Accelerating Electric Vehicle Adoption: A Vision for Minnesota

Minnesota Department of Transportation
Minnesota Pollution Control Agency
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Executive Summary

A STATEWIDE VISION FOR ELECTRIC VEHICLES

The transportation industry is changing. Technological advancements like electric vehicles can help reduce environmental impacts, reliance on foreign oil, and the cost of driving. Minnesota can prepare for this change by embracing electric vehicles and moving toward a sustainable transportation system.

Minnesota is working to become the Midwestern leader for plug-in electric vehicle (EV) use. In 2018, there were nearly 7,000 EV registrations total in the state. Over 600 public charging station outlets are located throughout the state. Accelerating Electric Vehicle Adoption: A Vision for Minnesota (Vision) is the first coordinated attempt to outline a statewide vision for increasing EV use.

20% EVs BY 2030

The Vision describes strategies for achieving the goal of powering 20 percent of the light-duty cars in the state with electricity by 2030. Half of these vehicles are expected to be plug-in hybrid electric vehicles (PHEV) and half battery electric vehicles (BEV). While the focus of this Vision is on light-duty passenger vehicles, it includes discussion of electric buses, including buses made by the Minnesota-based company, New Flyer of America.

The goal is admittedly ambitious. However, progress towards the goal is important and complementary to other state efforts to promote clean energy technologies, advanced technology jobs, cleaner air, and improved health for populations adjacent to transportation facilities and roadways.

STRATEGIES TO MAXIMIZE EV BENEFITS

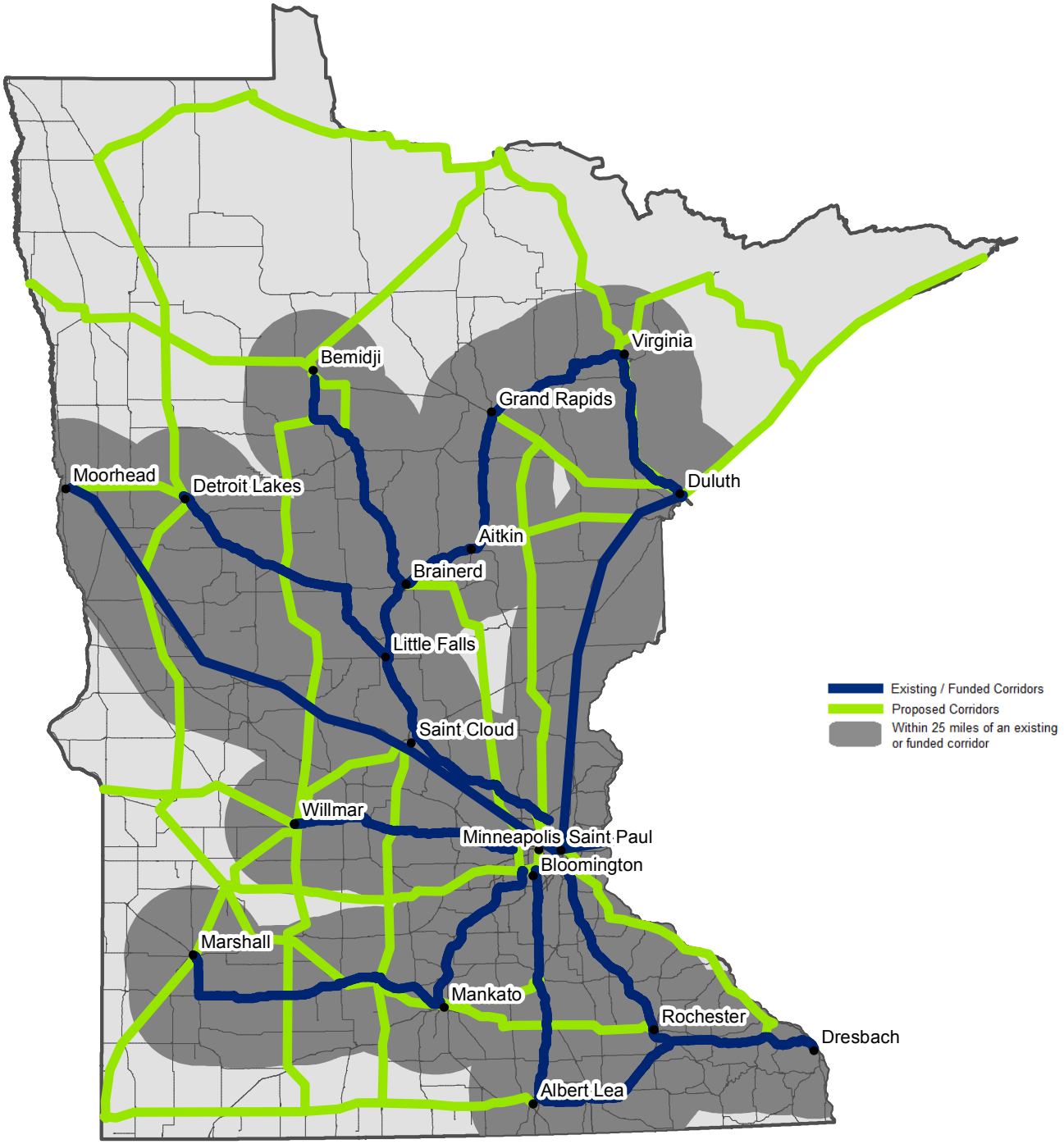
Maximizing the benefits of the shift to electric passenger vehicles requires a multifaceted approach:

- Accelerate EV sales and use through education and other methods
- Build out EV charging infrastructure
- Coordinate on regional and national initiatives to expand EV charging opportunities
- Prioritize renewable energy to charge EVs

Photo Credit: Drive Electric Minnesota

Minnesota is working to become the leading state for plug-in electric vehicle use in the Midwest.

FIGURE 1. A VISION MADE POSSIBLE



This map shows potential charging station corridors along highways that will reduce barriers to EV adoption and allow EV travel throughout the state. The blue lines show corridors that either already exist or have received funding and will be built soon. The shaded region around the existing and funded corridors shows the approximate level of access EV drivers will have once these corridors are in place. Additionally, Appendix D shows the corresponding number of stations that could be built along these corridors to increase EV travel throughout the state.

Photo Credit: Drive Electric Minnesota

Introduction

The Vision provides background on EVs, describes current efforts to support use, and outlines strategies for their continued growth. It also supports strategic future investments in EV charging infrastructure. The Vision is informational only and is not an official endorsement of a particular technology or charging location.

THE VISION FOCUSES ON LIGHT-DUTY ELECTRIC VEHICLES

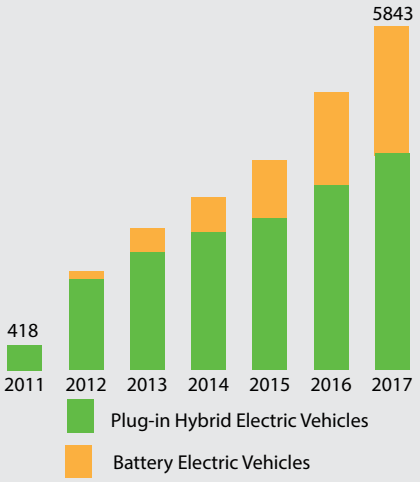
The focus is on light-duty passenger vehicles because they are readily available for purchase and use. Light-duty vehicles are the leading contributor to greenhouse gas emissions from transportation in Minnesota. In 2014, light and medium duty vehicles made up 63% of Minnesota's transportation-related greenhouse gas emissions. It is also worth noting that trains have relied on electric motors for decades, and the use of hybrid electric motors in school and transit buses is well established. While still relatively new, fully electric transit and school buses are becoming available to cities and schools. Testing is also occurring on medium-duty delivery and heavy-duty electric trucks.

SUPPORT FOR ELECTRIC VEHICLES IS INCREASING

The evolution of EVs has advanced from models best suited for commuting or traveling short distances to vehicles that can travel more than 200 miles per charge. Increased EV battery storage capacity paired with the installation of fast-charging stations along interstate and highway corridors will soon allow EV drivers to travel throughout the Midwest. One of the first federally designated "electric highways" is the Great Lakes Zero Emission Corridor, which promotes EV fast charging to allow west to east travel along Interstate 94 (I-94) from Moorhead, Minnesota to Port Huron, Michigan. The I-94 Corridor will intersect with another fast-charging corridor running north-south along Interstate 35 (I-35) and feed into other national charging station corridors.

Globally, energy market forecasters anticipate electric vehicles will reach 54 percent of new car sales and a quarter of all cars on the road by 2040.[1] Should this prediction hold, it could mean 100,000 EV sales annually in Minnesota in 20 years.

FIGURE 2. MINNESOTA CUMULATIVE ELECTRIC VEHICLE REGISTRATIONS (2011-2017)



Source: Auto Alliance (ZEV Sales Board)

Electric vehicle registrations in Minnesota have drastically increased from 2011 to 2017. This graph reflects cumulative EV registrations from 2011 to 2017.

Photo credit: PlugInConnect, Electric Vehicle Owners at State Capitol

Collaboration Advances EVs

Partnerships encourage EV adoption

Electric vehicle enthusiasts in Minnesota first organized through Drive Electric Minnesota (DEMN) in 2010, which is currently led by the Great Plains Institute. This multi-stakeholder partnership encourages deployment of EVs and charging infrastructure. DEMN includes the state's largest utilities and electric cooperatives, state and local governments, automakers and auto dealers, charging equipment and service providers, businesses, and non-profit organizations.

The Minnesota Plug-in Electric Vehicle Owners Circle is one of the nation's most active volunteer EV owner groups. The group provides EV education through direct public engagement at events.

The American Lung Association in Minnesota was recently awarded Department of Energy funding for Midwest Electric Vehicle Opportunities: Learning, eVents, and Experience (EVOLVE). The seven state regional effort demonstrates how to use plug-in electric vehicles with local showcases that provide test drives and brand neutral education.

State agencies support EVs

State agencies occupy a unique space in Minnesota's EV landscape. The Minnesota Pollution Control Agency and Minnesota Department of Transportation are working together to connect stakeholders, identify resources, and encourage a strategic statewide approach to promoting EV use and the installation of charging infrastructure. All Minnesota state agencies are working together to promote EVs in the state fleet by setting a goal of 20 percent electric vehicles in the state fleet by 2027. This begins with a plan to procure 150 PHEV and BEVs within the next three years, which will save the state fuel and maintenance costs. State agencies are also actively evaluating the potential for installing Level 2 and DC fast charging stations at state owned facilities and office buildings.

EV Basics

Types of Electric Vehicles

BATTERY ELECTRIC VEHICLES

BEVs run entirely on electricity stored in a battery to power an electric motor. The batteries are recharged using electricity from a wall socket or a dedicated charging unit. Recent models travel over 200 miles per charge. Uses Level 1, Level 2, and DC fast chargers.

PLUG-IN HYBRID ELECTRIC VEHICLES

PHEVs have an electric motor and a conventional gasoline or diesel engine. Compared to a battery electric vehicle, this extends the total driving range but lowers the all-electric range. Some can travel more than 50 miles on electricity alone, and all can operate solely on gasoline (similar to a conventional hybrid). Uses Level 1 and Level 2, but not DC fast chargers.

Source: US Department of Energy Alternative Fuels Data Center

Benefits of Electric Vehicles

LESS MAINTENANCE

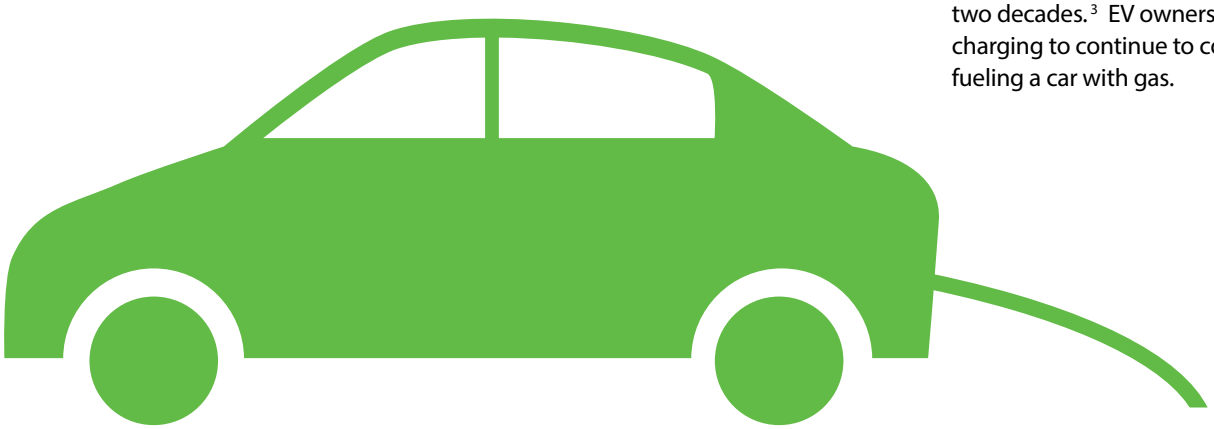
The electric vehicle motor and drive-train are much simpler and have hundreds fewer parts than a gas-powered car. This significantly reduces maintenance time and costs. For example, a BEV has no oil pump, exhaust system, water pump, or gas pump to maintain. Oil changes, transmission fluid changes, spark plugs, and muffler replacements can be taken off the "to do" list.

RAPID ACCELERATION

Electric vehicles can accelerate rapidly because they have instant 100 percent torque at zero rotations per minute (RPMs). The performance advantage can be useful for safety purposes in traffic, and drivers report that this feature also makes EVs fun to drive.

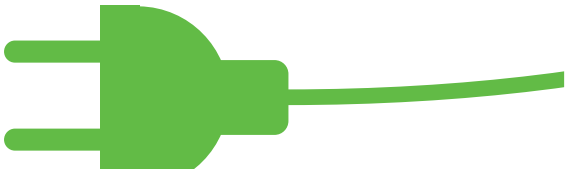
LOWER ENERGY COSTS

On average, charging an EV at home costs about ten cents per kilo-watt hour (kWh). At that rate, a 100 mile charge costs about three dollars, compared to about ten dollars to fuel a gasoline-powered car driving the same distance.[2] According to estimates by the U.S. Energy Information Administration, gas prices will increase over the next two decades.[3] EV owners can expect charging to continue to cost less than fueling a car with gas.



ENVIRONMENTAL BENEFITS

Depending upon the model and source of electricity, EVs are three to four times more energy efficient than gas-powered cars. When operating on battery power, EVs do not generate emissions from the tailpipe, which benefits local air quality and public health, especially in high traffic and dense neighborhoods.



Charging Basics

THREE DIFFERENT TYPES OF STATIONS OFFER VARYING LEVELS OF CHARGING SPEED

The level of electrical power a charging station draws and provides determines how fast it will charge an electric vehicle.

- Level 1: 120 volts (AC)
- Level 2: 240 volts (AC)
- Fast Charging: 50-350 kW (DC)

For more detail, see Appendix A. As the amount of power a charging station draws and provides increases, charging gets faster (Table 1).

FAST CHARGING STATIONS

Direct current (DC) fast chargers significantly decrease charging time compared to Level 1 or Level 2 charging. Currently, about 2,200 fast chargers exist in the US. There are about 25 in Minnesota. Fast charger output is available at 50, 150, or 350 kilowatts (kW). The majority are 50 kW chargers, which provide a 100 mile charge in 35 minutes. 150 kW chargers provide the same amount of charge in twelve minutes, while 350 kW take five to seven minutes.

TABLE 1. ELECTRIC VEHICLE CHARGING STATION SPEED COMPARISON

Type of Station	Speed of Charge (miles per minute)	Est. Per Installed Station Cost (USD)	Minutes of Charge to Drive 100 miles
Level 1 120 Volt (AC)	0.1	$500 - $1,000	1080 (18 hours)
Level 2 240 Volt (AC)	0.4	$2,000 - $5,000	240 (4 hours)
50 kW (DC)	2.9	$60,000 to $100,000	35
150 kW (DC)	8.7	$100,000 to $150,000	12
350 kW (DC)	20.4*	$150,000 and up	5

CHARGING AT HOME

Charging an EV can be as simple as plugging it into an outlet

Photo Credit: Plug-in Connect

Charging station at an apartment in Bloomington, MN

RESIDENTIAL CHARGING

Charging an EV can be as simple as plugging the charging cable that comes with the car into a wall outlet in a garage. A recent study by the Idaho National Laboratory revealed that over 80 percent of EV charging occurs at home overnight.[4] EV owners may choose to use Level 1 or 2 for charging at home.

- Level 1: Drivers plug into a garage wall outlet or wall-mounted charging station for Level 1 charging (120 volts). For 100 miles of range, Level 1 charging takes 12 to 18 hours.
- Level 2: An electrician must install a Level 2 charger. Level 2 chargers are wall-mounted and provide 240 volts of power. A full charge takes two to four hours.
- For long-term use, auto manufacturers recommend having an electrician install a Level 1 or 2 station in the garage. These can typically be purchased on-line or at a local hardware store.

MULTI-UNIT HOUSING CHARGING

Providing charging options for residents of apartments, townhouses, and condominiums can foster increased EV use. Apartment dwellers make up 12 percent of Minnesota's population. Fortunately, multi-unit building owners are increasingly installing charging stations or conduit to support future stations as a way of distinguishing their properties from others in the market. For more information on multi-unit housing charging, see the following reference:

- Minnesota specific case studies and tools for building owners or managers

NEW CONSTRUCTION

When funds are limited, installing conduit or raceways makes it easier to install charging stations later. This can prevent or minimize the cost of future charging stations. Another option is to install a limited number of charging stations along with conduit to allow for expansion later.

INSTALLATION COSTS VARY FOR DIFFERENT CHARGING STATIONS

Several factors influence the cost of installing an electric vehicle charging station. Faster, more powerful charging stations are more expensive to purchase and install. Also, installation costs increase the further a station is from electrical service. Trenching, conduit, and wiring costs can all increase the cost of an installation. These factors need to be weighed when choosing the optimal charging station type and location.

CHARGING AWAY FROM HOME

Charging options are available at work and public destinations

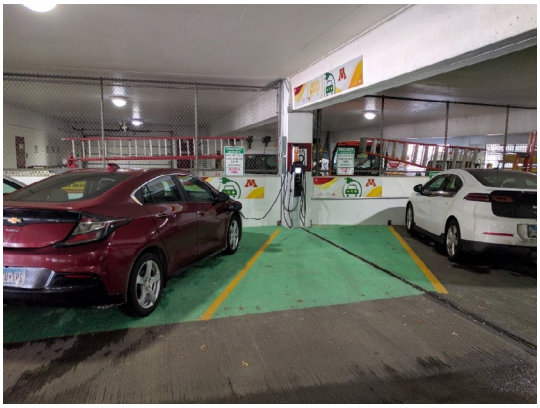


Photo Credit: University of Minnesota

WORKPLACE CHARGING

Workplace charging is the second most common way to charge EVs. Workplace charging could provide EV owners an extra 15 to 70 miles of range depending on the charging infrastructure available. This matches the characteristics of 90 percent of commuters who drive less than 40 miles one-way to work.[5] Several employers in the state provide charging including 3M, Andersen Corporation, State of Minnesota Capitol Campus, Risdall Advertising, and the University of Minnesota. Employers cite sustainability goals and employee retention as justification for providing this employee benefit. For more information on workplace charging, see the following references:

- Workplace Charging Simple Concept tool
- US Department of Energy list of businesses that provide workplace charging

Fast charging station at the Savage Goodwill store

CHARGING ON THE GO

Fast charging between destinations allows EV drivers to travel longer distances and stop along the way to charge, much like gas stations for gas vehicles. The owner of a charging station determines the cost users will pay to charge their car. Fast charging equipment and electricity costs are higher, so those costs are typically passed on to users. Rates vary from $8 to $12 for 200 miles of range.

DESTINATION CHARGING

Some locations offer charging as a perk to customers and visitors, sometimes for free and sometimes for a charge. Examples include some grocery stores and various Minnesota State Parks. Destination charging is typically Level 1 or 2. Level 2 charging will cost a business about $0.34 to $0.84 per hour of charging. Drivers are typically charged $.80 to $1 per hour of charging, or about $2 for 50 miles of range.

Find your nearest charging station at plugshare.com or the Alternative Fuels Data Center. For more detail, see Appendix F.

Photo Credit: Drive Electric Minnesota

What are the Benefits of Electric Vehicles in Minnesota?

- Support for State and Local Economies
- Reduced Greenhouse Gas Emissions
- Increased Electricity Sector Efficiency
- Support for Environmental Justice and Social Equity
- Improved Air Quality and Public Health

EV Benefits: State and Local Economies

ELECTRIC VEHICLES CREATE JOBS AND GREATER ENERGY INDEPENDENCE

Using electricity to power transportation leverages changes in the electricity sector to create local jobs. Minnesotans spend about $11 billion annually on transportation fuel, most of which is imported from outside the state.[6] As Minnesota's electricity providers continue to be national leaders in developing renewable energy from wind, solar, hydroelectricity, and biomass, more electricity is produced locally. Installing renewables in Minnesota creates clean energy jobs in manufacturing, installing, operating, and maintaining wind turbines, solar panels, etc. Currently, the clean energy industry employs over 54,000 workers in Minnesota.[7] The number of jobs in the clean energy sector increased by 78 percent between 2000 and 2014. During the same period, Minnesota's overall employment grew by 11 percent.

The state needs a new system of transportation fueling to power EVs that includes affordable and accessible EV charging to support EV travel by those who live, work, and/or play in the Twin Cities and Greater Minnesota. To better understand the potential economic benefits of this new fueling system to Minnesota communities, the University of Minnesota Extension modeled potential economic benefits to Greater Minnesota from expanding the state's electric vehicle fast charging network. The study found that EV fast charger installation and maintenance can provide new employment opportunities across the state, including the need to hire and train new employees.

The University of Minnesota study indicates that installing just 75 50-kW and 75 150-kW DCFCs in Greater Minnesota would generate $14.2 million in economic activity (Table 2). This includes $4.6 million in labor income. Communities and businesses that host charging stations may also see economic benefits as EV drivers eat or shop while their vehicles charge.

TABLE 2. TOTAL EMISSIONS CONTRIBUTION, CONSTRUCTION OF 75 50 KW AND 75 150 KW FAST-CHARGING ELECTRIC VEHICLE CHARGERS IN GREATER MINNESOTA

	Output (millions)	Employment	Labor Income (millions)
Direct	$9.2	50	$3.3
Indirect	$2.6	10	$0.6
Induced	$2.4	20	$0.7
Total	$14.2	80	$4.6

Estimates by University of Minnesota Extension

EV Benefits: Reduced Greenhouse Gas Emissions

MINNESOTA'S GOAL: 30% REDUCTION BY 2025

The 2007 Next Generation Energy Act (NGEA) set greenhouse gas (GHG) reduction targets of 30 percent by 2025 and 80 percent by 2050, from a 2005 baseline (Appendix B). Exploring medium-term, sector-specific goals helps the state work to reduce GHGs in each sector of the economy. Drawing a path from the 2025 target to the 2050 target means that each sector – including light-duty passenger vehicles – needs to achieve a 37 percent reduction by 2030. Slower growth in vehicle miles traveled and Federal Corporate Average Fuel Efficiency (CAFE) standards, will drive progress toward the target, but more action is needed to meet it. State action to promote EVs may be even more important, as the federal government has stated its intent to re-evaluate and reduce the stringency of the CAFE standards. This would result in higher emissions from passenger cars and light trucks into the future.

FIGURE 4. 2030 ANNUAL WELL-TO-WHEEL EMISSIONS
Average pounds per year from a single vehicle*

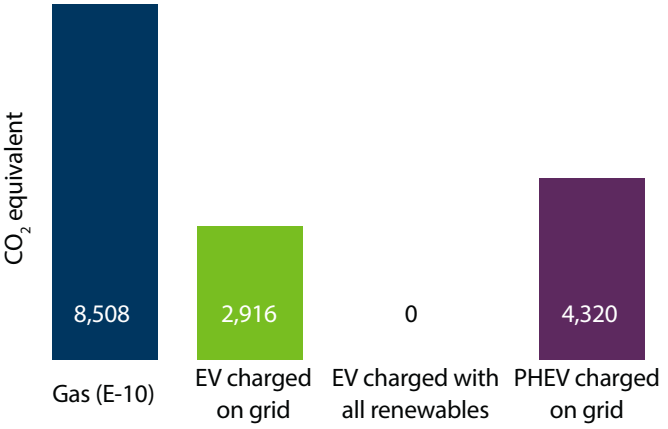
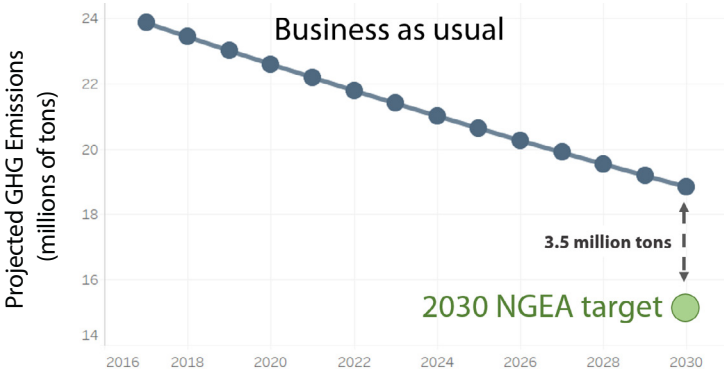


FIGURE 5. 2030 PROJECTED GHG EMISSIONS FROM PASSENGER VEHICLES*



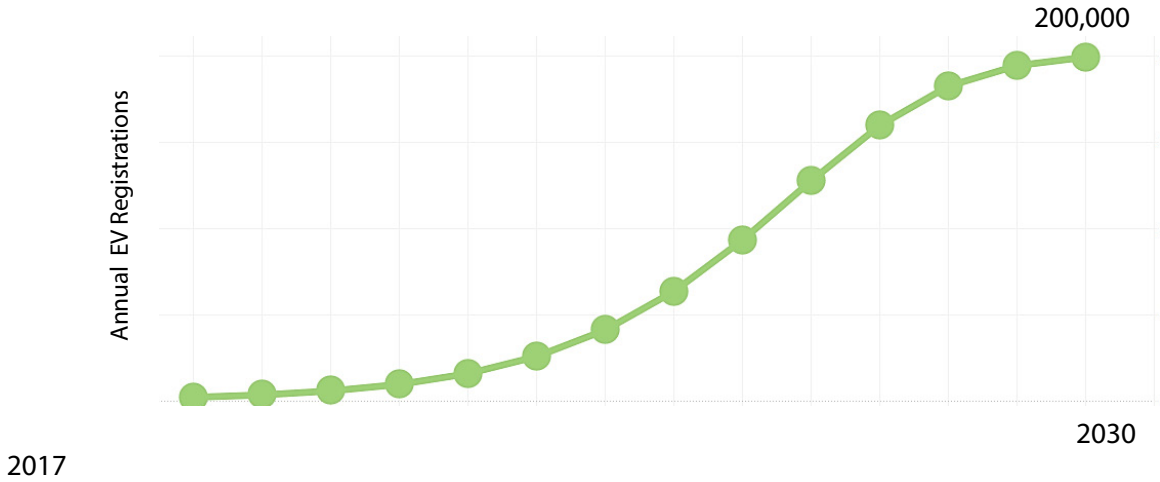
THE STATUS QUO WILL NOT ACHIEVE THE GOAL

A 3.5 million ton gap in GHG emission reductions will remain if Minnesota relies solely on CAFE standards to meet NGEA interim targets for 2030. Shifting 20% of the light-duty vehicles in the state to PHEVs and BEVs is one way to close the gap. Additionally, power for at least 10% of these vehicles must come from wind or solar electricity beyond the renewables expected to come onto the general grid.

SHIFTING 20% OF MINNESOTA'S LIGHT-DUTY FLEET TO EVS WILL CLOSE THE GAP

Figure 6 shows the amount of annual EV sales needed to achieve the 20% level. 200,000 vehicles would be about 60% of all new vehicles sold. A Minnesota Department of Transportation analysis found that this scenario could maintain or increase revenue for the agency assuming the full price of EVs is more than non-EVs (Appendix C).

FIGURE 6. ANNUAL EV REGISTRATIONS NEEDED TO REACH 20% OF FLEET IN 2030*



*Source: All charts developed by Minnesota Pollution Control Agency

Photo Credit: Drive Electric Minnesota

EV Benefits: Electricity Sector Efficiency

EVs CAN USE RENEWABLE ENERGY AND EVEN OUT ELECTRICITY DEMAND

Electric vehicles can support electricity generation from renewable sources and optimize electricity use. Smart charging stations can use technology to charge electric vehicles with renewable energy. The stations reduce the amount of power drawn from the grid when wind and solar electricity generation is low, and increase the power drawn when electricity from renewable sources becomes available. In addition, the intelligent controls can help balance utility load levels throughout the day by charging EVs when demand for electricity is lower. For example, on a hot day when electricity use for air conditioning is high, a smart charging station can draw less power for charging when demand is high, but ensure the EV is charged within an acceptable time frame. Lower cost time of use electricity rates offered by a number of Minnesota utilities encourage EV drivers to charge overnight and during times of lower electricity demand to even out grid load.

These types of electricity demand controls and incentives will become increasingly important as more renewable sources of electricity come onto the grid. By encouraging utility customers to even out the grid load and use renewables, electric vehicles can help slow growth in electricity costs -- even for customers who do not drive EVs. The role of EVs in future energy markets extends to predictions about their vital role within demand-led flexibility markets, a potential energy market revenue stream, due to this ability to control the amount and time of charging.[8]

Case Study: Smart EV Charging with Solar Power at the Greenway Building

Photo Credit: Drive Electric Minnesota

The Minnesota Pollution Control Agency, Wellington Management, ZEF Energy, and Great Plains Institute partnered on a new smart EV charging technology deployed at the Greenway Building in south Minneapolis. The technology developed by ZEF Energy allows a normal Level 2 EV charging station to "talk" to rooftop solar generation on-site. When the solar system is at full capacity ,the EV charger charges at full speed. When the solar is not producing, the EV charging is dialed back to a slower charging speed. Because it is workplace charging, and cars tend to be plugged in all day, the consumer is not impacted by the variable charging speed.

The project demonstrates how EVs can help integrate variable wind and solar production into the electric grid at low cost. This will prove increasingly useful as more and more renewables and EVs come online.

Photo Credit: Drive Electric Minnesota

EV Benefits: Environmental Justice and Social Equity

EVs REDUCE POLLUTION IN OVERBURDENED COMMUNITIES

Vehicle emissions can contribute to respiratory and cardiac health issues especially for the elderly, children, and those with existing health problems. Neighborhoods near major roadways and transportation facilities (e.g., urban interstates and rail yards) can be exposed to greater amounts of vehicle emissions.

A 2015 study by Minnesota Pollution Control Agency (MPCA) researchers found that while communities of color and lower income communities tend to own fewer vehicles, do less driving and use public transit more often than other groups, they are also exposed to higher levels of traffic-related pollution. This is because busy roadways, and their associated air pollution, often run through communities color and low-income communities. Many of these communities, therefore, bear a disproportionate burden of traffic-related health impacts while contributing less to vehicle pollution.

Regardless of the source of electricity, EVs can improve air quality in these communities because they have no tailpipe emissions, which can reduce air pollution near roadways.

Other parts of the country are implementing innovative programs to incentivize the use of EVs to clean the air and improve health in underserved communities. In California, the Charge Ahead California Initiative offers EV equity programs. Examples include scrap-and-replace vouchers for low-income residents to replace their old vehicles with new or used EVs and electric car-sharing programs in disadvantaged communities. These programs help address environmental justice in low-income communities of color by bringing clean vehicle technology to those who might not otherwise be able to afford it and by creating economic opportunity through increased mobility, cost savings, and jobs.[9]

Additionally, Replacing diesel buses with electric versions brings EV technology to those who cannot afford to purchase their own vehicle. Low-income communities and communities of color rely more heavily on transit to get to where they need to go. EV buses reduce emissions in these communities and provide a smooth, quiet ride to transit users.

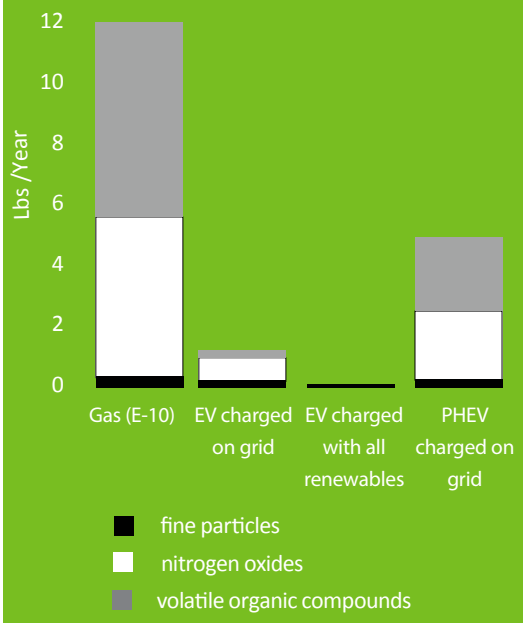
Replacing school buses is also an opportunity to decrease diesel exposure among children. Reducing these exposures is especially important in lower-income communities and communities of color where there are higher rates of hospitalizations from asthma in children.

EV Benefits: Improves Air Quality and Public Health

EVs have the potential not just to reduce GHG emissions, but also other air pollutants. Vehicles make up about a quarter of the air pollution emissions in Minnesota and traffic emissions are one of the primary sources of health risks from outdoor air pollution in the state. Reducing emissions from tailpipes, therefore, has the potential to benefit to public health.

When running on battery power, EVs have zero tailpipe emissions, which reduces exposures to harmful air pollutants. Although there are often emissions from the source of electrical power, EVs can still reduce emissions in the state. This is due partly to their efficient use of energy and partly to the fact that the electricity grid is getting cleaner as the state moves from coal and towards renewables and natural gas. In Minnesota, when looking at the "well-to-wheel" emissions of producing energy and using it to drive a vehicle, driving an EV instead of a gas-powered vehicle reduces the emissions of nitrogen oxides, fine particles, and volatile organic compounds. These are all pollutants that scientists have found are often in higher concentrations and can contribute to health effects in communities along busy roadways.

FIGURE 7. 2030 ANNUAL WELL-TO-WHEELS EMISSIONS PER VEHICLE



ELECTRIC BUSES REDUCE AIR POLLUTION

100% ELECTRIC BUSES HELP MINNESOTANS BREATHE CLEANER AIR

Great River Energy, a Minnesota utility, is supporting a project to replace diesel school buses with electric powered buses. Diesel buses create air quality concerns when children are directly exposed to diesel emissions from buses idling in school zones.

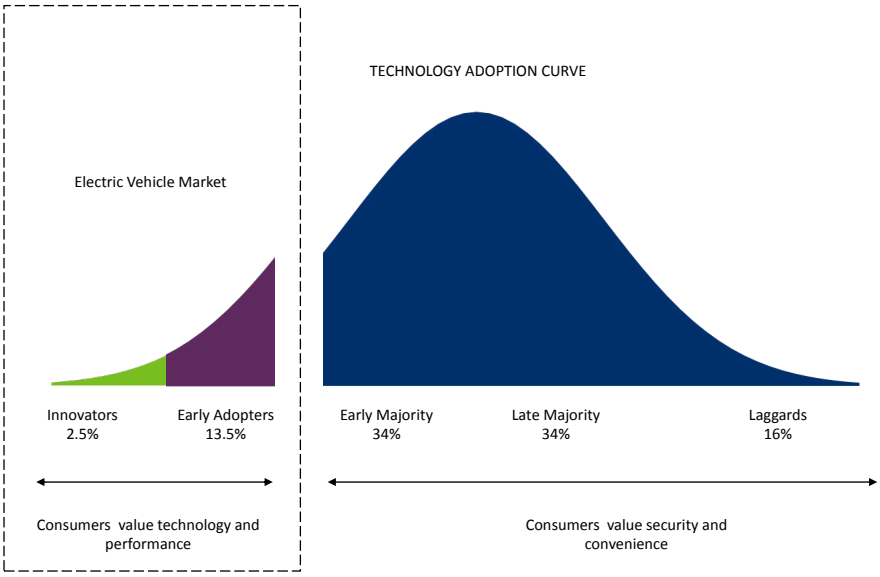
Some Minnesota transit providers are beginning to adopt EV technology as well. Both Metro Transit and Duluth Transit will soon begin operating EV buses on some transit lines.

What are the Challenges?

AN INCOMPLETE CHARGING NETWORK, PERCEIVED HIGH COSTS, LACK OF INCENTIVES, AND LOW VEHICLE AVAILABILITY MUST BE ADDRESSED TO ACHIEVE 20% EV ADOPTION BY 2030 IN MINNESOTA.

EVs offer a number of advantages to consumers, including low total cost of ownership from considerably lower maintenance (hundreds of fewer parts) and fuel costs, quiet operation, fast acceleration at low speeds (low end torque), home charging/refueling convenience, support for cleaner air and reduced GHG emissions, and reduced dependence on imported energy. However, addressing challenges is necessary before widespread market penetration can be expected.

The EV market is rapidly maturing. The market is still in the "early adopter/ visionary" phase of consumer adoption and only just beginning to enter the "early majority" phase. While early adopters value technology and performance, early majority consumers value solutions and convenience. Major obstacles to attracting the "early majority" EV consumers include the following:



Challenges

NEXT STATION
200 miles

Incomplete charging network and knowledge

The national network of fast charging along inter-city and interstate corridors is incomplete, there are a lack of home charging options for multi-family building residents, and charging infrastructure at destinations and workplaces remains inconsistent. Even in corridors and cities with extensive charging, there is a general lack of knowledge about how and where to charge. A key turning point for charging occurred when non-luxury BEVs came to market in 2018 with over 200 mile ranges (Tesla Model 3, Chevy Bolt). The latest Nissan Leaf model has a longer driving range at 150 miles per charge. This increases EV range to support longer distance travel and reduces the frequency of charging. Longer range EVs will be particularly important in bringing access to EV technology to Greater Minnesota, where people must travel longer distances on a daily basis.

Perceived high cost

Many consumers perceive EVs to be expensive. This may be partly because consumers are more familiar with luxury models, which have overshadowed the existence of other lower-cost EVs. Yet, Battery costs have been trending downwards. If that trend continues, electric and gas-powered vehicles may achieve price parity in the next decade.[11]

Lack of incentives for EV sales

Unlike states with higher electric vehicle market penetration, Minnesota does not have policies or incentives to promote electric vehicle purchases by individuals. For example, other states have successfully increased electric vehicle sales by using incentives like sales tax credits.

Vehicle availability and the EV sales experience

The availability of EVs in Minnesota is less than some other states because manufacturers have focused inventory and marketing in states with Zero Emission Vehicle (ZEV) regulations (Appendix G) that require vehicle manufacturers to sell certain amounts of EVs in the state each year. One consequence is that automakers and dealers may have less experience selling EVs.

Strategies to Advance Electric Vehicles

Accelerate Sales and Use

- Incentives
- Education
- Bulk Buy Discounts
- Electric Buses

Build Out Charging Infrastructure

- Workplace charging
- Fast charger stations

Coordinate on Regional and National Initiatives

- Consistency in regions and states

Prioritize Renewable Energy to Charge Electric Vehicles

- Install fast charging stations along interstates and highways statewide by 2030

Accelerate Electric Vehicle Sales and Use

Incentives, consumer education, bulk-buy programs, and outreach to fleet managers can accelerate EV sales and use. Ride and drive events let people experience EVs first hand. Future endeavors are expected to include further developing EV car sharing programs.

INCENTIVES: THE MOST IMPORTANT FACTOR IN EV ADOPTION

A study by the International Council on Clean Transportation found that financial incentives are the most important factor in increasing EV adoption. Minnesota lacks a state tax rebate or other state incentive, but offers other incentives to increase sales.

Utility incentives: Some Minnesota utilities and electric cooperatives offer incentives. The incentives generally fall into two categories: lower electric rates and rebates for charging equipment. Great River Energy cooperatives, Xcel Energy, Otter Tail Power Company, and others offer discounted electricity for EV drivers who charge off peak (typically at night). This is a win-win because consumers can use electricity at a price that is equivalent to paying $0.60 per gallon, while utilities benefit from reduced demand during peak hours. Many utilities and cooperatives also offer rebates (generally around $500) for purchasing home charging equipment or upgrading electrical service. Additionally, Great River Energy and its member cooperatives offer the Revolt Program, which upgrades EV drivers to 100 percent renewable electricity at no extra charge.

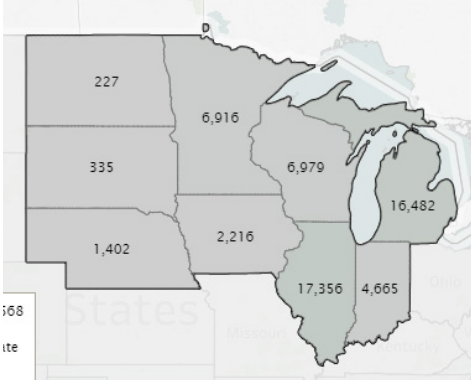
Utilities in other states have gone even further by offering purchase incentives for buying EVs or sales incentives to auto sales staff for selling them. These steps could be considered in Minnesota as well.
State tax rebate or incentive: 13 states offer some kind of sales incentive for the purchase of EVs, including sales tax reductions, income tax credits, or direct incentives. Minnesota does not offer any tax incentive or direct incentive for EV adoption.

Carpool lane access: Four states offer access to carpool lanes for EVs. Carpool, or restricted lane access, is a meaningful financial incentive in areas where consumers have the option to pay more to enter restricted access lanes or where congestion causes significant delays.

ASIDE FROM POLICY, MINNESOTA'S GREATEST OPPORTUNITY TO INCREASE EV SALES IS THROUGH EDUCATION

Minnesota's greatest opportunity to increase EV sales without new state policy is through collaborative marketing and education. Education demystifies EVs and familiarizes customers with their benefits. Many efforts are already underway, including ride and drive events, larger events like the Electric Room at the Twin Cities Auto Show and National Drive Electric Week, and individual promotions and advertising and marketing efforts by utilities and electric cooperatives. Drive Electric MN serves as the information clearinghouse highlighting all such efforts.

FIGURE 8. UPPER MIDWEST ELECTRIC VEHICLE SALES



Data Source: Auto Alliance ZEV Sales Dashboard

STANDARDS CAN ENCOURAGE LOW CARBON FUEL USE

Clean fuel, or low carbon fuel, policies encourage the development and use of lower-carbon transportation fuels. A Low Carbon Fuel Standard (LCFS) was first enacted in California in 2007. Similar policies exist in British Columbia and Oregon, and are under consideration in Washington state and Canada. Clean fuel standards require a decrease over time in the average lifecycle GHG emissions of all transportation fuels. These policies are technology-neutral and allow the market to determine the lowest cost and most practical path for reducing carbon intensity over time.

Fuel producers of biofuels, petroleum, compressed natural gas, and electricity are assigned a carbon score based on GHG emissions associated with their production and use. Fuels whose lifecycle GHG emissions are under the level of the standard get incentives, which supports their development.

Electricity to power EVs is considered a low carbon fuel under most policies. Other low-carbon transportation fuels typically include biodiesel, ethanol, and hydrogen. The fewer GHGs each fuel emits, the more LCFS credits it earns. In 2016 alone, the LCFS created over $92 million in credits that were used for point-of-sale rebates for EVs, rebates for Level 2 charging equipment, and funding for electrification of public transportation, as well as development and implementation of better low-carbon fuel technology.

BULK BUY DISCOUNT PROGRAMS OFFER LOWER EV PRICES

A bulk buy, or negotiated discount program, is a valuable way to increase individual EV adoption without needing state incentives. It provides valuable vehicle marketing to automakers, helping automakers sell EVs.

In 2015, Boulder and Denver Counties coordinated a bulk buy on solar panels for individual homeowners and wondered if the model would also work for EVs. They issued a request for proposals (RFP) to auto manufacturers, and two manufacturers ended up participating in what was the first EV bulk buy in the country.

Following suit, Drive Electric Minnesota issued its first RFP to auto manufacturers in Fall 2015 and offered its first bulk buy program in March 2016 to coincide with the Twin Cities Auto Show. It offered three subsequent bulk buy programs to individual consumers and fleet managers that, when combined with a manufacturer discount and federal tax credit, provided a 40-50 percent discount on an EV's full retail price. As an example, the discount program reduced the price of a 2017 Nissan Leaf from $34,000 to $16,500.

An active committee of utilities, electric cooperatives, nonprofits, state and local governments, auto dealers, and other partners marketed the program through social media, email communication, and events. Drive Electric Minnesota estimates that around 90 percent of eligible EVs sold during the period of the discount programs occurred through the discount program, and sales were significantly higher during months when the discount program was offered.

Photo credit: City of Eden Prairie

Photo credit: Dakota County, Linden Hills Park

FLEET EV ADOPTION

Fleet EV adoption is an important part of accelerating EV use. In addition to increasing overall adoption and improving air quality, it creates an early market that rewards auto dealers' efforts to become certified and train sales staff to sell EVs. Fleets can provide an additional opportunity to market EVs separately from the individual EV market.

Because of the lower cost of fueling and maintenance, EVs can save money for fleet operators. This is the case for light duty vehicles as well as several types of heavier vehicles like buses and trucks. The U.S. Department of Energy Alternative Fuels Database lists available EVs in many vehicle categories.

The Minnesota Department of Administration has led the way by committing to a 20 percent EV state fleet by 2027. The state has several EVs on state contract, and recently was among the first to purchase Chevrolet Bolts in the Midwest. The order included 22 Bolts that state agencies and partnering local governments are using. The state's commitment makes it easier for local governments to benefit from EVs, since they can easily purchase vehicles that are on state contracts. Cities throughout the state, including Minneapolis, Edina, and Elk River, have purchased EVs using the state contract.

The Sustainable Growth Coalition, in collaboration with Drive Electric Minnesota, is similarly researching opportunities for private businesses to incorporate EVs into their fleets.

Police departments are already using EVs for parking, monitoring and ticketing. Some police departments are considering plug-in hybrid sport utility vehicles (SUVs). The SUV plug-in hybrid electric drive train provides rapid acceleration, while the gas engine ensures there are no driving range limitations and also has light-duty towing capacity. Some cases make more sense than others, and work is needed to identify how to match EVs with essential fleet needs.

More work is needed to collect data on vehicle fleets in the state and determine where opportunity lies. For example, BEVs are ideal for mail and parts delivery routes that require traveling the same distance each day. BEVs are also ideal for traveling to nearby meetings. Some utilities and electric cooperatives are covering some or all of the cost of fleet analysis studies for local governments and businesses in their service territory. These studies gather the data needed to determine the feasibility of and economic savings from shifting to EVs.

NOT JUST LIGHT-DUTY VEHICLES: TRANSIT PROVIDERS TRANSITION TO ELECTRIC BUSES

Replacing transit buses with electric versions has the potential to reduce emissions in areas overburdened with pollution, especially since buses move along busy roadways and stop and idle frequently. Electric transit buses have the added benefit of being highly visible to the community and getting the general public more used to the idea of EVs.

The Duluth Transit Authority purchased seven electric transit buses through a Federal Transportation Administration Low and No Emission grant. They serve select routes within the City of Duluth with the goal of testing their performance in an extreme climate and steeper terrain. The buses are equipped with long-range batteries, allowing them to serve daily- and peak-commuter routes and recharge in the garage overnight and during off-peak periods. Metro Transit also has plans to begin incorporating EV transit buses into its fleets.

There are several advantages to replacing diesel buses with electric versions, including:

- Longer service life due to fewer parts needing maintenance in an electric- vs. diesel-powered bus
- Lower operations & maintenance costs due to better reliability, fewer moving parts, and fuel savings
- Reduced bus garage heating and air conditioning costs due to fewer diesel engines idling in garages, which reduces expensive, winter heating and ventilation needs
- A quiet, smooth propulsion providing an improved ride experience
- EV buses, like electric cars, can be a grid resource – charging when the electricity load is off-peak to better integrate renewable electricity, and potentially serving as a storage resource

There are several manufacturers of EV transit buses nationally, including BYD, Proterra, New Flyer, and others. New Flyer notably plans to manufacture electric buses in St. Cloud and Crookston, Minnesota.

Photo credit: Proterra

Early deployment will explore the potential for transit agencies to save money, while making the electric system operate more efficiently and saving money for electricty customers. By 2019, Metro Transit plans to have eight fully-electric buses in their fleet. Based on a one-year life cycle cost analysis by Metro Transit, which includes a $300,000 higher initial purchase cost for a 40-foot electric bus, there are $15,000 in fuel cost savings and $10,000 in maintenance cost savings per year, resulting in a simple 12-year payback or return on investment for each bus. As the technology advances, the return on investment is expected to continue to improve.

ELECTRIC BUSES PROVIDE OPPORTUNITIES FOR SCHOOLS

Electric school buses offer obvious benefits in terms of cleaner air for children. They can also potentially offer a benefit for the electric grid by being available to offer grid-connected battery storage when they are not being driven. Great River Energy and Dakota Cooperative Electric Association piloted EV school buses in 2018. The pilot marked the first plug-in electric school bus in the state and one of the first projects in the nation.

University and business complex electric shuttles are another potential opportunity for electric bus fleets in Minnesota.

ELECTRIC VEHICLE CAR SHARING PROGRAMS HOLD PROMISE

Pilot projects in other states are exploring the opportunity for EV car sharing. These programs can help bring the benefits of EVs to people who might not otherwise have access to them. These programs fall into two categories. The first is a car sharing program like HourCar that allows members to borrow an EV. The second is a leasing program for ride hailing (Uber, Lyft) drivers.

Notably, Maven is working with Lyft and Uber to make Chevrolet Bolts available to drivers of ride hailing services under a week-by-week leasing arrangement that includes fuel and insurance. This can allow someone who may not own a car or want to use their own car to still make money driving for these services. Currently, this opportunity is not offered in Minnesota, but the state might consider partnering with private sector companies to encourage them to come to the state.

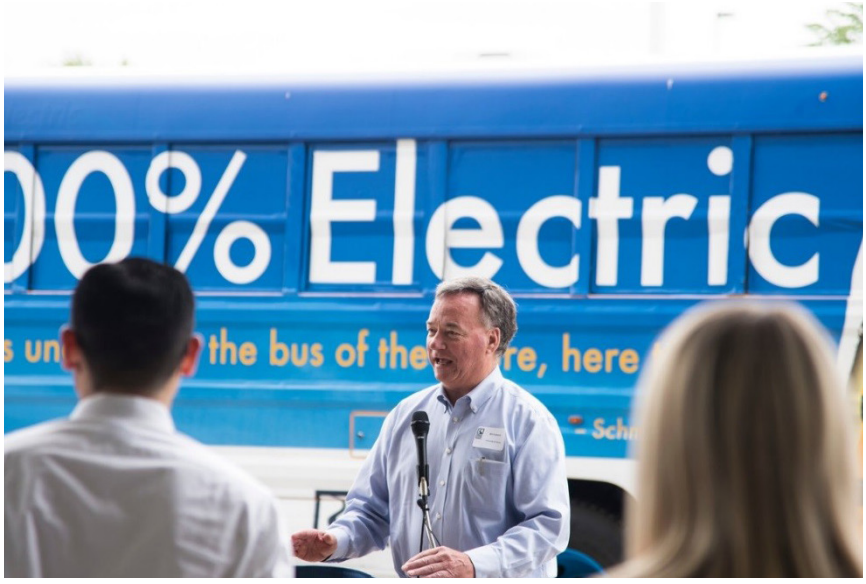
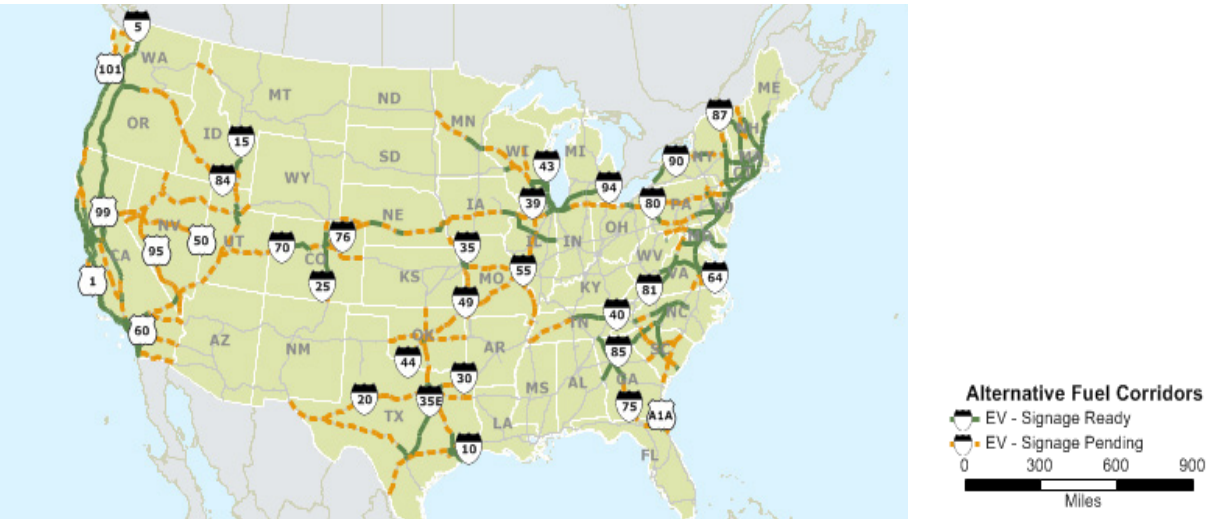


Photo credit: Drive Electric Minnesota

FIGURE 9. MAP OF U.S. DEPARTMENT OF TRANSPORTATION DESIGNATED FAST CHARGING CORRIDORS



Source: Federal Highway Administration

Build Out Electric Vehicle Charging Infrastructure

Minnesota is focusing on expanding the availability of EV charging in multi-family buildings, workplaces, and public destinations, since they are largely beyond the control of potential EV owners. This Vision does not discuss strategies to expand opportunities for single-family home owners or renters to charge at home because they can do so with an existing outlet or install a charger on their own. This section of the Vision recommends actions to support a minimum basic level of service.

EXPAND WORKPLACE CHARGING

Additional workplace charging stations can address a barrier to EV adoption, particularly for those with a long commute or who cannot charge at home (e.g. apartment dwellers without off-street parking and charging stations). Many employers already offer workplace charging in Minnesota, however, there is potential for continued growth.

STATEWIDE FAST CHARGING CORRIDORS ARE CRITICAL

Charging stations are best situated near restaurant or retail amenities that electric vehicle drivers can take advantage of while waiting for their vehicle to charge. Another option is to install fast charging stations in downtown areas, as was done in Pine City and Sturgeon Lake, to draw customers into downtown to support local businesses and spur local economic development.

Additional DC fast charging in non-urban areas is critical to supporting convenient long distance EV travel. The Federal Highway Administration's national zero emission corridors are intended to raise awareness about this need and promote investment in DC fast chargers along critical corridors. Specifically, the goal is to encourage installation of DC fast chargers at increments of no more than 50 to 70 miles.

To allow EV drivers to conveniently travel anywhere in Minnesota, the state would need a network of 85 DC fast charging stations installed at 50 to 70 mile increments on key state transportation corridors. The approximate cost of one 150 kW DC fast charger is $120,000. Completing the 85 charger network described in Figure 10 would cost about $10 million. Figure 10 shows funded and proposed corridors for creating a charging network based on critical economic connections within the state, as well as the number of vehicles using a particular roadway. The map highlights connections where charging stations may be needed between population centers (e.g., St. Cloud to Granite Falls may need a charger in Willmar or Paynesvillle). However, many additional connections will be possible if the network is completed as outlined (e.g., Detroit Lakes to Fergus Falls). For more detail, see Appendix D.

HIGHER CHARGING STATION POWER CREATES A FASTER CHARGE

Today, drivers expect to fill their gasoline tank in about six minutes every 200 miles. By comparison, the most common fast chargers on today's market are 50 kilowatt (kW) stations that take about 30 minutes for 80 miles of travel. The next generation of fast chargers are likely 150 kW stations for installations along interstate and highway corridors.

MPCA PLANS TO DISTRIBUTE VW FUNDS

Volkswagen (VW) was caught cheating on emissions standards in its diesel cars and SUVs. The federal government took the company to court and reached a settlement. As part of that settlement, VW must spend $2 billion nationwide on EV charging stations and education.

The settlement also provides states with funding to implement diesel emission reduction programs that will replace old diesel vehicles and equipment with new versions. The settlement allows states to use up to 15% of their funds on EV charging stations. In Minnesota, the MPCA is designated to receive the funds and develop and implement the program.

MPCA has committed to spending the maximum 15% of Phase I (2018-2019) funds on EV charging stations. Approximately $1.4 million is going towards fast-charging corridors along highways across the state. Over $150,000 is dedicated to Level 2 chargers for workplaces, multi-unit dwellings, and public spaces. The MPCA has also designated $1.76 million to replace heavy-duty diesel vehicles with electric versions. These funds will help build out the state's charging infrastructure and will provide a space for exploring emerging heavy-duty electric technology.

EV-READY CITIES CAN LEAD THE WAY

In addition to state agencies, cities play a role in building out electric vehicle charging infrastructure. The Great Plains Institute (GPI) has identified five principles for what constitutes an EV-ready city:

1) Policy: Acknowledge EV benefits and support development of charging infrastructure

2) Regulation: Implement development standards and regulations that enable EV use

3) Administration: Create transparent and predictable EV permitting processes

4) Programs: Develop public programs to overcome market barriers

5) Leadership: Demonstrate EV viability in public fleets and facilities

FIGURE 10. MAP OF EXISTING AND PROPOSED EV CHARGING CORRIDORS IN MINNESOTA

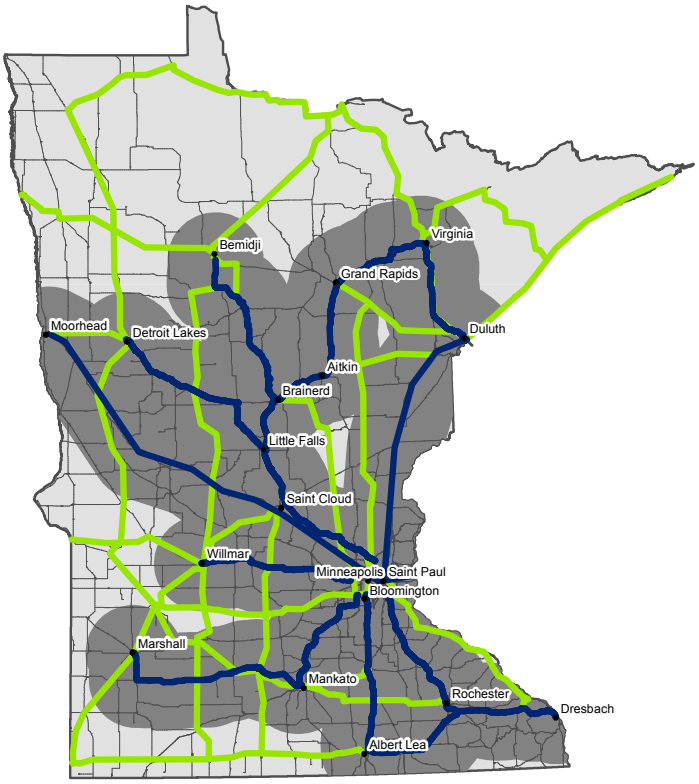


Photo Credit: Idaho National Laboratory

Coordinate on Regional and National Electric Vehicle Initiatives

Coordination on charging station infrastructure is important for electric vehicle drivers to have a consistent experience recharging their vehicle's batteries. Charging station connector standards, consistent signage and mapping, determination of charging corridor priorities, and funding sources are all important for maintaining uniformity.

REGIONAL AND NATIONAL COORDINATION

The Minnesota Department of Transportation is working with the U.S. Department of Transportation, Argonne National Laboratories, and the National Renewable Energy Laboratory to determine the optimal build out of charging stations in the Midwest and nationally.

As the state U.S. Department Energy Clean Cities Coordinator, the American Lung Association in Minnesota is working nationally with other states to coordinate alternative fueling corridors including charging station corridors for electric vehicles. American Lung MN is working with Energetics Incorporated on the Federal Highway Administration's project to Develop and Implement Regional Alternative Fuel Convenings of state Transportation Department staff. American Lung will host a convening in Saint Paul, MN to identify gaps along nearby corridors and state borders where strategically placed alternative fuel facilities should be located to establish a foundation for ubiquitous alternative fuel infrastructure in the U.S.

Coordination will help regions establish uniform standards and connected corridors for EVs.

THE GREAT LAKES ZERO EMISSION CORRIDOR SUPPORTS EVs

Minnesota is also working with national partners to develop EV charging infrastructure and seek national funding for EV promotion efforts in the Midwest.

Minnesota, Wisconsin, Illinois, Indiana, Michigan, and the City of Detroit coordinated with a number of nonprofits and the US Department of Energy Clean Cities to respond to a Federal Highway Administration (FHWA) request to designate alternative fuel corridors throughout the country.

In November 2016, FHWA designated Interstate 94 from Moorhead, Minnesota, to Port Huron, Michigan as a Zero Emission Corridor. The five states and City of Detroit subsequently signed a Memorandum of Agreement to re-brand the corridor as the Great Lakes Zero Emission Corridor (ZEC).

The designation has no funding, but will raise awareness about EVs, help the signatories apply for national funding/grants, and encourage private charging station investment along the corridor. The goal of the ZEC is to encourage installation of charging stations in 50 mile increments to allow EV drivers to travel throughout the Midwest, as early as 2018. The corridor designation will help address concerns about long distance EV travel by raising awareness about the increasing convenience of EV travel between cities and states.

Charging stations were installed along I-35 from the Twin Cities Metro Area to Duluth in 2017. Fast charger stations located in Forest Lake, Pine City, Sturgeon Lake and in Duluth allow EV drivers to reach destinations along the North Shore of Lake Superior. Additional fast chargers are expected to be installed along the North Shore in the future. Clean Cities partners are also working together to complete the I-35 charging corridor south of the Twins Cities Metro Area through the state of Missouri.

FIGURE 11. GREAT LAKES ZERO EMISSION CHARGING CORRIDOR (I-94)

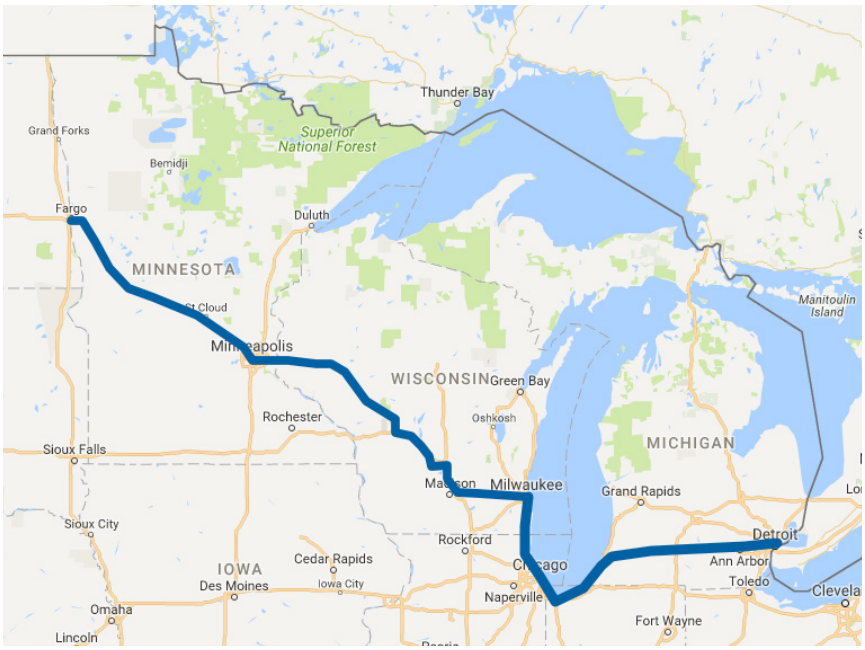


Photo Credit: Minnesota Department of Transportation, Sign for I-94 Great Lakes Zero Emission Corridor near St. Cloud

Photo Credit: Plug Into MN
Charging stations along I-35 between the Twin Cities and Duluth

Photo Credit: Albert Lea – Riverland Community College and Austin Utilities

Prioritize Renewable Energy to Charge Electric Vehicles

Electric vehicles are different from other vehicles because they can directly use renewable wind- or solar-generated electricity to charge the batteries and power the vehicle. There are a number of ways this can occur: an electric vehicle driver can have rooftop solar on their home, they can sign-up for a community solar or wind program through their utility, and they can charge at public stations that are participating in wind programs or have solar on-site. While electric vehicles do not generate tailpipe emissions, the fuel source used to power them matters. Powering electric vehicles with renewable energy further reduces their environmental impacts because the energy source does not generate emissions.

MINNESOTA HAS SEVERAL SOLAR - POWERED EV CHARGING STATIONS

A partial list of solar charging sites in Minnesota includes: Riverside Community College in Albert Lea, Como Park Lakeside, McMurray Fields, SunRay Library, River Centre (in Saint Paul), the Haaf Parking Ramp and the Davis Center (Minneapolis Public School headquarters) in Minneapolis, and the Minnesota State Capitol complex (corner of Rice Street and University).

DRIVERS CAN SIGN UP FOR UTILITY RENEWABLE ENERGY PROGRAMS TO REDUCE EMISSIONS FROM EVS

As more renewable sources come onto the electric grid, driving an electric vehicle will become cleaner. However, drivers can sign up for utility renewable energy programs to foster this progression. For more detail, see "Utility Electric Vehicle Programs" (p. 31) and Appendix E.

Photo Credit: Drive Electric Minnesota

Utility Electric Vehicle Programs

UTILITIES CAN BENEFIT THEIR CUSTOMERS THROUGH EV PROGRAMS

The benefits EVs can offer to utilities and their consumers have prompted utilities around the country to explore the most appropriate ways to be supportive. A recent study found that EVs could benefit Minnesota by $4.6 billion to $30 billion, depending on the rate of adoption. These benefits could extend to non-EV owners -- particularly if EV charging occurs off peak (between 9pm and 9am) when utilities can maximize the available wind resource.[11]

Minnesota electricity providers initiated groundbreaking programs to support and encourage EV use. Utilities in Minnesota were among the first in the country to offer time-of-use rates. In Xcel territory for example, customers can pay the off-peak rate to charge at night, and/or elect to charge with renewable energy. Some utilities in the state offer rebates for installing a home charging station. Information about utility programs for EV drivers is available at mncharging.org. This resource includes information about programs for powering EVs with renewable solar or wind generated electricity.

Utility EV programs can support EV adoption for customers through investments in EV charging infrastructure, education, rate promotion, evaluation and administration, and EV incentives. Minnesota utilities and co-operatives are involved in most of these areas. Many utilities are supporting increased EV charging availability through rebates, investment in distribution infrastructure, and cost-share for fast charger projects. Education can take various forms, including education of commercial customers on the cost-savings potential of fleet electrification, hosting ride and drive events for customers, and investing in web, social media, earned media, and advertising. Several Minnesota utilities are developing programs to support electrification of transit buses, school buses, and other heavy-duty vehicles. Several utilities offer favorable rate structures to encourage off-peak charging and charging with renewable electricity.

Utilities play a key role in providing information about EVs. The Associated Press and National Opinion Research Center for Public Affairs noted that in matters of energy issues, "local utility companies are the only source of information completely or very much trusted by a majority of the public" (2012). Trust in local utility companies is rated at 52 percent -- higher than trust in any other institutions mentioned in the survey. Local utilities are viewed as the energy experts in the communities they serve (AP-NORC, 2012). Utilities may be a highly trusted source of information about EVs as well, and two-thirds of those surveyed expected utilities to make such information available.

The Midcontinent Transportation Electrification Collaborative released a whitepaper in April 2018, supported by stakeholder groups representing a range of perspectives, that asserts that EVs offer benefits to utilities and utility customers and should be supported. The whitepaper states that "utilities can support increased adoption and beneficial integration of EVs into the electric system to benefit their customers".

The Minnesota Public Utilities Commission, seeing the growing interest in EVs, opened a generic EV docket in December 2017 to gather information on the potential impacts on the electric system and utility customers, the degree to which utilities can impact the rate of adoption, and possible tariff options to facilitate wider availability of EV charging. Given the level of interest by stakeholders, regulators, and utilities, it is very likely that utility EV programs will expand over time and play a growing role in supporting increased EV adoption and charging, with increasing benefits for all Minnesotans.

Photo Credit: Drive Electric Minnesota

Looking to the Future

Electric vehicles are part of an evolution in transportation. EVs provide a starting place for considering how we get around and what future mobility options will look like. These vehicles can readily link to smart grid technologies and be paired with automation. Combined, these technologies can drive lower operating costs, more efficiently use energy, and result in less air pollution. A study of passenger vehicle automation by the University of California Davis showed that if the three revolutions of urban transportation—passenger vehicle automation, electrification, and ride sharing—are combined, carbon emissions from all transportation sources worldwide can be reduced by more than 80 percent.

To follow are some of the advancements and future considerations for electric vehicles.

National Travel by Electric Vehicle

The next generation of ultra-fast charging stations will use 150 kW to provide 200 miles of range in 23 minutes. Stations like these will be installed along interstate and highway corridors in the near future. The intent is to place these ultra-fast charger stations at an average of about 50 to 70 mile increments along interstates and highways, and ideally at a distance no greater than two miles off an exit ramp.

Automakers and charging station manufacturers are working on the next generation of ultra-fast charging technology. This includes development of 350 kW stations that provide 200 miles of range in 10 minutes. The Trans-European transport network will include twenty-five 350 kW stations, connecting the Netherlands, Belgium, Germany, and Austria. The stations will be used by electric buses and trucks initially. Passenger vehicles will be soon to follow. The network is expected to be complete in 2018.

Minnesota is collaborating with regional and national entities to plan for the expansion of fast charging corridors in the state (as described on p. 26).

Smart Charging

Using electricity to power vehicles unlocks the potential for intelligent or smart charging technology. Smart charging stations use computerized controls to draw most of their power during peak solar and wind electricity generation, which optimizes clean, renewable electricity use.

An example is a workplace that has a rooftop solar array and uses smart charging stations. These stations can detect and regulate the best time for charging employee electric vehicles. Since vehicles will likely be parked for eight hours or more, charging can occur more slowly than it might otherwise. Electricity drawn for charging can vary with the ebb and flow of the solar electricity production. Throughout the day when sunlight levels are high and more solar electricity is generated, the charging station will use more electricity. This function is called solar synchronization. At times of the day when sunlight levels are lower, resulting in less electricity generation, the stations will reduce their electricity draw. By the end of the workday, the smart stations will have both optimized solar electricity use and provided a fully charged vehicle ready for the drive home.

Day ahead wind forecasts can be used by smart charging stations to time their power draw with expected high levels of wind electricity generation. Fleet vehicles, which are primarily plugged in at night, can take advantage of this source of renewable electricity. Currently, this technology leverages renewable energy use on the grid based on data from a grid-tied solar array or wind forecast information. As this technology progresses, it has the potential to include an aggregation of smart charging stations that can directly respond to regional renewable energy production and pricing signals on the wholesale electricity market.

Automated Driving

This technology can be activated to allow computers linked to on-board sensors to control all or a portion of driving. In the future, this technology is expected to significantly reduce accidents caused by human error. Research and testing of autonomous driving for both passenger and transit vehicles continues. Some levels of automation are already available, as in present in some Tesla models.

In 2018, Minnesota established the Governor's Advisory Council on Connected and Automated Vehicles. The council is responsible for consulting with stakeholders on issues related to connected and automated vehicles. It will ultimately develop a report recommending changes in statutes, rules and policies to prepare for a future in which automated vehicles are more common. As the council develops recommendations, it will consider the potential impacts of electrification on automated vehicles in Minnesota.

Broader Transportation Electrification

The Vision focuses on light-duty vehicles, but large vehicle electrification holds promise as well. Electric versions of buses, delivery vans, and heavy-duty trucks are available, and schools and transit agencies are already piloting them in Minnesota. Like light-duty EVs, electric heavy-duty vehicles can provide benefits like lower emissions and cost savings.

In the next five years, 25 percent of the vans that deliver in urban areas are expected to be electric. According to Green Fleet, "The promise of all-electric medium-duty (Class 3-7) trucks is compelling. Fleets can eliminate fossil fuel use (and cost), achieve zero direct emissions, and reap the PR benefits that come with touting their commitment to sustainability...High profile fleets, such as Frito-Lay, Staples, and Coca-Cola, have all made big investments in E-Trucks that can haul as much as 16,000 pounds, with a range up to 100 miles on a single charge."[12]

Low speed and fixed routes with lots of stops are ideal for electric heavy duty vehicles. Starting and stopping helps charge the vehicles' batteries. Also, planning for and installing charging infrastructure for vehicles that travel the same route every day is easier than planning for those whose routes vary. When drivers know where they can charge, the process becomes much more efficient.

Powering heavy-duty equipment with electricity instead of diesel can save operators money on fuel. Fuel is consistently one of the largest costs for long haul trucking according to the American Transportation Research Institute.[13]

Widespread electric heavy-duty vehicle use will not occur until several challenges are addressed. Currently, purchasing an electric truck costs more than purchasing a diesel-powered truck. The lack of existing charging infrastructure is also a problem. And, heavy-duty trucks have large batteries that take a long time to charge. Truck drivers are unlikely to be willing to wait an hour to charge their vehicle.

Some companies are exploring electric heavy-duty automation. Daimler Trucks is currently testing a self-driving Freightliner on Nevada roads. IHS Automotive, an industry research firm believes autonomous truck sales could reach 60,000 per year by 2035. If battery range limitations can be addressed, the trucking industry could be a prime early market for automated vehicle technology.

Minnesota's Vision

This Vision for EV adoption challenges Minnesota to grab onto an opportunity for a cleaner, modern, and more equitable transportation system. EVs are an opportunity to reduce emissions and make our electric power sector more efficient. They are an opportunity save drivers money and hassle. Minnesota has taken important first steps to become a leader in EV adoption in the Midwest, and there is much left to do on our road to an EV future for all Minnesotans.

Appendices

Appendix A. Charging Connectors and Standards

LEVEL 1 AND 2 CHARGING STANDARD

A standard connection called J-1772 is used for all Level 1 and Level 2 charging throughout the globe. Tesla models can use this same connection with an adapter. This connection standard was established through the International Society of Automotive Engineering.

J1772 Level 1 and Level 2 Standard
Source: zemotoring.com

DIRECT CURRENT (DC) FAST CHARGING STANDARDS

With the exception of Tesla models, electric vehicles use one of two types of connectors or standards for charging. European and US models use the CCS Combined Charging System. Asian models use CHAdeMO standard connectors.

The majority of the public stations in MN have both types of charging station connectors or standards available for use. Tesla vehicles can charge using the CHAdeMO connector with an adapter.

CCS Combined Charging System (left) CHADdeMO (right)
Source: cleantechnica.com

Tesla Supercharger connector
Source: insideevs.com

Currently, the charging technology used by stations in the cross-country Tesla Super Charger network limits their use to only Tesla models. Tesla developed this technology early on prior to the CCS and CHAdeMO standards.

Appendix B. Minnesota Next Generation Act Goals

The Minnesota Next Generation Energy Act, based on 2005 emission levels, contains the following state wide green house gas (GHG) reduction requirements:

- 15% reduction by 2015
- 30% reduction by 2025
- 80% reduction by 2050

Appendix C. Summary of Transportation Revenue Effects for NGEA Electric Vehicle Goal Scenario

Source: Minnesota Department of Transportation

Analysis assumes 20% of total light duty (LD) vehicle fleet is EV in year 2030. That means >60% of 2030 new sales are EVs. Business as usual (BAU) based on current fleet mix of EVs at 4% of stock and 6% of sales. Taxes collected under the 2030 sales profile are evaluated for 2030 - 2039 to create a 10-year estimate for the revenue effects of EVs displacing non-EVs on a 1:1 basis. Revenue estimates for the remainder of the LD fleet are not included here.

Assumptions:

EV revenue based on MVST + registration taxes + $75 annual EV fee
EV price ≤ non-EV + $16,000
Displaced non-EV average MPG = 38 (EIA projection for year 2030) ± 12

Conclusions:

Higher EV price premiums increase transportation revenues.
High EV price premium + high non-EV MPG (upper-right corner of table) produces highest additional transportation revenue.

$8,000+ EV price premiums over non-EV options in 2030 could have double-digit revenue gains.

Even a small ($4,000) EV price premium would keep revenue unchanged or increase up to 9% if displacing higher-MPG vehicles.

Even at vehicle price parity, revenue est. to fall less than 10%.

10-Year Absolute Revenue Change (billions)

		Avg MPG: non-EVs displaced by EVs						
		26	30	34	38	42	46	50
EV price premium	$16,000	$0.2	$0.3	$0.3	$0.3	$0.3	$0.3	$0.3
	$12,000	$0.1	$0.2	$0.2	$0.2	$0.2	$0.2	$0.3
	$8,000	$0.1	$0.1	$0.1	$0.1	$0.2	$0.2	$0.2
	$4,000	($0.0)	$0.0	$0.0	$0.1	$0.1	$0.1	$0.1
	$0	($0.1)	($0.1)	($0.0)	($0.0)	$0.0	$0.0	$0.0
	($4,000)	($0.2)	($0.1)	($0.1)	($0.1)	($0.1)	($0.1)	($0.1)
	($8,000)	($0.2)	($0.2)	($0.2)	($0.2)	($0.2)	($0.1)	($0.1)

Percent Revenue Change (green = revenue greater than BAU)

		Avg MPG: non-EVs displaced by EVs						
		26	30	34	38	42	46	50
EV price premium	$16,000	20%	23%	25%	27%	29%	30%	31%
	$12,000	13%	16%	18%	20%	21%	23%	24%
	$8,000	6%	9%	11%	13%	14%	15%	17%
	$4,000	(0%)	2%	4%	6%	7%	8%	9%
	$0	(7%)	(5%)	(3%)	(1%)	0%	1%	2%
	($4,000)	(14%)	(11%)	(10%)	(8%)	(7%)	(6%)	(5%)
	($8,000)	(20%)	(18%)	(17%)	(15%)	(14%)	(13%)	(12%)

Appendix D. Electric Vehicle Fast Charging Station Corridors

The following list is for the maps on page 5 and 27. In this exercise there is a total of 85 fast charging stations at about 50 mile increments along each roadway for a cost of about $10 million. This network of charging stations would provide service covering the entire state.

TABLE 4. FAST CHARGING CORRIDORS BY POPULATION CENTER AND ROADWAY TRAFFIC VOLUME

Roadway - Population Centers	Distance (miles)	Number of Fast Charging Stations
Hwy 1 Hwy 169 Hwy 53 Ely to Virginia to Eveleth to Duluth	115	2
Hwy 1 Ely to Illgen City (Hwy 61)	60	1
Hwy 10 Little Falls to Detroit Lakes to Moorhead	146	3
Hwy 10 Minneapolis to Saint Cloud to Little Falls to Brainerd (Hwy 371)	136	3
Hwy 11 (Hwy 71) Karlstad to Warroad to Baudette to International Falls	159	3
Hwy 12 Willmar to Benson to Ortonville	73	1
Hwy 12 Bloomington to Wilmar	100	2
Hwy 14 Mankato to New Ulm	30	1
Hwy 14 Rochester to Owatonna to Mankato	90	2
Hwy 15 New Ulm to Fairmont (I-90)	49	1
Hwy 15 Saint Cloud to New Ulm	95	2
Hwy 169 - Hwy 60 Minneapolis to Mankato	82	2
Hwy 169 (Hwy 18) Grand Rapids to Brainerd to Minneapolis	168	3
Hwy 2 Crookston to Bemidji to International Falls	196	4
Hwy 2 Crookston to East Grand Forks	25	1
Hwy 210 (I-35 S) Brainerd to Duluth	115	2
Hwy 212 Bloomington to Glencoe	50	1
Hwy 212 Glencoe to Granite Falls	71	1
Hwy 23 Saint Cloud to Wilmar to Marshall to Granite Falls to Beaver Creek (I-90)	207	4
Hwy 371 (Hwy 2) Bemidji to Brainerd	100	2
Hwy 52 Rochester to Saint Paul	80	2
Hwy 53 International Falls to Virginia	98	2
Hwy 59 Karlstad to Thief River Falls to Detroit Lakes to Redwood Falls to New Ulm	358	7
Hwy 60 Fairbault to Mankato	44	1

TABLE 4. FAST CHARGING CORRIDORS BY POPULATION CENTER AND ROADWAY TRAFFIC VOLUME (CON'T)

Hwy 61 Duluth to Grand Marais	110	2
Hwy 61 Grand Marais to Grand Portage	35	1
Hwy 61 Saint Paul to Red Wing to Winona to Dakota (I-90)	138	3
Hwy 65 (Hwy 2) Grand Rapids to Cambridge	140	3
Hwy 65 Cambridge to Minneapolis	44	1
Hwy 71, Hwy 14 Redwood Falls to Windom	47	1
Hwy 71, Hwy 200 Bemidji to Park Rapids to Willmar to Redwood Falls (I-90)	238	5
I-35 Duluth to Minneapolis/Saint Paul	155	3
I-35 Minneapolis to Fairmont to Albert Lea	100	2
I-90 Albert Lea to Dresbach (eastern border)	117	2
I-90 Albert Lea to Fairmont to Beaver Creek (western border)	155	3
I-94 Moorhead to Saint Cloud to Saint Paul	240	5

Appendix E. Minnesota Electric Vehicle Utility Programs

TABLE 5. MINNESOTA UTILITY PROGRAMS OFFERING RENEWABLE ENERGY PROGRAMS FOR ELECTRIC VEHICLES

Agralite Electric Cooperative
Arrowhead Electric Cooperative
BENCO Electric Cooperative
Brown County
Connexus
Co-op Light & Power
Crow Wing Power
Dakota Electric - Wellspring
East Central Energy
Federated Rural Electric Assn
Goodhue County Co-op Electricity Assn
Itasca Electric Co-op
Itasca ManTrap Electric Co-op
Kandiyohi Power Cooperative
Lake Country Power
Lake Region Electric Cooperative
McLeod Co-op Light & Power
Meeker Cooperative Light & Power
Mille Lacs Energy Co-op
MN Power - Wind Program
MN Valley Electric Co-op
Nobles Co-op Electric
North Itasca Electric Co-op
Olivia -Clean Energy Choice Program
Ottertail - Tailwinds Program
Peoples Energy
Redwood Electric Cooperative
Runeston Electric Association
South Central Electric Association
Stearns Co-op Electric Association
Steele Waseca Cooperative Electric
Todd-Wadena Electric Cooperative
Wright Hennepin Co-op Electric Assn
Xcel - Windsource for EVs

TABLE 6. MN UTILITY PROGRAMS OFFERING ELECTRIC VEHICLE CHARGING 'TIME OF USE' RATES

Connexus
Dakota Electric Association
Lake Region Electric Cooperative
Minnesota Power
Ottertail Power
Wright-Hennepin Co-op Electric Assn.
Xcel Energy

Appendix F. EV Charging Maps

The plugshare.com map is updated on an ongoing basis to provide location, availability, and cost/rate information. The U.S. Department of Energy (DOE) map retains a record of stations across the country.

FIGURE 12. PLUGSHARE.COM

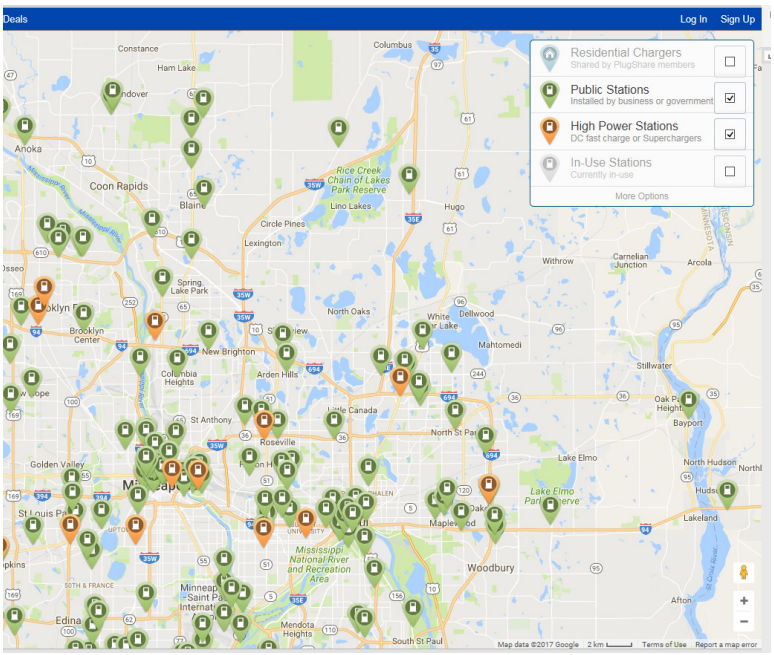
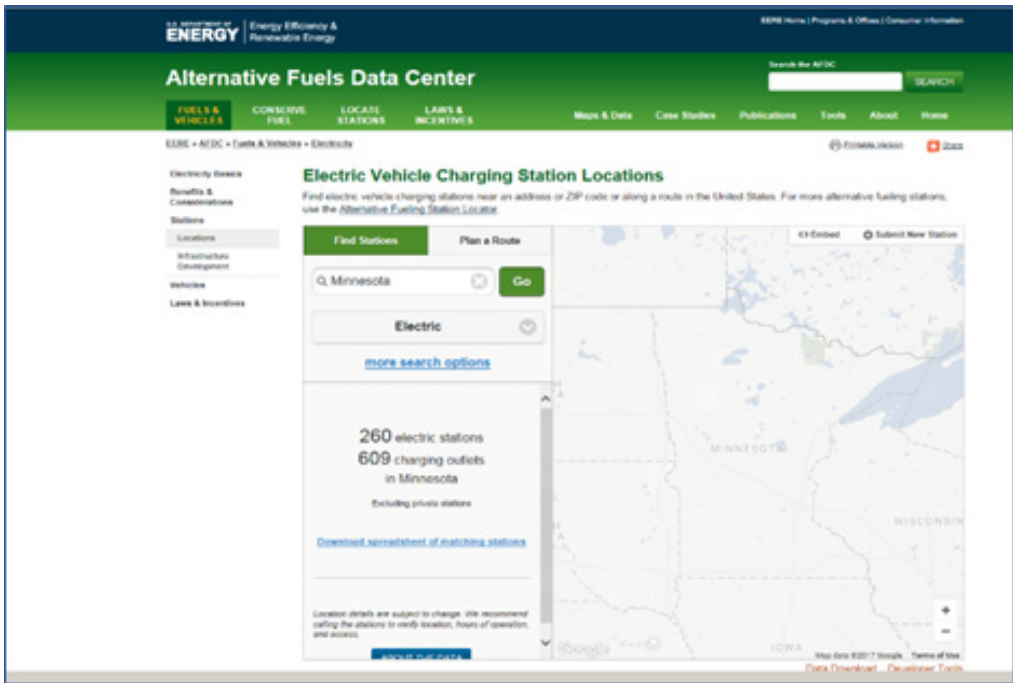


FIGURE 13. U.S. DEPARTMENT OF ENERGY NATIONAL MAP



Appendix G. Plug-in Electric Vehicles Currently Available

TABLE 7. PLUG-IN ELECTRIC VEHICLES AVAILABLE IN THE MIDWEST

Manufacturer	Model	Electric Miles Range	MPGe/MPG
Audi	A3 E-Tron	17	86/39
BMW	i3	114	124(39)
BMW	i8	15	76/28
BMW	X5 xDrive40e	14	56/24
BMW	330E	14	72/31
BMW	530E	16	72/29
BMW	740E	14	64/27
Chevrolet	Bolt	238	119
Chevrolet	Volt	53	106/42
Chrysler	Pacifica Hybrid (PHEV)	16	84/32
Ford	Focus Electric	76	110
Ford	Fusion Energi	21	97/42
Honda	Clarity PHEV	48	110/42
Nissan	Leaf	150	114
Porsche	Panamera S E-hybrid	16	62/25
Porsche	Cayenne S E-hybrid	14	65/25
Tesla	Model 3	220-310	110
Tesla	Model S	249-335	101
Tesla	Model X	238-295	92
Toyota	Prius Prime	25	133/54
Volvo	XC90 T8	14	53/25
Volvo	XC90 T8	19	62/27

Source: Table data (January 2018) from PluginConnect.com

Appendix H. Wayfinding Signage for Charging Stations

Wayfinding signage helps EV and PHEV drivers navigate to charging stations from other locations, such as a freeway exit. The Federal Highway Administration defines the minimum standards for signage, which it publishes in the Manual on Uniform Traffic Control Devices (MUTCD), updated every five to six years. The standards in the MUTCD apply to all signage on public highways, streets, bikeways, and private roads open to the public, such as at shopping centers and airports. FHWA has approved the following interim designs for charging station signs:

D9-11bp

D9-11bp

Appendix I: Cities Making Progress on Electric Vehicle Readiness across Minnesota

28 cities across Minnesota are looking forward and are getting ready for broad adoption of EVs.

Led by the Great Plains Institute (GPI) and Clean Energy Resource Teams (CERTs), Cities Charging Ahead! (CCA) is a peer cohort of 28 cities working together across Minnesota exploring EV readiness. Participating cities receive technical assistance focused on actions and best practices, based on the GreenStep Cities program, that cities can implement to accelerate the adoption of EVs such as:

- Including EVs in city purchasing plans
- Installing electric charging infrastructure in public parking areas
- Providing guidance on electric vehicle-ready development in the private sector

Funding is provided through the Carolyn Foundation, Energy Foundation, and in partnership with Xcel Energy, which provides support and resources in line with the company's long-term clean energy plan to electrify transportation.

Most of the cities participate in a regional cohort that meets every other month for three-hour in-person meetings with other cities in their area to learn, share, and discuss their questions, needs, resources, challenges, and opportunities. Each regional cohort chooses the direction of the topics they want to cover in their cohort meetings. The Metro region began with fleets, while the Southeast started with energy, climate, and comprehensive planning. The Northeast cohort just met for the first time in August and are still determining the direction in which they want to go. There are 16 cities in the Metro cohort, four in the Northeast, and five in the Southeast, with three additional cities in Greater Minnesota.

In addition to in-person meetings, GPI has hosted three webinars. The first focused on an overview of the project and GreenStep Cities best practices, the second focused on electric charging and charging stations, and the third focused on EV readiness in private development.

The CCA team is currently developing two comprehensive decision-flow charts focused on EV and EV-charging station purchasing to provide members with pros and cons of different options to help them make an informed decision to meet their specific community needs. The plan is to share these tools with cities not involved in the current effort once they are ready for prime time.
Cities Charging Ahead! is currently slated to continue through early 2019, and there may be a second round, depending on interest and funding. If you are interested in getting involved or partnering with CCA, please contact Diana McKeown at dmckeown@gpisd.net. You can find more information about CCA at the bottom of http://www.betterenergy.org/greenstep-cities.

Sources

[1] Bloomberg New Energy Finance https://about.bnef.com/blog/electric-vehicles-accelerate-54-new-car-sales-2040/
[2] Calculation Assumptions: 25 miles per gallon efficient vehicle running on gas at $2.50 per gallon.
[3] U.S. Energy Information Administration Annual Energy Outlook Report www.eia.gov/outlooks/aeo page 50
[4] Plugged In: How Americans Charge Their Electric Vehicles Idaho National Laboratory
[5] Charging While Your Work Guide pca.state.mn.us/sites/default/files/charging-while-you-work-guide.pdf page 2
[6] Minnesota's 2025 Energy Action Plan mn.gov/commerce/policy-data-reports/energy-data-reports/mn-action-plan.jsp page 9
[7] The Clean Jobs Midwest Survey cleanjobsmidwest.com/state/minnesota
[8] Michael Liebreich Industry Keynote: Global Summit 2017 Bloomberg New Energy Finance vimeo.com/214732046
[9] The Greenlining Institute greenlining.org/publications/online-resources/2016/electric-vehicles-equity-toolkit/
[10] Three Revolutions in Global Transportation University of California Davis www.itdp.org/wp-content/uploads/2017/04/UCD-ITDP-3R-Report-FINAL.pdf
[11] Electric Vehicle Cost-Benefit Analysis: Minnesota https://www.mjbradley.com/reports/electric-vehicle-cost-benefit-analysis-minnesota
[12] Green Fleet www.greenfleetmagazine.com/channel/electric/article/story/2014/01/the-state-of-all-electric-trucks-in-the-u-s-medium-duty-market-grn.aspx
[13] An Analysis of the Operational Costs of Trucking: 2015 Update American Transportation Research Institute atri-online.org/wp-content/uploads/2015/09/ATRI-Operational-Costs-of-Trucking-2015-FINAL-09-2015.pdf page 28
*Fast Charger Assumptions: Constant charge rates occur throughout the charging session and the recipient EV has a large enough battery to take all the kWh. Battery technology over the next couple of years may hamper the ability to charge at rates consistently over 200kW Source: ZEF Energy

Resource Links

Drive Electric MN provides a central clearinghouse for all EV activities in the state at www.DriveElectricMN.org.

MN Plug-in Electric Vehicle Owners Circle
www.pluginconnect.com/mnpevowners.html

Great River Energy Revolt Program
http://www.energywisemn.com/revolt/

Dakota Electric Time of Use Rates
https://www.google.com/#q=dakota+county+time+of+use+rates+electric+vehicles

Xcel Energy Electric Vehicle Rate Plan
https://www.xcelenergy.com/staticfiles/xe/PDF/Marketing/MN-EV%20Rate-Contractor-Set-Up-Guide-MN.pdf

Autonomous Driving
https://www.nhtsa.gov/technology-innovation/automated-vehicles

U.S. DOE National Charging Station Map
http://www.afdc.energy.gov/fuels/electricity_locations.html

National Map of Charging Corridors
https://www.fhwa.dot.gov/environment/alternative_fuel_corridors/maps/evus/

ZEV Sales Dashboard Comparison with other states
https://autoalliance.org/energy-environment/zev-sales-dashboard/

Annual Auto Sales in Minnesota
autoalliance.org/in-your-state/MN/pdf/?export

ZEV Sales Dashboard
autoalliance.org/energy-environment/zev-sales-dashboard/

Transportation Electrification Beyond Light Duty: Technology and Market Assessment
https://info.ornl.gov/sites/publications/Files/Dev296070.pdf

Review charging stations in MN and elsewhere
Plugshare.com