Benefits of Clean Mobility in Michigan

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PSC

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KEY FINDINGS

Clean Fuels Michigan engaged Public Sector Consultants (PSC) to assess the benefits of clean fuel vehicles for Michigan. Clean fuel vehicles are less-polluting alternatives to fossil fuels and include biofuels, propane, natural gas, hydrogen fuel cells, hybrids, and electrification. Clean fuel vehicles are becoming more prevalent due to advances in technology, policy changes, and interest in the potential environmental and health benefits of clean fuel vehicles. The key findings of this report include:

- Technology and policy changes will push the vehicle sector increasingly toward clean fuel vehicles.
- Michigan's existing electricity infrastructure creates many opportunities for the deployment of electric vehicles (EVs) since the system already delivers electricity throughout the state. In addition, there are currently 346 electric charging stations operating in Michigan. This figure does not include home charging stations. Michigan's energy infrastructure is also well situated to support other clean fuels, such as propane or natural gas, if they become prevalent in powering vehicles.
- Michigan currently has 29,000 direct clean fuel vehicle jobs. Including indirect and induced employment, clean fuel vehicles contribute over 69,000 jobs to Michigan's economy.
- The clean fuel vehicles sector contributes $18.8 billion to Michigan's economy each year and generates over $700 million in state and local taxes when direct, indirect, and induced effects are incorporated.
- Clean fuel vehicles emit fewer greenhouse gases than traditionally fueled vehicles.
- Replacing traditionally fueled vehicles with clean fuel vehicles would reduce air pollution. All clean fuel technologies, except flexible fuel vehicles (FFVs), emit fewer volatile organic compounds (VOCs), oxides of nitrogen (NOx), oxides of sulfur (SOx), and particulate matter (PM) than traditionally fueled vehicles.
- Reducing air pollution through the increased use of clean fuel vehicles can have important health benefits for Michigan. Air pollution can cause harmful health effects, including triggering asthma attacks and exacerbating cardiovascular disease, cancer, diabetes, and potentially autism. Reducing air pollution will improve Michiganders' health and reduce public and private health expenditures.
- An American Lung Association study (2016) of ten states found that having the majority of a state's vehicle fleet be emissions free by 2050 could reduce vehicle related air pollution health costs by 88 percent. The improvement in air quality Michigan would likely see from a transition to clean fuel vehicles would lead to Medicaid cost savings.
- Michigan is a leader in clean fuel innovation. From 2011 to 2016, the state submitted over 3,162 clean technology transportation patents, the most in the nation. Michigan also leads on a per-capita basis, submitting 32 patents per 100,000 residents—more than double the next highest state.

OVERVIEW

Clean fuels are less polluting alternatives to fossil fuels and include biofuels, liquified petroleum gas (i.e., propane), natural gas, hydrogen fuel cells, hybrids, and electrification. Traditionally fueled vehicles currently dominate the vehicle market—in Michigan, 82 percent of registered vehicles are gasoline powered and 6 percent are diesel powered. An additional 11 percent are FFVs, which can run on combination of gasoline and ethanol, with an ethanol blend of up to 83 percent. Although these FFVs can use blended fuel, many are powered almost exclusively with gasoline.

While traditionally fueled vehicles represent the present, clean fuel vehicles are the future. Several powerful factors will result in vehicles being increasingly powered by clean fuels, including concerns about greenhouse gas emissions, air pollution, and the continued availability of inexpensive oil over the long term. In addition, recent technological advances are making clean fuel vehicles less expensive and more reliable.

While market forces increasingly push the mobility sector toward clean fuels, policy changes accelerate this process. Some countries are setting dates for ending the sale of gasoline- and diesel-powered vehicles. Norway's end date is 2025; France and the United Kingdom 2040; and Germany, India, and China have announced an intention to set such dates in the future (Lippert 2017).

The move toward clean fuel vehicles has large potential upsides for Michigan and the nation. Reducing dependence on foreign oil will have important national security implications. Clean fuel vehicles emit fewer greenhouse gases and are less polluting, and the reduced air pollution from clean fuel vehicles will have important health benefits for Michiganders.

At the same time, the change to clean fuel vehicles represents a significant threat to Michigan's economy. Michigan has long been the center of the U.S. auto industry, producing more cars and trucks than any other state. In 2014, Michigan assembly lines produced more than 2.3 million cars. Michigan also has 13 original equipment manufacturer (OEM) assembly plants, 35 OEM component plants, and more than 1,700 manufacturing establishments (Detroit Regional Chamber 2018). Michigan's automotive industry directly supports 15 percent of the state's workforce (Michigan Automotive Office n.d.).

As vehicle technologies change, there is a risk that vehicles using new technologies will be developed and produced elsewhere. The policy environment, research capacity, and system infrastructure can all influence where clean fuel vehicles are manufactured and sold. For example, the Toyota Mirai is one of the first hydrogen fuel cell vehicles to be sold commercially. It is currently only sold in markets with the infrastructure to support refueling. Japan is one of these markets, with roughly 90 demonstration hydrogen fuel sites. To accelerate the adoption of the technology, Japan plans to build 80 additional stations by 2022 and 900 stations by 2030 (Reuters Staff 2018). In the U.S., the Mirai is currently only sold in California, which currently has 33 retail hydrogen fueling stations and 29 more under development (California Fuel Cell Partnership 2018).

Fortunately, Michigan is well situated to stay a leader in mobility through clean fuel vehicle technology and the development of CAVs, which are often clean fuel vehicles. The state is home to 375 research and development (R&D) centers, representing more than 70 percent of the country's automotive R&D spending, and has important research assets, such as the Mcity test facility at the University of Michigan (U-M) and the American Center for Mobility (ACM). Michigan's powerhouse research universities are leaders in developing battery technology and other clean fuel technologies, and the state's 91 education and training institutions that offer over 650 automotive-based degrees and programs help ensure that Michigan will have the talent it needs to support this industry (Michigan Automotive Office n.d.).

Even with these advantages, however, it is important that Michigan policymakers pay close attention to the industry and its needs. With 15 percent of the state's workforce directly dependent on the automotive industry, this industry critical to the state's future. It is essential that the state's policy environment remains conducive to the development, production, and use of clean fuel vehicles. Other states and regions are implementing policies to encourage the use of clean fuel vehicles. As noted, California is installing hydrogen refueling stations. Other states are subsidizing the conversion of gasoline and diesel vehicles to clean fuels (e.g., Ohio's Alternative Fuel Vehicle Conversion Grant Program) and subsidizing the commercialization of clean fuel technologies through programs (e.g., Kentucky's New Energy Ventures). While the efficacy of such programs is not clear, Michigan policymakers should pay careful attention to efforts in other states that could undermine Michigan's competitive advantage in developing and manufacturing clean fuel vehicles. Additionally, policymakers should look for policy opportunities that can help cement the state's advantage.

THE FUTURE OF MOBILITY

INTRODUCTION

A variety of technological and social forces are converging to change the way we get around. This is expected to result in a different, more holistic approach to person and cargo transportation, termed "mobility." These changes are already underway, as evidenced by the recent rapid growth of carsharing and ridesharing; the growing viability of electric and alternatively powered vehicles; advances in deploying innovative, lightweight materials to build cars and trucks; and the growth of connected and automated vehicles.

Two key technologies are driving these changes—innovative mobility services (IMS) and connected and automated vehicles. Both technologies have the potential to change transportation on a global scale, and to improve safety, significantly alter transportation costs, and change traffic patterns and congestion. They also may have profound impacts on the prospects of clean fuels in Michigan.

As these changes come to fruition, stakeholders in Michigan aim to leverage the state's unparalleled automotive heritage to become the center of CAV development and a major provider of IMS. This emerging mobility industry could drive job creation, talent retention, and economic development, and improve quality of life. However, it also presents a variety of risks and threats if other regions or states overtake Michigan's place as the center of automotive technology.

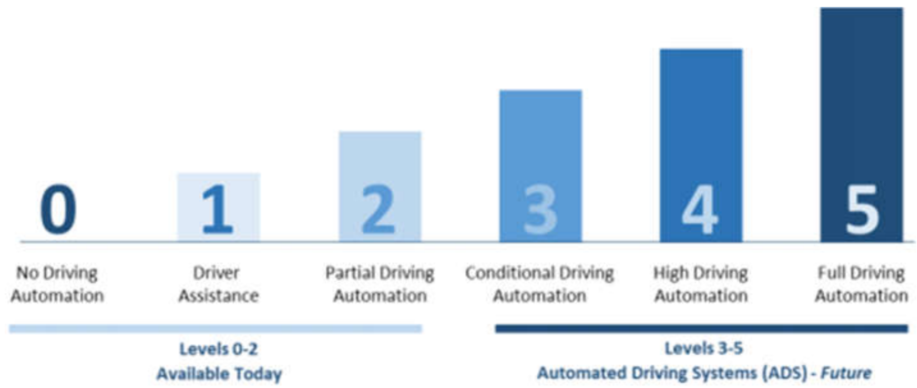
TERMINOLOGY

To understand the future of mobility, two key terms require definition. The first is innovative mobility services. IMS marries transportation and technology and includes "solutions enabled by emerging technologies and wireless connectivity that allow for more convenient, efficient, and flexible travel" (Center for Automotive Research 2017). Noteworthy examples include carsharing, ridehailing, ridesharing, microtransit, and bikesharing. These and other mobility-as-a-service options are currently in development, and some are seeing dramatic growth in various markets worldwide.

Related, but distinct from IMS, is the concept of a connected and automated vehicle (CAV), which can refer to a variety of vehicle technologies currently under development. These technologies vary in their application—some work at the level of the vehicle, some at the level of the overall transportation system, and some at both. Many types of connectivity and automation are feasible, as are many ways to combine them.

Most popular media on this topic focuses on the "automated" portion of CAV—that is, the driverless car. To become driverless, these vehicle systems perform three functions: monitoring (via cameras, radar, and lidar), agency (information processing), and action (physical actuation systems). The automotive industry and regulators are currently using a taxonomy of six levels of driving automation (SAE International 2016). This standard defines vehicle capabilities, how people can use them, and to what extent they can rely on the technologies (Exhibit 1).

EXHIBIT 1. Levels of Driving Automation



Source: SAE International 2016

Detailed discussion of each of these technologies, however, is outside this report's scope, which focuses on a few key definitions and areas of current R&D to inform how changes in mobility will impact clean fuels.

TIMELINE FOR DEPLOYMENT

As referenced earlier, a variety of IMS applications are in deployment (e.g., ridesharing services like Uber and Lyft) and are already shifting our current transportation system. Assuming demand for these services grows, their offerings may also expand due to the implementation of CAVs.

As this report's publication date, there are just a handful of automated vehicles in operation around the world running using fully automated driving systems (level five). These vehicles are generally low-speed, limited-range shuttles that operate in controlled environments with few conflicts.

However, many automakers and technology developers are working to bring road-ready, automated driving system-equipped vehicles to market for use on public roads in real-world conditions in the next few years. The highest level of automation currently available to consumers is level two (e.g., Tesla's Autopilot 8.0). European automaker Audi announced its 2019 A8 model will have a level three capability. Other companies, such as GM, Ford, Waymo, and Volvo, are developing and testing level three and four systems. Most automakers promise to launch level four vehicles around 2020 initially as part of ridehailing services to better control deployment (Center for Automotive Research 2017).

A RANGE OF IMPACTS

Tracking the connection between IMS and CAV technologies is critical to understanding the potential opportunities and challenges that will come with this ever-evolving technological race. IMS and CAVs will likely have profound impacts on transportation systems, though the precise magnitude of these impacts remains highly uncertain. Much depends on how CAVs will be used, who owns them, public and private infrastructure investment decisions, public policy and regulation, and overall transportation costs. There are numerous questions around the future of mobility, questions that could pose dramatic changes for a variety of economic sectors, including insurance, finance, and cybersecurity.

For the purposes of this report, however, some of the most critical questions are clear. Michigan's clean fuel industry will be impacted profoundly by the following questions:

- Fuel sources and drivetrains: How will CAVs be fueled? Will they be built to run purely on battery technology, or will fleets be a mix of gasoline and electric technology?
- Energy requirements: How much energy will they require to operate?
- Travel demand: How much will we drive CAVs? How will CAVs change travel demand and vehicle miles traveled?

The following subsections attempt to answer these key questions in greater detail.

Fuel Sources and Drivetrains

As of the publishing date of this report, automakers are engaging in a significant debate about fuel sources and drivetrains and, in some cases, staking out divergent market positions. For example, GM joined Nissan, Mercedes Benz, and others when it affirmed a commitment to deploying CAVs that rely solely on vehicle electrification, whereas Ford Motor Company has proposed adopting hybrid-electric technology to maximize mileage and keep vehicles on the road (Hawkins 2017).

Much of the gas versus electric debate has to do with how the vehicles will be used. Given how long it currently takes to recharge an EV, Ford hopes stay ahead with longer fuel ranges than EVs. If autonomous vehicles can be out on the road continuously, operating like ride shares or driverless taxicabs, any time they're off the road is time spent not making money. Ford plans to keep its autonomous hybrids driving for about 20 hours per day, thus leading them to bet on hybrid-electric technology as the way to go.

Fiat Chrysler Automobiles (FCA) is taking a more collaborative and less costly approach, developing vehicles and technologies with different partners. FCA is working with Waymo to pursue a plug-in hybrid electric Pacifica minivan while also pursuing a potential partnership with Hyundai on a hydrogen fuel cell-powered vehicle (Lawrence 2017).

Decisions about how to fuel these vehicles are some of the many critical factors that will go into CAV design, but whether Michigan benefits from CAVs depends greatly upon whether Michigan-based automakers bet on the right kinds of technologies. Home to Ford, GM, and the U.S. headquarters for FCA, Michigan may benefit from major OEMs taking divergent positions on the drivetrain of autonomous vehicles, since this reduces the potential threats to Michigan's automotive sector by spreading the risk of one model working better than another over three large automakers. As technology advances and clean fuels become more prevalent, global automotive manufacturers have momentous decisions to make about the kinds of products they build and the services they provide.

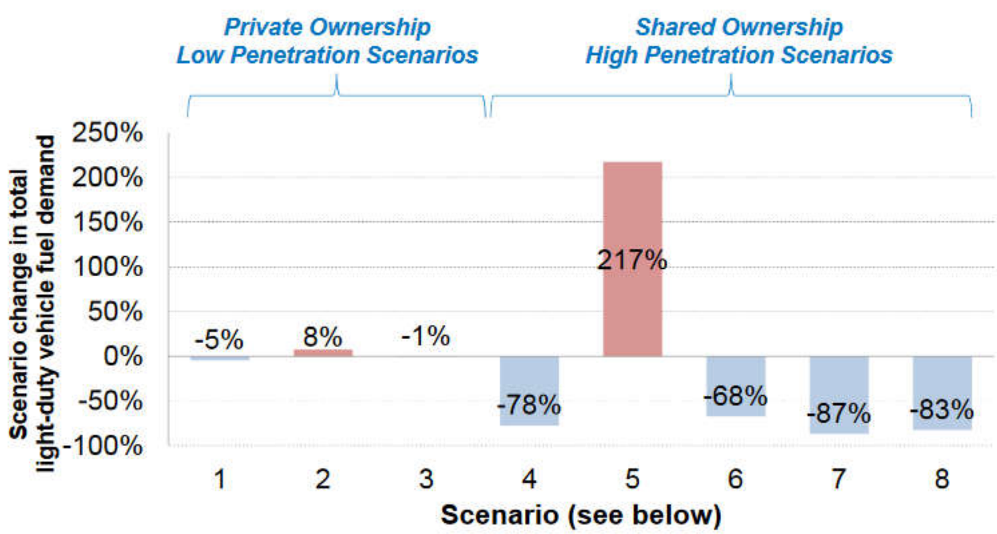
Energy Requirements

The question of how these new vehicles will be powered also depends on how much energy they require. In some current applications, self-driving technology has proven to require large sources of energy. BorgWarner Inc. estimated that some of today's prototypes for fully autonomous systems consume two to four kilowatts of electricity, which is akin to driving around town while running 50 to 100 laptops continuously (Coppola and Day 2017).

The energy drain takes place because of the computing power required to fuel autonomous features—a level four or five vehicle operating without human intervention, for example, requires processing data from laser, radar, and camera sensors, which makes meeting existing fuel economy and carbon emissions targets approximately 5 to 10 percent more challenging (Coppola and Day 2017).

Recent research shows that energy consumption of light-duty vehicles may vary substantially when these vehicles are equipped with automated and connected technology. For example, to test light-duty vehicles, the National Renewable Energy Laboratory developed eight scenarios based on completed studies and simulations (Brown, Gonder, and Repac 2014). In the most positive scenario, automated vehicles could help reduce energy consumption of light-duty vehicles by 83 percent. In the most negative scenario, they could increase energy use by as much as 217 percent. This very wide difference reflects the variety of possible scenarios. Policymakers can influence the path taken. For example, governments could choose to develop and implement policies that would make the positive scenarios more likely by incenting technologies that lead to more favorable outcomes.

EXHIBIT 2. Scenarios of the Energy Consumption of Connected and Automated Vehicles



Number	Scenario Name	Active Effects
1	Private ownership, fuel savings only	Platooning, some efficient driving, efficient routing
2	Private ownership, fuel-use increase only	Travel by underserved populations
3	Private ownership, combined effects	Platooning, some efficient driving, efficient routing, travel by underserved populations
4	Shared vehicles, fuel savings only	Platooning, efficient driving, efficient routing, lighter vehicles, less time looking for parking, higher occupancy
5	All identified potential fuel-use increases	Travel by underserved populations, faster travel, more travel
6	Vehicle electrification	Electrification
7	All identified potential fuel savings	Platooning, efficient driving, efficient routing, lighter vehicles, less time looking for parking, higher occupancy, electrification
8	All scenarios	All effects

Source: Brown, Gonder, and Repac 2014

Travel Demand and Vehicle Miles Traveled

How CAVs are fueled is a critical question in the development and deployment of this technology. However, automakers alone don't drive the demand for how much we travel, and therefore, how much fuel we use. As society moves toward a future where most vehicles are self-driving, how and how often people travel by car and other transportation modes could change significantly. The most common tool of measurement for how much we drive is VMT, defined by the Federal Highway Administration (FHWA) as a measurement of miles traveled by vehicles within a specified region over a specified time period.

After rising steadily each decade of the 20th century, VMT has tapered off in many states in recent years. In fact, in Michigan, it has been declining for several years. For example, in 2008, Michiganders drove 101.8 billion miles, whereas by 2015, that total had dropped to 95.1 billion miles. Given Michigan's population decline over those years, VMT per capita is a potentially more revealing measure than total VMT. Even when adjusting for changes in population, Michiganders drove less in recent years—with Michigan's VMT per capita moving from 10,179 in 2008 to 9,584 in 2015, a 5.8 percent decline (Bureau of Transportation Statistics 2017; FHWA 2017).

But recent trends in VMT alone cannot predict the future. Several studies and simulations have estimated the potential impact of CAVs on VMT, specifically the impact of self-driving vehicles. These studies have been based on local case studies and on business models like automated taxis. While it is premature to draw conclusions on the overall effect that CAVs will have on travel patterns, it is possible to identify which factors will likely increase or decrease VMT. It is also important to note that many of these factors could have an amplified effect when taken together.

VMT is influenced by a variety of factors, and CAV technology is most likely to affect VMT through changes in these factors. Influences that could increase or decrease VMT are explored in Exhibit 3.

EXHIBIT 3. Factors Contributing to CAV and VMT

Factors to Increase VMT	Factors to Decrease VMT
Increased travel time due to lower value of travel time	Shared automated vehicle programs
Zero occupancy VMT	Reduced vehicle ownership
Reduced trip chaining	Increased vehicle occupancy (e.g., ridesharing)
Shifts away from mass transit and biking	First- and last-mile solutions combined with mass transit
Sprawling land development patterns	Reduced parking demand
Remote parking locations	Dense land development patterns
Increased mobility of nondrivers (elderly, youth)	
Private ownership of automated vehicles	

Source: Center for Automotive Research 2017

MICHIGAN'S ROLE IN THE FUTURE OF MOBILITY

Michigan's role in the future of mobility has several components. As outlined previously, in the private sector, many Michigan-based auto manufacturers are investing heavily in research and development of both CAVs and IMS. This includes Michigan's longstanding OEMs, including GM, Ford, and FCA, but Southeast Michigan is also home to an increasing number of other automakers conducting CAV R&D. For example, Toyota has a development arm working on self-driving cars in Ann Arbor, and FCA has teamed up with Waymo (a division of Google's parent company, Alphabet) to work on CAVs at a development center in Novi (Boudette 2017).

The location of these sites is due in part to a considerable university- and public-sector investment in development and deployment of these technologies. Michigan has long been the site of significant state- and federally-supported CAV research and testing initiatives, including a 2005 U.S. Department of Transportation connected vehicle proof of concept project.

But perhaps the strongest draw is in Ann Arbor, the home of Mcity, and in Ypsilanti, the home of the ACM. Mcity is a 32-acre testing ground that opened in 2015. It features simulated city streets, intersections and storefronts where carmakers and others can test CAVs. Dozens of companies, including GM, Toyota, Honda, BMW, and Intel, conduct research there in collaboration with U-M. The ACM, a 500-acre facility located at the historic Willow Run site in Ypsilanti, is designed to enable safe validation and certification of CAV technology, and has many unique features to simulate real-world driving conditions (PlanetM 2018).

State government is invested, too. The Michigan Department of Transportation (MDOT) has led several connected vehicle tests and pilot deployments aimed at enabling vehicle-to-vehicle and vehicle-to-infrastructure communication. MDOT is focusing its efforts on four initial CAV applications: red light violation warning, work zone warning, road weather management, and pavement condition monitoring (PlanetM 2018). To that effect, for example, MDOT has equipped 15 vehicles from its fleet with sensors capable of collecting and transmitting information on pavement condition as part of the Vehicle-based Information and Data Acquisition System project.

SUPPLY CHAIN OF CLEAN FUELS

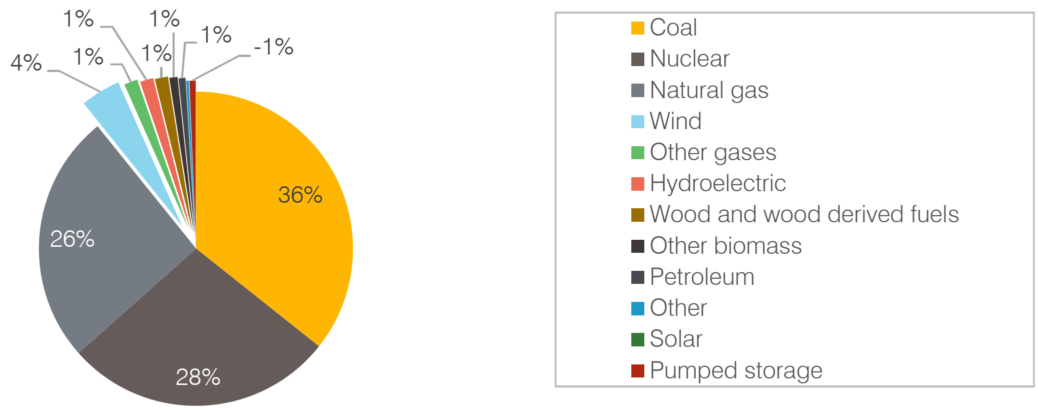
Because vehicles have used gasoline and diesel for decades, an effective supply chain has been developed to deliver these fuels to motorists. Notably, Michigan has thousands of service stations across the state where drivers can refuel. Because clean fuel vehicles are powered with fuels being used for other purposes, Michigan does have existing supply chains in place for these fuels, but the extent to which these supply chains can already readily support easy vehicle refueling varies by fuel type. In this section, the supply chains for the following clean fuels are examined: electricity, natural gas—both compressed (CNG) and liquified (LNG), propane, ethanol, biodiesel, and hydrogen.

ELECTRICITY

Vehicles powered by electricity, either exclusively or in part, have grown in popularity as new models have offered expanded range and improved performance, but one of the biggest drivers for electric and plug-in hybrid vehicle adoption is the prevalence of electric infrastructure in Michigan and across the nation. There are 58 providers delivering electricity across the state—eight investor-owned utilities, nine electric cooperatives, and 41 municipal electric utilities. These companies deliver electricity to every corner of the state, serving more than four million residential accounts (U.S. EIA November 2017a).

Michigan's electric infrastructure is part of the international bulk power grid serving central Canada, Ontario, the Great Plains, the Midwest, southeastern states, and the entire eastern seaboard. This means the state's electric supplies are intertwined with those of neighboring states and provinces. However, much of Michigan's electricity demands are met by resources in our state. Michigan is home to 253 different power-producing facilities capable of producing 29,083 MWs of electricity (U.S. EIA January 25, 2018). Exhibit 4 provides a breakdown the state's electricity supply fuel sources.

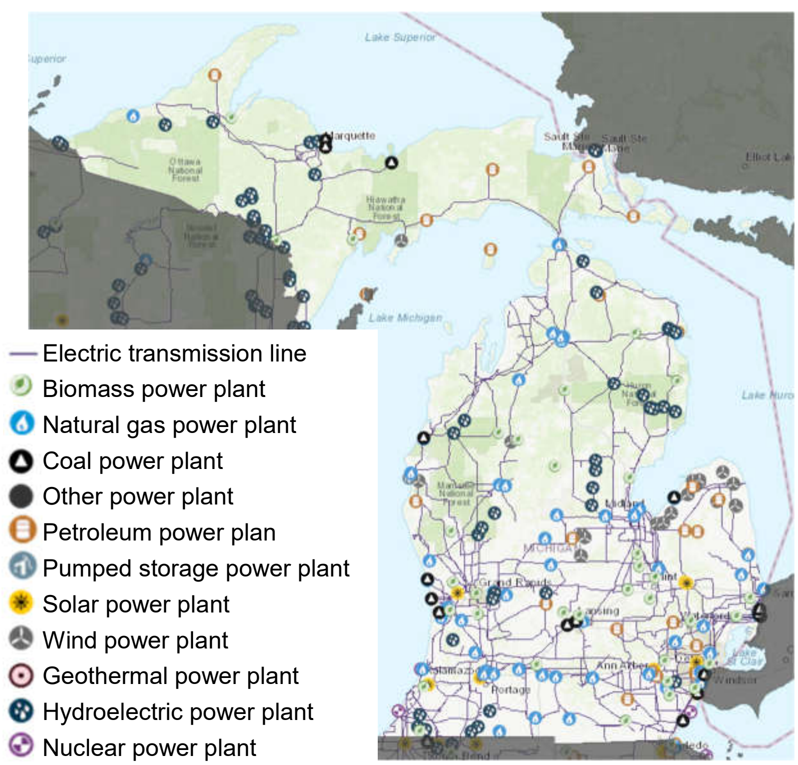
EXHIBIT 4. Annual Electric Generation, 2016



Source: U.S. EIA November 2017

Michigan's electric resources are deployed throughout the state and transported via high-voltage electric transmission lines. A map of Michigan's electric infrastructure is shown below in Exhibit 5.

EXHIBIT 5. Electric Infrastructure Map

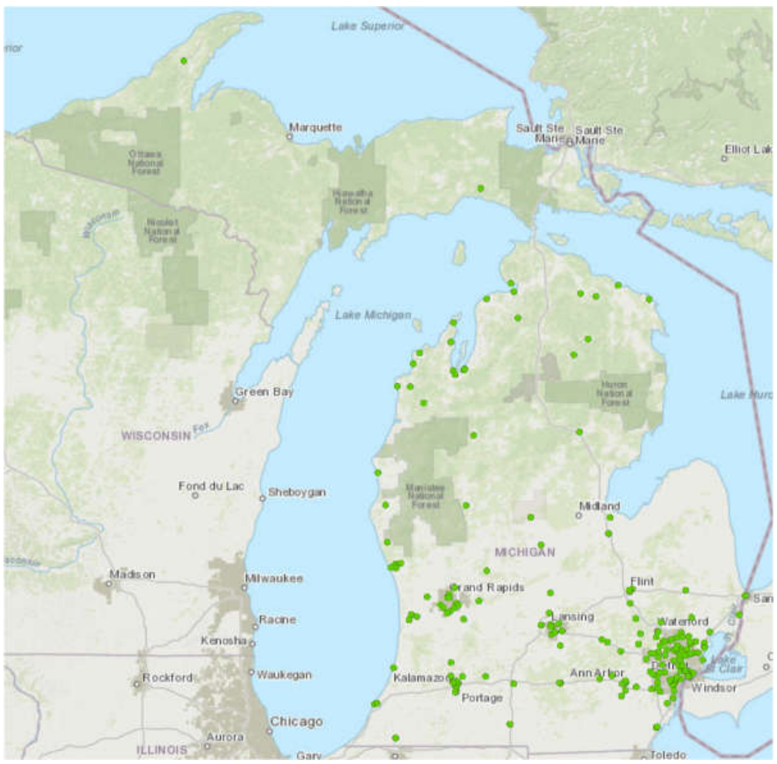


Source: U.S. EIA n.d.

Michigan's existing electric infrastructure creates many opportunities for the deployment of EVs because the system already delivers electricity throughout the state to households, businesses, and industrial customers. The transportation sector currently consumes, less than 1 percent of Michigan's total electricity demand (U.S. EIA November 2017b).

According to the U.S. Department of Energy's (U.S. DOE's) Alternative Fuel Data Center there are 346 EV charging stations operating in Michigan; this figure does not include home charging stations (U.S. DOE February 27, 2018). A map of Michigan's current EV charging stations is available in Exhibit 6.

EXHIBIT 6. Electric Vehicle Charging Stations, February 2018



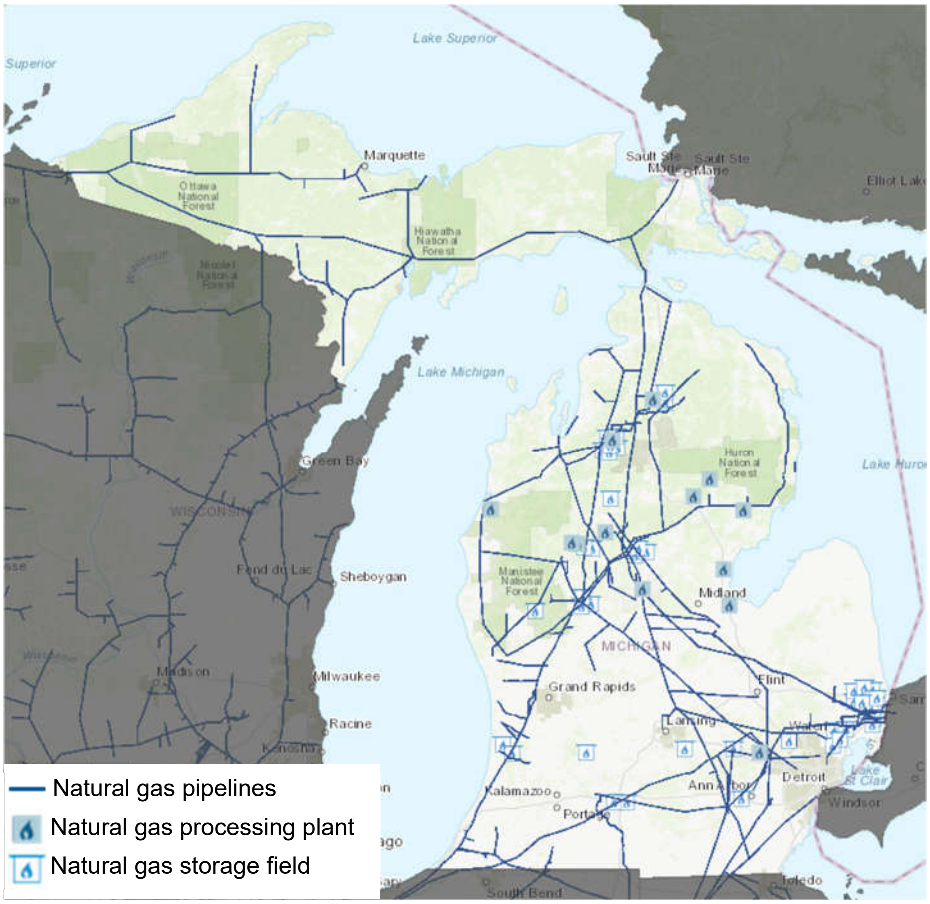
Source: U.S. EIA February 27, 2018

NATURAL GAS

Like the state's electric system, Michigan's existing natural gas infrastructure is expansive. Michigan's Antrim gas field in the northern Lower Peninsula is one of the top 100 producing natural gas fields in the U.S. (U.S. EIA n.d.). In 2016, the state produced 99,149 million cubic feet of natural gas from 9,577 production wells (U.S. EIA January 2018a). Michigan also has the capacity to process the natural gas it produces using the 13 processing plants in the state, which have a capacity of 126 MMcf/d (U.S. EIA January 2018b).

While the state does produce some of its own natural gas, annual consumption is much higher than the amount produced. Natural gas produced in Michigan represents about 15 to 20 percent of the total gas consumed in the state (MPSC 2018). Since Michigan's consumption outpaces its production, the state must depend on interstate pipelines to meet its natural gas needs. There are ten pipelines delivering natural gas to Michigan, representing import capacity of nearly 10,000 million cubic feet per day (U.S. EIA May 11, 2017). Despite relying on natural gas imports, Michigan can insulate itself from supply shocks that may impact other natural gas importers because of existing abundant underground storage capacity. Michigan is home to 10 percent of the nation's underground natural gas storage capacity—the most of any state. A map of Michigan's natural gas infrastructure is shown below in Exhibit 7.

EXHIBIT 7. Natural Gas Infrastructure Map



Source: U.S. EIA n.d.

There are 11 natural gas utilities in Michigan providing service to 3.2 million residential accounts in the state through 58,000 miles of distribution mains and 54,200 miles of service lines (U.S. EIA January 2018c). Though natural gas is consumed for home heating and other uses across Michigan, less than one percent of the state's total natural gas consumption is for transportation. Natural gas used for transportation must first be compressed or liquified before it fuels a vehicle.

There are 24 CNG fuel pumps operating in the state. Most of the compressed natural gas dispensed is compressed onsite for use in vehicles (U.S. EIA February 27, 2018). Use of LNG for vehicles is less common than the use of CNG since the fuel is less practical. There are no LNG fueling stations in the state of Michigan, and the fuel cannot be transported in existing natural gas pipelines, as it needs to be cooled and stored at -260°F; thus, LNG is delivered to consumers via trucks (U.S. DOE April 12, 2017).

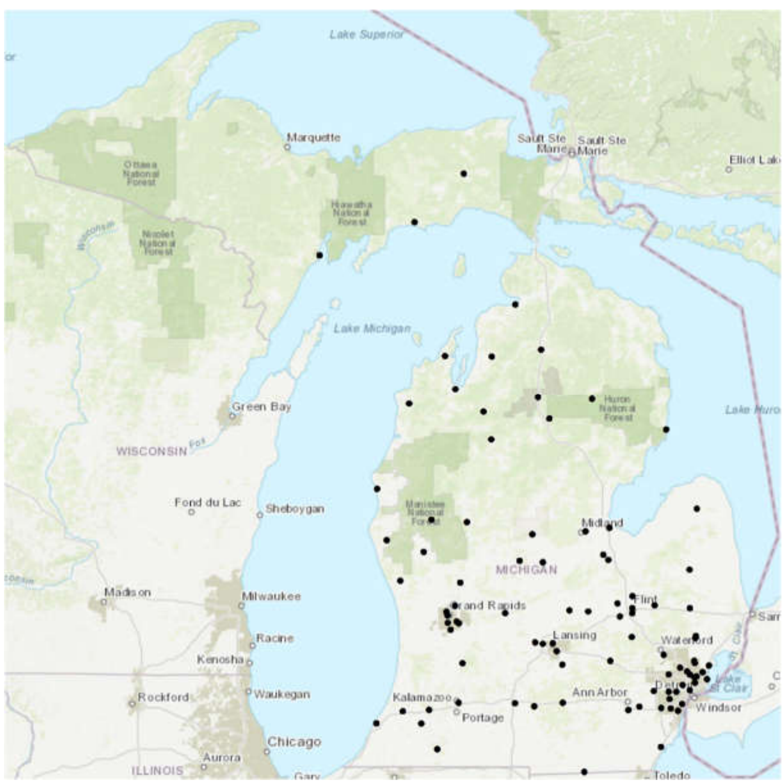
PROPANE

Propane is a very important fuel in Michigan. In 2017, the state consumed 328.7 million gallons of propane—the tenth most in the nation (U.S. EIA February 22, 2018). There are over 300,000 households using propane for home heating in Michigan. However, before propane can be used as fuel for homes or vehicles, it must first be separated from other hydrocarbon gas liquids (HGLs) present in the natural gas stream. Propane is just one type of HGL produced as a by-product of natural gas processing and crude oil refining. For propane to be sold as fuel, it must first be separated from the other HGLs through a process called fractionation, but Michigan has limited processing facilities for propane production. Because of this, Michigan relies on propane delivery from out of state, and roughly half of the propane supply comes from facilities in Sarnia, Ontario. The remainder of Michigan's propane supply comes from producers throughout the U.S. and Canada (U.S. EIA December 13, 2017).

Since propane is predominately used as a heating fuel, the demand varies during the year. This can create seasonal issues related to propane supply and price. Michigan avoids serious market swings by storing propane underground, just as it does with natural gas. Suppliers also utilize above-ground storage at distribution terminals for propane. From storage, propane is transported to customers via specialized delivery trucks.

There are 107 propane fueling stations in the state, shown in the map in Exhibit 8.

EXHIBIT 8. Propane Fueling Stations, February 2018



Source: U.S. EIA February 27, 2018

BIOFUELS—ETHANOL AND BIODIESEL

Biofuel describes a broad category of fuels produced from an assortment of plant material. In this paper, two different biofuels are explored—ethanol and biodiesel.

Ethanol is a renewable fuel that can be made from plant materials, such as corn, switchgrass, sugar beets, sugar cane, or wheat. In the U.S., the most ethanol is produced from corn (U.S. EIA May 2017a). Since corn is the main feedstock for ethanol production, the bulk of ethanol production facilities are located in the Midwest. The largest producers of ethanol are Iowa, Nebraska, Illinois, Minnesota, and Indiana (NEO 2018). Michigan is home to five ethanol plants with the combined capacity to produce 269 million gallons per year (U.S. EIA June 20, 2017).

Following processing, ethanol is transported to fuel terminals via truck and train to be blended with gasoline. Over 97 percent of all U.S. gasoline is blended with ethanol in some proportion, usually 10 percent ethanol (U.S. EIA May 2017b).

FFVs operate using fuel that is up to 83 percent ethanol and 15 percent gasoline (E85).[1] They are the most common clean fuel vehicle in Michigan, likely because the infrastructure for E85 fuel is analogous to traditional gasoline stations and the vehicle technology is similar to standard gasoline vehicles. E85 fueling stations are the most common alternative fuel station in Michigan, with 253 stations operating.

Unlike ethanol, which is produced directly from plant matter, biodiesel is produced from vegetable oils, animal fats, and other cooking oils. In 2017, the U.S. produced 1,595 million gallons of biodiesel. Over 50 percent of the nation's biodiesel production capacity comes from just five states—Texas, Iowa, Missouri, Illinois, Indiana. Michigan has two biodiesel producers with a production capacity of 10 million gallons per year (U.S. EIA February 26, 2018).

Biodiesel is distributed from producers to fuel terminals and wholesalers predominately by truck and train. Michigan only has nine biodiesel fueling stations.

HYDROGEN

Hydrogen is one of earth's most abundant resources, but it is only found naturally in compounds with other elements. To use hydrogen as a fuel, it must first be separated from other elements. Over 95 percent of the hydrogen fuel produced in the U.S. comes from a process called steam methane reforming (U.S. EIA November 2010).

Nearly all hydrogen produced domestically is used in petroleum refining, metallurgical treatments, fertilizer production, and food processing and most is produced in California, Louisiana, and Texas (U.S. EIA November 7, 2017). Before being transported, Hydrogen must be pressurized, and the compressed gas is then delivered via truck to refueling stations or other end users.

Hydrogen transportation infrastructure is still very limited. California has made efforts in recent years to expand the availability of hydrogen fueling stations and car makers have begun offering hydrogen vehicles in the state, but across the rest of the country much needs to be done to support hydrogen vehicles.

[1] Although labeled E85, gasoline-ethanol blends have between 51 percent and 83 percent ethanol.

Michigan has two hydrogen fueling stations for private use (Flint and Dearborn) and zero public hydrogen charging stations.

ECONOMIC CONTRIBUTION OF CLEAN FUELS FOR TRANSPORTATION TO MICHIGAN

Clean fuels economic activity is important to Michigan. Clean Jobs Midwest (2017) estimates that Michigan is home to 92,000 clean energy jobs, and Michigan's almost 50,000 clean energy jobs in manufacturing is more than any other state. Not surprisingly, Michigan has many clean energy jobs related to advanced transportation. Clean Jobs Midwest estimates that the state has almost 29,000 direct clean fuel jobs relating to vehicles. In this section, we provide estimates of the full economic contribution of clean fuel vehicles, including the direct, indirect, and induced contributions. [2]

The direct contribution relates to the jobs, labor income, and economic output from firms directly involved with clean fuel vehicles (a firm manufacturing vehicles). The indirect contribution represents the jobs, labor income, and economic output from the purchases of the firms included in the direct impact (a firm hiring a trucking company for support), while the induced contribution represents the economic contribution from the employees of these firms (e.g., a firm's employees purchasing goods at a store).

These economic contributions were estimated using the IMPLAN model. IMPLAN is an input/output model of the economy designed to estimate direct, indirect, and induced effects. Developed in the 1970s by the U.S. government, the IMPLAN model has been refined through the years and is used by business, government, and nonprofits to estimate economic impacts. To support the IMPLAN analysis, we allocated the 29,000 direct jobs across industry sectors using national estimates of clean fuel vehicle jobs. These estimates were produced by the U. S. DOE in 2017. DOE's analysis found approximately 39 percent of the direct clean fuel motor vehicle jobs were concentrated in the manufacturing sector; 38 percent in repair, maintenance, and other services sector; 21 percent in wholesale trade, distribution, and transport; and just over 2 percent in professional and business services. The U.S. DOE estimates were used to allocate the 29,000 direct jobs across industry sectors prior to their input into the IMPLAN model.

EXHIBIT 9. Economic Contribution of the Clean Fuel Vehicle Sector

Impact Type	Employment	Labor Income	Output
Direct Effect	28,586	$2,201,777,315	$11,626,584,647
Indirect Effect	18,201	$1,262,162,116	$4,101,682,008
Induced Effect	22,607	$988,325,792	$3,073,728,627
Total Effect	69,394	$4,452,265,222	$18,801,995,281
Multiplier	2.43	2.02	1.62

Source: PSC IMPLAN analysis. Columns may not total due to rounding.

Exhibit 9 shows the results of the IMPLAN analysis. As noted, almost 29,000 people are directly employed in the clean fuel vehicle sector. The employment total rises to approximately 69,000 when

[2] This paper contains estimates of the economic contributions of these jobs. It is not a full economic impact study in that we do not attempt to estimate how many of these jobs would still be in Michigan in the absence of this economic activity. In other words, this study contains the gross economic impact of clean fuel vehicle manufacturing rather than the net impact.

indirect and induced jobs are included. This represents a multiplier effect of 2.43, meaning for each direct job in the sector, Michigan has an additional 1.43 jobs resulting from indirect and induced employment.

The sector has $2.2 billion in direct labor income and $4.5 billion in labor income when indirect and induced employment is included, representing approximately $450 of labor income per capita in Michigan. The sector's economic output is approximately $18.8 billion when direct, indirect, and induced employment are included, an economic contribution of over $1,800 per person.

The IMPLAN model also estimates the state and local taxes generated by economic activity. The clean fuel vehicle sector generates an estimated $730 million in state and local taxes for Michigan each year.

ENVIRONMENTAL BENEFITS OF CLEAN FUELS

In 2016, the U.S. consumed 3.3 billion gallons of petroleum for transportation uses—up 2.3 percent from the previous year (U.S. Department of Transportation June 2017). This represents 70 percent of U.S.'s total petroleum use and is responsible for 27 percent of the nation's greenhouse gas (GHG) emissions (National Renewable Energy Laboratory 2016). The development of clean fuel vehicle technologies has the potential to decrease the U.S.'s dependence on petroleum and reduce the amount of harmful emissions due to transportation.

The environmental benefits offered by clean fuel vehicles vary by technology and fuel type. This paper examines the environmental impact of the following clean fuel vehicle technologies—FFVs powered by ethanol, CNG vehicles, LNG vehicles, liquified petroleum gas (propane) vehicles, diesel vehicles powered by biodiesel, hydrogen fuel cell vehicles, hybrid EVs, plug-in hybrid EVs, and purely electric vehicles.

This report relies on data from the Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) Model developed by scientists at the Argonne National Laboratory. The GREET Model measures the life cycle energy use and emission impacts from clean fuel vehicle technologies to provide a complete accounting of emissions from the raw energy source to the vehicle on the road—referred to as "well-to-wheel." Well-to-wheel (WTW) emissions are broken down into two categories, well-to-pump (WTP) and pump-to-wheel (PTW). WTP emissions capture all emissions related to fuel production, processing, and distribution, and PTW represents all emissions during the vehicle operations. The GREET Model provides emissions rates for clean fuel vehicles in grams per mile. This allows us to examine not only the mile-for-mile difference in emission rates, but also to quantify the annual emissions reductions from the clean fuel vehicles currently deployed in Michigan.

EMISSIONS RATES

Using standard gasoline-powered vehicles as a baseline, this paper compares the emissions rates of seven environmental contaminants for ten different clean fuel vehicle technologies to determine whether and how much clean fuel vehicles benefit the environment. Exhibit 10 provides a comparison of emission rates by contaminant and vehicle type.

EXHIBIT 10. Comparative Emissions from Clean Fuel Vehicles

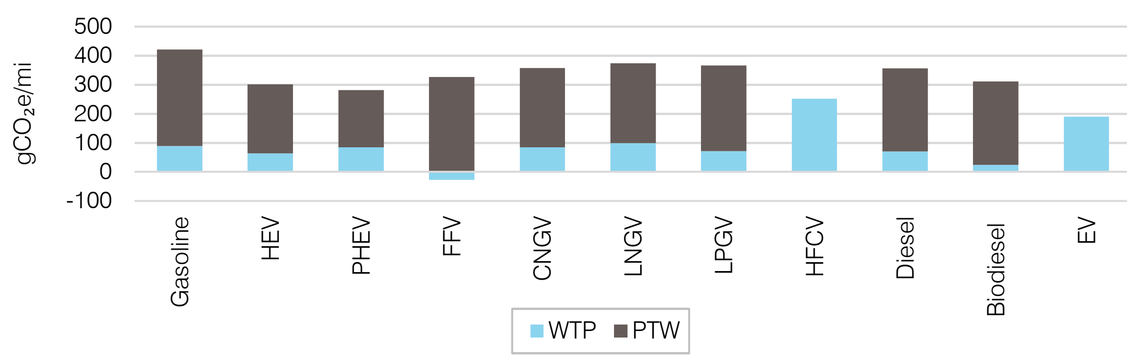
	Total Energy	Fossil Energy	GHG	VOC	CO	NOx	PM10	PM2.5	SOx
Gasoline	100%	100%	100%	100%	100%	100%	100%	100%	100%
Hybrid electric (HEV)	-29%	-29%	-28%	-27%	-1%	-23%	-11%	-15%	-29%
Plug-in hybrid electric (PHEV), 10 miles	-33%	-34%	-33%	-39%	-19%	-30%	-9%	-18%	10%
Flexible fuel, corn	24%	-40%	-29%	21%	3%	66%	107%	59%	184%
Compressed natural gas	-5%	1%	-15%	-39%	3%	13%	-29%	-39%	-24%
Liquid natural gas	-1%	6%	-11%	-43%	1%	-9%	-28%	-31%	-42%
Liquified petroleum gas (LPGV)	-10%	-4%	-13%	-31%	0%	-17%	-25%	-29%	-13%
Hydrogen fuel cell (HFCV)	-33%	-30%	-40%	-90%	-96%	-43%	-29%	-45%	2%
Diesel vehicle	-21%	-16%	-15%	-59%	3%	-15%	-20%	-20%	-42%
Biodiesel vehicle, 20%	-18%	-29%	-26%	-58%	3%	-13%	-20%	-20%	-34%
Electric vehicle	-53%	-58%	-55%	-95%	-98%	-57%	6%	-27%	206%

Source: PSC calculations using data compiled from Argonne National Laboratory 2017.

Greenhouse Gases

All clean fuel vehicle technologies examined in this report have lower GHG emissions per mile than traditional gasoline-powered vehicles. EVs have the lowest levels of greenhouse gas emissions, emitting less than half as many greenhouse gases per mile than a gasoline-powered vehicle. CNG, LNG, LPG, and diesel vehicles provide the least benefit compared to gasoline vehicles, only reducing emissions by 15, 11, 13, and 15 percent respectively. Vehicles' GHG emissions per mile are shown in Exhibit 11.

EXHIBIT 11. Well-to-wheel Greenhouse Gas Emissions, Grams Carbon Dioxide Equivalent Per Mile

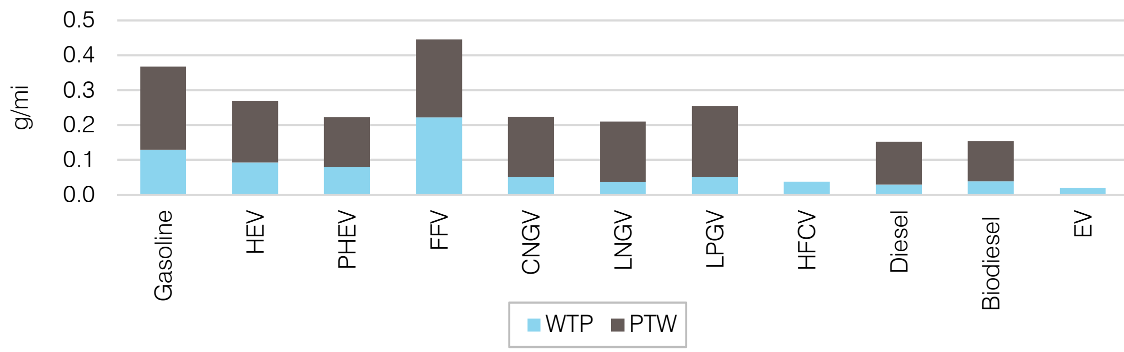


Source: Argonne National Laboratory 2017

Volatile Organic Compounds

Clean fuel vehicle's emissions of VOC vary widely. VOCs include a variety of chemicals, some of which may have short- and long-term adverse health effects (U.S. Environmental Protection Agency 2017). Of the technologies examined, only FFVs emitted more VOCs than gasoline vehicles. FFV and gasoline vehicles actually emit roughly the same amount of VOCs during vehicle operation, but the amount of VOCs emitted during the processing of ethanol production is much higher. All other clean fuel vehicle technologies examined offer improved emissions compared to gasoline vehicles, but hydrogen fuel cell and electric vehicles performed the best by far, reducing emissions by greater than 95 percent. A breakdown of VOC emissions by vehicle type is shown in Exhibit 12.

EXHIBIT 12. Well-to-wheel Volatile Organic Compounds Emissions, Grams Per Mile

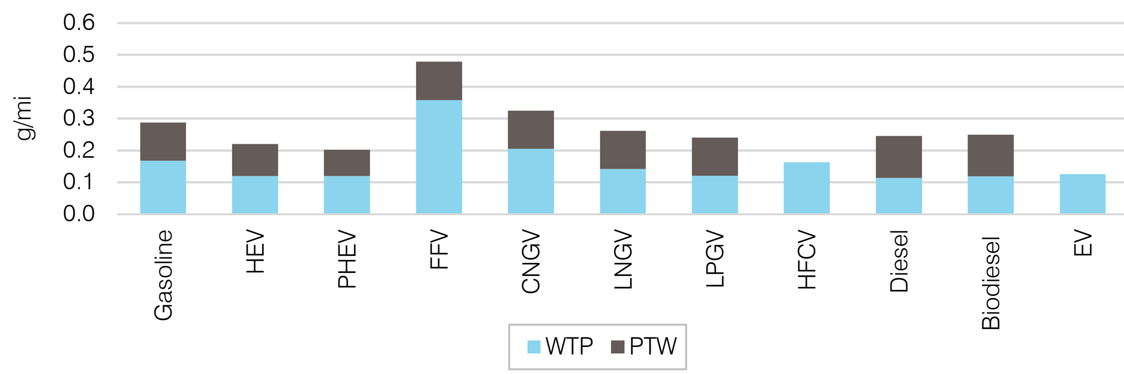


Source: Argonne National Laboratory 2017

Oxides of Nitrogen

Eight out of the ten clean fuel vehicle technologies examined have reduced NOx emission rates. EV and HFCV again provide the greatest reduction in emissions compared to gasoline vehicles. This is due, in part, to these technologies having zero NOx emissions during vehicle operations and their only emissions are due to fuel production and distribution. Only FFV and CNGV have higher NOx emissions than traditional gasoline vehicles due primarily to the fact that there are higher rates of NOx produced during the fuel processing and disposition. The NOx emission rates are provided in Exhibit 13.

EXHIBIT 13. Well-to-wheel NOx Emissions, Grams Per Mile

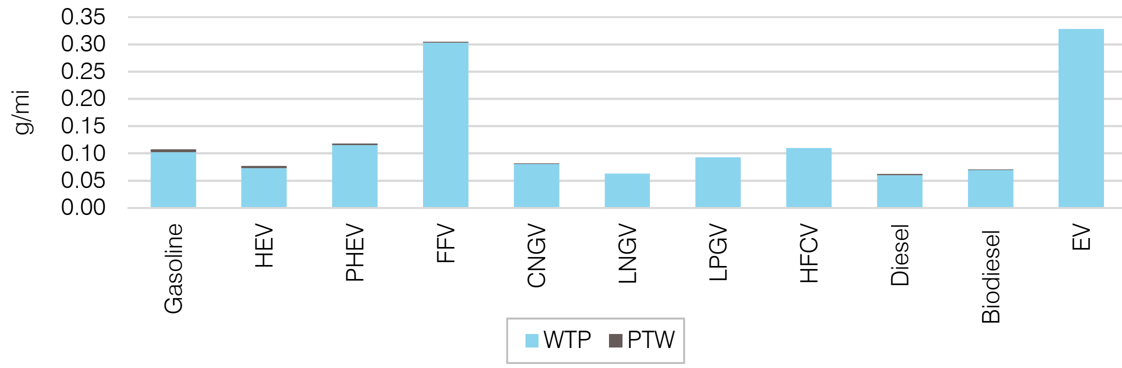


Source: Argonne National Laboratory 2017

Oxides of Sulfur

Nearly all of the SOx emissions from vehicles are generated from WTP. EVs have the highest rate of SOx emission per mile, due primarily to the burning of coal to generate electricity. Similarly, FFVs have a high rate of SOx emissions because of the amount of fossil energy consumed during the production of ethanol. The other clean fuel vehicles that produce more SOx per mile than gasoline vehicles are HFCV and PHEV.

EXHIBIT 14. Well to Wheel SOx Emissions, grams per mile

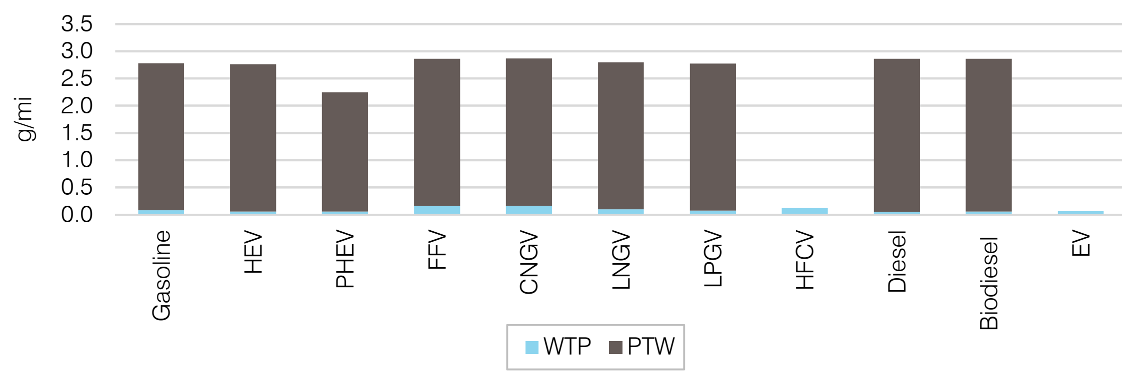


Source: Argonne National Laboratory 2017

Carbon Monoxide (CO)

All of the vehicles examined have roughly the same rate of CO emissions during the WTP phase; however, emissions from PTW are varied. EV and HFCV have no CO emissions during vehicle operation. PHEV also have lower CO emissions than gasoline vehicles during vehicle operation. The remaining seven vehicle types emit essentially the same level of CO as traditional gasoline vehicles. CO emission rates are shown in Exhibit 15.

EXHIBIT 15. Well-to-wheel CO Emissions, Grams Per Mile

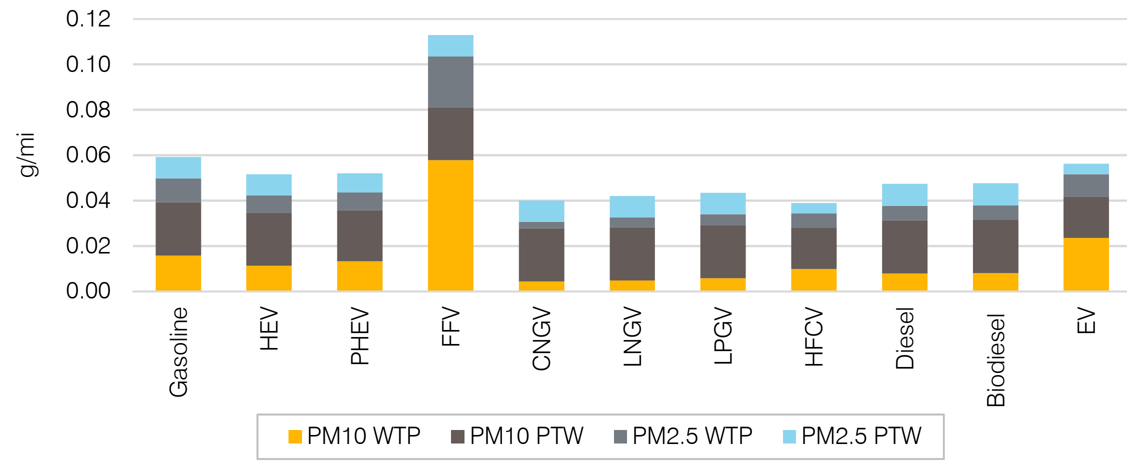


Source: Argonne National Laboratory 2017

Particulate Matter 2.5 and 10

All clean fuel vehicle technologies examined have lower PM emissions than traditional gasoline vehicles except for FFVs. The increased emissions from FFVs are attributed to the production of ethanol.

EXHIBIT 16. Well-to-wheel PM 2.5 and PM 10 Emissions, Grams Per Mile



Source: Argonne National Laboratory 2017

EMISSION REDUCTIONS

According to data obtained from the Michigan Department of State, there are more than 16 million vehicles—model year 1984 or newer—registered in the state. Of those vehicles, 1.88 million are considered clean fuel vehicles as categorized in this paper, representing 11.7 percent of all Michigan vehicles. The largest portion of alternative fuel vehicles in the state are FFV, which comprise 93 percent of the alternative fuel vehicles registered in Michigan. The state's data does not differentiate between HEV and PHEV, and combined, these vehicles only make up 0.8 percent of the cars in the state. EVs are the third most prevalent alternative fuel vehicle, representing just 0.3 percent of all vehicles in the state. Exhibit 17 provides a complete breakdown of vehicles registered in Michigan.

EXHIBIT 17. Michigan Vehicle Registrations, 1984 or Newer as of March 2018

Vehicle Fuel Type	Number of Vehicles	Percent
Alcohol	1	0.00%
Electric and Gas Hybrid[3]	124,768	0.78%
Convertible	7,912	0.05%
Diesel	954,907	5.94%
Electric	4,981	0.03%
Flexible	1,752,236	10.90%
Gas	13,235,963	82.30%
Ethanol	13	0.00%
Liquid Natural Gas	0	0.00%
Compressed Natural Gas	958	0.01%
Propane	735	0.00%
Unknown	447	0.00%
Electric and Diesel Hybrid	3	0.00%

[3] Hybrid electric and plug-in hybrid electric vehicles cannot be separated in the Secretary of State registration data.

Total	**16,082,924**

Source: PSC calculations based on data provided by the Michigan Department of State Commercial Services Division.

While clean fuel vehicles have the potential to benefit the environment through reduced emissions when compared to gasoline vehicles, the overall impact of the clean fuel vehicles currently registered in Michigan is mixed. Based on the state's current deployment of clean fuel vehicles, annual GHG, and VOCs, emissions have been reduced; however, emissions for the five other pollutants examined increased. This is because FFV, which make up the bulk of the clean fuel vehicles currently on the road in Michigan, provide only limited environmental benefits. As previously outlined, FFVs perform worse than traditional gas vehicles on six of the seven emissions studied. FFVs resulted in a reduction in greenhouse gas emissions, totaling 3.1 million tons annually, but an increase in the six other pollutants examined. However, it is important to note that this estimate assumes that FFVs are fueled using an 83 percent ethanol blend. FFVs also can run using unleaded gasoline, and realistically, many of them do.[4] FFVs doing this would have the same emissions as traditional gasoline-powered vehicles.

Despite the environmental impact of FFVs, other alternative fuel vehicles examined show the potential for emissions reductions; however, due to limited deployment to date, they have had less impact on the state's emissions overall. A complete breakdown of the emissions impact for the current deployment of alternative fuel cell vehicles is provided in Exhibit 18.

EXHIBIT 18. Annual Emissions Reduction from Clean Fuel Vehicles in Michigan

	HEV/PHEV[5]	FFV[6]	CNGV	LNGV	LPGV	HFCV	Diesel	Biodiesel	EV	Total (tons)
GHG	-221,943	-3,181,530	-905	0	-600	0	-921,146	0	-17,112	-4,343,235
VOC	-183	2,011	-2	0	-1	0	-3,059	0	-26	-1,260
CO	-41	2,021	1	0	0	0	1,091	0	-201	2,871
NOx	-124	4,968	1	0	-1	0	-606	0	-12	4,227
PM2.5	-6	307	0	0	0	0	-57	0	0	243
PM10	-8	1,093	0	0	0	0	-111	0	0	974
SOx	-57	5,133	0	0	0	0	-642	0	16	4,450

Source: PSC calculations using Argonne National Laboratory 2017.

Though Michigan's current deployment of clean fuel vehicles is limited, nearly all of the clean fuel vehicle technologies examined—with the exception of FFVs—will produce environmental benefits as deployment increases. Specifically, as Michigan's electric generation portfolio continues to transition away from coal to cleaner fuels and renewable resources HEVs, PHEVs, and EVs will yield greater environmental benefits.

[4] Almost all gasoline has at least some ethanol in it, generally between 10 and 15 percent. The ethanol-blended fuel that FFVs can use has an ethanol concentration of between 50 and 83 percent.

[5] HEV and PHEV vehicles cannot be separated in the registration data.

[6] The FFV estimates in Exhibit 18 assume that all FFV vehicles in Michigan are using fuel made with 83 percent ethanol. These vehicles can also run on traditional gasoline and many do this exclusively.

HEALTH BENEFITS OF CLEAN FUELS

Burning petroleum and other substances to fuel vehicles creates a significant amount of pollution. As highlighted in the previous section, the environmental benefits offered by clean fuel vehicles vary by technology and fuel type. The development of clean fuel vehicle technologies has the potential to bring a variety of health benefits to Michigan, including reducing harmful emissions of air toxins and particulate matter. Reductions in exposure to unhealth air may lead to improved public health in Michigan communities. These improved public health outcomes may also lead to significant monetary savings, particularly savings associated with reduced Medicaid expenditures.

AIR POLLUTION AND AIR QUALITY

Although clean fuel vehicle technologies have the potential to improve human health in several ways, the primary benefits are experienced through improved air quality. More specifically, in comparison with petroleum-based fuel, increased deployment of most clean fuel vehicle technologies should lead to reductions in one or both of the two key forms of harmful air pollution in the U.S.—particulate matter and ozone.

Referred to colloquially as soot, PM is a complex mixture of particles and liquid droplets made up of acid, organic chemicals, metals, sand, soil, and dust particles. These particles are tiny—30 times smaller than the diameter of a human hair—allowing them to pass into human airways and lodge deep in the lungs, where they can cause both breathing and circulatory problems. The metals present in particulate matter, such as lead and mercury, can cause cancer.

Ozone is another air pollutant, often referred to as smog in common parlance, a term first used in the early 1900s in London to describe the combination of smoke and fog created by industrial air pollution that plagued the city at the time. More than just smoke plus fog, ozone is created in the atmosphere when hydrocarbon vapors react with three emissions compounds—VOCs, NOx, and CO—while in the presence of sunlight. Not only can ozone damage property and ruin sunny summer days (by saturating the light), it causes health problems. As people inhale ozone, it oxidizes, reacting chemically with the body's internal tissues to create inflammation. The result can be respiratory problems, irritated eyes, or other inflammation-related health issues.

Michigan is a sizeable state in terms of land area, and air quality across the states varies. Michigan currently ranks 24th in the country in PM-related air quality, with an average of 8.8 micrograms of PM per cubic meter of air. This is lower than the national average of 9.5 micrograms (United Health Foundation 2018). Monitoring data shows that Michigan has seen decreases in PM air pollution over time to get to this rate of 8.8 micrograms; in 2008, the average for Michigan was 13 micrograms—showing a 32 percent decrease in a decade (United Health Foundation 2018). However, there are still concentrated areas of particulate matter air pollution to be concerned about, particularly in urban areas. For example, according to the American Lung Association (2018), the Detroit-Warren-Ann Arbor region is ranked 18th highest in the country for annual particle pollution out of 184 metropolitan areas.

Ozone is another matter. According to 2014 data, over 20 Michigan counties received a failing grade for their smog levels, including heavily populated counties. A number of these communities are located on the state's west side, along the shores of Lake Michigan, where high ozone levels have been a historic problem (Shaffer 2017). The source of this pollution is assumed to be upwind urban areas, including

Chicago and Milwaukee, but the Lake Michigan Ozone Study, funded through a partnership of agencies, including NASA, the National Oceanic and Atmospheric Administration, and the National Science Foundation, is currently collecting more data.

HEALTH IMPACTS

The health of Michigan citizens is closely tied to the quality of the air they breathe. There is ample evidence linking outdoor air pollution with negative health outcomes. Poor air quality is a contributor to premature mortality, as well as asthma attacks and other respiratory problems. This section details some of the specific health impacts.

Asthma

One of the most obvious health benefits to shifting to cleaner transportation fuel sources and improving air quality is limiting harmful asthma attacks. Asthma is a chronic disease affecting the lungs, which is characterized by episodes of inflammation and a narrowing of the small airways in response to certain triggers. An environmental trigger, such as air pollution, can contribute to asthma and lead to an asthma attack, which can include wheezing, breathlessness, coughing, chest tightness, and disturbed sleep.

The prevalence of asthma in the U.S., along with several other health indicators, is tracked through the Behavioral Risk Factor Surveillance System, a national survey from the U.S. Centers for Disease Control and Prevention (CDC). In the most recent data from 2015, Michigan outpaces the national average in terms of the prevalence of asthma in adults both for individuals who currently have asthma and for individuals who were diagnosed at any point in the past.

Nationally, 9.2 percent of adults have been told that they currently have asthma and 14.3 percent of adults have been told they had asthma at some point in time (CDC 2015). In Michigan, these numbers are slightly higher, with 10.2 percent of adults currently suffering with asthma and 15.7 percent of Michiganders reporting asthma at some point in their health history (MDHHS 2017). However, children in Michigan fair better than the national average, 7.7 percent of Michiganders under the age of 18 currently suffer from asthma, compared to the national rate of 8.4 percent (CDC 2017).

While the development of asthma seems to have a genetic component, outside factors are what trigger asthma attacks. In recent years, there is a growing body of research that has found strong connections between air pollution and asthma attacks.

Other Health Impacts

Asthma is not the only chronic disease or condition exacerbated by outdoor air pollution. There are several other harmful health impacts of air pollution, including:

- **Cardiovascular disease:** In a 2006 study, researchers found that exposure to high ozone levels for as little as one hour was linked to a particular type of cardiac arrhythmia, one that itself increases the risk of premature death and stroke (American Lung Association 2017).
- **Cancer:** In late 2013, the International Agency for Research on Cancer, part of the World Health Organization, concluded that particle pollution could cause lung cancer. Polluted air has also been linked to urinary tract/bladder cancer (American Lung Association 2017).
- **Diabetes:** New research has found evidence that long-term exposure to PM air pollution may increase the risk of developing diabetes (American Lung Association 2017).

- **Autism:** There is now evidence to suggest that pregnant women who are exposed to outdoor air pollution are more likely to have a child diagnosed with autism (Harvard T.H. Chan School of Public Health 2014).
- **Mental health issues:** Scientists have found links between particle pollution and mental health concerns. A study of 27,000 residents in Seoul, Korea, found that breathing PM pollution over many years led to an increased risk of major depressive disorder (American Lung Association 2017).

HEALTHCARE COST IMPACTS

Given the myriad number of negative health impacts of outdoor air pollution, a switch to sources of cleaner transportation fuels that can reduce air pollution will lead to positive health benefits for Michigan residents. This includes fewer hospitalizations, reduced healthcare costs, and lives saved.

Researchers are still working to quantify the precise benefits of improved outdoor air quality on a number of health issues. However, the evidence of poor air quality resulting in profound healthcare costs has been documented for one chronic disease: asthma.

Asthma attacks can be disruptive and expensive. For example, sometimes attacks can require emergency treatment and hospitalization, forcing an asthma sufferer to miss school or work. According to recent data, there are nearly 17,000 asthma hospitalizations each year in Michigan (MI Air MI Health 2015). The average cost of a Michigan asthma-related hospital stay is $11,671, translating to over $394 million spent each year in Michigan on asthma hospitalizations.

Given that outdoor air pollution, including ozone and PM, is a known asthma trigger, reducing vehicle-related air pollution could have a sizable healthcare cost savings. The burden of air pollution is not typically spread evenly over communities, and numerous studies have demonstrated a link between socioeconomic status and harm from air pollution (American Lung Association 2018). Many of these studies have focused on the Medicaid population, and therefore, one way of measuring potential cost savings is through Medicaid spending related to asthma, which disproportionately affects low-income and minority populations, resulting in much of the care for asthma being paid for by the Medicaid program.

According to data from the Michigan Department of Health and Human Services, over $132 million per year of Michigan Medicaid dollars are dedicated to asthma care (MI Air MI Health 2015). Given the scenarios outlined in the previous section, with the exception of FFVs, all other alternative fuel vehicle technologies have lower comparative emissions for the kinds of harmful compounds that cause air pollution. Therefore, increased deployment is likely to lead to reduced healthcare costs overall, as well as reductions to Michigan's Medicaid spending burden.

A 2016 American Lung Association study estimated the negative health costs from the vehicle fleets of ten states. This study found an overall societal health costs of $11.82 per 16-gallon tank of gas used in these states. These costs consisted of asthma attacks, workdays lost due to respiratory illness, premature deaths, heart attacks, and emergency room visits and hospitalizations. The study examined a scenario in which 100 percent of the vehicles sold in 2050 were EVs, with 65 percent of the overall vehicle fleet consisting of EVs. Under this scenario, the health costs associated with passenger vehicle pollution across the ten states would fall by 88 percent, from $24 billion per year to just $3 billion.

INNOVATION

Cleantech, shorthand for clean technology, encompasses technology and business sectors that include clean energy as well as environmental and sustainable or green products and services (Cleantech.org 2015). Michigan is the national leader in developing cleantech transportation patents, submitting 22.3 percent of all cleantech transportation patents in the U.S. from 2011 to 2016. Innovators in Michigan submitted over 3,162 cleantech transportation patents—a significant lead of more than a thousand patents over the second highest state, California, which submitted 2,130 transportation patents. Michigan continues to rank number one in cleantech transportation patents on a per-capita basis, submitting 32 cleantech transportation patents for every 100,000 residents. This rate is more than double the next highest state, Connecticut, which submits just 14 transportation patents per 100,000 residents (Brookings 2017).

EXHIBIT 19. Cleantech Transportation Patents by State Location of Inventor, 2011 to 2016

State	Cleantech Transportation Patents	Rank	Patents Per Capita	Per Capita Rank
Michigan	3162.97	1	31.94	1
California	2130.12	2	5.53	7
Illinois	842.18	3	6.55	5
Washington	671.39	4	9.55	3
Texas	591.32	5	2.21	28
Florida	549.18	6	2.77	20
Connecticut	509.86	7	14.21	2
New York	501.68	8	2.55	25
Indiana	498.70	9	7.58	4
Ohio	496.11	10	4.28	11
Pennsylvania	340.84	11	2.67	22
Wisconsin	325.11	12	5.66	6
Massachusetts	312.18	13	4.65	10
Minnesota	292.56	14	5.38	8
Arizona	269.98	15	4.04	14
South Carolina	243.14	16	5.06	9
Virginia	221.00	17	2.67	21
New Jersey	202.45	18	2.27	26
Colorado	193.04	19	3.63	17
Georgia	173.85	20	1.73	37
North Carolina	169.61	21	1.71	38
Oregon	158.10	22	3.99	15
Maryland	131.83	23	2.22	27
Missouri	122.64	24	2.03	31
Utah	111.26	25	3.80	16
Iowa	105.42	26	3.40	18
Tennessee	78.68	27	1.21	44
Kansas	76.97	28	2.66	23
Oklahoma	76.43	29	1.98	32
Nevada	57.91	30	2.05	30
New Hampshire	56.43	31	4.26	12

State	Cleantech Transportation Patents	Rank	Patents Per Capita	Per Capita Rank
Louisiana	56.14	32	1.21	43
Alabama	48.65	33	1.01	47
Maine	42.50	34	3.20	19
Kentucky	37.77	35	0.86	48
New Mexico	36.60	36	1.76	36
North Dakota	30.62	37	4.21	13
Idaho	29.33	38	1.80	35
Nebraska	27.53	39	1.47	41
Hawaii	22.54	40	1.60	40
Rhode Island	19.97	41	1.89	33
Delaware	19.96	42	2.15	29
Mississippi	17.62	43	0.59	49
Vermont	16.64	44	2.66	24
Montana	16.32	45	1.60	39
South Dakota	15.33	46	1.81	34
Arkansas	14.10	47	0.48	51
West Virginia	10.70	48	0.58	50
Alaska	8.17	49	1.11	45
Wyoming	7.49	50	1.29	42
District of Columbia	7.18	51	1.10	46

Source: Brookings 2017

The Detroit-Warren-Dearborn metropolitan area and the Ann Arbor metropolitan area rank first and fifth respectively in the county in clean transportation patents. The Detroit-Warren-Dearborn area is by far the national leader with 2,169 clean transportation patents from 2011 to 2016; nearly four times as many as the next leading metropolitan area of Los Angeles-Long Beach-Anaheim with just 571 clean transportation patents. Less than 100 patents separate fifth-ranked Ann Arbor from the Los Angeles metro region, with Ann Arbor innovators submitting 494 clean transportation patents (Brookings 2017). Other Michigan metropolitan areas that rank well include Flint (38th highest), Grand Rapids-Wyoming (59th), Monroe (66th), and Lansing-East Lansing (71st).

Michigan is a national leader in this area of innovation due to its historic status as the home of the American auto industry. In addition, Michigan State University, the University of Michigan, and Wayne State University, which together are responsible for 94 percent of all federally funded research occurring in Michigan, help the state maintain its lead in innovation (University Research Corridor 2018).

Michigan's dominance in cleantech transportation research is a critical competitive advantage for the state, and maintaining this lead is important to ensuring that Michigan leads in transportation equipment manufacturing. As more and more vehicles move toward clean technologies, forerunners in cleantech innovation have an advantage in securing vehicle production, and spearheading innovation in cleantech transportation will help to ensure that Michigan remains a top performer in automobile manufacturing throughout the 21st century.

CONCLUSION

Clean fuel vehicles represent the future of mobility. Advances in technology combined with interest in reducing greenhouse gas emissions and air pollution will continue to move the market toward these vehicles. Michigan, as a center for traditional vehicle manufacturing and R&D, is well situated to be a leader in the development and production of clean fuel vehicles. However, the state should not simply assume that its leadership role is preordained. The auto sector directly supports 15 percent of Michigan employment, and it is essential that focus remain on the development of clean fuel vehicles to ensure that Michigan remains the country's automotive leader for generations to come. The clean fuel vehicle sector already annually contributes over 69,000 jobs to Michigan's economy, and almost $19 billion in economic activity. As clean fuel vehicles become more commonplace, these totals will grow rapidly, if Michigan can maintain its dominance in clean fuel vehicle R&D and production.

The move toward clean fuel vehicles will also have important environmental and health benefits for Michigan. The transition to clean fuel vehicles will mean cleaner air for Michigan residents—reducing asthma attacks, resulting in fewer days lost to work due to respiratory illness, and lowering overall Medicaid expenditures, among other benefits.

Policymakers need to ensure that the policy environment in Michigan remains supportive of the development, manufacture, and use of clean fuel vehicles. The auto sector is too important to Michigan to risk losing some or all of it to other states and nations as technologies and consumer use patterns change.

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