Alternative Fuels & Vehicle Electrification

This paper is based on work completed as part of The University of Minnesota's Transportation Futures Project. More information about The Transportation Futures Project can be found on the project homepage.

INTRODUCTION

Methods of powering vehicles have changed in recent decades. Desires to reduce environmental impacts, reliance on foreign oil, and the cost of driving have led to the development of alternative energy sources for cars such as biofuels, natural gas, and electricity. While gasoline remains the dominant fuel internationally and domestically, government subsidies and advances in technology have made alternative fuels more readily available to the public. The effects of alternative fuel usage on the transportation system will vary depending on several factors. This paper will introduce technologies on the market today as well as those that are in early research stages, and the possible implications on the transportation network locally and more generally.

BIOFUELS

Today, drivers in Minnesota and nationally often see different blends of gasoline at the pumps, and more vehicles that accept these fuels have become widely available. Biofuels, which can broadly be described as biomass (organic material) converted directly to fuels, have been around for as long as cars have[1], and are found in almost all gasoline types today—not just those specifically marked at the pump as such.[2] While 95 percent of U.S. gasoline contains biofuels (usually 10 percent ethanol, 90 percent gasoline), there continues to be research and development towards vehicle technology and fuel production in order to increase the availability of these fuels to customers. In addition, state and federal regulation encourages continued innovation.

Types of Biofuels

Ethanol: The most common biofuel found at gas stations today is ethanol, which can be derived from a variety of plant species such as sugar beet, sugarcane, corn, and wheat[3]. Most ethanol available in Minnesota is derived from corn. After fermentation and chemical reactions, the leftover products are blended with gasoline at varying levels. E10, E15, and E85— or 10, 15, and 85 percent ethanol, respectively—are all currently available in Minnesota.

- E10: As mentioned above, most gasoline is blended with 10 percent ethanol (E10) and is not explicitly noted at the pumps. The U.S. Environmental Protection Agency classifies E10 as "substantially similar" to gasoline and is legal for use in all gasoline-powered vehicles.[4]
- E15: Containing only slightly more ethanol than E10, E15 is approved only for model year 2001 and newer vehicles.[5]
- E85: Depending on geography and season, pumps listed as E85 contain between 50 and 83 percent ethanol and may only be used in flexible fuel vehicles (FFV). Although drivers using E85 will see lower gas mileage, this ethanol blend is often considerably cheaper than other conventional gasolines due to laws and regulations that affect the price.[6]

Biodiesel: Most often used as a blend with conventional petroleum diesel, biodiesel is produced with vegetable oils, animal fats, or recycled restaurant grease.[7] Similar to ethanol, blends can range from as low as two percent to 100 percent. The most common biodiesel blend in the U.S. is

[1] National Geographic
[2] NREL, 2015
[3] Levinson, D. et al. "The Transportation Futures Project: Planning for Technology Change." , Minnesota Department of Transportation Research Services & Library, 2015.
[4] U.S. DOE
[5] Ibid.
[6] Ibid.
[7] Alternative Fuels Data Center

B20 (20 percent biodiesel, 80 percent petroleum diesel) and is approved for most vehicles after 1994.[8] Vehicles that are not technically "alternative fuel vehicles" are able to run on B20. Many transit fleets run on some level of biodiesel blend.

Local Context

Minnesota began incentivizing and regulating biofuel production and consumption as early as 1980, when the state passed a series of legislative acts. With continued policy since then, the state has sought to create a new market for its agricultural products, reduce fossil fuel dependence, and help meet the U.S. EPA standards for air quality in the Twin Cities area.[9]

Minnesota currently has 293 E85 fueling stations—more than any other state.[10] This number is projected to grow after a 2015 federal grant provided funding to retailers for expansion of E85 pumping stations.[11] In 2015, Minnesota ranked fifth in production of both ethanol and biodiesel in the U.S.[12]

Retailers offering lower blends of biodiesel (B5 and B10) can be found across the state.[13] However, there are only three locations currently offering B20 and above. Minnesota state statute calls for differences in blending throughout the year because of the state's cold climate—B10 in the summer months and B5 from October through March.[14] The state hopes to blend B20 during summer months by 2018.[15]

Current and Future Trends

Food security is often discussed when talking about fuel that is derived from a food source. Ethanol is made from the starch and sugars of plants (those materials that are edible). However, research continues on technologies that allow the conversion of inedible fibrous material to fuel, called cellulosic fuel. In addition to the food security benefit of using inedible parts of the plant for fuel, the production of cellulosic ethanol has the potential to be less environmentally harmful than both gasoline and ethanol derived from corn.[16] As the techniques for producing cellulosic ethanol become more refined and less costly, it may replace traditionally produced ethanol.

In addition to cellulosic ethanol, research is also exploring fuels derived from algae. Algae are tiny aquatic organisms that convert sunlight into energy that is often stored in natural oils. Although the process is in its infancy, this oil can be refined to create biofuel—up to sixty times the amount per acre than that of land based plants currently used for biofuels.[17] While biofuel from algae is far from commercially available, there has been a significant amount of investment in the future use of algae for fuel.[18]

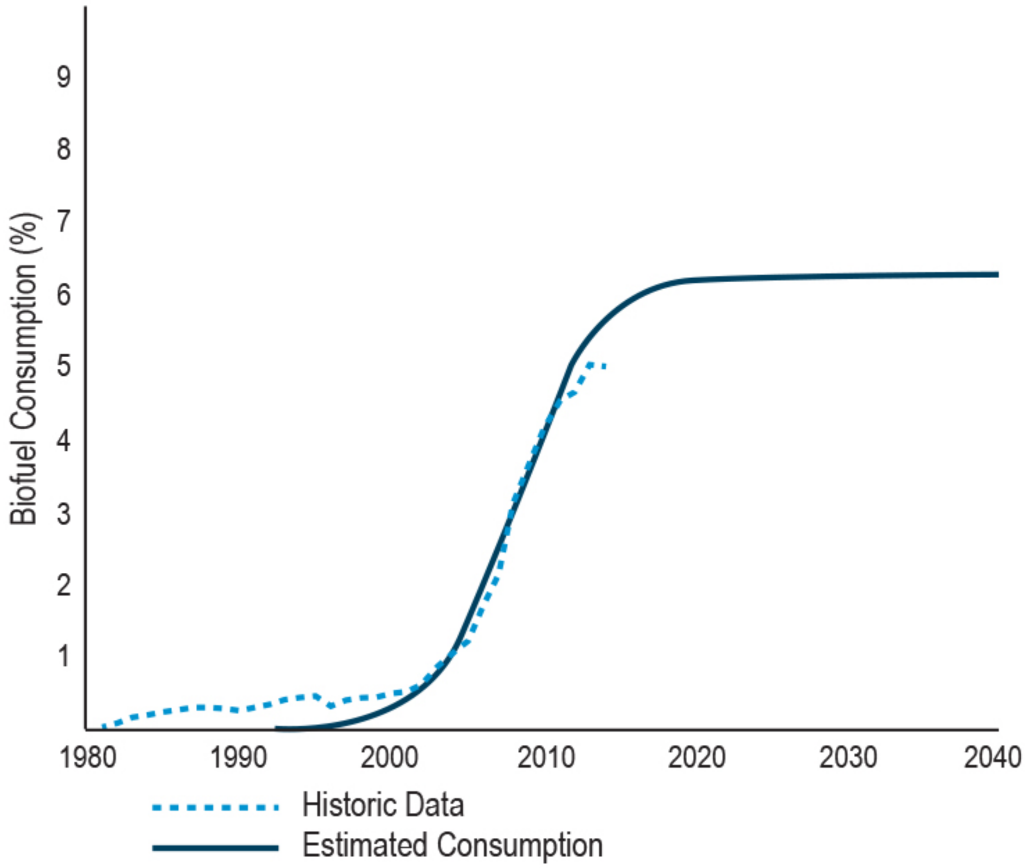
In an effort to develop the alternative fuels market, the Energy Independence and Security Act of 2007 (EISA) requires 36 billion gallons of renewable fuel be blended into domestic transportation fuels each year by 2022. However, it is unclear if these targets will be reached. In late 2015, the EPA mandated that more than 18 billion gallons of biofuels be blended into the fuel supply in 2016, yet this falls short of the 22.5 billion envisioned for that year in the 2007 EISA.[19]

Researchers at the University of Minnesota project that the national rate of biofuel consumption will level off near the current level of consumption, as shown in Figure 1. The production of biofuels is projected to increase, but will remain stable relative to total fuel use (both total fuel use and biofuel

8 Biodiesel Basics
9 Levinson, D. et al. "The Transportation Futures Project: Planning for Technology Change." , Minnesota Department of Transportation Research Services & Library, 2015.
10 Twin Cities Clean Cities Coalition
11 Meerseman, 2015
12 State of Nebraska
13 Biodiesel locator map
14 Minnesota Department of Agriculture
15 Ibid.
16 Center for Climate and Energy Solutions
17 Energy.gov
18 Casey, 2015
19 Neuhauser, 2015

production will increase proportionally). As technology develops and fuel mandates incentivize greater production of fuels from non-food sources, such as those from cellulose, there may be larger supplies of advanced and cellulosic fuels available.[20]

Figure 1: Historic and projected biofuel consumption as a percent of total transportation fuels[21]



NATURAL GAS

Although similar to the gas that is used for heating and cooking, natural gas used for vehicle fuel accounts for only 0.1 percent of all domestic natural gas usage,[22] and must first be compressed (CNG) or liquefied (LNG) before being used in vehicles.

While there are currently 300,000 miles of natural gas transmission pipelines operating in the US,[23] there is limited fueling infrastructure in place (roughly 500 publicly-available filling stations[24]). Existing gasoline vehicles can be converted to run on natural gas, but they must meet regulations to ensure safety in both the vehicles and the facilities where they are parked and maintained.

Widespread use of light duty natural gas vehicles is limited by the low number of public fueling stations. Personal vehicles like these require the wide geographic distribution of standard gas stations seen today. However, medium and heavy duty vehicles in a fleet that return to the same location everyday could benefit from natural gas. These vehicles, which often run on diesel and operate in a limited range, may see reduced operational

[20] Levinson, D. et al. “The Transportation Futures Project: Planning for Technology Change.” , Minnesota Department of Transportation Research Services & Library, 2015.
[21] Levinson, D. et al. “The Transportation Futures Project: Planning for Technology Change.” , Minnesota Department of Transportation Research Services & Library, 2015.
[22] U.S.. Energy Information Administration
[23] U.S. Energy Information Administration
[24] CNG Now

costs and GHG emissions by switching to natural gas.[25] Medium and heavy-duty vehicles do not have the same alternative fuel options as small, light duty vehicles, which leaves natural gas as a potential option for achieving some of the environmental and operational benefits. When burned, natural gas produces less carbon dioxide, particulate matter, nitric oxide and nitrogen dioxide emissions than diesel fuels, but higher levels of methane. In order to encourage natural gas use in heavy-duty vehicles, sufficient refueling infrastructure must be in place to enable full deployment. Los Angeles has recently deployed CNG refueling stations throughout the metropolitan area, which has allowed LA Metro to adopt a bus fleet powered entirely by natural gas. [26]

While traditional natural gas is considered a fossil fuel and non-renewable, renewable natural gas (RNG) can be produced through the decomposition of organic materials and is considered an advanced biofuel.[27] It can be produced from landfills, livestock operations, and wastewater treatment plants.[28]

Local Context

There are currently 12 CNG filling stations scattered across Minnesota, of which nine are open to the public. Kwik Trip, an upper Midwest gas station and convenience store, continues to expand its network of alternative fuel stations across Minnesota, Iowa, and Wisconsin. In these three states, there are currently 27 Kwik Trip stations offering CNG alongside standard fuels. As of the end of 2015, there were no LNG filling stations in Minnesota.

Similar to other alternative fuels, Minnesota has regulation in place that taxes CNG at a reduced rate relative to that of gasoline. However, unlike 24 other states, there are no tax incentives or rebates available to drivers or fleet managers wishing to convert their vehicles to run on CNG.[29]

In 2014, St. Cloud Metro Bus added 23 CNG powered buses to their fleet, making them the first transit system in the state to convert to CNG.

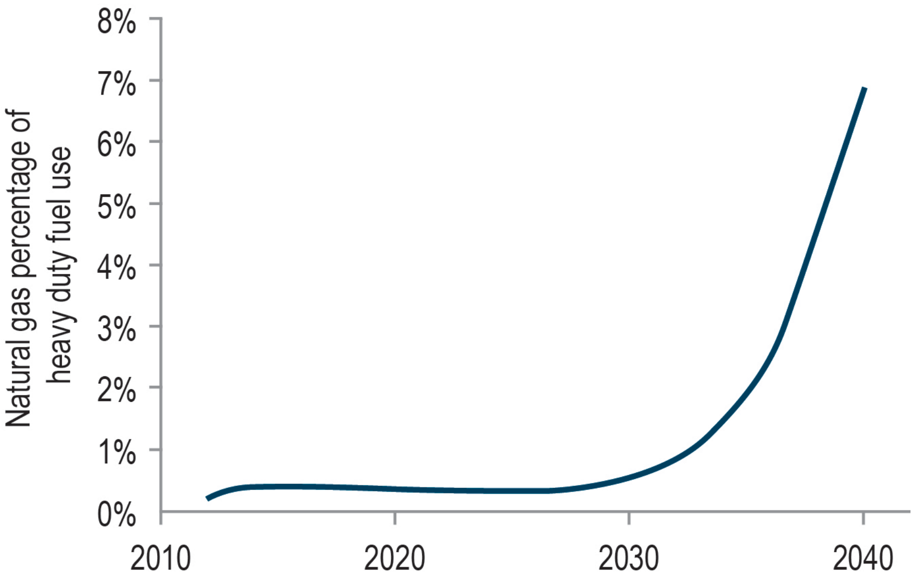
Current and Future Trends

According to the U.S. Energy Information Administration, the estimated consumption of CNG by vehicles as well as CNG vehicles in use has grown each year since 1995.[30] With the passing of federal Energy Policy Act of 1992 (EPAct), state agencies are required to either decrease the use of petroleum by their fleet, or purchase alternative fuel vehicles like those powered by natural gas. Following this legislation, a large proportion of vehicles purchased by state agencies were those powered by CNG. However, recent advances in flex fuel vehicles (E85, biodiesel), which are also classified as alternative vehicles by EPAct, have shifted agencies towards stocking their fleets with biofuel-consuming vehicles.

Despite the disadvantages, the benefits of natural gas as a transportation fuel have resulted in an increased adoption rate of the energy source for heavy-duty vehicles. As shown in Figure 2, University of Minnesota researchers predict that natural gas will be consumed at increasing rates for heavy-duty vehicle use, but they do not predict natural gas to become the dominate fuel. By 2040 the percentage of natural gas use is expected to reach 7 percent of total fuel used by heavy-duty vehicles.[31]

[25] AFDC
[26] Levinson, D. et al. "The Transportation Futures Project: Planning for Technology Change." , Minnesota Department of Transportation Research Services & Library, 2015.
[27] Alternative Fuels Data Center
[28] Ibid.
[29] CNG Minnesota
[30] Energy Information Administration
[31] Levinson, D. et al. "The Transportation Futures Project: Planning for Technology Change." , Minnesota Department of Transportation Research Services & Library, 2015.

Figure 2: Natural gas portion of heavy duty fuel use projection from 2012 to 2040 [32]



OTHER ALTERNATIVE FUELS

Hydrogen

Though still in it's infancy for use in vehicles, hydrogen has been used as a power source since the 1950s in spacecraft.[33] In vehicle applications, the reaction of air and hydrogen in a fuel cell produces electrons, which can then be used to power the drivetrain of a vehicle, much like the power stored in a battery. Models of hydrogen powered cars are deployed and available very minimally. Currently, there are three mass produced vehicles on the road, all available exclusively in California, where eighteen hydrogen filling stations present the best option for available infrastructure.[34] Hydrogen vehicles produce only heat and pure water as emissions, making them an attractive alternative to vehicles producing emissions affecting air quality. However, there is still much development needed to expand the infrastructure appropriate to support a broader market.

Propane

Propane, which is produced as a byproduct of oil refining and natural gas processing, is used primarily in the home for cooking and heating. In rural areas, propane is often used as an energy source. It accounts for two percent of all energy use in the U.S., and less than two percent of that is used for transportation fuel.[35] Similar to natural gas, the use of propane is often used by fleet managers. The Eastern Carver County school district in Chaska, Minnesota recently switched to propane powered buses as part of their regularly scheduled fleet replacement plan.

[32] Levinson, D. et al. "The Transportation Futures Project: Planning for Technology Change." , Minnesota Department of Transportation Research Services & Library, 2015.
[33] Alternative Fuels Data Center
[34] Davies, 2016
[35] Alternative Fuels Data Center

Dimethyl Ether

Dimethyl ether (DME) is a synthetically produced alternative to diesel fuel. DME fuel has similar energy efficiency and power ratings to diesel engines, but with lower emission levels. DME lacks carbon-to-carbon bonds, so there are virtually no particulate emissions from burning DME.[36] In September 2015, Oberon Fuels of San Diego partnered with Ford and others in a three year study to research, design, and test the first DME-powered passenger vehicle.[37] This follows several years of DME field testing for use in heavy-duty trucks by Swedish carmaker Volvo,[38] where it has received certification in the U.S. for production of DME from food wastes.[39]

VEHICLE ELECTRIFICATION

While electric vehicles have been around in some form as long as those powered by gasoline, it wasn't until the oil shortages of the 1970s that the auto industry began considering them as a viable option. However, with low gas prices through the 1980s and the limitations of existing electric vehicle technology and infrastructure, they were abandoned until once again resurfacing with General Motor's EV1 following the Energy Policy Act of 1992.[40]

For the majority of the 2000s, Toyota led the electric vehicle market with its hybrid Prius model. In recent years, both plug-in hybrid and fully electric models have given drivers additional alternatives to the conventional gas-only vehicle. Though often more costly upfront than a vehicle with a conventional internal combustion engine, this cost is decreasing with new technology. Together with savings from gasoline and maintenance, more drivers are considering this alternative.

Differences in Electric Vehicles

TYPES OF POWERTRAIN

Hybrid Electric Vehicles (HEVs) like the Toyota Prius run on both electricity and gasoline. During different stages of driving, the electric motor or the standard combustion engine may take over. The batteries powering the electric motor are charged by the car itself, using both the energy generated by the gas engine as well as energy generated during braking to recharge the battery. An HEV does not need to be plugged in to charge, which provides the driver a range limited only by the availability of gasoline. The gasoline powered engine is the main power source, with the electric motor acting to increase fuel economy.[41]

Plug-In Hybrid Electric Vehicles (PHEVs) like the Chevrolet Volt also switch between combustion engine power and electric motor depending on driving stage. They may also charge with regenerative braking technology, but receive their primary charge from plugging into the electricity grid—often through a wall outlet. The battery powered electric motor is the main power source, with the gasoline engine acting to extend the range of the vehicle.[42]

Fully Electric Vehicles (EVs) like the Nissan Leaf or Tesla use power drawn directly from the electricity grid and store it on board in batteries. There is no gasoline engine on board. The range of these vehicles is limited to the capacity of the batteries and amount of energy stored in them.

TYPES OF VEHICLES

Considering all three above powertrains, the majority of electric vehicles are light-duty passenger cars. As of early 2016, there were 22 fully electric passenger makes and models, and two SUVs. At that same time, there were 27 plug-in hybrid passenger makes and models and three SUVs.

---

36 AFDC
37 Oberon Fuels
38 Volvo
39 McMullen, 2016
40 Energy.gov
41 McEachern, 2012
42 Ibid.

Hybrid electric vehicles were offered in a far greater number. In 2016, there were 50 passenger vehicle options and 15 SUVs available on the market.[43]

Heavy duty vehicles like semi-trucks are often required to travel long distances between stops, making current battery technology with limited range impractical. To accommodate the power requirements and mileage driven by heavy duty vehicles, batteries need to be much larger (and thus, heavier), which cuts down on the cargo a truck can carry. However, a Georgia Tech study found there are alternatives to diesel engines available in medium-duty urban delivery vans. Along delivery routes with frequent starting and stopping, electric trucks are more energy efficient, emit less greenhouse gases, and have a lower total cost of ownership than their diesel counterparts. In suburban delivery settings, these differences are much smaller, and the total cost of ownership of the electric vehicle was found to be slightly greater than the diesel vehicle. The researchers noted that these findings were dependent on fuel prices, electricity generation source, and delivery route.[44] There are currently five models of fully electric medium-duty delivery vans on the market.[45]

Hybrid electric buses have been in operation in transit agency fleets around the country since the mid-2000s. In 2015, hybrid buses comprised 16.7 percent of U.S. transit buses.[46]

Electric Vehicles and the Environment

The effect of electric vehicles on the environment varies depending on many factors. Each of the above vehicle types will have different impacts, and within each of these types there will be variation. Every model of vehicle performs differently, and every driver faces different conditions, behaves differently, and utilizes a different power source and unique grid mix of electricity. While fully electric vehicles produce no tailpipe emissions, there are indirect emissions related to the generation of the electricity. The level of these emissions depends on the method of power generation associated with a particular charging station or wall plug-in. Because of these factors, it is very difficult to say with certainty how each vehicle will impact the environment. This segment will attempt to address some of the environmental effects of electric vehicles.

TAILPIPE IMPACTS

Tailpipe emissions are the environmental impacts that come directly from operation of the vehicle. The internal combustion engine found in standard gasoline cars as well as hybrid vehicles (both HEVs and PHEVs) runs on fuel derived from oil. When this fuel is burned, it releases exhaust that contains various pollutants that affect air quality and adds to greenhouse gases in the atmosphere.

Hybrid electric vehicles (HEVs) and plug in hybrid electric vehicles (PHEVs) use both a conventional internal combustion engine and electric motor during operation. The degree to which each of these produce tailpipe emissions depends largely on the intensity and duration each engine is working while driving. More generally, the average tailpipe emissions of an HEV or PHEV will be less than that of a gasoline-only.

Fully electric vehicles have no gasoline engine on board, and therefore do not have any tailpipe emissions.

ELECTRICITY GENERATION IMPACTS

Although fully electric vehicles do not produce emissions from their tailpipe, environmental impacts are tied to the generation of electricity necessary to charge their batteries. Depending on how this electricity is generated—the “grid mix” (fossil fuels, renewable sources or some combination of both)—the environmental impact will vary.

EVs may be charged at both public and personal charging stations, each with different accompanying grid mixes. As a result, it is often difficult to determine if the electricity used for a certain car is “emission free” or associated with pollutant generation. Many public charging stations will advertise themselves as zero emission (marked with a Zero Emission Charging decal in the Twin Cities)—indicating the electricity being supplied comes from renewable sources like wind or solar. Furthermore, owners who charge their vehicle at home in their driveway or garage may purchase

---

[43] AFDC
[44] Lee, D.Y. et. al. Electric Urban Delivery Trucks: Energy Use, Greenhouse Gas Emissions, and Cost-Effectiveness *Environmental Science & Technology* 2013 47 (14), 8022-8030
[45] AFDC
[46] APTA, 2016

renewable energy certificates (RECs) from energy companies. These RECs are required to be directly linked to generation of renewable energy and are “retired” after use. Only when additional renewable energy is generated can additional RECs be issued to a customer.

EFFICIENCY OF ENERGY USE

In addition to supplementing gasoline engines for added fuel efficiency, electric motors use energy more efficiently than their gasoline counterparts. Whereas only 17 to 21 percent of gasoline’s energy is converted to movement because of losses to heat and mechanical friction, an electric motor has fewer moving parts and does not rely on high temperature combustion for movement. Electric motors convert as much as 59 to 62 percent of the energy stored in the electricity to movement.[47] As a result, an electric vehicle could travel roughly 118 miles on the energy found in a gallon of gasoline, making it far more energy efficient than the 24 miles per gallon an average light duty vehicle consumes.[48]

LIFE CYCLE EFFECTS

Often and easily overlooked, life cycle effects refer to those that can be associated with all life stages of the vehicle. The environmental impacts of a vehicle (or any product) are not limited only to its operation. The raw materials used to build the vehicle must first be extracted. The extraction of rare metals found in electric vehicle batteries is energy intensive, requiring mining and significant chemical use.[49] The raw materials are then refined, manufactured and assembled, and transported to the dealership where the consumer buys the finished product. At the end of the car’s life, the vehicle must be destroyed. All of these stages require energy, which requires resources (often in the form of electricity and fuel). A recent report found that electric vehicles powered by battery produce less than half the greenhouse gas emissions of comparable gasoline powered vehicles over the course of their lifetime.[50]

Local Context

Minnesota currently has 526 electric vehicle plug-in ports at hundreds of public stations[51] scattered across the state.[52] These stations vary in the rate at which they can deliver a full charge to a vehicle. While the majority of these stations are Level 2 (roughly 70 miles of range in two to four hours of charging), a number of stations in and around the Twin Cities are DC Fast Chargers, which offer a complete charge in less than an hour.[53] Several groups are working to install rapid charging stations in Greater Minnesota, which would allow more travel throughout the state. Drive Electric Minnesota, a partnership of businesses, utilities, non-profits, and state and local governments, promotes and supports the advancement and use of electric vehicles in the state. This includes procurement of EVs and the build out of charging infrastructure.

In addition to the supporting infrastructure necessary for EVs, incentive programs have given prospective EV buyers more reason to switch to fully electric or hybrid plug-in models. At the federal level, new PHEV or EV purchases qualify for a tax credit ranging from $2,500 to $7,500 through the American Recovery and Reinvestment Act of 2009.[54] Locally, a number of Minnesota utilities offer EV charging at off-peak hours for a reduced rate.[55] Great River Energy, through the REVOLT Program, offers renewable energy credits for EV wind power for the life of the vehicle at no additional charge to customers. Xcel Energy has a similar offering through their Drive with Gusto Program.

In cold weather climates like Minnesota, electric vehicles do not perform as well as they do in moderate temperatures. Batteries do not run as efficiently in the cold. In addition, electric vehicles cannot scavenge excess heat that comes from an internal combustion engine to warm the cabin and therefore must generate heat using the battery. As a result, the range of an EV can be lowered by as much as 57 percent in the cold.[56]

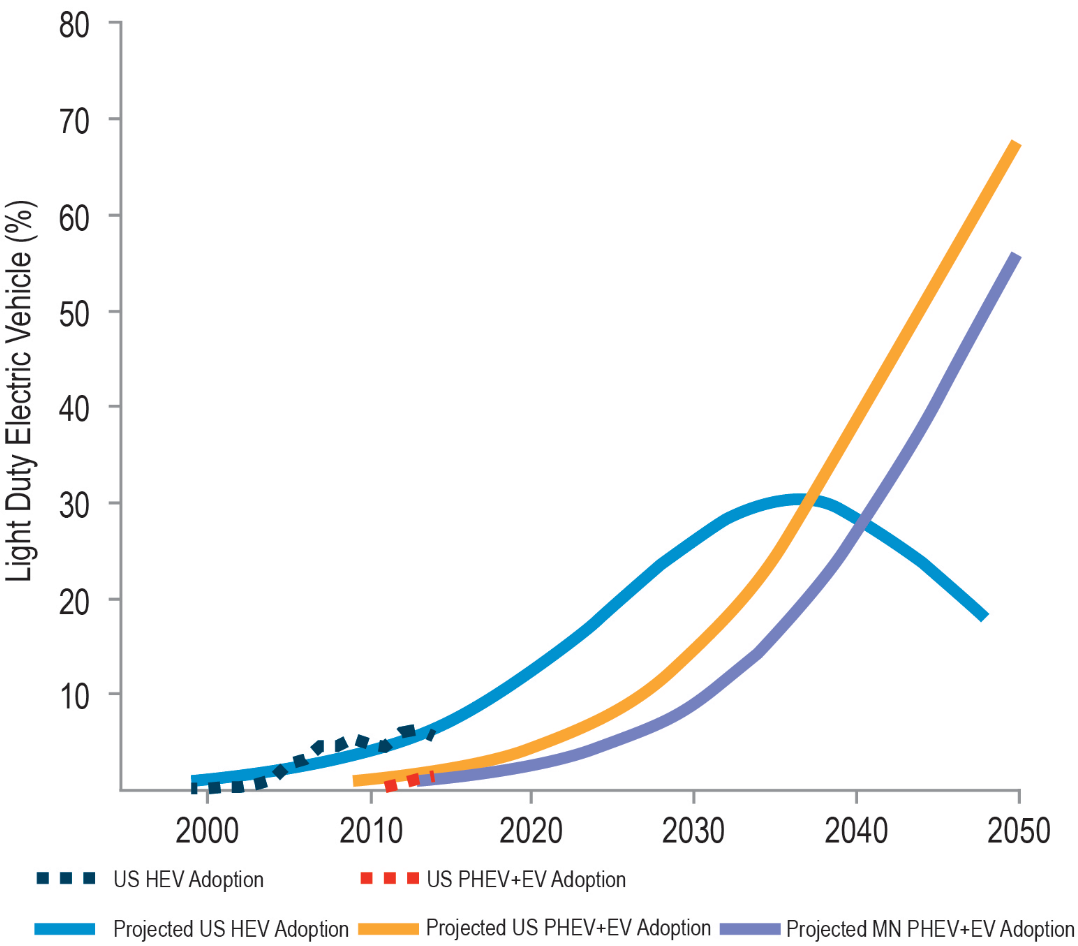
47 EPA
48 Kukkonen, J. (2016, February 16). Telephone Interview.
49 Wade, 2016
50 Union of Concerned Scientists
51 A charging port refers to the individual cable or connector which plugs into the vehicle to provide charge. A single charging station may have multiple ports, allowing more than one vehicle to charge simultaneously.
52 Twin Cities Clean Cities Coalition
53 Harlow, 2015
54 IRS.gov
55 AFDC
56 Orwig, 2016

In Greater Minnesota, the Duluth Transit Authority is set to receive six fully electric buses and two charging stations as part of a Federal Transit Administration grant. The award is part of the FTA's Low or No Emission Vehicle Deployment Program, which provides U.S. transit agencies with resources to make their fleets more environmentally sustainable.[57]

Current and Future Trends

As EV technologies continue to improve, it is likely that they will increase in popularity and availability. As shown in Figure 3, University of Minnesota researchers predict HEVs to continue to increase until the mid-2030s, at which point they are predicted to be overtaken by the adoption of PHEVs and EVs. Indeed, in 1995, there was one EV model available to the public—in 2015, there were 27.[58] However, they project adoption of PHEVs and EVs in Minnesota will likely be slower than the rest of the country, because of the challenges of operating EVs in a cold climate.

Figure 3: Historic and projected HEV adoption rate of new HEVs, PHEVs, and EVs[59]



And although most EVs cannot yet match the range of a gasoline powered vehicle, this barrier will likely become less significant as the number of charging stations increase. Continued incentives to property owners interested in charging stations will further the growth of this technology. As part of The West Coast Green Highway project, Washington, Oregon, and California are installing DC Fast Chargers along Interstate 5 from Baja California to British Columbia, Canada in an effort to provide a continuous network of rapid charging opportunities along the west coast.[60] The project is structured as a public-private partnership, and costs are shared between drivers, the public sector, and the private sector.

57 FTA, 2015
58 AFDC
59 Ibid.
60 West Coast Green Highway

As a potential alternative or compliment to current charging technology, testing is currently underway for wireless chargers embedded in pavement,[61] which could help support electric autonomous vehicle infrastructure.[62] A transmitting pad positioned on the ground creates a connection to a receiving pad on the vehicle and sends a magnetic field of frequency. This magnetic field generates a current to a coil, which charges the vehicle's battery.[63]

For most drivers, the biggest hurdle to buying an EV appears to be the upfront cost and limited range.[64] A fully-electric Tesla Model S has a range of 265 miles, but begins around $70,000. On the other side of the spectrum, a Nissan Leaf has a range of 107 miles, and starts around $29,000. However, in March 2016, Tesla unveiled the Model 3, which the company claims will have a range of 215 miles starting at $35,000. General Motors announced they will soon offer the Chevy Bolt, an EV with a similar range and cost. The increased range and lower cost of the vehicles is largely due to better battery efficiency and decreases in the cost to make them. Often the most expensive component of the vehicle, the cost of batteries has decreased 65 percent between 2010 and 2015.[65]

Finally, as electricity generation in Minnesota continues to shift away from coal dominated to include a large contribution from wind, EVs and plug-in hybrids will become a cleaner alternative to conventional gasoline vehicles. Between 2000 and 2014, the proportion of Minnesota's total electricity coming from coal decreased from 66 to 49 percent, whereas the proportion coming from wind increased from 1.4 to 17 percent.[66]

THE FUTURE OF ALTERNATIVE FUELS AND VEHICLE ELECTRIFICATION

Since 1995 the number of alternative fuel vehicles on the road has increased from a 250,000 to nearly 1.25 million.[67] While the majority of vehicles added have been flex fuel vehicles, there have also been gains in the number of hybrid and electric cars. Thanks to federal policies that subsidize the manufacture and sale of these vehicles, more drivers are beginning to see the financial and environmental benefit of trading in their gasoline powered cars. However, these incentives have expiration quotas. The most popular electric vehicle incentive, which offers as much as a $7,500 tax credit with the purchase of an EV or PHEV, will begin to phase out once an individual manufacturer sells 200,000 electric vehicles in the United States.

Regardless of incentives, with gas prices as low as they are in early 2016, the attraction of alternative fuel vehicles remains in question. If people are interested in alternative fuels for the price savings, incentives alone may not compete with a two-dollar gallon of gas. In addition, the use of alternative fuels and electrification for the trucking and freight industry is still unknown. While there have been significant developments in biodiesel, DME, natural gas and propane, fuel prices and innovation in battery technology will likely dictate the rate at which electricity is advanced for use in heavy-duty applications.

Environmental pressures will be part of the conversation as long as the transportation sector continues to play such a large role in greenhouse gas emissions and air quality. Alternative fuel vehicles have the power to make a big impact on the environment, but this depends on where the fuel comes from. With regard to biofuels, the burning of organic material can be offset by the emissions that are collected through planting additional feedstocks, although inputs to those plants are tied to emissions. Electric vehicles, although lacking direct tailpipe emissions, do generate emissions depending on the grid mix of the electricity provider. Only when grid mixes move towards renewable sources like solar or wind will the operation of electric vehicles truly be considered emission free. The next five to ten years will likely see an increasingly diverse mix of vehicle power sources on Minnesota roads. Beyond ten years, researchers at the University of Minnesota have projected ever increasing electrification of vehicles, but much remains uncertain, particularly when it comes to medium and heavy duty vehicles.

---

61 Harris, 2016
62 Levinson, D. et al. "The Transportation Futures Project: Planning for Technology Change." , Minnesota Department of Transportation Research Services & Library, 2015.
63 Cooney, 2016
64 Wernick, 2016
65 Harrington, 2016
66 EIA
67 AFDC