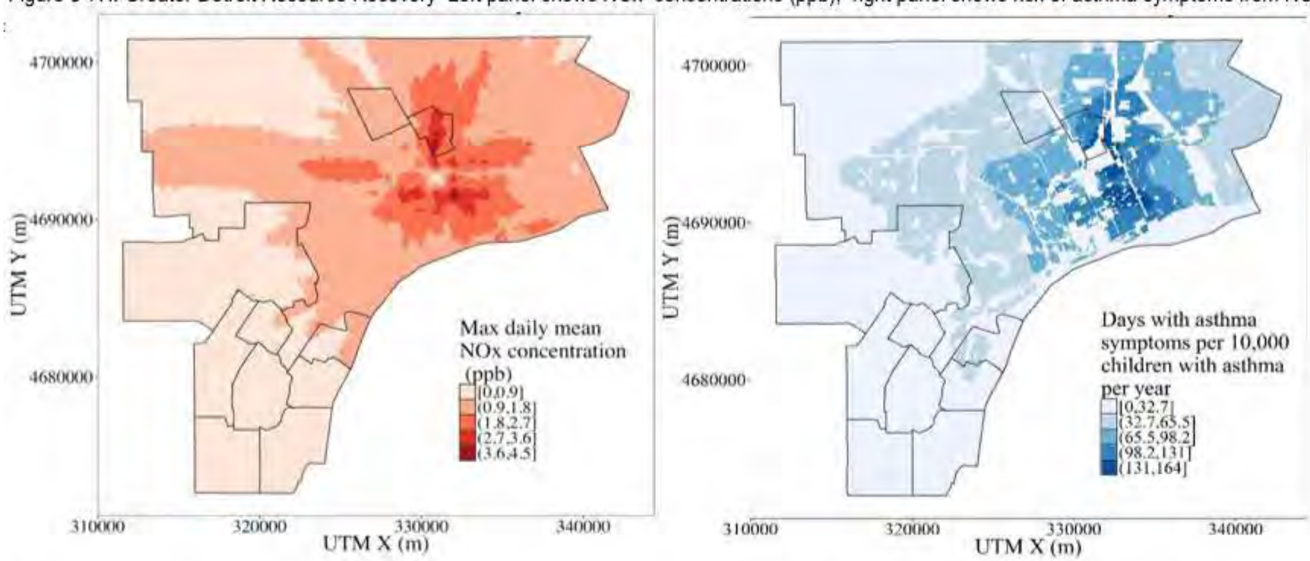


Figure 5-7I. AK Steel Left panel shows NOx concentrations (ppb); right panel shows risk of asthma symptoms from NOx exposure.

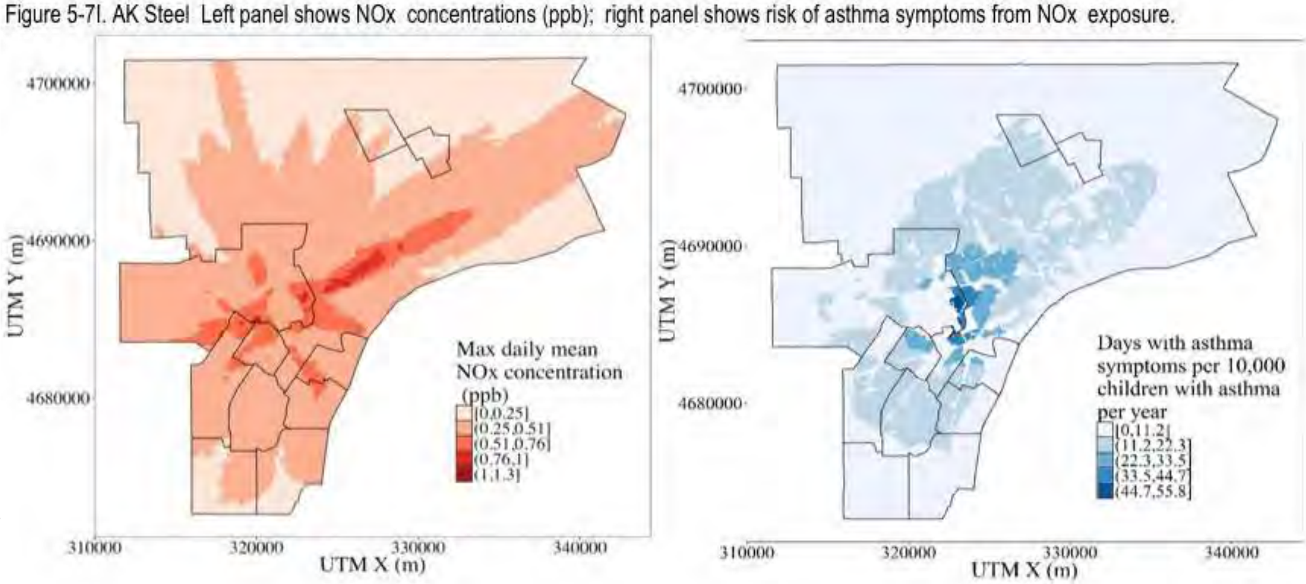


Figure 5-7J. Carmeuse Lime Left panel shows NOx concentrations (ppb); right panel shows risk of asthma symptoms from NOx exposure.

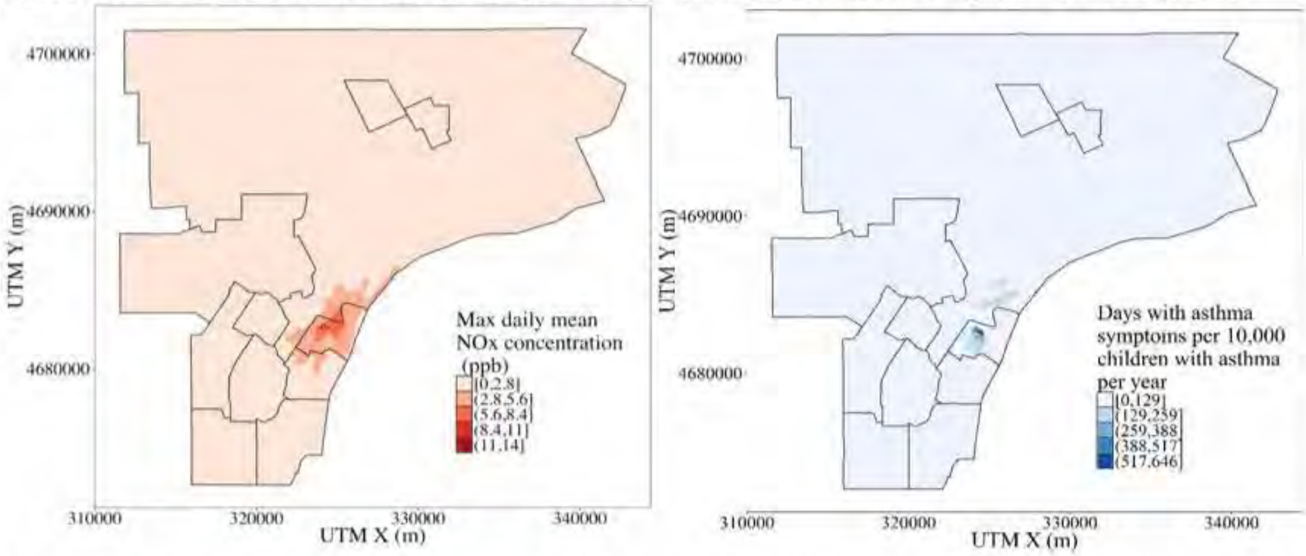


Figure 5-7K. Marathon Left panel shows NOx concentrations (ppb); right panel shows risk of asthma symptoms from NOx exposure.

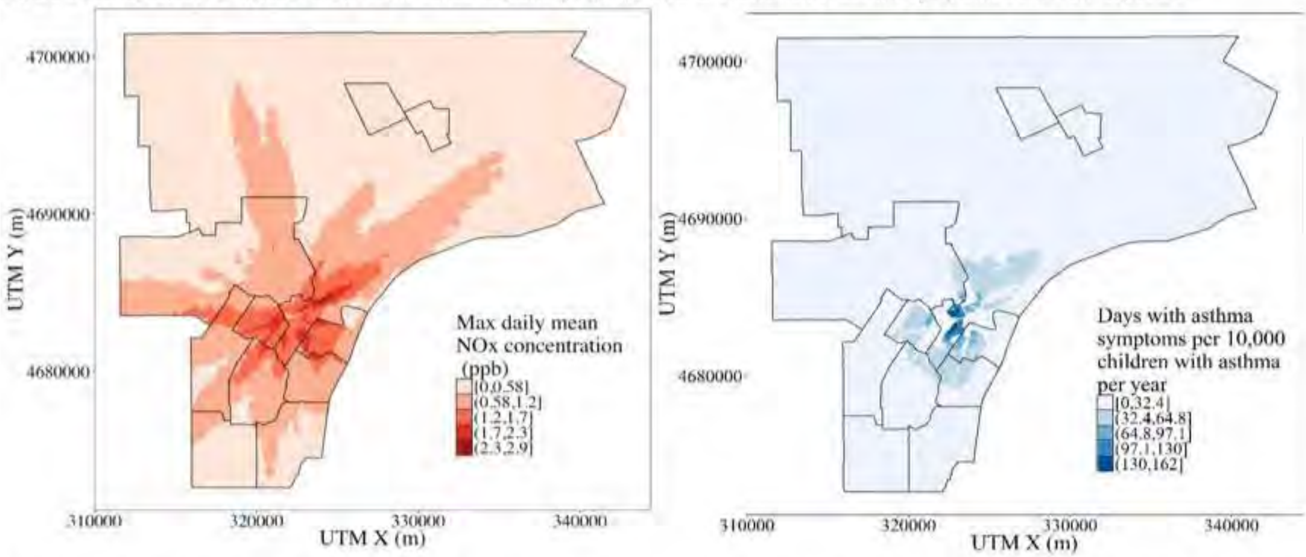
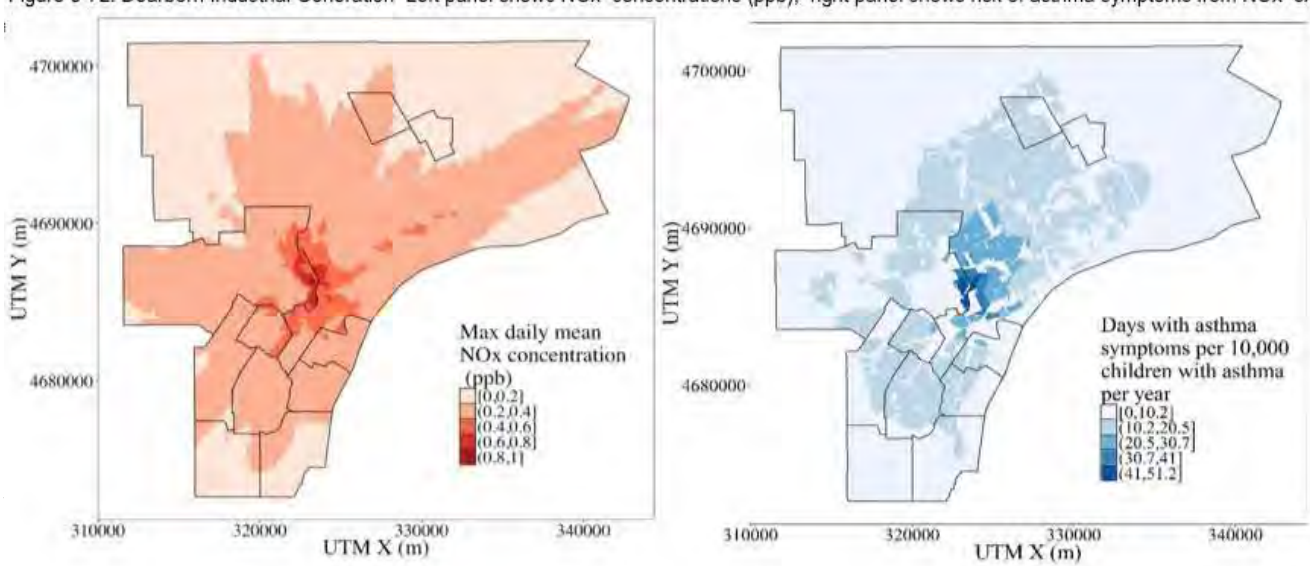


Figure 5-7L. Dearborn Industrial Generation Left panel shows NOx concentrations (ppb); right panel shows risk of asthma symptoms from NOx exposure.



5.5.4 Health impacts and areas affected by mobile source emissions

Figure 5-8 shows annual average $PM_{2.5}$ concentrations due to on-road exhaust emissions across the modeled area. Concentrations are highest at or near major roads, and concentrations drop quickly moving away from roadways. Using block-level data, the annual average $PM_{2.5}$ concentration across the study area averaged 0.35 $\mu g/m^3$, the 99th percentile was 1.65 $\mu g/m^3$, and the highest concentration was 3.25 $\mu g/m^3$. These estimates exclude entrained dust, pavement wear, tire wear, brake wear, and other non-exhaust PM. They also consider only primary emissions of $PM_{2.5}$.

Figure 5-8. Annual $PM_{2.5}$ concentrations predicted in the Detroit area due to on-road mobile source exhaust emissions for the 25 m raster based on interpolating the 150 m receptor grid

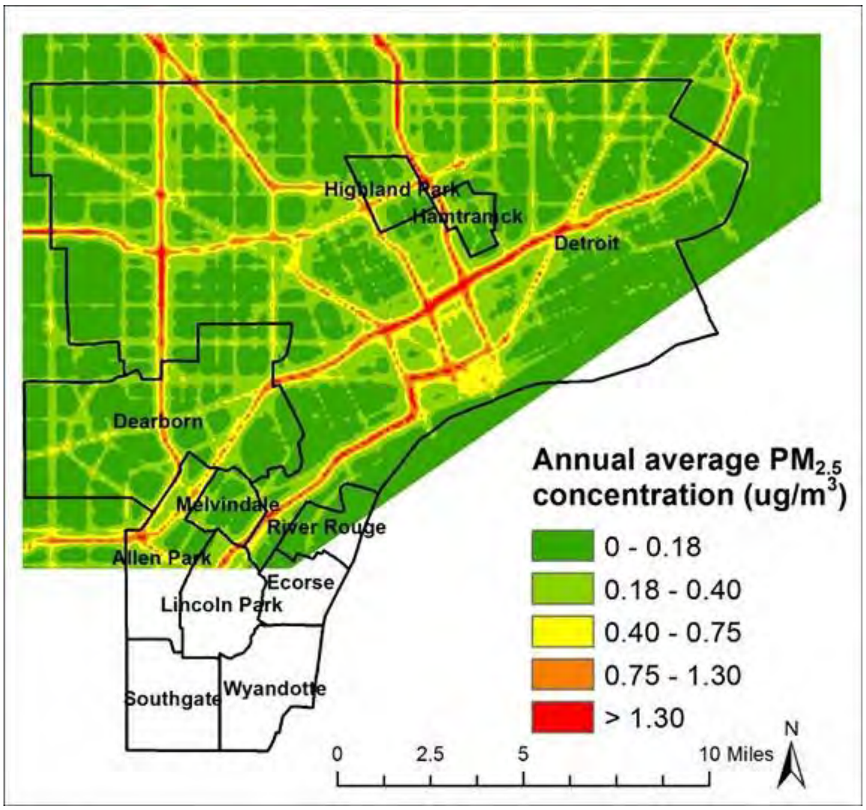


Table 5-13 (left portion) summarizes the total health burden attributable to $PM_{2.5}$ exposures in Detroit, Highland Park, Hamtramck, and the Down River communities. The estimated health impacts represent impacts to the entire study area, not just the portion covered by the mobile source receptor grid. Health impacts attributable to $PM_{2.5}$ exposures from on-road mobile sources in the study region (right portion of Table 5-13), include 1 pneumonia hospitalization, over 7,000 minor-restricted activity days, 209 DALYs, and $106 million in monetized impacts, most of which (96%) was due to premature mortality.

This work is made possible by National Institute of Health and Environmental Sciences, RO1ES022616, and the Fred A. and Barbara M. Erb Family Foundation. Additional support was provided by the Michigan Center on Lifestage Environmental Exposures and Disease (M-LEEaD), #P30ES017885.

The burden of disease due to on-road emissions (as DALYs) is approximately 0.3% of the total health burden attributable to $PM_{2.5}$ exposures. This percentage may appear small, but collectively it represents a significant health burden. Still, the health impacts from traffic emissions are smaller than those estimated for point sources (Table 5-12). This results for several reasons: (1) relatively few people live very close to major roads;[9] (2) vehicle emissions vary over the day (higher at rush hour, lower the rest of the day); (3) predicted concentrations and exposures from on-road emissions represent a relatively small part of the total $PM_{2.5}$ concentration, and (4) the region with estimates of on-road $PM_{2.5}$ did not include some of the Down River communities (but 88% of the population was covered). However, estimated health impacts likely underestimate actual health impacts for several reasons: (1) only primary on-road emissions of $PM_{2.5}$ were considered, and entrained $PM_{2.5}$, secondary $PM_{2.5}$, and other pollutants were not considered; (2) health impact functions used to estimate impacts were based on studies that may not fully reflect the greater toxicity of diesel exhaust and other traffic-related pollutants; (3) exposure in vehicle cabins and to commuters was not considered; (4) time activity patterns were not considered, i.e., people were assumed to stay at home; (5) the susceptibility of the Detroit population and the population living in Detroit was only partially addressed; and (6) results use annual concentrations (although the daily or hourly fluctuations in $PM_{2.5}$ are not expected to significantly affect these results).

Table 5-13. Summary of health impacts (per year) associated with $PM_{2.5}$ exposures from all sources and exposure from exhaust emissions from mobile sources in Detroit.

Outcome (age group)	Impacts attributable to $PM_{2.5}$ exposures from all sources (per year)	Impacts attributable to $PM_{2.5}$ emissions from mobile sources (per year)
All-cause mortality (>29)	554	11
Infant mortality (0-1)	7	0
Asthma hospitalization (<65)	107	2
COPD hospitalization (>65)	21	0
CVD hospitalization (>65)	130	2
Pneumonia hospitalization (>65)	58	1
Non-fatal heart attack (18+)	25	1
Asthma ED visit (0-17)	374	11
Asthma exacerbation (as cough, 6-14)	224,799	4,311
Asthma exacerbation (as wheeze, 6-14)	18,003	423
Asthma exacerbation (as SOB, 6-14)	22,833	333
Minor restricted activity day (18-64)	365,937	7,238
Work loss day (18-64)	64,441	1,252
DALYs	10,367	209
Monetized impacts (million 2010$)	5,449	106

[9] An estimated 28% of the population lives in census blocks that adjacent (or within 200 m) of freeways and state highways. However, because blocks can be large, many fewer individuals actually live very near these major roads.

This work is made possible by National Institute of Health and Environmental Sciences, RO1ES022616, and the Fred A. and Barbara M. Erb Family Foundation. Additional support was provided by the Michigan Center on Lifestage Environmental Exposures and Disease (M-LEEaD), #P30ES017885.

Abbreviations: COPD: chronic obstructive pulmonary disease; CVD: cardiovascular disease; DALYs: disability-adjusted life years; ED: emergency department; SOB: shortness of breath.

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6. CUMULATIVE RISK: AIR POLLUTION & POPULATION VULNERABILITY

2016

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6 CUMULATIVE RISK: AIR POLLUTION AND POPULATION VULNERABIITY

6.1 Vulnerability: Factors that influence health effects of exposure

Some communities or individuals may be more vulnerable than others to the adverse effects of exposure to air pollutants. In this document, we use the term "susceptibility" or "more strongly affected" when describing those who are likely to have a stronger or more negative health effect at any given level of exposure. We use the term "vulnerability" when we are referring to those who are more likely to be exposed to higher levels of a pollutant. Note that some groups, such as children, may be both more vulnerable to high levels of exposure and more susceptible to the adverse effects of those exposures (see below for more detail).

Note: *Sometimes the terms susceptibility and vulnerability are used interchangeably, and sometimes they are lumped together and referred to as "at-risk" populations, or those who experience increased risk of adverse health effects of exposure to air pollutants.*

Below, we detail several of the factors that increase susceptibility or vulnerability to air pollutants. Area-specific statistics on several of these for Detroit, the tri-county area, and for the seven-county Southeast Michigan are available in Table 6-1. Table 3-2 shows at a glance the evidence base for specific vulnerable or susceptible populations for each of the six criteria pollutants covered by the Environmental Protection Agencies' National Ambient Air Quality Standards (NAAQS).

Genetic: Children with asthma who have a genetic susceptibility and low vitamin C intake are more susceptible to adverse health effects from exposure to the air pollutant ozone (O_3) than children without genetic susceptibility.[1]

Behavioral: Individuals with reduced intake of Vitamins E and C are at risk for ozone-related health effects.[2] Those with iron deficiency are more susceptible to negative health effects of exposure to lead.[3] Diets rich in antioxidants (found in many fruits and vegetables) may provide some protection against adverse effects of exposure to airborne particulate matter (PM). Thus, people living in neighborhoods with poor access to foods that are rich in antioxidants, including vitamins E and C, and iron, may be more susceptible to adverse health effects of exposure to ozone, lead, and PM.

People who spend a lot of time outdoors, working, playing or exercising, are more vulnerable to adverse health effects from outdoor air pollution, including ozone[4] and sulfur dioxide (SO_2)[5] as they are likely to breathe in more of these pollutants.

---

[1] Moreno-Macias H, Dockery D, Schwartz, J, et al. 2013. Ozone exposure, vitamin C intake, and genetic susceptibility of asthmatic children in Mexico City: a cohort study. Respir Res 2013; 14(1): 14. doi: 10.1186/1465-9921-14-14

[2] Moreno-Macias H, Dockery D, Schwartz J, et al. 2013. Ozone exposure, vitamin C intake, and genetic susceptibility of asthmatic children in Mexico City: a cohort study. Respir Res. 2013; 14(1): 14. doi: 10.1186/1465-9921-14-14

[3] Baker RD, and Greer FR. 2010. Diagnosis and Prevention of Iron Deficiency and Iron-Deficiency Anemia in Infants and Young Children (0–3 Years of Age). American Academy of Pediatrics Clinical Report. 126:5

[4] EPA (Environmental Protection Agency). 2016. Integrated Science Assessment of Ozone and Related Photochemical Oxidants. Available: https://cfpub.epa.gov/ncea/isa/recordisplay.cfm?deid=247492 [Accessed 4 April 16].

[5] ATSDR (Agency for Toxic Substances & disease Registry). 2016. Sulfur Dioxide. Available: http://www.atsdr.cdc.gov/phs/phs.asp?id=251&tid=46 [Accessed 4 April 16].

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Existing health conditions: Several health conditions are associated with more adverse health effects at any given level of exposure to some air pollutants. For example, those with asthma or other existing lung diseases such as cardiopulmonary disease (COPD), cardiovascular disease, obesity, and metabolic disorders are more adversely affected by exposure to ozone.[6] There is also suggestive evidence that pre-existing health conditions may make an individual more susceptible to adverse health effects of exposure to nitrogen oxides (NO, NO_2, NO_x)[7], and particulate matter (PM).[8]

Children: There is substantial evidence that children are more strongly affected by exposure to air pollutants, including $PM_{2.5}$ and ozone. Exposure can result in developmental effects that increase risks for some diseases later in life (e.g., metabolic disorders, asthma) and may also exacerbate some existing conditions (e.g., more severe asthma attacks). Because children are growing and developing, and breathing in a greater volume of air per body size, they are more susceptible to the adverse impacts of air pollutants.[9] In addition, because children tend to spend more time out of doors than adults, they may also have higher levels of exposure to air pollutants in outdoor air.

Pregnant women and infants: While the evidence is not yet certain, there is concern that pregnant women and infants have heightened vulnerability to adverse health effects of air pollution. For women, this concern is due to heightened respiration (intake of air) during pregnancy and for infants, the concern is due to developmental stages. There is evidence to suggest that pregnant women may be more susceptible to adverse health effects of NO_2, carbon monoxide (CO), and SO_2.[10]

Adults 60 or older: There is evidence that older adults (definitions vary, but generally refers to those older than 60-65 years of age) are more susceptible to adverse health effects of exposure to Ozone. There is suggestive evidence that older adults are more susceptible to negative health effects from NO_2, PM, CO, and SO_2 and lead.[11]

Race and ethnicity: Some studies have found that non-Latino Black and Latinos in the United States are more likely to live near to pollutant sources, or in areas with higher levels of contamination in the air, water and/or

[6] EPA (Environmental Protection Agency). 2016. Integrated Science Assessment of Ozone and Related Photochemical Oxidants. Available: https://cfpub.epa.gov/ncea/isa/recordisplay.cfm?deid=247492 . [Accessed 4 April 16].

[7] EPA (Environmental Protection Agency). 2016. Integrated Science Assessment for Nitrogen Dioxide. Available: https://www.epa.gov/isa/integrated-science-assessment-isa-nitrogen-dioxide-health-criteria [Accessed 4 April 16]..

[8] EPA (Environmental Protection Agency). 2016. Integrated Science Assessment for Particulate Matter. Available: https://www.epa.gov/isa/integrated-science-assessment-isa-particulate-matte r [Accessed 4 April 16].

[9] Department of Health and Human Services, The Center for Disease Control and Prevention. 2016. Healthy People 2000. Available: http://www.cdc.gov/nchs/data/hp2000/hp2k01.pdf [Accessed 4 April 16].

[10] EPA (Environmental Protection Agency). 2016. Integrated Science Assessment for Nitrogen Dioxide. Available: https://www.epa.gov/isa/integrated-science-assessment-isa-nitrogen-dioxide-health-criteria [Accessed 4 April 16]. and EPA (Environmental Protection Agency). 2016. Integrated Science Assessment for Sulfur Dioxide. Available: https://www.epa.gov/isa/integrated-science-assessment-isa-sulfur-dioxide-health-criteria [Accessed 4 April 16]. .

[11] Simoni M, Baldacci S, Maio S, et al. 2014. Adverse effects of outdoor pollution in the elderly. Journal of Thoracic Disease. (1):34-45. doi: 10.3978/j.issn.2072-1439.2014.12.10.

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soil.[12] These differences often persist after accounting for disproportionate representation of NLB and Latinos in areas with lower socioeconomic status.[13]

Socioeconomic status: There is evidence that people with lower socioeconomic status are more likely to live near sources of air pollutants and other pollutants.[14] They may also be more susceptible to adverse health effects of air pollutants, as described below.

Income: Those with low household incomes are more likely to live in poor quality housing (see below), have reduced access to health insurance, and live in communities with higher levels of exposures. These and other factors associated with low incomes may combine to create a stronger or more adverse effect of exposure to air pollutants like PM on health.[15]

Housing: Poor housing conditions can also negatively impact communities and individuals' ability to protect themselves from adverse health effects of exposure to air pollutants.[16] For example, older houses may lack the capacity to support air conditioners that clean pollutants from indoor air. Older and poorly maintained houses may also contain higher levels of molds and allergens, which may exacerbate or compound the effects of exposure to air pollutants.

Education: Education status or attainment can also impact a communities (or individuals) ability to withstand an environmental insult.[17] There is suggestive evidence that lower education can make an individual more susceptible to PM exposure.

Community preparedness: Differences across communities in terms of emergency preparedness or access to health care may influence susceptibility to adverse effects of air pollutants. For example, communities with emergency medical response systems with greater capacity are likely to have faster response times in, for example, transporting a child with a severe asthma attack to a health care setting. Thus the adverse health effects for children in such communities may be smaller than those for children in communities with poorer systems.

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[12] Downey L, Hawkins B. 2009. Race, income, and environmental inequality in the United States. Social Perspectives Author manuscript; available in PMC 2009 Jul 2. Published in final edited form as: Social Perspectives 2008 Dec 1; 51(4): 759–781.doi: 10.1525/sop.2008.51.4.759

[13] Mohai P, Lantz P, Morenoff J, House J. 2011. Racial and socioeconomic disparities in proximity to polluting industrial facilities. American J of Public Health. 2009; S649-S656.

[14] Mohai P, Lantz P, Morenoff J, House J. 2011.Racial and socioeconomic disparities in proximity to polluting industrial facilities. American J of Public Health, 2009; S649-S656.

[15] EPA (Environmental Protection Agency). 2016. Integrated Science Assessments. Available: https://www.epa.gov/isa [Accessed 4 April 16].

[16] EPA (Environmental Protection Agency). 2016. Integrated Science Assessments. Available: https://www.epa.gov/isa [Accessed 4 April 16].

[17] EPA (Environmental Protection Agency). 2016. Integrated Science Assessments. Available: https://www.epa.gov/isa [Accessed 4 April 16].

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6.2 Table 6-1. Vulnerability: Factors that influence health effects of exposure

Vulnerability: Factors that influence health effects of exposure											
		Location							P<0.05?		
		Southwest n=84,122	Central n= 29,458	Eastside n= 240,621	Westside n= 352,462	CITY n= 706,663	Tri-County	Seven-county	City vs. 3-Cnty	City vs. 7-Cnty	3-County vs. 7-Cnty
Demographic	Children < 5	9.5%	4.0%	6.4%	6.8%	6.8%	6%	5.90%	Y	Y	Y
	Adults >=60	13.9%	17.8%	17.0%	18.5%	17.5%	19.50%	19.40%	Y	Y	N
	% People of Color	80.8%	82.1%	93.2%	94.6%	91.8%	40.8%	36.41%	Y	Y	Y
	% Non Hispanic Black	33.9%	73.5%	88.6%	91.0%	82.8%	30.90%	26.60%	Y	Y	Y
	% Hispanic	43.9%	1.4%	0.8%	1.5%	6.0%	4.2%	4.00%	Y	Y	Y
	Median Household Income*	$27K	$22K	$26K	$30K	$28K	$56K	$57K	Y	Y	N
	% Households < Poverty	20.2%	22.9%	22.1%	19.5%	20.7%	9.5%	9.10%	Y	Y	Y
	% Unemployed	12.9%	13.3%	14.4%	15.2%	15.6%	9.7%	9.2%	Y	Y	Y
	% Renters	55.3%	76.2%	48.5%	44.8%	49.0%	32.40%	31.70%	Y	Y	Y
	Median Home Value*	$44K	$83K	$45K	$55K	$51K	$122K	$130K	Y	Y	Y
	Residents >25 with < HS Diploma	39.9%	17.7%	23.9%	19.2%	23.1%	13.70%	12.70%	Y	Y	Y
Health Risk	Diesel PM (non-cancer)	1.47	1.91	1.25	1.36	1.36	1.13	1.08	Y	Y	Y
	Cancer Mortality Risk (per million)*	49.73	49.21	38.52	38.96	40.59	36.41	35.55	Y	Y	Y
	Respiratory Mortality Risk*	1.69	2.18	1.60	1.75	1.71	1.67	1.64	Y	Y	N

*Mean across census tracts in the area

Table 6-1. Vulnerability: factors that influence the health effects of exposure outlines four areas of Detroit, the City of Detroit, the tri-county area and the seven county area. For expanded Figure, please see Appendix.

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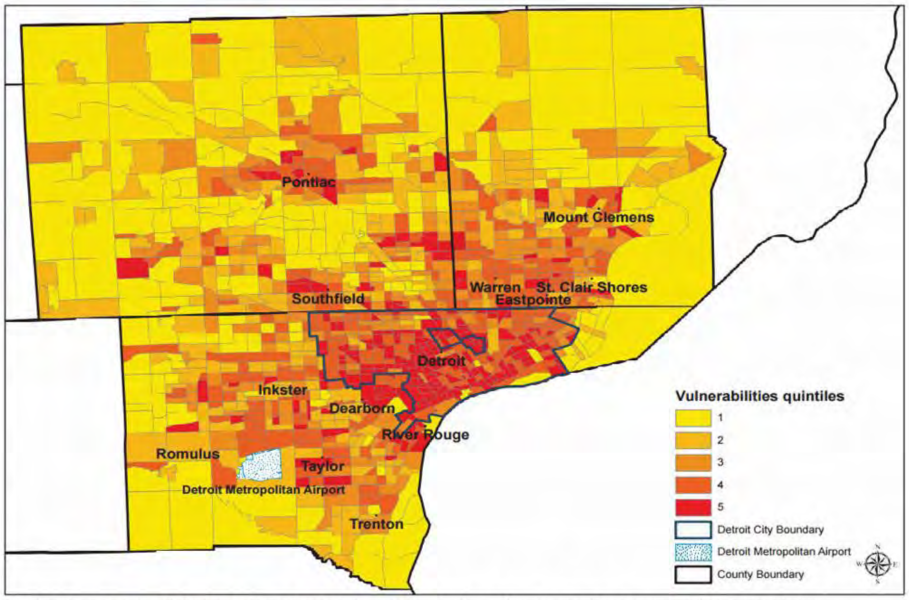
6.3 Figure 6-1. Tri-county: Vulnerable populations

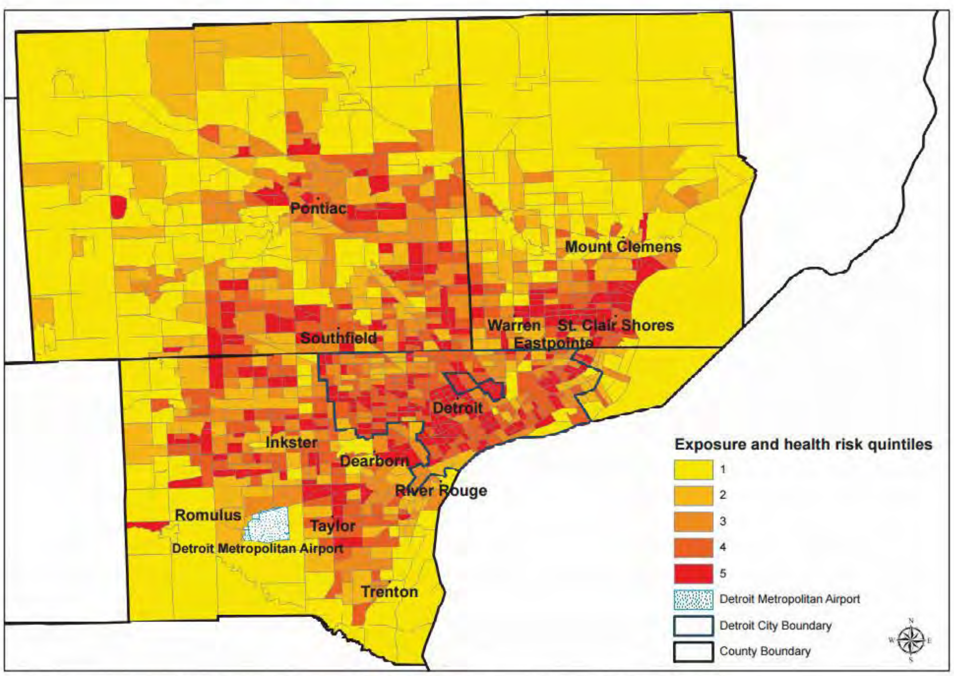
Vulnerable Populations in the Detroit Tri-County Area



Cumulative impact polygons (CI) include: residential areas, child care facilities, health care facilities, schools and playgrounds. Vulnerabilities includes: % below the national poverty level, % renters, median house value (reverse coded), % > age 24 with < high school completion, children age < 5, adults age >= 60, and linguistic isolation.

6.4 Figure 6-2. Tri-county map: Exposure and health risk

Environmental Exposure and Health Risk in the Detroit Tri-County Area



Cumulative impact polygons (CI) include: residential areas, child care facilities, health care facilities, schools and playgrounds.
Exposure and Health risk include: 2011 NATA estimates of respiratory risk, cancer risk and diesel PM (non-cancer) concentration.

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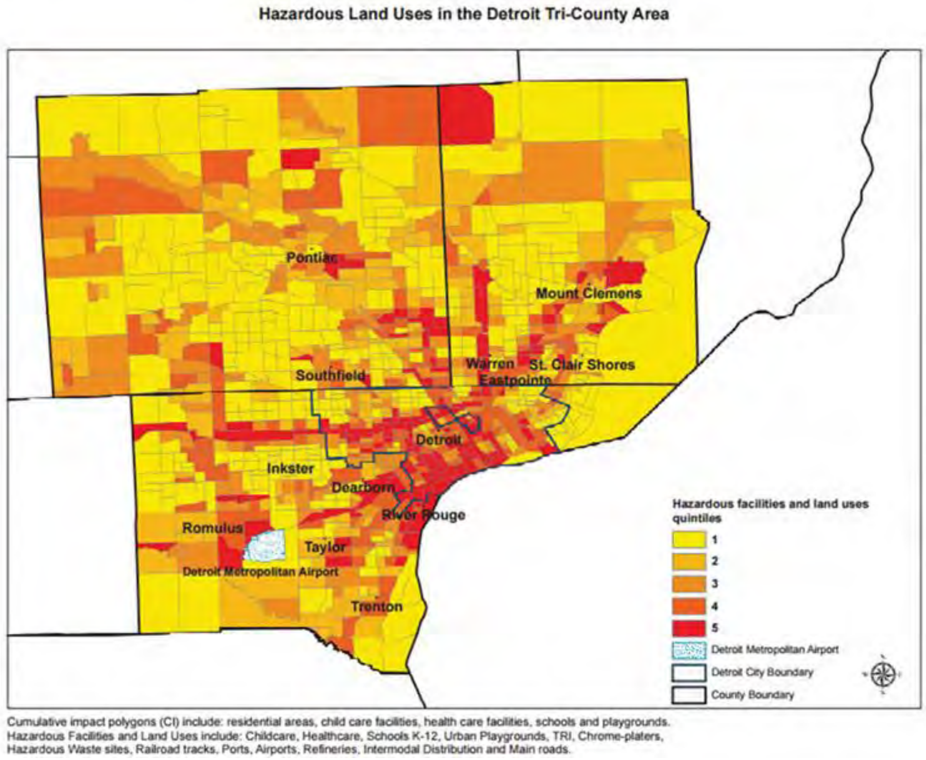
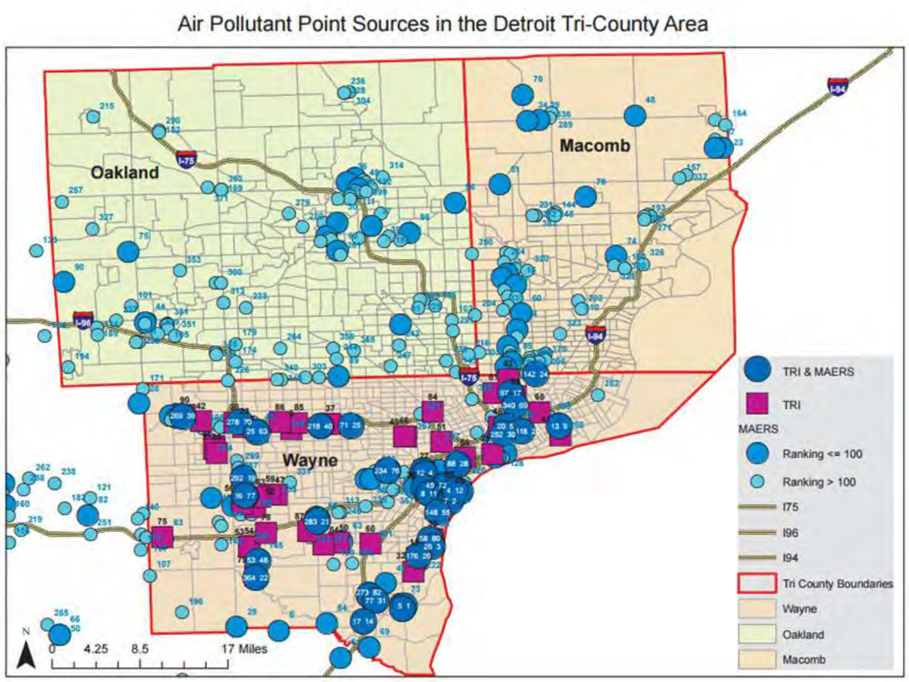
6.5 Figure 6-3. Tri-county map: Hazardous land uses in the Detroit tri-county area



6.6 Figure 6-4. Tri-county map: Toxic release inventory (TRI) sites and Michigan Air Emission Reporting System (MAERS) Sites



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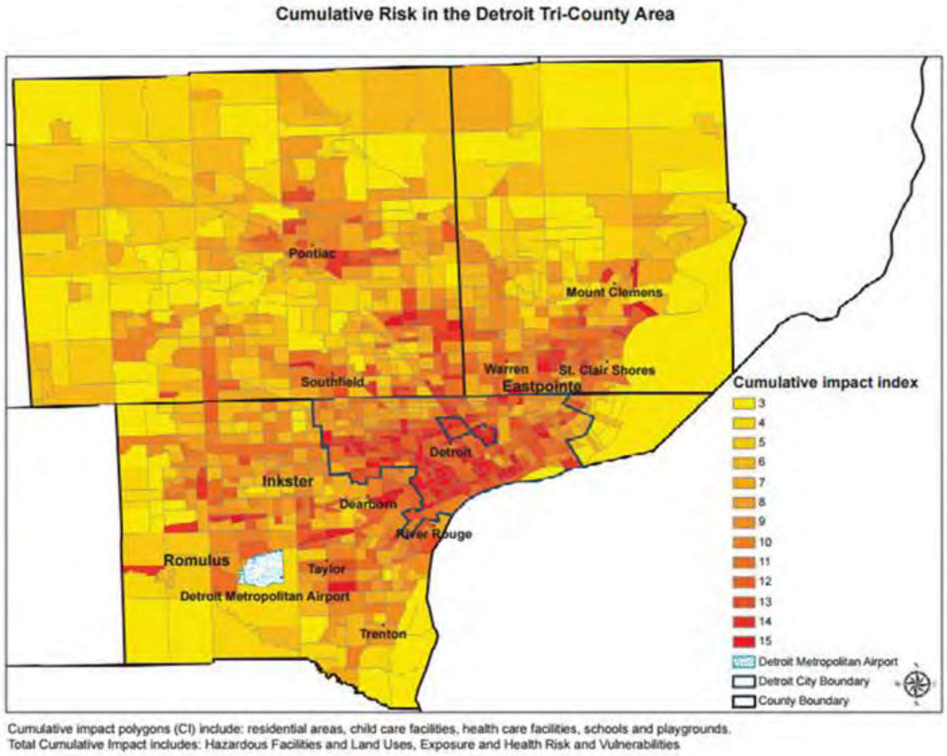
6.7 Figure 6-5. Tri-county: Cumulative risk



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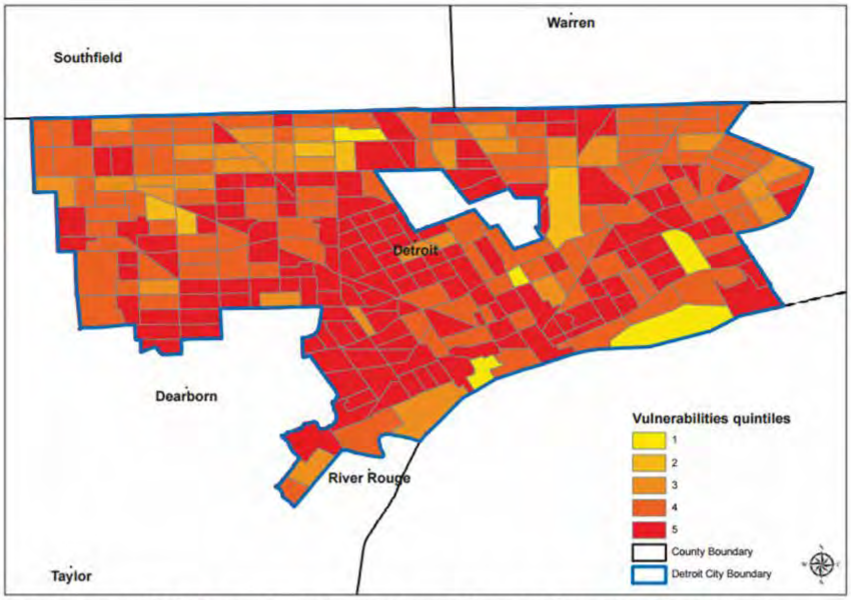
6.8 Figure 6-6. City of Detroit: Vulnerable populations

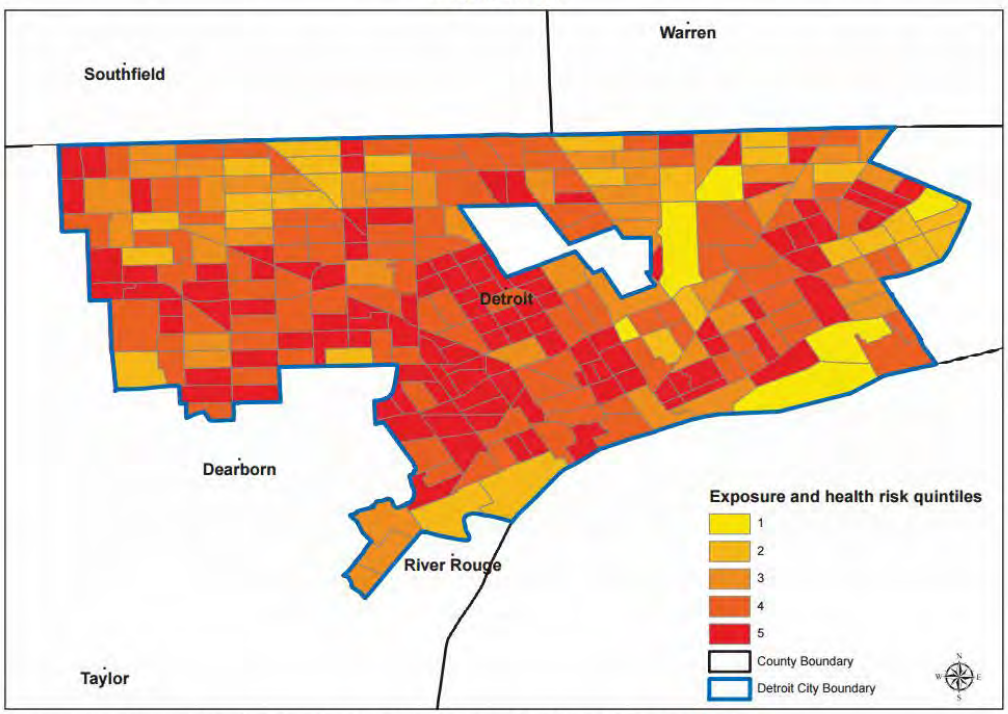
Vulnerable Populations in the City of Detroit



Cumulative impact polygons (CI) include: residential areas, child care facilities, health care facilities, schools and playgrounds. Vulnerabilities includes: % below the national poverty level, % renters, median house value (reverse coded), % > age 24 with < high school completion, children age < 5, adults age >= 60, and linguistic isolation.

6.9 Figure 6-7. City of Detroit: Exposure and health risk

Figure 3: Exposure and health risk quintile scores at the tract level (mapped on CI polygons) City of Detroit



Cumulative impact polygons (CI) include: residential areas, child care facilities, health care facilities, schools and playgrounds. Exposure and Health risk include: 2011 NATA estimates of respiratory risk, cancer risk and diesel PM (non-cancer) concentration.

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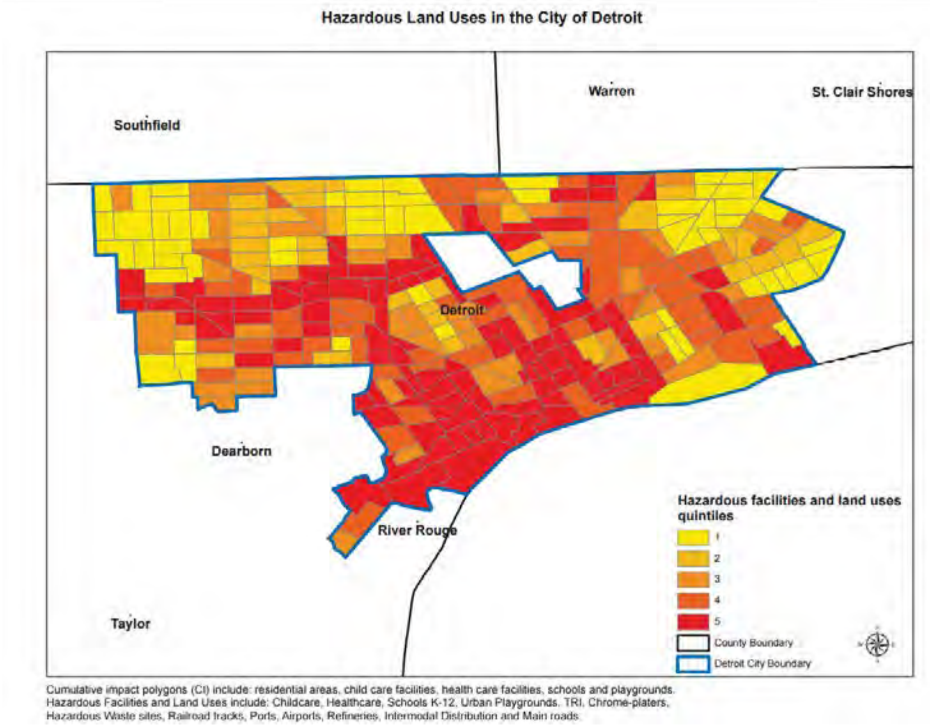
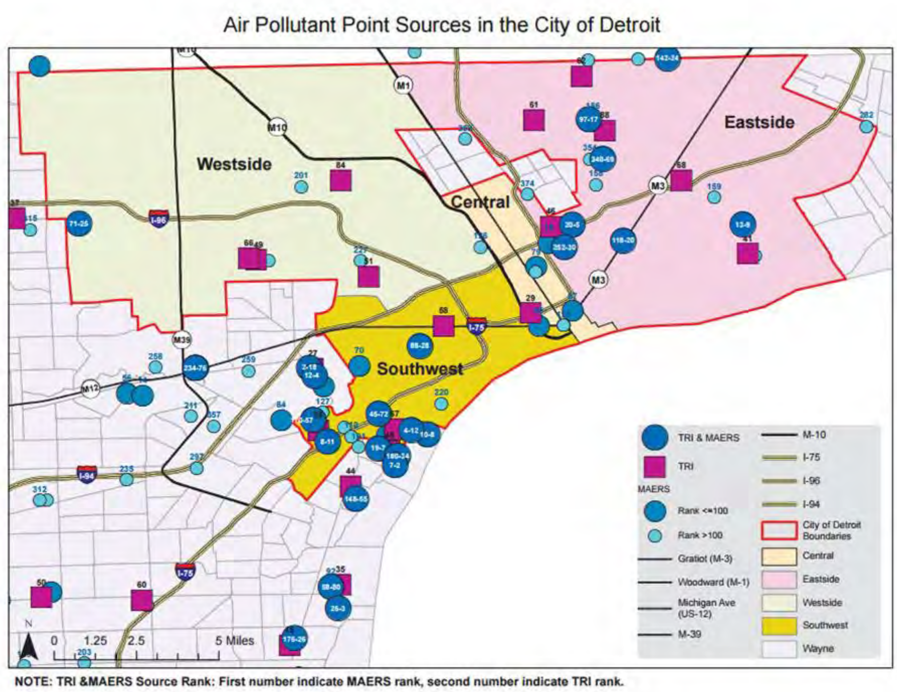
6.10 Figure 6-8. City of Detroit: Hazardous land uses



6.11 Figure 6-9. City of Detroit: Toxic release inventory (TRI) sites and Michigan Air Emission Reporting System (MAERS) Sites



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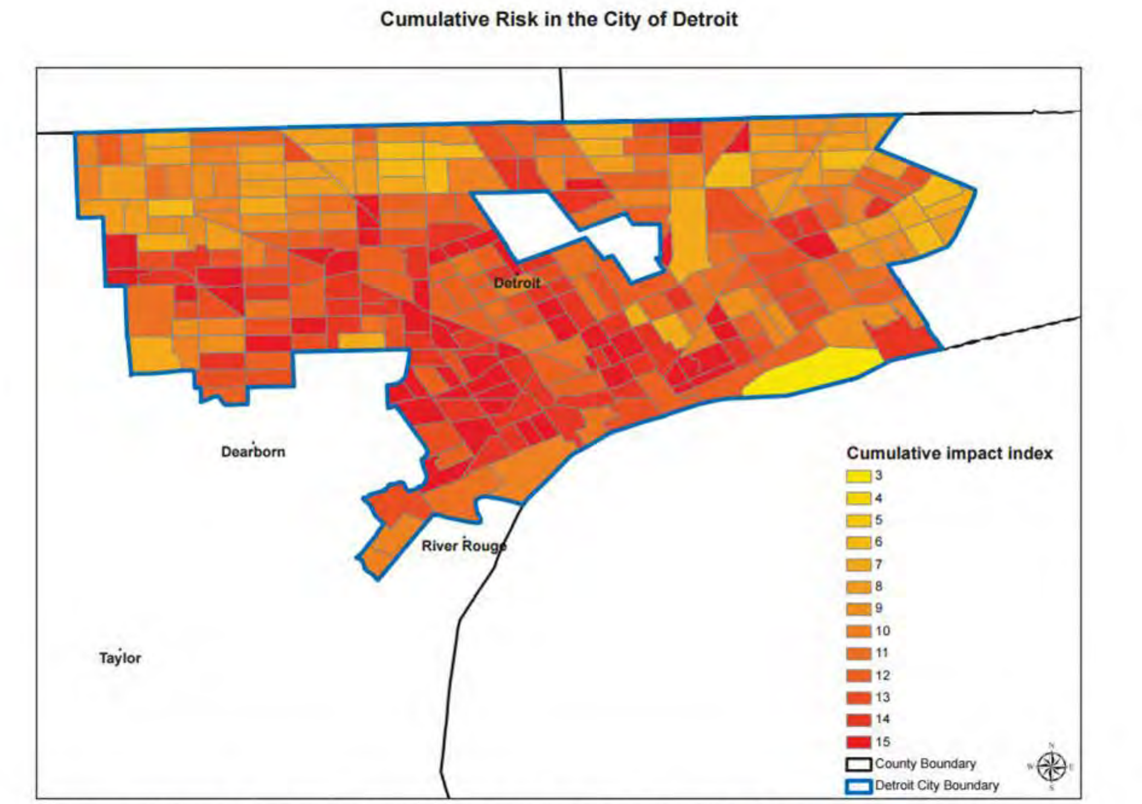
6.12 Figure 6-10. City of Detroit: Cumulative risk



Cumulative impact polygons (CI) include: residential areas, child care facilities, health care facilities, schools and playgrounds.
Total Cumulative Impact includes: Hazardous Facilities and Land Uses, Exposure and Health Risk and Vulnerabilities

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6.13 SOUTHWEST DETROIT

2016

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Tables

Figures

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6.14 Southwest Detroit

Southwest (SW) Detroit residents live near a number of large air pollution sources that can increase pollution exposures, and also experience multiple exposures in the social environment, increasing their risk of and vulnerability to adverse health outcomes. The population of SW Detroit is approximately 84,000 (see Figure 6-1, Section 6.2), and it contains several of the most densely populated areas of the city, with some areas showing population growth, and with large proportions of populations considered more vulnerable to adverse effects of air pollutants (e.g., children).[1] (See Section 6.13.3 below and Table 6-1).

Air quality monitoring in SW Detroit is described in Section 4. SW Detroit has a number of air quality monitors, including several that are source-oriented monitors designed to pick up impacts from industry, such as the Dearborn site. SW Detroit has had, and continues to have, the highest levels of SO_2, $PM_{2.5}$ and toxics pollutants that have been measured in Detroit, and in many cases, in Michigan.

Below we describe sources of air pollutants in SW Detroit, as well as population and community characteristics that may influence vulnerability to adverse effects of exposures.

6.13.1 Point sources

Table 6-2 shows point sources of pollutants located within the boundaries of Southwest Detroit. For each facility, the **Rank** indicates the rank order of this site in relation to others reporting to the Michigan Air Emissions Reporting System (MAERS), with the number "1" indicating the greatest number of pounds of emissions. Trends over time (2010-2014) are also shown, filtered to exclude some variations in emissions over time (see text in Section 4.3 for a more detailed description), as well as the **rate of change** over that same 5 year period (see text, Section 4.3).

[1] Data Driven Detroit. 2010. Population Density Map and Population Growth Maps. http://www.datadrivendetroit.org/web_ftp/Data_Mapping/Maps/BG_PopDenistySqMile.pdf and http://www.datadrivendetroit.org/web_ftp/Data_Mapping/Maps/BG_PctPopChg00to10.pdfA [Accessed 14 March 15].

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Rank	Facility	NOx			SO2			PM2.5			PM10			VOC			CO		
		5 Year Filtered Average	Note	Annual Change (%/yr)	5 Year Filtered Average	Note	Annual Change (%/yr)	5 Year Filtered Average	Note	Annual Change (%/yr)	5 Year Filtered Average	Note	Annual Change (%/yr)	5 Year Filtered Average	Note	Annual Change (%/yr)	5 Year Filtered Average	Note	Annual Change (%/yr)
8	**Marathon**	408			163		24	94.6	(3)	43	94.5			558.9		-10	128		
10	**EES Coke Battery LLC**	1193	(1)		2050	(1)		18.9	(1)		433.5	(3)		200.0	(3)		370	(1)	
38	**Detroit Wastewater Treatment**	281			56			0.1	(3)		4.7			56.1			2	(1)	
45	**St. Mary's Cement**	5			0			0.0			42.6	(1)		0.0			4		
70	**EDW Levy Co Plant**	0			0			0			12.2		-44	0.0			0		
88	**Magni Industries**	0			0			0			6.3		6	34.4		5	0		

Table 6-2: Point source emissions of conventional pollutants (tons/year) in Southwest Detroit. Excerpted from full Table 5-4. Note indicates type of variation. 1= one or two low values excluded; 2=one or two high values excluded; 3=based on last two years of data.

Health Effects: Health effects associated with exposure to the pollutants listed in Table 3-1 include increased risk of respiratory problems (e.g., asthma exacerbations and hospitalizations, COPD, cardiovascular effects). See Health Effects Table 3-1 for a complete listing. Section 5.5.3 provides quantitative estimates of health impacts from the two largest of these point sources for three pollutants: $PM_{2.5}$, NO_x, and SO_2.

Table 6-2 shows emissions of toxic air pollutants for facilities located in SW Detroit, as reported in the Toxic Release Inventory (TRI). For each facility, pounds per year of toxics reported are shown. This table shows the rank order for each facility for SW Detroit, with "1" indicating the highest emissions of toxics. The full table is shown in Section 5.2.3.

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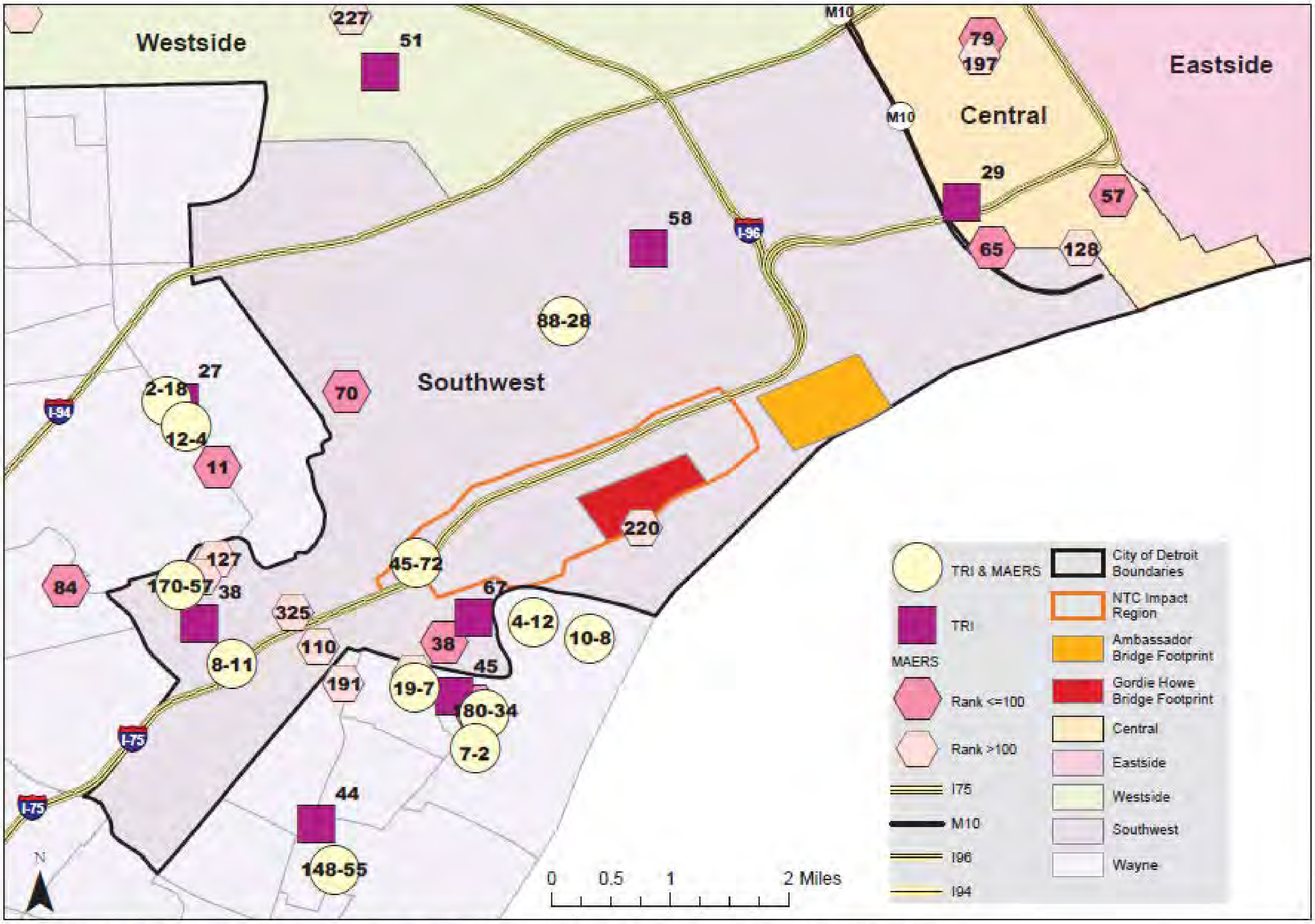
Rank	Facility	Acids	VOC	Metals and Metal Compounds	Nitrogen Compounds	Sulfur Compounds	Other
8	EES Coke Battery LLC	41754	16500	24	14246	15740	0
11	Marathon	9759	12763	101	15484	7513	21
28	Magni Industries	0	1994	719	0	0	0
38	Air Products & Chemicals INC/Detroit Hydrogen	0	55	0	3078	0	0
57	EDW C Levy Co Plant	0	0	109	0	0	0
58	Inland waters pollution control Detroit facilities	0	89	0	0	0	0
67	Superior materials 32	0	56	0	0	0	0
72	St. Mary's cement	0	0	17	0	0	0

Table 6-3: Emissions of toxics pollutants (pounds/year) by facility in Southwest Detroit by pollutant type. Average 2010-2014. In approximate rank by total TRI emissions. Excerpted from Table 5-6.

Figure 6-11 maps locations of facilities that are point sources of air pollutants located in or immediately adjacent to Southwest Detroit. Symbols indicate facilities that emit conventional air pollutants reported in the Michigan Air Emissions Reporting System (MAERS) and air toxics reported in the Toxic Release Inventory (TRI), as described in the legend. Numbers indicated for each facility reflect its ranking in the listing of MAERS emissions (Table 5-4) and the listing of toxic emissions (Table 5-7).

This work is made possible by National Institute of Health and Environmental Sciences, RO1ES022616, and the Fred A. and Barbara M. Erb Family Foundation. Additional support was provided by the Michigan Center on Lifestage Environmental Exposures and Disease (M-LEEaD), #P30ES017885.

Air Pollutant Point Sources in the City of Detroit - Southwest Region



NOTE: TRI & MAERS Source Rank: First number indicate MAERS rank, second number indicate TRI rank.

Figure 6-11: Air pollutant point sources in Southwest Detroit.

Wayne County, Michigan is currently (2015) in compliance with National Ambient Air Quality Standards for five of the six criteria pollutants (ozone, PM, NO_x, CO, lead). However, it does not meet the National Air Ambient Quality Standard (NAAQS) for sulfur dioxide (SO_2).

While many point sources in SW Detroit and the surrounding area emit SO_2, about 85% of SO_2 emissions in the county are emitted by coal-fired power plants burning coal to produce electricity. DTE Energy's River Rouge, and Trenton Channel facilities and EES Coke at U.S. Steel are all located in or adjacent to SW Detroit; DTE's Monroe facility is some distance to the south but also affects air quality in SW Detroit. Brief periods of exposure (as short as 5 minutes) to SO_2 can lead to asthma exacerbation and other serious health concerns.[2] Section 5.5.2 quantifies the health impacts of SO_2 (and other pollutants) in Detroit; Section 5.5.3 shows maps of SO_2 concentrations across Detroit. The SO_2 Fact Sheet provides more information on the health effects of SO_2.

[2] TBD

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SW Detroit residents are exposed to SO_2 and other pollutants from DTE's coal-fired power plants and from other industrial sources, see Figure 4-11. DTE Energy installed two scrubbers on its power plant located in Monroe, Michigan in 2009 and two additional scrubbers in 2015: together these scrubbers have significantly reduced emissions of SO_2 from this plant. However, scrubbers have not been added to other large SO_2 point sources affecting SW Detroit residents: the DTE River Rouge plant, the DTE Trenton Channel plant, and the EES Coke LLC Subsidiary at U.S. Steel. Together, these three plants emit 33,317 tons of SO_2 annually. As shown in Figure 4-11, SO_2 emissions from these and other facilities affect residents of SW Detroit, and SO_2 exposure has been linked with exacerbations of asthma among children living in these areas.[3] In March 2016, DTE proposed replacing 4 coal-fired boilers at DTE Trenton Channel with 5 natural gas boilers, which should significantly decrease SO_2 and $PM_{2.5}$ emissions at this facility, although the largest boiler at Trenton Channel will continue to burn coal without a scrubber.

Several other sources of SO_2, while smaller in terms of tons/year, produce localized "hotspots" of high SO_2 concentrations, most notably Carmeuse Lime. The 2015 SO_2 State Implementation Plan (SIP) designed to attain the SO_2 NAAQS in Detroit proposes to increase the stack height at this facility (from 60 to 100 feet) in order to reduce this SO_2 hotspot. (No emission reductions are anticipated at this facility.) The SIP may lower SO_2 emissions at US Steel, which also produces localized SO_2 hotspots.

Overall, SW Detroit has an unusually high density of heavy industry, including steel mills, a large refinery, coking plants, power plants, incinerators, and other large industrial emitters. In addition to SO_2 emissions, these facilities emit significant quantities of other pollutants, including $PM_{2.5}$, NO_x, volatile organic compounds, semi-volatile compounds, metals, and toxic pollutants. Many of these pollutants are not well characterized in emissions inventories.

6.13.2 Mobile sources

Mobile sources emit NO_x, $PM_{2.5}$, VOCs, CO, diesel exhaust and other pollutants, which significantly increase the exposure of SW Detroit residents to air pollutants. Emissions result when a vehicle is idling and on the road, and also when refueling. Importantly, a large truck produces considerably more emissions than a car, and trucks are responsible for a large share of both $PM_{2.5}$ and NO_x emissions. The area also contains extensive off-road sources (such as construction equipment); these are quantified in Section 5.4.

Main Sources: Major freeways, including I-75 and I-94, run through SW Detroit. In addition to local traffic, international traffic moves through SW Detroit on its way to and from Canada via the Ambassador Bridge. Sections of the freeways running through SW Detroit contain the highest traffic counts (number of vehicles per day) in the city. According to the Michigan Department of Transportation, sections of both I-75 and I-94 have average daily vehicle traffic over 100,000. The volume of average daily total vehicle traffic and daily truck traffic volume on major roadways through Southwest Detroit is shown in Table 6-4.

[3] Batterman, S. Publication TBD.

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Highway	2013 Average Daily Vehicle Traffic (cars/day)[4]	2013 Average Daily Commercial Vehicle Volume (trucks/day)[5]
I-75 (Fisher Fwy)	95,700 - 106,500	11,400 - 11,500
I-94	117,300 - 126,400	11,000
Ambassador Bridge	13412	6441
M-12	11,300 - 22,300	610 – 780
M-85 (w Fort St)	7,000 - 27,500	620 - 3,300
M-10	95,300 - 107,100	870 – 1600

Table 6-4: Average daily vehicle traffic and average daily commercial vehicle volume, Southwest Detroit

Of particular concern is the amount of commercial traffic the area receives, most of which is diesel-powered trucks and buses. Commercial traffic includes heavy duty diesel trucks that drive through SW Detroit across the Ambassador Bridge to Canada. These large vehicles produce most of the on-road mobile source emissions of $PM_{2.5}$ (See Section 5.3). In 2013, MDOT found that sections of I-75 and I-94 which run through SW Detroit have some of the heaviest commercial traffic in the entire state of Michigan, with an average 24-hour volume of truck traffic of over 10,000 trucks.[6] (See Diesel Fact Sheet: Appendix TBD). Pollutant emissions associated with traffic will shift with the construction of the Gordie Howe (formerly called the New International Trade Crossing or NITC) Bridge, to be located just 2 miles south of the Ambassador Bridge (see Figure 6-12). Government traffic projections predict traffic volume on the NITC Bridge will reach up to 10 million crossings a year by 2030. This is a 50% increase in vehicle crossings from those currently occurring on the Ambassador Bridge.[7]

Owners of the Ambassador Bridge have also petitioned to construct a second 'twin' alongside the existing bridge. The project is currently stalled awaiting permits, and it is unclear when or if construction would start.[8] Any additional bridge projects, however, would likely alter or increase truck and vehicle traffic in Southwest Detroit.

[4]MDOT (Michigan Department of Transportation). 2014. MDOT Traffic Volumes. Available: http://mdot.maps.arcgis.com/apps/Viewer/index.html?appid=18a4b2f2ba3b4e079e935f8835862c73 [Accessed 17 March 15].

[5] MDOT (Michigan Department of Transportation). 2014. MDOT Traffic Volumes. Available: http://mdot.maps.arcgis.com/apps/Viewer/index.html?appid=18a4b2f2ba3b4e079e935f8835862c73 [Accessed 17 March 15].

[6] Michigan Department of Transportation. 2013. Commercial ADT Maps. Available: http://www.michigan.gov/mdot/0,4616,7-151-11151_11033_11149_11162-30009--,00.html [Accessed 17March 15].

[7] Gallagher, J. 2011. Future Traffic A Key Rumble in the Bridge Debate. Detroit Free Press. Available: http://archive.freep.com/article/20110713/BUSINESS04/107130399/Future-traffic-key-rumble-bridge-debate [Accessed 19 March 15].

[8] Spangler, T. 2016. Approval for new bridge span could come in March. Available: http://www.freep.com/story/news/local/michigan/2016/01/04/approval-new-bridge-span-could-come-march/78278380/ [Accessed 4 April 2016].

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Health Effects: Substantial health effects have been demonstrated for people who live, work, or go to school near major freeways. In particular, those who live within about 150 meters (about 500 feet) of roadways with high volumes of traffic, and in particular, diesel truck traffic, experience increased risk of respiratory and cardiovascular health effects. Health impacts from on-road traffic is quantified in Section 5.5.4. See Health Effects Table 3-1 for greater detail. Approximately 69,000 persons (about 10% of Detroit's population) lives within 150 meters of such heavily trafficked roadways.

Vehicles and the related infrastructure (e.g., fuel distribution facilities) are among the largest emitters of NO_x and VOCs in the urban area. In summer, the NO_x emitted by vehicles and other sources combines with VOC emissions from vehicles and other sources to produce ground-level ozone (O_3), another pollutant which is harmful to health. Currently, O_3 levels in Detroit are very close to the new (2015) National Ambient Air Quality Standard for O_3. Section 4.3 provides further information on O_3 trends in Detroit.

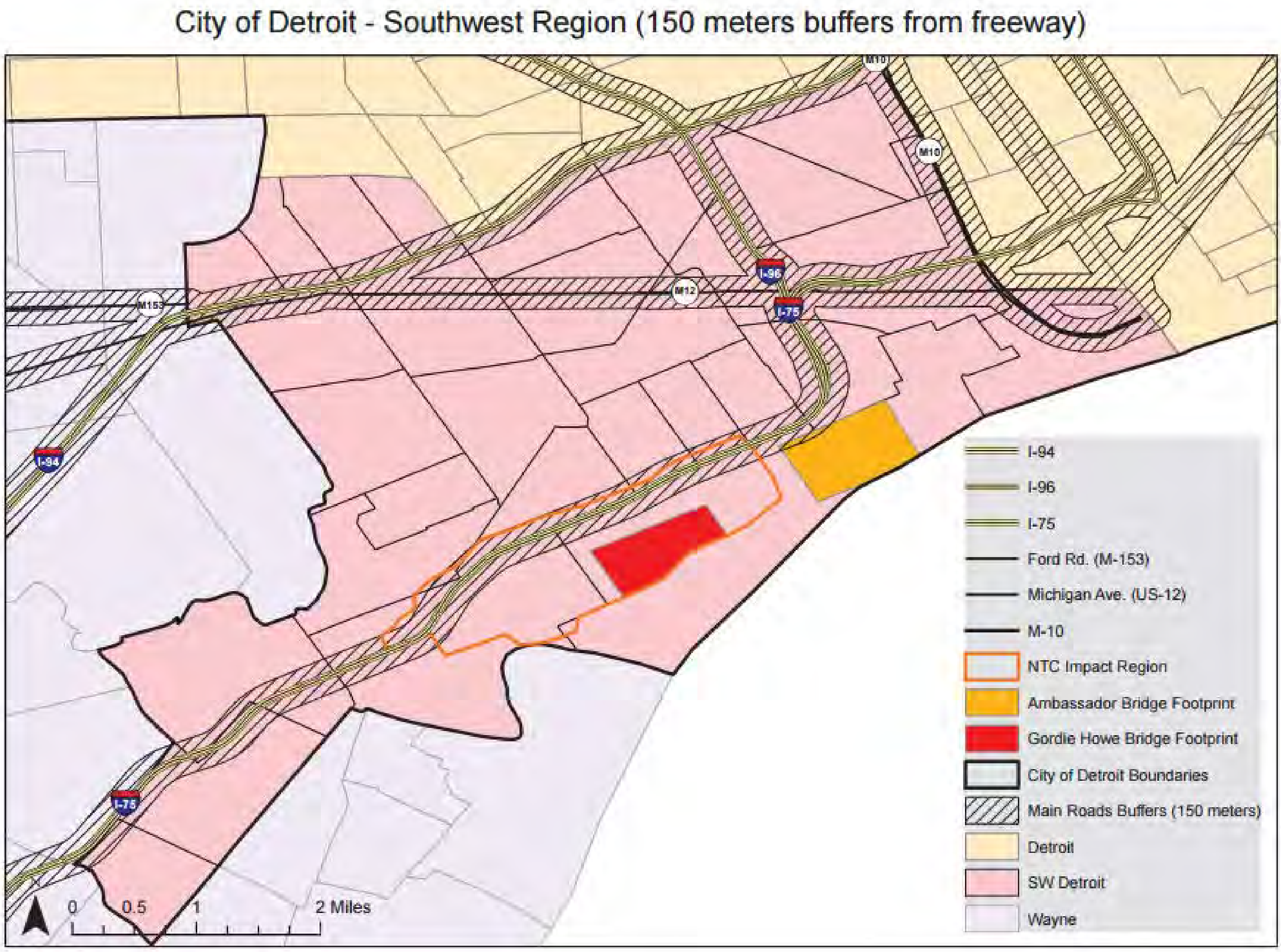

Figure 6-12: 150 meter roadway buffers in Southwest Detroit

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6.13.3 Vulnerability

As described in Section 6, some communities or individuals may be more vulnerable to the adverse effects of exposure to air pollutants because they are exposed to higher levels, or because they are more adversely affected by exposure than others. Low income communities and communities of color are disproportionately likely to be exposed to high levels of air pollutants. Existing health conditions, low levels of some nutrients in the diet, young age, older age, and poor housing condition can increase the severity of health effects from exposure to air pollutants. As shown in Table 6-1, residents of Southwest Detroit are more likely to be exposed to higher levels of diesel PM and have higher cancer mortality risk than the city as a whole, or than the surrounding tri-county area.

In addition, SW Detroit has a higher percentage of children (9.5%), an age group that is particularly vulnerable to adverse health effects associated with exposure to air pollutants, than other areas of the City. SW Detroit has a large proportion of Hispanic/Latino residents (43%), who may experience particular stressors associated with immigration surveillance. 39.9% of SW Detroit residents age 25 and over have less than a high school diploma, and a greater proportion of the population of this area of the city rent rather than own their homes. Young age, and living in rental properties are associated with increased health risks associated with exposure to air pollutants. See Figures 6-5 and 6-10 for maps showing the Cumulative Vulnerability Index for census tracts in the Tri-County Area and Detroit, respectively.

6.13.4 Cumulative risk

Figure 6-13 maps the Cumulative Risk Index for census tracts in Southwest Detroit, along with point sources of conventional air pollutants (MAERS) and toxics (TRIs), major freeways traveling through the area, and the footprints of the existing Ambassador Bridge and the proposed Gordie Howe International Bridge.

The cumulative risk score is the sum of three indices assessing proximity of population to hazardous land uses (e.g., railyards, freeways), exposure to air pollutants and associated health risks (e.g., diesel PM, respiratory risk, cancer risk), and vulnerabilities (e.g., percent below poverty, percent children under age 5). Briefly, these are calculated by rank ordering census tracts in the Tri-County area by each indicator, and constructing quintiles with 1=low and 5=high exposure or vulnerability. The sum of the risk and vulnerability scores creates a cumulative risk score ranging from 3 (lowest cumulative risk) to 15 (highest cumulative risk).[9] Note that all census tracts in SW Detroit fall into the upper ranges of risk (darker oranges and reds) when ranked against all census tracts in the Tri County Area (Figure 6-6).

[9] Schulz AJ, Mentz GB, Sampson N, Ward M, Anderson R, deMajo R, et al. 2016. RACE AND THE DISTRIBUTION OF SOCIAL AND PHYSICAL ENVIRONMENTAL RISK: A Case Example from the Detroit Metropolitan Area. DuBois Review. In Press.

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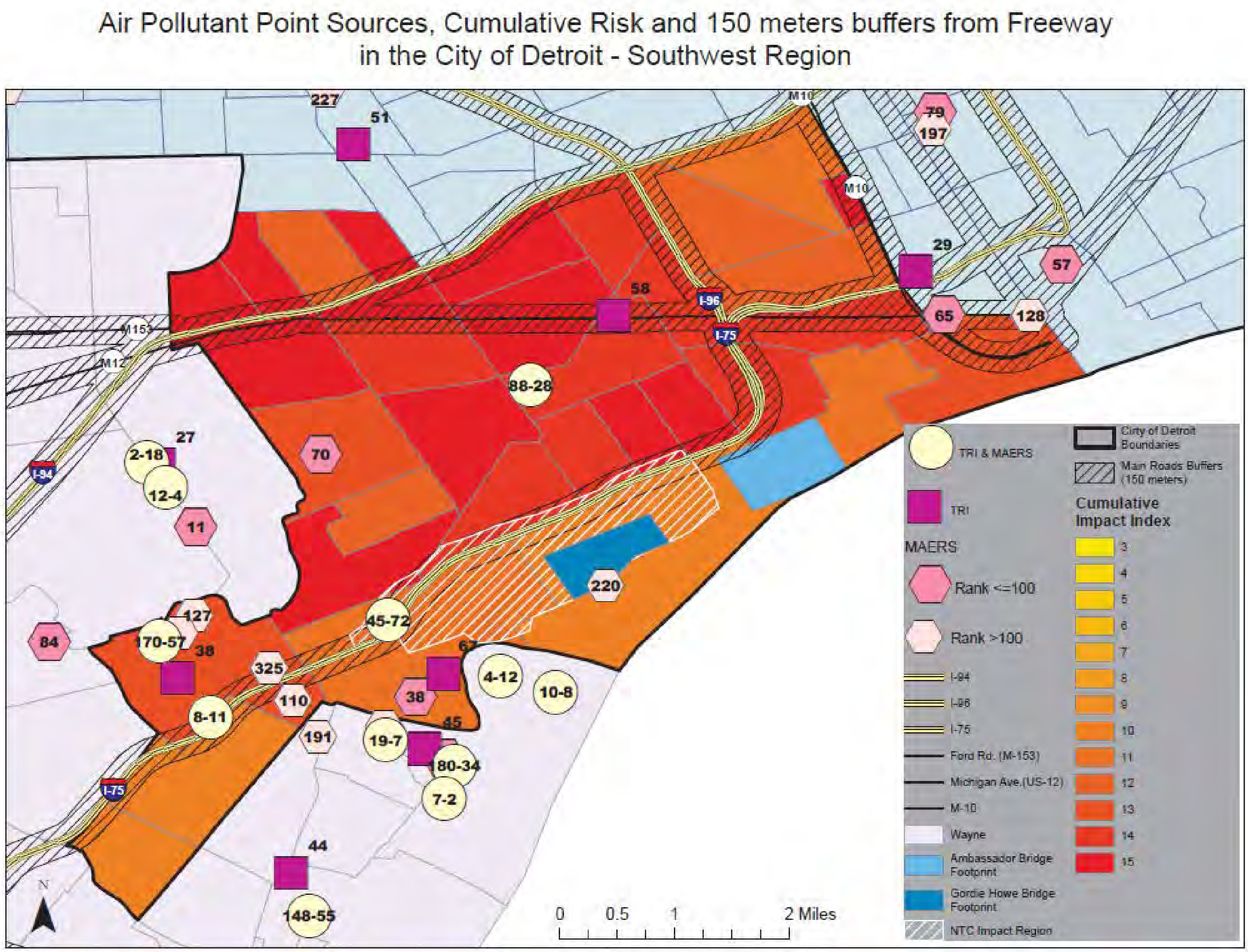

NOTE: TRI & MAERS Source Rank: First number indicate MAERS rank, second number indicate TRI rank.
Cumulative impact polygons (CI) include: residential areas, child care facilities, health care facilities, schools and playgrounds.
Total Cumulative Impact includes: Hazardous Facilities and Land Uses, Exposure and Health Risk and Vulnerabilities

Figure 6-13: Cumulative risk index, 150 meter roadway buffers, MAERS and TRI emission sources in SW Detroit.

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6.14 CENTRAL DETROIT

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Tables

Figures

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6.14 Central Detroit

Residents of Central Detroit residents live near several pollution sources that can increase pollution exposures, and also experience multiple exposures in the social environment that increase their risk of and vulnerability to adverse health outcomes. Central Detroit is home to approximately 29,000 residents. (See Section 6.14.3 below and Table 6-1).

Air quality monitoring in Central Detroit is described in Section 4. Below we describe pollutant sources of exposure for Eastside Detroit residents, along with a description of population and community characteristics that may influence vulnerability to adverse effects of exposures.

6.14.1 Point Sources

Table 6-5 shows point sources of pollutants located within the boundaries of Central Detroit. For each facility, the **Rank** indicates the rank order of this site in relation to others reporting to the Michigan Air Emissions Reporting System (MAERS), with 1 indicating the greatest number of pounds of emissions. Trends over time (2010-2014) are also shown, filtered to exclude some variations (see text in Section 4.3 for a more detailed description), as well as the **rate of change** over that same 5 year period (see text, Section 4.3). There are also several sources of pollution located outside of Central Detroit that contribute to pollutant levels, including coal fired power plants located downwind (see Figures 5-5A-5-7L, for example).

		NOx			SO2			PM2.5			PM10			VOC			CO		
Rank	Facility	5 Year Filtered Average	Note	Annual Change (%/yr)	5 Year Filtered Average	Note	Annual Change (%/yr)	5 Year Filtered Average	Note	Annual Change (%/yr)	5 Year Filtered Average	Note	Annual Change (%/yr)	5 Year Filtered Average	Note	Annual Change (%/yr)	5 Year Filtered Average	Note	Annual Change (%/yr)
57	Beacon Heating Plant	96	(1)	-30	0	(1)		4.6	(1)		4.6	(1)		3.7	(1)		48	(1)	
65	Walsh-Higgins IRS Computer Center	0	(1)	-99	0	(1)		0	(1)		0	(1)	-99	0			0	(1)	-99
79	Wayne State University	37		-4	1		14	3.0		-7	3.9			2.2		-6	32		-7

Table 6-5: Point Source Emissions of Conventional Pollutants (tons/year) in Central Detroit.

Table 6-5 shows 5-year average emissions (filtered to exclude some variations, see text in Section 4.3), and rate of change over 5 year period (see text in Section 4.3). Excerpted from full Table 5-4.

Health Effects: Health effects associated with exposure to the pollutants in Table 3-1 include increased risk of respiratory problems (e.g., asthma exacerbations and hospitalizations, COPD, cardiovascular effects). See Health Effects Table 3-1 for a complete listing. Section 5.5.3 provides quantitative estimates of health impacts from several of these point sources for three pollutants: $PM_{2.5}$, NO_x, and SO_2.

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Rank	Facility	Acids	VOC	Metals and Metal Compounds	Nitrogen Compounds	Sulfur Compounds	Other
29	**Difco Laboratories Inc**	0	1227	0	0	0	0

Table 6-6: Emissions of Toxics (pounds/year) by facility in Central Detroit by pollutant type. Average 2010-2014. In approximate rank by total TRI emissions. Excerpted from Table 5-6.

Table 6-6 shows emissions of toxic air pollutants by facility located in Central Detroit, as reported in the Toxic Release Inventory (TRI). For each facility, pounds per year of toxics reported are shown. This table shows the rank order for each facility for SW Detroit, with 1 indicating the highest emissions. The full table is shown in Section 5.2.3.

Figure 6-14 maps locations of facilities that are point sources of air pollutants located in or immediately adjacent to Southwest Detroit. Symbols indicate facilities that emit conventional air pollutants reported in the Michigan Air Emissions Reporting System (MAERS) and air toxics reported in the Toxic Release Inventory (TRI), as described in the legend. Numbers indicated for each facility reflect its ranking in the listing of MAERS emissions (Table 5-6) and the listing of toxic emissions (Table 5-7).

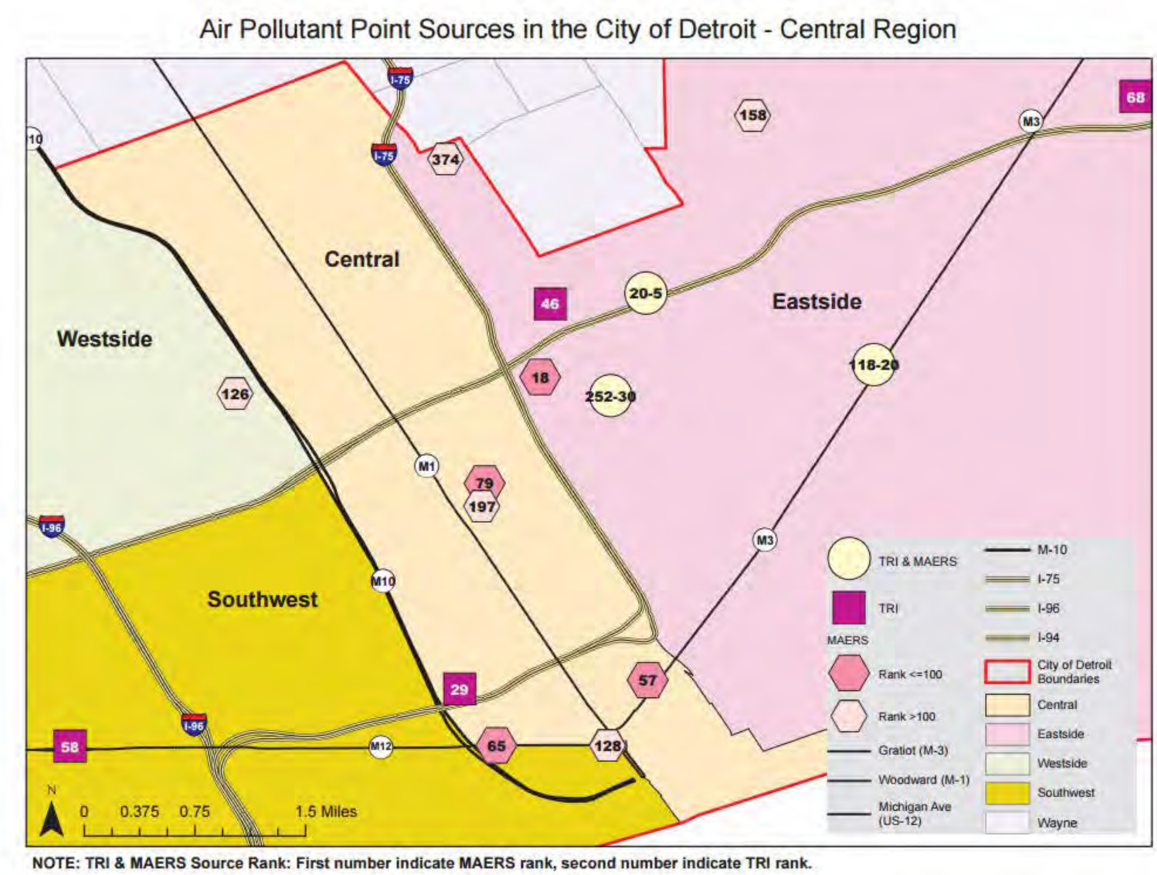

Figure 6-14: Air Pollutant Point Sources in Central Detroit.

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Section 5.5.2 quantifies health impacts of SO_2, $PM_{2.5}$ and NO_x in Detroit, and includes maps showing concentrations of each of these pollutants across Detroit.

6.14.2 Mobile Sources

Mobile sources emit NO_x, $PM_{2.5}$, VOCs, CO, and diesel exhaust, which significantly increase the exposure of Central Detroit residents to air pollutants. Emissions result when a vehicle is idling and on the road, and also when refueling. Importantly, a large truck produces considerably more emissions than a car, and trucks are responsible for a large share of both $PM_{2.5}$ and NO_x emissions. The area also contains extensive off-road sources; these are quantified in Section 5.4.

Main Sources: Major highways, including M-1 (Woodward Avenue), M-10 (John C. Lodge Freeway), I-94 (Edsel Ford Freeway), and I-75/I-375 (Chrysler Freeway) run through and around Central Detroit. The sections of highway that pass through Central Detroit are some of the most heavily trafficked in the city. According to Michigan Department of Transportation (MDOT) data, I-75, I-94, and M-10 have average daily traffic volumes of over 100,000 vehicles.[1] These highways also host large amounts of commercial truck traffic. In 2013, I-94 and I-75 both had an average of more than 10,000 trucks per day.[2] Emissions from commercial truck traffic, which include particulate matter from burned diesel fuel, are of particular concern due to adverse effects on human health. These large vehicles produce most of the on-road mobile source emissions of $PM_{2.5}$ (See Section 5.3).

Highway	2013 Average Daily Vehicle Traffic (cars/day)[3]	2013 Average Daily Truck Volume (trucks/day)[4]
I-75/I-375 (Chrysler Fwy)	133,000 – 162,200	Approx. 10,500
I-94	136,200 – 144,100	6,700 – 11,000
M-10 (John C. Lodge Fwy)	95,300 – 132,900	1,001 – 5000
M-1 (Woodward Ave)	17,700 – 20,700	301 – 1000

Table 6-7: Average Daily Vehicle Traffic and Average Daily Truck Volume, Central Detroit

Health Effects: Substantial health effects have been demonstrated for people who live, work, or go to school near major freeways. In particular, those who live within about 150 meters (about 500 feet) of roadways with high volumes of traffic, and in particular, diesel truck traffic, experience increased risk of respiratory and cardiovascular health effects. See Health Effects Table 3-1 greater detail. Approximately 69,000 (about 10%) of Detroit's population lives within 150 meters of such heavily trafficked roadways

[1] MDOT (Michigan Department of Transportation). 2014. MDOT Traffic Volumes. Available: http://mdot.maps.arcgis.com/apps/Viewer/index.html?appid=18a4b2f2ba3b4e079e935f8835862c73 [Accessed 17 March 15].

[2] MDOT (Michigan Department of Transportation). 2014. MDOT Traffic Volumes. Available: http://mdot.maps.arcgis.com/apps/Viewer/index.html?appid=18a4b2f2ba3b4e079e935f8835862c73 [Accessed 17 March 15].

[3] MDOT (Michigan Department of Transportation). 2014. MDOT Traffic Volumes. Available: http://mdot.maps.arcgis.com/apps/Viewer/index.html?appid=18a4b2f2ba3b4e079e935f8835862c73 [Accessed 17 March 15].

[4] MDOT (Michigan Department of Transportation). 2014. MDOT Traffic Volumes. Available: http://mdot.maps.arcgis.com/apps/Viewer/index.html?appid=18a4b2f2ba3b4e079e935f8835862c73 [Accessed 17 March 15].

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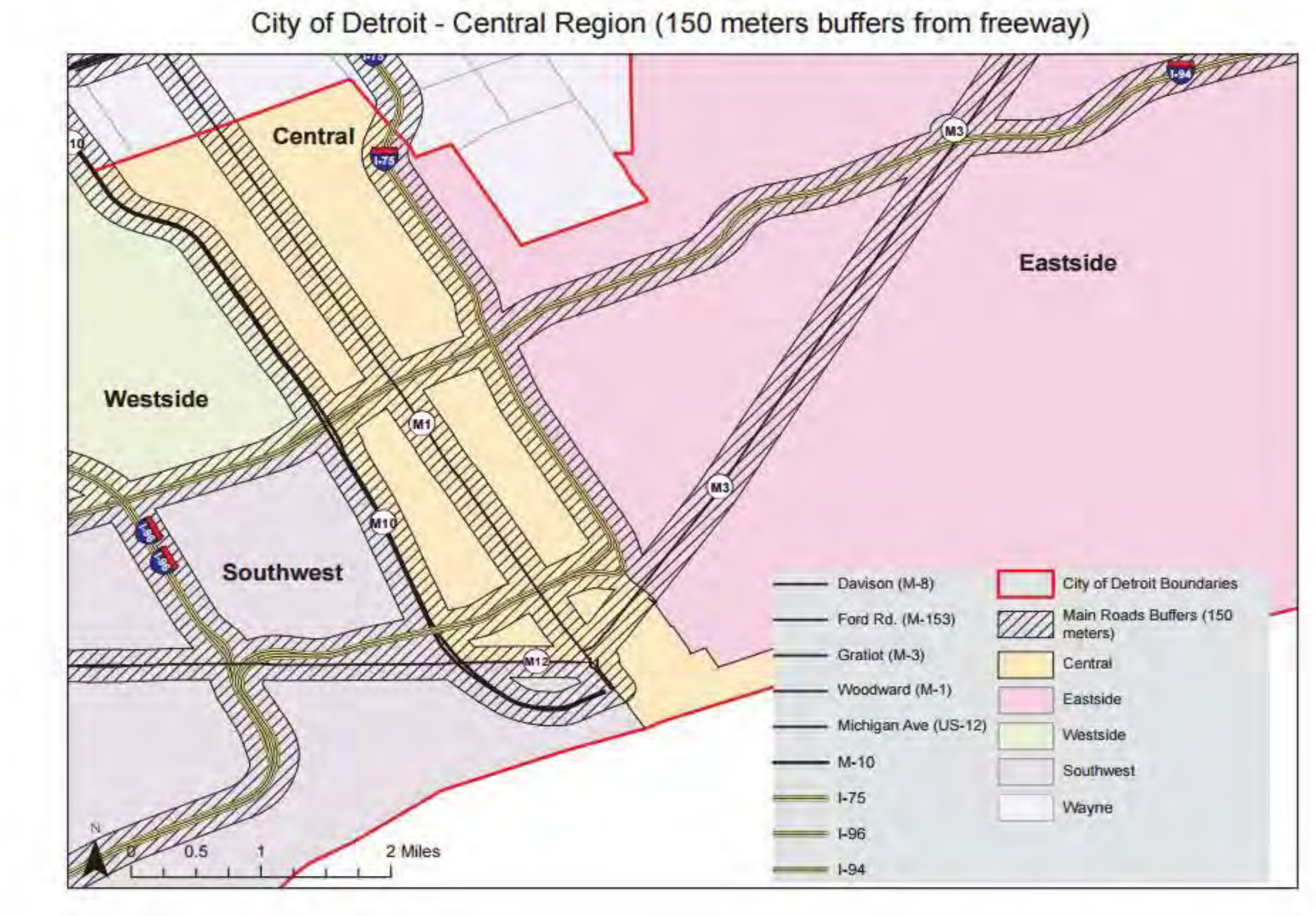

Figure 6-15: 150 Meter Roadway Buffers in Central Detroit

6.14.3 Vulnerability

Some communities or individuals may be more vulnerable to the adverse effects of exposure to air pollutants. Existing health conditions, low levels of some nutrients in the diet, young age, older age, and poor housing condition can place people at increased risk of exposure to air pollutants. As shown in Table 6-1, residents of Central Detroit are more likely to be exposed to higher levels of Diesel PM and have higher cancer mortality risk than the Tri-County Area.

Central Detroit has a larger proportion of people of color (82%) compared with the Tri-County Area, and a larger proportion of renters (76%) which may increase health risks associated with exposure to air pollutants. A greater proportion of residents of Central Detroit have completed high school (83%) and a smaller proportion of households have children under the age of 5 (4%) compared with other areas of the city, or with the Tri County Area. Figures 6-5 and 6-10 for maps show the Cumulative Vulnerability Index for census tracts in the Tri-County Area and Detroit, respectively, including the Central Detroit area.

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6.14.4 Cumulative Risk

Figure 6-16 shows the cumulative risk scores for residents of Central Detroit, along with point and mobile pollutant sources. Cumulative risk is the sum of three indices assessing proximity of population to hazardous land uses (e.g., railyards, freeways), exposure to air pollutants and associated health risks (e.g., Diesel PM, respiratory risk, cancer risk), and vulnerabilities (e.g., percent below poverty, percent children under age 5). Briefly, these are calculated by rank ordering census tracts in the Tri-County area by each indicator, and constructing quintiles with 1=low and 5=high exposure or vulnerability. The sum of the risk and vulnerability scores creates a cumulative risk score ranging from 3 (lowest cumulative risk) to 15 (highest cumulative risk). Note that all census tracts in Central Detroit fall into the upper ranges of risk (darker oranges and reds) when ranked against all census tracts in the Tri County Area Figure 6-6. See Appendix (TBD) for a more complete description of the methods for constructing the cumulative risk scores.

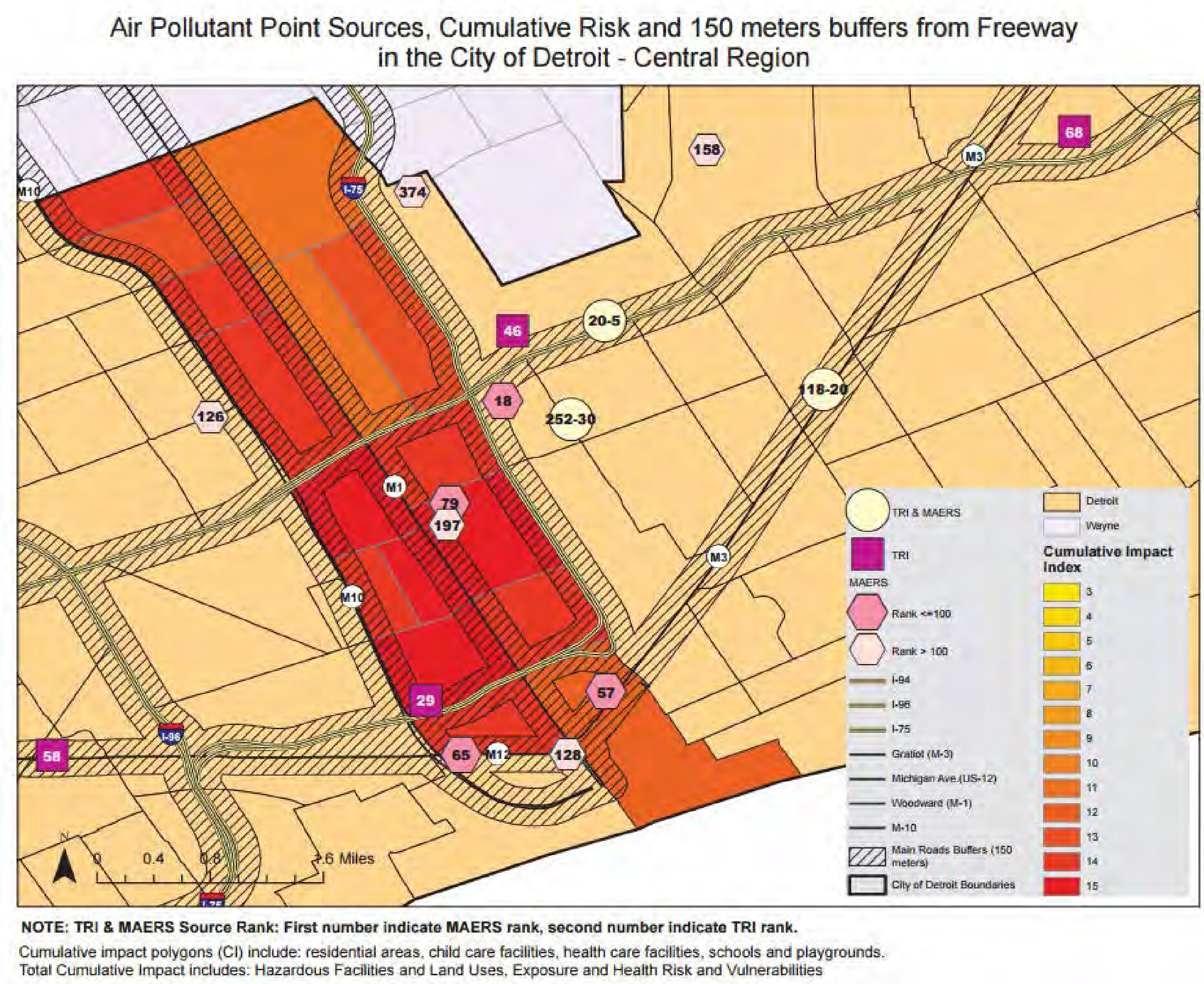

Figure 6-16: Cumulative Risk, 150 Meter Roadway Buffers, Pollutant Sources in Central Detroit.

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6.15 WESTSIDE DETROIT

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Tables

Figures

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6.14 Westside Detroit

Residents of Detroit's Westside live near several air pollution sources that affect pollution exposures, and also experience exposures in the social environment that may increase their risk of and vulnerability to adverse health effects of pollutant exposures. Approximately 350,000 people live on Detroit's Westside. (See Section 6.15.3 below and Table 6-1).

Air quality monitoring in Westside Detroit is described in Section 4. Below we describe pollutant sources of exposure for Westside Detroit residents, along with a description of population and community characteristics that may influence vulnerability to adverse effects of exposures.

6.14.1 Point sources

Table 6-8 shows that one facility with point sources of pollutants (listed in MAERS) is located within the boundaries of Detroit's Westside (see Table 6-8). Its **Rank** indicates the rank order of this site in relation to others reporting to the Michigan Air Emissions Reporting System (MAERS), with the number "1" indicating the greatest number of pounds of emissions based on the five year average tons of emissions. **Five-year average emissions** (2010-2014) are also shown, filtered to exclude some variations (see text in Section 4.3 for a more detailed description), as well as the **rate of change** over that same 5 year period (see text, Section 4.3).

Rank	Facility	NOx			SO2			PM2.5			PM10			VOC			CO		
		5 Year Filtered Average	Note	Annual Change (%/yr)	5 Year Filtered Average	Note	Annual Change (%/yr)	5 Year Filtered Average	Note	Annual Change (%/yr)	5 Year Filtered Average	Note	Annual Change (%/yr)	5 Year Filtered Average	Note	Annual Change (%/yr)	5 Year Filtered Average	Note	Annual Change (%/yr)
71	**Detroit Diesel Corporation**	55	(1)	-31	7		-9	2		-10	3		-8	13.6			32		-8

Table 6-8: Point source emissions of conventional pollutants (tons/yr) in Westside Detroit.

Shows 5-year average emissions (filtered to exclude some variations, see text in section 1.3), and rate of change over 5 year period (see text). Excerpted from full Table 5-4.

Health Effects: Health effects associated with exposure to pollutants in Table 3-1, include increased risk of respiratory problems (e.g., asthma exacerbations and hospitalizations, COPD, cardiovascular effects). See Health Effects Table 3-1 for a complete listing. Section 5.5.3 provides quantitative estimates of health impacts from the two largest of these point sources for three pollutants: $PM_{2.5}$, NO_x, and SO_2.

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Rank	Facility	Acids	VOC	Metals and Metal Compounds	Nitrogen Compounds	Sulfur Compounds	Other
25	**Detroit Diesel Corp, Redford Facility**	0	384	0	0	0	12630
49	**Houghton International Inc**	0	0	0	0	0	1073
51	**Park Metallurgical Corp**	0	0	24	533	0	0
66	**PVS Nolwood Chemicals Inc**	163	8	10	8	0	29
84	**DCI Aerotech**	0	0	0	7	0	0

Table 6-9: Emissions of toxic pollutants (pounds/year) by facility in Westside Detroit by pollutant type. Average 2010-2014. In approximate rank by total TRI emissions.

Table 6-9 shows emissions of toxic air pollutants by facility located in Westside Detroit, as reported in the Toxic Release Inventory (TRI). For each facility, pounds per year of toxics reported are shown. This table shows the rank order for each facility located in Westside Detroit, with the number "1" indicating the highest emissions. The full table is shown in Section 5.2.3.

Figure 6-17 maps locations of facilities that are point sources of air pollutants located in or immediately adjacent to Westside Detroit. Symbols indicate facilities that emit conventional air pollutants reported in the Michigan Air Emissions Reporting System (MAERS) and air toxics reported in the Toxic Release Inventory (TRI), as described in the legend. Numbers indicated for each facility reflect its ranking in the listing of MAERS emissions (Table 5-6) and the listing of toxic emissions (Table 5-7).

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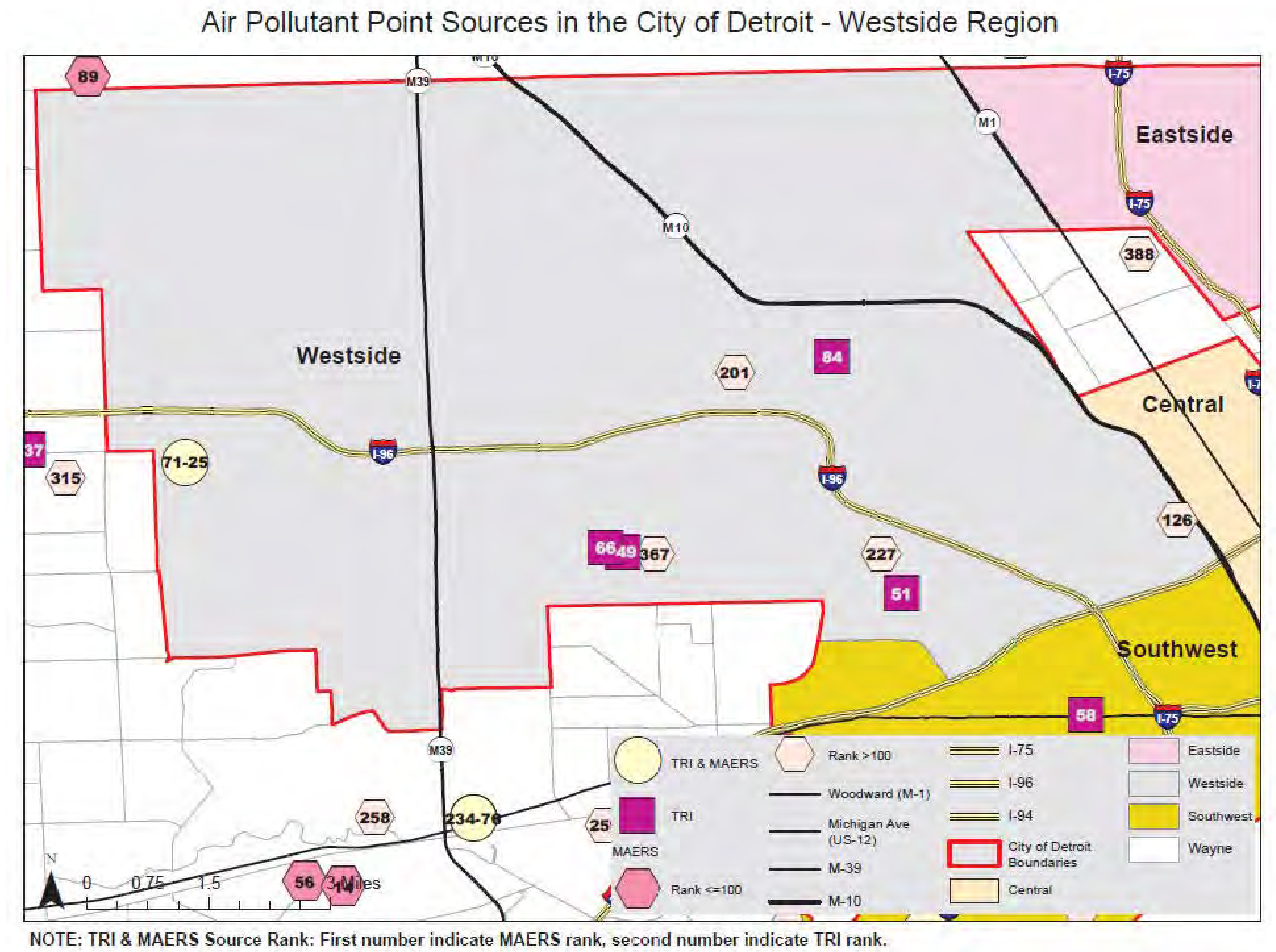

Figure 6-17: Air pollutant point sources in Westside Detroit.

Many other point sources located outside Westside Detroit affect air quality in this area. Impacts of these sources are shown in Section 5.5, and Section 5.5.2 quantifies the health impacts of SO_2, $PM_{2.5}$, and NO_x in Detroit.

6.14.2 Mobile sources

Mobile sources emit NO_x, $PM_{2.5}$, VOCs, CO, diesel exhaust and other pollutants, which significantly increase the exposure of Westside Detroit residents to air pollutants. Emissions result when a vehicle is idling and on the road, and also when refueling. Importantly, a large truck produces considerably more emissions than a car, and trucks are responsible for a large share of both $PM_{2.5}$ and NO_x emissions. The area also contains extensive off-road sources; these are quantified in Section 5.4.

Main Sources: Major freeways, including I-96, M-39 (Southfield Freeway), and M-10 (John C Lodge Freeway), US-24 (Telegraph Road), and M-5 (Grand River Avenue) run through Westside Detroit. Sections of highway are heavily trafficked. According to Michigan Department of Transportation (MDOT) data, I-96, M-39 and M-10 all

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experience daily vehicle volumes of over 90,000 cars per day.[1] There is also heavy truck traffic on some sections of highways in the Westside area. Both I-96 and M-39 in the Westside section have average daily commercial volumes of 4,000-5,000 trucks per day.[2] Emissions from commercial traffic, which can include diesel exhaust and $PM_{2.5}$, can be particularly harmful to human health and are of particular concern. These large vehicles produce most of the on-road mobile source emissions of $PM_{2.5}$. (see Section 5.3).

Highway	2013 Average Daily Vehicle Traffic (cars/day)[3]	2013 Average Daily Truck Volume (trucks/day)[4]
I-96	99,600 - 157,200	5,400 - 5,600
M-39 (Southfield Fwy)	91,800 - 151,800	4,400 - 5,000
M-10 (John C Lodge Fwy)	93,000 - 134,100	1,600 - 2,200
US-24 (Telegraph Rd)	58,300 - 83,500	710 - 1,800
M-5 (Grand River Ave)	7,700 - 23,100	380 – 410

Table 6-10: Average Daily Vehicle Traffic and Average Daily Truck Volume, Westside Detroit

Health Effects: Substantial health effects have been demonstrated for people who live, work, or go to school near major freeways. In particular, those who live within about 150 meters (about 500 feet) of roadways with high volumes of traffic, and in particular, diesel truck traffic, experience increased risk of respiratory and cardiovascular health effects. Health impacts from on-road traffic is quantified in Section 5.5.4. See Health Effects Table 3-1 for greater detail. Approximately 69,000 (about 10%) of Detroit's population lives within 150 meters of such heavily trafficked roadways.

Vehicles and the related infrastructure (e.g., fuel distribution facilities) are among the largest emitters of NO_x and VOCs in the urban area. In summer, the NO_x emitted by vehicles and other sources combines with VOC emissions from vehicles and other sources to produce ground-level ozone (O_3), another pollutant which is harmful to health. Currently, O_3 levels in Detroit are very close to the new (2015) National Ambient Air Quality Standard for O_3. Section 4.3 provides further information on O_3 trends in Detroit.

[1] MDOT (Michigan Department of Transportation). 2014. MDOT Traffic Volumes. Available: http://mdot.maps.arcgis.com/apps/Viewer/index.html?appid=18a4b2f2ba3b4e079e935f8835862c73 [Accessed 17 March 15].

[2] MDOT (Michigan Department of Transportation). 2014. MDOT Traffic Volumes. Available: http://mdot.maps.arcgis.com/apps/Viewer/index.html?appid=18a4b2f2ba3b4e079e935f8835862c73 [Accessed 17 March 15].

[3] MDOT (Michigan Department of Transportation). 2014. MDOT Traffic Volumes. Available: http://mdot.maps.arcgis.com/apps/Viewer/index.html?appid=18a4b2f2ba3b4e079e935f8835862c73 [Accessed 17 March 15].

[4] MDOT (Michigan Department of Transportation). 2014. MDOT Traffic Volumes. Available: http://mdot.maps.arcgis.com/apps/Viewer/index.html?appid=18a4b2f2ba3b4e079e935f8835862c73 [Accessed 17 March 15].

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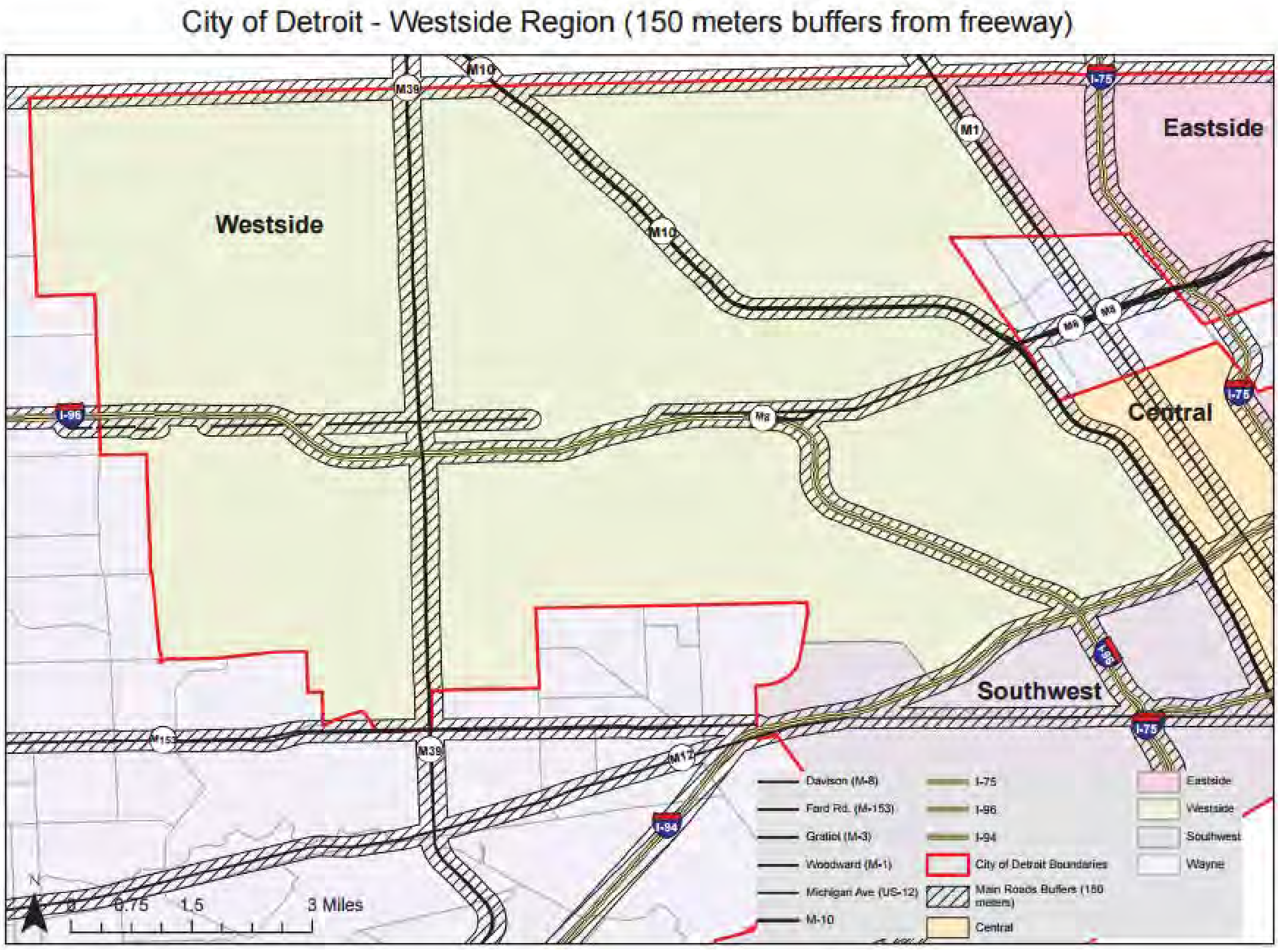

Figure 6-18: 150 meter roadway buffers in Westside Detroit.

6.14.3 Vulnerability

As described in Section 6, some communities or individuals may be more vulnerable to the adverse effects of exposure to air pollutants because they are exposed to higher levels, or because they are more adversely affected by exposure than others. Low income communities and communities of color are disproportionately likely to be exposed to high levels of air pollutants. Existing health conditions, low levels of some nutrients in the diet, young age, older age, and poor housing condition can increase the severity of health effects from exposure to air pollutants. As shown in Table 6-1, residents of Westside Detroit have exposures to Diesel PM, respiratory and cancer mortality risk that are comparable to those for the city as a whole, although higher than for the surrounding Tri-County area.

The proportion of young children (6.8%) and adults over age 60 (18.5%) in Westside Detroit is comparable to the City as a whole (6.8% and 17.5%, respectively). A greater proportion of Westside Detroit residents have completed high school, compared to the city as a whole, median household income is slightly higher, and the proportion of renters is slightly lower compared to other areas of the city. About 91% of residents of Detroit's

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Westside are non-Hispanic Black. See Figures 6-5 and 6-10 for maps showing the Cumulative Vulnerability Index for census tracts in the Tri-County Area and Detroit, respectively.

6.14.4 Cumulative risk

Figure 6-19 shows the cumulative risk scores for residents of Westside Detroit, along with point and mobile pollutant sources. The cumulative risk score is the sum of three indices assessing proximity of population to hazardous land uses (e.g., railyards, freeways), exposure to air pollutants and associated health risks (e.g., Diesel PM, respiratory risk, cancer risk), and vulnerabilities (e.g., percent below poverty, percent children under age 5). Briefly, these are calculated by rank ordering census tracts in the Tri-County area by each indicator, and constructing quintiles with 1=low and 5=high exposure or vulnerability. The sum of the risk and vulnerability scores creates a cumulative risk score ranging from 3 (lowest cumulative risk) to 15 (highest cumulative risk).[5] Note that all census tracts in Westside Detroit fall into the mid- to-upper ranges of risk (oranges and reds) when ranked against all census tracts in the Tri County Area (Figure 6-6).

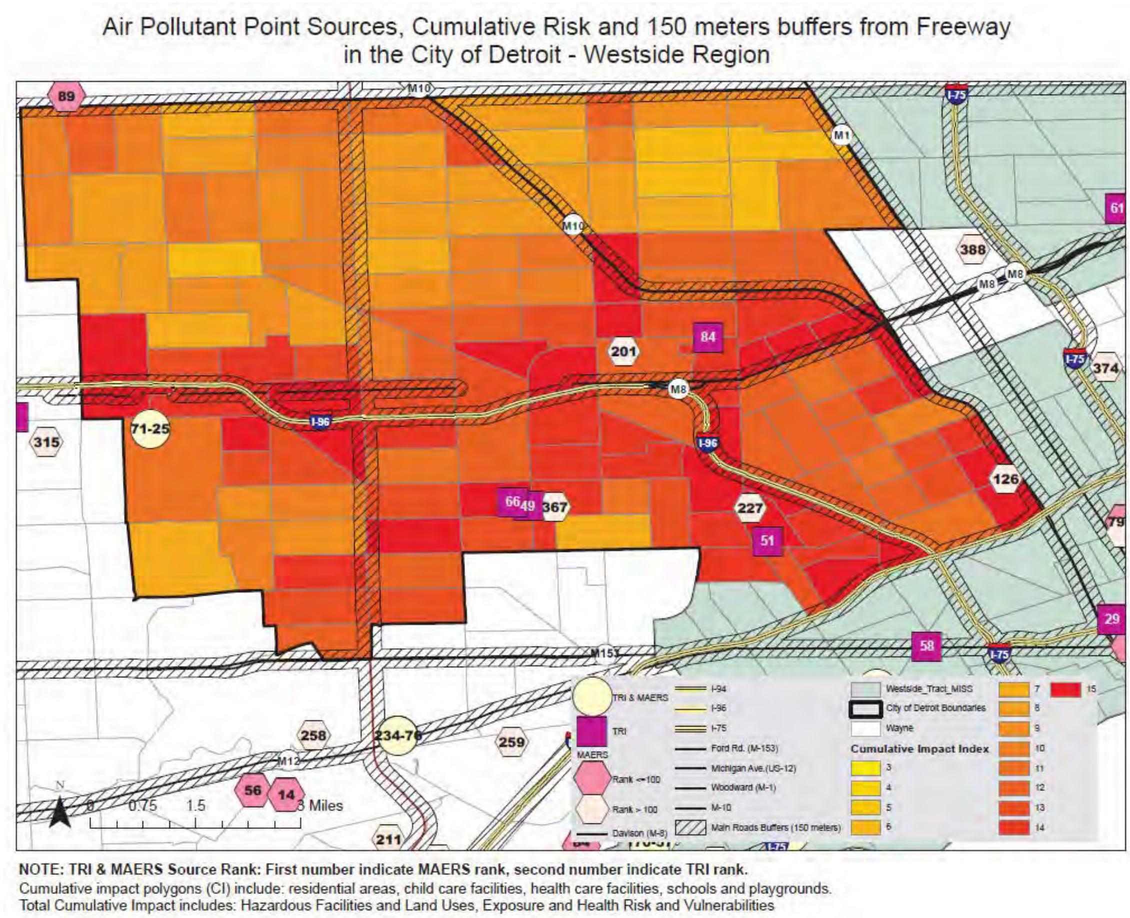

Figure 6-19: Cumulative risk index, 150 meter roadway buffers, and point sources of pollutants in Westside Detroit.

[5] Schulz, A.J., Mentz, G.B., Sampson, N, Ward, M., Anderson, R., deMajo, R., Israel, B.A., Lewis, T.C., Wilkins, D. 2016. RACE AND THE DISTRIBUTION OF SOCIAL AND PHYSICAL ENVIRONMENTAL RISK: *A Case Example from the Detroit Metropolitan Area. DuBois Review. In Press.*

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6.16. EASTSIDE DETROIT

2016

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Tables

Figures

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6.16 Eastside Detroit

There are several air pollution sources in Eastside Detroit that can increase pollution exposures. Eastside Detroit residents also experience a number of exposures in the social environment that can increase vulnerability to adverse health outcomes of air pollution exposures. About 240,000 people lived on Detroit's Eastside in the 2010 census. (See Section 6.14.3 below and Table 6-1).

Air quality monitoring in Eastside Detroit is described in detail in Section 4. Below we describe specific sources of air pollutants in Eastside Detroit, as well as population and community characteristics that may influence vulnerability to adverse effects of exposures

6.16.1 Point sources

Table 6-11 shows point sources of pollutants located within the boundaries of Southwest Detroit (see Figure 6-21). For each facility, the **Rank** indicates the rank order of this site in relation to others in the 7-county SE Michigan area reporting to the Michigan Air Emissions Reporting System (MAERS), with a "1" indicating the greatest number of pounds of emissions. Trends over time (2010-2014) are also shown, filtered to exclude some variations (see text in Section 4.3 for a more detailed description), as well as the **rate of change** over that same 5 year period (see text, Section 4.3).

		NOx			SO2			PM2.5			PM10			VOC			CO		
Rank	**Facility**	5 Year Filtered Average	Note	Annual Change (%/yr)	5 Year Filtered Average	Note	Annual Change (%/yr)	5 Year Filtered Average	Note	Annual Change (%/yr)	5 Year Filtered Average	Note	Annual Change (%/yr)	5 Year Filtered Average	Note	Annual Change (%/yr)	5 Year Filtered Average	Note	Annual Change (%/yr)
13	**Jefferson North Assembly Plant, Daimlerchrysler**	59			0			2.7	(1)	-68	24.3	(1)		587.6	(1)	21	19	(1)	-34
18	**Greater Detroit Resource Recovery Facility**	1612		-13	141			0.2			22.1	(1)	26	6.4	(1)		283		
20	**General Motors Corporation**	186	(1)	-13	302			5.1	(1)	-14	5.7	(1)	-25	233.0			74		-12
97	**Fitzgerald Finishing Company**	6		10	0		10	0.4		10	0.4		10	36.7		20	5		10

Table 6-11: Facility emissions of conventional pollutants (tons/yr) in Eastside Detroit.Shows 5-year average emissions (filtered to exclude some variations, see text in Section 4.3), and rate of change over 5 year period (see text). Excerpted from full Table 5-4.

Health Effects: Health effects associated with exposure to the pollutants in Table 3-1 include increased risk of respiratory problems (e.g., asthma exacerbations and hospitalizations, COPD, cardiovascular effects). See Health Effects Table 3-1 for a complete listing. Section 5.5.3 provides quantitative estimates of health impacts from several of these point sources for three pollutants: $PM_{2.5}$, NO_x, and SO_2.

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Rank	Facility	Acids	VOC	Metals and Metal Compounds	Nitrogen Compounds	Sulfur Compounds	Other
5	**General Motors GM VA Detroit-Hamtramck Assembly Center**	52600	17381	362	0	0	3397
9	**FCA US Jefferson North Assembly Plant**	15	8933	236	3	0	89580
17	**Fitzgerald Finishing LLC**	3064	9433	0	0	0	0
20	**Ajax Metal Processing Inc**	268	7376	0	0	0	13595
24	**3M CO-Detroit**	0	1583	0	0	0	0
30	**EQ Detroit Inc**	1319	1220	3	1650	0	1691
41	**Alco Products LLC**	0	328	0	0	0	0
46	**Arco Alloys Corp**	0	0	250	0	0	0
61	**Alpha Resins LLC**	0	49	0	0	0	20
62	**MT Elliot Tool & Die Manufacturing**	0	0	46	0	0	0
68	**PVS Technologies Inc**	0	0	0	0	0	28
69	**Detroit Axle Plant***	0	0	7	0	0	0
88	**Cadillac Oil Co**	0	3	0	2	0	0

Table 6-12: Emissions of toxics pollutants (pounds/year) by facility in Eastside Detroit by pollutant type. Average 2010-2014. In approximate rank by total TRI emissions. Excerpted from Table 5-6

Table 6-12 shows emissions of toxic air pollutants by facility located in Eastside Detroit, as reported in the Toxic Release Inventory (TRI). For each facility, pounds per year of toxics reported are shown. This table shows the rank order for each facility for SW Detroit, with "1" indicating the greatest number of pounds emitted. The full table is shown in Section 5.2.3.

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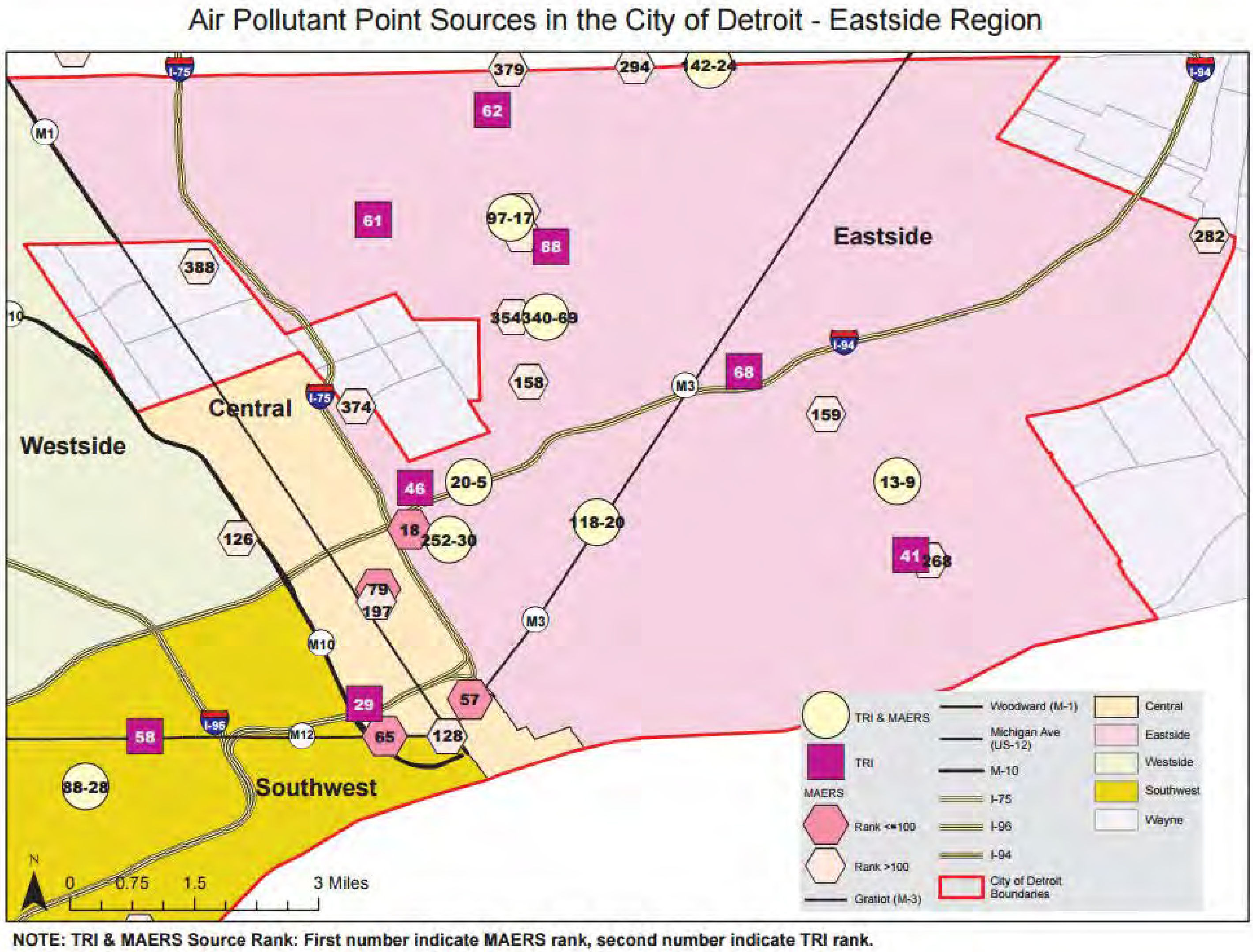

Figure 6-20: Air pollutant sources in Eastside Detroit.

Figure 6-20 maps locations of facilities that are point sources of air pollutants located in or immediately adjacent to Eastside Detroit. Symbols indicate facilities that emit conventional air pollutants reported in the Michigan Air Emissions Reporting System (MAERS) and air toxics reported in the Toxic Release Inventory (TRI), as described in the legend. Numbers indicated for each facility reflect its ranking in the listing of MAERS emissions (Table 5-6) and the listing of toxic emissions (Table 5-7).

Eastside residents are potentially exposed to emissions from the Jefferson North Assembly Plant and the General Motors Assembly plants, each of which report sizable emissions of VOCs and acids. Sizable emissions of NOx are reported from the Greater Detroit Resource Recovery Facility, also located on Detroit's Eastside. Fitzgerald Finishing and Ajax Processing report substantial emissions of VOCs and acids. Sources outside of Eastside Detroit are also exposed to emissions occurring elsewhere in the region, as depicted in Figure 5.5.3.

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6.16.2 Mobile sources

Mobile sources such as cars and trucks emit NO_x, $PM_{2.5}$, VOCs, CO, diesel exhaust, and other pollutants. Emissions from mobile sources occur both when a vehicle is driving or idling, and while refueling. Larger trucks produce a greater amount of emissions than small vehicles. Heavy duty diesel vehicles are large emitters of $PM_{2.5}$ and other pollutants. The NO_x emitted by vehicle traffic (and other sources) can combine with VOC emissions from vehicles (and other sources) to produce ground-level ozone, another pollutant which can be harmful to human health.

Main Sources: There are two major highways running through the Eastside neighborhood, I-75 (Chrysler Freeway) and I-94, as well as several less trafficked highways. According to the Michigan Department of Transportation (MDOT), the sections of I-75 and I-94 highways within the Eastside neighborhood have average daily vehicle counts of over 100,000 cars per day. These two freeways also experience heavy commercial (e.g., trucks and buses) traffic, with daily counts of commercial traffic over 6,000 for I-94 and over 10,000 for I-75.[1] Emissions from commercial truck traffic, which can include particulate matter from burned diesel fuel, can be particularly harmful to human health and are of particular concern. These large vehicles produce most of the on-road mobile source emissions of $PM_{2.5}$ (see Section 5.3). The average daily total vehicle traffic and daily truck traffic volume on major roadways in Eastside Detroit is shown in Table 6-13.

Highway	2013 Average Daily Vehicle Traffic (cars/day)[2]	2013 Average Daily Truck Volume (trucks/day)[3]
I-75/I-375 (Chrysler Fwy)	133,000 - 176,800	10,500 - 11,600
I-94	110,200-154,800	6,600 - 6,700
M-53 (Van Dyke St)	9,600 - 18,500	1,400 - 1,700
M-3 (Gratiot Ave)	12,300 - 31,700	620 - 1,200
M-102 (8 Mile Rd)	40,300 - 61,100	870 - 2,200

Table 6-13: Average Daily Vehicle Traffic and Average Daily Truck Volume, Eastside Detroit

Health Effects: Substantial health effects have been demonstrated for people who live, work, or go to school near major freeways. In particular, those who live within about 150 meters (about 500 feet) of roadways with high volumes of traffic, and in particular, diesel truck traffic, experience increased risk of respiratory and

[1] MDOT (Michigan Department of Transportation). 2014. MDOT Traffic Volumes. Available: http://mdot.maps.arcgis.com/apps/Viewer/index.html?appid=18a4b2f2ba3b4e079e935f8835862c73 [Accessed 17 March 15].

[2] MDOT (Michigan Department of Transportation). 2014. MDOT Traffic Volumes. Available: http://mdot.maps.arcgis.com/apps/Viewer/index.html?appid=18a4b2f2ba3b4e079e935f8835862c73 [Accessed 17 March 15].

[3] MDOT (Michigan Department of Transportation). 2014. MDOT Traffic Volumes. Available: http://mdot.maps.arcgis.com/apps/Viewer/index.html?appid=18a4b2f2ba3b4e079e935f8835862c73 [Accessed 17 March 15].

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cardiovascular health effects. Health impacts from on-road traffic are quantified in Section 5.5.4. Also see Health Effects Table 3-1. Approximately 69,000 (about 10%) of Detroit's population lives within 150 meters of such heavily trafficked roadways.

Vehicles and the related infrastructure (e.g., fuel distribution facilities) are among the largest emitters of NO_x and VOCs in the urban area. In summer, the NO_x emitted by vehicles and other sources combines with VOC emissions from vehicles and other sources to produce ground-level ozone (O_3), another pollutant which is harmful to health. Currently, O_3 levels in Detroit are very close to the new (2015) National Ambient Air Quality Standard for O_3. Section 4.3 provides further information on O_3 trends in Detroit.

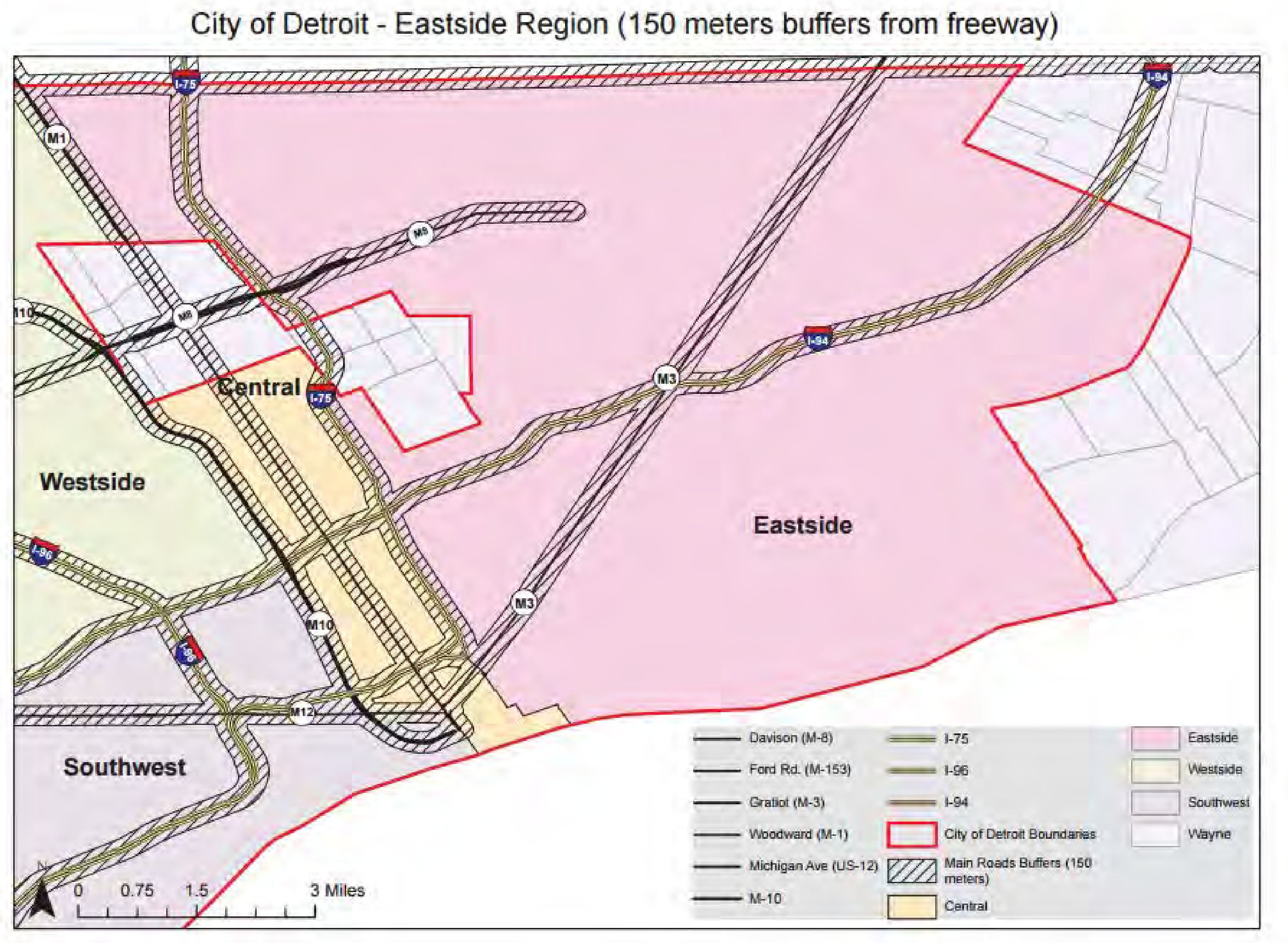

Figure 6-21: 150 meter roadway buffers in Eastside Detroit.

6.16.3 Vulnerability

As described in Section 6, some communities or individuals may be more vulnerable to the adverse effects of exposure to air pollutants because they are exposed to higher pollutant concentrations, or because they are more adversely affected by exposure than others. Low income communities and communities of color are

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disproportionately likely to be exposed to high levels of air pollutants. Existing health conditions, low levels of some nutrients in the diet, young age, older age, and poor housing condition can increase the severity of health effects from exposure to air pollutants. As shown in Table 6-1, exposures to diesel PM, and respiratory risk associated with air pollution on Eastside Detroit that are lower than the Detroit City average but higher than the Tri-County average, and air pollution-associated cancer risk is lower than the City or the Tri-County area.

Eastside Detroit has proportions of children under age 5 and adults over age 60 that are comparable to the City as a whole. The proportion non-Hispanic Black (88%) is slightly higher than the city (83%) and substantially greater than the Tri-County Area (31%). Similarly, the proportion with less than a high school education, below poverty, and renters are comparable to those for Detroit, but larger than for the Tri-County area. See Figures 6-5 and 6-10 for maps showing the Cumulative Vulnerability Index for census tracts in the Tri-County Area and Detroit, respectively.

6.16.4 Cumulative Risk

Figure 6-22 shows the cumulative risk scores for residents of Eastside Detroit, mapped along with point and mobile air pollutant sources. This score is the sum of three indices assessing proximity of population to hazardous land uses (e.g., railyards, freeways), exposure to air pollutants and associated health risks (e.g., diesel PM, respiratory risk, cancer risk), and vulnerabilities (e.g., percent below poverty, percent children under age 5). Briefly, these are calculated by rank ordering census tracts in the Tri-County area by each indicator, and constructing quintiles with 1=low and 5=high exposure or vulnerability. The sum of the risk and vulnerability scores creates a cumulative risk score ranging from 3 (lowest cumulative risk) to 15 (highest cumulative risk).[4] A majority of census tracts in Eastside Detroit fall into the mid-to- upper ranges of risk (oranges and reds) when ranked against all census tracts in the Tri County Area Figure 6-6.

[4] Schulz, A.J., Mentz, G.B., Sampson, N, Ward, M., Anderson, R., deMajo, R., Israel, B.A., Lewis, T.C., Wilkins, D. 2016. RACE AND THE DISTRIBUTION OF SOCIAL AND PHYSICAL ENVIRONMENTAL RISK: *A Case Example from the Detroit Metropolitan Area. DuBois Review. In Press.*

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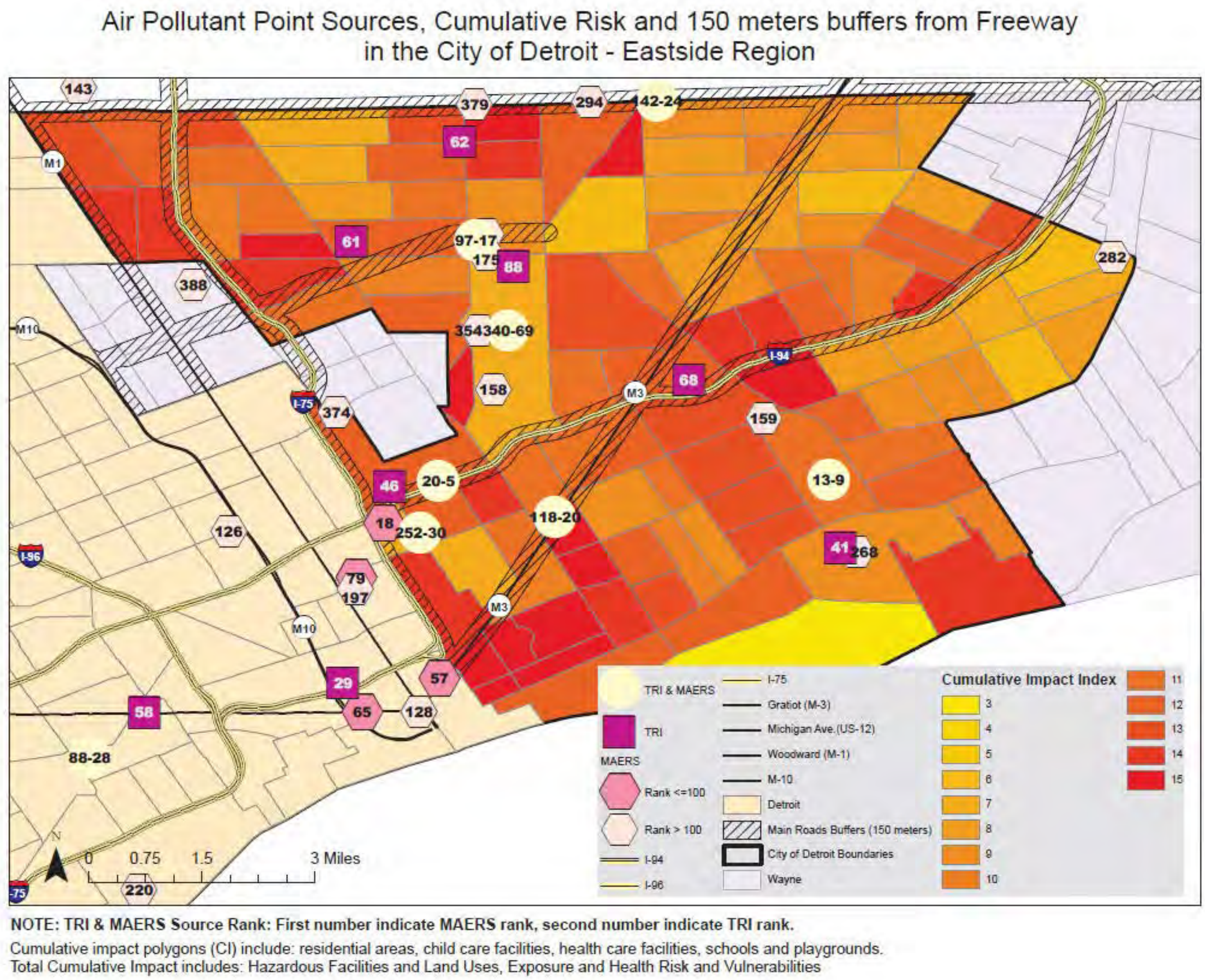

Figure 6-22: Cumulative risk index, 150 meter roadway buffers, and pollutant sources in Eastside Detroit

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7.1 MOBILE SOURCE CONTROLS: DIESEL ENGINE RETROFITS

2016

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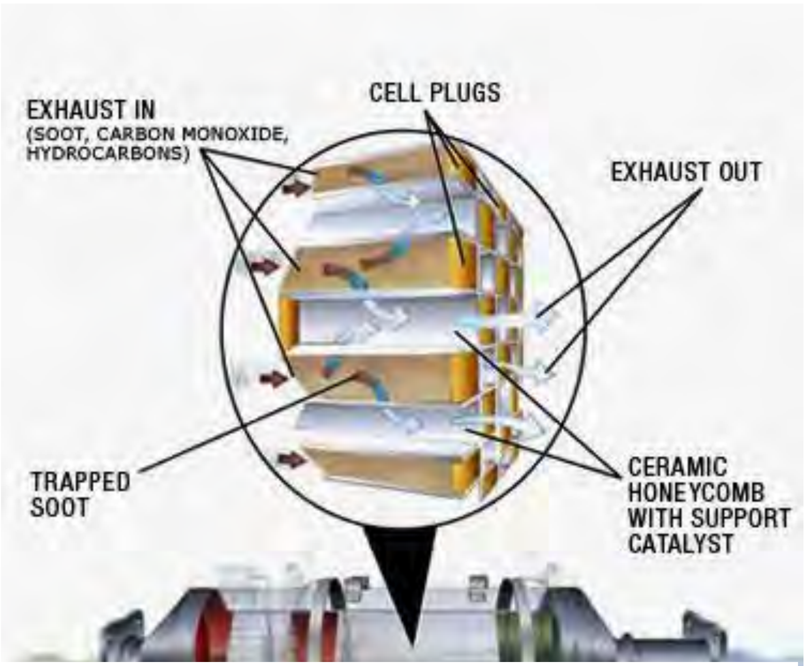
7.1 Mobile Source Control: Diesel Engine Retrofits

7.1.1 What is a diesel retrofit?

Retrofitting diesel engines involves installing more modern and effective emission controls on older diesel engines (especially those built before 2007) to reduce the amount of pollutants emitted. Diesel retrofits can be used on trucks, school buses, off-road construction vehicles (e.g. dump trucks and cranes), diesel-powered equipment (e.g. generators and pumps), ships and trains.



7.1-1: Diesel particulate filter (DPF) with catalyst. Exhaust flows through t hat remove particles. Taken from: https://www.demanddetroit.com/part /parts/emissions.aspx

7.1.2 What types of retrofits can be used?

Several types of retrofits are used. Installing engine and exhaust system emissions control devices is one of the most cost-effective approaches. The most common are diesel particulate filters (DPFs - see Figure 7.1 – 1) or traps installed on exhaust systems, and diesel oxidation catalysts (DOCs). DPFs and DOCs can be combined, as shown in the picture at right. This filter removes over 90% of the particulate matter ($PM_{2.5}$).[1]

Other approaches to reducing diesel exhaust emissions include installing idle reduction devices (Section 7.4), rebuilding or replacing the engine, replacing the vehicle, using cleaner fuels, and replacing diesel engines with electric motors.

7.1.3 Why is this important?

Diesel engines have long lives, and thousands of older vehicles and engines remain in use today. These old engines have few if any emissions controls, and they emit considerable amounts of pollutants like particulate matter ($PM_{2.5}$), nitrogen dioxide (NO_x), and other pollutants. Diesel exhaust accounts for 20% percent of $PM_{2.5}$ concentrations at Detroit monitoring sites, and a larger amount at “hot spots” where there are large numbers of vehicles.[2] Both on- and off-road vehicles are very important in Detroit. About 68% of diesel emissions in

[1] Detroit Demand Performance. 2016. Making It Easy to Stay Compliant. Available: https://www.demanddetroit.com/parts-service/parts/emissions.aspx [accessed 2 February 2016].

[2] MDEQ AQD (Michigan Department of Environmental Quality Air Quality Division). 2008. State Implementation Plan Submittal for Fine Particulate Matter (PM2.5). Available: http://www.michigan.gov/documents/deq/deq-aqd-air-aqe-PM25-SIP-Final-2008_238092_7.pdf [accessed 11 April 2016]. – Appendix G: Overview of Recent Detroit PM Source Apportionment Studies. http://www.michigan.gov/documents/deq/deq-aqd-air-aqe-Appendix-G-Detroit-PM-Source-Apportionment_238078_7.pdf. Accessed Jan. 4, 2015.

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Wayne County come from highway (on-road) traffic[3], and about 22% from non-road vehicles (like construction equipment).[3] Roughly 70,000 – 90,000 trucks travel on major corridors (I-75, I-94, I-96, M10 and M39) in Detroit daily,[4] and the International Bridge crossing has as many as 6900 trucks a day (2.5 million annually).[5]

Retrofitting old vehicles and engines with filters and other modifications can significantly reduce the emissions, and can be more cost-effective than vehicle replacement.[6]

7.1.4 Implications for Health

7.1.4.1 Which pollutants are affected by diesel engine retrofits?

Diesel engine retrofits reduce emissions of several hazardous pollutants, including $PM_{2.5}$, NO_x, and CO.

7.1.4.2 What health effects can be mitigated?

Reduced emissions of diesel exhaust would lead to improvements in respiratory diseases such as asthma; reduced lung diseases such as chronic obstructive pulmonary disease (COPD), bronchitis, emphysema, and lung cancer; fewer heart attacks and cases of hypertension; and reduced irritation of the nose, throat, and lungs.[7]

7.1.5 What is happening in Detroit?

Diesel retrofitting and replacement. Southwest Detroit Environmental Vision (SDEV)'s *Clean Diesel Program* is a successful public-private partnership that has reduced diesel pollution in Southwest Detroit, South Dearborn and surrounding areas. This program is funded by the Michigan Department of Environmental Quality (MDEQ), the Michigan Department of Transportation (MDOT), the Environmental Protection Agency (U.S. EPA) and local business partners. As of late 2014, this program had:

- Replaced 47 old trucks and 8 old school buses with new, cleaner models
- Upgraded 5 old truck engines and 6 old marine engines with new, cleaner engines
- Replaced 7 diesel refrigeration units with electric plug-in units, and
- Installed pollution controls on 140 trucks and idle reduction technology on 40 trucks
- Replaced over 75 old diesel engines with new, low polluting engines.[8]

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[3] CAPHE (Community Action to Promote Healthy Environments). 2016. Diesel Pollutant Fact Sheet. Available: http://caphedetroit.sph.umich.edu/project/diesel/ [accessed 11 March 2016].

[4] SDEV (Southwest Detroit Environmental Vision). Truck Traffic and Air Quality in Southwest Detroit Fact Sheet. Available file:///C:/Users/klrice/Downloads/Anti-Idling%20Fact%20Sheet.pdf [accessed 11 March 2016].

[5] PBOA (Public Border Operations Association). 2016. Available: http://publicborderoperators.org/index.php/traffic [accessed 2 February 2016].

[6] EPA (Environmental Protection Agency). 2007. The Cost-Effectiveness of Heavy Duty Diesel Retrofits and Other Mobile Source Emission Reduction Projects and Programs. Available: http://www3.epa.gov/otaq/stateresources/policy/general/420b07006.pdf [accessed 11 March 2016].

[7] Community Action to Promote Healthy Environments, Health Effects of Air Pollutants Chart.

[8] SDEV (Southwest Detroit Environmental Vision, Clean Diesel Program Fact Sheet). Available: http://www.sdevweb.org/wp-content/uploads/2013/02/Clean-Diesel-Program-One-Pager-Revised-11-4-14.pdf [accessed 3 February 2016].

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School bus replacement. In 2015, Detroit Public Schools (DPS) acquired 35 propane gas-fueled buses. These buses are cleaner, and operating costs are about 50 percent less than diesel buses. Roughly 30% of DPS's school bus fleet uses propane autogas.[9]

The City of Detroit and several other City organizations developed and are implementing anti-idling polices, please see CAPHE anti-idling Section 7.4.

7.1.6 What best practices have been used elsewhere?

Diesel retrofit and clean diesel programs have been successfully used elsewhere, and many of these could be used effectively in Michigan.

Require low-pollution construction equipment. Rhode Island created a state-level *Clean Construction Diesel Retrofit Program* in 2010 requiring all heavy-duty vehicles contracted by the state with federal monies to be equipped with modern pollution control devices, adhere to the state anti-idling law, limit idling to 5 minutes, and use clean burning ultra-low sulfur diesel fuel (ULSD).[10] The law imposes relatively low costs to construction companies, and vehicle emissions were lowered by 20-90%.[11]

Force retirement of older trucks**.** To accelerate fleet turnover, California in 2008 and the Ports of Los Angeles and Long Beach in 2006 established regulations that forced the retirement of older diesel trucks. At the Port, the average fleet age decreased from 12.7 years in 2008 to 2.5 years in 2010. The new trucks are equipped with diesel particle filters and other technologies, which significantly reduced emissions of CO (30%), NO_x (48%) and $PM_{2.5}$ (54%).[12]

Fleet replacement. Replacing vehicles is more effective than promoting alternative transport modes or using truck restriction lanes. A 2009 study of the I-710 Freeway in the San Pedro Bay Ports (SPBP) area in California found that fleet replacement with cleaner (especially zero-emission) trucks yielded the most emission reductions compared to alternative modes of transportation and truck restriction lanes.[13]

[9] Crain's Detroit Business. 2015. Detroit students to ride to school on propane-fueled buses. Available: http://www.crainsdetroit.com/article/20150902/NEWS/150909990/detroit-students-to-ride-to-school-on-propane-fueled-buses [accessed 3 February 2016].

[10] RI DEM (Rhode Island Department of Environmental Management). 2014. Mobile Source Pollution Reduction: Clean Construction—Diesel Retrofit Program. Available: http://www.dem.ri.gov/mobile/pdf/story4.pdf [accessed 11 April 2016].

[11] The University of Rhode Island Transportation Center and Outreach Center. (2014). Diesel Emission Reduction in Construction Equipment. Available: http://ntl.bts.gov/lib/51000/51500/51514/S000118.pdf [accessed 3 February 2016].

[12] Bishop, GA, Schuchmann, BG, Stedman, DH. 2012. Emission Changes Resulting from the San Pedro Bay, California Ports Truck Retirement Program. Environmental Science & Technology 46(1): 551-558.

[13] Lee G, Soyoung IY, Ritchie SG, Saphores J, Sangkapaichai M, Jayakrishnan R. 2009. Environmental impacts of a major freight corridor: a study of I-710 in California. Transportation Research Record: Journal of the Transportation Research Board 2123: 119-128.

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7.1.7 How many people could be affected in Detroit by diesel retrofits?

The number of people affected by diesel retrofits depends on how many engines are modified or replaced. Those who would benefit most are those who live, work, and spend time near major freeways, sites with heavy diesel truck traffic, or construction and industrial sites using diesel engines.

Sites in Detroit where people could be affected include:

- Ambassador Bridge and the future site of the Gordie Howe Bridge
- The new Industrial Park and Logistic Center in Eastside
- Truck and rail transfer stations, for example the Container Port on West Fort Street
- Schools where buses are queuing
- Bus terminals
- People living or working near freeways such as I94 and I75 (an estimated 69,000 Detroit residents live within 150 meters of a major highway)
- People living or working on surface streets with considerable truck traffic, such as Fort Street and Michigan Avenue
- People living or working near construction sites and other locations where diesel vehicles or diesel engines operate.

Two groups are particularly important to mention. These include children riding on diesel school buses, especially since about 70% of DPS's bus fleet is diesel,[14] and truck drivers, who frequently have high occupational exposure to diesel exhaust. Both groups are particularly vulnerable to adverse health effects from exposure to diesel exhaust, and would benefit from actions taken to retrofit or replace diesel engines.

7.1.8 Applicable Strategies for Detroit and/or Michigan:

Expand diesel retrofit programs and fleet and engine replacements. Retrofitting and replacement programs are cost-effective ways to reduce diesel emissions,[15] and public-private partnerships can make them financially feasible for many business owners. In addition, incentive programs can be used to promote retrofit programs. Increased federal and state level funding for these types of programs could help organizations, like SDEV, continue and increase their efforts.

Laws and ordinances at State and local levels. Vehicles and equipment using diesel engines, especially larger engines (in heavy-duty vehicles) can be legally required to use pollution control devices.

Require low-emission vehicles and construction equipment in city contracts. City Council can impose stipulations that require the use of pollution control devices in construction, hauling, and other activities.

[14] Crain's Detroit Business. 2015. Detroit students to ride to school on propane-fueled buses. Available: http://www.crainsdetroit.com/article/20150902/NEWS/150909990/detroit-students-to-ride-to-school-on-propane-fueled-buses [accessed 3 February 2016].

[15] EPA (Environmental Protection Agency). 2007. The Cost-Effectiveness of Heavy Duty Diesel Retrofits and Other Mobile Source Emission Reduction Projects and Programs. Available: http://www3.epa.gov/otaq/stateresources/policy/general/420b07006.pdf [accessed 3 February 2016].

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Include low-pollution construction equipment language in Community Benefits Agreements.

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CAPHE PHAP-RM

7.2 INDOOR AIR FILTERS FOR SCHOOL, HOME, & COMMERCIAL USES

2016

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Figures

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7.2 INDOOR AIR FILTERS FOR SCHOOL, HOME, AND COMMERCIAL USES

7.2.1 What are indoor air filters?

Indoor air filters are devices that remove can certain air pollutants from air that is passed through them. Most air filters remove particles, including dust, small particles (including much $PM_{2.5}$), pollen, allergens, animal dander, and fibers. Some filters can remove gases, such as sulfur dioxide (SO_2), odors, and volatile organic compounds. When designed and used appropriately, air filters can reduce indoor exposure to harmful air pollutants, like $PM_{2.5}$.

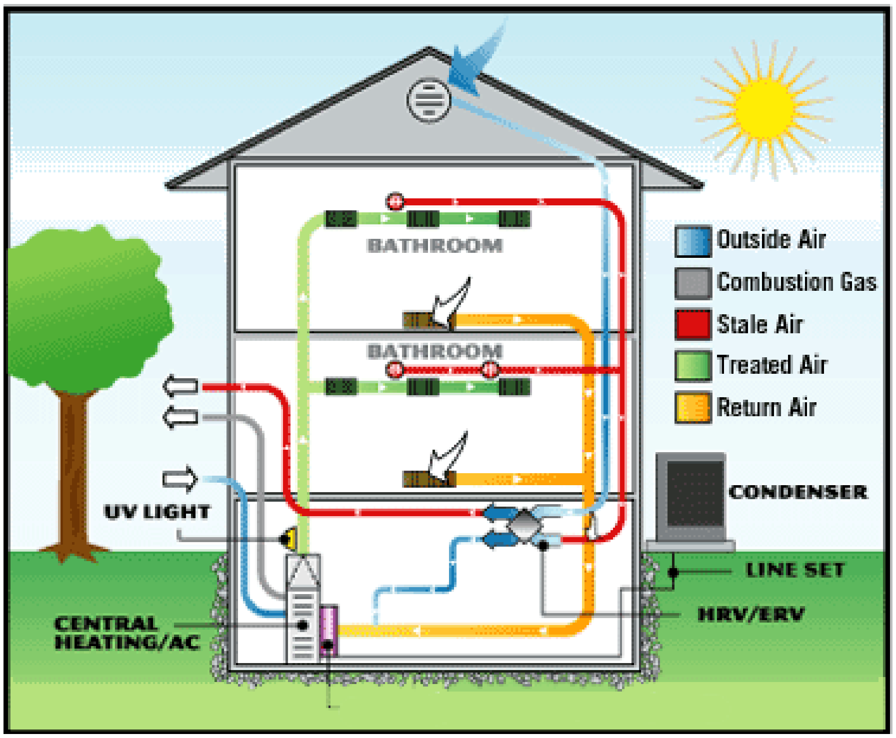

Figure 7.2-1: Illustration of a residential forced-air HVAC system. All such systems have a central heating system where filters can be installed, and vents for treated and return air. This system has several features that are not typical of most systems, including UV disinfection, and an air-to-air heat exchanger in the basement with controlled makeup (intake) and exhaust air (arrows to left of house) to improve efficiency and increase air exchange rates.[1]

[1] Green Living Ideas. The Basics of HVAC. Available: http://greenlivingideas.com/2014/09/26/the-basics-of-hvac/ [accessed 9-13-16].

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7.2.2 What types of air filters can be used, and where can they be used?

Many types of air filters can be installed in homes, businesses and schools. One type of filter is installed in forced-air heating, ventilation, and air conditioning systems (HVAC, see Figure 7.2-1). These can clean air throughout the house (or the space ventilated by the HVAC system) when the system is operating. While all forced air systems are supposed to have filters, which are often called "furnace filters," generic filters are very low quality and remove very little $PM_{2.5}$. Sometimes the filter is missing, and often it has not been changed for a long period. Frequently, furnace filters can be upgraded with a more effective filter that fits in the same space. Changing filters each season is needed to maintain their effectiveness.

A second type of device is a free standing or portable filter unit. These can be installed anywhere there is an electrical power outlet. These portable units clean the air in a single room (and help to clean air in nearby rooms). These filters can operate year round, including times when a forced air system is not being used (e.g., when heating or cooling is not being used.) This type of filter is also useful when a house or building does not have a forced air system, for examples, in houses with steam radiators or baseboard heat.

Figure 7.2-2: HEPA air filter/purifier, an example of a free-standing air filter.[2]

There are also many types of filters that can be used in forced air systems or portable filters, including paper-like, fabric/cloth, fiberglass, and others. Filters are typically rated using the minimum efficiency rating value (*MERV*). You should select a MERV value of at least 11 or 13. Filters need to be replaced each season as they

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[2] HEPA Air Filter Example. Available: http://www.air-purifiers-america.com/products/alen-t500-hepa-air-purifier-w-hepa-odorcell-filter?variant=948368571&gclid=CJfplam97coCFYIBaQodXUUFjA [accessed 9-13-16].

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lose effectiveness, even though they may appear to be clean. One type of filter, called a HEPA filter (for high efficiency particle arrestance), can capture over 99% of particles. However, this particular type of filter is expensive and generally cannot be used in forced air systems. Fortunately, less expensive air filters can be very effective.

Filters are also available that remove gases like sulfur dioxide (SO_2), ozone (O_3), volatile organic compounds (VOCs), and odors. These filters are much bigger and heavier than the typical filter, and they are only rarely found in homes or commercial buildings. They can work well, but they are relatively expensive and require regular replacement. Some are sold as freestanding or portable devices.

Several types of filters are sold that should not be used because they are not effective or they produce dangerous byproducts, including ozone. These include products sold as "*ionizers*" and "*electronic air cleaners*" (which use electrostatic precipitators).

Most filters are relatively inexpensive. For example, you can replace an ineffective $2 furnace filter with a high quality filter that costs about $15 to $20. Filters should be changed every season to ensure that they remain effective. Freestanding filters can cost roughly $100 to $300 and consume $5 to $10 of electricity each month.

Both HVAC and free-standing filters are effective in reducing PM levels only when windows and outside doors are closed. Pollutants in air blowing in through windows and doors generally overwhelms the filter's cleaning ability.

7.2.3 Why is this important?

The average person spends over 90% of their time indoors.[3] Air pollution found indoors arises from indoor sources, such as cooking, smoking and vacuuming, as well as outdoor sources, such as traffic and power plants. Outdoor pollutants enter building via the ventilation system, windows, doors, and other openings in the building. Indoor air filters can significantly reduce the amount of both indoor and outdoor PM pollution you breathe. As a result, using filters to improve or maintain air quality can reduce your exposure from both outdoor and indoor sources of particulate matter. Among the mitigation strategies considered, filters are unusual in this regard.

Indoor air quality is important in schools, where children spend much of their day during the school week. Many of Detroit's schools are old buildings that suffer from mold, ventilation problems, and heating and cooling issues.[4] Detroit children also suffer from high rates of asthma, which can be exacerbated by some school's conditions.

[3] Klepeis NE, Nelson WC, Ott WR, Robinson JP, Tsang AM, Switzer P, et al. 2001. The National Human Activity Pattern Survey (NHAPS): a resource for assessing exposure to environmental pollutants. Journal of exposure analysis and environmental epidemiology 11:231-52.

[4] Detroit Free Press. 2016. Trying to teach in DPS amid decay: It's a travesty. Available: http://www.freep.com/story/news/local/michigan/detroit/2016/01/14/detroit-schools-problems/78804118/ [accessed 11 February 2016].

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Section 7.2.8 quantifies the benefit of using filters in Detroit, and includes an analysis of using filters in schools and in homes.

7.2.4 Which pollutants are affected by using air filters?

Indoor air filters can remove or reduce the concentrations of $PM_{2.5}$, PM_{10}, pet allergens, tobacco smoke, some respiratory viruses, dusts, and other particles.[5,6,7]

As mentioned above, some filters can remove gases like sulfur dioxide (SO_2), ozone (O_3), volatile organic compounds (VOCs) and odors. These filters are uncommon. They are found in some special environments, for example, cleanrooms, certain manufacturing facilities, and buildings and shelters that might be exposed to high concentrations of hazardous chemicals (e.g., industrial and chemical warfare agents).

7.2.5 What health effects can be mitigated?

Indoor air filters can lower concentrations and exposures to $PM_{2.5}$ and PM_{10}. This can reduce the incidence of respiratory diseases (such as asthma), decrease respiratory inflammation and irritation, and lessen irritation of the nose, throat, and lungs. Lower $PM_{2.5}$ levels are associated with fewer premature mortalities; reduced incidence of heart attacks, hypertension, and adverse birth effects; and reduced risk of cancer.[8] Section 7.2.8 quantifies the benefit of using filters in Detroit, and includes an analysis of using filters in schools and in homes.

7.2.6 What is happening in and around Detroit?

Filters in schools. As a result of 2015 litigation by the US Department of Justice and the Michigan Department of Environmental Quality, AK Steel agreed to install air filters in the Salina Elementary and Salina Intermediate Schools. This was negotiated as a *Supplemental Environmental Project* (SEP),[9] a part of a larger settlement (fines totaled $1.35 million) to resolve 42 violation notices from the Michigan Department of Environmental Quality.[10]

Using HEPA filters in Homes**.**

In 2012-13, Community Action Against Asthma provided 89 households with freestanding HEPA air filters. Filters were placed in the child's bedroom or sleeping area. Monitoring for nearly a year showed that when used,

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[5] CARB (California Air Resources Board). Research Projects. Available: http://www.arb.ca.gov/research/single-project.php?row_id=64797 [accessed 12 February 2016].

[6] Du L, Batterman S, Parker E, Godwin C, Chin JY, O'Toole A, et al. 2011. Particle concentrations and effectiveness of free-standing air filters in bedrooms of children with asthma in Detroit, Michigan. Building and Environment 46: 2303-2313.

[7] Brown KW, Minegishi T, Allen JG, McCarthy JF, Spengler JD, MacIntosh DL. 2014. Reducing patients' exposures to asthma and allergy triggers in their homes: an evaluation of effectiveness of grades of forced air ventilation filters. Journal of Asthma 51:585-94.

[8] EPA (Environmental Protection Agency). Integrated Science Assessments (ISAs). Available: https://www.epa.gov/isa [accessed 29 February 2016].

[9] The United States Department of Justice. 2015. United States of America and the Michigan Department of Environmental Quality v. AK Steel Corporation. Available: http://www.justice.gov/sites/default/files/enrd/pages/attachments/2015/05/19/env_enforcement-2523241-v1-ak_steel_lodged_decree.pdf [accessed 11 February 2016].

[10] The Detroit News. 2015. AK Steel to pay $1.35M fine, install filters at schools. Available: http://www.detroitnews.com/story/business/2015/05/20/ak-steel-fine-install-filters-schools/27658285/ [accessed 11 February 2016].

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filters dramatically reduced particle concentrations.[11] Filters were often used improperly, possibly to reduce electricity costs or due to noise and drafts.[12]

7.2.7 What are the best practices?

Schools buildings

Improve HVAC system filters. In schools near a major highway in Las Vegas, enhanced filters in the school's HVAC system decreased children's exposure to particle concentrations (including diesel exhaust) by 74-97%.[11] These filters were installed as a *Supplemental Environmental Project* associated with the widening of the interstate highway.

Utilize the guidance in US Environmental Protection Agency's *Indoor Air Quality Tools for Schools*.[12] This includes guidance on selecting and using filters, and many other topics.

Require new construction or renovations to improve indoor environmental quality. New and renovated buildings should incorporate enhanced filters, low emission materials[13] and other measures to improve indoor environmental quality. A "green design" rating program for buildings, called LEED (Leadership in Energy and Environmental Design), utilize points for air quality. LEED certification provides independent verification of a building or neighborhood's green feature, allowing the design, construction, operations and maintenance of resource-efficient, high-performing, healthy, cost-effective buildings.[14] This certification is a good indication of a "green" building, but does not necessarily ensure that high performance filters are installed or properly maintained.

Use air filter management programs or filter committees**.** The Thames Valley District School Board in Canada used an air filter management program to bring together an air filter company, school officials, and school personnel (from purchasing, maintenance, and health and safety departments) for quarterly meetings to

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[11] Du L, Batterman S, Parker E, Godwin C, Chin JY, O'Toole A, et al. 2011. Particle concentrations and effectiveness of free-standing air filters in bedrooms of children with asthma in Detroit, Michigan. Building and Environment 46: 2303-2313.

[12] Batterman S, Du L, Parker E, Robins T, Lewis T, Mukherjee B, et al. 2013. Use of free-standing filters in an asthma intervention study. Air Quality, Atmosphere and Health 6:759-767.

[11] McCarthy MC, Ludwig JF, Brown SG, Vaughn DL, Roberts PT. 2012. Filtration effectiveness of HVAC systems at near-roadway schools. Indoor Air 23:196-207.

[12] EPA (Environmental Protection Agency). Indoor Air Quality Tools for Schools Action Kit. Available: http://www.epa.gov/iaq-schools/indoor-air-quality-tools-schools-action-kit [accessed 2 March 2016].

[13] For more information about low emissions materials, see LEED (Leadership in Energy and Environmental Design). 2016. Lo emitting materials. Available: http://www.usgbc.org/credits/schools-new-construction-healthcare/v4-draft/eqc2 [accessed 4 April 2016].

[14] USCBC (U.S. Green Building Council). 2016. LEED. Available: http://www.usgbc.org/leed [accessed 22 February 2016].

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monitor filter change schedules and to troubleshoot problems, resulting in improved maintenance and air quality in the schools.[15]

Form school-community partnerships. Public schools in Hartford, Connecticut created a district-wide wellness program to address rising rates of asthma, which used school teams, and health and environmental organizations, and US EPA's *Indoor Air Quality Tools for Schools*[16] material to engage and train teachers, staff and parents on indoor air quality risks and what they can do about them. The district saw a decrease in asthma-related visits to school-based care providers.[17]

Improve preventive maintenance. The Hartford initiative described above incorporated a preventive maintenance program, which included quarterly cleaning and filter change-out, repairing roof leaks, a comprehensive "Green Clean" janitorial cleaning program with environmentally-friendly material, and established guidelines for renovation projects (e.g., controlling emissions during construction and using low emitting materials).[18]

Legislation addressing air quality. In 2003, Connecticut enacted Public Act No. 03-220 that required school districts to adopt and implement an indoor air quality program that "provides for ongoing maintenance and facility reviews necessary for the maintenance and improvement of the indoor air". It also allows boards of education to establish an indoor air quality committee to increase staff and student awareness. [19]

Homes

Use high-performing filters in homes with forced air systems. Homes in Atlanta and Chicago using high efficiency filters (rated MERV 12 or above) reduced levels of asthma triggers, such as cat dander and $PM_{2.5}$, by over 50%.[20]

When using high-performing filters in forced air systems, run the forced air system continuously. With high performing filters, you can continuously run your forced air system by using "fan" mode, which will filter air even if you are not heating or cooling your home. This can further reduce $PM_{2.5}$ levels. This strategy should be used only if the windows are closed.

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[15] NAFA (National Air Filtration Association). 2016. Air Filtration for Schools. Available: https://www.nafahq.org/air-filtration-for-schools/ [accessed 12 February 2016].

[16] EPA (Environmental Protection Agency). Indoor Air Quality Tools for Schools Action Kit. Available: http://www.epa.gov/iaq-schools/indoor-air-quality-tools-schools-action-kit [accessed 3-2-16].

[17] EPA (Environmental Protection Agency). 2014. Hartford Public Schools: Using IAQ Management to Address Asthma in an Urban District. Available: http://www2.epa.gov/sites/production/files/2014-08/documents/Hartford.pdf [accessed 11 February 2016].

[18] East Hartford Public Schools. Indoor Air Quality Tools for Schools (TFS) IAQ Program. Available: http://www.easthartford.org/page.cfm?p=7588 [accessed 12 February 2016].

[19] East Hartford Public Schools. Indoor Air Quality Tools for Schools (TFS) IAQ Program. Available: http://www.easthartford.org/page.cfm?p=7588 [accessed 12 February 2016].

[20] Brown KW, Minegishi T, Allen JG, McCarthy JF, Spengler JD, Macintosh DL. 2014. Reducing patients' exposures to asthma and allergy triggers in their homes: an evaluation of effectiveness of grades of forced air ventilation filters. Journal of Asthma 51:585-94.

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Use freestanding filters. These filters can significantly reduce $PM_{2.5}$ concentrations in portions of your home such as bedrooms and living areas. These filters can be used in homes with or without a forced air system.

Eliminate or reduce indoor sources of pollutants, such as smoking.

Commercial buildings

Require new construction or renovations to improve indoor environmental quality. New and renovated buildings should incorporate enhanced filters, low emission materials, and other measures to improve indoor environmental quality. "Green" buildings, designed according to LEED or other criteria, explicitly consider indoor air quality in their design, construction and use. [21]

Use tax credits for HVAC improvements. Section 179d of the US tax code, popularly known as the green building tax deduction, offers up to $1.80 per square foot to businesses for installing heating, cooling and ventilation systems (HVAC). Qualifying systems must reduce the building's total energy and power cost by at least 50%.[22]

7.2.8 What is the benefit of using air filters in Detroit?

Air filters can be used in many buildings, including schools, homes, and commercial locations. Homes and businesses using improved air filters would especially benefit children and individuals with allergies and/or asthma. In 2014, approximately 178,000 children under the age of 18 lived in Detroit.[13] Between 2012 and 2014, 11.3% of Detroit children and 15.5% of Detroit adults had asthma.[14]

Detroit has many older homes (most were built between 1939 and 1951), many of which use steam or hot water heat. Stand-alone filters can be used in these homes. Often, when these homes are renovated, forced-air systems are installed, which permits the use of enhanced HVAC filters.

Filter strategies evaluated

The remainder of this section estimates the health benefits of using enhanced air filters at homes and schools in the Detroit area. Three strategies are considered where filters could be installed and used:

- Schools (K-12) located near major roads, major industrial sources and construction sites. This strategy prioritizes the application of filters where outdoor PM concentrations are higher. This strategy focuses on schools within 200 m of major roads, and estimates effects on children's health.

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[21] LEED (Leadership in Energy and Environmental Design). Available: http://www.usgbc.org/leed [accessed 3-2-16].

[22] Poplar Network. Available: http://www.poplarnetwork.com/news/5-green-building-tax-incentives-2015 [accessed 2-11-16].

[13] US Census Bureau. Demographic and housing estimates- 2010-2014 American Community Survey 5-Year Estimates. Available: https://www.census.gov/acs/www/data/data-tables-and-tools/data-profiles/2014/. [accessed 04.15.16]

[14] DeGuire, P., Cao, B., Wisnieski, L., Strane, D., Wahl, R., Lyon-Callo, S., Garcia, E., 2016. Detroit: The current status of the asthma burden. Michigan Department of Health and Human Services.

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- All schools (K-12). Because PM is broadly distributed spatially, there are potentially significant benefits using filters at all schools. This analysis is otherwise similar to the first.
- All homes. Children and adults spend between 60 and 80% of each day indoors at home[15], so there are potentially significant benefits for using filters at home. This strategy estimates health benefits for both children and adults.

Analysis methods

This analysis considered Detroit and several nearby communities affected by PM from local emission sources. The study area, highlighted in Figure 7.2-3, has a population of 1,010,956 and included 392 schools with a K-12 enrollment in 2014-2015 of 145,593.[16] Of these 392 schools, 309 had an enrollment of greater than 0. (For comparison, K-12 school enrollment was 91,771 in Detroit, and 275,544 in Wayne County.) These students, as well as teachers and staff, could benefit from high performance filters placed in school buildings.[24] Figure 7.2-3 shows the locations of the schools, as well as the air quality monitoring sites from which ambient $PM_{2.5}$ measurements are used.

Schools near roads were determined using road network data from the Michigan Center for Geographic Information, geocoding school locations, and identifying schools within 200 m of freeways and state highways. Of the 392 schools, 75 schools are considered "near road" schools, and 58 showed enrollment (greater than 0) for the 2014-2015 year. An estimated 24,490 children attended the near-road schools.

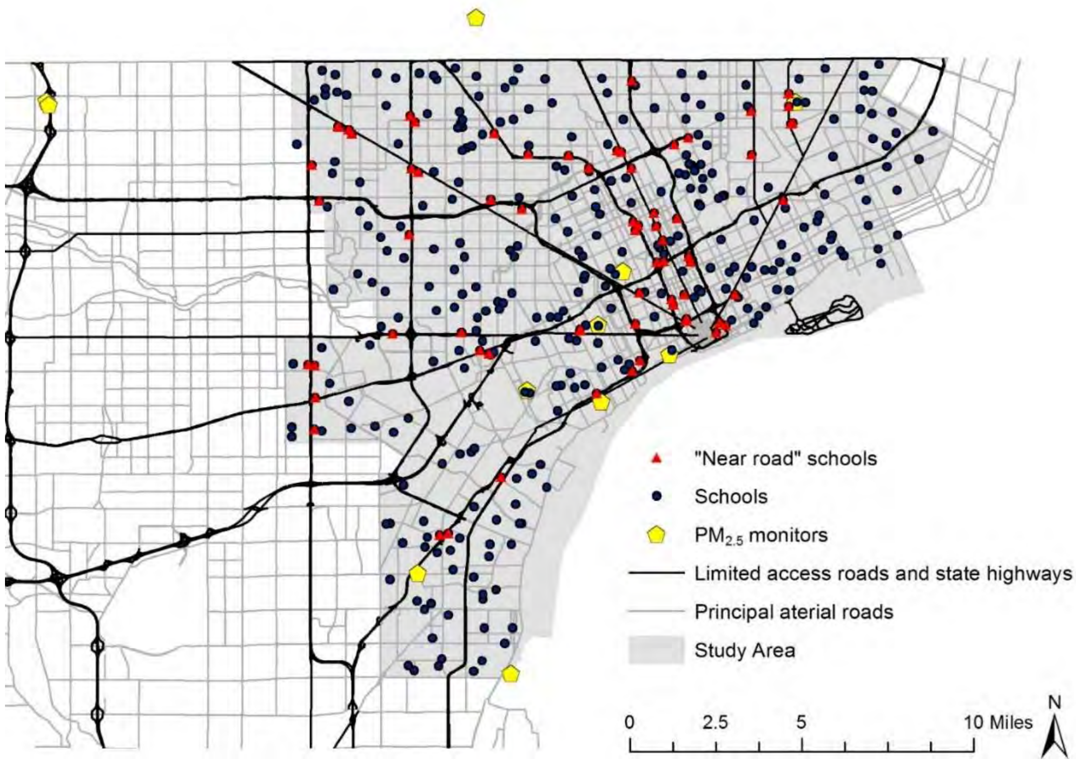
[15] U.S. EPA. Exposure Factors Handbook 2011 Edition (Final). U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-09/052F, 2011.

[16] Michigan School Data, https://www.mischooldata.org/DistrictSchoolProfiles/EntitySummary/Summary.aspx, accessed 2/1/2016.

[24] Shaughnessy RJ, Haverinen-Shaughnessy U, Nevalainen A, Moschandreas D. 2006. A preliminary study on the association between ventilation rates in classrooms and student performance. Indoor Air 16:465-8.

This work is made possible by National Institute of Health and Environmental Sciences, RO1ES022616, and the Fred A. and Barbara M. Erb Family Foundation. Additional support was provided by the Michigan Center on Lifestage Environmental Exposures and Disease (M-LEEaD), #P30ES017885.

Figure 7.2-3. Locations of schools and air quality monitoring stations. One monitor (Ypsilanti, MI) not shown.



Many factors affect filter effectiveness, including the type of filter, filter air flow, air flow circulation, use schedule (e.g., full-time or intermittent), room and building size, air exchange rate and penetration of outdoor pollutants indoors, the nature of indoor particle sources, the outdoor PM concentration. To account for these factors, a range of indoor particle removal efficiencies is considered (25, 50 and 75%), with the most likely value being about 50% for HVAC type filters. Indoor PM sources were not considered. Particle penetration of 100% was considered, that is, without a filter, indoor and outdoor PM concentrations are equal. Estimates assume near-full-time operation of filters in both homes and schools. These assumptions are discussed later.

Monitored $PM_{2.5}$ concentrations at 12 Detroit area monitoring sites over the 2012-2014 period (using high quality Federal Reference Method monitors) were used to estimate exposures and health impacts. "School year" exposures use PM data for only those days that fell within the school year (weekends and weekdays in summer were excluded). "All year" exposures do not exclude any monitoring days. Exposures estimates, including the effect of utilizing filters, accounted for the amount of time students spend in schools (7 hours per day, 177 days per year) or at indoors at home (approximately 15 hours per day, 365 days per year). For schools near major roads or other larger pollution sources, daily PM concentrations were estimated using the highest daily concentration in the monitoring network (average school day concentration of 12.2 $\mu g/m^3$). For schools not near major roads or industry and all homes, $PM_{2.5}$ concentrations used typical concentration in the

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monitoring network (10.1 µg /m^3 for school days and 10.4 µg/m^3 for all days). Again, health benefits of using filters were estimated by reducing the indoor concentrations by 25%, 50% and 75%. The analysis assumes none of the schools or homes currently use effective air filters.

Health impacts for children from filter use

For children, the following health outcomes were considered: asthma exacerbations (as cough, wheeze, or shortness of breath) among children ages 6-14; ED visits for asthma among children ages 6-18; and asthma hospitalizations among children ages 6-18. Baseline rates for exacerbations used the NEXUS study,[17] which were applied to all schools in the analysis; and baseline rates for asthma ED visits and hospitalizations used ZIP code level data for schools in Detroit and county level data for schools outside of Detroit.[18,19] Health impact functions giving the $PM_{2.5}$ concentration-response relationship used the epidemiological literature,[20] which was assumed to be linear given the small range of exposure concentrations used. Enrollment in grades K to 8 was used to estimate the schools' age 6-14 population; the total enrollment at each school was used to estimate the population under the age of 18. The asthma prevalence of children in Detroit (11.3%,[21]) was used to estimate how many children were at risk of asthma exacerbations.

Table 7.2-1 summarizes the "baseline" or current asthma incidence and outcomes for children in the study area, and estimates outcomes and impacts attributable to $PM_{2.5}$ exposure at both homes and schools, assuming homes and schools do not currently use filters. Currently, asthma causes 659 hospitalizations for asthma, 7,166 ED visits for asthma, 2 million days with cough, and a total annual monetized impact of $245 million, for example. Asthma outcomes due to $PM_{2.5}$ exposure at schools (school days only) and at home (all year), account for 0.75 and 1.89%, respectively, of the overall asthma health burden (applies to hospitalizations, ED visits, and exacerbations). This estimate applies across the study area, and impacts will depend on where the child lives or goes to school. The incidence estimates in Table 7.2-1 are slightly higher than the incidence data reported in the most recent asthma surveillance report for Detroit, MI, which reported 440 hospitalizations and 4,600 ED visits for asthma among Detroit children covered by Medicaid,[22] largely because Table 7.2-1 consider a larger

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[17] Batterman, S., et al., SO2 Exposures and Health Effects on Children with Asthma in Detroit, manuscript in development, 2016.

[18] DeGuire, P., Cao, B., Wisnieski, L., Strane, D., Wahl, R., Lyon-Callo, S., Garcia, E., 2016. Detroit: The current status of the asthma burden. Michigan Department of Health and Human Services.

[19] Michigan Department of Health and Human Services [MDHHS], 2016. Michigan Asthma Surveillance, Data and Reports [WWW Document]. URL http://www.michigan.gov/mdhhs/0,5885,7-339-71550_5104_5279-213824--,00.html (accessed 2.8.16).

[20] The health impact assessment uses the same health impact functions as a previous case study of $PM_{2.}$ health impacts in Wayne County, MI. See Martenies, S.E., Wilkins, D., Batterman, S.A., 2015. Health impact metrics for air pollution management strategies. Environment International 85, 84–95.

[21] DeGuire, P., Cao, B., Wisnieski, L., Strane, D., Wahl, R., Lyon-Callo, S., Garcia, E., 2016. Detroit: The current status of the asthma burden. Michigan Department of Health and Human Services.

[22] DeGuire, P., Cao, B., Wisnieski, L., Strane, D., Wahl, R., Lyon-Callo, S., Garcia, E., 2016. Detroit: The current status of the asthma burden. Michigan Department of Health and Human Services.

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study population, e.g., Detroit and the surrounding communities, and estimates include all children, not just those children covered by Medicaid.

Table 7.2-1. Current (baseline) asthma-related impacts for children in study area. Shows total impacts and impacts attributable to $PM_{2.5}$ exposures at schools and homes during the school year (weekdays from September 1 to June 15) and at homes during the full year. Baseline case (no filters).

Outcome (age group)	Estimated Incidence (per yr)	Number of PM2.5 attributable health impacts: School Exposures (1) (per school yr)	Home Exposures (1) (per school yr)	Home Exposures (per yr)	% Attributable: School Exposures (school year) (%)	Home Exposures (all year) (%)
Asthma hospitalization, cases (6-18)	659	2	7	14	0.37	1.00
Asthma ED visits (6-18)	7166	46	119	252	0.64	1.65
Asthma exacerbations (as cough, 6-14)	1,778,282	25,735	65,242	138,782	1.45	3.67
Asthma exacerbations (as wheeze, 6-14)	1,130,220	2,061	5,217	11,115	0.18	0.46
Asthma exacerbations (as SOB, 6-14)	1,073,190	2,613	6,617	14,096	0.24	0.62
DALYs (years)	1,956	34	85	181	1.71	4.34
Monetized impacts (million 2010$)	244.57	1.82	4.63	9.84	0.75	1.89

Abbreviations: DALYs: disability-adjusted life years; ED: emergency department; SOB: shortness of breath

Note (1): Considers only 177 days during the school year.

Table 7.2-2 summarizes the potential health benefits for children (as the number of avoided health impacts) of reducing $PM_{2.5}$ exposures for the three air filter strategies (using filters at schools near highways, in all schools and in all homes). Of the estimates in Table 7.2-2, filters installed in schools are likely to reduce PM exposure by about 50%. Filters installed at homes would likely reduce exposures by a lower fraction, likely by 25%. (Higher rates are technically possible but unlikely in practice.)

- The greatest benefits are installing filters in all homes, since children spend most of their time indoors at home.[23] This represents approximately 9,000 homes to be equipped with filters (based on asthma incidence and 81,000 households with children under the age of 18 in Detroit[24]).
- Using filters in the 309 schools where enrollment is >0 obtains benefits that are 39% of those obtained from installing filters in all homes. This represents a significant efficiency, since each filter system benefits all the children in the school (an average of 471 children attend each of the schools in the analysis).

[23] U.S. EPA. Exposure Factors Handbook 2011 Edition (Final). U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-09/052F, 2011.

[24] US Census Bureau. Selected social characteristics in the United States- 2010-2014 American Community Survey 5-Year Estimates. Available: https://www.census.gov/acs/www/data/data-tables-and-tools/data-profiles/2014/. (accessed 04.15.16)

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- Using filters in the 58 schools near major roads is about 20% more effective (in terms of reducing adverse impacts) than installing filters at schools not near major roads since PM exposure is about 20% higher. However, the 58 schools near roads tended to have lower enrollments, on average than other schools in the analysis (e.g., 422 students per near-road school compared to 482 students per non-near road school), which diminished the estimated health impacts. However, these schools experience higher overall exposures to $PM_{2.5}$, and potentially rates of asthma incidence are higher at these schools, thus, the analysis may underestimate the benefit of filters.

Table 7.2-2. Health benefits for children of using air filters in schools and homes of children with asthma. Outcomes show the number of avoided health impacts during the school year, September 1 to June 15, and for all year. Does not consider exposure at home during non-school days. Most likely case is highlighted.

Avoided health impacts per year	Filters installed at all schools (during the school year)			Filters installed at near-road schools only (during the school year)			Filters installed at all homes (operating all year)		
	% $PM_{2.5}$ removed by Filter								
	25%	**50%**	75%	25%	**50%**	75%	**25%**	50%	75%
Asthma hospitalization (6-18)	1	**1**	2	0	**0**	0	**3**	7	10
Asthma ED visit (6-18)	11	**22**	34	2	**5**	8	**61**	124	187
Asthma exacerbation (as cough, 6-14)	6196	**12,556**	19,072	1,031	**2,094**	3,188	**33,406**	67,701	102,843
Asthma exacerbation (as wheeze, 6-14)	512	**1,026**	1,543	86	**173**	260	**2,763**	5,537	8,320
Asthma exacerbation (as SOB, 6-14)	648	**1,300**	1,955	109	**219**	329	**3,497**	7,012	10,545
DALYs (years)	8	**16**	25	1	**3**	4	**43.7**	88.5	134.2
Monetized impacts (million 2010$)	0.44	**0.89**	1.35	0.07	**0.15**	0.23	**2.38**	4.82	7.31

Abbreviations: DALYs: disability-adjusted life years; ED: emergency department; SOB: shortness of breath

Note: Impacts have been rounded to the nearest whole integer

Health benefits for the total population from filter use

For the total population (children and adults), the following health outcomes were considered in addition to the health outcomes included for children: all-cause mortality in adults older than 29 years; infant mortality for children less than 1 year of age; asthma hospitalizations for persons less than 65 years; hospitalizations for chronic obstructive pulmonary disease (COPD), cardiovascular diseases (CVD) and pneumonia in adults over the age of 64; non-fatal heart attacks in adults over the age of 17; and minor restricted activity days (MRAD) and work loss days in adults ages 18 to 64. Baseline rates come from multiple sources at different spatial scales: mortality rates use ZIP code level data and reported deaths for 2009-2013; asthma hospitalization rates use ZIP

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code level for Detroit[25] and county level data outside of Detroit[26]; rates of COPD, CVD and pneumonia hospitalizations are available at the county level[27]; area-specific rates of non-fatal heart attacks, MRAD and work loss days are unavailable, so nationally representative rates are used.[28,29,30] Health impacts estimates use health impact functions with concentration-response coefficients drawn from the epidemiological literature.[31] Age-stratified populations at the block-level were estimated using block level populations from the 2010 US Census and block group age distribution data from the 2013 5-year American Community Survey.[32,33]

For the total population, exposures consider the amount of time spend indoors at the residence each day, which varies by age.[34] $PM_{2.5}$ exposures for the full year were considered. The area-wide annual mean $PM_{2.5}$ concentration was used to estimate the number of attributable deaths, and daily mean concentrations were used to predict morbidities.

Table 7.2-3 provides an estimate of the current (or baseline case) health impacts attributable to $PM_{2.5}$ exposure among the study population. This analysis does not consider spatial differences in concentration, or weight exposures based on the time spent in different locations. The most common attributable outcomes are the low-severity morbidities, e.g., asthma exacerbations and minor-restricted activity days. The predominant fraction (96%) of the health burden (measured as DALYs) is due to all-cause mortality (adults >29 years) and infant mortality.

[25] DeGuire, P., Cao, B., Wisnieski, L., Strane, D., Wahl, R., Lyon-Callo, S., Garcia, E., 2016. Detroit: The current status of the asthma burden. Michigan Department of Health and Human Services.

[26] Michigan Department of Health and Human Services [MDHHS], 2016. Michigan Asthma Surveillance, Data and Reports [WWW Document]. URL http://www.michigan.gov/mdhhs/0,5885,7-339-71550_5104_5279-213824--,00.html (accessed 2.8.16).

[27] Michigan Department of Health and Human Services [MDHHS], 2014. Hospitalizations by Selected Diagnosis [WWW Document]. URL http://www.mdch.state.mi.us/pha/osr/CHI/hospdx/frame.html (accessed 2.8.16).

[28] National Hospital Discharge Survey [NHDS], 2007. Number and rate of discharges by first-listed diagnostic categories [WWW Document]. Data Highlights- Selected Tables. URL http://www.cdc.gov/nchs/nhds/nhds_tables.htm#number (accessed 11.24.14).

[29] Ostro, B.D., Rothschild, S., 1989. Air pollution and acute respiratory morbidity: An observational study of multiple pollutants. Environmental Research 50, 238–247. doi:10.1016/S0013-9351(89)80004-0

[30] Ostro, B.D., 1987. Air pollution and morbidity revisited: A specification test. Journal of Environmental Economics and Management 14, 87–98. doi:10.1016/0095-0696(87)90008-8

[31] The health impact assessment uses the same health impact functions as a previous case study of $PM_{2.5}$ health impacts in Wayne County, MI. See Martenies, S.E., Wilkins, D., Batterman, S.A., 2015. Health impact metrics for air pollution management strategies. Environment International 85, 84–95.

[32] US Census Bureau, 2015. TIGER/Line® with Selected Demographic and Economic Data [WWW Document]. URL http://www.census.gov/geo/maps-data/data/tiger-data.html (accessed 7.2.15).

[33] US Census Bureau. American Community Survey 5-year Estimates. URL https://www.census.gov/programs-surveys/acs/ (accessed 2.16.16).

[34] U.S. EPA. Exposure Factors Handbook 2011 Edition (Final). U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-09/052F, 2011.

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Table 7.2-3. Current (baseline) estimates of health impacts among the total population in the study area attributable to $PM_{2.5}$ exposures.

Outcome (age group)	Attributable Impacts per year
All-cause mortality (>29)	554
Infant mortality (0-1)	7
Asthma hospitalization (<65)	107
COPD hospitalization (>65)	21
CVD hospitalization (>65)	130
Pneumonia hospitalization (>65)	58
Non-fatal MI (18+)	25
Asthma ED visit (0-17)	374
Asthma exacerbation (as cough, 6-14)	224,799
Asthma exacerbation (as wheeze, 6-14)	18,003
Asthma exacerbation (as SOB, 6-14)	22,833
Minor restricted activity day (18-64)	365,937
Work loss day (18-64)	64,441
DALYs	10,367
Monetized impacts (million 2010$)	5,449

Abbreviations: COPD: chronic obstructive pulmonary disease; CVD: cardiovascular disease; DALYs: disability-adjusted life years; ED: emergency department; MI: myocardial infarction (heart attack); SOB: shortness of breath

Table 7.2-4 (left side) summarizes health impacts among the total population in the study area attributable to $PM_{2.5}$ exposures at homes, considering the amount of time spent indoors at home each day. The estimates for asthma are the same as shown earlier in Table 7.2-1; estimates for ED visits for asthma are higher because they consider all children under 18 years of age. Health impacts attributable to $PM_{2.5}$ exposures at home for the total study population range from 5 infant deaths to 240,000 minor-restricted activity days, annually, representing 7,457 DALYs and $4.1 billion in monetized impacts per year. Mortality (all-cause adult and infant mortality) accounts for 97% of the DALYs and monetized impacts.

Table 7.2-4 (right side) presents the potential health benefits for the total population in the study area due to reducing $PM_{2.5}$ exposures using air filters in <u>all</u> homes. As noted earlier, the most likely reduction of $PM_{2.5}$ by filters is likely around 25%. Achieving the benefits in Table 7.2-4 would require installation and full time operation of filters in all households. There are an estimated 254,197 occupied housing units in Detroit, MI.[35]

[35] US Census Bureau. Selected social characteristics in the United States- 2010-2014 American Community Survey 5-Year Estimates. Available: https://www.census.gov/acs/www/data/data-tables-and-tools/data-profiles/2014/. (accessed 04.15.16)

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Filters used in all homes (with 25% effectiveness) would reduce asthma exacerbations by about 225,000 (defined using cough), avoid 1,825 DALYs, and represents a health benefits with a monetized value of $1,015 million, each per year. In comparison, the use of filters at all schools during the school year (with 50% effectiveness) would reduce about 12,000 asthma exacerbations (as cough), avoid 16 DALYs, and represents a total monetized value of $0.89 million (Table 7.2-2). The health benefit of using filters in all homes is much larger, a result of the larger population affected, the greater amount of time spent at home, and the sensitivity of adults to health impacts (including mortality).

Table 7.2-4. Current (baseline) health impacts, impacts attributable to $PM_{2.5}$ exposure, and health benefits from using filters. Considers the total population in the study area and $PM_{2.5}$ exposure at home. Number of avoided health impacts per year. Most likely case is highlighted.

	Baseline health impacts assuming no homes use air filters			Benefits of installing filters in all homes at the number of avoided impacts		
				Percent $PM_{2.5}$ removal		
Outcome (age group)	Estimated Incidence (per yr)	Number of PM2.5 attributable health impacts (per yr)	% Attrib.	**25%**	50%	75%
All-cause mortality (>29)	10,048	422	4.20	**103**	208	314
Infant mortality (0-1)	165	5	3.08	**1**	3	4
Asthma hospitalization (<65)	3,122	71	2.26	**17**	35	53
COPD hospitalization (>65)	1,737	17	1.00	**4**	9	13
CVD hospitalization (>65)	7,896	106	1.35	**26**	53	80
Pneumonia hospitalization (>65)	1,412	47	3.34	**12**	23	35
Non-fatal MI (18+)	1,459	25	1.71	**6**	12	19
Asthma ED visit (0-17)	9,616	374	3.89	**91**	183	278
Asthma exacerbation (as cough, 6-14)	1,778,282	138,782	7.80	**33,406**	67,701	102,843
Asthma exacerbation (as wheeze, 6-14)	1,130,220	11,115	0.98	**2,763**	5,537	8,320
Asthma exacerbation (as SOB, 6-14)	1,073,190	14,096	1.31	**3,497**	7,012	10,545
Minor restricted activity day (18-64)	4,910,560	240,908	4.91	**58,010**	117,467	178,418
Work loss day (18-64)	1,367,402	42,424	3.10	**10,361**	20,884	31,570
DALYs	190,237	7,457	3.92	**1,825**	3,676	5,553
Monetized impacts (million 2010$)	99,520	4,147	4.17	**1,015**	2,044	3,088

Abbreviations: COPD: chronic obstructive pulmonary disease;
CVD: cardiovascular disease;
DALYs: disability-adjusted life years;
ED: emergency department;
MI: myocardial infarction (heart attack);
SOB: shortness of breath
Note: Impacts have been rounded to the nearest whole intege

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Accuracy and uncertainty of results

Many factors affect the accuracy and uncertainty of the health benefits predicted for filter use in schools, homes, and other buildings. The results did not consider the potential health benefits of reducing exposures to $PM_{2.5}$ that originate from indoor sources, which can be very significant, and thus estimated health benefits are conservative. Also, for schools, only children were considered. Teachers and staff in study schools (roughly 14,500 individuals) would also benefit from filter use. On the other hand, the analyses may exaggerate benefits of filters since many homes and school already have filters (though few will have high performance filters); this was one of the reasons why the filter effectiveness at homes was lowered to 25%. The many factors that affect filter effectiveness have been mentioned, e.g., type and use of filter, and thus a range of filter effectiveness was considered. Estimates of most likely conditions were highlighted. The fraction of homes and schools that actually install and use high performance filters was not estimated. Use of high performance filters and continuous use of HVAC systems requires additional electrical energy. In Detroit, much of the energy is generated using coal-fired power plants, thus, some additional pollution will result from filter use, but this was not considered in the analysis, although the incremental increase in electricity consumption due to filter use will be small.

7.2.9 Applicable Strategies for Detroit

Use high performance filters (MERV 11 and above) in homes, schools and commercial buildings. Buildings near major roads, construction sites, and other air pollution sources could be prioritized. The analysis in the preceding section shows significant benefits.

Create multi-stakeholder "Air Filter Management Programs" and/or "Filter Committees" for schools.

Create strategies for businesses to upgrade ventilation and filter systems.

Increase awareness of tax credits for green building.

Use certification systems to encourage green buildings and obtain points for improved air quality in the rating systems.

Create and use regular maintenance schedules for filter replacement, and couple with preventative measures in schools, homes and commercial spaces.

Use the EPA's *Indoor Air Quality Tools for Schools*.[25]

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[25] EPA (Environmental Protection Agency). Indoor Air Quality Tools for Schools Action Kit. Available: http://www.epa.gov/iaq-schools/indoor-air-quality-tools-schools-action-kit [accessed 3-2-16].

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Encourage the City of Detroit and other municipalities to pass ordinances stipulating that schools adopt and implement an air quality and indoor environment program, a preventative maintenance program with appropriate maintenance schedule

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7.3 BUFFERS & BARRIERS

2016

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Figures

Table

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7.3 Buffers and Barriers

7.3.1 What are buffers?

Buffers are strips of land, vegetation or physical barriers located between sources of pollution (e.g., roadways) and homes, schools or other places where people spend time and may be exposed to those pollutants. Buffers can reduce people's exposure to harmful air pollutants by absorbing and trapping some of the pollutant. So, while buffers don't decrease air pollution emissions, they can reduce human exposures by lowering air pollution concentrations.

7.3.2 What types of buffers can be used and where can they be used?

There are three main types of buffers that can be useful for reducing exposure to air pollution:

1) vegetative buffers (i.e. green buffers)
2) sound walls and,
3) spatial buffers.

Selecting which buffer type is appropriate and where they can be implemented largely depends on the physical characteristics of the area and the specific goals, as described in more detail below.

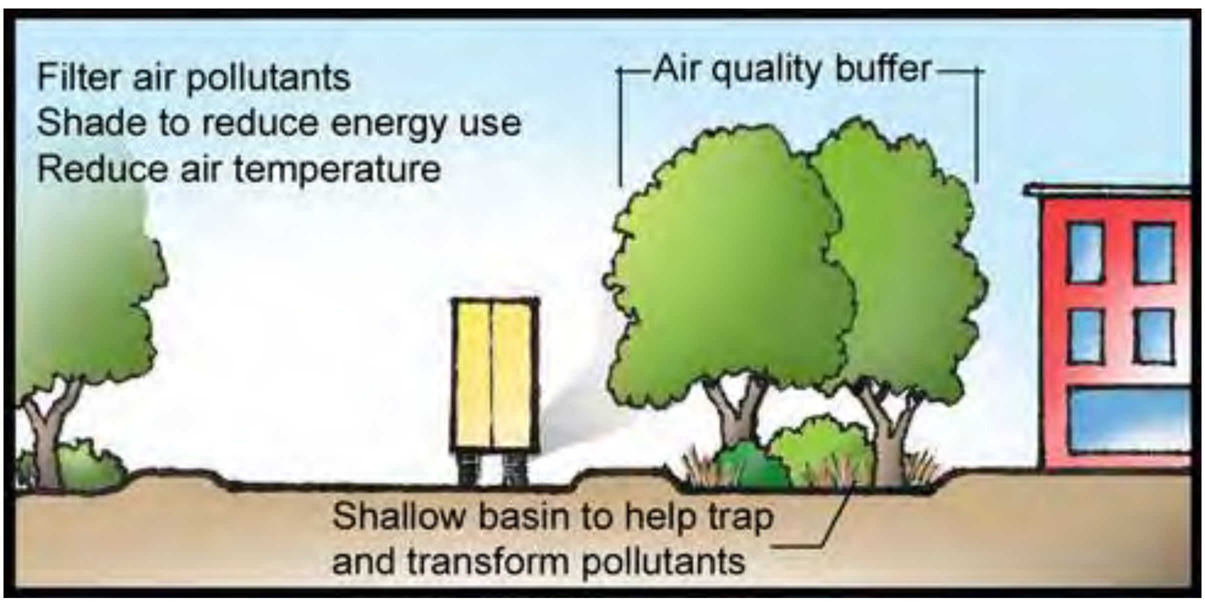

Figure 7.3 – 1. Vegetative buffers.

1) Vegetative buffers are different species of trees, shrubs and other vegetation that are planted around pollution sources, or between pollution sources and people. Vegetative buffers separate people from sources of pollution and can trap pollutants before they reach people through the air. Small amounts of air pollution can be absorbed through the plant's stomata (small openings largely on the underside of the leaf). The majority of pollutants are deposited on tree surfaces (to either be recirculated later or dropped by leaf-fall and twigs). Vegetative buffers also can reduce temperatures by shading structures, thus reducing energy use.[1]

[1] USDA (United States Department of Agriculture National Agroforestry Center). Conservation Buffers: Air Quality Buffers. Available: http://nac.unl.edu/buffers/guidelines/6_aesthetics/3.html [accessed 3 March 2016].

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Tree species, soil types, and location all play an important role in the effectiveness of vegetative buffers. For example, the greatest pollutant removal is attained by planting vegetation in the areas with the highest pollution or 'hot spots', like traffic junctions and at traffic lights.[2] Additional considerations are choosing plants that can withstand exposure to roadway conditions, including exposure to pollutants, soil, de-icing salts that may be used, heat and other effects, for example, if planted near roadways. *Note: This information will be developed further in a separate document at a later point.*

2) Sounds Walls, a form of **non-vegetative buffers,** are physical structures that can reduce people's exposure to noise as well as harmful air pollutants. Primarily built along major roadways to reduce traffic noise to the surrounding neighborhood, sound walls also influence the distribution of pollutants from traffic along those roadways.

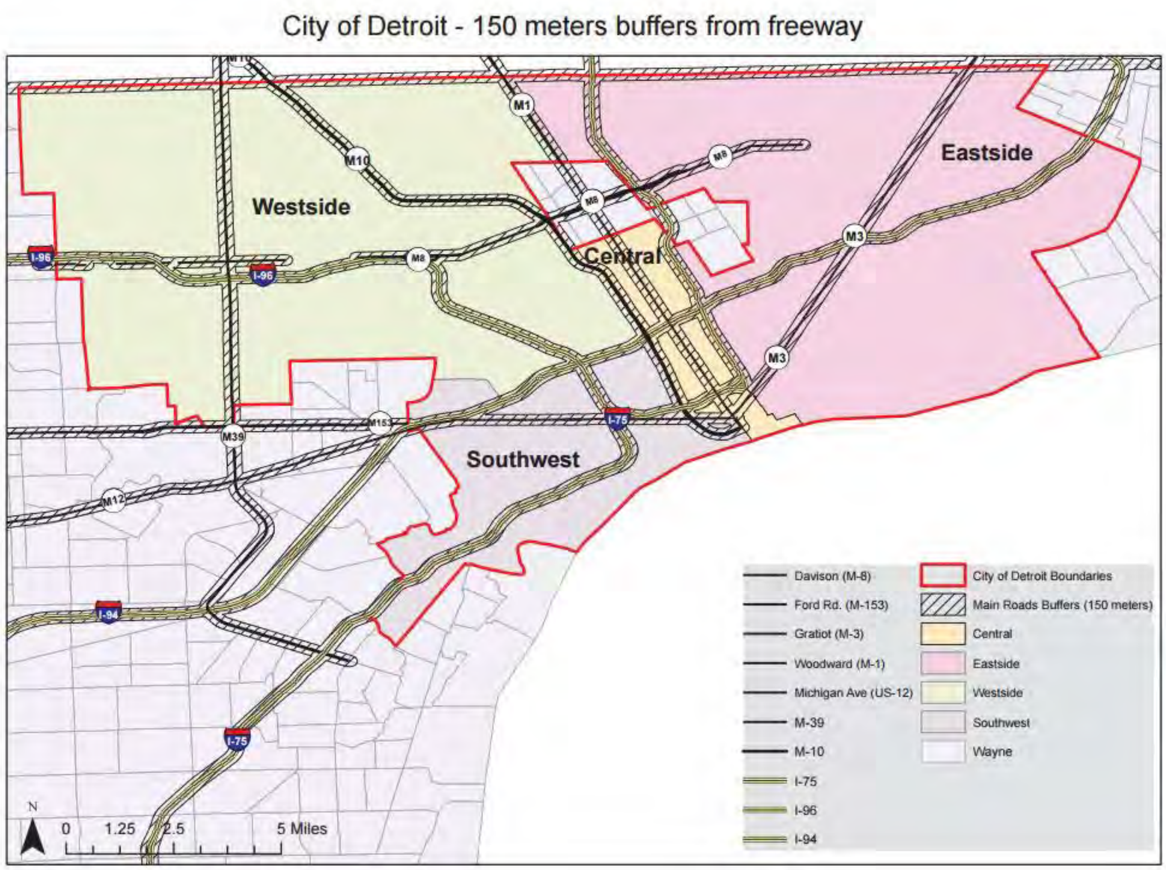

Figure 7.3 – 2. Spatial buffers along major highways in the City of Detroit.

3) Spatial buffers are another form of **non-vegetative buffer**. Often, concentrations of air pollutants from vehicle emissions are highest close to their source, and are lowered as distance from the source increases. Spatial buffers work by creating greater physical separation between the pollution source and places where people are, such as schools, playgrounds, childcare centers, health care facilities, rehabilitation centers,

[2] Mitchell R, Maher BA. 2009. Evaluation and application of biomagnetic monitoring of traffic-derived particulate pollution. Atmospheric Environment 43:2095-2103.

This work is made possible by National Institute of Health and Environmental Sciences, RO1ES022616, and the Fred A. and Barbara M. Erb Family Foundation. Additional support was provided by the Michigan Center on Lifestage Environmental Exposures and Disease (M-LEEaD), #P30ES017885.

convalescent centers, hospitals, retirement homes, or residences. Spatial buffers around roadways can be supplemented with vegetation and sound barriers, particularly if the buffer is close to the roadway, enhancing the protection of people nearby.

7.3.3 Why is this important?

Living next to highly travelled roadways is associated with negative health outcomes.[3] In 2009, the EPA estimated more than 45 million people in the US lived within 300 feet of a highway with 4 or more lanes, a railroad, or an airport. Population trends suggest this number is increasing. Many schools and childcare centers are located within a few hundred feet of highways, particularly in urban areas. Furthermore, air pollution from cars and trucks may negatively impact those who drive to work. Every day, the average American spends more than an hour in travel, most of which takes place on major roadways.[4]

In the City of Detroit an estimated 69,000 (about 10%) residents live within 150 meters (about 500 feet) of a major freeway. Roughly 70,000 – 90,000 trucks travel on major corridors (I-75, I-94, I-96, M10 and M39) in Detroit daily,[5] and as many as 6,900 trucks a day (2.5 million annually) cross the International Bridge.[6] There are approximately 75 public schools within 200 meters of large highways, these trucks emit high proportions of heavy diesel vehicles.[7] In 2014-2015, 58 of these schools were in operation with an estimated 24,490 students in attendance.

As noted above, trees can be important natural filters for air pollution. Most current estimates suggest that between 17-22% of Detroit's land has tree coverage, [8, 9] although one recent analysis estimates coverage at 28%.[10] The majority of estimates are substantially below the American Forests' recommendation of 30% for a temperate city.[11] Planting additional trees in strategic locations in Detroit has the potential to both improve air quality and health for city residents, and can also help to reduce adverse health effects associated with extreme heat events that can affect urban areas.

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[3] Boehmer, T.K, Foster, S.L., Henry, J.R., Woghiren-Akinnifesia, E.L., Fuyuen, F.Y. (2013) Residential Proximity to Major Highways-United States, 2010, in *Morbidity and Mortality Weekly Report*. Centers for Disease Control and Prevention, November 22, 2013/62(03);46-50.

[4] EPA (Environmental Protection Agency). 2015. Near Roadway Air Pollution Health. Available: http://www3.epa.gov/otaq/nearroadway.htm [accessed 3 March 2016].

[5] CAPHE (Community Action to Promote Healthy Environments). 2016. Diesel Pollutant Fact Sheet. Available: http://caphedetroit.sph.umich.edu/project/diesel/ [accessed 3 March 2016].

[6] PBOA (Public Border Operations Association). 2016. Traffic Data. Available: http://publicborderoperators.org/index.php/traffic [accessed 10 February 2016].

[7] Wu YC, Batterman SA. 2006. Proximity to Schools in Detroit, Michigan to automobile and truck traffic. J Expo

[8] Urban Ecosystem Analysis SE Michigan and City of Detroit: Calculating the Value of Nature. 2006. American Forests Report. www.americanforests/analysis/php Accessed April 20, 2016
and Greening of Detroit. 2016. A Healthier and Greener Detroit: Policy Recommendations for How Trees can be used to improve public health in Detroit. Available: http://www.greeningofdetroit.com/ [accessed 3 March 2016].

[9] Greening of Detroit. 2016. A Healthier and Greener Detroit: Policy Recommendations for How Trees can be used to improve public health in Detroit. Available: http://www.greeningofdetroit.com/

[10] Nowak, D.J., Greenfield, E.J. 2012. Tree and impervious cover change in US cities, in *Urban Forestry and Urban Greening 11*, 21-30.

[11] Greening of Detroit. 2016. A Healthier and Greener Detroit: Policy Recommendations for How Trees can be used to improve public health in Detroit. Available: http://www.greeningofdetroit.com/ [accessed 3 March 2016].

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Buffers can be a cost effective strategy that can be implemented at a variety of scales, from small to large. Buffers can also enhance visual interest, screen undesirable noise, filter unpleasant odors, and separate human industrial from residential or leisure activities, improving quality of life for residents, and the desirability of Detroit neighborhoods.

7.3.4 Implications for Health

7.3.4.1 Which pollutants are affected by buffers?

Buffers can reduce concentrations of several hazardous pollutants, including ozone (O_3), particulate matter (PM), nitrogen oxides (NO_X), sulfur dioxide (SO_2), and carbon monoxide (CO).[12] Estimates of the effectiveness of trees and tree canopies in removing pollutants depends on many factors, including the pollutant and density of the canopy, and estimates range from under 1% to about 13%. [12, 13, 14] Even the smaller removals can be effective, however, consider the potentially very large extent of vegetated areas.

Properly installed windbreaks (i.e., continuous rows of trees or shrubs planted to provide a wind barrier) can lower concentrations of CO and $PM_{2.5}$ generated by vehicles on the roadway by 12-40%. Similarly, sound walls can reduce concentrations of these traffic related pollutants near the roadway (within 15-20 m) by 15 to 50%. Depending on how sound walls are constructed, they may shift pollutants to other areas, so these need to be positioned so that pollutants are not directed into residential areas.[15] When sufficient separation distance is provided between ground level sources of pollution (such as vehicles) and people, spatial buffers can reduce concentrations from these local sources as much as 80%.[16]

Buffers, walls and windbreaks work most effectively for those sources that release pollutants at or near ground level (like exhaust emissions from vehicles, and entrained dust from storage piles) and that are located just upwind of the buffer or barrier. Vehicle emissions of $PM_{2.5}$ and diesel exhaust are particularly important examples of such sources and pollutants. Different strategies are needed for pollutants emitted by large industrial sources with elevated stacks (like power plants), and secondary pollutants (like ozone and $PM_{2.5}$), although tree canopies can provide smaller reductions in pollutant concentrations.

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[12] Nowak, DJ, Crane, DE, Stevens, JC. Air pollution removal by urban trees and shrubs in the United States. Urban Forestry and Urban Greening 4:115-123.

[13] Bealey WJ, McDonald AG, Nemitz E, Donovan R, Dragosits U, Duffy TR, et al. 2007. Estimating the reduction of urban PM10 concentrations by trees within an environmental information system for planners. Journal of Environmental Management 85:44–58.

[14] Mitchell R, Maher BA. 2009. Evaluation and application of biomagnetic monitoring of traffic-derived particulate pollution. Atmospheric Environment 43:2095-2103.

[15] Brechler, J. and Fuka, V. (2014) Impact of Noise Barriers on Air-Pollution Dispersion. Natural Science, 6, 377-386. http://dx.doi.org/10.4236/ns.2014.66038

[16] NRCS (Natural Resources Conservation Services). 2004. Using Windbreaks to Reduce Odors Associated with Livestock Production Facilities. Available: http://www.nrcs.usda.gov/wps/portal/nrcs/detail/mo/about/?cid=nrcs144p2_012665 [accessed 3 March 2016].

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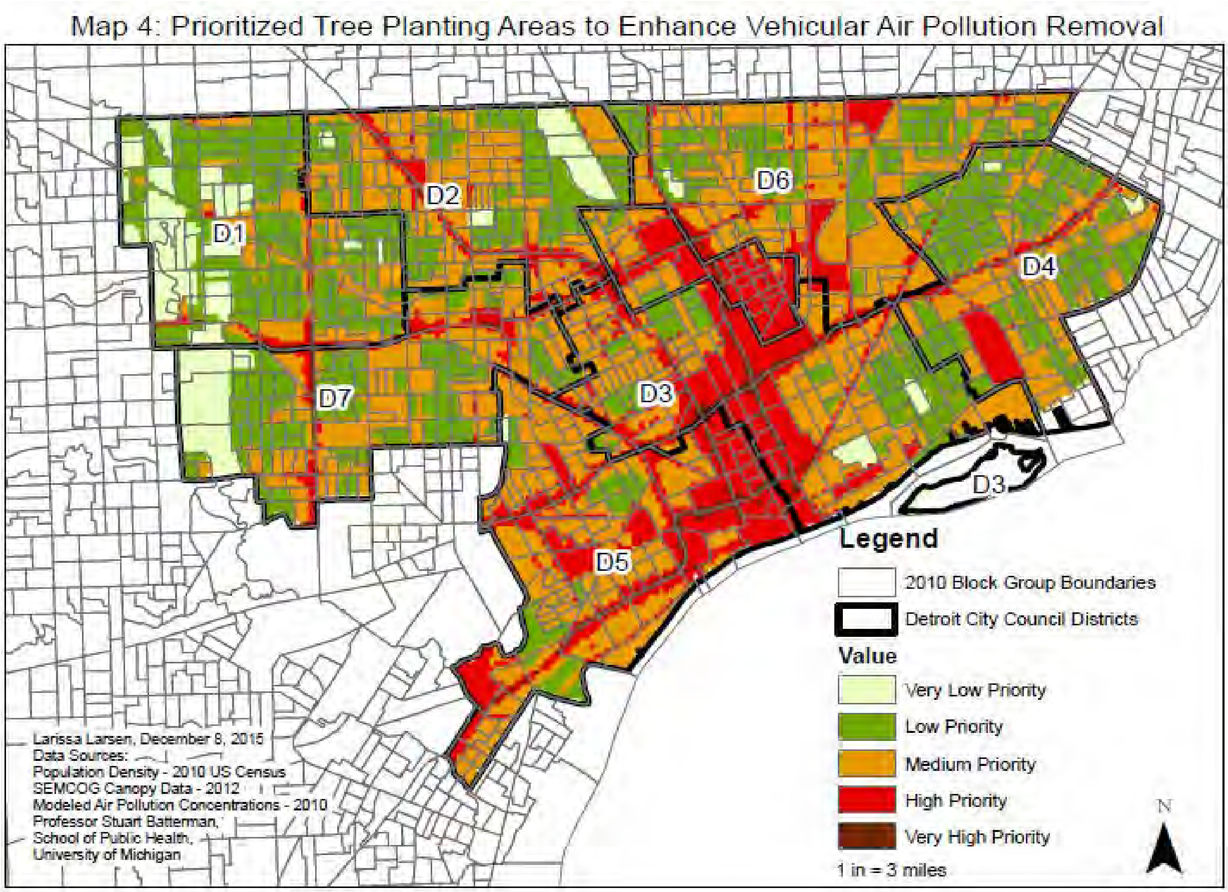
7.3.4.2 What health effects can be mitigated?

Using buffers could lead to improvements over time in respiratory diseases such as asthma and reduced lung irritation, coughing, and difficulty breathing; reduced lung diseases; fewer heart attacks, irregular heartbeat, and cases of cardiovascular disease; fewer low birth weight infants; and cancer.[17, 18 19]

7.3.5 What is happening in Detroit?

Prioritizing Tree Planting Locations to Enhance Air Pollution Removal along Detroit's Roadways Project. Based on an approach conducted in New York City in 2011,[20] CAPHE combined three spatial layers of information including pollution concentration (for $PM_{2.5}$ and NO_2), population density, and lack of tree canopy, to create an index of priority planting areas. Figure 7.3 – 3 provides results from this analysis, ranging from very low priority tree planting areas, to very high priority tree planting areas. These findings will be expanded to identify specific recommendations for tree planting, including tree species information and information on impervious surfaces where planting may not be feasible.[21]



[17] EPA (Environmental Protection Agency). 2015. Near Roadway Air Pollution Health. Available: http://www3.epa.gov/otaq/nearroadway.htm [accessed 3 March 2016].

[18] [13] ARB (California Environmental Protection Agency Air Resources Board). 2005. Air Quality and Land Use Handbook: A Community Health Perspective. Available: http://www.arb.ca.gov/ch/handbook.pdf [accessed 3 March 2016].

[19] EPA (Environmental Protection Agency). 2016. Near-Source Air Pollution Research. Available: http://www.epa.gov/air-research/near-source-air-pollution-research [accessed 3 March 2016].

[20] Morani, A., Nowak, D.J., Hirabayashi, S., and Calfapietra, C. 2011. How to select the best tree planting locations to enhance air pollution removal in the MillionTreesNYC initiative, *Environmental Pollution 159*, 1040-1047.

[21] Larsen, L. (Unpublished). Prioritizing tree planting locations to enhance air pollution removal along Detroit's roadways.

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Figure 7.3 – 3. Prioritized Tree Planting Areas to Enhance Vehicular Air Pollution Removal

Carbon Buffering Pilot Program. Detroit Future City is working with The Greening of Detroit to prioritize sites and implement carbon buffers based on air quality measures, public land availability, and the future adjacent land uses. The primary goal of this program is to improve air quality in neighborhoods near expressways with green infrastructure that absorbs carbon dioxide, particulate matter, and other pollution from traffic.[22]

Green Buffers Plan in Southwest Detroit. The Southwest Detroit Community Benefits Coalition, in partnership with Detroiters Working for Environmental Justice (DWEJ) was awarded a Kresge Foundation Innovation Planning Grant to develop a green buffers plan to protect the Delray neighborhood and surrounding areas in Southwest Detroit from air pollution from industrial facilities and the future Gordie Howe International Bridge connecting Detroit to Windsor, which will be located in this community.[23]

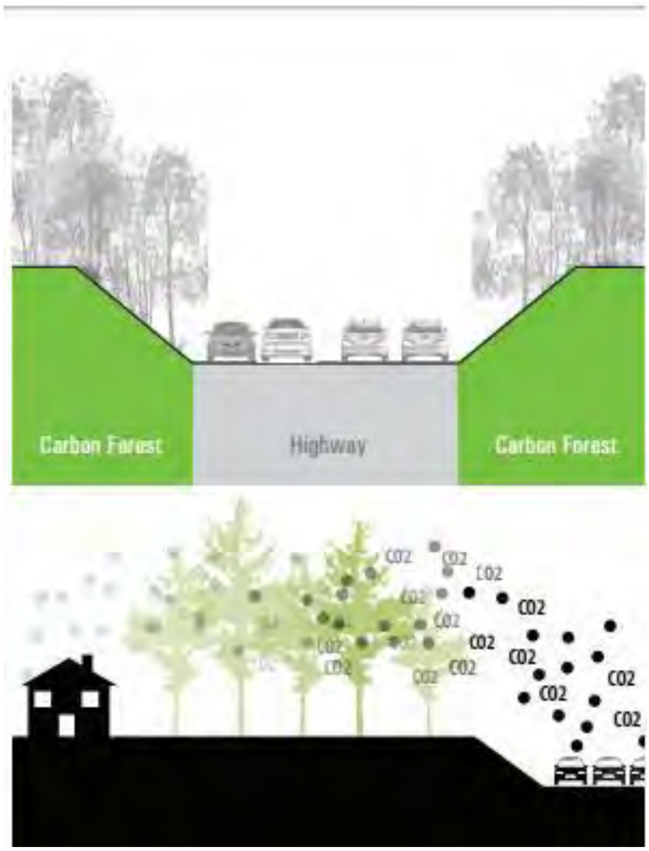

Figure 7.3 – 4. Carbon Buffering Pilot Program. Detroit Future City.

A Healthier and Greener Detroit: Policy Recommendations for How Trees can be used to Improve Public Health in Detroit. In 2015 the Greening of Detroit partnered with the Institute for Population Health (IPH) to establish the "Healthier and Greener Detroit" (HGD) workgroup, with representatives from many Detroit based organizations.[18] Funded through a grant from Trees Forever, they developed policy recommendations for the targeted use of trees to mitigate some of Detroit's most serious public health problems, including: respiratory illness, heat stress, and mental health. One of their main goals is to increase Detroit's tree canopy from 16.6% to 30% by 2025.[24]

Noise Abatement Program. Michigan Department of Transportation (MDOT) has a Noise Abatement Program that includes the use of sounds walls. While the primary goal of this program is to reduce noise pollution, sound walls can lower concentrations due to vehicle-related emissions in nearby neighborhoods. MDOT implements barriers when an area meets its 'feasibility' and 'reasonableness' criteria. These criteria consider whether a barrier can be implemented, the amount it would lower

[22] Detroit Future City. 2014. Carbon Buffering Pilot Program. Available: http://detroitfuturecity.com/wp-content/uploads/2014/12/Carbon-Buffering.pdf [accessed 3 March 2016].

[23] Southwest Detroit Community Benefits Coalition. 2015. Green Buffers Planning Project in Southwest Detroit. Available: http://www.swdetroitcbc.org/archives/51 [accessed 3 March 2016].

[18] These included the Asthma and Allergy Foundation of America Michigan Chapter, Data Driven Detroit, Detroit Future City, Detroiters Working for Environmental Justice, Henry Ford Health System, Office of City Councilman Scott Benson, State of Michigan Department of Community Health, U.S. Forest Service, University of Michigan, and Wayne State University.

[24] The Greening of Detroit. 2016. A Healthier and Greener Detroit: Policy Recommendations for How Trees can be used to improve public health in Detroit. Available: http://www.greeningofdetroit.com/ [accessed 3 March 2016].

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noise pollution, and the number of people affected.[25]

7.3.6 What are the best practices elsewhere?

Policy support for spatial buffers. The California Environmental Quality Act (CEQA) created an air quality land use handbook that helps decision-makers determine whether a proposed development will result in environmental and health impacts and how to identify appropriate measures to reduce adverse impacts. The handbook includes spatial buffering recommendations for the siting of sensitive land uses including: residences, schools, daycare centers, playgrounds, or medical facilities. See *Recommendations for Siting Sensitive Land Uses Table*:[26]

[25] MDOT (Michigan Department of Transportation). 2016. Noise Abatement. Available: http://www.michigan.gov/mdot/0,1607,7-151-58298---F,00.html [accessed 3 March 2016].

[26] CARB (California Environmental Protection Agency Air Resources Board). 2005. Air Quality and Land Use Handbook: A Community Health Perspective. Available: http://www.arb.ca.gov/ch/handbook.pdf [accessed 3 March 2016].

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Source Category	Advisory Recommendations
Freeways and High-Traffic Roads	• Avoid Siting new sensitive land uses within 500 feet (152 meters) of a freeway, urban roads with 100,000 vehicles/day, or rural roads with 50,000 vehicles/day.
Distribution Centers	• Avoid siting new sensitive land uses within 1,000 feet (305 meters) of a distribution center that accommodates more than 100 trucks per day, more than 40 trucks with operating transport refrigeration units (TRUs) per day, or where TRU unit operations exceed 300 hours per week. • Take into account the configuration of existing distribution centers and avoid locating residences and other new sensitive land uses near entry and exit ports.
Rail Yards	• Avoid siting new sensitive land uses within 1,000 feet (305 meters) of a major service and maintenance rail yard. • Within one mile (1,609 meters) of a rail yard, consider possible siting limitations and mitigation approaches.
Ports	• Avoid siting new sensitive land uses immediately downwind of ports in the most heavily impacted zones. Consult local air districts.
Refineries	• Avoid siting new sensitive land uses immediately downwind of petroleum refineries. Consult with local air districts and other local agencies to determine an appropriate separation.
Chrome Platers	• Avoid siting new sensitive land uses within 1,000 feet (305 meters) of a chrome plater.
Dry Cleaners Using Perchloroethylene	• Avoid siting new sensitive land uses within 300 feet (92 meters) of any dry cleaning operation. For operations with two or more machines, provide 500 feet (152 meters). For operations with three or more machines, consult with the local air district. • Do not site new sensitive land uses in the same building with perc dry cleaning operations.
Gasoline Dispensing Facilities	• Avoid siting new sensitive land uses within 300 feet (92 meters) of large gas stations (defined as a facility with a throughput of 3.6 million gallons (13.6 million liters) per year or greater). A 50 foot (15 meter) separation is recommended for typical gas dispensing facilities.

Table 7.3 – 1. Recommendations for citing sensitive land uses.[7]

Mapping city trees. The City of Lancaster, Pennsylvania used surveying technology (LiDAR) and aerial imagery to determine where tree canopy currently existed and where there was potential for tree canopy. They found that 28% of the City's land area was covered in tree canopy. More importantly, they identified large areas (45% of total land area) where trees could be planted to increase the City's tree canopy. This information will

[7] California Environmental Protection Agency. 2005. Air Quality and Land Use Handbook: A Community Health Perspective. Available: http://www.arb.ca.gov/ch/handbook.pdf[accessed 9-13-16]

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be utilized to set feasible planting goals and prioritize locations.[27] See above for estimates using a similar process in Detroit.

Master Plan – Air Pollution Emission Reduction Policies. San Jose, California included air pollution emission reduction policies in their Envision San Jose 2040 Master Plan. Policy Air 2.5 encourages the use of pollution absorbing trees and vegetation in buffer areas between substantial air pollution sources and sensitive land uses, where appropriate and feasible.[28]

Community workshop and partner meetings. In Buffalo, New York, the Clean Air Coalition of Western New York hosted a local organization that designs and implements green buffers to protect vulnerable neighborhoods. They held a community workshop and facilitated meetings with stakeholders. The members also met with nine Common Council members. As a result, the Peace Bridge Authority (i.e., an international compact entity between the State of New York and Canada) announced that it will spend $3 million on green infrastructure to improve air quality and buffer vulnerable neighborhoods from diesel exhaust.[29]

Trees and sound walls combined near schools/vulnerable sites. The US Environmental Protection Agency (EPA) recently recommended that sound walls and/or vegetation should be planted around roadways adjacent to schools to reduce air pollution. EPA suggests that a well-designed sound wall can reduce pollutant concentrations from vehicle sources on the order of 15 to 50%, and that the combined use of trees and sound walls may reduce downwind vehicle pollution by up to 60%. To select appropriate tree and shrub species specific for vegetative buffers, the EPA recommends consulting the U.S. Department of Agriculture's (USDA's) i-Tree Species tool, as well as experts from plant nurseries, city government, or the U.S. Forest Service.[30]

Carefully consider both type and placement of vegetation for greatest impact. A review of literature showed that it is important to consider plant species type, leaf characteristics, plant density, and placement of plants as these characteristics influence the reduction of air pollution. It is recommended to consult guidelines, such as the USDA National Agroforestry Center plant selection criteria for air pollutant removal. [31]

7.3.7 What are the benefits of using buffers in Detroit?

Buffer strategies evaluated

The remainder of this section estimates the health benefits of buffers located along freeways in Detroit. We consider two strategies:

- Assuring that all residents live more than 150 meters (500 feet) from freeways and roads with more than 10,000 vehicles per day.

[27] The City of Lancasin place. Can we apply any of ster. 2011. Green Infrastructure Plan. Lancaster, PA: CH2M Hill, Inc. Available: http://cityoflancasterpa.com/sites/default/files/documents/cityoflancaster_giplan_fullreport_april2011_final_0.pdf [accessed 3 March 2016].

[28] The City of San Jose. 2007. Envision San Jose 2040: General Plan. Available: http://www.sanjoseca.gov/DocumentCenter/View/19425 [accessed 3 March 2016].

[29] Clean Air Organizing for Health and Justice. 2014. 2014 Annual Report. Buffalo, NY: The Clean Air Coalition of W.N.Y. Available: http://www.cacwny.org/wp-content/uploads/2012/03/CA-Annual-Report-2014.pdf [accessed 3 March 2016].

[30] EPA (Environmental Protection Agency). 2015. Best Practices for Reducing Near-Road Pollution Exposure at Schools. Available: http://www.epa.gov/sites/production/files/2015-10/documents/ochp_2015_near_road_pollution_booklet_v16_508.pdf [accessed 3 March 2016].

[31] USDA (United States Department of Agriculture National Agroforestry Center). Air Quality Buffers. Available: http://nac.unl.edu/buffers/docs/6/6.3ref.pdf [accessed 3 March 2016].

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- Increasing vegetation along freeways and roads with more than 10,000 vehicles per day, to create vegetative buffers between mobile air pollutants and residences located within 150 meters (500 feet) of those roadways.

Analysis methods

This analysis considered Detroit and the surrounding Tri-County area. The Tri-county area had a population of 3,962,783 in 2009, and the population of Detroit was 706,663 in that same year (see Figure 6-1). We estimated the number of residents living within 150 meters (500 feet) of freeways and roads with more than 10,000 vehicles per day, using census data and GIS techniques and following methods described by Beelen and colleagues (2007).[32] The measure for proximity to highways was defined as an indicator variable of 'living within 150 m from a highway (I-75, I-94, I-96, I-275, M-10 and M-39) and/or within 150 m of a local road with traffic volumes over 10,000 vehicles/day (M-8 (Davison), M-12 (Michigan Av), M-153 (Ford Road), M-1 (Woodward),M-3 (Gratiot).[33] Mortality was assessed using mortality data from the Michigan Department of Health and Human Services (MDHHS), between January 1, 2008 and December 2012. Cause of death was coded according to the International Classification of Diseases 10th revision (ICD-10). Causes of death were grouped into all-cause mortality, cardiopulmonary mortality, cardiovascular mortality, respiratory mortality and lung cancer mortality.

Diesel PM was obtained from the 2011 NATA concentration estimates, and modeled at the census tract levels using exposure in quintiles (1=low, 5=high). Percent tree canopy coverage at the census tract level was derived from the 2011 National Land Cover Database (NLCD), and entered in models using quintiles (1=low, 5=high). A cumulative risk index made up of exposure and health risks, cumulative vulnerabilities and hazardous land uses and facilities was also created at the census tract level. Methods used to create this measure are detailed in Schulz et al. (2016).[34]

We used multivariate multilevel longitudinal models to assess the independent and joint effects of diesel PM concentrations, tree canopy and proximity to freeways on different measure of mortality, with a focus on cardiopulmonary mortality due to its strong association with air pollutants. Models adjusted for individual level: age; gender; race/ethnicity categorized in Hispanic, Non-Hispanic black , Non-Hispanic white(ref); educational attainment categorized in less than high school education, high school education and more than high school education(ref); smoking status categorized in smoker at the time of death, former smoker and non-smoker (ref); and marital status.

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[32] Beelen, R., Hoeke, G., van der Brandt, P., Goldbohm, R., Schouten, L., Jerret, M., Hughes, E., Armstrong, B. and Brunekreef, B. (2008). Long term effects of traffic related air pollution on mortality in a Dutch cohort. Environmental Health Perspective 116:202

[33] Beelen, R., Hoeke, G., van der Brandt, P., Goldbohm, R., Schouten, L., Jerret, M., Hughes, E., Armstrong, B. and Brunekreef, B. (2008). Long term effects of traffic related air pollution on mortality in a Dutch cohort. Environmental Health Perspective 116:202

[34] Schulz, A.J., Mentz, G.B., Sampson, N, Ward, M., Anderson, R., deMajo, R., Israel, B.A., Lewis, T.C., Wilkins, D. 2016. RACE AND THE DISTRIBUTION OF SOCIAL AND PHYSICAL ENVIRONMENTAL RISK: *A Case Example from the Detroit Metropolitan Area. DuBois Review. In Press.*

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We calculated the relative risk of cardiopulmonary mortality for those residing <150 meters from heavily trafficked roadways compared to those living >=150 meters. We then divided the cardiopulmonary mortality rate (number of cardiopulmonary deaths/total population) by the relative risk of cardiopulmonary mortality based on proximity to heavily trafficked roadways, to estimate the number of cardiopulmonary deaths averted per year if all Detroit residents were to live >=150 meters from a major roadway. Similarly, we calculated the relative risk of cardiopulmonary mortality for each 15% increase in tree canopy coverage, and applied that relative risk to estimate the number of cardiopulmonary deaths averted if tree canopy coverage were increased by 15%, 30% and 45% along major roadways.

7.3.8 Estimated health benefits of buffers in Detroit

The number of people affected by buffers depends on how many are implemented, what type, where they are implemented, the scale (small to large), and how long it takes for then to grow and/or be installed. Using the metrics described above, we estimate that 69,000 Detroit residents live within 150 meters (500 feet) of a major freeway or a road with >10,000 vehicles per day. Similarly, reducing the number of schools located close to a major freeway would result in substantial health benefits to children from reduced exposure.[35]

Approximately 16 - 20% of cardiopulmonary mortality is attributable to exposure to PM.[36] For Detroit, this suggests that between 544-625 of the 3,400 cardiopulmonary deaths each year are attributable to PM. Of those, approximately 10% (54-63) live <150 meters from a freeway. Applying the relative risk of 1.16 (the relative risk of cardiopulmonary mortality due to living <150 meters from a freeway derived from our models) to those cardiopulmonary deaths <150 meters from freeway, we estimate that if all Detroit residents lived at least 150 meters from a major freeway, there would be 9-10 fewer cardiopulmonary deaths per year attributable to diesel $PM_{2.5}$.

Using a similar method, we estimate that increasing vegetation by 45% within the 150 meter buffer areas along those same freeways, would contribute to a reduction of 2 to 6 cardiopulmonary deaths per year attributable to diesel $PM_{2.5}$. These estimates do not include reductions in asthma events, hospitalizations, and other adverse health outcomes, detailed in Section 5.4.4. Furthermore, they are conservative as they do not consider improvements in mental well-being, property values, or reductions in severe heat events associated with climate change, co-benefits of increased vegetation.

Those who live, work, and spend time near major freeways could benefit from the implementation of buffers. Additional sites in Detroit that could use buffers:

- Ambassador Bridge and the future site of the Gordie Howe Bridge
- The new Industrial Park and Logistic Center in Eastside
- Truck and rail transfer stations, for example the Container Port on West Fort Street
- Schools near major roadways
- Along major freeways such as I94 and I75
- Along major traffic routes, such as Fort Street and Michigan Avenue

[35] WHO (World Health Organization). Available: http://www.who.int./gho/phe/outdoor_air_pollution/en/ [Accessed 20 April 2016].
[36] WHO (World Health Organization). Available: http://www.who.int./gho/phe/outdoor_air_pollution/en/ [Accessed 20 April 2016].

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7.3.9 Applicable strategies for Detroit

Require minimum setbacks of 150 meters (500 feet) or more between sensitive land uses and freeways and heavily trafficked roadways, railyards, distribution centers and other sources of air pollutants. Such setbacks would reduce exposures to children attending schools, and to residents in their homes and neighborhoods, resulting in reduced cardiopulmonary mortality, as well as reduced asthma hospitalizations and exacerbations.

Expand vegetative buffer projects throughout the City of Detroit. Given the existing momentum for greening projects in Detroit, it is feasible to implement vegetative buffers that complement or expand on current efforts to use vegetation as an air pollution mitigation measure. Areas can be prioritized by analyzing different spatial layers, similar to the approach mentioned above in Figure 7.3 – 3.

Implement vegetative buffers along major roadways. Increasing tree canopy or other vegetation along freeways would reduce exposure to near-roadway pollutants, particularly for residents who live, work or go to school near high traffic roadways.

Increase City of Detroit tree canopy. Increasing tree canopy in Detroit to the 30% recommended by the American Forest Service could reduce mortality among Detroit residents. Increases in tree canopy have been associated with reduced asthma prevalence, reduced mental distress, increased life satisfaction and decreased mortality,[37] particularly for those who live nearby.

Create policies requiring buffers. A consideration for land use that is environmentally friendly (e.g. spatial buffers, use of greenery) in future construction and design plans can be legally mandated and enforced.

Request buffers in Community Benefits Agreements and/or to be incorporated in future development projects. Similarly to enacting policy that encourages the use of buffers, incorporating buffers into Community Benefits Agreements will provide a contract legally mandating the inclusion of buffers. Additionally, it makes sense to consider the use of buffers in the design phase of a project, rather than following its completion.

Create partnerships with relevant organizations like The Greening of Detroit and state/local authorities. Working with relevant and interested organizations can provide valuable insight, skills and knowledge. It is important to work with state and local authorities to ensure buffer plans are complementary to city plans.

[37] The Greening of Detroit. 2016. A Healthier and Greener Detroit: Policy Recommendations for How Trees can be used to improve public health in Detroit. Available: http://www.greeningofdetroit.com/ [accessed 3 March 2016].

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CAPHE PHAP-RM

7.4. POINT SOURCE CONTROLS

2016

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Tables

Figures

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7.4 Emissions controls for point sources

7.4.1 What are emission controls for point sources?

Point source controls are approaches that either reduce the amount of pollutant generated by an industrial process (sometimes called pollution prevention controls) or equipment that prevents air releases of pollutants (called "end of pipe" or emissions controls). The types of controls selected for a facility depend on many factors, including the type and amount of pollutant to be controlled, the processes used at the facility, the size of the facility, available space for control equipment, and regulatory requirements.

7.4.2 What types of emissions controls can point sources use?

Controls can be classified as controls for gas phase pollutants like SO_2, NO_x and VOCs, and controls for particulate pollutants. Some controls affect both gas and particulate phase pollutants, and often gas and particulate controls can interact, so it is generally best to consider the entire process or facility when evaluating controls.

7.4.2.1 Gas phase pollutants

Gas-phase emission controls include fuel switching, burner modification, absorption, adsorption, condensation and combustion. These controls often control multiple pollutants at once, and several have very high (>90%) removal efficiencies. Tables 7.4-1A-C summarize commonly used controls for SO_2, VOCs and NO_x, respectively. Table 7.4-1A also lists several facilities in Detroit for which SO_2 controls would be technically feasible, based on Reasonable Available Control Technology (RACT) analyses performed recently.[1]

Controls described in Tables 7.4-1A-C are also considered when developing plans to reduce ground-level ozone (a secondary pollutant) since NO_x and VOCs are important precursors.

An example of one control system, a spray tower wet scrubber system used for flue gas desulfurization (FGD) is depicted in Figure 7.4-1. Typical FGD systems include a variety of chemical processes, monitoring controls, and generate liquid wastes and sludges that must be treated or disposed. These systems can be expensive to install and operate, particularly when added to an existing facility. However, costs of FGD systems have decreased significantly in the past decades. Moreover, FGD systems can remove over 90% of SO_2.[2] The installation and operation of large control systems also provides jobs.[3]

The cost estimates in Table 7.4-1 are generalized and provided by US EPA. Facility-specific factors will alter costs.

[1] The RACT analysis was provided in appendices of: Michigan Department of Environmental Quality [MDEQ], 2015. Proposed sulfur dioxide one-hour national ambient air quality standard state implementation plan. Air Quality Division, Lansing, MI.

[2] EPA (Environmental Protection Agency). 2003. Air pollution control technology fact sheet: Flue gas desulfurization. Available: http://www3.epa.gov/ttn/catc/dir1/ffdg.pdf [accessed 18 February 2016].

[3] Construction of the very large FGD system at the DTE facility in Monroe, Michigan provided 900 temporary construction jobs and 40 full-time operator jobs DTE Energy. 2016. Emissions Controls. Based on: https://www2.dteenergy.com/wps/portal/dte/aboutus/environment/details/generation%20and%20emissions/emissions%20controls [accessed 18 February 2016].

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Figure 7.4-1. Schematic design of the absorber of a flue-gas desulfurization (FGD). From https://upload.wikimedia.org/wikipedia/commons/d/d0/Flue_gas_desulfurization_unit_EN.svg

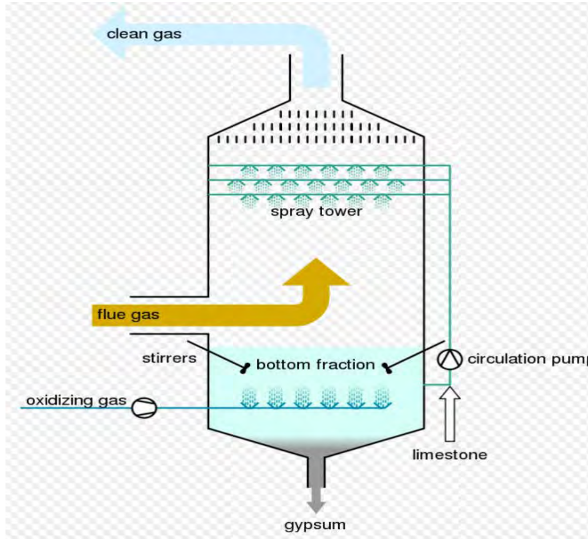

Table 7.4-1A. Control technologies for SO_2.[4,5]

Technology	Efficiency	Approach	How it works	Other pollutants removed	Facilities Where Technologically Feasible	Cost per ton removed	Disadvantages
				Sulfur Dioxide			
Sorbent Injection	10-50%	Removal from waste stream	A material is injected into the waste stream that binds to and removed the pollutant	HCl	Coal and oil combustion (US Steel, DTE River Rouge, DTE Trenton Channel)		Solid waste production
Fuel blending	20-60%	Pollution prevention	Sulfur-containing fuels are blended with low-sulfur fuels to reduce SO2 emissions		Facilities that burn coal as fuel (US Steel, DTE River Rouge)		Sulfur content in coal is variable; can lead to decreased electrical output
Fuel switching	30-90%	Pollution prevention	Sulfur-containing fuels are replaced with low-sulfur alternatives		Facilities that burn coal as fuel [Carmeuse Lime, US Steel (with retrofit), DTE River Rouge]		Not all burners can use alternative fuels
Dry Scrubbing (Flue Gas Desulfurization)	50-80%	Removal from waste stream	Solid materials (typically sodium bicarbonate) is injected into a waste stream to react with SO2	HCl	Coal and oil combustion (US Steel, DTE River Rouge, DTE Trenton Channel)	$150-300 (>2000 MMBtu/h), $500-4000 (<2000 MMBtu/h)	Solid waste production
Spray dryer absorber	80-90%	Removal from waste stream	Limestone is injected into the waste stream to react with SO2	HCl	Coal and oil combustion (US Steel)	$150-300 (>2000 MMBtu/h), $500-4000 (<2000 MMBtu/h)	Solid waste production
Wet Scrubbing (Flue Gas Desulfurization)	90-98%	Removal from waste stream	A material (e.g., soda ash) is dissolved in water and injected in the waste stream to remove acid gases	PM2.5, HCl, some water soluble VOCs	Coal and oil combustion (Carmeuse Lime, US Steel, DTE River Rouge, DTE Trenton Channel)	$200-500 (>4000 MMBtu/h), $500-5000 (<4000 MMBtu/h)	Sludge and wastewater production; increased water usage

[4] Schnelle, K.B., Brown, C.A., 2001. Air Pollution Control Technology Handbook. CRC Press.
[5] US Environmental Protection Agency [US EPA], n.d. Clean Air Technology Center Technology Transfer Network [WWW Document]. URL https://www3.epa.gov/ttncatc1/products.html#aptecfacts (accessed 5.8.16).

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Table 7.4-1B. Control technologies for VOCs.[6,7]

Technology	Efficiency	Approach	How it works	Other pollutants removed	Facilities Where Technologically Feasible	Cost per ton removed	Disadvantages
			Volatile Organic Compounds (VOCs)				
Thermal incineratio	25-99%	Removal from waste stream	VOCs in the waste stream are burned with natural gas or propane in a combustion chamber	PM (soot)	Facilities with continuous streams of mixed hydrocarbons	$440-3600	No recovery of organics; heat recovery can reduce fuel consumption; not recommended for halogen- or sulfur-containing compounds
Catalytic incineratio	25-99%	Removal from waste stream	VOCs in the waste stream are burned in the presence of a catalyst that promotes oxidation	NOx, CO, PM	Facilities with low concentrations of known VOCs in the waste stream	$105-5500	Catalysts can be "poisoned" by particulate matter
Condensation	50-95%	Removal from waste stream	VOC vapors in a waste stream are cooled, and the liquid condensate is collected	Hazardous air pollutants	Facilities with high VOC concentrations in waste streams		Limited applicability; high volatile compounds can be challenging due to high boiling points
Adsorption	50-98%	Removal from waste stream	Waste streams are passed through an absorbing liquid (either water or an organic solvent) that absorbs VOCs	Hazardous air pollutants	Facilities with large volumes of air flow with dilute pollution levels;		Selective applicability; requires specific humidity and temperature conditions
Absorption	90-98%	Removal from waste stream	Waste streams are passed through solid media (e.g., activated charcoal or silica gel) and VOCs are removed	Hazardous air pollutants	Facilities where acid gases are of concern (e.g., HCl, HF, SiF4)		Limited applicability
Flares	>98%	Removal from waste stream	VOCs are separated from the waste stream and burned in an open or closed flame		Facilities with flammable VOC streams, especially useful for sudden or unexpected concentrated flows of VOCs	$17-6500	No recovery of organics; can only be used when VOC emissions are high (unless supplemented with a fuel); does not work for halogenated compounds

[6] Schnelle, K.B., Brown, C.A., 2001. Air Pollution Control Technology Handbook. CRC Press.
[7] US Environmental Protection Agency [US EPA], n.d. Clean Air Technology Center Technology Transfer Network [WWW Document]. URL https://www3.epa.gov/ttncatc1/products.html#aptecfacts (accessed 5.8.16).

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Table 7.4-1C. Control technologies for NO_x.[8,9]

Technology	Efficiency	Approach	How it works	Other pollutants removed	Facilities Where Technologically Feasible	Cost per ton removed	Disadvantages
				Nitrogen Dioxide:			
Low excess air	0-25%	Pollution prevention	The amount of air near a burner is controlled to prevent excess NOx formation				May increase carbon monoxide emissions; flame might be longer and less stable
Selective non-catalytic reduction	30 to 50%	Removal from waste stream	Ammonia or urea is used to reduce NOx to nitrogen gas (N2)		Wide range of boiler configurations and fuels, including coal, oil, gas, biomass, and waste; thermal incinerators, solid waste combustion units, cement kilns, process heaters, glass furnaces	$400-2500	Requires a specific temperature window to be effective
Low-NOx burners	40-65%	Pollution prevention	Reduces NOx formation by burning in under "fuel rich" conditions to limit the amount of oxygen present			$250-4300	Longer flames might impinge on the walls of the combustion chamber in retrofits
Sorbent injection	60%	Removal from waste stream	A material is injected into the waste stream and reacts with the pollutant	Sulfuric acid			Creates solid waste or sludge (though some "wastes" can be resold as byproducts, e.g. ammonium nitrate)
Selective catalytic reduction	70-90%	Removal from waste stream	Ammonia is used to reduce NOx to N2 in the presence of a catalyst, which allows the reaction to take place at a lower temperature	VOCs, PM (some catalysts)	Electrical utility boilers, industrial boilers, process heaters, gas turbines, internal combustion engines, nitric acid plants	$1000-10,000	High initial costs, some ammonia emissions (ammonia "slip"); particulates can "foul" the catalyst
Water/steam injection	up to 50%	Removal from waste stream	Water is injected into a combustion chamber to lower the temperature and reduce NOx to N2				Results in a loss of efficiency
Flue gas recirculation	Up to 80%	Removal from waste stream	Flue gas is sent back through the combustion chamber and NOx is reduced by reacting with hydrocarbons				Affects heat transfer and system pressures

[8] Schnelle, K.B., Brown, C.A., 2001. Air Pollution Control Technology Handbook. CRC Press.
[9] US Environmental Protection Agency [US EPA], n.d. Clean Air Technology Center Technology Transfer Network [WWW Document]. URL https://www3.epa.gov/ttncatc1/products.html#aptecfacts (accessed 5.8.16).

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7.4.2.2 Particulate matter pollutants

Particulate matter (PM) controls focus on removing PM from the waste stream. Table 7.4-2 summarizes common PM controls. Some control technologies treat only larger particles, e.g., cyclones (Figure 7-4-2) separate out the larger particles from the waste stream, often as a "pre-treatment" step. Other control technologies, e.g., electrostatic precipitators (Figure 7.4-3) and baghouses are better suited for smaller particles like $PM_{2.5}$.

PM control costs ranged from \$0.47 to \$444 per ton removed for cyclones, and from \$77 to \$2600 for wet scrubber systems. PM controls also can remove other pollutants, e.g., metals. Preferred PM controls now mostly utilize baghouses, which have the highest efficiencies for the smaller particles.

Table 7.4-2. Control technologies for particulate matter.[10,11]

Technology	Efficiency	Approach	How it works	Other pollutants removed	Facilities Where Technologically Feasible	Cost per ton removed	Disadvantages
Cyclones	30-90%	Removal from waste stream	Larger particles are separated from the waste stream using centrifugal force		Facilities where large particles need to be collected (>10 um). Typically used as a "precleaner"	\$0.47-440	Not effective for PM less than 10 um in diameter
Wet Scrubbers	50-99%	Removal from waste stream	Water is sprayed into the waste stream to collect and remove fine particulate matter	Hazardous air pollutants (HAPs), inorganic gases, some hydrophilic VOCs	Utility, industrial and commercial boilers, chemical manufacture, mineral products, wood pulp and paper, rock products, asphalt manufacture, steel manufacturing, incinerators	\$77 to 2600 (Venturi scrubbers)	Need to reheat scrubbed effluent, sludge generation, increased wastewater
Baghouses	95-55%	Removal from waste stream	Waste streams are passed through fabric filters which remove PM	Metals (except mercury), some particulate HAPs	Utility boilers, industrial boilers, ferrous and non-ferrous metals processing, mineral products, asphalt manufacture, grain milling	\$41-372	High temperatures can require specialty fabrics, cannot be operated in moist environments
Electrostatic precipitators	90-99%	Removal from waste stream	Particles in a waste stream and charged and collected on a plate with the opposite electrical charge	Metals (except mercury), some particulate HAPs, acid mists and VOCs	Utility boilers, industrial boilers, chemical manufacture, non-ferrous metals processing, petroleum refining, mineral products, wood pulp and paper, incineration	\$38-570	Ozone is generated during gas ionization, ESPs can have large footprints, dry precipitators are not good for sticky or moist particles, wet precipitators generate sludge

[10] Schnelle, K.B., Brown, C.A., 2001. Air Pollution Control Technology Handbook. CRC Press.
[11] US Environmental Protection Agency [US EPA], n.d. Clean Air Technology Center Technology Transfer Network [WWW Document]. URL https://www3.epa.gov/ttncatc1/products.html#aptecfacts (accessed 5.8.16).

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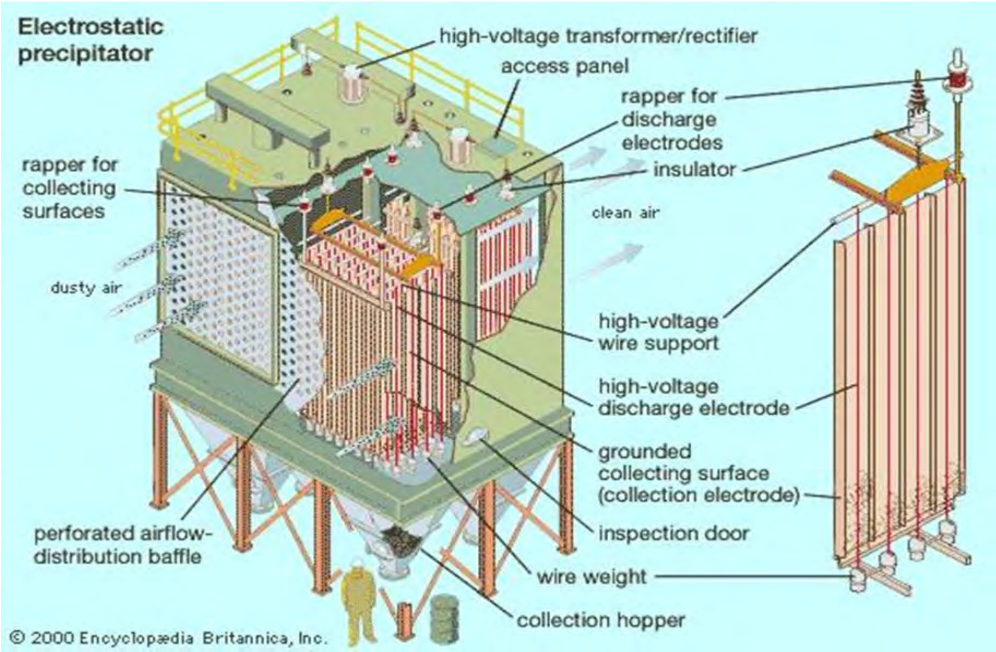
Figure 7.4-2. Diagram of a cyclone used to remove large particles from a waste stream.

Figure 7.4-3. Diagram of an electrostatic precipitator used to remove fine particles from a waste stream.



7.4.2.3 Multipollutant and preferred controls

An example of a control technology that can address multiple pollutants at once is a wet scrubber (as shown earlier in Figure 7.4-1), which uses a liquid to remove pollutants from the waste stream. Alkaline compounds can be added to the scrubber liquid to react with acid gases in the waste stream. These types of wet scrubber

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systems can be very effective in removing SO_2, acid gases, and particles. However, they create a liquid waste and have other disadvantages (pressure drop, operating and construction costs, etc.)

One current and preferred technology for SO_2 is dry powdered lime injection, possibly with carbon to remove mercury, and a baghouse to remove PM as well as the reacted lime and carbon. For PM alone, bag houses are preferred due to their very high efficiencies. Also, filter bags have become very sophisticated, and can incorporate catalysts to remove NO_x and other pollutants.

Site-specific factors, especially related to engineering and cost (see below), are always important factors in selecting appropriate controls. Emissions controls decisions must also consider, among other factors, the space available, pressure drop, operating temperature range, scalability, cost and availability of reagents, process monitoring requirements, system reliability, control efficiency, and the waste generated.

7.4.3 Air quality management and point source controls

The selection, installation, and use of emissions controls is part of air quality management (AQM), which more broadly involves designing strategies to ensure that air quality meets the National Ambient Air Quality Standards (NAAQS) and other objectives. Air quality managers have many options, e.g., elimination of sources, emissions controls, siting decisions and monitoring. However, most strategies involve point and non-point source emissions controls. Air pollution strategies can use:

- Single pollutant approaches that require controls at specific facilities to reduce concentrations at air quality monitoring and other sites for a single pollutant. Reduction targets are identified by combining information from emissions inventories, monitoring networks, and air quality models.[12] This is the approach used most often when designing state implementation plans to address NAAQS non-attainment like SO_2.

- Multi-pollutant, risk based approaches that favor controls that address multiple pollutants. This can encompass pollutants for which an area is in non-attainment as well as additional pollutants of concern. This may yield strategies that are more cost-effective and do more to reduce health disparities from ambient air pollutant exposures than single-pollutant strategies.[13,14] The use of cumulative impact assessments to consider multiple sources and pollutants is an example where multipollutant approaches can be employed.

- Uniform approaches where all sources in an area are subject to the same emissions reduction requirements to meet a reduction target, e.g., uniform 25% reduction to obtain a 25% reduction in concentrations (similar to a "rollback" approach). This simple strategy can impose higher costs per ton

[12] National Research Council [NRC]. 2004. Air quality management in the United States. National Academies Press, Washington, DC.
[13] Wesson K, Fann N, Morris M, Fox T, Hubbell B. 2010. A multi-pollutant, risk-based approach to air quality management: Case study for Detroit. Atmospheric Pollution Research 1: 296–304.
[14] Fann N, Roman HA, Fulcher CM, Gentile MA, Hubbell BJ, Wesson K, et al. 2011. Maximizing Health Benefits and Minimizing Inequality: Incorporating Local-Scale Data in the Design and Evaluation of Air Quality Policies. Risk Analysis 31:908–922; doi:10.1111/j.1539-6924.2011.01629.x.

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of pollutant removed on smaller emitters because many costs associated with pollution abatement (e.g., administrative or capital costs) are fixed, but the total amount of pollution to be removed is small.[15]

- "Largest-first" approaches where source controls are applied to the largest sources in an area first until a reduction goal is met.
- Health-based approaches where controls are applied to sources with the largest population health impacts first. This focuses on facilities that have characteristics that result in little dispersion of pollutants (e.g., stacks that are low to the ground) and/or are located near exposed populations.

There many considerations that influence the selection of controls (or combination of controls) for a facility. These are site-specific and can include: the characteristics of the pollutants, e.g., chemical composition and size distribution; characteristics of the waste stream, e.g., temperature and flow rates; how the control system might affect the performance of the industrial process, e.g., pressure drops, temperature requirements; facility characteristics, e.g., the size of the facility and whether space is available; utility needs of the control technology; generation of wastewater and solid waste; and economic considerations, e.g., capital and operating costs.

7.4.3.1 Costs and benefits

The total cost of control includes capital costs and operating costs. These costs are important as they determine what is feasible and can be imposed in a permit. Costs vary depending on the size of the facility. Typically, costs are expressed as dollars per ton of pollutant removed.

Evaluation of emissions controls should use a life cycle approach, and design, construction, operating and decommission costs can be important. There are typically economies to scale. In addition, control systems, especially end-of-pipe controls, demonstrate increasing costs to remove higher and higher fractions of pollutants, e.g., removing the first 50% of pollution may cost $500 per ton, but getting the second 50% can be far more expensive (or practically impossible).

Resources for estimating the cost of emissions controls include:

- *EPA Air Pollution Cost Control Manual*, which provides guidance to facilities and regulators on how to estimate costs for point source air pollution control devices. The current version of the manual was published in 2002; the manual is currently being updated, and is expected to be released in 2017. The manual includes guidance for estimating control costs for volatile organic compounds (VOCs), oxides of nitrogen (NO_x), sulfur dioxide (SO_2) and acid gases, and particulate matter (PM).[16]
- Air pollution abatement cost functions, which can be used to make more general estimates about the cost of reducing emissions based on factors such as industrial sector and pollutant.[17] Between 1973 and

[15] Becker RA. 2005. Air pollution abatement costs under the Clean Air Act: evidence from the PACE survey. Journal of Environmental Economics and Management 50:144–169; doi:10.1016/j.jeem.2004.09.001.

[16] US Environmental Protection Agency [US EPA]. 2002. EPA Air Pollution Control Cost Manual: Sixth Edition.

[17] Hartman RS, Wheeler D, Singh M. 1997. The cost of air pollution abatement. Applied Economics 29:759–774; doi:10.1080/000368497326688.

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2005, the US Census Bureau collected data on the cost incurred by industry to comply with environmental regulations[18], and these data can be used to inform cost functions.

The cost-effectiveness or cost-benefit ratio for an emissions controls depends on the total cost of the control (life cycle costs) and the estimated health and other benefits (as avoided adverse health outcomes or monetized impacts). Resources for estimating the health benefits of a point source control technology include:

- Estimates of impacts per ton of pollutant, which are based on sector-specific emissions inventories, air quality modeling, and health impact functions.[19,20] These estimates are typically drawn from nation-wide studies and can be useful for screening analyses, but they do not account for location-specific factors that are important for estimating the health impacts from point sources, e.g., source location, release point characteristics, meteorology, and the distribution and sensitivity of exposed populations.[21]
- Quantitative health impact assessment tools such as *US EPA's Benefits Mapping and Analysis Program* (BenMAP)[22] or the *Framework for Rapid Emissions Scenario and Health Impact Estimation* (FRESH-EST)[23] which combine air quality data (e.g., monitoring and/or modeling results) with population and health outcome data to estimate health benefits of pollution control technologies. These types of tools can be tailored to the urban scale to better account for the location-specific factors that influence health benefit estimates.[24]

7.4.4 Why is this important?

Point sources in the Detroit area emit a significant amount of criteria and hazardous air pollutants, as described in Section 5 of this Resource Manual. Emissions controls on point sources can help eliminate air pollution before it reaches surrounding communities. This is especially important for Detroit for several reasons:

- Many point sources are old and generally do not have modern emissions controls. If newly constructed or substantially modified, these sources may be required to meet more stringent emission requirements specified under Michigan and federal law (see Section 7.6). This applies to industrial sources in Detroit using coal, diesel, and other fuels.

  No facility burning coal in Detroit has modern emission controls with the exception of DTE Monroe. These sources are responsible for nearly all SO_2 emissions since coal contains a considerable amount of

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18 US Census Bureau. Pollution Abatement Costs and Expenditures Survey. Available: https://www.census.gov/econ/overview/mu1100.html [accessed 6 May 2016].

19 Fann N, Baker KR, Fulcher CM. 2012. Characterizing the $PM_{2.5}$-related health benefits of emission reductions for 17 industrial, area and mobile emission sectors across the U.S. Environ Int 49:141–151; doi:10.1016/j.envint.2012.08.017.

20 US Environmental Protection Agency [US EPA]. 2013. Technical support document: Estimating the benefit per ton of reducing PM2.5 precursors from 17 sectors.

21 Fann N, Fulcher CM, Hubbell BJ. 2009. The influence of location, source, and emission type in estimates of the human health benefits of reducing a ton of air pollution. Air Qual Atmos Health 2:169–176; doi:10.1007/s11869-009-0044-0.

22 US Environmental Protection Agency [US EPA]. 2016. Environmental Benefits Mapping and Analysis Program - Community Edition (BenMAP-CE). Available: https://www.epa.gov/benmap [accessed 6 May 2016].

23 Milando CW, Martenies SE, Batterman SA. 2016. Assessing Concentrations and Health Impacts of Air Quality Management Strategies: Framework for Rapid Emissions Scenario and Health impact ESTimation (FRESH-EST). Env Int. Submitted.

24 Hubbell BJ, Fann N, Levy JI. 2009. Methodological considerations in developing local-scale health impact assessments: balancing national, regional, and local data. Air Quality Atmosphere and Health 2:99–110; doi:10.1007/s11869-009-0037-z.

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sulfur, flue gas sulfurization is not used (all sulfur in coal is thus emitted), and these sources are large. Major coal users in Detroit include electrical generating units (DTE Trenton Channel, DTE River Rouge), other large boilers (Wyandotte Municipal Power, Guardian, JR Whiting), steel producers, coke producers, and the cement industry.

- There is a high intensity of industrial activity, especially in southwest Detroit
- Large populations live very close to many of the industrial sources
- A number of factors increase the vulnerability and susceptibility of these populations.
- Point source emissions can be very large.
- Some point sources have poor dispersion of pollutants due to source characteristics, e.g., short stack heights or large nearby structures that cause plume downwash that can cause high concentrations.

7.4.5 Which pollutants are affected by using emissions control technologies?

Point source emissions controls can be used to reduce emissions of any pollutant, but most attention has focused on the criteria pollutants (PM, NO_x, SO_2, CO, and lead), volatile organic compounds (VOCs), and metals and other hazardous air pollutants. Current emissions from point source facilities were described in Section 5 of the resource manual.

7.4.6 What health effects can be mitigated?

A number of adverse health effects could be mitigated by using point source controls to reduce pollutant emissions. The type of health effects mitigated by point source controls depends on which pollutants are reduced. These health effects range from minor outcomes, e.g., missed school or work days due to respiratory symptoms, to severe outcomes, e.g., respiratory disease, cardiovascular disease, cancer, and premature mortality. Some impacts are described below.

7.4.7 What is happening in and around Detroit?

SO_2. Portions of Wayne County are out of compliance with the National Ambient Air Quality Standards (NAAQS) standards for SO_2. A number of regulatory actions have resulted, including the development of a State Implementation Plan (SIP) that was recently submitted to EPA;[25] a PTI that was recently approved for DTE Trenton Channel, and a rule change that was proposed for US Steel. These involve several aspects.

- DTE Energy will reduce SO_2 emissions from the Trenton Channel Plant. A recently approved PTI for (April, 2016) will shut-down four coal boilers, and install five smaller natural gas boilers. This will reduce SO_2 emissions by 5,392 tons/year (based on MAERS emissions data, averaged over 2010-2014). A large coal boiler without flue gas desulfurization (FGD) will remain at this facility; this boiler had emissions of 15,431 tons/year (same data source).

[25] MDEQ (Michigan Department of Environmental Quality). 2015. Proposed sulfur dioxide one-hour national ambient air quality standard state implementation plan. Available: http://www.deq.state.mi.us/aps/downloads/SIP/SO2SIP.pdf [accesses 7 March 2016].

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In the SIP, DTE identified wet or dry FGD as ways to reduce SO_2 emissions (90% was feasible), however, this option was considered too costly. Instead, DTE proposed the use of lower sulfur coal instead, which would provide smaller reductions. However, the PTI appears to supersede this.

- DTE River Rouge may use lower sulfur coal to reduce emissions, based on the SIP.
- DTE installed four FGD systems on their largest plant at Monroe, Michigan from 2009 through 2015. This is one of the largest power plant in the Midwest.[26] SO_2 emissions have decreased considerably [27] although this facility has been operating since 1968 for many decades (without SO_2 controls). SO_2 emissions (MAERS latest, 2014) were 6,286 tons, compared to 114,674 tons/year prior to the scrubbers (2005-2008 average). The installation of the new system created over 600 jobs and an estimated 300 associated jobs.
- MDEQ is negotiating with US Steel to reduce SO_2 emissions.
- MDEQ in the SIP will require Carmeuse Lime to increase their stack height from 60 to 120 feet to increase dispersion and reduce ground level concentrations. No emission reduction is proposed for this facility. This primitive control measure, a now rarely invoked "dilution is the solution to pollution" approach, will distribute SO_2 over a broader region, may not meet good engineering practice which limits stack heights, and may not be approved by US EPA.
- Marathon has requested at PTI that would increase SO_2 emissions by 22 tons in the designated non-attainment area. We have noted deficiencies in the information provided by MDEQ, the cumulative risk experienced by residents of the affected area due to multiple air pollutants, the high levels of vulnerable residents in that area of the city, and other issues in the analysis and approach.[28]

PM. MDEQ maintains enforces and encourages PM emission reductions, including a program to control fugitive dust.

O_3. If the region nearby areas are designed as non-attainment for O_3, then further emissions controls on O_3 precursors VOC and/or NO_x may be required. This may address point, non-point and mobile sources. Some impact on point sources is anticipated.

VOCs. There are many point sources with VOC emissions, including Marathon, painting and coating operations, coke facilities, etc. VOC controls include maintenance and operational controls (including leak detection and repair operations) and flaring. Marathon, an important VOC source, is the subject of a class action lawsuit that may spur additional emission reductions.[29]

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[26] Barton Malow. 2016. Building Innovative Solutions. Available: http://www.bartonmalow.com/projects/dte-monroe [accessed 7 March 2016] and DTE Energy. 2016. Emissions Controls. Available: Click Here [accessed 7 March 2016].

[27] PR Newswire. 2009. DTE Energy environmental project will create 900 jobs. Available: http://www.prnewswire.com/news-releases/dte-energy-environmental-project-will-create-900-jobs-78770632.html [accessed 18 February 2016].

[28] CAPHE. 2016. Issues regarding the proposed Permit to Install for Marathon Petroleum Company LP (A9831) Permit Number 118-15 and 122-15 Letter from CAPHE.

[29] Residents living next to the Marathon refinery in Southwest Detroit filed a class action lawsuit in U.S. District Court on 2/22/16 alleging the refinery's fumes and noise cause a perpetual nuisance harming their lives. The lawsuit seeks an excess of $5 million

This work is made possible by National Institute of Health and Environmental Sciences, RO1ES022616, and the Fred A. and Barbara M. Erb Family Foundation. Additional support was provided by the Michigan Center on Lifestage Environmental Exposures and Disease (M-LEEaD), #P30ES017885.

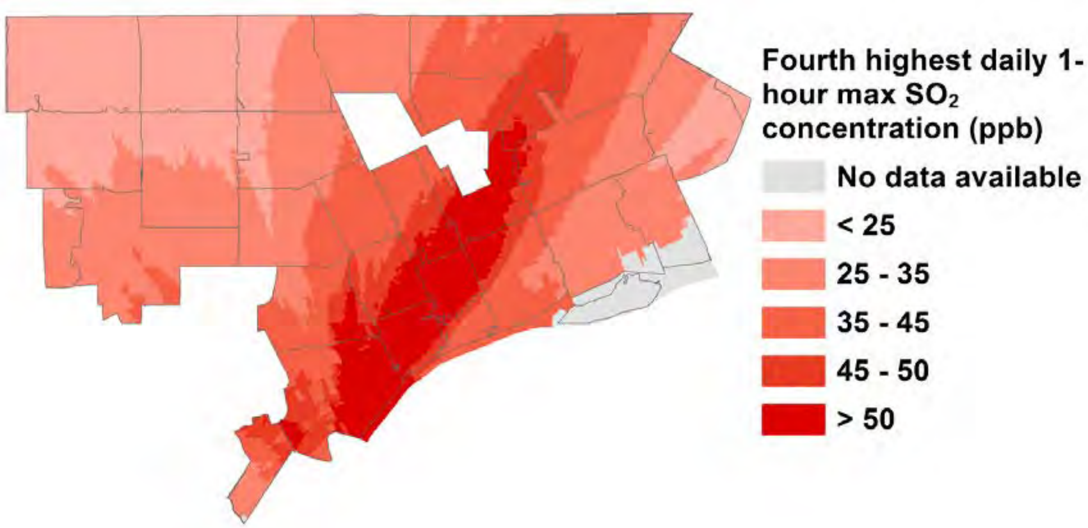
Other activity pertinent to point source emissions controls involve several large industrial facilities, including the Detroit Resource Recovery Authority's solid waste incinerator (see below) and the steel mills.

7.4.8 What are the benefits of using point source controls in Detroit

7.4.8.1 Reducing asthma-related health impacts due to point source emissions of SO_2

As described in Section 4 of this resource manual, portions of Wayne County have been designated as non-attainment of the 1-hour SO_2 NAAQS. Figure 7.4-4 shows the fourth highest daily 1-hour maximum concentrations estimated at the block level predicted from nine major point source emissions of SO_2 in the area (US Steel - Ecorse, US Steel - Zug Island, EES Coke, DTE River Rouge, DTE Trenton Channel, Carmeuse Lime, DTE Monroe, AK (formerly Severstal) Steel, Dearborn Industrial Generation, and Marathon Refinery) in 2010.[30] Concentrations are highest in southwest Detroit and extent northeast due to prevailing winds in the area. Point source controls on SO_2 emissions would decrease concentrations. As noted above, modest reductions in SO_2 emissions are called for the SO_2 State Implementation Plan that was submitted to US EPA in May 2016.

Figure 7.4-4. Peak SO_2 concentrations from major point source emissions of SO_2



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dollars, as well as a court order that Marathon cease the release of all contaminants into what it calls the "class area," which includes residential neighborhoods within the blocks of the factory bounded by Pleasant Street to the north, Schaefer Highway to the south, Basset Street to the east and Edsel and South Patricia streets to the west. Information from Detroit Free Press. 2016. Refinery neighbors sue Marathon over pollution impacts. Available: http://www.freep.com/story/news/local/michigan/detroit/2016/02/22/refinery-neighbors-sue-marathon-over-pollution-impacts/80764434/ [accessed 3 March 2016].

[30] The major point sources include those discussed in the MDEQ Proposed SIP. The analysis discussed in Section 7.4.8.1 uses SO_2 emissions in 2010, which differs from (but are similar to) the 5 year filtered average used in the analysis presented in Section 4 of this manual. The following tons of SO_2 emitted by each facility in 2010 were used in the analysis (ranked lowest to highest): Marathon Refinery: 104 tons; Carmeuse Lime: 358 tons; Dearborn Industrial Generation: 464 tons; AK (Severstal) Steel: 650 tons; EES Coke: 1917 tons; US Steel (Ecorse & Zug Island): 3926 tons; DTE River Rouge: 14,421 tons; DTE Trenton Channel: 23,469 tons; DTE Monroe: 47,602 tons. DTE Trenton Channel and Monroe will have reduced emissions at present.

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As an example of the benefits of source controls, we present an analysis of a simplified source control alternative or "scenario" that would eliminate SO_2 emissions from the three largest sources: DTE Monroe, DTE Trenton Channel, and DTE River Rouge. Complete eliminating of SO_2 emissions at these facilities would require changing the fuel source from coal to natural gas, using highly effective emissions controls, shuttering the plants, or some combination of controls. While full elimination might seem unrealistic, the analysis also pertains to intermediate reductions, e.g., a 50% reduction in emissions at these facilities would confer 50% of the benefits. (Methods used are detailed in Section 5.5.1).

Figure 7.4-5A maps the annual and highest daily mean concentrations of SO_2 due to 2010 emissions at most major sources near Detroit, MI (A); Figure 7.4-5B shows the same plots with the same scale, but displays the outcome of the test scenario that eliminates emissions from the River Rouge, Trenton Channel and Monroe power plants. Concentrations are substantially reduced by excluding these sources.

Health impacts for the change in SO_2 concentrations were estimated, specifically, the number of ED visits for asthma, hospitalizations for asthma, and respiratory symptoms days (defined as a day with cough, wheeze, or shortness of breath). The impacts were estimated using the quantitative health impact assessment (HIA) methods described in Section 5.5.1, which uses predicted daily average concentrations, health impact functions from the epidemiological literature,[31] and local demographic and health data.[32]

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[31] Asthma hospitalization and ED visits use ZIP code level data for Detroit and county level data outside of Detroit; asthma exacerbation rates use Detroit data Population data come from the American Community Survey. Concentration-response coefficients are drawn from the peer-reviewed literature.

References: Wasilevich, E., Lyon-Callo, S., Rafferty, A., Dombkowski, K., 2008. Detroit- the epicenter of asthma burden, Epidemiology of Asthma in Michigan

Michigan Department of Health and Human Services [MDHHS], 2016. Michigan Asthma Surveillance, Data and Reports [WWW Document]. URL http://www.michigan.gov/mdhhs/0,5885,7-339-71550_5104_5279-213824--,00.html (accessed 2.8.16)

US Census Bureau, 2015. TIGER/Line® with Selected Demographic and Economic Data [WWW Document]. URL http://www.census.gov/geo/maps-data/data/tiger-data.html (accessed 7.2.15); US Census Bureau. American Community Survey 5-year Estimates. URL https://www.census.gov/programs-surveys/acs/ (accessed 2.16.16).

Li, S., Batterman, S., Wasilevich, E., Elasaad, H., Wahl, R., Mukherjee, B., 2011. Asthma exacerbation and proximity of residence to major roads: a population-based matched case-control study among the pediatric Medicaid population in Detroit, Michigan. Environ Health 10, 34

Schildcrout, J.S., Sheppard, L., Lumley, T., Slaughter, J.C., Koenig, J.Q., Shapiro, G.G., 2006. Ambient Air Pollution and Asthma Exacerbations in Children: An Eight-City Analysis. Am. J. Epidemiol. 164, 505–517

Linn, W.S., Szlachcic, Y., Gong, H., Kinney, P.L., Berhane, K.T., 2000. Air pollution and daily hospital admissions in metropolitan Los Angeles. Environ Health Perspect 108, 427–434

[32] Asthma hospitalization and ED visits use ZIP code level data for Detroit and county level data outside of Detroit; asthma exacerbation rates use Detroit data Population data come from the American Community Survey. References:

Wasilevich, E., Lyon-Callo, S., Rafferty, A., Dombkowski, K., 2008. Detroit- the epicenter of asthma burden, Epidemiology of Asthma in Michigan

Michigan Department of Health and Human Services [MDHHS], 2016. Michigan Asthma Surveillance, Data and Reports [WWW Document]. URL http://www.michigan.gov/mdhhs/0,5885,7-339-71550_5104_5279-213824--,00.html (accessed 2.8.16)

US Census Bureau, 2015. TIGER/Line® with Selected Demographic and Economic Data [WWW Document]. URL http://www.census.gov/geo/maps-data/data/tiger-data.html (accessed 7.2.15); US Census Bureau. American Community Survey 5-year Estimates. URL https://www.census.gov/programs-surveys/acs/ (accessed 2.16.16).

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Results of the quantitative HIA are summarized in Table 7.4-4. Two cases are shown: base case with current emissions; and the alternative case (or scenario) that excluded SO_2 emissions from the three DTE facilities. The alternative case reduced asthma-related health outcomes among children and adults in Detroit due to SO_2 exposure by 28%. These results are conservative because the assessment considered only the Detroit population, while SO_2 impacts extend well beyond the city (Section 5.5.3). As noted earlier, benefits would be proportional to the degree of emissions control, e.g., installing FGD systems that remove 90% of SO_2 (rather than eliminate it completely) would achieve 90% of the listed impacts.

This analysis only considers SO_2 controls. Additional benefits would result from controls on multiple pollutants at these sources, which is discussed next.

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Figure 7.4-5A. Annual and highest daily mean SO_2 concentrations estimated at the block level for emissions at nine major sources of SO_2 near Detroit, MI in 2010

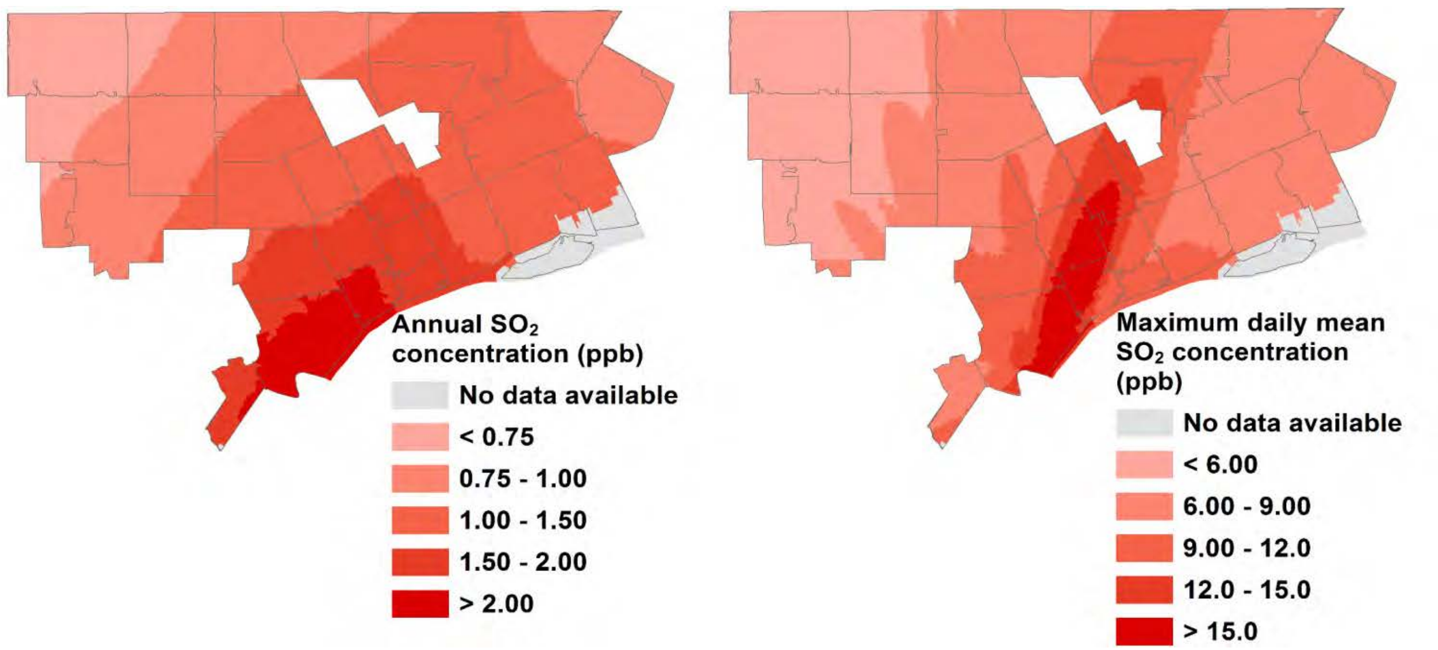

Figure 7.4-5B. Annual and highest daily mean SO_2 concentrations estimated at the block level after excluding DTE River Rouge, DTE Trenton Channel and DTE Monroe from the dispersion model.

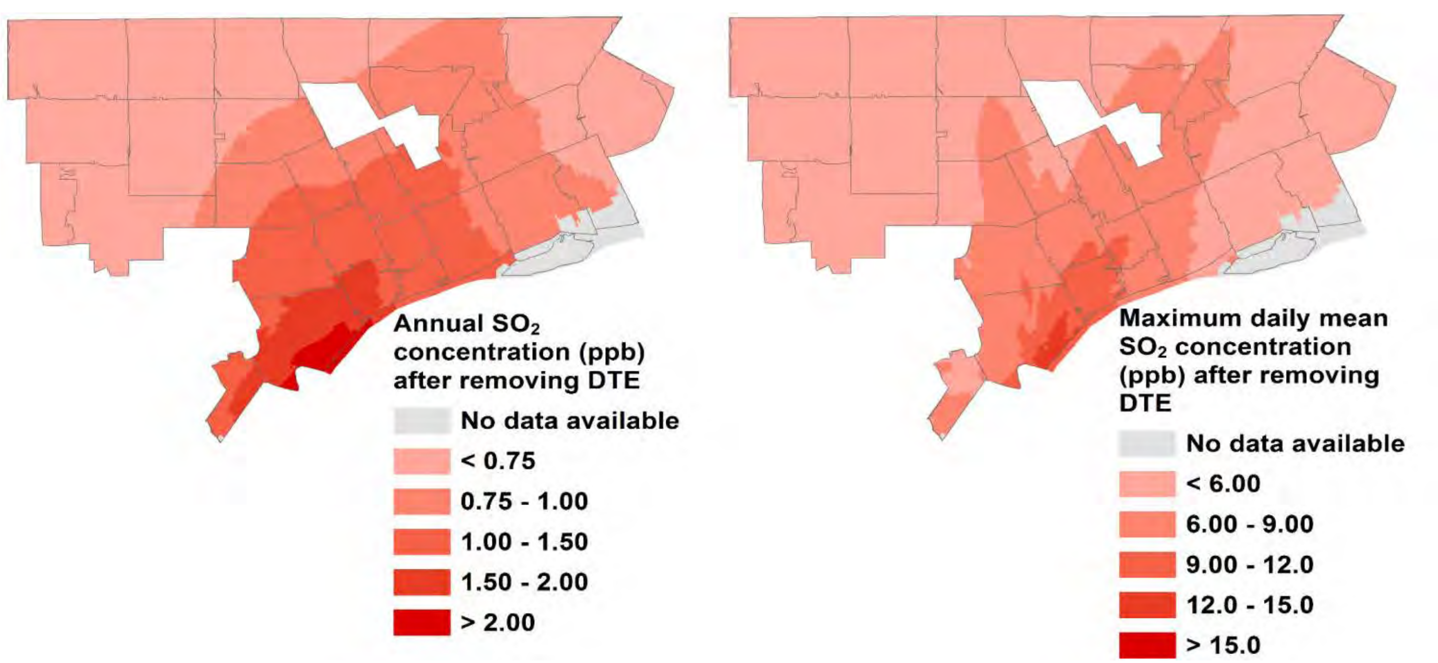

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Table 7.4-3. Health impacts attributable to SO_2 emissions from major point sources in 2010 for base and alternative cases.

	Base case: Health impacts attributable to SO_2 emissions from 9 major point sources near Detroit, MI			Alternative case: Health impacts attributable to SO_2 emissions from major sources excluding three coal-fired power plants			
Asthma-related Outcome (age group)	Attributable impacts (cases per year)	DALYs (years)	Monetized impacts ($ per year)	Attributable impacts (cases per year)	DALYs (years)	Monetized impacts ($ per year)	Percent Difference
Exacerbations (6-14 years)	3965	4.36	$229,975	2849	3.13	$165,228	-28.1
ED visits (<18 years)	65	0.09	$27,858	47	0.06	$20.056	-27.2
Hospitalization (<65 years)	7	0.04	$115,961	5	0.03	$83,255	-28.6
Total		4.49	$373,794		3.23	$268,540	-28.0

7.4.8.2 Reducing health impacts from point source emissions

As detailed in Section 5.5.2 of the Resource Manual, exposure to $PM_{2.5}$, NO_x and SO_2 from point source emissions can have significant health impacts. Table 7.4-4 summarizes the health impacts due to emissions of $PM_{2.5}$, NO_x and SO_2 from 24 facilities.[33] These facilities were selected either because they are large pollutant emitters (the first 16 sources listed in the table), or because they are in close proximity to exposed populations (last 8 sources in the table). Results for some facilities (notably St. Mary's Cement and BASF Corporation) are preliminary and may change after review of the dispersion modeling data. The results show that:

- The 24 facilities account for 75% of the total health impacts attributable to point source emissions.
- Current emissions of NO_x, SO_2 and $PM_{2.5}$ from point sources incur a total of 971 DALYs per year and $550 million per year in monetized health impacts.

Considering health impacts from all point sources and the three pollutants, reducing $PM_{2.5}$ emissions would potentially have the greatest health benefits. This is because $PM_{2.5}$ is associated with a number of severe health outcomes, including cardiovascular diseases and premature mortality.

- Exposure to $PM_{2.5}$ causes all of the mortality (including all-cause, IHD, lung cancer, and infant). In addition, $PM_{2.5}$ causes most of the hospitalizations, including all hospitalizations for CVD, pneumonia, and non-fatal heart attacks. For asthma exacerbations, $PM_{2.5}$ causes all ED visits for asthma, and all cases

[33] This table is also shown in Section 5.5.2 of this manual.

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of shortness of breath, minor restricted activity days, and work loss day. For the summary measures, $PM_{2.5}$ causes 98.4% of the total DALYs and 99.3% of the monetized impact.

- Exposure to NO_x causes 32% of hospitalizations for asthma, 38% of ED visits for asthma, 54% of hospitalizations for COPD, and 57% of asthma aggravations with one or more symptoms.
- Exposure to SO_2 causes 39% of the hospitalizations for asthma, 47% of ED visits for asthma, 100% of ED visits for asthma using the Detroit-based epidemiology study, and 45% of hospitalizations for COPD.

Table 7.4-4. Health impacts attributable to $PM_{2.5}$, NO_x, and SO_2 average emissions (2010-2014) from point sources near Detroit, MI.[34]

Health Outcome or Metric (age)	DTE Monroe	DTE Trenton Channel	DTE River Rouge	JR Whiting Co.	US Steel	EES Coke	AK Steel	Carmeuse Lime	Dearborn Industrial Generation	Guardian Industries	GM Hamtramck	Marathon Petroleum	Greater Detroit Resource Recovery	Carleton Farms Landfill	Daimler Chrysler Technology	A123 Systems	Detroit Wastewater Treatment Plant	St Mary's Cement	Beacon Heating Plant	Detroit Diesel Corporation	Jefferson North Assembly Plant	BASF Corporation	Wyandotte Dept. of Municipal Power	Ford Motor Co. Rouge Complex	Other Point Sources	Total Point Sources
Mortality (number of cases)																										
All Cause (>29)	0.1	0.2	0.0	0.4	3.7	0.4	2.2	0.2	0.6	1.1	0.1	0.5	0.1	0.6	0.2	1.1	0.0	4.5	0.0	0.1	0.2	4.7	0.0	0.2	7.4	28.6
IHD (>29)	0.1	0.2	0.0	0.4	3.1	0.4	1.8	0.2	0.5	0.9	0.0	0.4	0.1	0.5	0.2	0.9	0.0	3.7	0.0	0.1	0.2	3.6	0.0	0.2	6.1	23.4
Lung Cancer (>29)	0.0	0.0	0.0	0.1	0.6	0.1	0.3	0.0	0.1	0.2	0.0	0.1	0.0	0.1	0.0	0.2	0.0	0.7	0.0	0.0	0.0	0.8	0.0	0.0	1.1	4.3
Infant (0-1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.3
Hospitalizations (number of cases/events)																										
Asthma (0-64)	1.7	1.0	1.1	0.4	2.6	1.0	0.9	0.8	0.6	0.5	0.2	0.4	0.6	0.2	0.1	0.2	0.1	0.8	0.0	0.1	0.1	0.8	0.1	0.1	3.4	17.9
COPD (>64)	10.6	6.4	6.8	2.2	12.4	5.9	3.2	5.0	3.3	2.4	1.4	2.1	4.2	1.1	0.5	0.0	1.1	0.5	0.1	0.6	0.6	0.6	0.6	0.4	14.6	86.7
CVD (>64)	0.0	0.0	0.0	0.1	0.8	0.1	0.5	0.1	0.1	0.3	0.0	0.1	0.0	0.1	0.1	0.3	0.0	1.0	0.0	0.0	0.0	1.2	0.0	0.0	1.7	6.6
Pneumonia (>64)	0.0	0.0	0.0	0.0	0.4	0.0	0.2	0.0	0.1	0.1	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.5	0.0	0.0	0.0	0.6	0.0	0.0	0.8	3.1
Non-fatal heart attack (>17)	0.0	0.0	0.0	0.0	0.2	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.3	0.0	0.0	0.0	0.3	0.0	0.0	0.4	1.7
ED visit for asthma (0-17)	20.6	11.8	13.2	4.6	26.3	11.0	8.3	8.8	7.2	4.5	2.7	3.9	6.8	2.1	1.0	1.1	1.7	4.6	0.2	1.0	1.2	4.2	1.0	0.8	31.2	179.6
ED visit for asthma-Detroit CR (0-17)	18.8	12.1	12.0	3.7	19.4	8.1	5.7	5.7	6.3	0.9	2.0	1.8	0.9	0.3	0.1	0.0	0.4	0.0	0.0	0.1	0.0	0.0	0.4	0.0	1.1	99.9
Asthma exacerbations and restricted days (number of cases, days)																										
Cough (6-14)	31	78	6	175	1,521	170	932	96	247	429	21	188	49	233	93	453	11	2,116	6	31	83	1,730	7	94	3,018	11,818
Shortness of breath (6-14)	3	8	1	17	149	17	91	9	24	42	2	18	5	23	9	44	1	209	1	3	8	173	1	9	298	1,165
Wheeze (6-14)	2	6	0	14	117	13	72	7	19	33	2	14	4	18	7	35	1	164	0	2	6	136	1	7	235	917
One or more symptoms (6-14)	1,496	873	973	312	1,781	855	468	754	497	332	203	311	654	149	78	0	172	64	16	93	95	56	87	69	2,459	12,847
One or more symptoms - Det CR (6-14)	4,375	2,842	2,816	861	4,655	1,945	1,374	1,401	1,538	219	452	447	208	67	13	0	0	0	0	0	0	0	0	0	654	23,868
Minor restricted activity day (18-64)	51	129	10	287	2,474	281	1,445	155	383	712	35	305	81	389	150	750	18	3,104	9	49	135	3,184	12	140	4,893	19,181
Work loss day (18-64)	9	22	2	50	428	49	250	27	66	123	6	53	14	67	26	130	3	538	2	8	23	555	2	24	850	3,327
Summary measures																										
Total DALYs (years)	4.4	7.6	1.7	15.0	127.6	15.4	73.4	8.8	19.9	36.3	2.1	16.0	5.1	19.6	7.9	37.0	1.1	153.3	0.5	2.5	7.5	149.3	0.7	7.0	251.7	971.4
Monetized Impact (2010 $millions)	2.0	4.1	0.6	8.5	71.3	8.4	41.7	4.7	11.1	21.0	1.1	9.0	2.6	11.3	4.4	21.6	0.6	86.0	0.3	1.4	4.0	88.7	0.4	4.0	141.8	550.5

[34] Note, results for the point source analysis are preliminary, and results may be updated.

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7.4.9 What are the best practices?

Air pollution controls have become very sophisticated. There are effective controls for many types of emissions at many types of sources, as well as ways to reduce the need for polluting fossil fuels. Here we mention only a few items.

Promote and enable clean energy. The low cost of natural gas, cost-competitiveness of solar and wind energy, concerns over greenhouse gases, SO_2 and other environmental concerns, policies including the President's Clean Energy Plan, and considerable activism[35] together are driving a major transition away from fossil fuels, especially coal. Clean energy sources can be used to reduce use of fossil fuels in residential, commercial and industrial sectors.

Provide incentives and remove regulatory and financial barriers regarding renewable energy. For example, community solar arrangements allow individuals and businesses to purchase shares in a renewable energy system not located on their property, however, public utilities like DTE can only offer community solar programs as pilot projects when approved by the Michigan Public Service Commission (PSC).[36]

Reform utility approaches and Public Service Commission rules to promote innovation and clean energy.[37] New York is trying to for example PSC rules to encourage solar and renewables; coal plants have already been shut down.

Get Detroit and other cities to commit to renewable energy targets. A number of smaller cities already obtain 100% of their energy from renewable sources, and other larger cities, including Grand Rapids and San Diego (population 1.4 million), have pledged to do so. San Diego's plan uses a method called community choice aggregation to determine where the electricity comes from, while utilities continue to operate the transmissions lines and manage the electrical grid.

Conduct regular inspections, evaluations and provide recommendations for emissions controls. As mentioned, many facilities are very old and have rudimentary emissions controls.

Improve flare efficiency. Flaring is a relatively primitive control technology with variable efficiency, yet is practiced widely at refineries and some other sources. In 2003, the Bay Area Air Quality Management District (BAAQMD) in California required that refineries conduct comprehensive, real-time monitoring of flare efficiency to ensure maximum combustion.[38] After implementation of the rule, the amount of flaring and emissions dropped considerably.[39]

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[35] Sierra Club. Coal is an outdated, backward and dirty 19th-century technology. Available: http://content.sierraclub.org/coal/about-the-campaign [accessed 3 March 16].

[36] Community solar: see http://www.ecocenter.org/clean-energy-programs#innovative_financing_programs (accessed 25 April 2016).

[37] New York State has a plan to use market forces to shake up the utility industry for this purpose called "Reforming the Energy Vision." New York Times, May 10, 2016/

[38] Bay Area Air Quality Management District. 2003. Flare monitoring at petroleum refineries. Available: www.baaqmd.gov/~/media/files/planning-and-research/rules-and-regs/reg-12/rg1211.pdf?la=en [accessed 18 February 2016].

[39]Bay Area Air Quality Management District. 2015. Available:http://www.baaqmd.gov/~/media/files/planning-and-research/rules-and-regs/workshops/2015/1215-1216-workshop/refinery-emissions-tracking-and-mitigation-workshops_march2015.pdf [accessed 18 February 2016].

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Reduce fugitive emissions. These may tend to require active attention to administrative and engineering controls, thus, inspection, operation and management programs need attention.

7.4.10 Applicable strategies for Detroit

Install up to date emissions control devices. Facilities should install emissions control devices that minimize the amount of pollution released into surrounding areas. This includes:

- Install FGD (flue gas desulfurization) systems at all coal-fired boilers and power plants.
- Install desulfurization systems for coke oven gas. Detroit is believed to have the only coke facility in country without such technology.
- Reduce SO_2 and PM emissions at steel facilities.
- Improve flare efficiency and monitoring at Marathon and other facilities as noted for BAAQMD in the previous section.
- Require low NO_x burners on all combustors.
- Provide incentives to modernize facilities and reduce emissions.

Utilize health impact evaluations when setting permits limits that determine controls necessary. In particular, evaluate cumulative impacts and impacts that below the NAAQS.

Install up to date emissions monitors and require verification of emissions. This is discussed in Section 7.6.

Increase process and combustion efficiency.

Eliminate open storage and material transfer processes that can result in fugitive releases

Utilize modern tools to detect and quantify VOC releases.

Shift to renewable and green fuels. A landscape with clean and renewable energy could transform the energy and physical landscape in Detroit. As noted in the previous section:

- Provide incentives for green energy. Use solar panels along buffers that also reduce noise and air pollution.
- Remove regulatory and financial barriers regarding renewable energy.
- Reform utility approaches and Public Service Commission rules
- Get Detroit and other cities to commit to renewable energy targets

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CAPHE PHAP-RM

7.5 MOBILE SOURCE CONTROLS: IDLING

2016

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7.5 Mobile Source Controls: Idling

7.5.1 What are idling controls?

Idling controls reduce the pollutant emissions from cars, trucks, buses, and construction equipment when engines are running but vehicles are not in motion. Idling controls restrict the amount of time that vehicles can idle, by using anti-idling technology, laws or regulations. These restrictions often target commercial trucks and buses, but emissions can also be reduced when anti-idling controls are used on other sources.

Idling also occurs on congested roads when vehicles are stuck in traffic. Measures that reduce such congestion, including public transit, carpooling, walking and cycling, and other transportation controls that reduce peak use of roads, can also reduce congestion and emissions. This fact sheet, however, focuses on idling controls for buses and commercial vehicles.

7.5.2 What can be done to reduce idling?

Several options exist to reduce idling. A cost-effective approach is to establish and enforce anti-idling laws, ordinances and regulations that require trucks, buses and other vehicles to turn off the engine when not in use.

Figure 7.5 - 1. Anti-idling signage.

Idling reduction technologies are also effective strategies for reducing pollution related to idling. These technologies include automatic engine shut down/start up systems, auxiliary power units, battery-operated heaters, and electrification systems that allow drivers to run some vehicle systems (e.g., heater and air conditioner) without operating the engine. Developing "shore power" outlet, infrastructure that allows trucks to plug in to electrical outlines at truck stops, is another common anti-idling method used to reduce idling at truck stops.

Other approaches to reducing idling include the use of signage, economic incentives, and anti-idling education and outreach to encourage people to turn off engines when vehicles are not in motion.

7.5.3 Why is this important?

Idling burns fuel unnecessarily, increases fuel costs, and produces emissions that are harmful to human health and the environment.[1] Diesel truck engines burn roughly a gallon of fuel per hour when idling and the EPA estimates that over one billion gallons of fuel are wasted each year due to this practice.[2]

[1] EPA (U.S. Environmental Protection Agency). 2010. Idle Reduction: A Glance at Clean Freight Strategies. Available: http://www3.epa.gov/smartway/forpartners/documents/trucks/techsheets-truck/420f09038.pdf. [accessed 9 February 2016].

[2] IDEM (Indiana Department of Environmental Management). 2016. Idle Reduction Alternatives. Available: http://www.in.gov/idem/airquality/2568.htm. [accessed 9 February 2016].

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Idling can also reduce the life of diesel engines by increasing wear on internal parts. Reducing idling minimizes these impacts and can reduce maintenance costs significantly.

Idling contributes to air pollution. Annually, truck engines that idle for long durations have been estimated to release 11 million tons of carbon dioxide (CO_2), 200,000 tons of oxides of nitrogen (NO_x), and 5,000 tons of particulate matter ($PM_{2.5}$) into the air.[3] CO_2 emissions contribute to climate change.[4] NO_x and $PM_{2.5}$ emissions directly affect the health of drivers, passengers, and nearby community members, and NO_x emissions also cause ozone pollution, another widespread air pollutant.[5] Idling vehicles also emit other pollutants, including carbon monoxide and black carbon.

Idling also causes noise pollution. In addition to being a nuisance, noise increases stress, discomfort, and can interfere with sleep.

Idling is a significant issue in Southwest Detroit. A 2013 survey indicated that truck pollution was one of the top concerns of residents living in City Council District 6 (which includes Southwest Detroit).[6] In 2015, about 2.5 million trucks crossed the Ambassador Bridge, equivalent to about 6900 trucks each day.[7] The international bridge, tunnel, and terminal areas are locations where a large number of large trucks idle while waiting to enter or leave the USA; idling emissions at these areas can be substantial.[8]

7.5.4 Which pollutants are affected by idle reduction strategies?

Idling controls reduce emissions of several hazardous pollutants, including particulate matter ($PM_{2.5}$), nitrogen oxide (NO_X), carbon dioxide (CO_2), carbon monoxide (CO), diesel exhaust, and volatile organic compounds (VOCs).

7.5.5 What health effects can be mitigated?

Reduced air pollution emissions from idling restrictions would contribute to improvements over time in respiratory diseases (such as asthma) and cardiovascular disease (such as hypertension). Pollutants emitted by idling vehicles, especially $PM_{2.5}$ and diesel exhaust, have been associated with other adverse health effects, including adverse birth outcomes, reproductive effects, premature death, cancer, nausea, vomiting, visual

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[3] NRDC (Natural Resources Defense Council). 2012. Smarten Up and Stop Idling. Available: http://www.nrdc.org/living/gettingabout/smarten-up-stop-idling.asp. [accessed 9 February 2016].

[4] NRC (Natural Resources Canada). 2015. Emission impacts resulting from vehicle idling. Available: http://www.nrcan.gc.ca/energy/efficiency/communities-infrastructure/transportation/cars-light-trucks/idling/4415. [accessed 9 February 2016].

[5] DEEP (Diesel Education & Emissions Project). 2012. Anti-Idling Toolkit For California Communities How to reduce diesel pollution and protect the health of your community. Greenaction for Health & Environmental Justice. Available: http://greenaction.org/wp-content/uploads/2013/01/DEEP-v1.pdf. [accessed 9 February 2016] and EDP (Environmental Defense Fund). 2009. Idling Gets you Nowhere: The Health, Environmental and Economic Impacts of Engine Idling in New York City. Available: https://www.edf.org/sites/default/files/9236_Idling_Nowhere_2009.pdf. [accessed 9 February 2016].

[6] DEA (The Detroit Environmental Agenda). 2013. Available: http://www.dwej.org/wp-content/uploads/2015/12/ElectionDraftAnnalieseEdits-nohyperlinks.pdf [accessed 2-10-16])

[7] PBOA (Public Border Operations Association). 2016. Available: http://publicborderoperators.org/index.php/traffic [accessed 2-10-16].

[8]PBOA (Public Border Operations Association). 2016. Available: http://publicborderoperators.org/index.php/traffic [accessed 2-10-16].

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impairments, cognitive decrements, kidney damage, fever, headaches, dizziness and other nervous system effects.[9] While there are many other sources of $PM_{2.5}$ and other pollutants, idling restrictions can help to reduce emissions and improve air quality in high traffic and congested areas.

7.5.6 What is happening in Detroit?

City of Detroit Anti-Idling Ordinance. The City of Detroit passed an anti-idling ordinance in 2010, which is enforced by the Detroit Police Department (Traffic Enforcement Division).[10] The anti-idling regulations include: a five minute consecutive idling limit in any 60-minute period, a written warning for a first offence, and a fine of $150 for the operator and $500 to the owner for a second offense. There are several exemptions to this rule, which include: when traffic conditions do not allow, when a truck is motionless for more than 2 hours and temperatures are below 25 degrees F, when trucks are undergoing state inspections, and during hybrid vehicle recharging. Also, idling restrictions do not apply to power auxiliary equipment, emergency vehicles, and electric, hydrogen or natural gas powered vehicles.[11]

Anti-Idling Workgroup. The Detroit-based Anti-Idling Workgroup worked with the City Council's Green Task Force, Detroit Police Department (DPD), local businesses, community members and other organizations to raise awareness about the Detroit ordinance, and to support and encourage enforcement.[12]

The 2013 Detroit Environmental Agenda notes several challenges to enforcing Detroit's anti-idling ordinance: 1) targeting of commercial delivery trucks rather than unnecessary idling near residential areas (the intent of the regulation); 2) no specific number or "hot-line" for residents to call to report a violation; 3) need for an efficient system to identify idling violation hot spots; and 4) a lack of awareness about the ordinance.[13]

Several other policies are related to idling and relevant to Detroit, and can help to assess and reduce impacts from truck traffic. These include designating, publicizing and enforcing truck routes in the city[14] , and using community truck surveys (often by partnering between NGOs, stakeholders, and volunteers) to identify the routes and numbers of trucks on them. These surveys raise awareness within communities and can be used to advocate for changes in truck routes.[15]

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[9] (Community Action to Promote Healthy Environments, Health Effects of Air Pollutants Chart.)

[10] SDEV (Southwest Detroit Environmental Vision). Anti-Idling. Available: http://www.sdevweb.org/issues/anti-idling/. [accessed 12-17-15].

[11] ATRI (American Transportation Research Institute). 2015. Compendium of Idling Regulations. Available: http://www.atri-online.org/research/idling/ATRI_Idling_Compendium.pdf. [accessed 12-17-15].

[12] SDEV (Southwest Detroit Environmental Vision). Anti-Idling. Available: http://www.sdevweb.org/issues/anti-idling/. [accessed 2-11-15].

[13] DEA (The Detroit Environmental Agenda). 2013. Available: http://www.dwej.org/wp-content/uploads/2015/12/ElectionDraftAnnalieseEdits-nohyperlinks.pdf [accessed 2-11-16])

[14] DEA (The Detroit Environmental Agenda). 2013. Available pg. 50: http://www.dwej.org/wp-content/uploads/2015/12/ElectionDraftAnnalieseEdits-nohyperlinks.pdf [accessed 2-10-16]

[15] SDEV (Southwest Detroit Community Benefits Coalition. Progress. Available: http://www.swdetroitcbc.org/projects-and-progress [accessed 2-11-16].)

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7.5.7 What best practices have been used elsewhere?

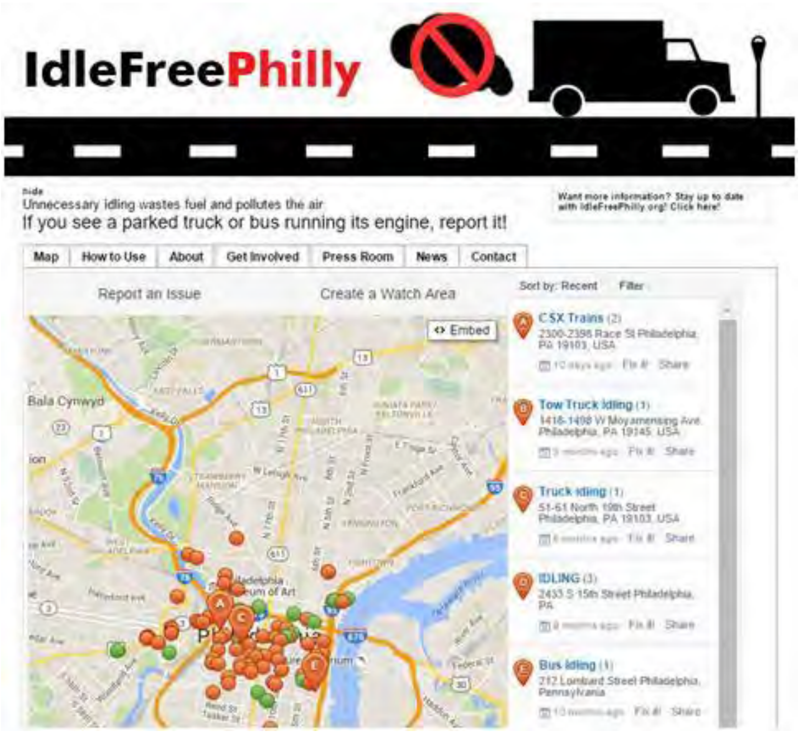

Figure 7.5 - 2. IdleFreePhilly web-based tool.

Combine an anti-idling hotline with a web-based tool. Philadelphia, Pennsylvania implemented anti-idling laws in 2008. The city's air pollution control agency, Air Management Services, is responsible for monitoring air pollutants and enforcing air quality standards. Residents can report idling violations in their neighborhood using a telephone hotline or a web-based mapping tool called IdleFreePhilly.org (http://www.idlefreephilly.org/) and clicking on the map where the idling issue is occurring.[16] This information is reported to Air Management Services, and the city's Clean Air Agency can issue a ticket if enough information is provided. In addition, the collected data allows the city to identify and address idling hot spots (see Figure 7.5 - 2).[17]

Write idling enforcement into local and state air quality rules. Connecticut, Massachusetts and Rhode Island's anti-idling regulations are incorporated into their State Implementation Plans (SIP), which is used to assure compliance with the National Ambient Air Quality Standards. The US Environmental Protection Agency has taken enforcement actions against trucking fleets in these states for alleged violations of the anti-idling regulations.[18]

Enable enforcement by multiple agencies. Chicago's 2009 anti-idling ordinance is enforceable by Department of Public Health (CDPH) inspectors, traffic control aides, parking enforcement aides, and police officers. Enabling multiple agencies to enforce anti-idling ordinances can help to alleviate enforcement issues faced by cities like Detroit.[19]

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[16] The Philadelphia Parking Authority. Available: http://www.philapark.org/2011/11/anti-idling-law/ [accessed 2-11-16].

[17] IdleFreePhilly. Available: http://www.idlefreephilly.org/ [accessed 2-11-16].

[18] EPA (Environmental Protection Agency). Idling. Available: http://www3.epa.gov/region1/eco/diesel/idling.html [accessed 2-11-16]

[19] City of Chicago. Available: http://www.cityofchicago.org/city/en/depts/cdot/supp_info/doing_our_share_forcleancairidlingreduction.html/ [accessed 2-11-16].

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Encourage EPA's SmartWay Transport Partnerships. These voluntary collaborations between the US Environmental Protection Agency and the freight industry aim to conserve fuel, reduce emissions, and improve transportation supply chain efficiency. For example, these partnerships establish individualized goals and approaches for companies to save fuel.[20] One such partner is Gemini Transport of Dearborn.

Create an anti-idling campaign. Dallas, Texas created an anti-idling campaign as part of its *Green Dallas* program. This included a sign program (requesting companies and organizations to post anti-idling signs), an educational component (featuring a website where people could learn more about the ordinance), and outreach to trucking companies, including distributing brochures at truck stops and trucking businesses.[21]

Utilize and/or require idling reduction technology. This technology can be on-board the trucks themselves, or on-site at truck stops. On-board options include automatic shut-down devices, auxiliary power units (generators), integrated battery or alternative powered devices, fuel operated heaters, and thermal storage systems. Onsite options include electrified truck stops where power is provided to trucks using the infrastructure available at the truck stop ("shore power").[22]

Create drivers lounges. Areas where drivers can relax while their trucks are being loaded or unloaded reduces their need to idle vehicles. Lounges can offer amenities like internet, cable TV, food and beverages, etc., to encourage their use.[23]

Create trainings for drivers. Anti-idling trainings could raise awareness in the trucking community. Community organizations could host training sessions to inform drivers and community members about fuel consumption, emissions and potential health risks associated with idling emissions.[24] For more information about the health concerns associated with excessive idling, see: http://www.nctcog.org/trans/air/vehicles/health.asp.

Use driver incentives. Idling can be minimized by rewarding drivers with the best fuel economy on a monthly or quarterly basis. Drivers could also compete to win a prize for the least idling time.[25]

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[20] EPA (Environmental Protection Agency). Idling. Available: http://www3.epa.gov/region1/eco/diesel/idling.html [accessed 2-11-16]
and EPA (Environmental Protection Agency). SmartWay. Available: http://www3.epa.gov/smartway/ [accessed 2-11-16].

[21] Green Dallas. Air Quality. Available: http://www.cleanairinfo.com/sustainableskylines/documents/Presentations/Track%202/08_Advancing%20Alternatives%20to%20Idling/08%20eric.pdf [accessed 2-11-16] and The Gateway Cities Air Quality Action Plan: Early Action Plan Final Report. 2012. Available: http://www.gatewaycog.org/media/userfiles/subsite_128/files/rl/AQAP-reports/EarlyActionPlanFinalReportMay2012.pdf [accessed 2-10-16].

[22] North Central Texas Council of Governments. Ways to Reduce Idling. Available: http://www.nctcog.org/trans/air/vehicles/waystoreduce.asp [accessed 2-11-16].

[23] North Central Texas Council of Governments. Ways to Reduce Idling. Available: http://www.nctcog.org/trans/air/vehicles/waystoreduce.asp [accessed 2-11-16].

[24] North Central Texas Council of Governments. Ways to Reduce Idling. Available: http://www.nctcog.org/trans/air/vehicles/waystoreduce.asp [accessed 2-11-16]

[25] North Central Texas Council of Governments. Ways to Reduce Idling. Available: http://www.nctcog.org/trans/air/vehicles/waystoreduce.asp [accessed 2-11-16]

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7.5.8 How many people would be affected in Detroit?

The number of people affected by idling depends on the number of people living near sites with high levels of trucks that idle.

Sites in Detroit where people could be affected include:

- Ambassador Bridge and the future site of the Gordie Howe Bridge
- The new Industrial Park and Logistic Center in Eastside
- Truck and rail transfer stations, for example, the Container Port on West Fort Street
- Schools where buses and cars are queuing
- Bus terminals
- People living or working near construction sites and other locations where diesel vehicles or diesel engines operate.
- Neighborhoods where trucks park
- Construction sites

Truck drivers are especially vulnerable to experiencing negative health effects from idling, due to the amount of time they are exposed, and how close they are to the emissions. Thus, they are particularly likely to benefit from reductions in idling.

7.5.9 Applicable strategies for Detroit and/or Michigan

Use an anti-idling hotline and a web-based tool[26] similar to the IdleFreePhilly intervention above.

Enable multi-agency enforcement of Detroit's 2010 Anti-Idling Ordinance. Empowering a greater range of people to enforce the anti-idling ordinance could enhance enforcement.

Create state-level anti-idling restrictions. Creating state-level idling restrictions could enable MDEQ and potentially federal agencies to enforce Detroit's anti-idling law.

Encourage or require idling reduction technology and driver lounges. Advocate for the use of idling reduction technologies and lounges for the customs plaza at the Gordie Howe Bridge.

Create incentives for drivers to reduce idling. This could include creating lounges at truck stops or loading stations, building awareness about the health risks of diesel emissions and idling, and creating reward programs that encourage less idling.

Build awareness through city-wide anti-idling campaign and signage, with particular focus near "hotspots" such as the Gordie Howe Bridge or intermodal facilities.

Encourage EPA's Smartway Partnerships.

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[26] This corresponds with recommendations from the 2013 Detroit Environmental Agenda report, see: (The Detroit Environmental Agenda. 2013. Available pg. 50: http://www.dwej.org/wp-content/uploads/2015/12/ElectionDraftAnnalieseEdits-nohyperlinks.pdf [accessed 2-10-16].

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7.6 ENHANCED COMPLIANCE, ENFORCEMENT, & AMBIENT MONITORING

2016

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7.6 Enforcement and monitoring

7.6.1 What are air pollution regulations and enforcement activities?

7.6.1.1 Type of air pollution regulations

Broadly, air pollution regulations can be placed into the following categories:

- Emission regulations. These regulations limit emission releases, usually at the source, for sources such as tailpipe emissions from vehicles, stack emissions from industry, and other emissions at gas stations, dry cleaners, and other smaller sources. Federal emission regulations, enforced by Michigan, include the New Source Performance Standards, for new sources, Reasonably Achievable Control Standards for modified sources, National Emission Standards for Hazardous Air Pollutants (NESHAPS), and standards on vehicle emissions.

  Michigan also regulates emissions of air toxics, including many VOCs and metals (other than lead). There are no ambient air quality standards for air toxics. Rather, a screening processing is used to restrict emissions of toxics for new or modified sources seeking a permit to install.

- Ambient air quality standards. These are limits on concentrations of specific pollutants in air that are intended to protect public health. They include the National Ambient Air Quality Standards (NAAQS), which apply to six pollutants (SO_2, NO_2, O_3, CO, lead, and particulate matter, including both $PM_{2.5}$, PM_{10}). Exceeding a NAAQS may result in an area being defined as non-attainment for that pollutant.

  The NAAQS (and other standards) evolve, and standards for some pollutants (notably $PM_{2.5}$, O_3, and SO_2) have become considerably more stringent as the science improves. The NAAQS consider pollutants individually, that is, the effects of exposures to multiple pollutants (part of a cumulative effects assessment) is not normally considered.

- Process standards. These standards specify what materials may be used, or how an activity may be performed. For example, these may restrict or ban the use of certain chlorinated solvents and ozone-depleting substances like Freon, or limit the sulfur content and volatility of fuels like gasoline and diesel.

- Reporting, disclosure and emergency planning requirements. These impose a duty on industry to inform authorities regarding quantity and nature of both routine and emergency emissions.

Air pollution regulations are set by federal, state and local laws, as described below.

7.6.1.2 United States Environmental Protection Agency (US EPA)

Under the Clean Air Act (CAA), the US Environmental Protection Agency (US EPA) sets limits on certain air pollutants through the National Ambient Air Quality Standards (NAAQS), and also specifies source standards that limit emissions of air pollutants coming from certain sources (described later). States may adopt stronger air pollution laws than the federal minimum, but not weaker pollution limits than those set by US EPA. In addition, US EPA must approve state, tribal, and local agency plans for reducing air pollution, and if a plan does not meet the necessary requirements, US EPA can issue sanctions against the state and, if necessary, take other

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actions. US EPA has a lay person-oriented description of the Clean Air Act.[1] Additional air quality activities of US EPA include:

- Setting national air quality standards and emission standards, including those on industries, vehicles, and fuels;
- Addressing interstate and international air pollution;
- Providing oversight on state plans and actions;
- Participating in reviews and approvals of transportation policies that receive federal funding to ensure that construction of highways and transit rail lines are consistent with state air quality goals and do not cause or contribute to new violations of the air quality standards, worsen existing violations, or delay attainment of air quality standards (called Conformity Analysis); and
- Funding research, air quality monitoring, emission reduction programs, and other programs. These funds also support state level programs like Michigan's.

Unfortunately, US EPA does not have a field or district office in Detroit. The Region V office is located in Chicago. Its office directory lists 378 individuals;[2] the number of individuals working on air quality related issues is not clearly identifiable due to overlapping areas.

US EPA delegates much of its regulatory authority to individual states, which implement much of the Clean Air Act and other applicable federal laws.

7.6.1.3 State of Michigan

The Michigan Department of Environmental Quality (MDEQ) enforces the Clean Air Act (CAA) under authority delegated from US EPA and Michigan laws pertaining to air pollution regulations. State administrative rules are in Part 55 (Air Pollution Control) of the Natural Resources and Environmental Protection Act, Public Act 451 of 1994, as amended (Act 451). The Air Quality Division (AQD) of the MDEQ is responsible for developing and implementing state air quality requirements and enforcing compliance with both state and federal air quality requirements. AQD activities include monitoring air quality, inspecting facilities, developing and enforcing permits, rules and standards, developing State Implementation Plans (SIPs) that outline how pollution will be reduced, involving the public and industries through hearings and comment opportunities, and other activities related to air quality.

MDEQ's main office is in Lansing, and there are ten MDEQ District or Field Offices, including:

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[1] The Plain English Guide to the Clean Air Act, United States Office of Air Quality Planning and Standards Publication No. EPA-456/K-07-001 Environmental Protection, Research Triangle Park, NC April 2007. https://www.epa.gov/sites/production/files/2015-08/documents/peg.pdf

[2] Culled from EPA Region V Expert's List: https://www.epa.gov/aboutepa/region-5-experts-list

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- Detroit District (Wayne County) Office at Cadillac Place, Suite 2-300, 3058 West Grand Blvd., Detroit, MI 48202-6058, 313-456-4700,
- Southeast Michigan District (handling Macomb, Oakland and St. Clair counties) at 27700 Donald Court, Warren, MI 48092-2793. 586-753-3700.

As of May 2016, the MDEQ Air Quality Division directory listed 182 personnel, with Lansing having 91, the Detroit Field office having 31, and the Southeast District having 17.[3]

When MDEQ identifies permit or other violations, they are required to take enforcement action. Enforcement action can include the levying of fines, requiring greater monitoring, or conducting facility inspections. Field offices conduct inspections and perform other analyses. Based on these inspections, MDEQ can issue Violation Notices (VNs) and obtain Administrative Consent Orders that may include various corrective actions and penalties. Prior to 1991, the Wayne County Air Pollution Control Commission enforced air quality laws in Detroit.

The MDEQ has a toll-free telephone number (800-662-9278) to report air pollution problems and other air quality issues. MDEQ Field office personnel investigate complaints and perform inspections that may address issues such as:

- Strong odors from commercial or industrial companies.
- Fall-out (such as soot, ash, or dust) that has settled on property.
- Excessive dust generation (from commercial or industrial operations).
- Open burning activities at commercial and industrial businesses.
- Events that cause significant health effects such as difficulties breathing, burning and itching of the skin or eyes, or life-threatening allergic reactions.

Michigan's support and capacity to address environmental problems was flagged in a federal audit of the water program in 2010, and, more recently, with widespread investigations related to the Flint water crisis. The governor's current budget recommendation (FY2016 and FY2017) for MDEQ is $487.9 million, of which AQD receives about 5% ($26.7 million). The funding level is fundamentally unchanged since 2000 when the AQD received $24.4 million.[4] Since 2000, MDEQ's staff has been cut by more than a quarter, and the agency's general fund budget declined nearly 60%. Since its formation in 1995, the MDEQ has accounted for a declining share state's general fund budget (1.16% in 1996, and 0.41% in 2015).[5]

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[3] Based on current staff directory http://www.michigan.gov/documents/Phone_List_86623_7.pdf and zip code information

[4] State budget office data, http://www.michigan.gov/budget/0,4538,7-157-11460_18526---,00.html

[5] "Michigan DEQ's Responsibility to Ensure Public Safety Collapsed in Flint," Resilience, http://www.resilience.org/stories/2016-01-25/michigan-deq-s-responsibility-to-ensure-public-safety-collapsed-in-flint

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Michigan has several documents on their website designed to assist business and the public on environmental laws.[6] Helpful guides on public participation are available from Michigan[7] and elsewhere. [8]

Michigan's air quality rules under Act 451 are organized as follows:

- Part 1 - Definitions.
- Part 2 – Air Use Approval (Air Permitting, Offsets, and Air Toxics). This is a key provision with two types of permits.

  Permit to Install (PTI) is a list of general and special conditions with which certain emission sources must comply. PTIs typically limit emission rates, hours of operation, amount and type of raw materials, and/or specifies the operation of air pollution control devices, monitoring devices, and stack heights. Typically, small sources are exempt from PTI requirements. If the proposed installation or modification of an emission unit or source meets the definition of a major Prevention of Significant Deterioration (PSD) or offset source, then the source may be subject to additional stringent regulations such as modeling emissions, installing best available control technology (BACT), and conducting a public hearing. The only way to avoid these added requirements is to accept restrictions limiting the maximum emissions (Potential to Emit) below the major source emission threshold levels using permit conditions. PTIs are free, do not expire, and do not need renewal, but may require MDEQ notification for installation, construction, reconstruction, relocation, or modification of the facility. PTI conditions are eventually folded into a facility's Renewable Operating Permit.

  Renewable Operating Permit (ROP) program is part of Title V of the US Clean Air Act Amendments of 1990. This clarifies which requirements apply to a facility that emits air contaminants. This applies to facilities that are "major sources",[9] acid rain, and waste incineration facilities. ROP's are typically renewed every five years, providing the opportunity for public comment on draft ROP's.

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[6] For a summary of air quality regulations in Michigan see http://www.michigan.gov/documents/deq/deq-ess-caap-manufguide-chap1_313400_7.pdf

[7] A Citizen's Guide To Participation in Michigan's Air Pollution Control Program, MDEQ, 2007 http://www.michigan.gov/documents/deq/deq-ess-caap-citizensguidetomiairpollutioncontrol_195548_7.pdf

[8] A Guide to Public Participation & The Clean Air Act, Washington University Interdisciplinary Environmental Clinic St. Louis ttp://www.cacwny.org/docs/Title%20V%20-%20The%20proof%20is%20in%20the%20permit.PDF

[9] There are four different types of major sources: major prevention of significant deterioration source (PSD), major offset source, major ROP source, and major HAP source. Each one of these major sources has different annual emissions threshold levels. For example, under the ROP program, a major source is one that has a potential to emit (PTE) exceeding 100 tons/year of any regulated air contaminant, 10 tons of a single hazardous air pollutant (HAP), or 25 tons of a combination of HAPs. Under PSD, a major source may be one that has a PTE great than 100 or 250 tons of any regulated air contaminant, depending on the type of source.

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- Part 3 – Emissions Limitations and Prohibitions – Particulate Matter. This rule limits PM emissions from industrial and other facilities, open burning of trash, trees, and brush,[10] and fugitive dust. It includes emission limits, and opacity limits that prevent businesses from discharging dense black or white smoke.
- Part 4 – Emissions Limitations and Prohibitions – Sulfur-Bearing Compounds. This rule established SO_2 limits and limits regarding the sulfur content of fuels. US EPA regulates most motor vehicle fuels; the Part 4 limitations apply to other sources, including coal.
- Part 6 – Emissions Limitations and Prohibitions – Existing Sources of Volatile Organic Compound (VOC) Emissions. This rule implements US EPA requirements regarding application of reasonable available control technology (RACT) for VOC releases.
- Part 7 – Emissions Limitations and Prohibitions – New Sources of VOC Emissions. When a new source is installed or an existing source is modified, emission rates are to be limited to the lowest of those resulting from an evaluation of four procedures (best available control technology or BACT[11]; maximum allowable emission rate specified by a US EPA New Source Performance Standard (NSPS)[12] the maximum allowable emission rate specified as a PTI condition; or the maximum allowable emission rate specified in the Part 6 rules). Part 6 rules also include screening analyses designed to ensure that maximum emissions do not exceed thresholds for acute or chronic health risks.
- Part 8 – Emissions Limitations and Prohibitions – Oxides of Nitrogen. These rules apply to larger fossil fuel-fired emission units, e.g., power plants, boilers/process heaters, stationary internal combustion engines, cement kilns, and stationary gas turbines.
- Part 9 - Miscellaneous Provisions.
- Part 10 – Intermittent Testing and Sampling – See next part.
- Part 11 – Continuous Emissions Monitoring

[10] Open burning of trash from a business is prohibited, and open burning from other sources is restricted. Public Act 102 of 2012 was signed into law on April 19, 2012, prohibiting the open burning of household trash that contains plastic, rubber, foam, chemically treated wood, textiles, electronics, chemicals or hazardous materials. The law amends the open burning provisions contained in Section 11522 of the Natural Resources and Environmental Protection Act (Public Act 451 of 1994). The changes took effect on October 16, 2012, and contain penalty provisions, which may be enforced by local units of government, should a local ordinance not exist. Open burning of brush, logs, stumps, and trees is prohibited within 1,400 feet of an incorporated city or village limit. The open burning of grass clippings and leaves is not allowed in municipalities having a population of 7,500 or more unless the local governing body has specifically enacted an ordinance authorizing it.

[11] BACT is defined as the most stringent emission limit or control technique that has either been achieved in practice for a category of emission units, is found in other state air quality rules, or is considered by the regulatory agency to be technically feasible and cost effective. A BACT analysis, performed as part of the permit review process, triggers continual use of technology that results in low emissions of air contaminants. The definition of BACT evolves as technology improves and/or as industry adopts technology.

[12] Under Section 111 of the Clean Air Act, U.S. EPA establishes new source performance standards (NSPS) for new or modified sources in particular industrial categories, which include emission limits for over 75 source categories. The NSPS requirements are found in the federal rules published in the Code of Federal Regulations (CFR).

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Parts 10 and 11 give MDEQ the authority to require sources to quantify their air emissions to verify compliance with the emission standards using short-term tests (Part 10) or Continuous Emission Monitoring Systems (CEMS). These are discussed later (Section 7.6.2.3)

- Part 14 – Clean Corporate Citizen Program. Michigan's Clean Corporate Citizen Program allows sources that have demonstrated environmental stewardship and a strong environmental ethic to receive public recognition and air quality permit processing benefits.
- Part 15 - Emission Limitations and Prohibitions-Mercury
- Part 16 - Organization, Operation, and Procedures
- Part 17 – Hearings. Hearings provide an opportunity for public input on rule changes, consent orders, PTIs, and ROPs. MDEQ may decide, at its discretion, to hold informational meetings, and typically holds informational meetings immediately preceding a hearing given large interest from the local community, for controversial projects, and for major sources. Public hearings are recorded and transcribed for MDEQ staff so they may review and respond to comments made during the public comment period and hearing process. If there are substantive written or oral comments made during the public comment and hearing process, the MDEQ develop a "Response to Comment Document." Typically, MDEQ provides 30 days' notice of pending actions on their web site. An extension of the public comment period may be granted at DEQ's discretion.
- Part 18 - Prevention of Significant Deterioration (PSD) of Air Quality. This requires a review of new and existing major sources prior to construction or modification. The rule is designed to ensure compliance with the national ambient air quality standards, the applicable PSD increment concentrations, and the requirement to apply best available control technologies on the project's emissions of air pollutants above significance. Somewhat complicated rules determine which sources fall into the PSD rules, but basically PSD applies if a major modification is made to the source that results in a significant emissions increase (by itself) and a significant net emissions increase (across the whole stationary source).
- Part 19 - New Source Review for Major Sources Impacting Nonattainment Areas

7.6.1.4 Southeast Michigan Council of Governments

As the 7-county metropolitan planning organization, SEMCOG has a role in air-quality planning, primarily to ensure conformity of transportation plans, that is, that long-range transportation plan and transportation improvement program are consistent with air quality goals established in state air quality implementation plan (SIPs). This applies primarily to O_3, NO_x and $PM_{2.5}$ pollutants. SEMCOG also promotes awareness in ozone action plans.

SEMCOG has a small staff (68 in total).[13] While a few staff have detailed knowledge about air quality, internal capacity is limited and SEMCOG will typically contract out air quality analyses. Most of SEMCOG's recent work

[13] SEMCOG (Southeast Michigan Council of Governments). Available: http://semcog.org/About-SEMCOG/Staff-Directory [accessed 5 May 2016].

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pertaining to air quality has been to assist with earlier SIP attainment plans for $PM_{2.5}$ and O_3 by quantifying emissions from vehicles, evaluating the effectiveness of potential emission control measures, and developing air quality attainment strategies.

7.6.1.5 Air quality regulations in practice

Emission reductions can be achieved by developing cleaner technologies, using cleaner fuels and feedstock, improving efficiencies in manufacturing or other processes, or adding pollution controls. Frequently, emission reductions demonstrate increasing costs, i.e., removing the first 25% of pollution is cheaper than the next 25%, and the costs of removing 90 or 99% of pollution may extremely high. To determine emission limits, MDEQ enters negotiations with industry, often months and sometimes years before a PTI or ROP is announced publically. Section 7.4 of the Resource Manual discusses emission controls for point sources and additional factors that influence emission limits and controls.

Facilities defined as "major" sources get special attention. If a facility emits more than 25 tons per year of any combination of Hazardous Air Pollutants (HAPs) or over 100 tons per year of other regulated pollutants, then Title V of the CAAA designates these as major sources that require a Title V permit. In Michigan, these permits are called Renewable Operating Permits (ROPs), as discussed above. The ROP application process includes an initial review by MDEQ, negotiation by MDEQ and industry to determine permit conditions, issuance of a draft permit, possible issuance of public information document, a public comment period, possibly a hearing for controversial cases, incorporation of comments, final review, a final permit and approval.[14] This application includes analysis of how the proposed emission increases will impact air quality, but the analysis generally is limited to only the facility seeking the permit and only the change at the facility proposed. Some facilities have many permits and large emissions from other sources at the facility -- these are rarely analyzed in this process.

Historically, MDEQ has denied very few air quality permits, but applications are routinely modified during the permitting process to ensure compliance with state and federal regulations.

Emission limits or other permit conditions may not be very stringent for a number of reasons:

- Older facilities are largely "grandfathered" out, that is, older facilities do not necessarily have to meet current standards. This is a particular issue in Detroit since many facilities date from the 1940s through the 1970s when few rules applied.
- The application of best available control technology (BACT) and similar rules incorporate cost and industry practices. Often, costs are inflated, and industry individually and collectively is reluctant to install new equipment or controls, thus, many BACT options are deemed too costly, undemonstrated, and infeasible.
- Air pollution regulations involve trade-offs or unintended consequences, both real and perceived, that may offset the desired benefits of the regulations. These can include economic penalties that cause a

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[14] MDEQ (Michigan Department of Environmental Quality). 2001. Title V Renewable Operating Permit Overview. http://www.michigan.gov/documents/deq/deq-aqd-field-ROP-Overview_458312_7.pdf [accessed 4 May 2016].

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loss of business competitiveness or threats to economic viability, as well as many other considerations as depicted in Figure 7.6-1. Thus, it is argued that regulations should consider both positive and negative impacts (and risks) in setting standards. Some of these impacts may be trivial, others important.

- Permitting rules do not fully consider health impacts (other than compliance with NAAQS and other ambient standards), cumulative effects, environmental justice, or other issues. There is a lag in NAAQS and other standards and guidelines, and the notion of a threshold or acceptable level of air pollution is no longer well accepted for $PM_{2.5}$ and some other pollutants.
- Information provided in permits, public information documents and other documents can be both very technical and very limited in score and relevance. FOIA requests, and associated fees, may be required to obtain additional material. For large sources undergoing a modification, for example, these documents describe only a component of the facility's operation and not its overall impact.
- Public participation may not be very effective for several reasons, including (1) a lack of technical capacity in potentially affected communities; (2) a lack of information provided by MDEQ regarding impacts; (3) difficulty in developing or coordinating responses given a 30 day comment period and no prior notice of a pending action; (4) the relatively few types of MDEQ decisions that can be contested; and (5) perceptions and reality that very few permits are denied.[15]
- MDEQ's negotiations with industry are not transparent nor made available to the public.
- Funding and agency influence by industry are continual concerns for state agencies like MDEQ.

[15] MDEQ maintains a calendar of pending actions: http://www.michigan.gov/deq/0,1607,7-135-3308_3325---,00.html

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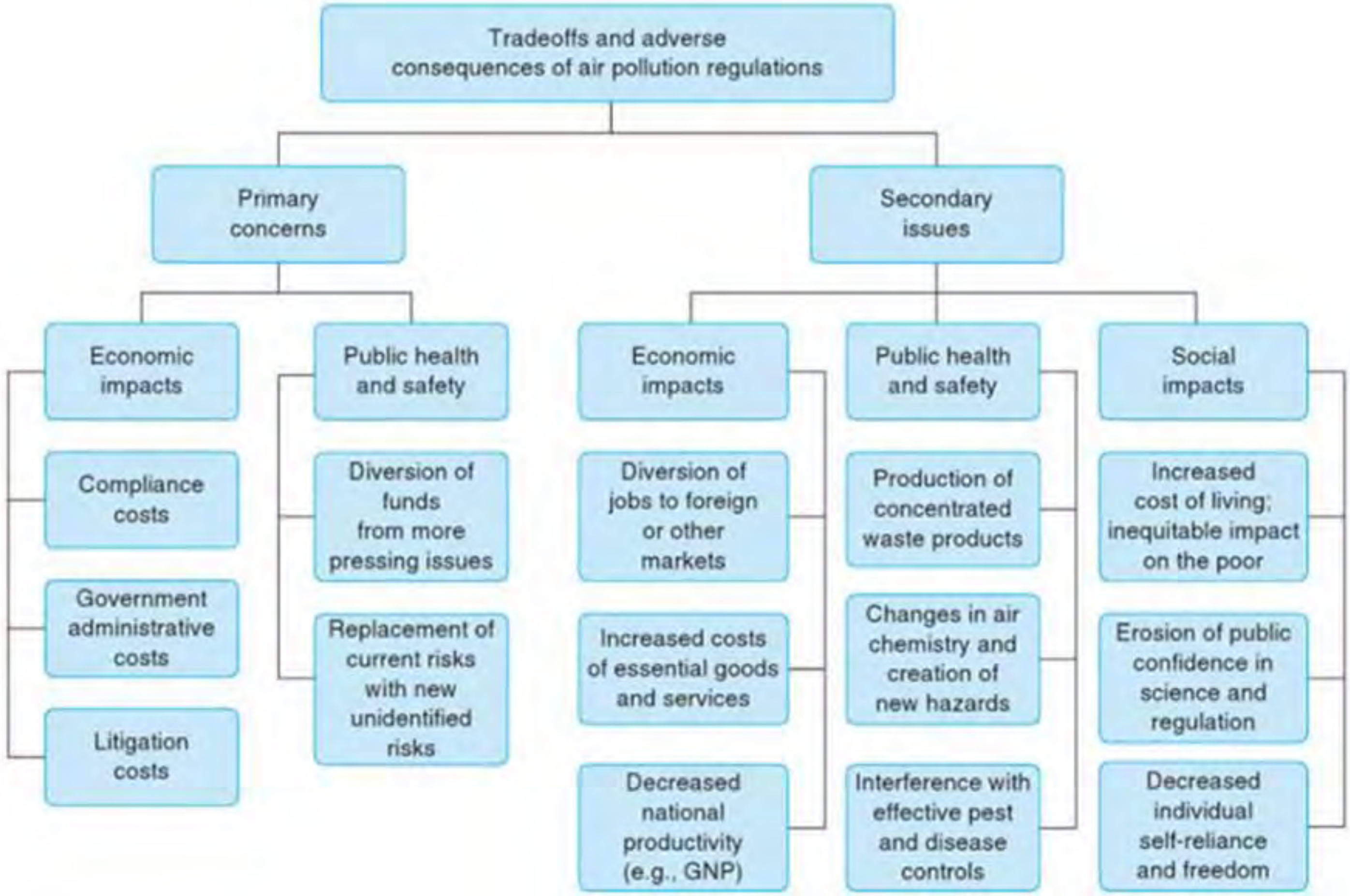
Figure 7.6-1. Potential trade-offs and consequences of air pollution regulations. From University of California Air Pollution Health Laboratory. No Permission obtained for reproduction



7.6.2 Air quality monitoring

Air quality monitoring (or surveillance) is one of the tools used enforce ambient air quality and emission standards. Air quality monitoring is conducted by US EPA, MDEQ, and sometimes county and local governments, tribes, industry, community organizations, researchers, and individuals. Air quality monitoring falls into several broad types, and ambient air quality monitoring, deposition and emissions monitoring are discussed in turn.

7.6.2.1 Ambient air quality monitoring

Ambient air quality monitoring was discussed in Section 4 of the Resource Manual. Ambient monitoring uses instruments that measure specific pollutants or parameters in outdoor air, most commonly the NAAQS pollutants (SO_2, NO_2, O_3, CO, lead and $PM_{2.5}$). This type of monitoring is used to measures the concentration of pollutants in the atmosphere which you may breathe.

The importance of ambient air monitoring should not be understated. Monitoring ambient air quality is the best way to tell if the air is getting cleaner, because monitors accurately report how much of a pollutant is in

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the air. However, monitoring has limitations due to spatial, temporal and parameter coverage. This means that there are only a limited number of sites that are monitored; many locations of interest do not have monitors; monitored variables focus on the six criteria pollutants (not toxics); and pollutant levels can change from hour-to-hour and day-to-day and some monitoring is intermittent (e.g., samples are taken every 3 or 6 days).

In Michigan, the state's ambient air quality monitoring network and the collected data are described by the MDEQ each year in its annual Air Monitoring Network Review[16], and its annual Air Quality Monitoring Reports[17]. US EPA also makes the same data available. Section 4 of the Resource Manual discussed monitoring performed by MDEQ and industry in the Detroit area. It also described many aspects of ambient air quality monitoring, including the number of sites, type of equipment, and that procedures used must meet US EPA guidelines.

All monitoring programs need quality assurance (QA) programs to (1) assess the quality of data collected; (2) ensure that the quality of the collected data is sufficient to address the intended use; and (3) improve the data collection process. MDEQ and US EPA programs are of high quality and meet QA requirements pertaining to most studies.[18] The importance of QA programs in all monitoring activities should not be underestimated.

7.6.2.2 Deposition monitoring

Deposition monitoring is a type of ambient monitoring that measures the rate at which pollutants accumulate or deposit on the ground or in a water body. Deposition is important to understand for the accumulation and concentration of pollutants in or on soils, plants, water bodies, fish, surface soil and dust. Deposition samples are used to measure, for example:

- Acid rain, which can lead to soil and water acidification and a variety of ecological impacts;
- Mercury and PCB accumulation in sediments and lakes, which can be taken up and biomagnified in fish;
- Pesticide spray from agricultural applications; and
- Lead and asbestos released as buildings are demolished

Deposition monitoring in urban areas is relatively rare outside the research context, although it is relevant for lead exposure in Detroit due to contaminated soils and brownfields present. It also may be relevant for deposition of other metals and organic compounds from steel mills, coke facilities, storage piles, and other sites.

7.6.2.3 Emissions monitoring

A third type of air quality monitoring, called emissions monitoring, measures the type and quantity of pollutants released from polluting or potentially polluting facilities. Often, emissions monitoring measures pollutants in

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[16] 2016 Air Monitoring Network Review, Michigan Department of Environmental Quality Air Quality Division. June 29, 2015, http://www.michigan.gov/documents/deq/deq-aqd-toxics-2016_Air_Mon_Network_Review_489490_7.pdf

[17] 2014 Air Quality Monitoring Report, Michigan Department of Environmental Quality Air Quality Division. June, 2015 http://www.michigan.gov/documents/deq/deq-aqd-amu-2014_Annual_Air_Quality_Report_492732_7.pdf

[18] This is a non-trivial issue. Illinois, for example, had to invalidate many years of $PM_{2.5}$ data. Also, without implementing an appropriate QA plan, the value of low-cost monitoring may be very limited.

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the process device itself or in the stack, and thus is called "stack" monitoring. Emissions monitoring can serve several purposes, the most common being:

- Accurately estimating the pollutant release rate from a source, say, in pounds per hour;
- Detecting whether emissions are acceptable, e.g., within normal procedures, or whether an operational issue or equipment failure of a pollution control systems has occurred;
- Confirming design or permit specifications that specify an emission limit or other restriction; and
- Aiding or optimizing process control.

Emissions monitoring may be required under federal law and/or MDEQ permits. Emissions monitoring complements ambient air quality monitoring discussed in the previous section. MDEQ has considerable discretion with respect to the emissions monitoring, and can set the parameters, frequency, averaging time and other aspects of emissions monitoring.

Examples of emissions monitoring include:

- Continuous emission monitoring systems (CEMS). All power plants covered by the Acid Rain Program (including DTE's facilities) must install CEMS under the 1990 CAAA that track SO_2 and NO_x emissions. These data are reported to EPA four times each year. There are monetary penalties if the facility releases more pollutants than are covered by their allowances.
- Opacity monitoring. This is a type of CEMS that may be required for large facilities (power plants) to ensure that particulate matter controls are functioning properly. Opacity is used as a surrogate for $PM_{2.5}$, which is more difficult to measure.

  Typically, facilities are prohibited from having visible plumes (other than steam) that may indicate excessive levels of gaseous or particulate pollutants. Visual observation of smoke is impossible at night; thus CEMS provide additional assurance that emissions are acceptable.
- Short-term (intermittent) emission (stack) tests. Some types of facilities require emissions tests as part of their permitting conditions, typically when the facility is first constructed and then periodically, e.g., every 5 years. For example, for incinerators, EPA rules requires demonstration of a minimum destruction and removal (DRE) efficiency, e.g., 99.9999% in the case of a hazardous waste incinerator (demonstrated by a "challenge" feedstock.)
- Vehicle inspection and maintenance (I&M) monitoring. A number of states require periodic inspections and/or emissions tests for vehicles. These may include visual inspections of the vehicle's emission control systems, as well as measurements of CO, NO_x and VOCs in tailpipe emissions. States on both US coasts have used these I&M programs as part of O_3 SIPs designed to reduce emissions; Michigan has never utilized such tests.
- Fugitive emissions monitoring and inspections. As a combination of ambient, perimeter, and source monitoring, air quality monitoring is sometimes used to find leaks or releases. The technology may

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utilize handheld or fixed instruments, temporary sites, and sometimes infrared and other types of cameras.

Without emissions monitoring, emission rates must be estimated, typically using an emission factor approach. This approach can be reasonably accurate for some pollutants and some sources. For example, it is easy to estimate SO_2 emissions based on the coal sulfur content and the number of tons of coal burned. However, estimates can be highly uncertain for pollutants like $PM_{2.5}$.

7.6.3 What types of air ambient air monitors can be used, and where can they be used?

There are several types of air quality monitoring and surveillance systems. These can be grouped into four categories

- Stationary monitoring networks
- Mobile monitoring (vehicles, aircraft)
- Remote sensing (satellite, DIAL – differential absorption LIDAR)
- Low-cost monitoring

There are many types of monitors that can be used.

- Federal reference method (FRM) or Federal equivalent method (FEM) monitors meet EPA requirements and are used to determine compliance with NAAQS and for other purposes. Typically, FRM/FEM monitors are operated by MDEQ, US EPA or industry (See Section 4.1). The equipment, which is relatively expensive, is installed in a climate-controlled trailer, building or other fixed site. These semi-permanent facilities require site access, security, power, telecommunications, relatively open land, and other constraints.
- Non-FEM monitors are used by MDEQ and researchers, also at fixed sites. These can measure pollutants such as volatile organic compounds (e.g., benzene), aldehydes (formaldehyde), semivolatile compounds (PAHs), metals (cadmium), diesel particulates, and ultrafine PM.
- Some monitors or data can be triggered or analyzed for directional sampling, which measures pollutants that come from a certain direction.
- Both continuous (real-time) and integrated (long duration) sampling technology is available for a number of pollutants.
- Mobile monitors are installed in vehicles (typically electrically-powered vans), and have been used to measure on-road or traffic-related pollutants.
- Handheld or portable instrumentation is used to measure some pollutants.
- Ground-based remote sensing systems can monitor a number of pollutants along a line of sight, typically using DIAL or FTIR technology.

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- Satellite-based remote sensing allows measurements or estimates of several pollutants, including PM and O_3, across relatively large areas. Currently, concentrations are estimated to a 1 x 1 km scale.
- Passive samplers include both natural surfaces like moss, and special adsorbents to sample primarily gases and vapors, to provide a long-term measure of concentration and deposition.
- Visibility monitoring is a measure of distance which related to haze and PM.
- Personal samplers are used to measure air in the breathing zone of an individual, and to account for an individual's activity and mobility through the day.
- Low cost monitors. These include several types relevant for community use discussed below.

As noted in Section 7.5.2.1, ambient air quality monitoring can be used to estimate population, source-impacted, and background exposures. Some important cases are described below.

- Population-oriented monitoring typically uses fixed site monitors placed in residential locations.
- Near-road monitors are placed within about 50 m (160 feet) of major highways, and measure CO, NO_x and sometimes other pollutants arising in part or largely from traffic-related emissions.
- Perimeter monitors are placed at or near the fence line of facilities to measure the impact of that facility's emissions, e.g., Marathon has four SO_2 monitors for this purpose, and lead deposition has been monitored around homes being demolished.
- Traffic surveys and traffic-related air pollutants can be monitored at high traffic areas.

Low-cost monitoring. In recent years, many so-called "low-cost" monitors and sensors have been used for individual or community-level air quality monitoring use.[19] EPA and others have developed some guidance for individuals and communities interested in employing low-cost air monitors or sensors within their community.[20] In many ways, low-cost monitoring represents a paradigm shift (see Figure 7-6-2). As noted above, while these low-cost monitors are not appropriate for all air monitoring uses, they can have many advantages and applications, including: [21]

- Measuring "personal" exposure of an individual by carrying the monitor throughout their day
- Identifying potential pollution hotspots to be further investigated
- Enabling and empowering community organizing and activism
- Supplementing existing air monitoring networks
- Increasing dialogue between citizen groups and state and federal environmental regulators

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[19] Low cost has been defined as under $5000 for a monitor; sensors runs from about $100 to about $20,000 for a single pollutant.

[20] EPA. 2014. Air Sensor Guidebook. Available: https://cfpub.epa.gov/si/si_public_record_Report.cfm?dirEntryId=277996 [accessed 25 Feb 2016].

[21] Snyder, E, et al. "The changing paradigm of air pollution monitoring". *Environ Science and Tech*, *47*(20), 11369-11377, 2013.

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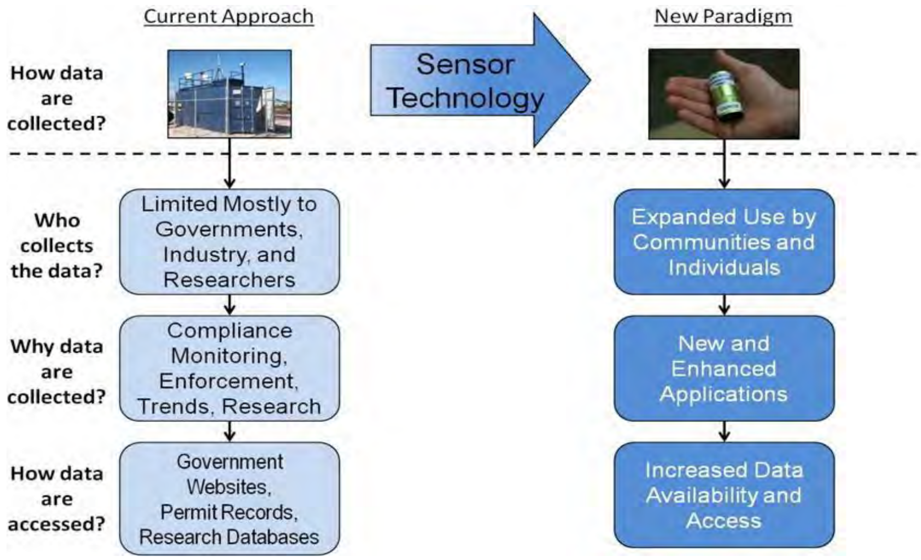
- Enhancing monitoring of fugitive emissions at facilities for compliance monitoring.

Figure 7.6-2. Differences between traditional stationary air monitoring and low-cost air monitoring systems.[22]



7.6.4 Why is this important?

Improving monitoring, permitting and enforcement can have a great impact on public health within a community. These activities help to ensure that regulatory decisions consider all stressors being experienced by a community; prevent the siting or operation of new polluting facilities; and decrease emissions of existing facilities. Monitoring data can provide the best data to community members to know what is in the air they breathe. To both community members and regulatory officials, monitoring data describes concentrations, exposure, emissions, the adequacy of source controls, and the performance of the overall air quality management strategy. Specific reasons why ambient air quality monitoring is important include:

- Monitoring data indicate current air quality, which is used in air quality alerts and ozone action days, for example.
- Historical monitoring data show trends that indicate whether air quality is changing.
- Monitoring data are the basis for determining compliance with air quality standards,[23] including both the primary health protective NAAQS and the secondary welfare protective NAAQS,[24] and to determine

[22] EPA. 2014. Air Sensor Guidebook. https://cfpub.epa.gov/si/si_public_record_Report.cfm?dirEntryId=277996 [25 Feb 2016].

[23] NAAQS Status is shown by county by US EAA at https://www3.epa.gov/airquality/greenbk/anayo_mi.html.

[24] Primary standards provide public health protection, including protecting the health of "sensitive" populations such as asthmatics, children, and the elderly. Secondary standards provide public welfare protection, including protection against decreased visibility and damage to animals, crops, vegetation, and buildings.

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whether further emission reductions or other actions are needed. These monitors may be placed at "hotspots," that is, locations where the highest concentration is expected.

- Monitors may be used to quantify impacts of specific sources, including industry and roadways. These are called "source-oriented" or "near-road" sites, respectively.
- Perimeter or fence line monitoring is sometimes required as part of a permit condition to ensure adequate control of fugitive dust or other emissions. This is relatively rare in Michigan although some landfills and waste sites employ such monitoring.
- Monitoring data aid source apportionments, which identify the source(s) that cause or contribute to air pollution, depend on monitoring data.
- Some monitoring sites are placed to determine "upwind" or "background" concentrations of pollutants that are transported into the area (called "transport-oriented" sites). This is particularly important for $PM_{2.5}$, ozone (O_3), and O_3 precursors to understand how much of the pollutants arise from local sources, and how much comes from elsewhere.
- Monitoring data provide exposure information that are used in risk and epidemiological studies aimed at understanding health and environmental impacts of air pollution.
- Monitoring data are sometimes used to estimate emissions and for a variety of research purposes, including evaluation/validation of dispersion and other models.

It is also important to make air quality monitoring data accessible. Much of the data is available on MDEQ or EPA websites for researchers. Simplified data interpretations are available for the public in several forms:

- Michigan EnviroFlash Program. This sends to subscribers an email message if the Air Quality Index is predicted to reach or exceed the health level selected by participants, plus notification when an air quality "Action!" Day (advisory) is announced. (Figure 7.6-3. http://www.deqmiair.org/notify.cfm)
- Air Quality Index (AQI). MDEQ has maps showing the current Air Quality Index, which considers both O_3 and $PM_{2.5}$. (Figure 7.6-4. http://www.deqmiair.org/index.cfm?page=home)
- Air quality maps for current or historical levels of O_3 and $PM_{2.5}$ with up-to-the hour results are available on the web. (Figure 7.6-5. http://www.deqmiair.org/ozonemaps.cfm?date=6%2F10%2F2015)
- Summaries of data are provided in MDEQ annual reports.

US EPA has both similar and more detailed information at https://www.airnow.gov.

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Figure 7.6-3. Example of Enviroflash email alert available from MDEQ.

MIair

Air Quality Notifications

Forecast for Detroit, MI
Today and Tomorrow's Forecast

Monday, Mar 7:	Moderate	**Yellow**	Particle Pollution (2.5 microns)
Tuesday, Mar 8:	Moderate	**Yellow**	Particle Pollution (2.5 microns)

Extended Forecast

Wednesday, Mar 9:	Moderate	**Yellow**	Particle Pollution (2.5 microns)
Thursday, Mar 10:	Moderate	**Yellow**	Particle Pollution (2.5 microns)
Friday, Mar 11:	Moderate	**Yellow**	Particle Pollution (2.5 microns)

FORECAST SUMMARY: Monday, March 7th, 2016 through Friday, March 11th, 2016 PM-2.5: 24-hour Fine Particulate concentrations will range from upper Good to low Moderate through the period. FORECAST DISCUSSION: A warmer, yet unsettled, weather pattern is setting up for this week. Chances for rain exist each day with the greatest threat being in the Wednesday/Thursday time-frame. Warm southerly winds over the current snow pack will cause increased surface moisture and fog is a good possibility late Monday/early Tuesday and again early Wednesday. By Wednesday, the snow will generally be gone across the southern portion of the state. Fine particulate on Monday was ranging from upper Good to lower Moderate. The plus for increased levels through mid-week will be the warmer temperatures causing the snow to melt; however, the on and off precipitation will hamper a significant pollution build-up. The early morning hours will likely experience the highest fine particulate concentrations through Thursday with hourly readings in the Moderate range. But, levels will drop off by mid-late morning due to increased winds, and also, in areas which experience heavier rains. Daily 24-hr fine particulate concentrations Monday through Thursday will range from upper Good to low Moderate. The frontal boundary causing the wet time-period is expected to sink southeast of the state Friday. Northeast winds behind the boundary will improve air quality back in the Good range. EXTENDED FORECAST: Extended forecast models show the Friday frontal boundary lifting back north Saturday. The boundary stalls across the state and the weekend looks to be a wet period with light winds. This may be another period of mostly Moderate fine particulate. We will be having another regional forecast call Friday to discuss the expected air quality conditions for the weekend into early next week. Forecast updated by Stephanie Hengesbach: Monday, March 7th, 2016 Next forecast update: Friday, March 11th, 2016

For additional information concerning the air quality forecast, and to view current Michigan air quality maps, data & information, select the MIair icon at: www.michigan.gov/air

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Figure 7.6-4. Example of AQ information available from MDEQ.

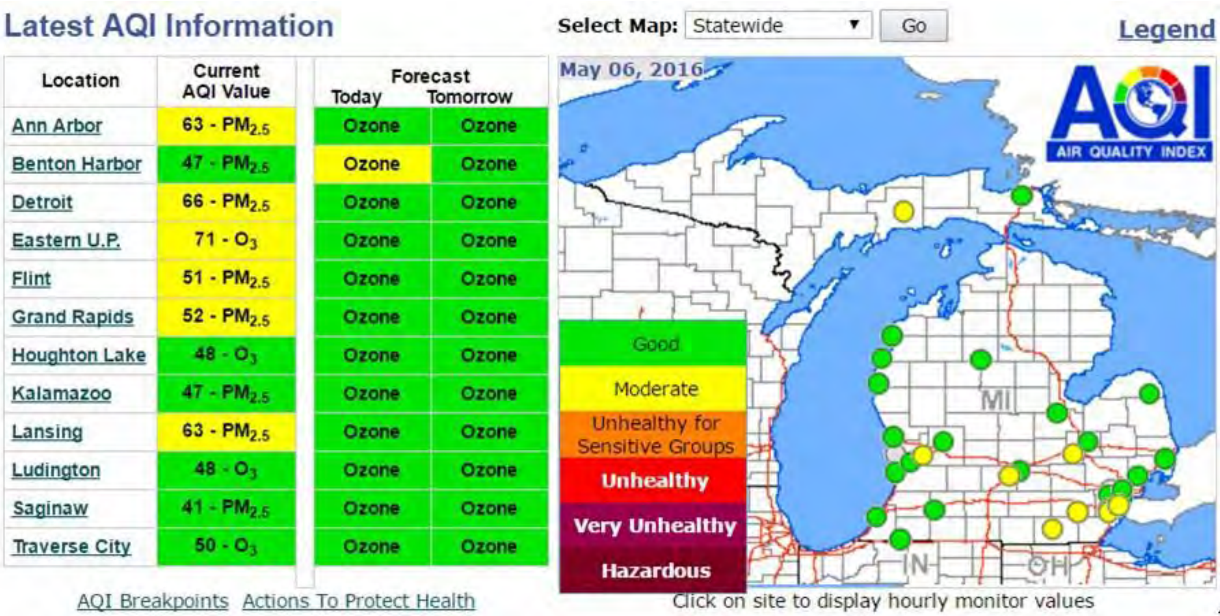
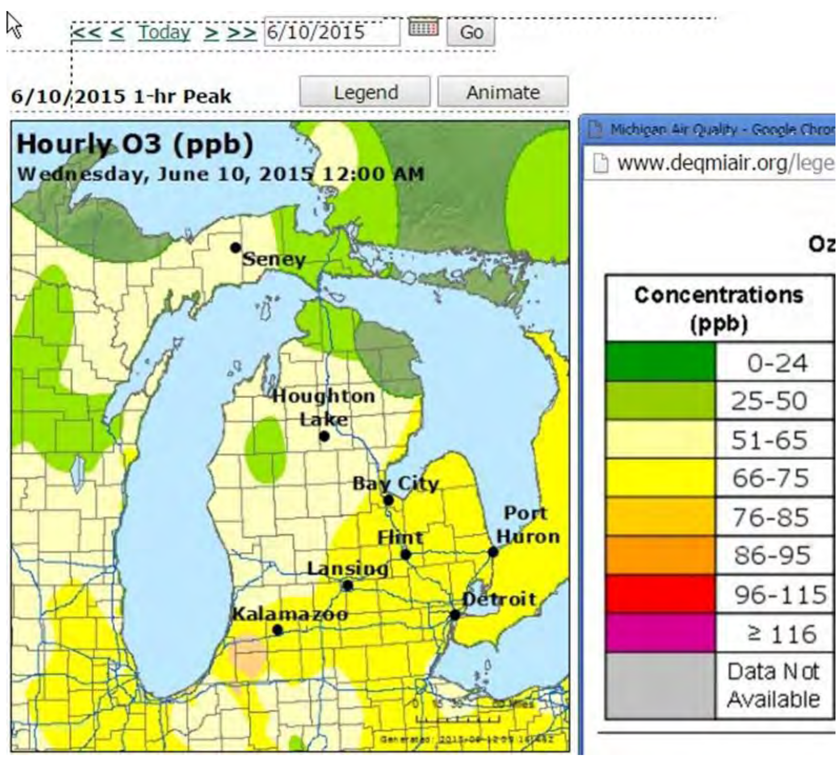


Figure 7.6-5. Example of air quality map for O_3 available from MDEQ.



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7.6.5 Which pollutants are monitored?

Monitoring in the Detroit area, as in other urban areas, includes the following:

- Criteria pollutants: $PM_{2.5}$, PM_{10}, O_3, NO_x, CO, SO_2 and lead.
- Toxics are monitored at a few sites.
- Diesel exhaust (or surrogates known as black carbon) is measured at a few sites.
- Bioaerosols are measured at one site (not by MDEQ).

Monitoring of ultrafine PM, reactive species, metals, organics, and other species is also conducted, but the number of sites and frequency of such measurements is comparatively low.

7.6.6 What is happening in and around Detroit?

- MDEQ operates a network of monitors in the state, with approximately ten sites in Wayne County and six in Detroit. As in most other cities, these emphasize the criteria pollutants. The network includes source-oriented sites (e.g., Dearborn), population sites (e.g., East-7 mile), and traffic-oriented sites (Eliza Howell and Schoolcraft College). See Section 4.2 for a discussion of the current monitoring network and needs for expansion.
- MDEQ obtained additional support in Sept. 2015 from US EPA to collect toxics data for 2 years at two near-road monitoring sites (Eliza Howell and School Craft College). This will encompass a large number of parameters (including carbonyls, continuous BTEX, carbon black, ultra-fine PM, metals, both continuous and filter-based). These data will aid source apportionments and other analyses.
- MDEQ has been discussing siting an additional monitor in southwest Detroit to respond to citizen requests.
- Marathon operates four sites providing continuous measurements of SO_2, H_2S, PM_{10} and volatile organic compounds such as benzene. A December 1, 2015 rule requires perimeter monitoring at refineries for benzene, which must not exceed 2.8 ppb, otherwise corrective actions will be required.
- Portions of Michigan may be in non-attainment of the new O_3 standards. MDEQ will make attainment and non-attainment recommendations to US EPA by Oct. 1, 2016, based on monitoring. Figure 7.6-5 shows the current status of O_3 attainment. In addition, O_3 will be monitored for a longer period (Mar – October, and instrumentation will be added to some sites to measure VOC precursors of O_3.
- The proposed SIP for SO_2 will soon be submitted to US EPA.
- The Detroit-based non-profit, Zero Waste Detroit, launched a campaign encouraging residents living near the Detroit Incinerator to call the MDEQ hotline and to send reports via email to the organization

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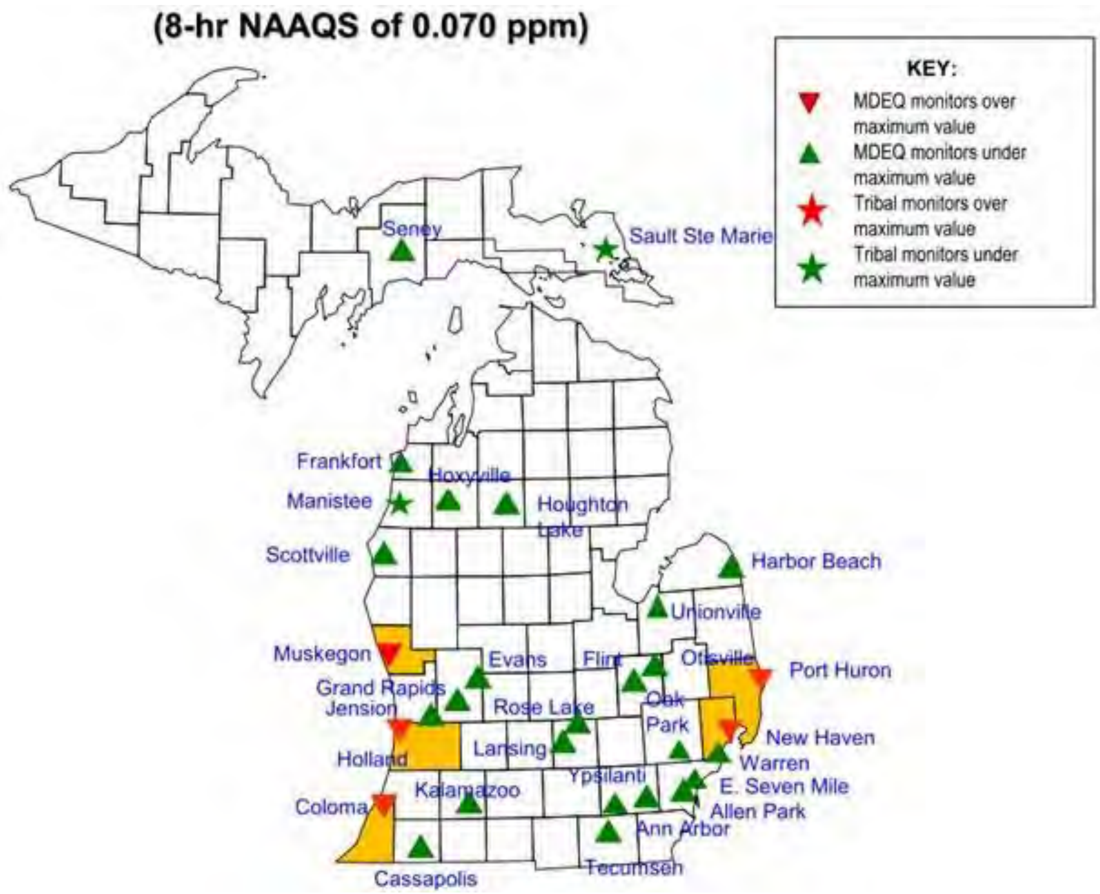
that includes information to help target enforcement actions, e.g., observations of visible smoke from the incinerator's stack.[25] See Figure 7.6-6.

Figure 7.6-6. Potential O_3 non-attainment areas. Uses 2013-15 data. From Fitzner, 2016. http://www.michigan.gov/documents/deq/deq-oea-tou-AirMonitoringWebinarPresentation_517496_7.pdf



[25] Zero Waste Detroit. 2016. Available: http://zerowastedetroit. org/our-work/report-an-odor. [Accessed 4 May 2016].

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Figure 7.6-7. Outreach materials from Zero Waste Detroit encouraging community reporting of air pollution concerns. Taken from: http://zerowastedetroit.org/our-work/report-an-odor

State and academic researchers have conducted many special monitoring studies. These include:

- Detroit Air Toxics Initiative (2005) and research investigating the toxicity of PM at Dearborn (Salinas School by EPA/MDEQ);
- Measurement of impacts around the bridge and intermodal facilities.
- Lead deposition around homes being demolished (UM);
- NO_x and PM monitored at fire stations across Detroit to improve the understanding of spatial patterns (WSU).
- Detroit Exposure and Aerosol Research Study (DEARS) to understand personal exposure
- NEXUS Near-Road Study to understand indoor and outdoor pollution and health effects from traffic-related air pollutants, focusing on the Eliza Howell site (US EPA and UM).
- Air quality and toxicology studies at Dearborn using concentrated air pollutants and animals (US EPA, MSU, UM).
- US EPA and others will be conducting a near-road study to investigate effects of sound barriers and vegetation.
- Truck survey and air quality measurements will be conducted by CBC and UM.

7.6.7 How many people could be affected in Detroit by improved monitoring and enforcement?

While increasing monitoring does not directly decrease air pollution emissions or exposures, it has the potential to identify areas of air pollution concern and to promote enforcement actions. For example, additional SO_2 monitoring might expand the geographic area and number of facilities covered by the SO_2 State Implementation Plan, and possibly lead to greater emission reductions. In addition, greater access to air monitoring data would allow individuals to limit their exposure during times of high air pollution levels.

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Greater enforcement of air pollution violations would impact both individuals living nearest to those facilities being targeted for enforcement, as well as others at greater distances that also receive exposure. The use of sophisticated analyses and approaches to enforcement and permitting decisions, including health oriented analyses and cumulative impact assessments, could affect large populations throughout Detroit and southeast Michigan, with those areas containing larger populations that are susceptible and vulnerable receiving the largest benefits.

7.6.8 What are the best practices? What is applicable to Detroit?

Best practices for monitoring and enforcement are in part drawn from programs in other areas. For enforcement-related practices, best practices that are applicable to Detroit include:

- Shift the approach used by regulators to public health and safety protection rather than the existing focus on compliance with applicable laws and rules.
- Routinely incorporate and use of analyses that investigate and consider human health effects, including health impact assessment (HIA) and cumulative impact assessment (CIA).

  Canada has requirements in this area, as does Minnesota.[26] Other states, including New Jersey and California, have begun investigating and implementing ways to incorporate CIA in permitting and enforcement practices.[27] [28] Overall, these approaches strive to evaluate a facility or permit's impact on a community, and thus give regulators and others a more accurate picture of risk and pollution burden within a community when making permitting decisions.

  Cumulative impact is "an analysis, characterization, and possible quantification of the combined risks to health or the environment from multiple agents or stressors", [29] and can include analyses of multiple pollutants, facilities, routes or pathways of exposure, multiple stressors (including chemical, physical, biological, economic or psychosocial). (A discussion of CIA is provided in Section 3.1.) Where applicable, the Minnesota rule requires an assessment of cumulative risk to individuals that accounts for the permit as well as existing pollution levels, demographics, existing disease burden within the community, current and historic pollution data, exposure data, and various socioeconomic indicators, e.g., poverty and racial make-up. It also includes considerable community engagement. The development of this rule used a series of stakeholder meetings, incorporated community feedback, and provided opportunities to open

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[26] The Minnesota Pollution Control Agency (MPCA) cumulative risk assessment statute and program indicates that MPCA may not issue a permit to a facility without analyzing and considering the cumulative levels and effects of past and current environmental pollution from all sources on the environment and residents of the geographic area within which the facility's emissions are likely to be deposited for certain facilities in Hennepin County. https://www.revisor.mn.gov/statutes/?id=116.07

[27] New Jersey Department of Environmental Protection. 2009. A preliminary screening method to estimate cumulative environmental impacts. Available: http://www.nj.gov/dep/ej/docs/ejc_screeningmethods20091222.pdf. [accessed 8 March 2016].

[28] OEHHA (Office of Environmental Health Hazard Assessment). 2010. Cumulative impacts: Building a scientific foundation. Available: http://oehha.ca.gov/ej/cipa123110.html. [accessed 8 March 2016].

[29] EPA (Environmental Protection Agency). 2003. Framework for Cumulative Risk Assessment. Available: https://www.epa.gov/sites/production/files/2014-11/documents/frmwrk_cum_risk_assmnt.pdf [accessed 25 Feb 2016].

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a dialogue on ways to better engage with stakeholders (i.e. better notification of permit review and comment periods).

CIA can be built into various parts of the regulatory process, including the permitting process, when identifying where to prioritize enforcement action, when deciding where and how many monitoring sites to maintain, and in setting health-protective standards.

MDEQ should initiate a CIA framework as a collaborative process conducted with stakeholders.

- Conduct periodic integrated and long-range air quality planning, including incorporation of transportation, buffers, green energy, and other trends.
- Provide additional funding for technical staff and inspectors to allow more frequent inspections, enhanced monitoring, and other analyses.
- Obtain additional staff at the Attorney General and Department of Justice offices responsible for enforcement. These staff can often pay for themselves by enforcing laws and collecting fines through consent orders, settlements, or judgments.
- Increase notification, information and transparency related to the permitting process, including posting received permit applications; increased time for review of draft materials; assessment of overall facility emissions, impacts and environmental performance in public information documents; and dedicated MDEQ staff to translate technical materials.
- Provide external technical assistance services and advisors for communities. The Superfund Program, for example, has a Technical Assistance Services for Communities (TASC) Program that provides scientists, engineers and other professionals to review and explain information to communities at no cost to communities; a Technical Assistance Grant (TAG) Program for non-profit incorporated community groups to contract with independent technical advisors to interpret and help the community understand technical information, and a similar Technical Assistance Plan (TAP) (funded by polluters) enabling community groups to retain the services of an independent technical advisor.[30] In some ways, these are similar to community benefit agreements.
- Provide more opportunities for meaningful public participation, potentially including use of balanced stakeholder advisory board.

  The public plays an important role in environmental decision making. Individuals living near an air pollution source may know more about the local environmental conditions than an environmental agency located several hours away, and citizens can offer a wide range of perspectives, views, and experiences that are not necessarily represented by the government or regulated industries.

[30] See https://www.epa.gov/superfund/technical-assistance-communities

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- Reduce emissions from point, non-point, non-road, and fugitive sources by reviewing and updating Act 451 rules.
- Improve emissions inventory data, particularly for PM and toxics.
- Require additional emissions monitoring and testing. Deficiencies in available PM and toxics data have been noted.

  In addition, some areas have used real-time air monitoring systems that can detect pollutant levels that are designated to be harmful to public health, and require real-time dissemination of this information and notification of communities and emergency personnel should a health protective standard be exceeded. This has been proposed recently by Louisiana for all major point sources[31,32] Warning systems have been used in industrial areas in the US, Canada, and elsewhere.
- Revamp and promote the Clean Corporate Citizen Program, and provide other incentives to encourage meaningful emission and exposure reductions. A stakeholder's panel should be involved.
- Utilize targeted studies to investigate toxics deposition, health risks, and other topics.
- Regularly evaluate program effectiveness and impact.
- Tighten permit conditions, including emission limitations and averaging times in PTIs and ROPs. This includes reducing the large differences between allowable (permitted) and actual emissions, and the differences between emission limitations at short and long averaging times.
- Incorporate community data in to enforcement action. Expand outreach by groups, such as Zero Waste Detroit, and create web-based systems for residents to report air pollution concerns. These reports should be incorporated in to MDEQ reporting systems to help target enforcement action.

Ultimately, permits that are effective and credible in controlling emissions may be the most critical element of enforcement.

Best practices for monitoring include the following:

- Additional source monitoring to better understand actual PM emissions.
- Increase industry monitoring, including fence line monitoring to measure pollution as it travels over the fence-line. This can be done either through legislation or through negotiation with individual facilities. There is relatively little monitoring considering the nature and magnitude of emissions in this area.
- Expand the SO_2 monitoring network. The SO_2 SIP relies heavily on modeling, but additional monitoring in areas identified as 'hotspots' by modeling is required.

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[31] House Bill No. 469, Louisiana House of Representatives. Available: https://www.legis.la.gov/legis/ViewDocument.aspx?d=998311.

[32] Associated Press. 2016. Bill requiring industrial air monitoring advances in house. Available: http://www.ktbs.com/story/31833042/bill-requiring-industrial-air-monitoring-advances-in-house. [accessed 4 May 2016].

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- Identify other monitoring gaps using a structured process with public input.
- Apply remote sensing and other technologies to develop spatially-resolved understanding of pollutant exposures.
- Provide further analyses of collected data to understand trends and apportionments.
- Deploy semi-permanent or transportable ambient monitoring equipment to understand spatial impacts from particular sources, particularly heavy industry in southwest Detroit, with sufficient data to develop annual average concentrations of toxics
- Fund and provide in-kind support for low-cost and community air monitoring activities. Use low-cost air monitoring systems to supplement existing monitoring networks, identify pollution hotspots and empower communities to document air pollution within their own neighborhood. A formal process to encourage collocation with existing MDEQ monitoring sites, assistance with data interpretation, quality assurance, and other actions could be taken to increase the value of data provided by low-cost monitoring.
- Enhance the websites and public information to allow more informative displays of source emissions and ambient monitoring results.

  For example, reports of odors, smoke, flaring and emissions around oil refineries and chemical plants in Louisiana are mapped on the web by a small NGO[33] using community-based reporting with narrative reports (via text or voicemail that are transcribed, tagged by content, and posted.[34] The map (see Figure 7.6-8) also includes reports of air emissions above permit limits reported by facilities to the National Response Center (NRC). Weekly summaries were sent to state and federal regulators. This mapping increased the understanding of locations of air quality concern and allowed communities to identify emissions that may impact health.

[33] Louisiana Bucket Brigade (LABB), has been using community mapping since 2005.

[34] Bera, R, Hrybyk, A. "iWitness Pollution Map: Crowdsourcing petrochemical accident research". *New Solutions,23*(3), 21-533, 2013.

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Figure 7.6-8. iWitness Pollution Map website. Red circles represent community or industry reports of air pollution. The size of the circle corresponds to the number of reports made during the specified time frame. Taken from: http://www.iwitnesspollution.org.

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7.6 CLEAN ENERGY

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Figures

Tables

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7.7 CLEAN ENERGY: Solar, wind, geothermal, and biomass

7.7.1 *What is clean energy?*

In this chapter, clean energy refers to renewable energy sources that have low emissions and lower environmental impacts than coal, petroleum and other fossil fuels.[1] Clean energy includes solar, wind, geothermal, biomass, and hydropower. Although biomass is sometimes considered a form of clean energy, it can be a significant contributor to greenhouse gases and other harmful air pollutants (see Section 7.7.2.4). Although some definitions of clean energy include nuclear power since this source of energy can have lower greenhouse gas emissions than traditional fossil fuel-based generation sources, we do not consider nuclear power extensively in this chapter. We do not include natural gas as a clean energy source since this fossil fuel does not share the same benefits as renewable energy (e.g., low greenhouse gas emissions), although this is one of the "cleaner" fuels and is widely touted as "clean." This chapter focuses on clean energy sources for electricity generation. (See Section 7.8 for more information on clean fuels.)

Clean energy lowers emissions of air pollutants, including both toxic pollutants and greenhouse gas emissions. This is accomplished by displacing "dirty" sources of energy, including coal, oil, diesel, gasoline, and other fossil fuels. Emissions can be reduced by improving energy efficiency, which reduces the energy required. Energy efficiency often is the most cost-effective and short-term strategy to reduce emissions and adverse impacts from "dirty" energy sources.

Today, nearly half (46.4%) of Michigan's electricity is generated by burning coal.[2] There are no active coal mines in Michigan, and coal is imported from Wyoming and Montana, by rail.[3] Because most of Michigan's coal-fired power plants are old and do not have modern emission controls, Michigan's electricity is a particularly "dirty" source of energy. The emissions, health and environmental impacts of coal-fired power plants, discussed in Section 5.5 of this Resource Manual, could be offset by clean energy. Nuclear power accounts for 26% of Michigan's electricity; [4] renewables could replace nuclear energy as older plants are phased out and decommissioned.

Currently, only about 8% of Michigan's electricity comes from renewable sources. Across the United States, the use of renewable energy is expected to rise over the next few decades. While energy forecasts are uncertain, one estimate is that renewable energy will account for about 18% of electricity in the U.S. in 2040, up from 13% in 2013, as shown in Figure 7.7-1. The largest gains in renewable energy are expected for solar

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1 EPA (Environmental Protection Agency). Energy and Environment. Available:https://www.epa.gov/energy/learn-about-energy-and-environment [accessed 3-2-16] and EPA (Environmental Protection Agency). State and Local Climate and Energy Program. Available: http://www3.epa.gov/statelocalclimate/local/topics/renewable.html [accessed 3-2-16].

2 US Energy Information Administration. 2016. State Profile and Energy Estimates: Michigan [WWW Document]. URL http://www.eia.gov/state/?sid=MI [accessed 5-22-16].

3 US Energy Information Administration. 2016. Michigan: State Profile and Energy Analysis. Available: https://www.eia.gov/state/analysis.cfm?sid=MI. [accessed 8-25-16].

4 US Energy Information Administration, 2016. State Profile and Energy Estimates: Michigan [WWW Document]. URL http://www.eia.gov/state/?sid=MI [accessed 5-22-16].

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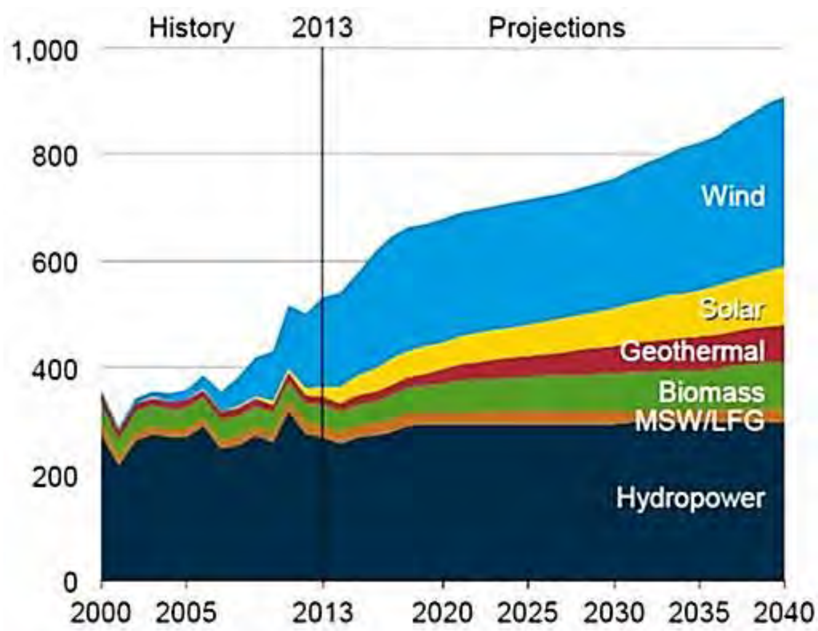
and wind.[5] Much larger increases in the renewable share are possible, and energy forecasts typically present bounding cases (best and worst-cases) to account for the uncertainty.

Figure 7.7-1. Historical and forecasted trends of renewable electricity generation by fuel type in the United States, 2000-2040. Data prior to 2013 are based on historical data. Data after 2013 are based on projections that assume the gross domestic product increases at an annual rate of 2.4% and that current laws and regulations do not change through 2040.[6]



7.7.2 *What types of clean energy can be used?*

7.7.2.1 *Solar*

Solar energy comes directly from the sun; technologies for harnessing this energy include photovoltaic cells, concentrated solar power (CSP, also called solar thermal technology), and passive solar heating. Solar energy is considered one of the cleanest and most abundant forms of clean energy.[7]

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5 US Energy Information Administration. 2015. Annual Energy Outlook 2015 with Projections to 2040. Available: http://www.eia.gov/aeo/ accessed 5-23-16].

6 US Energy Information Administration. 2015. Annual Energy Outlook 2015 with Projections to 2040. Available: http://www.eia.gov/aeo/ [accessed 5-23-16].

7 EPA (Environmental Protection Agency). Solar Energy. Available: http://www3.epa.gov/climatechange/kids/solutions/technologies/solar.html [accessed 3-2-16].

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Photovoltaic (PV) cells absorb light and convert it to electricity; cells are placed together to form solar panels. Figure 7.7-2 provides a sketch of a PV cell, which generates electricity when photons from the sun "knock loose" electrons within the PV cell semiconductor material that then form an electrical current. Solar panels can be installed on existing structures, e.g., roofs and shade covers over parking lots, or directly on the groud. Solar panels can have a "fixed" orientation or can turn to "track" the sun's path across the sky, which maximizes generating potential. Distributed PV systems place panels near "load centers" (locations where electricity is used), e.g., on a building's roof; such systems may or may not be connected to the grid. In a centralized PV system, large numbers of solar panels are grouped together in a single location (sometimes called "solar farms" or "solar parks"), connected to the electrical grid, and electricity is distributed to consumers.[8]

The price of PV has fallen dramatically in recent years and these systems are often very competitive to other energy systems. PV costs may be lower than wind systems of comparable size.[9] Once installed, solar panels have low maintenance and low operating costs. After recovering the installation costs, electricity from solar panels is essentially "free." In addition, surplus power may be sold back to the grid, which is sometimes called net metering. However, regulatory policies are presently in flux regarding the ability to do this, the price may not be very favorable, and there may be limits on the capacity that can be purchased. A bill in Michigan, S.B. 438, currently under consideration would create disincentives for such sales. This is clearly unfavorable for clean energy.

8 Woods Institute for the Environment, 2010. Distributed vs. Centralized Power Generation. Available: https://woods.stanford.edu/sites/default/files/files/Solar-UD-Distributed-vs-Centralized-Power-Generation-20100408.pdf [accessed 5-21-16].

9 National Renewable Energy Lab, US Department of Energy, 2016. Energy Technology Cost and Performance Data: Distributed Generation Renewable Energy Estimate of Costs [WWW Document]. URL http://www.nrel.gov/analysis/tech_lcoe_re_cost_est.html (accessed 5-22-16).

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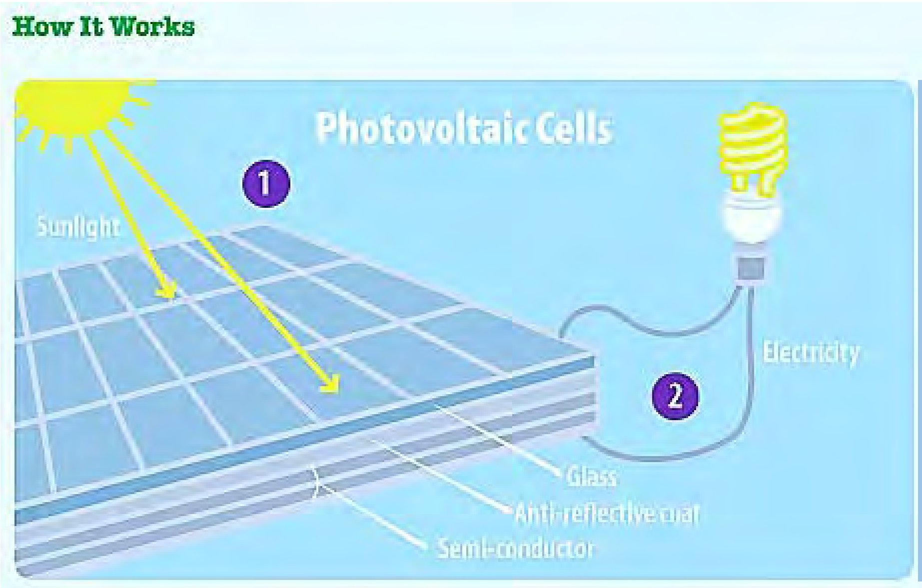
Figure 7.7-2. Schematic of a photovoltaic cell.[10]



1. Sunlight hits the surface of the photovoltaic cell.

2. A material call a semi-conductor converts the light into electricity.

Click here to watch a video

Concentrated solar power (CSP) systems work by directing light from the sun in order to capture the thermal energy. Figure 7.7-3 shows one configuration of a CSP facility. Sunlight is captured by mirrored panels and directed at a pipe containing water or other heat-absorbing materials. This material flows through the pipes, where the heat is exchanged with water to generate steam that turns the turbine generator. CSP facilities for electricity generation are large industrial operations and operate as centralized systems. There are other types of CSP systems that are used to generate hot water (solar water heaters) for businesses and residences. These systems are relatively uncommon, and likely not cost effective in Michigan.

[10] EPA (Environmental Protection Agency). Solar Energy. Available: http://www3.epa.gov/climatechange/kids/solutions/technologies/solar.html [accessed 3-2-16].

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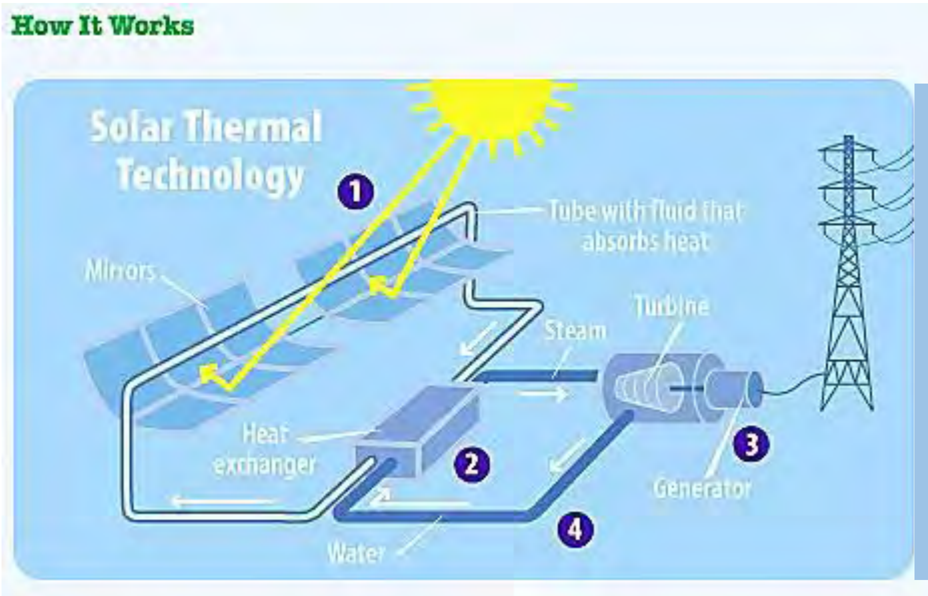
Figure 7.7-3: Schematic of a concentrated solar power system.[11]



1. Mirrors or reflectors concentrate the sun's rays to heat a special kind of liquid.

2. The heat from this liquid boils water to create steam.

3. Steam spins a turbine that is connected to a generator, which creates electricity.

4. The steam cools and condenses back to water, which is recycled, reheated, and converted into steam again.

Click here to watch a video

Passive and solar heating systems are used in buildings, not to generate electricity, but to provide space heating and cooling and to reduce overall energy consumption.[12] In passive solar buildings, solar energy is utilized in the winter to heat the building; in summer, solar energy can be rejected to keep the buildings cool. The design of such buildings include large, south facing windows with overhangs that allow sunlight in during the winter when the sun is closer to the horizon and block sunlight during summer months when the sun is higher in the sky; heat-retaining building and flooring materials; a high degree of thermal insulation; specialized windows, and other features. [13]

Solar energy has several disadvantages. First, it is an intermittent resource, i.e., solar panels can only generate electricity when the sun is shining, and the number of sunny days varies by location. Figure 7.7-4 shows solar resources across the United States. Michigan has relatively modest potential for PV power (approximately 4.0-4.5 kWh/m^2/day).[14] The highest potential is in the desert southwest, e.g., California, Nevada, Utah, Arizona, New Mexico, and Texas. Due to increases in efficiency of solar panels and reductions in production costs, PV is increasingly cost-effective, even in areas with intermittent sunshine. Second, if a large number of solar panels is integrated with the electrical grid, intermittency can lead to instability in the availability of

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[11] EPA (Environmental Protection Agency). Solar Energy. Available: http://www3.epa.gov/climatechange/kids/solutions/technologies/solar.html [accessed 3-2-16].

[12] Department of Energy, 2016. Passive Solar Home Design [WWW Document]. URL http://energy.gov/energysaver/passive-solar-home-design [accessed -.22-16].

[13] EPA (Environmental Protection Agency). Solar Energy. Available: http://www3.epa.gov/climatechange/kids/solutions/technologies/solar.html [accessed 3-2-16].

[14] National Renewable Energy Lab, US Department of Energy, 2016. Dynamic Maps, GIS Data, and Analysis Tools [WWW Document]. URL http://www.nrel.gov/gis/maps.html [accessed 5-22-16].

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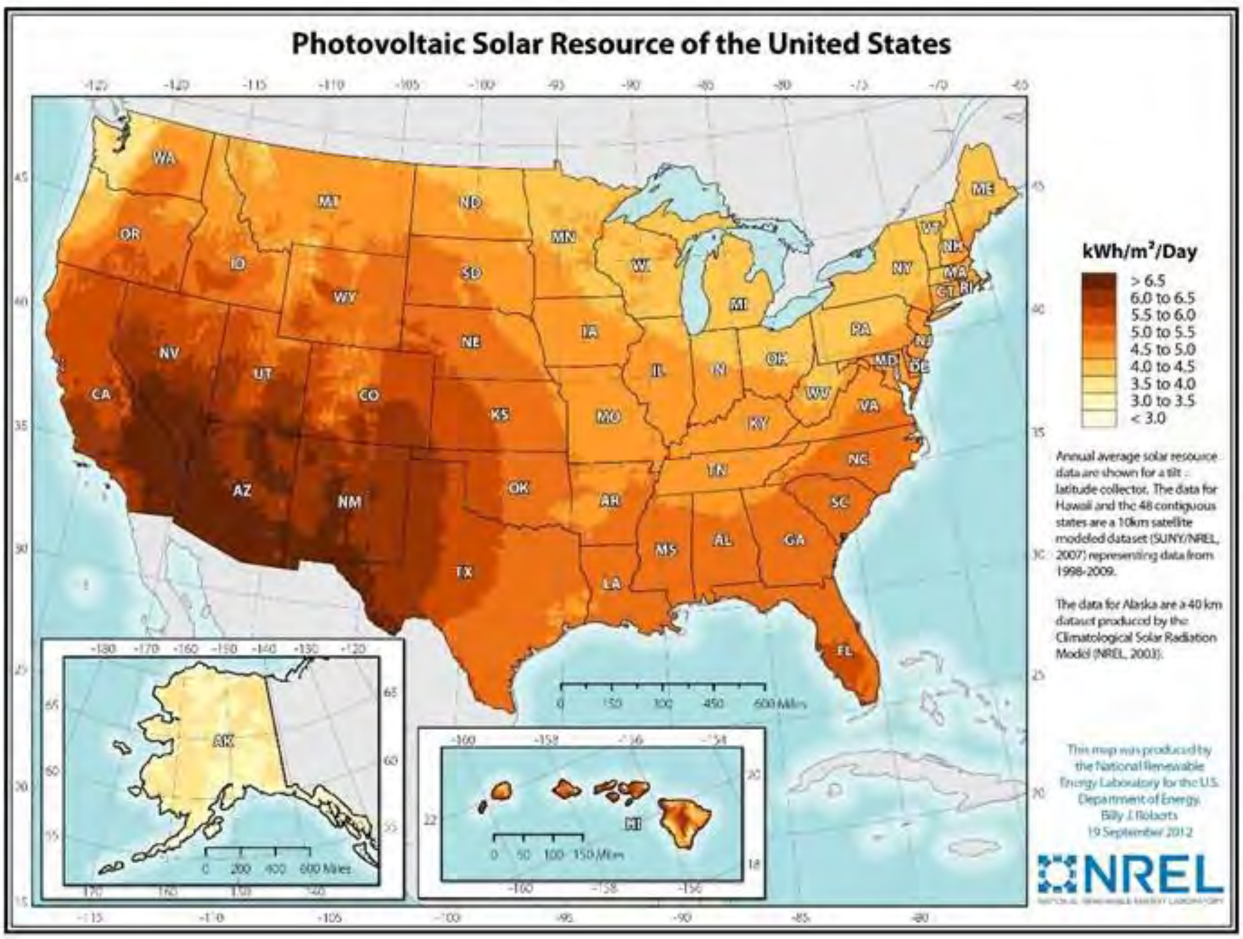
electricity and can reduce the ability to meet demand.[15] Potential solutions to this challenge include the use of new tools and technologies to monitor the electrical grid and better integrate PV systems, and improved storage systems (e.g., batteries) to even out the supply and demand for electricity.[16] Third, solar places different demands on the electric distribution grid, which is not optimized for this purpose, and the current policy, regulatory, and economic structures often do not promote solar and other clean energy options. Fourth, solar requires appropriate siting, building and panel orientation, and unobstructed sun.

Figure 7.7-4: Solar resource (as kWh/m^2/day) across the entire United States. From the National Renewable Energy Laboratory.[17]



[15] US Department of Energy, 2016. Grid Performance and Reliability [WWW Document]. URL http://energy.gov/eere/sunshot/grid-performance-and-reliability [accessed 5-22-16].

[16] US Department of Energy, 2016. Systems Integration [WWW Document]. URL http://energy.gov/eere/sunshot/systems-integration [accessed 5-22-16].

[17] National Renewable Energy Lab, US Department of Energy, 2016. Dynamic Maps, GIS Data, and Analysis Tools [WWW Document]. URL http://www.nrel.gov/gis/maps.html [accessed 5-22-16].

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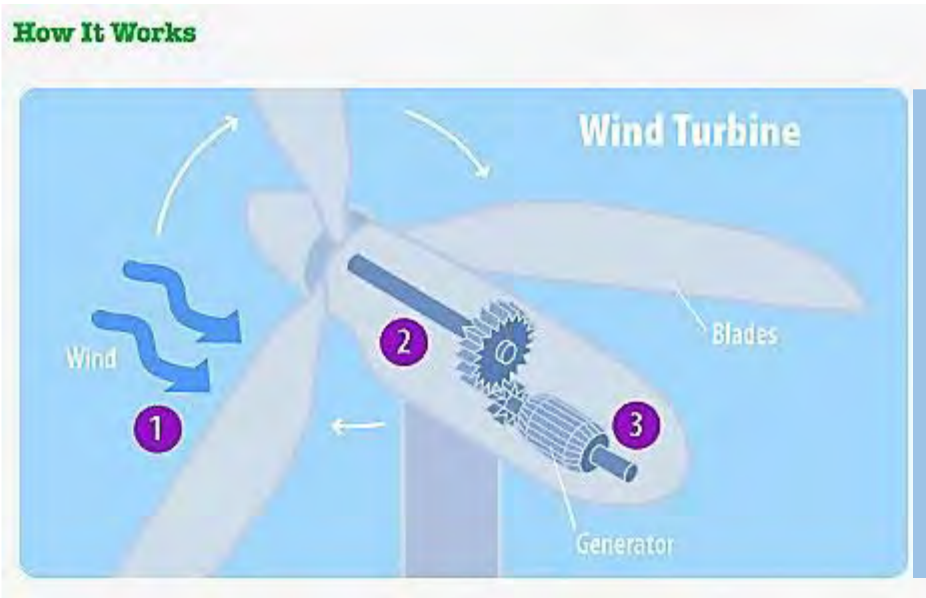
7.7.2.2 *Wind*

Wind energy is produced using wind turbines, large structures that use rotating blades to power a generator and produce electricity (Figure 7.7-5).[18] Michigan ranks 12th in the nation for generating electricity from wind turbines, with over 20 commercial wind farms that collectively can generate 1500 MW of electricity.[19] Locations are shown in Figure 7.7.6. Wind farms can be combined with other land uses, specifically agriculture as well as others, because the turbine towers have small footprints.

Figure 7.7-5: Schematic of a wind turbine.[20]



1. As the wind blows over the blades of a wind turbine, it causes the blades to lift and rotate.
2. The rotating blades turn a shaft that is connected to a generator.
3. The generator creates electricity as it turns.

As with solar power, wind power has advantages and disadvantages.[21] Advantages are that wind is a free, infinite and cost-effective source of power generation that does not emit greenhouse gases or air pollutants. The current cost of electricity from wind is low, between 4 and 6 cents per kWh,[22] and comparable to many other (more polluting) sources of electricity. Its primary disadvantage, like solar power, is its intermittency since the wind does not blow consistently. Thus, wind power faces the same challenges of integrating with existing power grids and being dispatched when needed. Additional disadvantages include: the possibility of

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18 EPA (Environmental Protection Agency). Wind Energy. Available: http://www3.epa.gov/climatechange/kids/solutions/technologies/wind.html [accessed 3-2-16].

19 US Energy Information Administration, 2016. State Profile and Energy Estimates: Michigan [WWW Document]. URL http://www.eia.gov/state/?sid=MI [accessed 5-22-16].

20 EPA (Environmental Protection Agency). Wind Energy. Available: http://www3.epa.gov/climatechange/kids/solutions/technologies/wind.html [accessed 3-2-16].

21 US Department of Energy, 2016. Advantages and Challenges of Wind Energy [WWW Document]. URL http://energy.gov/eere/wind/advantages-and-challenges-wind-energy [accessed 5-22-16].

22 US Department of Energy, 2016. Advantages and Challenges of Wind Energy [WWW Document]. URL http://energy.gov/eere/wind/advantages-and-challenges-wind-energy [accessed 5-22-16].

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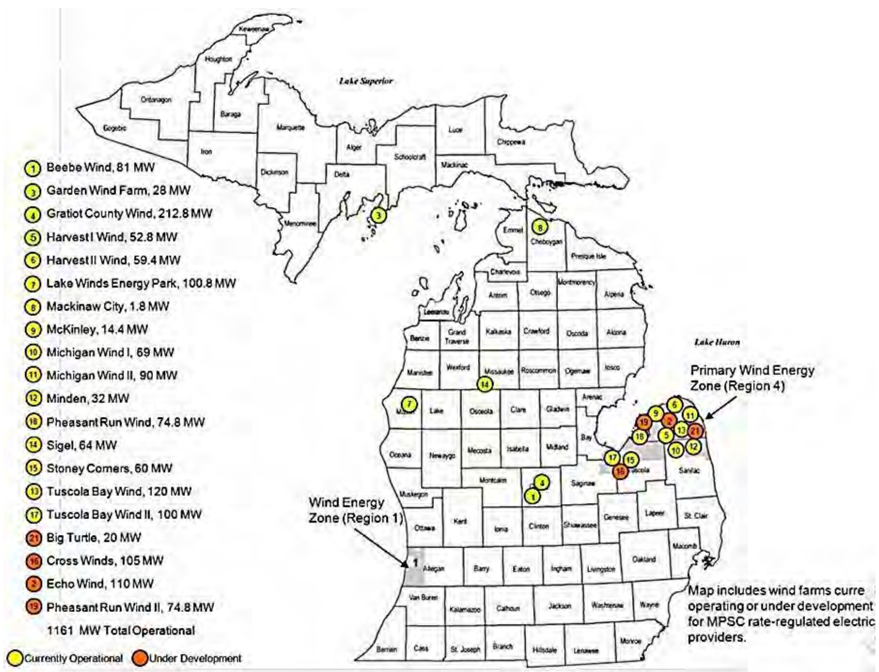
competing land uses, e.g., it may be more profitable to use the land for a different use; concerns over noise and aesthetics that lead to lack of community support for wind projects; concerns that turbines may be harmful to wildlife, especially birds; and the need for appropriate sites.

Figure 7.7-6: Stony Corners Wind Farm, one of the first utility scale wind farms in Michigan.[23]

Figure 7.7-7: Location of known wind projects in Michigan as of 2013.[24]



[23] Heritage Sustainability Energy. Available: http://heritagewindenergy.com/projects/stoney-corners-wind-farm/ [accessed 6-2-16].

[24] LARA, Michigan, Report on the implementation of P.A. 295 wind energy resource zones http://www.michigan.gov/documents/mpsc/2014WERZReport_449308_7.pdf [accessed 6-1-16].

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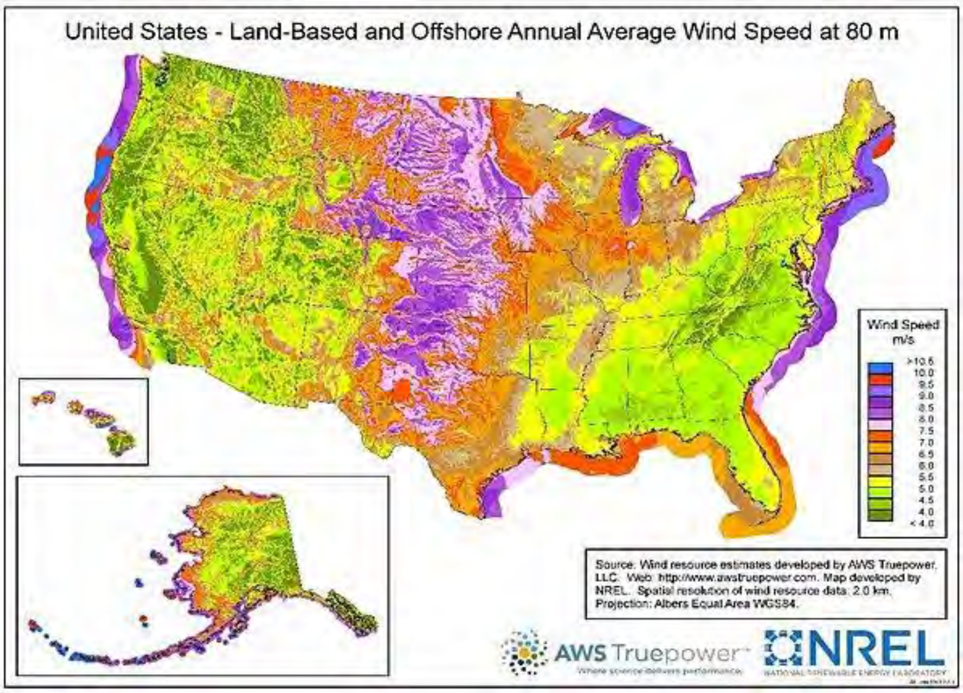
Figure 7.7-8 shows wind resources across the United States.[25] Southeast Michigan has modest land-based annual wind speeds (5 - 6.5 m/s), but there is considerable potential for off-shore wind power in the Great Lakes, and in the "thumb" of Michigan, as shown in the previous figure. Across the US, the greatest land-based wind resources are in the Great Plains region, which is sparsely populated, thus capitalizing on this wind resource would require new transmission lines to bring electricity to more densely populated areas.[26]

Figure 7.7-8: Map showing the annual average land-based and offshore wind speeds (at 80 m) for the US.[27] Bottom: location of known wind projects in Michigan as of 2013.[28]



25 US Department of Energy, 2016. Advantages and Challenges of Wind Energy [WWW Document]. URL http://energy.gov/eere/wind/advantages-and-challenges-wind-energy [accessed 5-22-16].

26 US Department of Energy, 2016. Advantages and Challenges of Wind Energy [WWW Document]. URL http://energy.gov/eere/wind/advantages-and-challenges-wind-energy [accessed 5-22-16].

27 National Renewable Energy Lab, US Department of Energy, 2016. Dynamic Maps, GIS Data, and Analysis Tools [WWW Document]. URL http://www.nrel.gov/gis/maps.html [accessed 5-22-16].

28 LARA, Michigan, Report on the implementation of P.A. 295 wind energy resource zones http://www.michigan.gov/documents/mpsc/2014WERZReport_449308_7.pdf [accessed 5-22-16].

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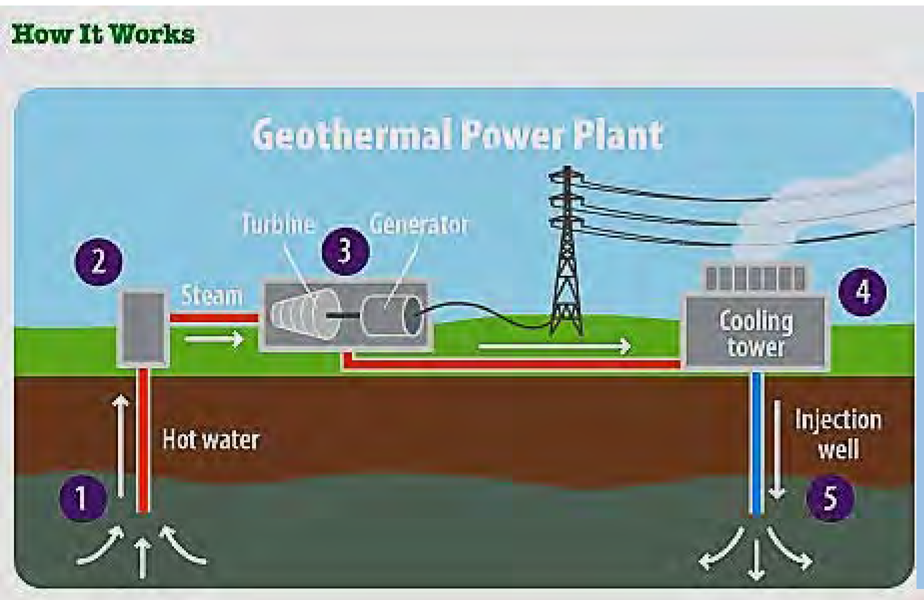
7.7.2.3 *Geothermal*

Geothermal energy is thermal energy generated and stored in the earth, arising from the hot dense core of the earth and from radioactive decay in the earth's crust. Examples of geothermal energy include geysers and hot springs, where groundwater is heated when it interacts with hot rocks below the surface of the earth.[29] Geothermal energy can be captured and used to generate electricity and provide thermal energy. Geothermal power plants use wells drilled 1-2 miles deep to pump steam or hot water to the surface.[30,31] Figure 7.7-7 shows a schematic of a typical geothermal plant. Hot water is pumped from the geothermal reservoir and used to generate steam that turns the turbine generator. The steam is condensed in a cooling tower and returned to the reservoir to be reheated.

Figure 7.7-9: Schematic of a geothermal power plant.[32]



1. Hot water is pumped from deep underground through a well under high pressure.
2. When the water reaches the surface, the pressure is dropped, which causes the water to turn into steam.
3. The steam spins a turbine, which is connected to a generator that produces electricity.
4. The steam cools off in a cooling tower and condenses back to water.
5. The cooled water is pumped back into the Earth to begin the process again.

Geothermal heat pumps are another type of geothermal technology that takes advantage of the relatively constant temperature of the earth. Geothermal heat pumps do not generate electricity; instead, they help to reduce energy demand. As depicted in Figure 7.7-10, in winter, surface temperatures are typically lower than

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[29] US Department of Energy, 2016. Geothermal Basics [WWW Document]. URL http://energy.gov/eere/geothermal/geothermal-basics [accessed 5-22-16].

[30] EPA (Environmental Protection Agency). Geothermal Energy. Available: http://www3.epa.gov/climatechange/kids/solutions/technologies/geothermal.html [accessed 3-2-16].

[31] US Department of Energy, 2016. Geothermal Electricity Generation [WWW Document]. URL http://energy.gov/eere/geothermal/electricity-generation [accessed 5-22-16].

[32] EPA (Environmental Protection Agency). Geothermal Energy. Available: http://www3.epa.gov/climatechange/kids/solutions/technologies/geothermal.html [accessed 3-2-16].

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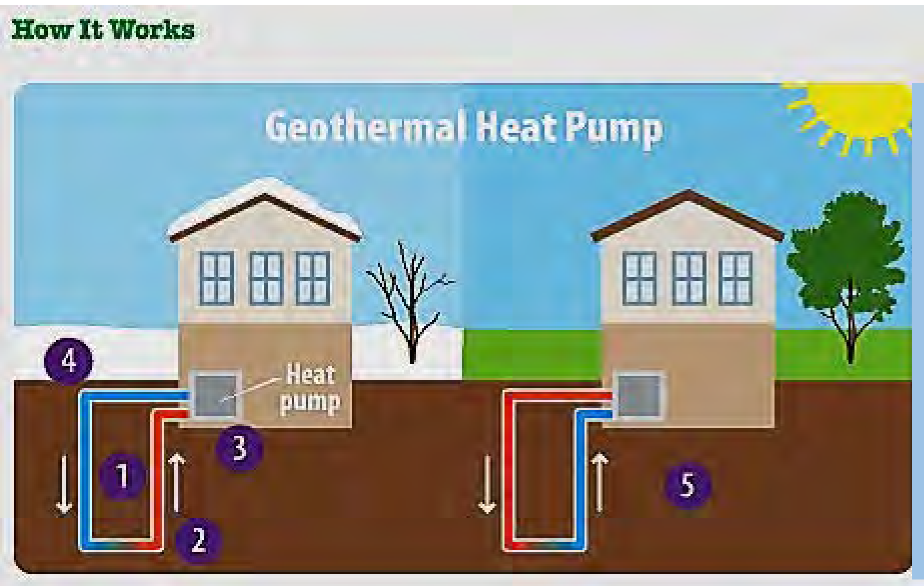
sub-surface temperatures (which are typically between 50-60° F), so heat from the ground can be transferred to water or refrigerants in a pipe system to provide heating. In the summer, surface temperatures are higher than ground temperatures, so excess heat in the building is transferred to the ground.[33]

Figure 7.7-10: Schematic of geothermal heat pump.[34]



1. Water or a refrigerant moves through a loop of pipes.

2. When the weather is cold, the water or refrigerant heats up as it travels through the buried loop.

3. Once it gets back above ground, the warmed water or refrigerant transfers heat to the building.

4. The water or refrigerant cools down, then is pumped back underground where it heats up once more, starting the process again.

A significant advantage of geothermal energy is its reliability, i.e., it does not have the variability or intermittency of wind or solar energy. This makes geothermal energy particularly useful for "base load" electricity generation (the minimum electricity needed essentially all of the time). In addition, geothermal plants can have small footprints and use less water than conventional power plants.[35] Its primary disadvantages are the limited number of suitable hydrothermal sites and the high costs of installation. Locations suitable for commercial or large scale geothermal energy extraction are called "hydrothermal" sites. Figure 7.7-11 shows identified hydrothermal sites across the US and the potential for "deep enhanced geothermal systems". There are no identified hydrothermal sites in Michigan. However, geothermal heat pumps can be used in Michigan, and these help improve the efficiency of heating and cooling systems. Note

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[33] EPA (Environmental Protection Agency). Geothermal Energy. Available: http://www3.epa.gov/climatechange/kids/solutions/technologies/geothermal.html) [accessed 3-2-16].

[34] EPA (Environmental Protection Agency). Geothermal Energy. Available: http://www3.epa.gov/climatechange/kids/solutions/technologies/geothermal.html) [accessed 3-2-16].

[35] US Department of Energy, 2016. Geothermal Basics [WWW Document]. URL http://energy.gov/eere/geothermal/geothermal-basics [accessed 5-22-16].

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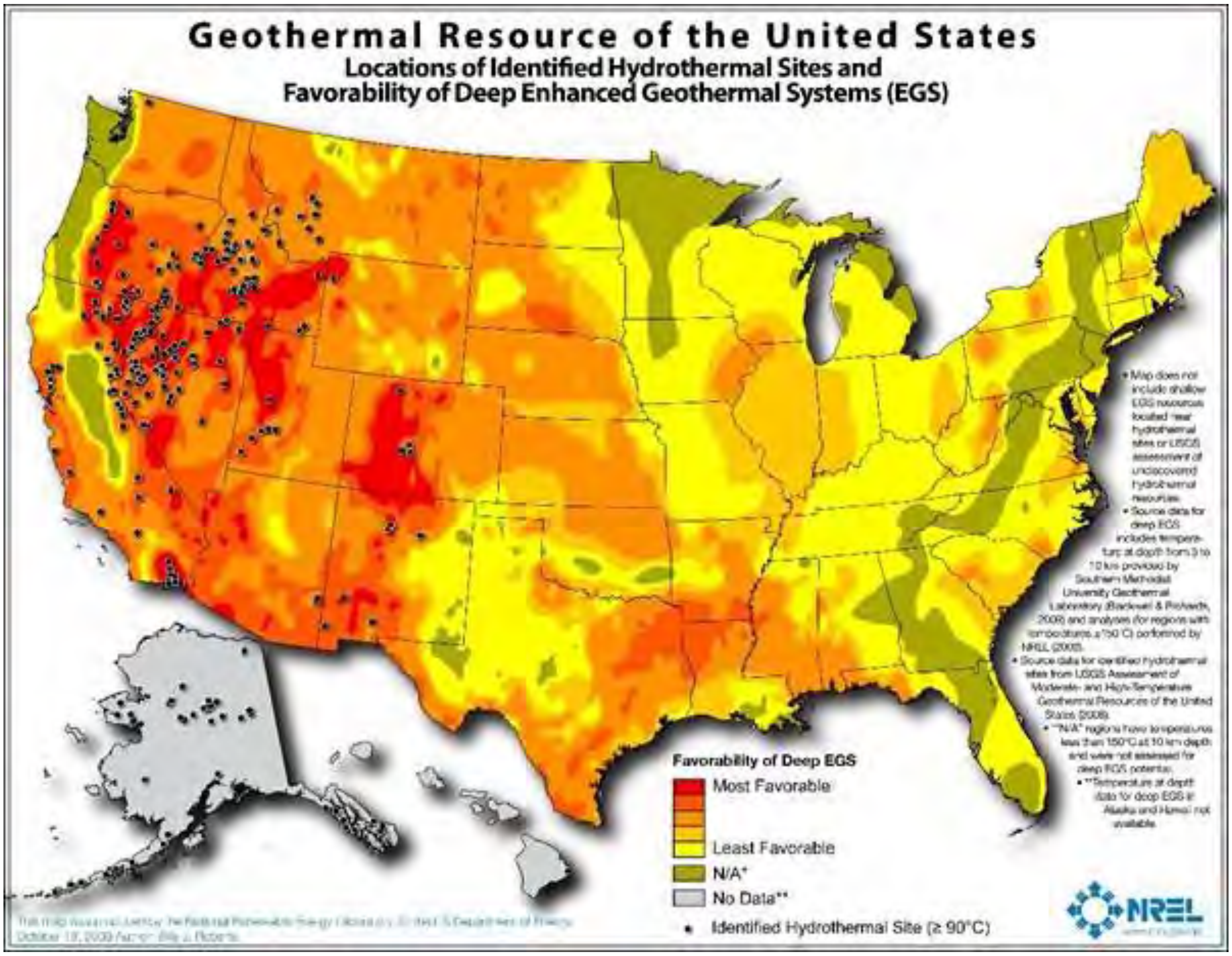
that these geothermal heat pumps still require electricity (although a reduced amount), and much of this electricity in Michigan is generated using dirty fuels.

Figure 7.7-11: Map showing identified hydrothermal sites and the potential for enhanced geothermal systems for the United States. Map from the National Renewable Energy Laboratory.[36]



7.7.2.4 *Biomass*

Biomass energy derives from plants and animals. It includes agricultural waste, forest residues, wood mill waste, urban wood waste and municipal waste.[37] Biomass can be burned directly, e.g., generating steam for

[36] National Renewable Energy Lab, US Department of Energy, 2016. Dynamic Maps, GIS Data, and Analysis Tools [WWW Document]. URL http://www.nrel.gov/gis/maps.html [accessed 5-22-16].

[37] US Department of Energy, 2016. Biomass Technology Basics [WWW Document]. URL http://energy.gov/eere/energybasics/articles/biomass-technology-basics [accessed 5-22-16].

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electricity generation. When combusted, biomass is often blended with other fuels, e.g., coal. Potentially less polluting ways to use biomass include conversion into biofuels (e.g., ethanol),[38] or gases (e.g., methane), or liquids (e.g., biodiesel).[39]

About 35% of Michigan's non-hydropower renewable energy comes from biomass, primarily from landfill gas, municipal solid waste, and forest residue.[40] Figure 7.7-12 shows the potential biomass resources at the county level across the United States. Wayne County has between 250 and 500 thousand tons of biomass made available each year. Other areas of southeast Michigan have more modest biomass resources. Some of the waste entering the Detroit Resource Recovery Facility, a mass-burn incinerator with energy recovery, is biomass.

An advantage of biomass energy is the reliability of the fuel source, thus, biomass can generate "base load" power. Its primary disadvantage is the production of air pollutant emissions. Biomass energy production can emit greenhouse gases, PM, NO_x, CO, VOCs, and potentially other hazardous air pollutants.

[38] EPA (Environmental Protection Agency). Biomass. Available: (http://www3.epa.gov/climatechange/kids/solutions/technologies/biomass.html) [accessed 3-2-16].

[39] US EPA. 2016. Biogas Opportunities Roadmap. Available: https://www3.epa.gov/climatechange/Downloads/Biogas-Roadmap-Factsheet.pdf [accessed 5-22-16].

[40] US Energy Information Administration, 2016. State Profile and Energy Estimates: Michigan [WWW Document]. URL http://www.eia.gov/state/?sid=MI [accessed 5-22-16].

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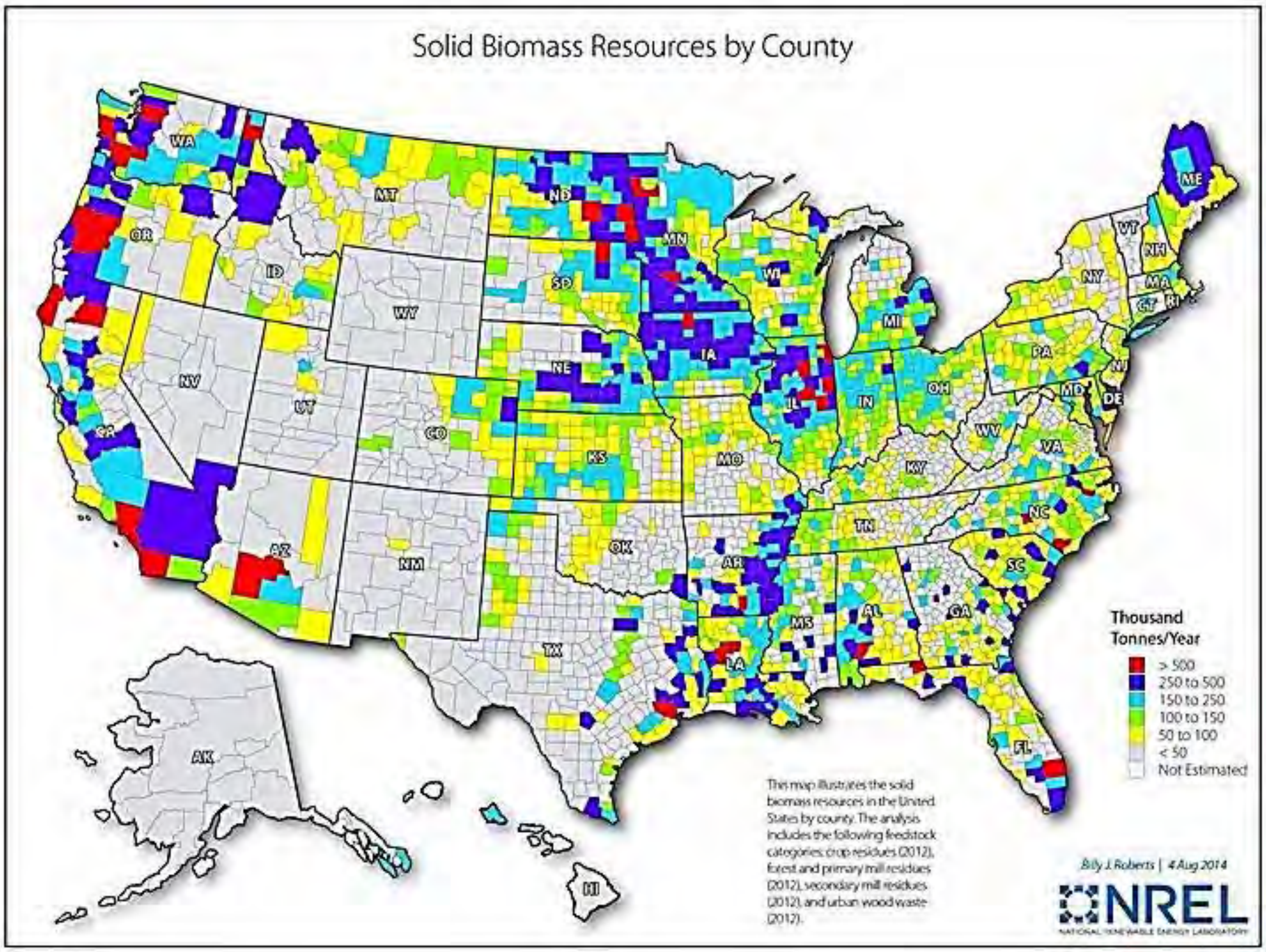
Figure 7.7-12: Tons of biomass resources available at the county level across the United States. Map from the National Renewable Energy Laboratory.[41]



7.7.2.5 *Cost of renewable energy*

Costs of clean energy depend on capital, fixed and variable costs, projected utilization and sales of energy, and fuel costs (if applicable). Costs are affected by economic incentives, including state and federal tax credits.[42] Presently, the key challenges to the economic viability of clean energy are the low cost of natural gas, the end of federal and state tax credits (including the expiration of Michigan's Renewable Portfolio Standard or RPS in 2015), and other policies favoring the use of renewable technologies. The low cost of natural gas is a challenge since many existing fossil fuel facilities can be retrofitted to burn natural gas, which has the effect of

[41] National Renewable Energy Lab, US Department of Energy, 2016. Dynamic Maps, GIS Data, and Analysis Tools [WWW Document]. URL http://www.nrel.gov/gis/maps.html [accessed 5-22-16].

[42] US Energy Information Administration. 2015. Annual Energy Outlook 2015 with Projections to 2040. Available: http://www.eia.gov/aeo/ [accessed 5-23-16].

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delaying the development of renewable resources. In addition, as energy efficiency improves, electricity production declines and demand decreases for new facilities, thus slowing the development of new facilities using renewable or cleaner technologies.

Table 7.7-1 shows the "levelized cost of electricity" (LCOE) for new generation facilities that would come online in 2020.[43] This LCOE represents the total cost per kilowatt-hour (kWh) of building and operating a new facility to generate electricity and represents an average cost. Location-specific factors are not considered, e.g., the local resource mix. Energy sources are divided into "nondispatchable" resources, which can be used to meet peak loads, and dispatchable resources, which can be used to generate "base load" electricity. Costs in the table are for utility-sized facilities. (They do not reflect costs for smaller units, e.g., solar panels installed on the roof of a residence.)

Costs vary regionally (Table 7.7-1). For dispatchable technologies, geothermal power has the lowest LCOE. For the non-dispatchable technologies, land-based wind power has the lowest LCOE, which is on par with some of the dispatchable technologies (e.g., combined cycle facilities that burn natural gas). LCOEs for solar PV facilities are slightly higher than traditional and advanced coal-fired facilities, but considerably less expensive than new facilities that use carbon capture and sequestration to limit emissions of greenhouse gases. As discussed earlier, an important challenge with directly replacing dispatchable resources with wind and solar is the intermittent availability of these resources. As integration with the grid and storage capacities improve, there may be more opportunities for solar and wind to replace more conventional fuels.

[43] US Energy Information Administration. 2015. Levelized cost and levelized avoided cost of new generation resources in the annual energy outlook 2015. Available: http://www.eia.gov/forecasts/aeo/pdf/electricity_generation.pdf [accessed 5-23-16].

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Table 7.7-1 Estimated levelized cost of electricity for new generation resources, 2020. Table from the US Energy Information Agency.[44]

	Range for Total System LCOE (2013 $/MWh)			Range for Total LCOE with Subsidies[2] (2013 $/MWh)		
Plant Type	Minimum	Average	Maximum	Minimum	Average	Maximum
Dispatchable Technologies						
Conventional Coal	87.1	95.1	119.0			
Advanced Coal	106.1	115.7	136.1			
Advanced Coal with CCS	132.9	144.4	160.4			
Natural Gas-fired						
Conventional Combined Cycle	70.4	75.2	85.5			
Advanced Combined Cycle	68.6	72.6	81.7			
Advanced CC with CCS	93.3	100.2	110.8			
Conventional Combustion Turbine	107.3	141.5	156.4			
Advanced Combustion Turbine	94.6	113.5	126.8			
Advanced Nuclear	91.8	95.2	101.0			
Geothermal	43.8	47.8	52.1	41.0	44.4	48.0
Biomass	90.0	100.5	117.4			
Non-Dispatchable Technologies						
Wind	65.6	73.6	81.6			
Wind – Offshore	169.5	196.9	269.8			
Solar PV[3]	97.8	125.3	193.3	89.3	114.3	175.8
Solar Thermal	174.4	239.7	382.5	160.4	220.6	351.7
Hydroelectric[4]	69.3	83.5	107.2			

[1]Costs for the advanced nuclear technology reflect an online date of 2022.
[2]Levelized cost with subsidies reflects subsidies available in 2020, which include a permanent 10% investment tax credit for geothermal and solar technologies.
[3]Costs are expressed in terms of net AC power available to the grid for the installed capacity.
[4]As modeled, hydroelectric is assumed to have seasonal storage so that it can be dispatched within a season, but overall operation is limited by resources available by site and season.
Note: The levelized costs for non-dispatchable technologies are calculated based on the capacity factor for the marginal site modeled in each region, which can vary significantly by region. The capacity factor ranges for these technologies are as follows: Wind – 31% to 40%, Wind Offshore – 33% to 42%, Solar PV- 22% to 32%, Solar Thermal – 11% to 26%, and Hydroelectric – 35% to 65%. The levelized costs are also affected by regional variations in construction labor rates and capital costs as well as resource availability.
Source: U.S. Energy Information Administration, *Annual Energy Outlook 2015*, April 2015, DOE/EIA-0383(2015).

7.7.2.6 *Why is this important?*

Coal-fired power plants make up 39% of the net electricity generation in the United States, and account for a large portion of air pollution (Figure 7.7-13). Natural gas power plants, which also contribute to greenhouse gas and air pollutant emissions, account for another 27% of electricity generation. The U.S. vehicle fleet also

[44] US Energy Information Administration. 2015. Levelized cost and levelized avoided cost of new generation resources in the annual energy outlook 2015. Available: http://www.eia.gov/forecasts/aeo/pdf/electricity_generation.pdf [accessed 5-23-16].

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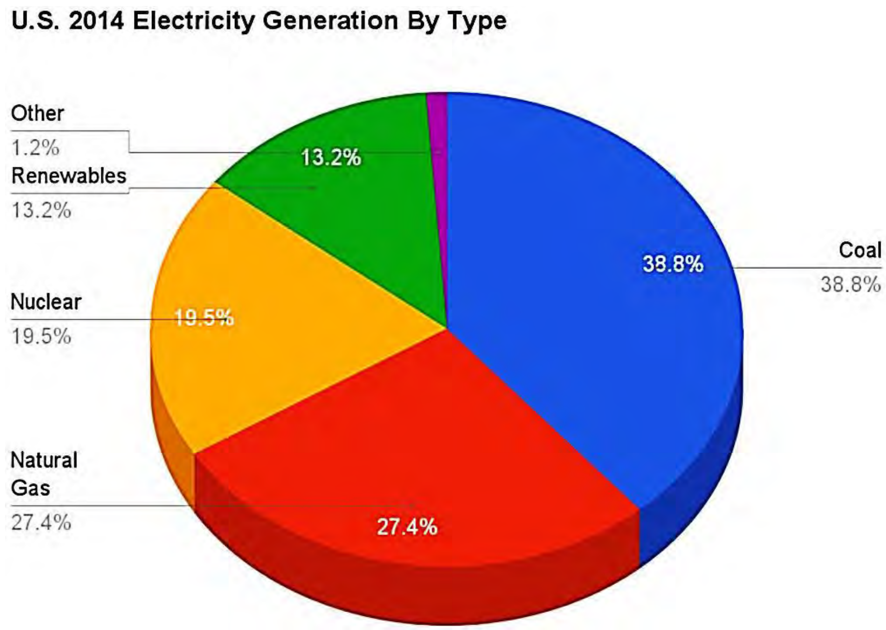
relies on fossil fuels. Replacing fossil fuels and "dirty" energy production with clean energy can play an important role in reducing adverse health effects from air pollution by substantially reducing pollution levels.

Figure 7.7-13: Net electricity generation in the United States by source.[45]



The fraction of electricity in Michigan produced through coal-fired power plants (the "coal-fired fraction") is 46.4%, exceeding the US average.[46] In southeast Michigan, DTE intends to retire one third of its coal-fired power plants by 2025, and switch to both natural gas and wind. They do not intend to retire the coal-fired power plant in Monroe, MI, their largest facility. This facility has been upgraded with SO_2 scrubbers to reduce emissions of this air pollutant.[47] Health impacts attributable to emissions from coal-fired power plants and other facilities in the region are discussed in Section 5.5.

Although there are no coal-fired power plants within the City of Detroit, four large facilities (DTE Monroe, DTE Trenton Channel, River Rouge, and Detroit Industrial Generation) are nearby and influence air quality within the city (see Section 5.5). This is especially important in Southwest Detroit, which is currently out of compliance with the EPA's SO_2 standards, largely due to the coal-fired facilities (power plants, steel mills, lime

[45] U.S. Energy Information Administration. Michigan State Profile and Energy Estimates. Available:http://www.eia.gov/state/?sid=MIhttp://www.eia.gov/electricity/monthly/epm_table_grapher.cfm?t=epmt_1_01[accessed 3-2-16].
[46] U.S. Energy Information Administration. Michigan State Profile and Energy Estimates. Available: http://www.eia.gov/state/?sid=MI [accessed 3-2-16].
[47] PLATTS McGraw Hill Financial. DTE to Cut Coal Fleet by a Third, Issue RFP for Gas Plant. Available: http://www.platts.com/latest-news/coal/louisville-kentucky/dte-to-cut-coal-fleet-by-a-third-issues-rfp-for-21786852 [accessed 3-2-16].

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and coke production. (For more information, see CAPHE SO2 Fact Sheet). DTE recently announced that three coal-fired power plants will be retired between 2020 and 2023: River Rouge, St. Clair, and Trenton[48].

Transitioning to the use of clean energy sources could offset the need for coal-fired power plants, which could lead to improvements over time in air quality. There are also many benefits of clean energy. As noted, renewable energy produces little if any greenhouse gas. Renewable energy diversifies the energy supply and reduces dependence of imported fuels. Renewable energy also can create and revitalize economic development, utilize vacant land productively, provide jobs (in manufacturing, installation, etc.), potentially increase the resiliency of infrastructure, and decentralize the energy sector.[49] Solar panels may be installed on buffers between emission sources and populations and provide energy, a co-benefit, as well as the pollution benefits discussed in Section 7.3 on Buffers.

7.7.3 *Implications for health*

7.7.3.1 *What pollutants are affected?*

Clean energy displaces fossil fuel energy and its attendant emissions of pollutants, including PM, NO_x, SO_2, CO, greenhouse gas emissions, and toxics such as mercury and arsenic.[50]

7.7.3.2 *What health effects can be mitigated?*

Adverse health effects mitigated by clean energy depend on the extent to which renewables replace conventional fuels, which determines pollutant reductions. Health effects range from minor outcomes, like missed school or work days due to respiratory symptoms, to severe outcomes, such respiratory disease, cardiovascular disease, cancer, and premature mortality.

7.7.4 *What is happening in Michigan?*

7.7.4.1 *The Michigan Renewable Energy Portfolio*

Michigan passed the Renewable Energy Portfolio (RPS) in 2008, also known as Public Act 295. The RPS states that by the end of 2015, 10% of Michigan's energy mix should be from renewable energy sources. This act incentivizes investment in renewable sources, creates a long-term planning framework and ensures that the state invests in cleaner energy sources. This can mitigate some of the negative health effects that disproportionately affect frontline communities in Michigan. For example, River Rouge, one of the dirtiest coal plants in the nation, sits in the River Rouge community where people of color make up 65% of the population.

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[48] Detroit Free Press. 2015. 25 Michigan coal plants are set to retire by 2020. Available: http://www.freep.com/story/money/business/michigan/2015/10/10/25-michigan-coal-plants-set-retire-2020/73335550/. [accessed 8-25-16].

[49] EPA (Environmental Protection Agency). State and Local climate Energy Program: Renewable Energy. Available: http://www3.epa.gov/statelocalclimate/state/topics/renewable.html [accessed 3-2-16].

[50] EPA (Environmental Protection Agency). Mercury and Air Toxics Standards (MATS): Cleaner Power Plants. http://www3.epa.gov/airquality/powerplanttoxics/powerplants.html [accessed 3-2-16].

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This Act expired at the end of 2015. The legislature is currently looking at various energy packages, led by Senator Nofs and Representative Nesbitt respectively.

7.7.4.2 *The Clean Power Plan*

President Obama and the EPA announced the Clean Power Plan on August 3, 2015. This plan reduces carbon pollution from power plants to affect climate change. Informed by years of outreach and public engagement, the final Clean Power Plan is designed to move the US towards lower-polluting, cleaner energy. The plan sets standards for power plants, and customized goals for states to cut the carbon pollution that is driving climate change.[51]

On February 9, 2016, the Supreme Court stayed implementation of the Clean Power Plan pending judicial review. The Court's decision was not on the merits of the rule. EPA firmly believes the Clean Power Plan will be upheld when the merits are considered because the rule rests on strong scientific and legal foundations.

7.7.5 ***What is happening in and around Detroit?***

7.7.5.1 *Organizing and activism*

Some activities to promote the transition to clean energy in Detroit (which provide networking opportunities for CAPHE) include:

- Detroit Climate Action Collaborative. This group has been working since 2011 to reduce greenhouse gas emissions in Detroit. They have advocated for increased efficiency for Detroit buildings and an increased investment in renewable energy in all sectors.[52]
- Sierra Club's Beyond-Coal Campaign. This campaign focuses on replacing coal with clean energy sources by mobilizing grassroots activists in local communities to advocate for the retirement of old and outdated coal plants, and to prevent new plants from being built. Their goal is to retire one-third of the nation's more than 500 coal plants by 2020.[53] Sierra Club actively participated in hearings and organizing in Michigan.
- American Lung Association. ALS has been active in advocating for clean air and against pollution emitted by Detroit's current energy sources.

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[51] EPA (Environmental Protection Agency). Clean power plan for existing power plants. Available: https://www.epa.gov/cleanpowerplan/clean-power-plan-existing-power-plants. [accessed 8-29-16].

[52] Detroiters Working for Environmental Justice. Detroit Climate Action Collaborative. Available: http://www.detroitclimateaction.org/) [accessed 3-2-16].

[53] Sierra Club. Coal is an outdated, backward and dirty 19th-century technology. Available: http://content.sierraclub.org/coal/about-the-campaign [accessed 3-2-16].

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- Clean Power Plan Environmental activists from across Michigan have rallied against the state's decision to suspend Clean Power Plan compliance strategies.[54] [55]

7.7.5.2 *Activity in Detroit and Michigan*

Cities across the United States and throughout the world are increasing the use of clean energy and improving energy efficiency, and many are phasing out and/or supplementing current sources with renewable energy sources. Examples elsewhere in the US are noted throughout this *Resource Manual*. For example, cities including Grand Rapids MI (population 192,294) and San Diego, CA (population 1.4 million) have pledged to obtain 100% of their energy from renewable sources by specific dates.

Some examples of Michigan activities are listed below. The first several are conducted by DTE, a publically-regulated utility. Note that DTE's actions require approvals by the Michigan's Public Utility Commission (PUC).

- DTE Solar Current Program. DTE has easement rights to locate solar arrays on suitable property in southeastern Michigan.[56]

- DTE Solar Currents Program – Ann Arbor. DTE installed 4000+ photovoltaic solar panels along 9.37 acres of the interchange of M-14 and US 23. This is the largest solar array in Michigan. It will provide enough energy to power 200 average sized homes.[57]

- DTE Wind Energy – Echo Wind Park. Echo Wind Park is located in Elkton, Chandler, and Oliver townships in Huron County, MI. Built on nearly 18,000 acres and 70 turbines, it has the capacity to power 52,000 homes.[58]

- Ikea Solar Energy. In Canton, Mil, this retailer has installed over 4900 solar panels that will reduce 971 tons of carbon dioxide (CO2), equivalent to the emissions of 204 cars or 134 homes.[59]

- 1-800-LAW-FIRM Southfield, MI and Solar Energy and Wind Turbines. This firm in Southfield (near Lodge and Lahser) installed 550 solar panels (Figure 7.7-14) and four wind turbines, which will generate

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[54] Midwest Energy News. Michigan halts Clean Power Plan work, but joins clean energy accord. Available: http://midwestenergynews.com/2016/02/16/michigan-halts-clean-power-plan-work-but-joins-clean-energy-accord/ [accessed 1 June 2016].

[55] Michigan United. Environmental groups call for clean power plan in Michigan. Available: http://www.miunited.org/environmental-groups-call-for-clean-power-plan-in-michigan/ [accessed 1 June 2016].

[56] DTE Energy. Solar Energy. Available: Click here for Webpage [accessed 3-2-16].

[57] MLive. Michigan's largest solar panel installation taking shape outside Ann Arbor. Available: http://www.mlive.com/news/ann-arbor/index.ssf/2015/05/ann_arbor_township_solar.html [accessed 3-2-16]. MLive. Michigan's largest solar panel array now up and running near Ann Arbor. Available: http://www.mlive.com/news/ann-arbor/index.ssf/2015/09/michigans_largest_solar.html [accessed 3-2-16].

[58] DTE Energy DTE. Echo Park Wind. Available: Click here for Webpage [accessed 3-2-16].

[59] IKEA. 2016. IKEA Plugs-in addition to Solar Installation at Detroit-Area Store. Available: http://www.ikea.com/us/en/about_ikea/newsitem/012716_pr-IKEA-Canton-solar [Accessed 5-19-16]. The conversion given in this article was created using the clean energy equivalent calculator at: www.epa.gov/cleanenergy/energy-resources/calculator.html

This work is made possible by National Institute of Health and Environmental Sciences, RO1ES022616, and the Fred A. and Barbara M. Erb Family Foundation. Additional support was provided by the Michigan Center on Lifestage Environmental Exposures and Disease (M-LEEaD), #P30ES017885.

$45,000 worth of energy per year, or about half of the building's energy use. This development received incentive financing from Detroit as well as federal tax credits ($300,000).[60]

Figure 7.7-14: Solar panels at 1-800-LAW FIRM.[61]

- Detroit-Wayne County Metro Airport and Wind Turbines. Metro Airport installed wind turbines that power the lights in their south cell phone lot in a very visible installation (at an airport entrance). The turbines produce energy worth $3000 annually.[62]
- The Detroit Zoo and Renewable Energy Credits: The Zoo in Royal Oak purchased Renewable Energy Credits and now gets 100% of its energy needs from wind energy sources. This is part of the Detroit Zoological Society's goals to promote sustainability and health literacy.[63]

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[60] Detroit Free Press. Law office makes $1M renewable energy investment. Available: http://www.freep.com/story/money/business/michigan/2014/12/03/law-office-environment-wind-solar/19863549/ [accessed 3-1-16]

[61] Detroit Free Press. Law office makes $1M renewable energy investment. Available: http://www.freep.com/story/money/business/michigan/2014/12/03/law-office-environment-wind-solar/19863549/ [accessed 3-1-16]

[62] Metromode Metro Detroit. Can Metro Detroit Develop a Wind Power Economy? Available: http://www.secondwavemedia.com/metromode/features/windpowermetrodetroit0346.aspx [accessed 3-2-16].

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- Kent County Michigan and geothermal energy. In 2008, Kent County initiated a plan to reduce energy use in county facilities and buildings. This included the installation of heat pumps in the County Courthouse (built to LEED standards, see Section 7.2 for more information on LEED standards) and the Correctional Facility, which decreased energy usage at these facilities by 45%.[64]

- PV installations. An increasing number of firms and residences are installing these systems, typically on flat roofs or on roofs or walls with southern exposure.

- Heat pumps. A number of homes and buildings in Michigan have long used these systems to improve energy efficiency.

- Michigan's Renewable Portfolio Standard (RPS). In 2008, Michigan required electric utilities to generate at least 10% of their energy from renewable resources, or to negotiate the equivalent using tradable renewable energy certificates. By 2015 all but three of Michigan's 72 utilities were on track to meet the target. These renewables included wind, solar, biomass and biogas.[65]

- Michigan Rebates and Incentives for Clean Energy. Michigan has rebates and incentives available to residents and businesses. For full listing, see: http://www.cleanenergyauthority.com/solar-rebates-and-incentives/michigan/

7.7.6 How many people would be affected in Detroit?

The number of people affected by the use of clean energy depends on the type of clean energy used, what it replaces, and where it is implemented. Switching to cleaner forms of energy could lessen the amount of pollutants generated by coal-fired power plants, a key source of pollution in and around the City of Detroit, replacing it with power generated by clean sources.

7.7.7 Applicable strategies for Detroit

Clean energy sources most appropriate for Detroit include much higher use of PV panels, heat pumps, and bioenergy. A landscape with clean and renewable energy could help transform the energy and physical landscape in Detroit, and help with economic revitalization. While Detroit is not a favorable location for cost-effective wind power, wind power-generated electricity still can be provided to Detroit from distant facilities, as encouraged by the renewable portfolio standards (RPS) discussed below.

Strategies to promote investment in renewable and clean energy are listed below.

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[63] Daily Detroit. Detroit Zoo Switches to Wind Power. Available: http://www.dailydetroit.com/2015/12/15/detroit-zoo-switches-to-wind-power/ [accessed 3-2-16].

[64] Energy.gov. A Michigan County Unearths Savings with Geothermal Energy. Available: http://energy.gov/articles/michigan-county-unearths-savings-geothermal-energy [accessed 3-2-16] and Kent County access Kent. Energy Use Reduction Program. Available: https://www.accesskent.com/Departments/BOC/Energy/ [accessed 3-2-16].

[65] NDRC (Natural Resource Defense Council). Renewable Energy for America: Harvesting the benefits of homegrown, renewable energy, Michigan. Available: http://www.nrdc.org/energy/renewables/michigan.asp [accessed 3-2-16]

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- Extend or create tax-credits for businesses and individuals. Create incentives, or utilize current incentives, to increase the use of renewable energy systems. Unfortunately, the Federal tax credits for solar PV, solar water heaters, geothermal heat pumps, and small wind systems expire after 2016, and Congress seems unlikely to renew this bill. On the other hand, costs of PV and some other renewable technologies have dramatically fallen, thus increasing the cost-effectiveness of renewables.
- Utilize tax credits or other incentives to promote geothermal heat pumps and energy efficiency in buildings.
- For new construction and major renovations of building, require or incentivize energy foot-printing or compliance with building certification systems, such as LEED. This can be applied to governmental, school, residences, and other buildings.
- In zoning and new construction, consider site orientation in building design to allow PV panel installation.
- Use solar panels on buffers designed to reduce pollutant exposure and noise, providing a significant co-benefit.
- Remove regulatory and financial barriers regarding renewable energy. This may include reforming utility approaches and Public Service Commission rules regarding purchase agreements for renewable energy.
- Commit Detroit, and other cities in the region to renewable energy targets.
- Commit DTE and other power generators in the region to transition to clean energy.
- Promote a more aggressive renewable portfolio standard, e.g., 25% renewable by 2025. (Michigan's current standard is 10% by 2016.)
- Ensure that all biomass collected in Detroit is used for clean biofuels. This includes food wastes, utility right-of-way clearing waste.
- Ensure that current waste-to-energy systems utilize state-of-the-art pollution controls, or are phased out to cleaner technology.
- Expand and certify green pricing programs that allow utility customers to volunteer to pay a small price premium in order to receive greater percentages of their power from renewable resources. For example, DTE has a program called "Green Currents, which enrolls about 23,000 customers (2014) with several options, e.g., you can pay an additional $0.02 per kilowatt hour to get 100% of your power from renewable sources. [66]

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[66] http://www.michigan.gov/mpsc/0,1607,7-159-16393_48209_49896-179571--,00.html

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