CAPHE PHAP-RM

7.1 MOBILE SOURCE CONTROLS: DIESEL ENGINE RETROFITS

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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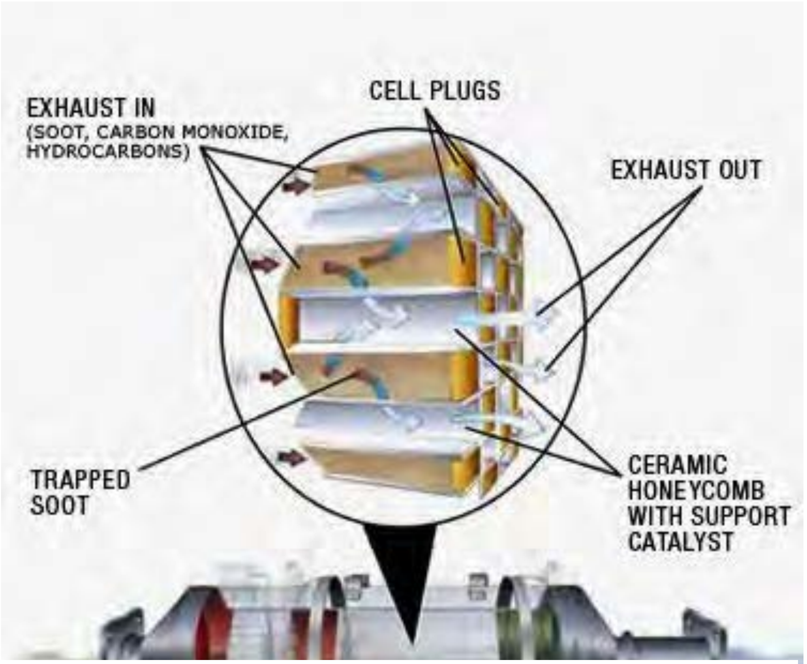
7.1 Mobile Source Control: Diesel Engine Retrofits

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]

[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

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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 $PM_{2.5}$.

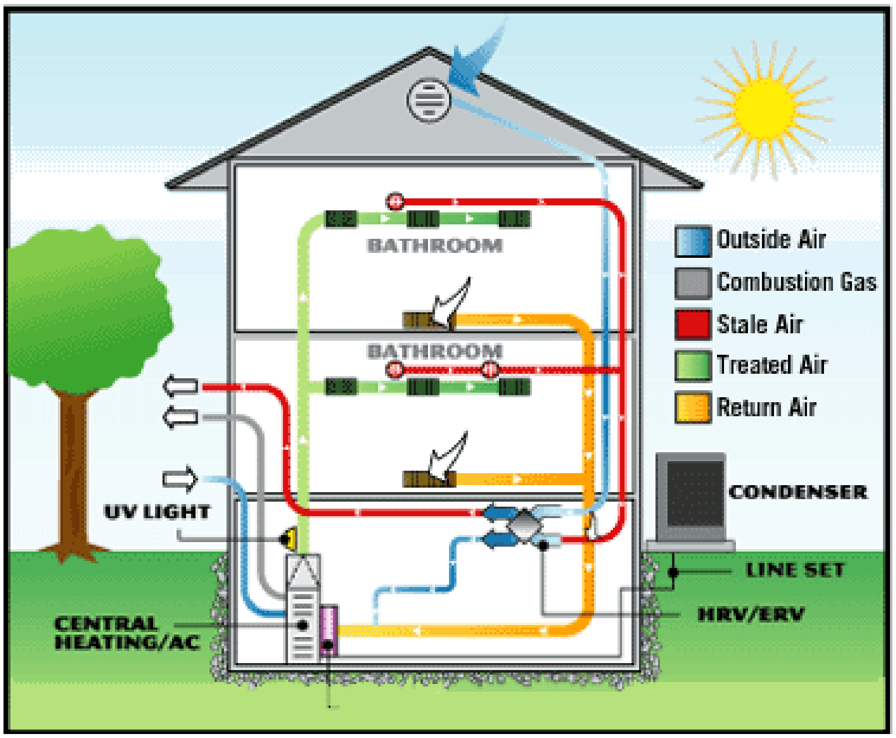

Figure 7.2-1: Illustration of a residential forced-air HVAC system. All such systems have a central heating system where filters can be installed, and vents for treated and return air. This system has several features that are not typical of most systems, including UV disinfection, and an air-to-air 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

[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.

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[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.

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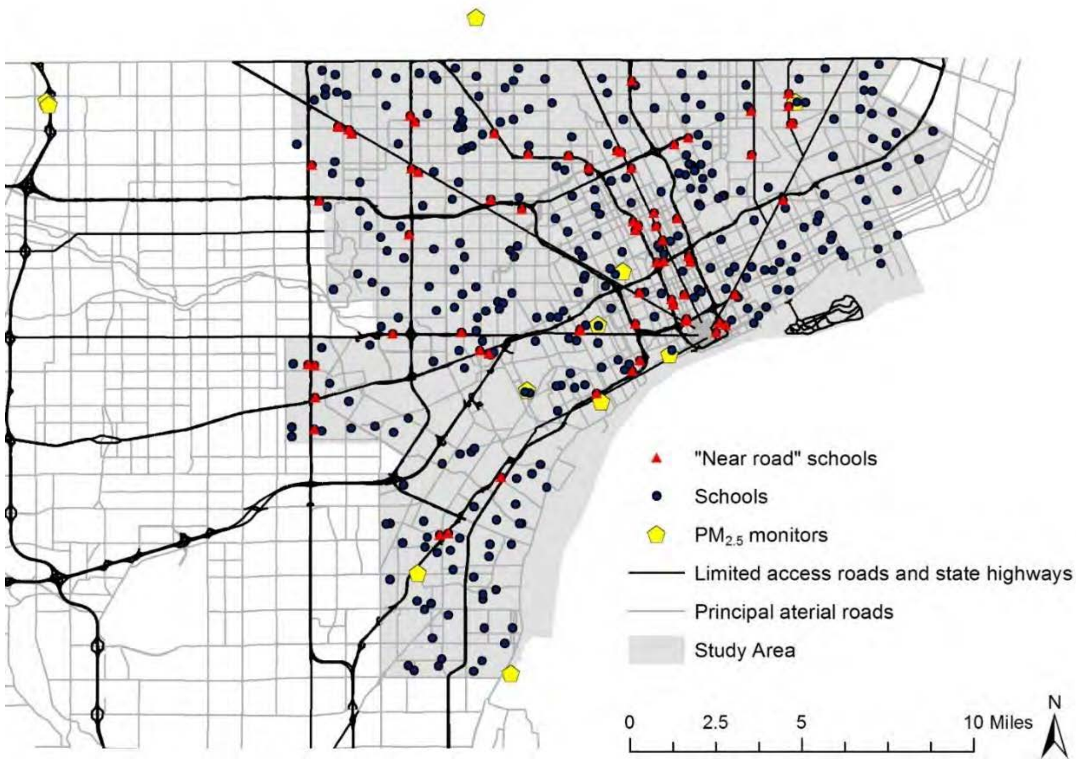
Figure 7.2-3. Locations of schools and air quality monitoring stations. One monitor (Ypsilanti, MI) not shown.



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.

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[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 all 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.

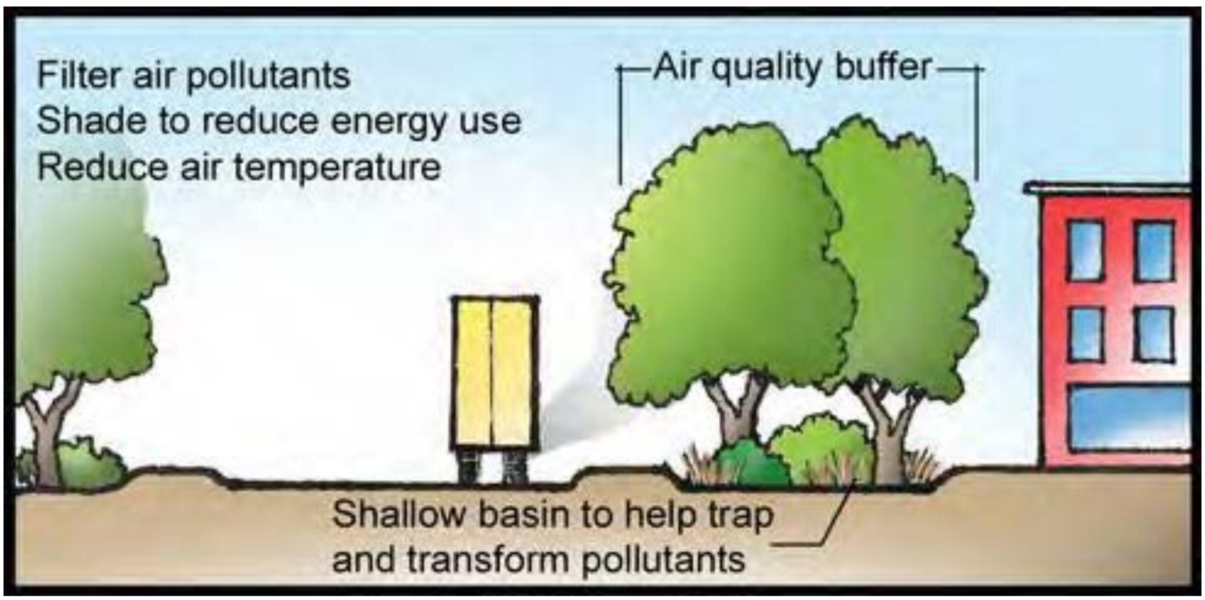

Figure 7.3 – 1. Vegetative buffers.

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.

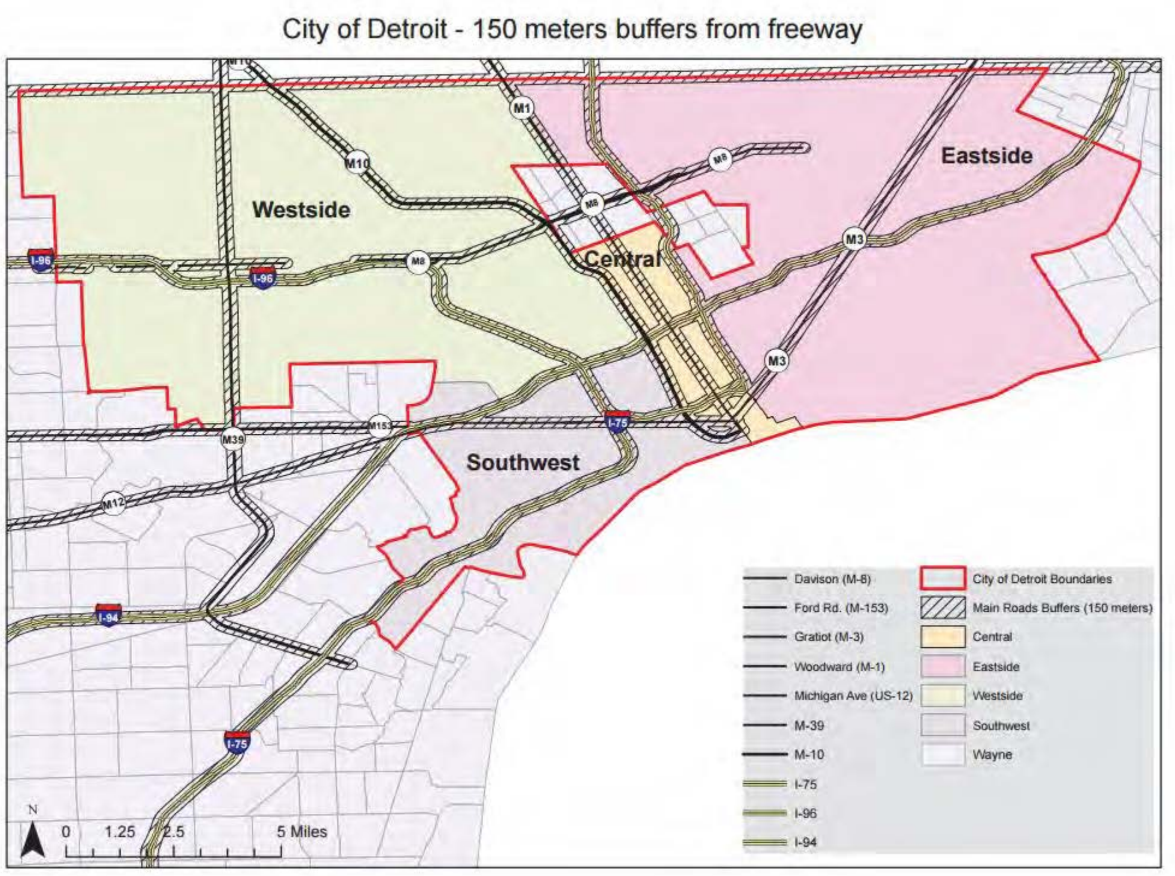

Figure 7.3 – 2. Spatial buffers along major highways in the City of Detroit.

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.

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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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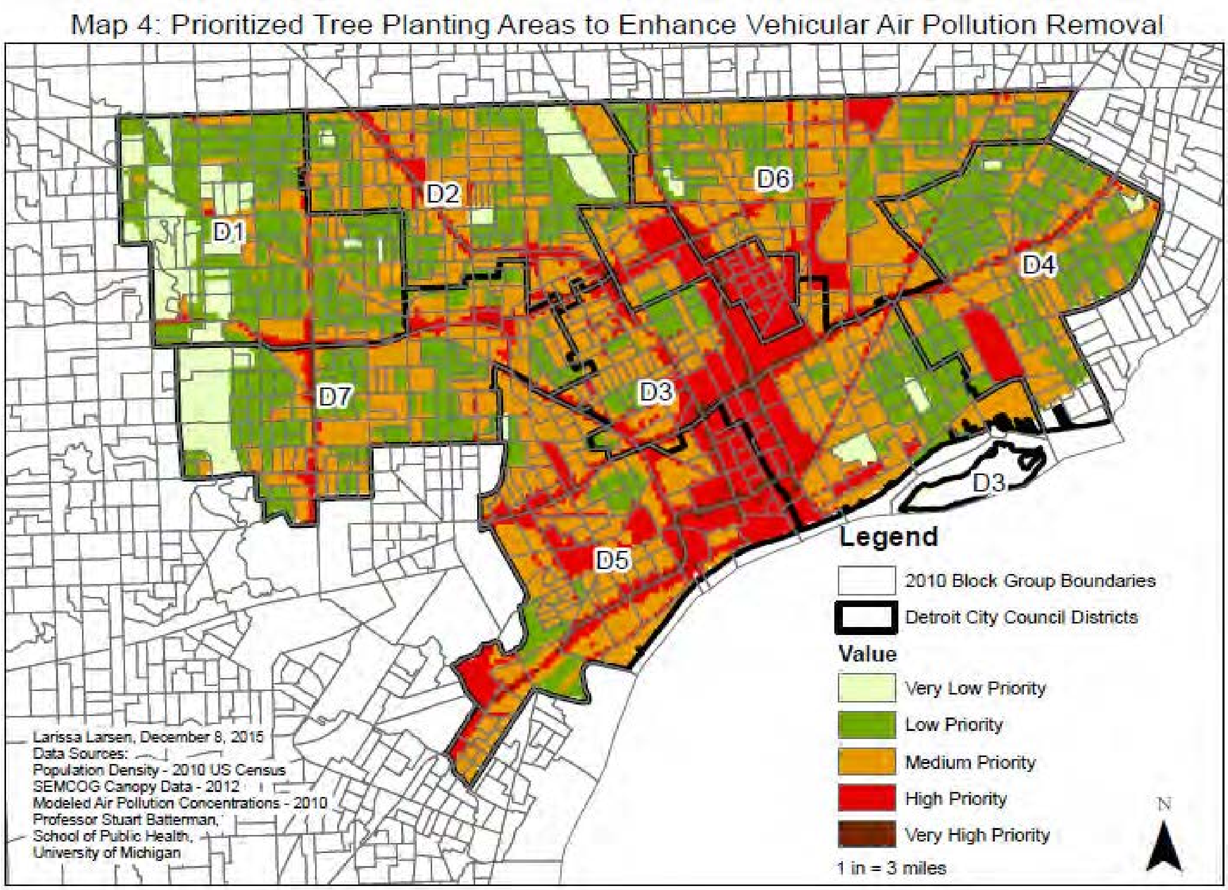
7.3.4.2 What health effects can be mitigated?

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]

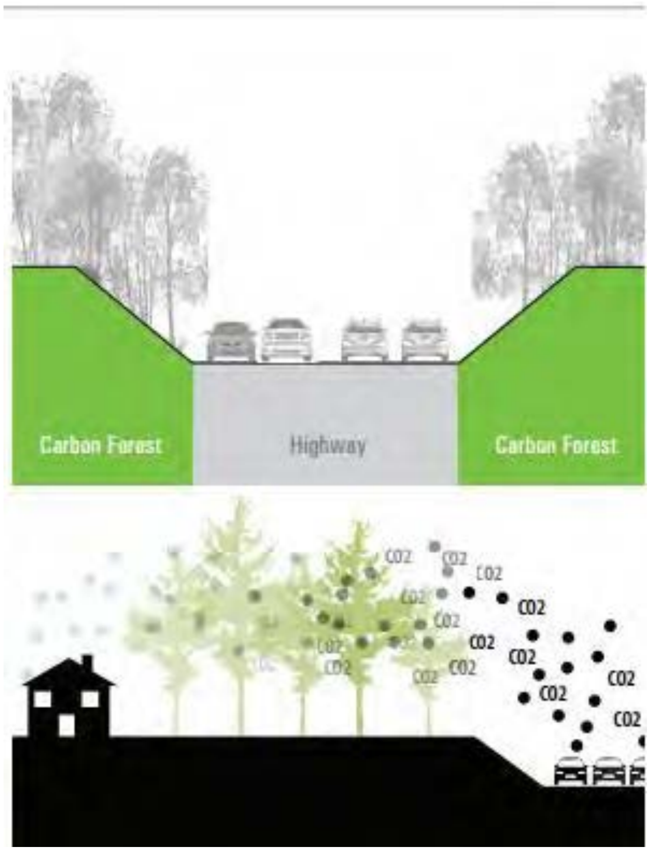

Figure 7.3 – 4. Carbon Buffering Pilot Program. Detroit Future City.

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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7.4. POINT SOURCE CONTROLS

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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.

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[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

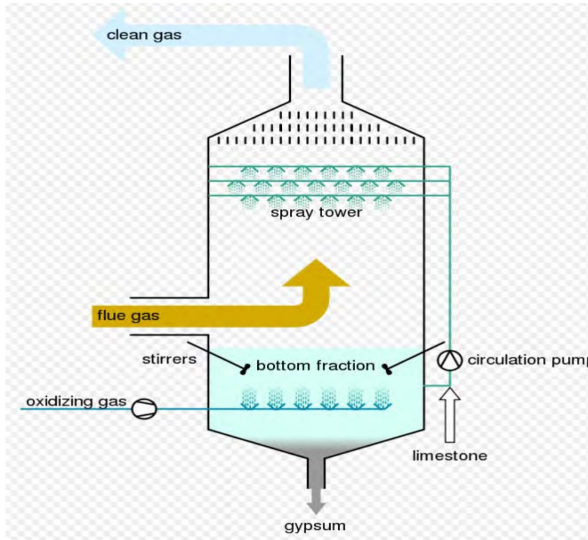

Table 7.4-1A. Control technologies for SO_2.[4,5]

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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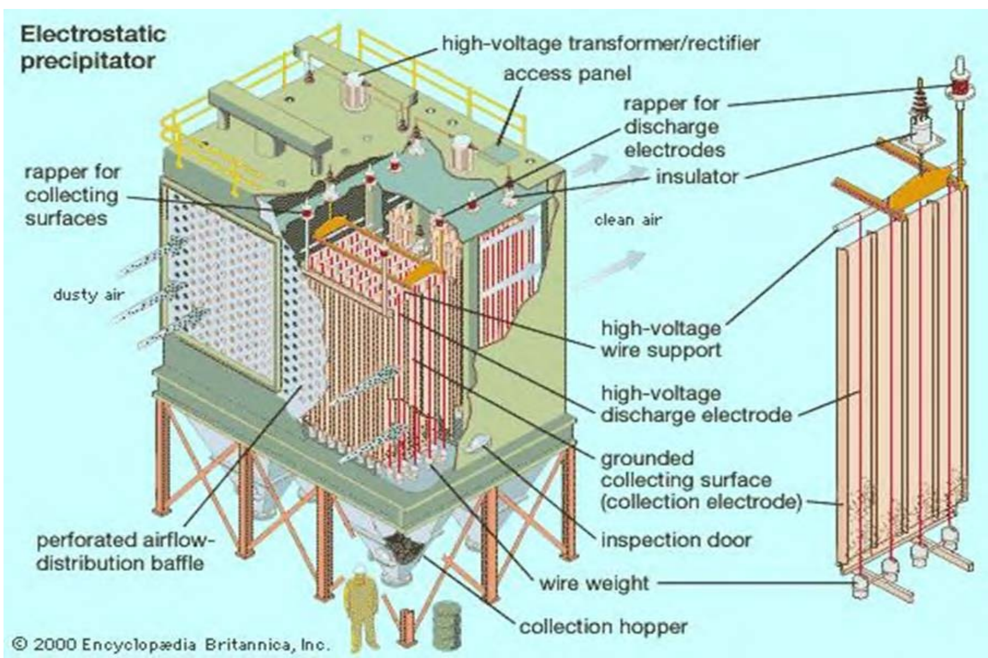
Figure 7.4-2. Diagram of a cyclone used to remove large particles from a waste stream.

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:

- <u>Single pollutant approaches</u> 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.

- <u>Multi-pollutant, risk based approaches</u> 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.

- <u>Uniform approaches</u> 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

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[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

[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

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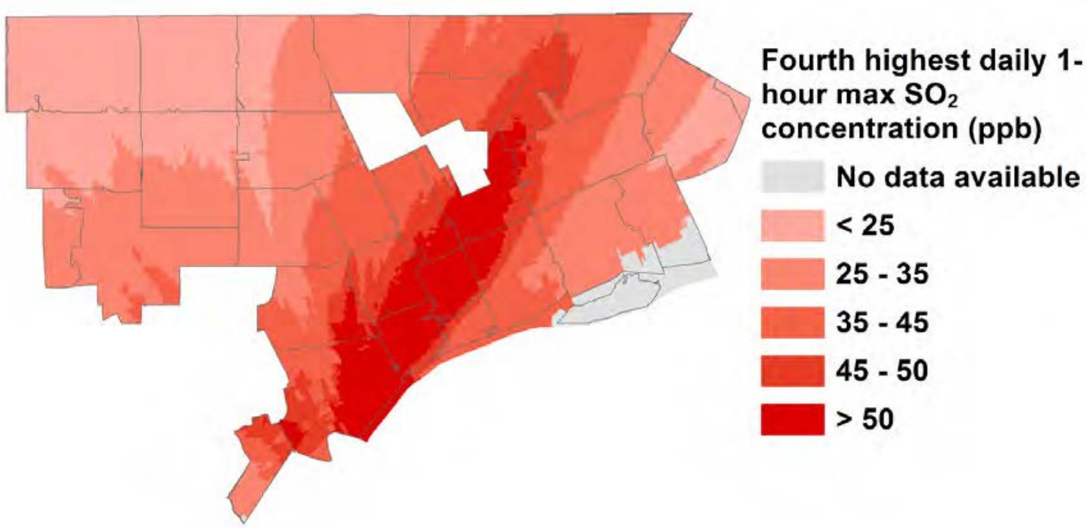
Other activity pertinent to point source emissions controls involve several large industrial facilities, including the Detroit Resource Recovery Authority's solid waste incinerator (see below) and the steel mills.

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



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

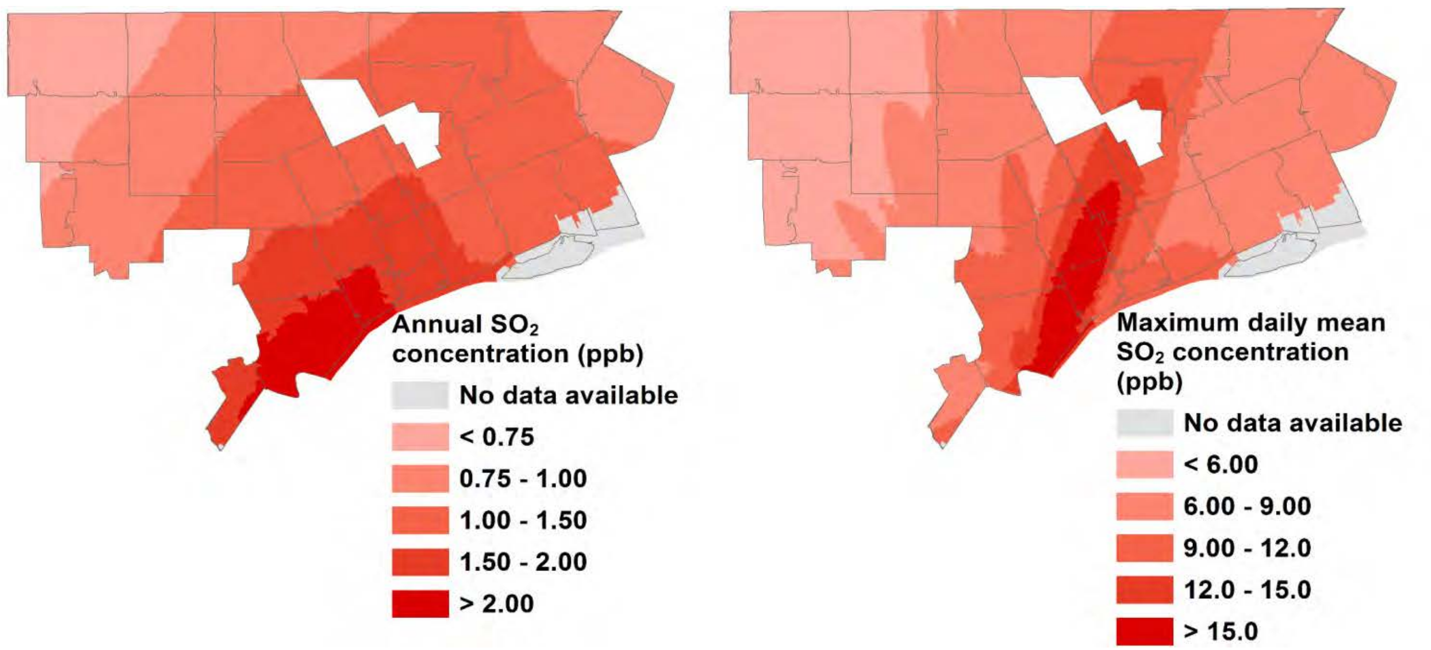

Figure 7.4-5B. Annual and highest daily mean SO_2 concentrations estimated at the block level after excluding DTE River Rouge, DTE Trenton Channel and DTE Monroe from the dispersion model.

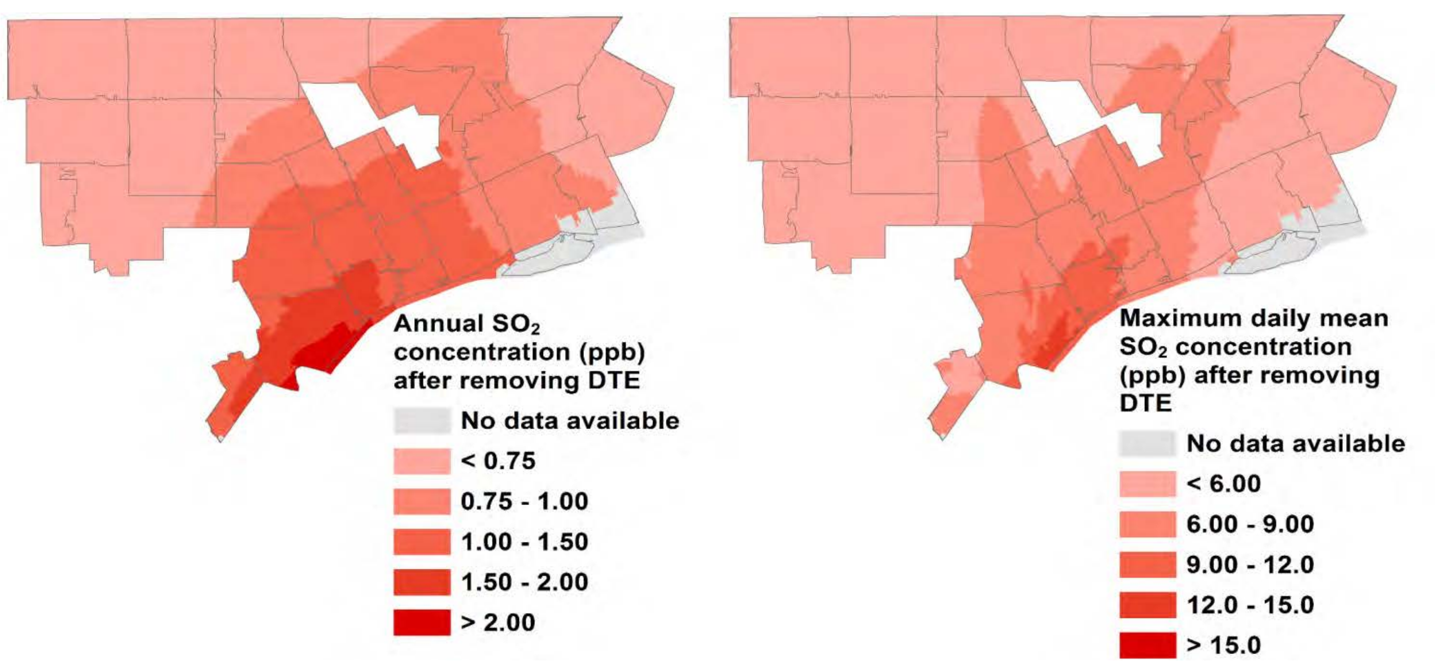

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Table 7.4-3. Health impacts attributable to SO_2 emissions from major point sources in 2010 for base and alternative cases.

	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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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]

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[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

[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?

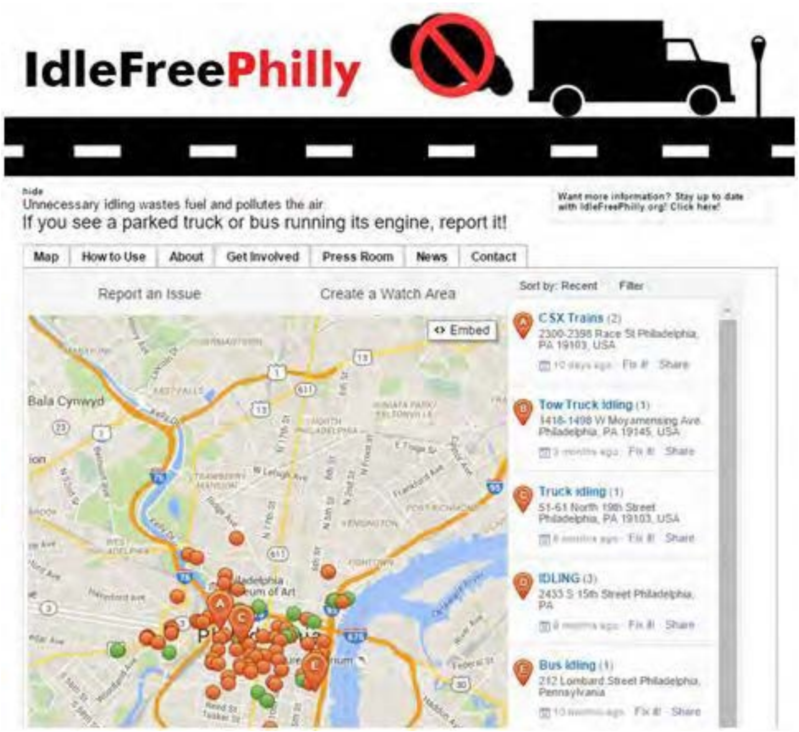

Figure 7.5 - 2. IdleFreePhilly web-based tool.

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]

[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_forcleenairidlingreduction.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

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[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

[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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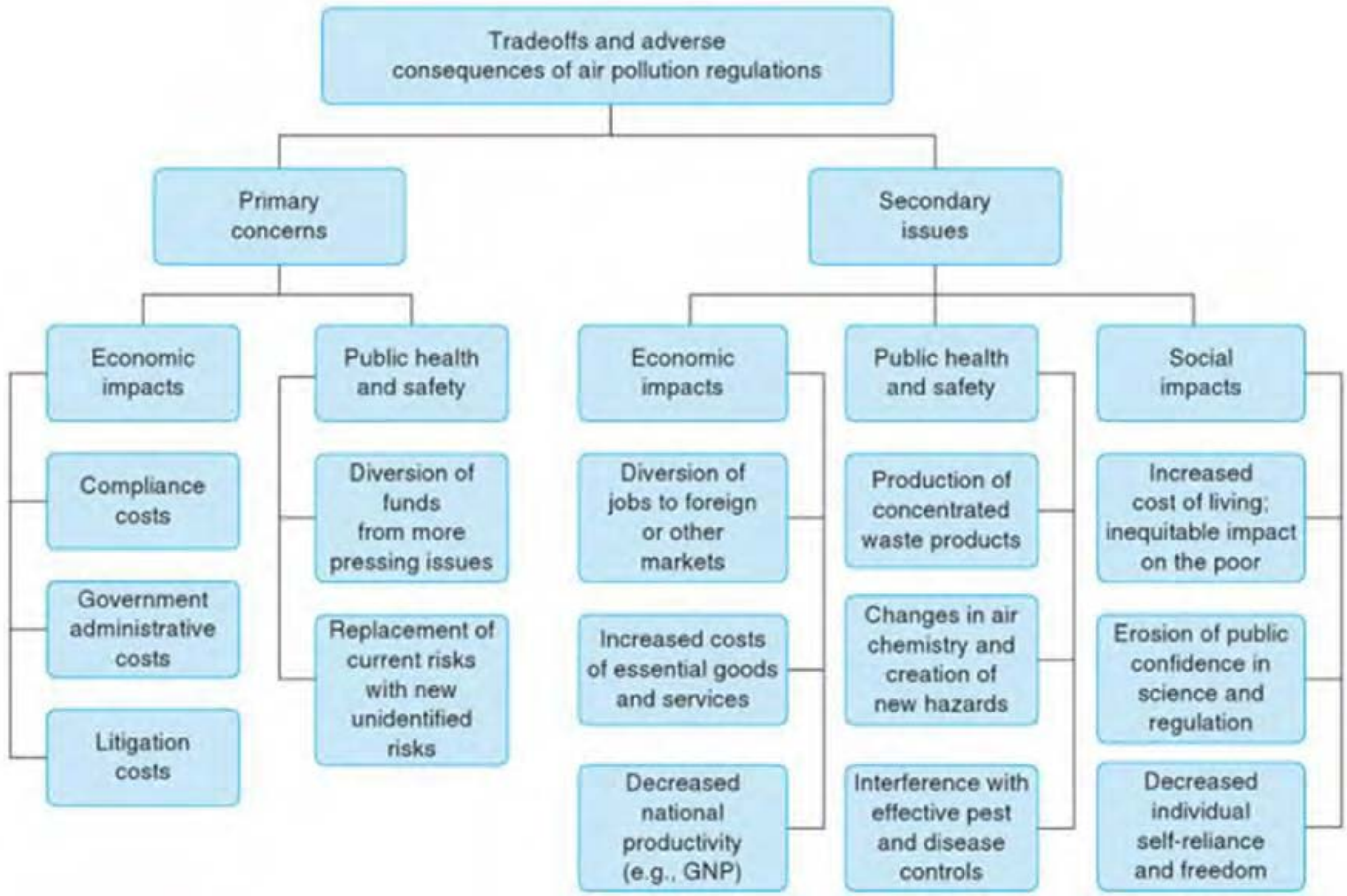
Figure 7.6-1. Potential trade-offs and consequences of air pollution regulations. From University of California Air Pollution Health Laboratory. No Permission obtained for reproduction



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:

- <u>Continuous emission monitoring systems</u> (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.
- <u>Opacity monitoring</u>. 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.
- <u>Short-term (intermittent) emission (stack) tests</u>. 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.)
- <u>Vehicle inspection and maintenance (I&M) monitoring</u>. 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.
- <u>Fugitive emissions monitoring and inspections.</u> 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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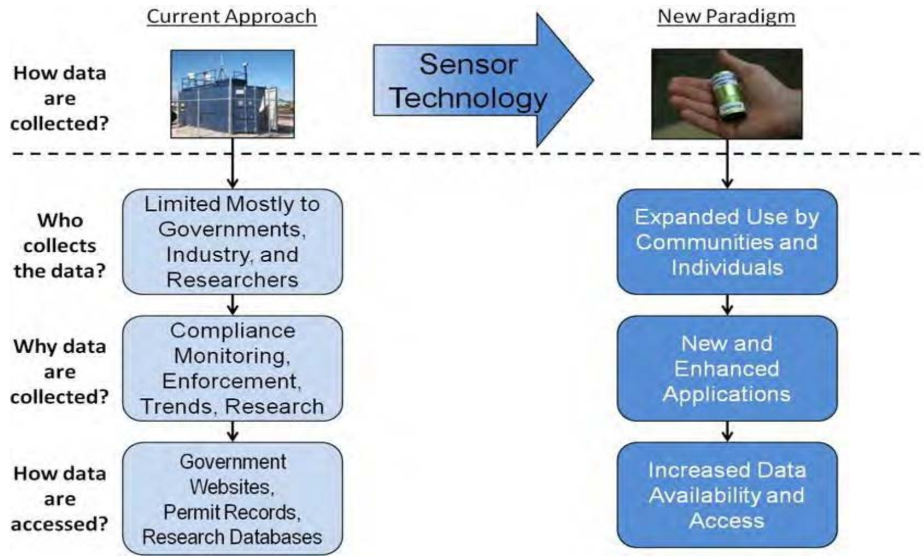
- Enhancing monitoring of fugitive emissions at facilities for compliance monitoring.

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.

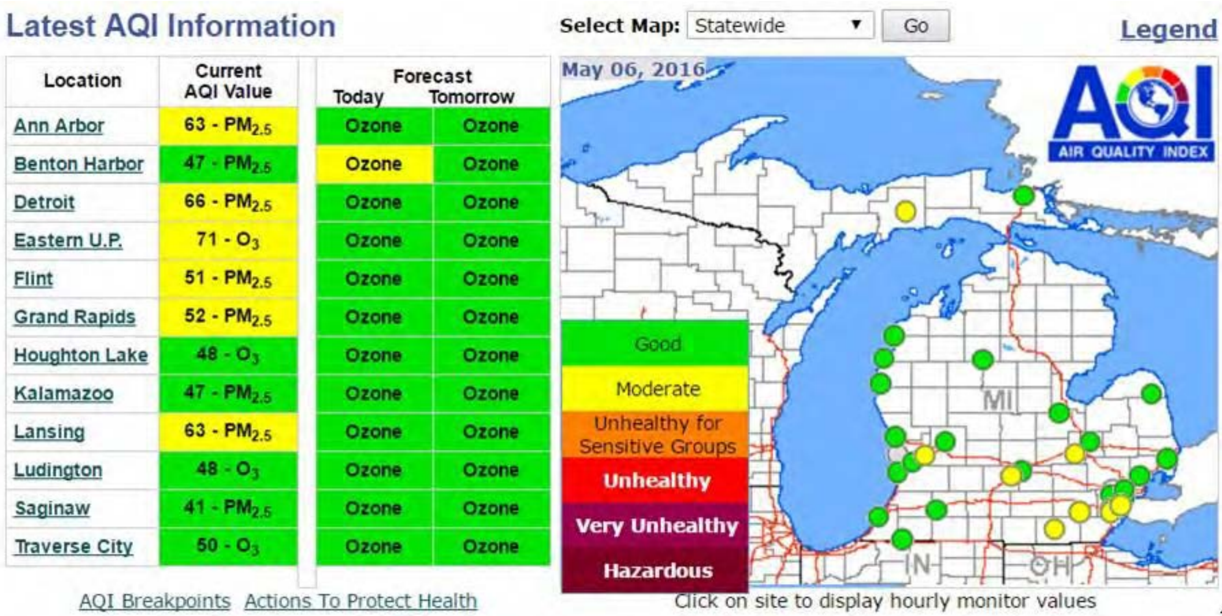
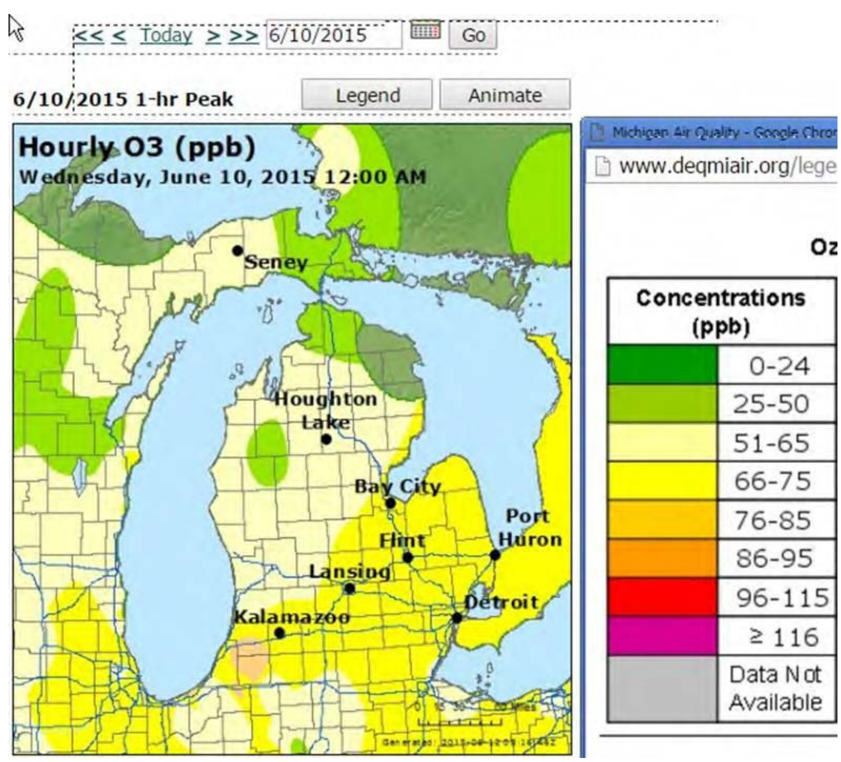


Figure 7.6-5. Example of air quality map for O_3 available from MDEQ.



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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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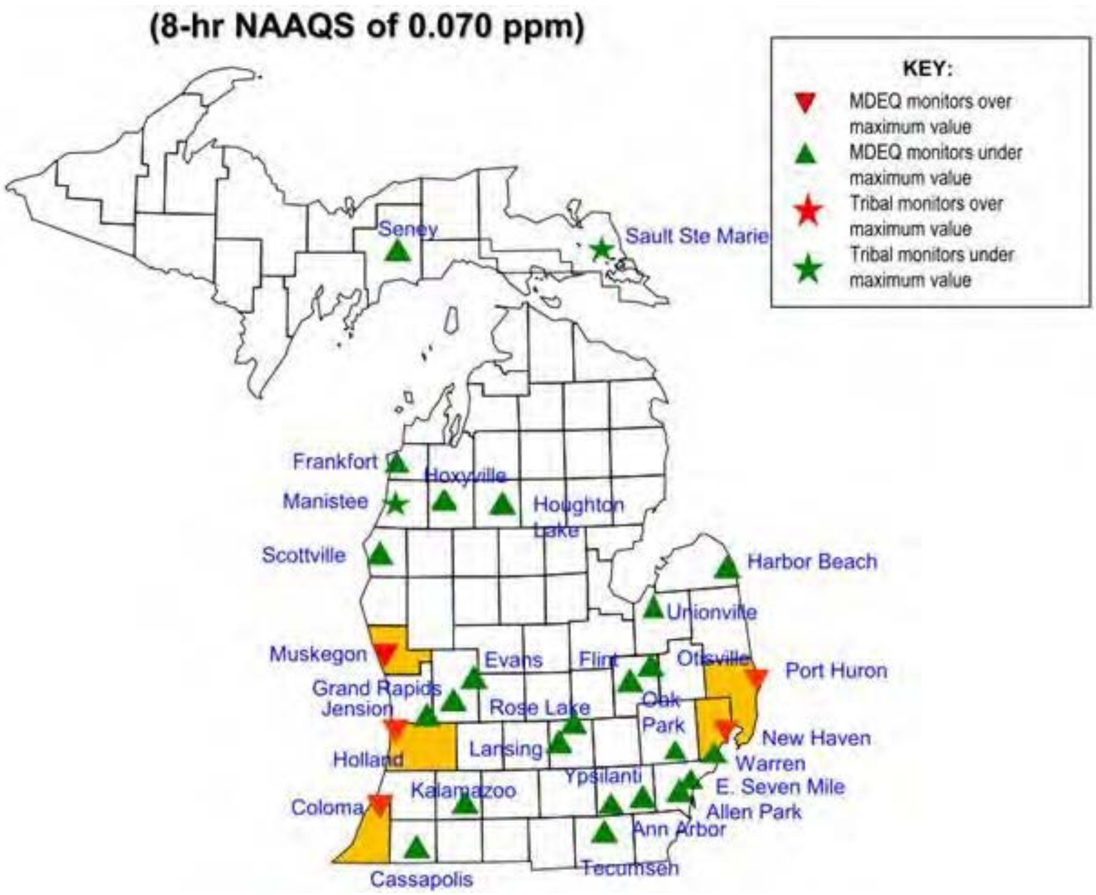
that includes information to help target enforcement actions, e.g., observations of visible smoke from the incinerator's stack.[25] See Figure 7.6-6.

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

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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

[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.

[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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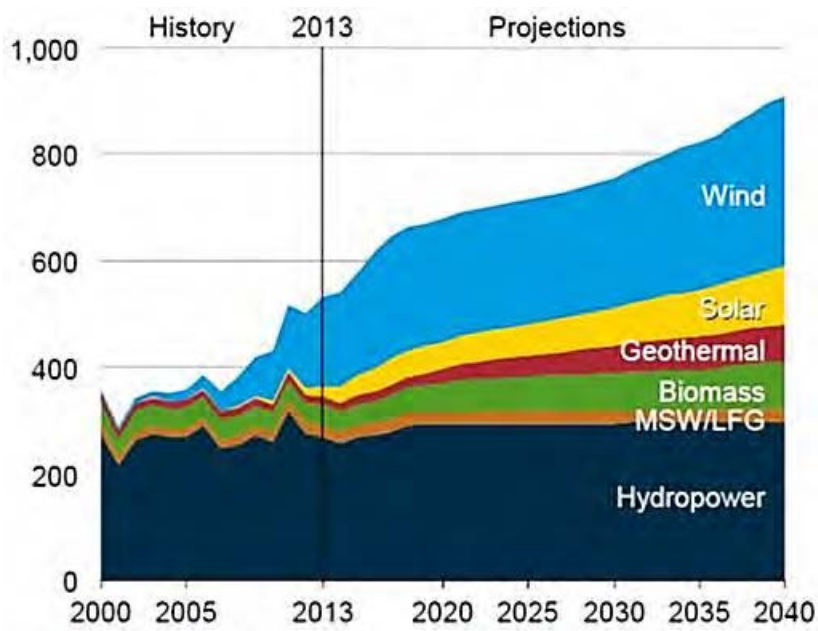
and wind.[5] Much larger increases in the renewable share are possible, and energy forecasts typically present bounding cases (best and worst-cases) to account for the uncertainty.

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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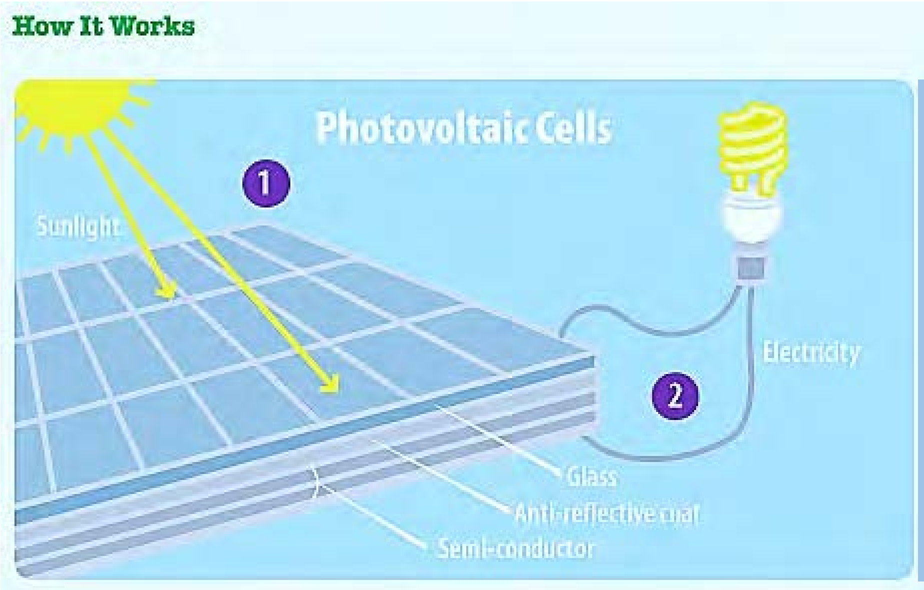
Figure 7.7-2. Schematic of a photovoltaic cell.[10]



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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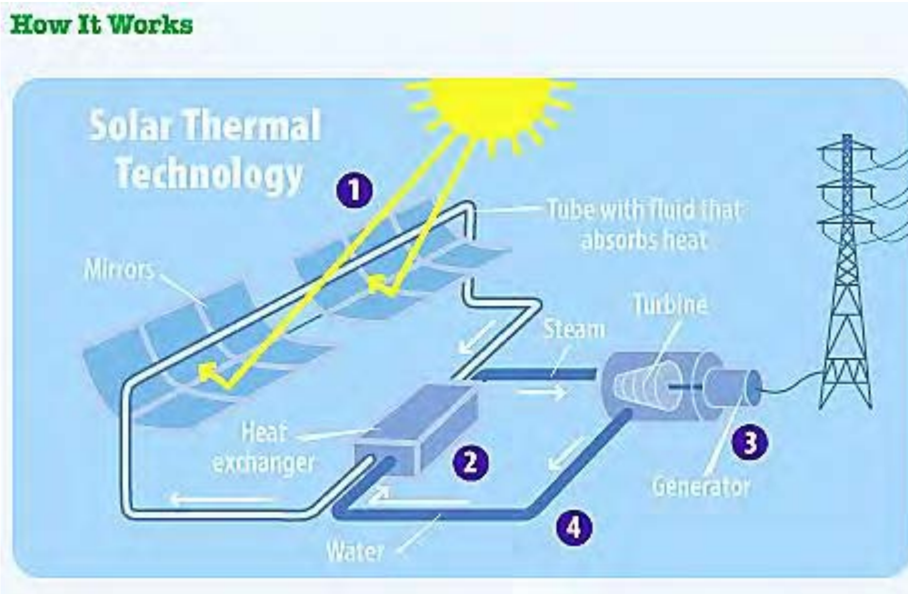
Figure 7.7-3: Schematic of a concentrated solar power system.[11]



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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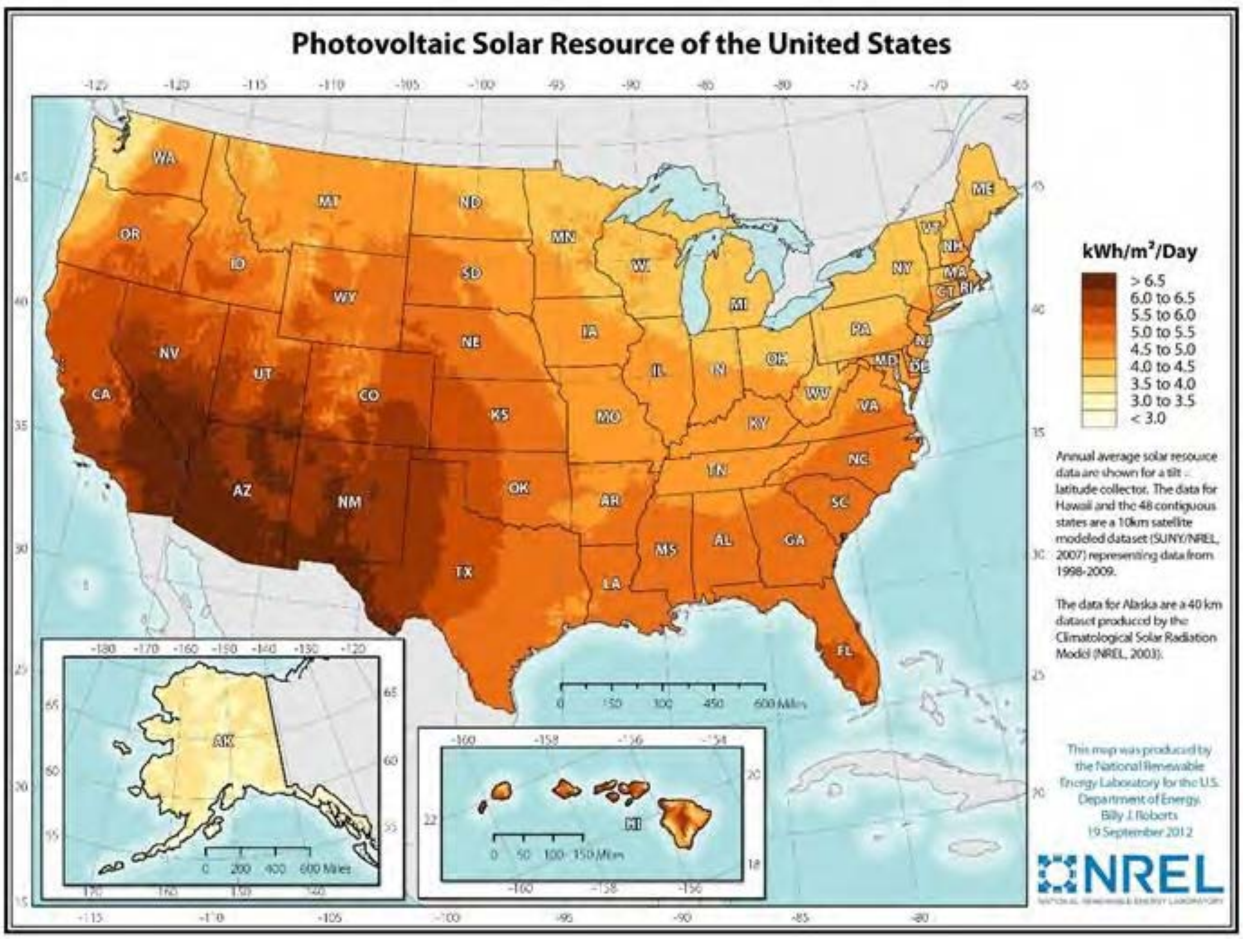
electricity and can reduce the ability to meet demand.[15] Potential solutions to this challenge include the use of new tools and technologies to monitor the electrical grid and better integrate PV systems, and improved storage systems (e.g., batteries) to even out the supply and demand for electricity.[16] 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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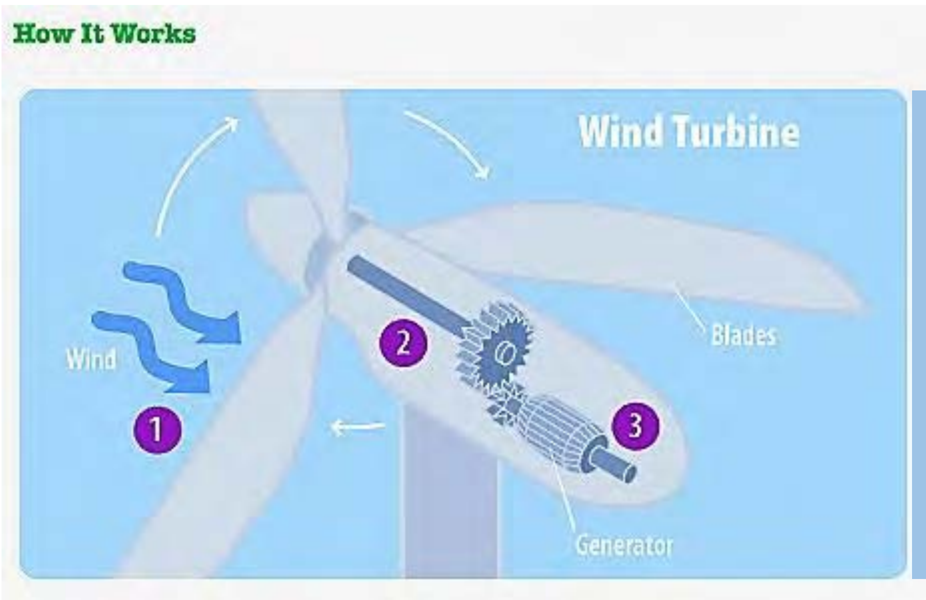
7.7.2.2 *Wind*

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

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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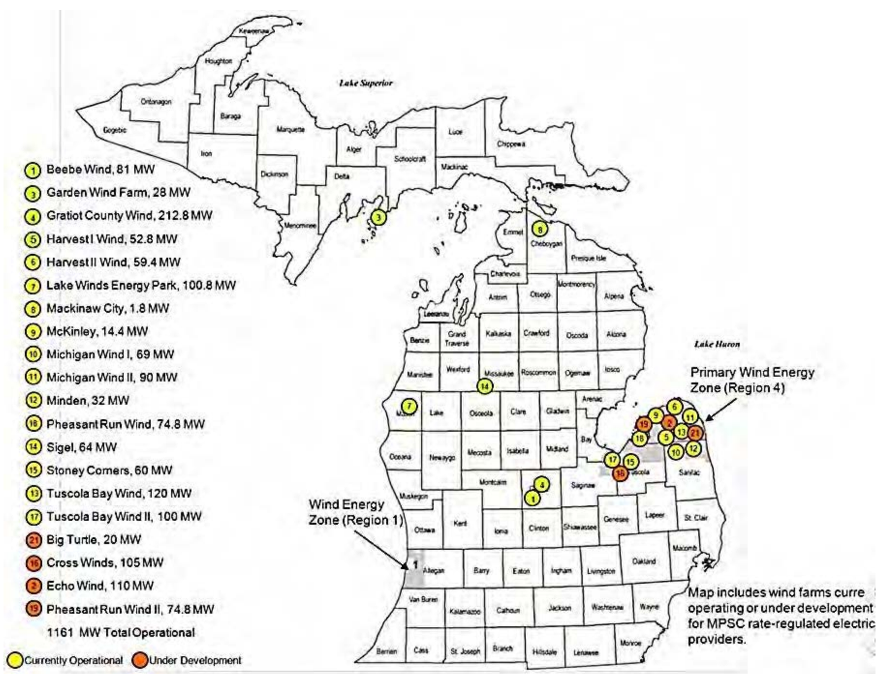
competing land uses, e.g., it may be more profitable to use the land for a different use; concerns over noise and aesthetics that lead to lack of community support for wind projects; concerns that turbines may be harmful to wildlife, especially birds; and the need for appropriate sites.

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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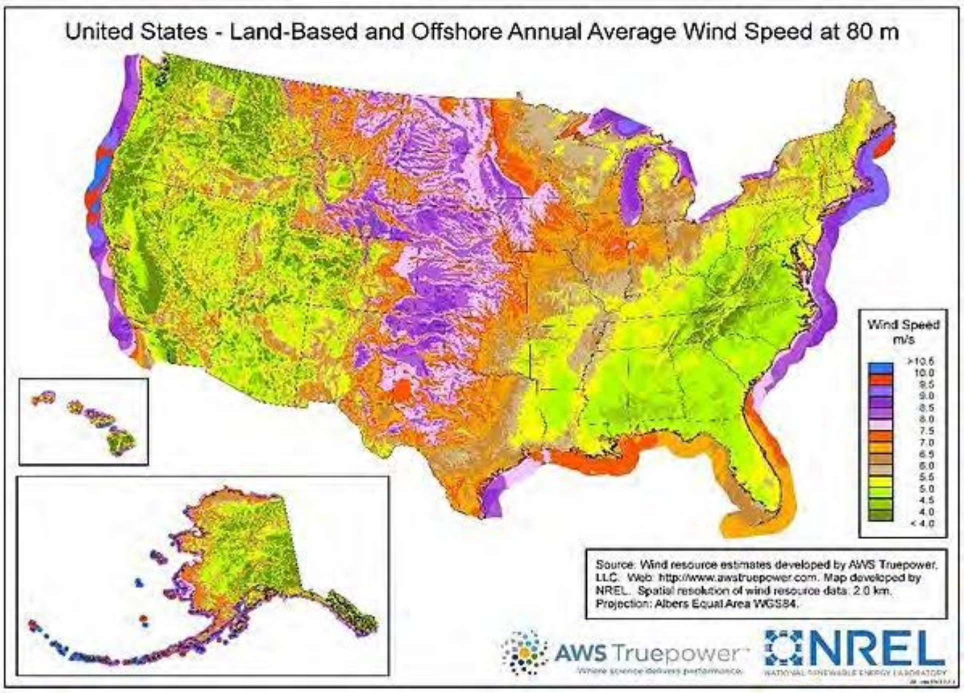
[Figure 7.7-8] shows wind resources across the United States.[25] Southeast Michigan has modest land-based annual wind speeds (5 - 6.5 m/s), but there is considerable potential for off-shore wind power in the Great Lakes, and in the "thumb" of Michigan, as shown in the previous figure. Across the US, 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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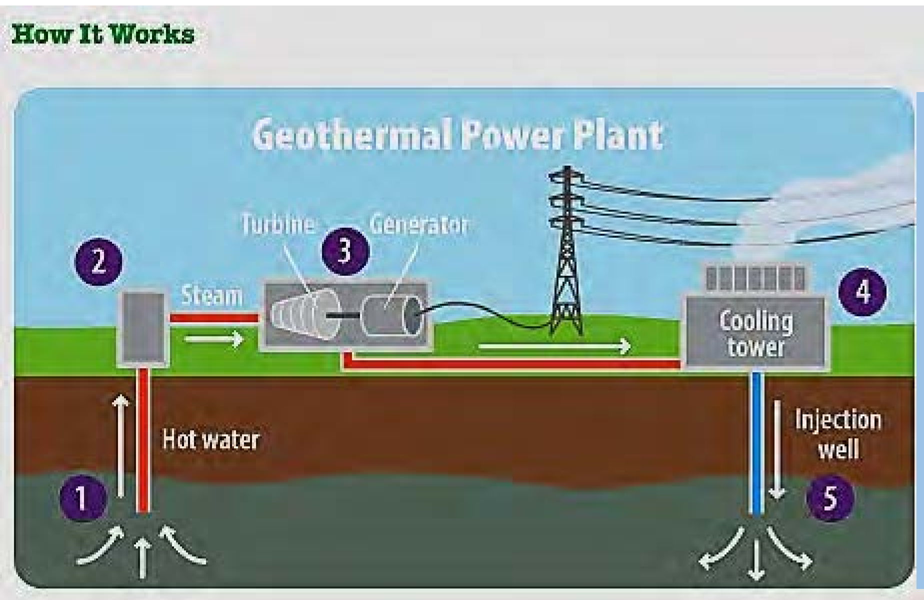
7.7.2.3 *Geothermal*

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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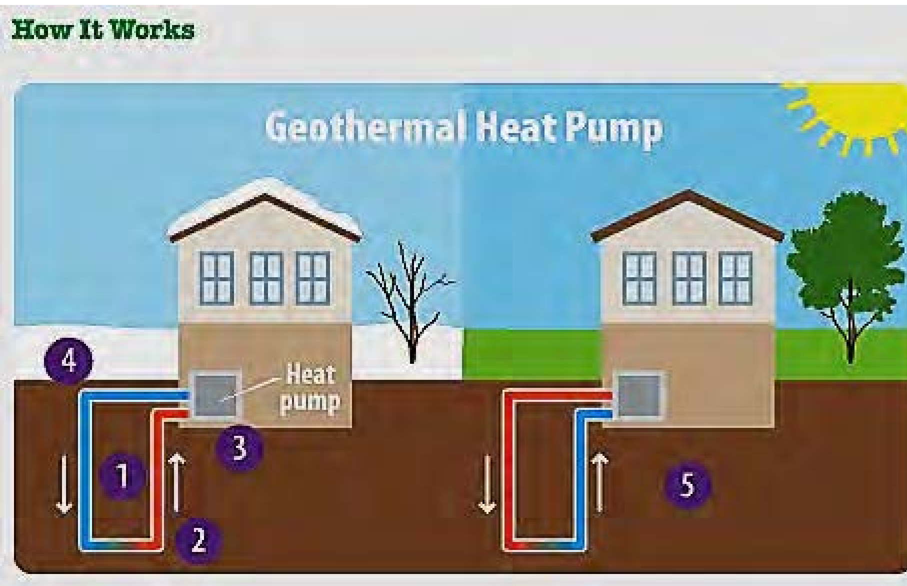
sub-surface temperatures (which are typically between 50-60° F), so heat from the ground can be transferred to water or refrigerants in a pipe system to provide heating. In the summer, surface temperatures are higher than ground temperatures, so excess heat in the building is transferred to the ground.[33]

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

[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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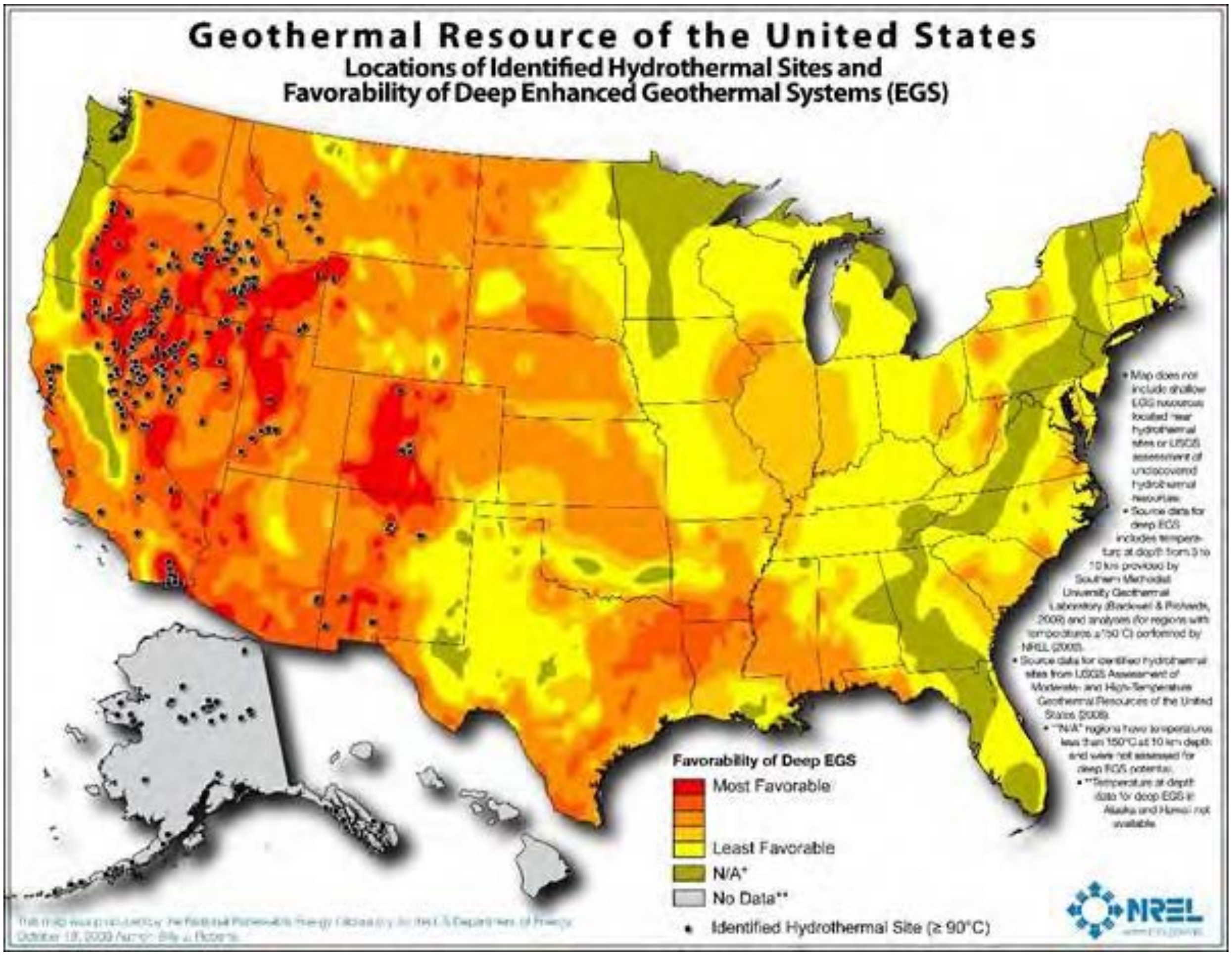
that these geothermal heat pumps still require electricity (although a reduced amount), and much of this electricity in Michigan is generated using dirty fuels.

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

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[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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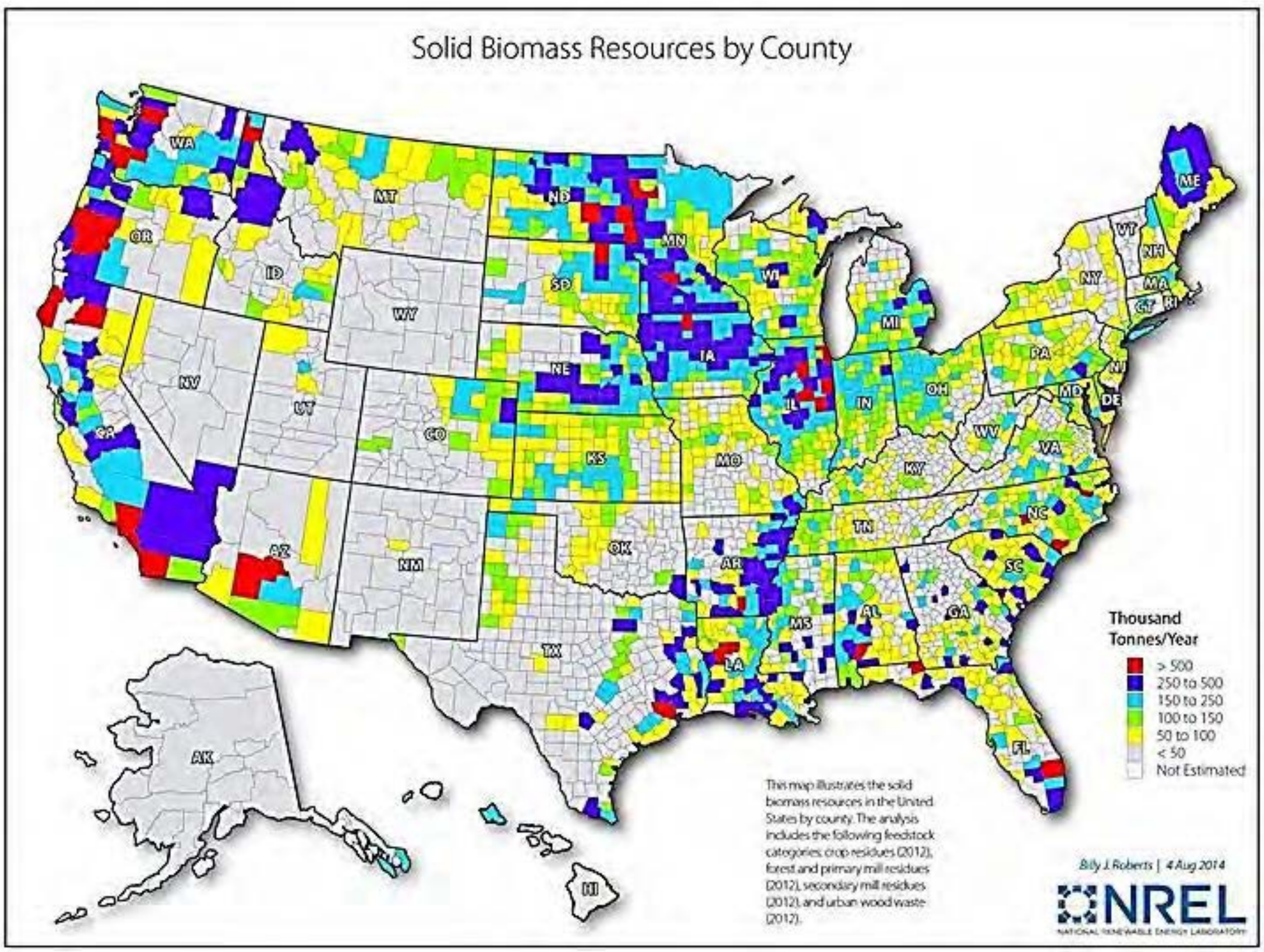
Figure 7.7-12: Tons of biomass resources available at the county level across the United States. Map from the National Renewable Energy Laboratory.[41]



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

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[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]

Plant Type	Range for Total System LCOE (2013 $/MWh)			Range for Total LCOE with Subsidies[2] (2013 $/MWh)		
	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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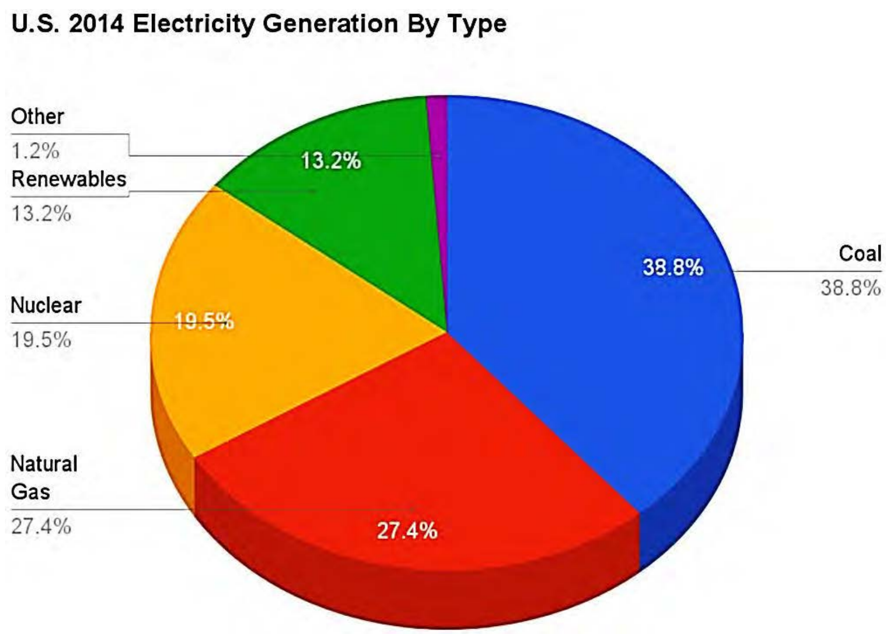
relies on fossil fuels. Replacing fossil fuels and "dirty" energy production with clean energy can play an important role in reducing adverse health effects from air pollution by substantially reducing pollution levels.

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

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$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]

[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]

[66] http://www.michigan.gov/mpsc/0,1607,7-159-16393_48209_49896-179571--,00.html

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