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An Overview of Electric Vehicles and Infrastructure

May 2024

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Research Methodology

A literature review was conducted to gather information about electric vehicles including economic costs and benefits, environmental impacts, legislative goals, and recent case studies. The findings inform recommendations for government agencies and policymakers to develop a more broad and equitable infrastructure for electric vehicles. Secondary data was sourced from AAA Newsroom, the Pennsylvania Department of Environmental Protection, the Pennsylvania Department of Transportation, and the U.S. Department of Energy.

Executive Summary

Research suggests that increasing the use of electric vehicles globally can reduce pricing and create environmental benefits, despite the fact that the initial purchase of electric vehicles is more expensive than a combustion engine vehicle. Policies that incentivize electric vehicle buyers are becoming more prevalent and aid in reaching CO2 and electric vehicle production benchmarks. Additionally, new technology in electric vehicle batteries can create a more domestic market and aid in reducing higher initial costs.

The average price of a new electric car in the United States is approximately $66,000.[1] Over the vehicle's lifetime electric vehicle owners are reported to spend $9,000 less on fuel and $4,600 less on maintenance costs than similar gasoline-powered vehicles.[2] Pennsylvania accounts for just under two percent of new registrations of electric vehicles. Leading states include California (37.1 percent), Florida (6.9 percent), and Texas (6.12 percent).[3] Federal standards require that half of all new vehicle sales be sales of electric vehicles by 2030.[4] Increased sales would result in the need to bolster electric vehicle infrastructure, approximated at $35 billion for the installation of new charging stations and $3 billion for upgrades to existing charging stations to accommodate 2030 goals.[5, 6] The Infrastructure Investment and Jobs Act, the Bipartisan Infrastructure Law, and the NEVI programs have been reported as adequate funding revenues for electric vehicle projects.[7]

This report synthesizes electric vehicle policies, environmental impacts, and regional and U.S goals of electric vehicle production and sales with global comparisons. Additionally, this study examines goals listed for the Commonwealth by the Pennsylvania Department of Environmental Protection and the Pennsylvania Department of Transportation. Furthermore, various case studies were identified as models for supporting the use of electric vehicles and the implementation of necessary infrastructure. This research informed the following recommendations:

Recommendations

1) Install 2,000 new electric vehicle charging ports at 800 individual locations (a 5-year goal) by 2028 to support and encourage growth of the electric vehicle market and increase range confidence.
2) Set goals for one charging site every 20 miles or less to ensure complete coverage of Interstates and Interstate look-alikes.
3) Goals for infrastructure should focus on interstate/long-distance travel, regional routes, and destination travel as primary goals. Secondary focuses include Emergency travel, commuter travel, medium/heavy duty freight.
4) Safe charging should be provided by installing chargers near well-functioning infrastructure and have a 24-hour lighting source.
5) Ensure installation of new charging stations are placed equitably.

Introduction

Electric vehicle use is increasing worldwide due to its environmental benefits and lowering cost. In terms of economic impact, AAA has determined that the cost of fueling an electric vehicle is two to four times less than the cost of fueling a gasoline-powered vehicle. Even though the initial investment is costlier, electric vehicle drivers secure long-term savings.[8] As the public and private sectors lean toward electrification, there is more incentive than ever to purchase or manufacture electric vehicles. With the increasing production of more electric vehicles, available charging stations must also be increased. In 2021, $7.5 billion in federal funds was given for charging infrastructure. These funds are primarily invested in alternative fuel corridors (AFCs), which offer charging infrastructures every 50 miles. To accelerate environmental benefits, state, national, and international policies have been implemented to regulate CO2 emissions and set electric vehicle production benchmarks. [9]

A number of obstacles are associated with electric vehicle production, including battery production. Many of these obstacles pertain to sustainability, though integration into the market also proves to be a challenge; consumers interested in purchasing vehicles sometimes avoid electric vehicles due to high cost and concern about proximity of charging stations. Most owners of electric vehicles are currently on private chargers, generally at their own homes. Public access to charging stations is limited in many areas, and the stations are particularly sparse in low-income communities.

Furthermore, electric vehicle batteries do not function optimally under colder temperatures. It has been found that electric vehicle batteries can lose from 15 to 20 percent of range in colder temperatures and that share increases significantly under severely cold temperatures. Similarly, the charging of an electric vehicle battery is inhibited by colder temperatures. Decreased battery life and increased charging times have created longer lines at charging stations during cold winter months.[10]

This report explores the concepts of earlier published research, focusing on the environmental and economic costs and benefits of electric vehicle usage and infrastructure. Electric vehicle battery production is evaluated as well. Finally, this report details policies and case studies that inform recommendations for future practice.

Economic Cost and Benefits

Electric Vehicle Manufacturing and Use

Global electric vehicle sales have increased by 55 percent from 2021 to 2022. Several factors can contribute to this increase. For instance, the numbers of available makers and models are increasing. The years 2022-2023 saw new electric vehicle announcements: fully electric fleets, lower prices, more investments, and integration with critical minerals.[11] Purchase incentives have reached $7,500.[12] Furthermore, increased competition will continue to lower the prices as more car manufacturers continue to join the electric vehicle market. Policies that incentivize the manufacturing and purchasing of electric vehicles influence more companies to join the markets and more consumers to purchase electric vehicles.

Conversely, the United States' ownership rates of electric vehicles are much lower in comparison to other developed nations, such as China and Norway. This can be attributed to the notion that, until very recently, electric vehicles have been considered luxury items due to their higher price tags. In contrast, electric vehicles are more affordable in other countries. The average price of a new electric car in the U.S. was approximately $66,524 in August 2022– over $20,000 more than the average for all new cars.[13] This price is 11 percent less than the 2022 median annual household income of $74,755, and over the average 4-year car loan is approximately 22.3 percent of total median income.[14] As of August 2023, the average price has reduced significantly by almost 20 percent to $53,376.[15] With more companies producing electric vehicle models, we will continue to see a more competitive market.[16] For example, 2024 models such as Nissan's Leaf starts at $29,280 and Chevrolet's Bolt at $26,500.[17,18]

In comparison, China's most inexpensive electric vehicle sells for $10,000 and the United States' least expensive electric vehicle is $16,500 more than that. Chinese manufacturers having the ability to sell electric vehicles for lower prices can be attributed to the fact that they control 41 percent of the world's cobalt mining and 28 percent of lithium – the two critical ingredients in long-range electric vehicles.[19] More than six out of every ten battery cells are made in China. According to the CEO of Infinity Stone Ventures, a corporation involved in the development of battery metals, "The Chinese have reached a point where they can manufacture cars efficiently like smartphones, whereas North America is still stuck trying to overhaul an outdated manufacturing supply chain." The United States produces less than two percent of the world's lithium and less than 0.4 percent of cobalt. The lack of domestic resources and production is a considerable factor in the higher costs of electric vehicles in the U.S.[20]

Over the vehicle's lifetime electric vehicle owners spend approximately $9,000 less on fuel and $4,600 less on maintenance costs than similar gasoline-powered vehicles.[21] However, electric vehicle owners may have to cover the costs of new batteries, which range in price from $2,500 to $10,000.[22] The benefits may not outweigh the challenges that the average customer face when considering an electric vehicle. According to a survey conducted by AAA, consumers are largely concerned about cost and battery charging capabilities.[23]

Reasons For Not Purchasing an Electric Vehicle in the U.S.	
Concern	**Percent**
Higher purchase price	60 percent
Worries there are not enough places to charge	60 percent
Concern about running out of charge when driving	58 percent
Unsuitable for long-distance travel	55 percent
High cost of battery repair or replacement	55 percent
Unable to install a charging station where they live	31 percent
Source: AAA NEWSROOM	

Electric Vehicle Infrastructure

As more consumers purchase electric vehicles, more public charging stations are needed. The tax burden required to meet federal standards (50 percent of all new vehicle sales being electric by 2030), could potentially cause widespread economic impacts. To support the goal of 50 percent zero-emission electric vehicle car sales, it is estimated that 1.2 million public charging stations and about 28 million private electric chargers would need to be installed by 2030 – with a price tag of $35 billion.[24]

The current U.S. power grid cannot support this rapid shift to electric vehicles. An entire system upgrade is required. An upgrade to a single direct-current-fast-charging (DCFC) station with four chargers would cost approximately $150,000. There are currently about 20,000 DCFC stations in the U.S., which would total $3 billion in upgrades.[25]

Widespread electric vehicle adoption in the U.S. will be significantly hindered unless a dependable and convenient charging infrastructure is available. These charging stations must also be compatible with a wide range of vehicles to reduce the anxiety associated with charging. Policies implemented state-wide can influence the availability of electric vehicle chargers and their costs. Studies have shown that even half a million public chargers will not be enough to support the number of electric vehicles on the road in 2030.[26]

Environmental Impacts

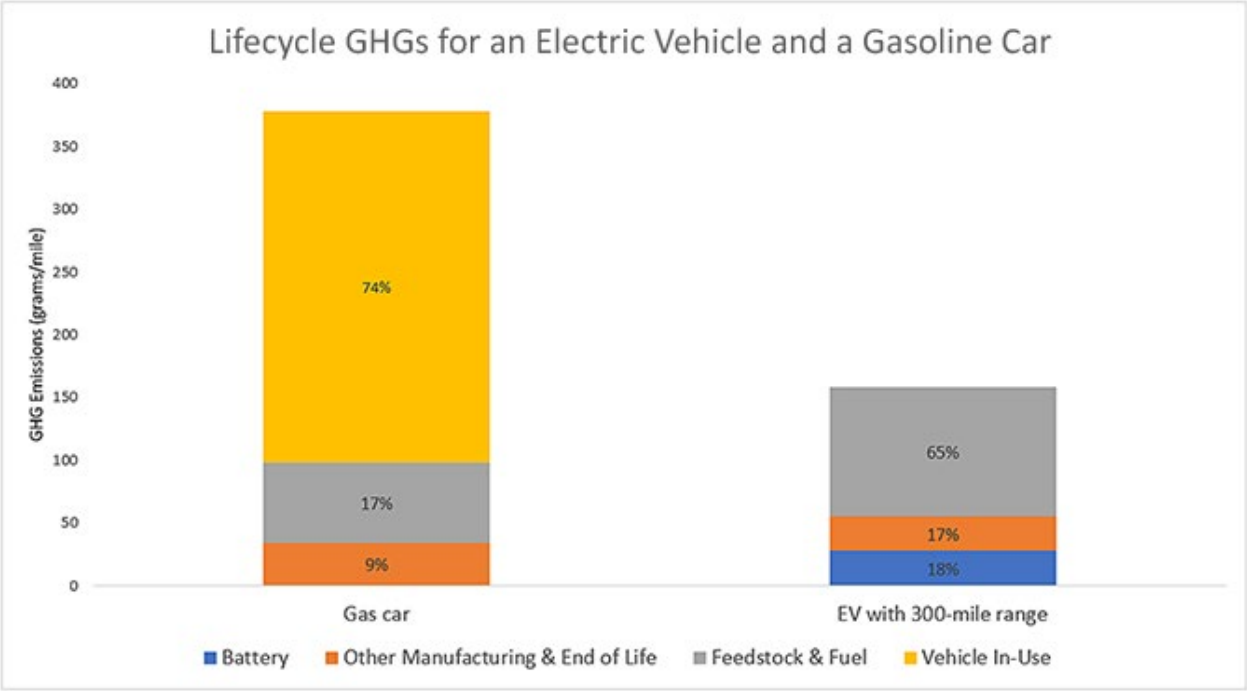
Electric Vehicle Manufacturing and Use

In 2021, the United States consumed 20 million barrels of petroleum per day – 30 percent more than China, which was in second place.[27] Electric vehicle chargers currently rely on electricity from power plants, which still use fossil fuels. Switching to clean energy would increase environmental benefits. In states like California, where the energy grid is often pushed to its limit during the summer months, residents may experience more blackouts as energy usage increases with electric vehicle sales. If chargers were powered by solar panels, the energy consumption would be cleaner and less demanding on already stressed power grids, such as California's.[28]

Electric vehicle production is energy intensive. More specifically, the batteries used in electric vehicles are challenging to make without the necessary materials found within the earth. Electric vehicle batteries consist of materials such as nickel, lithium, cobalt, and others. Mining for these battery components can cause massive amounts of ecosystem destruction and ruin the surrounding natural resources. Use of these raw materials – specifically cobalt – have also led to environmental and human rights concerns. Mines may leak hazardous chemicals, for instance. Almost 70 percent of the world's cobalt supply comes from the Democratic Republic of Congo, where mine workers (including children) dig with hand tools at significant risk to their health and safety. Additionally, extracting metals from their ores requires smelting – a process that emits sulfur dioxide. Other battery parts like lithium require large amounts of groundwater, taking away from local farmers and herders. Production of these batteries is about 50 percent more water-intensive than production of traditional combustion engine batteries. The technology to create a safer battery for electric vehicles is still in progress.[29]

Electric vehicles are cleaner for the environment than combustion engines. Even though they release emissions during manufacturing, the amount of emissions saved while the electric vehicles are in use yields significant benefit. The Department of Energy found that electric vehicles create 3,932 lbs. of CO2 equivalent per year, compared to 11,435 lbs. for gasoline vehicles.[30] The transportation sector was responsible for 29 percent of all carbon emissions in 2021, and as electric vehicle manufacturing becomes more efficient with new technology, this percentage will decrease.[31]

The chart below depicts the estimates of greenhouse gas emissions for a conventional vehicle compared to an electric vehicle. Overall, the gas car releases more emissions, but the electric vehicle has a more emissions-intensive manufacturing and fueling process. Because charging electric vehicles requires electricity and the foundation of charging is based on fossil fuels, charging indirectly emits greenhouse gases. Still, the emissions involved with electric vehicle charging are less than the emissions involved with conventional gas cars driving. As technology develops and policy reforms the electric grid that powers electric vehicle chargers, the emissions associated with electric vehicles will decrease.[32]



There is currently no way to recycle electric vehicle batteries. The used batteries are shipped to facilities that specialize in battery disassembly. Parts like steel, copper, and aluminum go into the nationwide recycling system. Other parts of the battery – lithium, cobalt, manganese, and nickel – are ground and purified. If this process is not done correctly and the battery is sent to a landfill, its cells will release toxins and pollute the environment. However, deconstructing parts of a battery is difficult because of the way they are manufactured and glued together. Manufacturing the batteries with recycling in mind may facilitate safe and appropriate disposal.[33]

Battery production is the most expensive aspect of electric vehicle manufacturing. Research exploring the future of battery reuse is underway. More than a dozen startups or corporations have taken part in the race to discover the secret to battery recycling. In one case, the Department of Energy has given a $2 billion conditional loan to build out a company (Redwood Material) that focuses on battery recycling and supply.[34] Economically, if electric vehicle batteries could be recycled, the supply of electric vehicles would increase and lower prices for consumers.

Development and Use of Electric Vehicle Infrastructure

The current state of batteries for electric vehicle use is an issue that must be addressed. Currently, research is underway to identify other battery options that take less time to produce. Researchers at the Oak Ridge National Laboratory have theorized and experimented with a cheaper and more efficient battery that relies on different materials and processes, and could be used for cell phones, appliances,

and electric vehicles. It is safer to make and can be distilled and reused. It could also yield more energy and reduce the cost of electric vehicle batteries. This technology is ready to be scaled up for commercial use, with a patent pending.[35]

Additionally, charging stations powered by clean energy would transform the electric vehicle market. These clean energy sources would include solar and wind power and would decentralize electric vehicle charging infrastructure. A shift away from a centralized charging network could provide more charging options in various locations. In Arnhem, Netherlands, ElaadNL (which researches and tests smart and sustainable charging of electric vehicles) has combined Electric Vehicle charging and renewable energy to accomplish this task. ElaadNL is an initiative of the joint Dutch Grid Operators, partnering with manufacturers from across the globe to test the latest techniques for charging electric cars, trucks, and buses. Using solar and wind energy, they have balanced the energy demands of charging points from around the country, reduced total demands, and (through the use of smart meters) receive insights for future designs.[36] The smart meters on ElaadNL's chargers collect data about the quality of electricity, available energy levels, and charger usage. Based on this data collection, the energy algorithms can direct where to send energy and determine the amount of energy to each charger. This optimizes the charger's use and the electric vehicle user's experience while charging.[37,38]

State Policy

Within Pennsylvania, there are 31 policies and programs related to electric vehicle markets.[39] These policies offer rebates, reimbursements, or grants for installing new charging stations, transitioning from combustion to electric vehicle buses and trucks, and buying electric vehicles. Specialized policies also address the infrastructure of electric vehicle charging stations and determine how and where to use federal funding efficiently and effectively. Additionally, Pennsylvania is one of 15 states to commit that all new commercial heavy-duty vehicles would be designated zero-emission vehicles by 2050.[40]

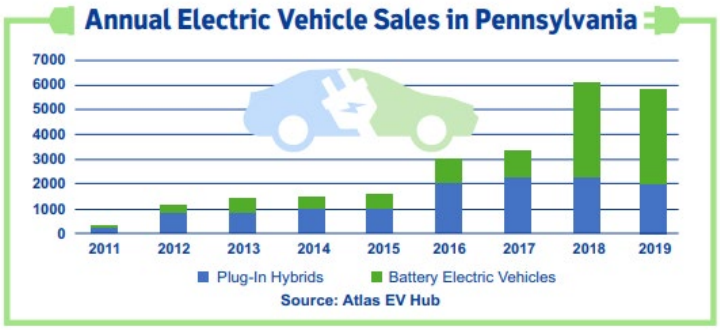
Even with numerous policies and programs, Pennsylvania accounts for just under two percent of new registrations of electric vehicles in the United States as of July 2023. In comparison, California accounted for the largest share of registrations. States leading in new electric vehicle registrations include California (37.1 percent), Florida (6.9 percent), and Texas (6.1 percent).[41] California is leading the electric vehicle sales for the United States and can be seen as a flagship state in implementing electric vehicle policy that will promote electric vehicle sales.[42] The state’s goal to reach 1.5 million electric vehicle sales by 2025 was reached two years earlier, in 2023. Aggressive tailpipe regulations and $2 billion in state incentives can be contributed to reaching this early goal. Additionally, California established a rigid timeline for the future of electric vehicles; by 2035, all car sales are intended to involve electric or plug-in hybrid vehicles.[43] California's achievement is similar to that of Norway, reaching milestones before the timeframe.

Electric Vehicle Registrations, Top 13 States		
State	# of EV Registrations	Percent
California	903,602	37.13%
Florida	167,990	6.90%
Texas	149,000	6.12%
Washington	104,050	4.28%
New Jersey	87,030	3.58%
New York	84,670	3.48%
Illinois	66,880	2.75%
Arizona	65,780	2.70%
Georgia	60,120	2.47%
Colorado	59,910	2.46%
Virginia	56,610	2.33%
Massachusetts	49,440	2.03%
Pennsylvania	47,440	1.95%
Source: U.S. Department of Energy		

Pennsylvania's milestones differ from California's. Pennsylvania aims for three of ten cars to be electric by 2033. Achieving this goal requires policy support for new infrastructure and strong incentives to aid in the increase of electric vehicle sales. Currently, grants are awarded to companies or private corporations that install charging stations.[44] Additionally, several policies offer rebates for switching school buses, transit buses, and freight trucks to electric, and policies offer rebates to aid with the cost of buying electric vehicles.[45]

If enacted, Pennsylvania's House Bill 1474 would add electric vehicle charging infrastructure as an eligible project type under Pennsylvania's Property-Assessed Clean Energy program.[46] This program has been reported to have facilitated over $250 million in private investments in clean energy that do not financially burden the Commonwealth.[47] As of November 15, 2023, House Bill 1474 was referred to an Environmental Resources and Energy subcommittee by the senate.[48]

Electric vehicle sales have been on the rise in Pennsylvania, reflecting a growing trend in electric vehicle adoption. With increasing awareness of environmental concerns and government incentive programs promoting electric vehicle use, more Pennsylvania residents are choosing electric vehicle options. The surge in sales in the latter half of the last decade indicates a shifting consumer preference toward cleaner and more energy-efficient vehicles in the state.[49]



As of 2020, Electric Vehicle registrations in the Philadelphia and Pittsburgh areas were greater than in the rest of the Commonwealth. This visual comparison of registrations reflects a growing interest in sustainable transportation within urban centers as well as in reaching rural markets. As electric vehicle infrastructure expands across the state, the number of rural electric vehicle registrations should also rise.[50]

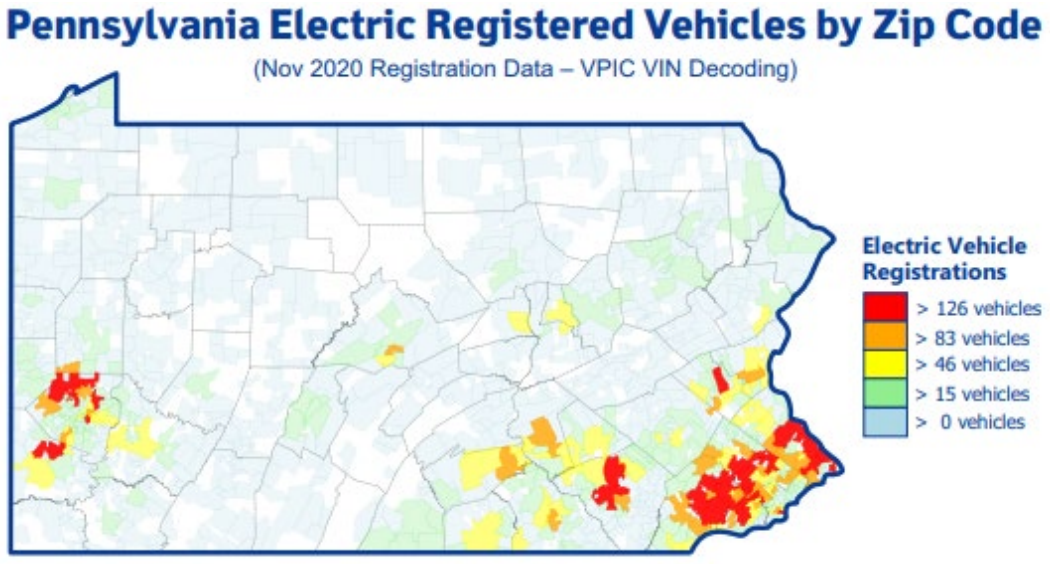


Image By the Pennsylvania Department of Environmental Protection

Adopting new charging stations will be critical to raise electric vehicle sales in Pennsylvania. There are more than 2,700 public electric vehicle chargers in 1,100 locations across the Commonwealth, and these numbers must double to support electric vehicle adoption fully.[51] Lack of infrastructure is one of the main barriers to buying an electric vehicle, so policymakers must focus on implementing the addition of more chargers.

In July 2022, the Pennsylvania Department of Transportation (PennDOT) issued a five-year Electric Vehicle Mobility Plan for the improvement of electric vehicle infrastructure. This plan identifies specific actions that PennDOT could take to help facilitate the transition to a more robust electric vehicle

infrastructure and lays the groundwork for future steps. These steps include the development of National Electric Vehicle Infrastructure (NEVI) to meet Federal Highway Administration's objectives. Recommendations include the installation of 2,000 new electric vehicle charging ports at 800 individual locations by 2028. PennDOT reports that 2,000 charging ports will cost between $250 Million (50/50 mix of L2/DCFC) and $500,000 Million (all DCFC)3, depending on the charger types. The Infrastructure Investment and Jobs Act, the Bipartisan Infrastructure Law, and the NEVI programs have been cited as adequate funding revenues for electric vehicle projects. The following infographic outlines the five-year plan.[52]

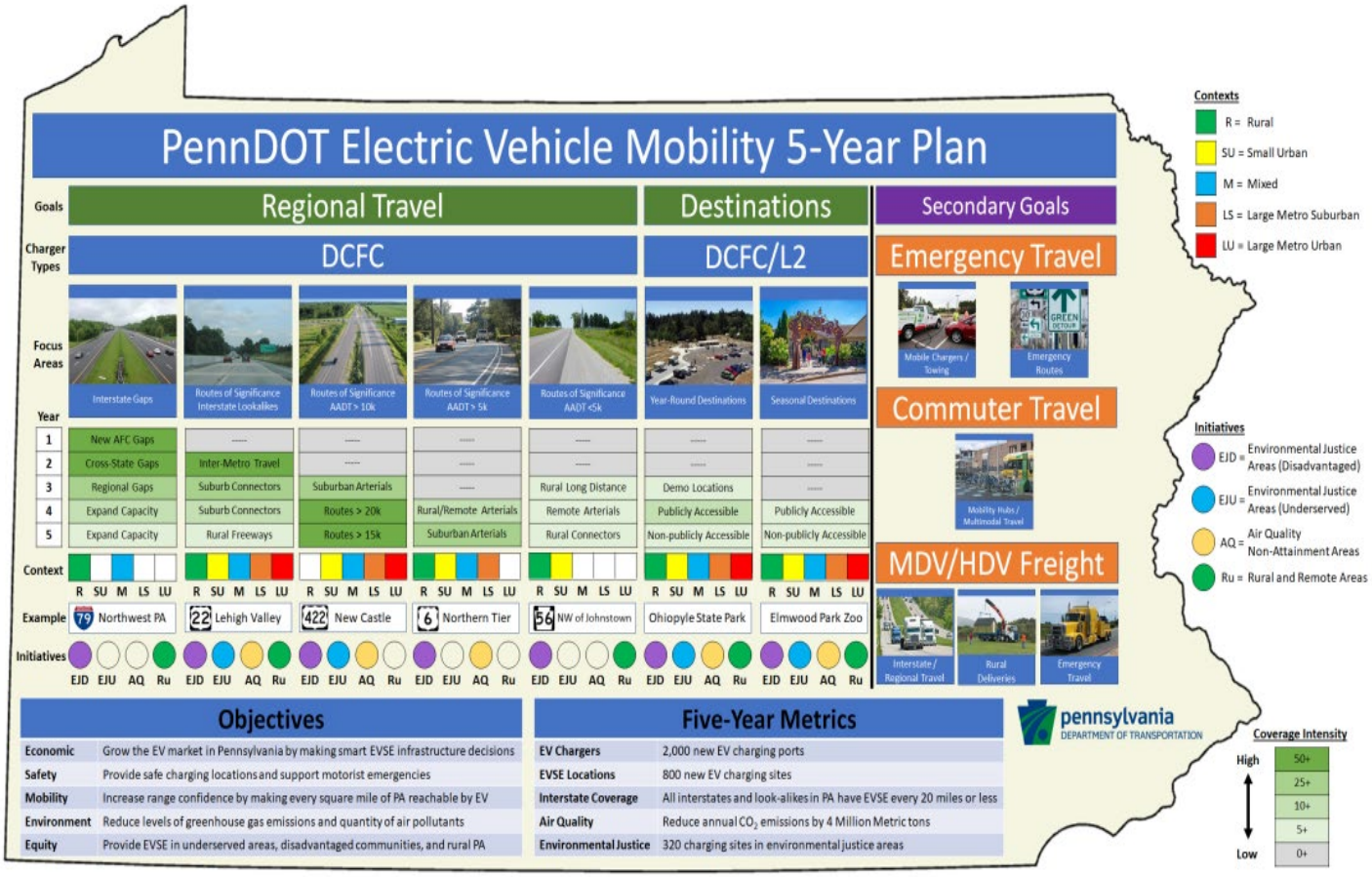


Image by The Pennsylvania Department of Transportation

Through the analysis of Pennsylvania's driving needs, PennDOT has identified three primary goals and three secondary goals to help execute the five-year plan. The three primary goals pertain to Interstate/Long-Distance Travel, Regional Routes of Significance, and Destination Travel. These primary goals center their efforts on alternative fuel corridors, traffic volumes, and year-round and seasonal destinations.[53]

PennDOT 2022 Goals of Electric Vehicle Infrastructure		
	Goals	**Focus Area**
Primary	Interstate/Long-distance Travel	Interstate Gaps Interstate Look-alikes
	Regional Routes of Significance	High to Very High Traffic Volumes Moderately High Traffic Volume Moderate Traffic Volume
	Destination Travel	Public Parks and Related Destinations Private, Non-Profit, and Other Destinations
Secondary	Emergency Travel	Mobile Charging/Towing Emergency Routes
	Commuter Travel	Mobility Hubs/Multimodal Travel
	Medium-Duty/Heavy-Duty Freight	Interstate/Regional Travel Rural Deliveries Emergency Travel
Source: The Pennsylvania Department of Transportation		

Additionally, PennDOT has recognized five objectives beyond improvements to electric vehicle infrastructure. These objectives include economic growth in the electric vehicle market, safety provisions at charging sites, increased range confidence, climate change advocacy, and charging equity. The following table details these objectives.[54]

PennDOT Additional Improvements Beyond Electric Vehicle Infrastructure	
Focus Area	**Recommendations**
Economic Grow the EV market	EVs are becoming more available as consumers demand the technology and the depletion of fossil fuels and climate change require the shift. PennDOT should not only support the growth in this market, but also help grow it by making smart EVSE location decisions.
Safety Provide safe charging	Improving the safe integration of EVs is paramount. When installing new charging locations, development should be near well-functioning infrastructure and amenities, and be well-lit for 24-hour charging. Emphasis should also be put on how to best assist motorists during emergencies.
Mobility Increase range confidence	Ensure motorists in Pennsylvania can drive EVs across the state with confidence for vehicle range and without other vehicle charging issues.
Environment Fight climate change	Compared to fossil-fuel vehicles, EVs generate fewer greenhouse gas emissions slowing climate change, reduce vehicle costs, and reduce vehicle pollution impacts. EVs will also reduce vehicle pollution to point sources and improve air quality, especially when paired with renewable energy sources.
Equity Locate EVSE equitably	Economic incentives often do not align with equitable technological proliferation. In the interest of providing EV access to a diverse population within Pennsylvania and aligning with goals of the Justice40 initiative, each goal should be fulfilled in an equitable way so all groups, including disadvantaged and underserved communities, can benefit from the positive outcomes.
Source: The Pennsylvania Department of Transportation	

A visualization of optimal locations for electric vehicle charger placement has been provided by PennDOT. Strategic positioning will enhance accessibility and convenience for electric vehicle owners. The map serves as a tool for policymakers and stakeholders to guide the deployment of electric vehicle charging infrastructure.[55]

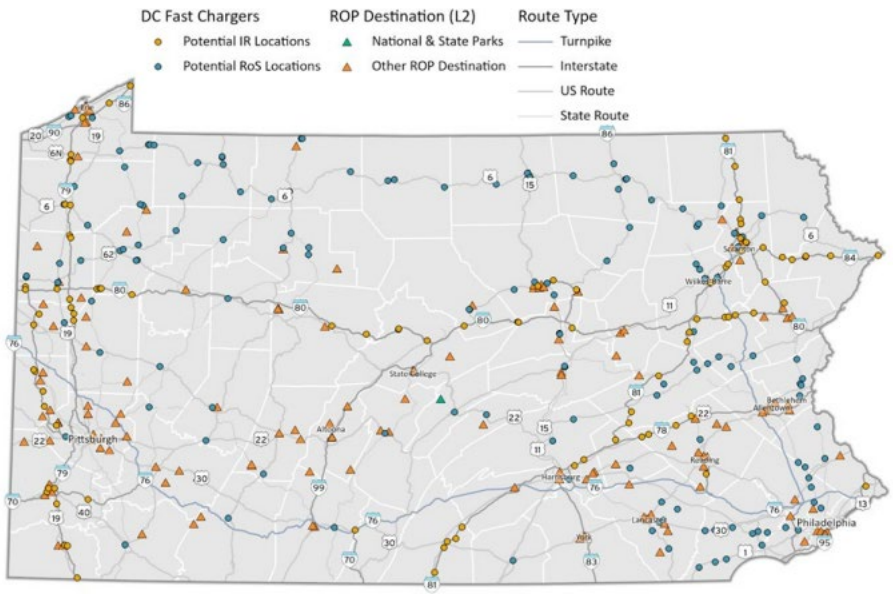


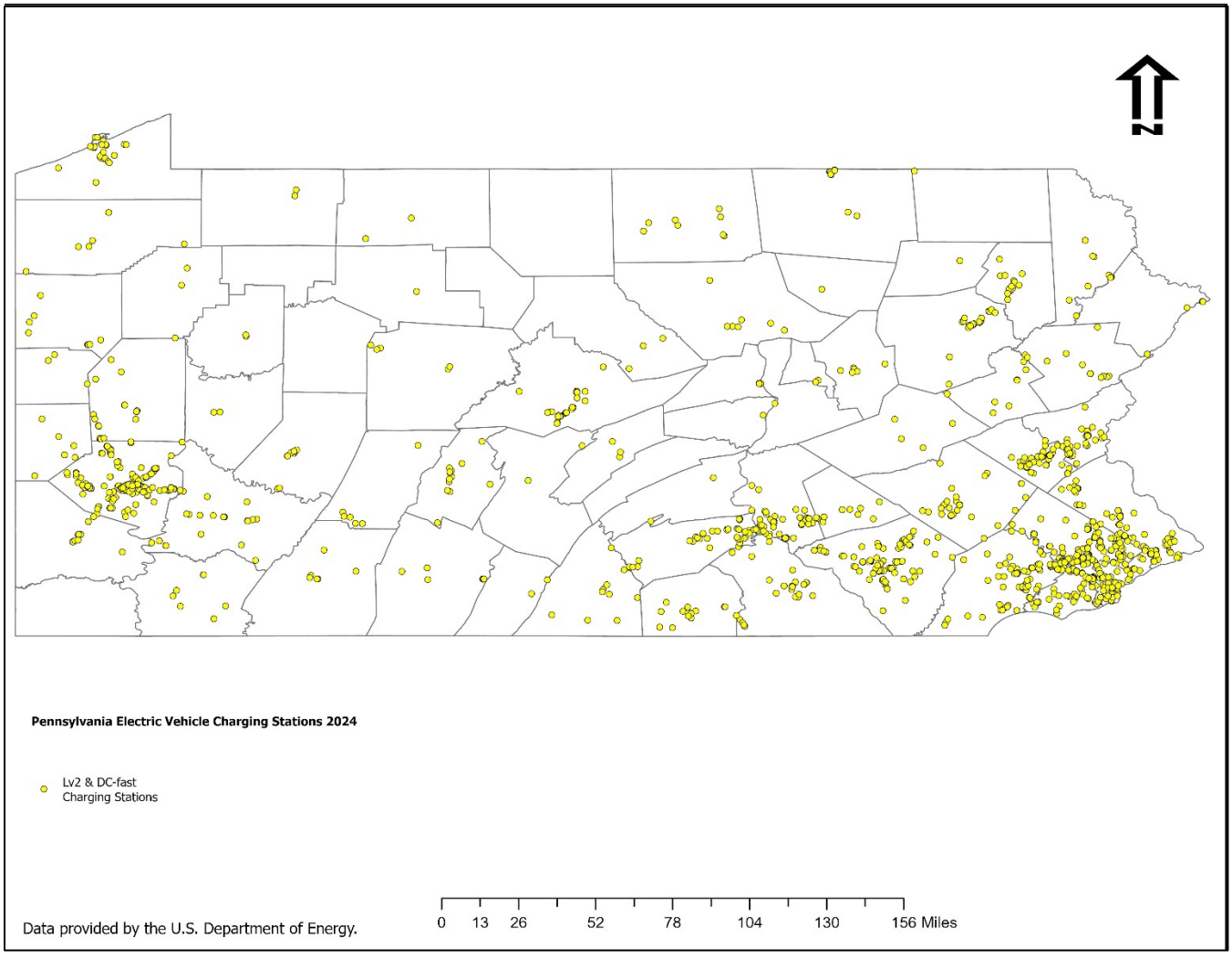
Image by The Pennsylvania Department of Transportation

PennDOT has also provided a metric for the success of the five-year plan. The following table succinctly outlines objectives, five-year targets, and their purposes. Additional information covering the PennDOT five-year Electric Vehicle Mobility Plan can be found on the Pennsylvania Department of Transportation's website.[56]

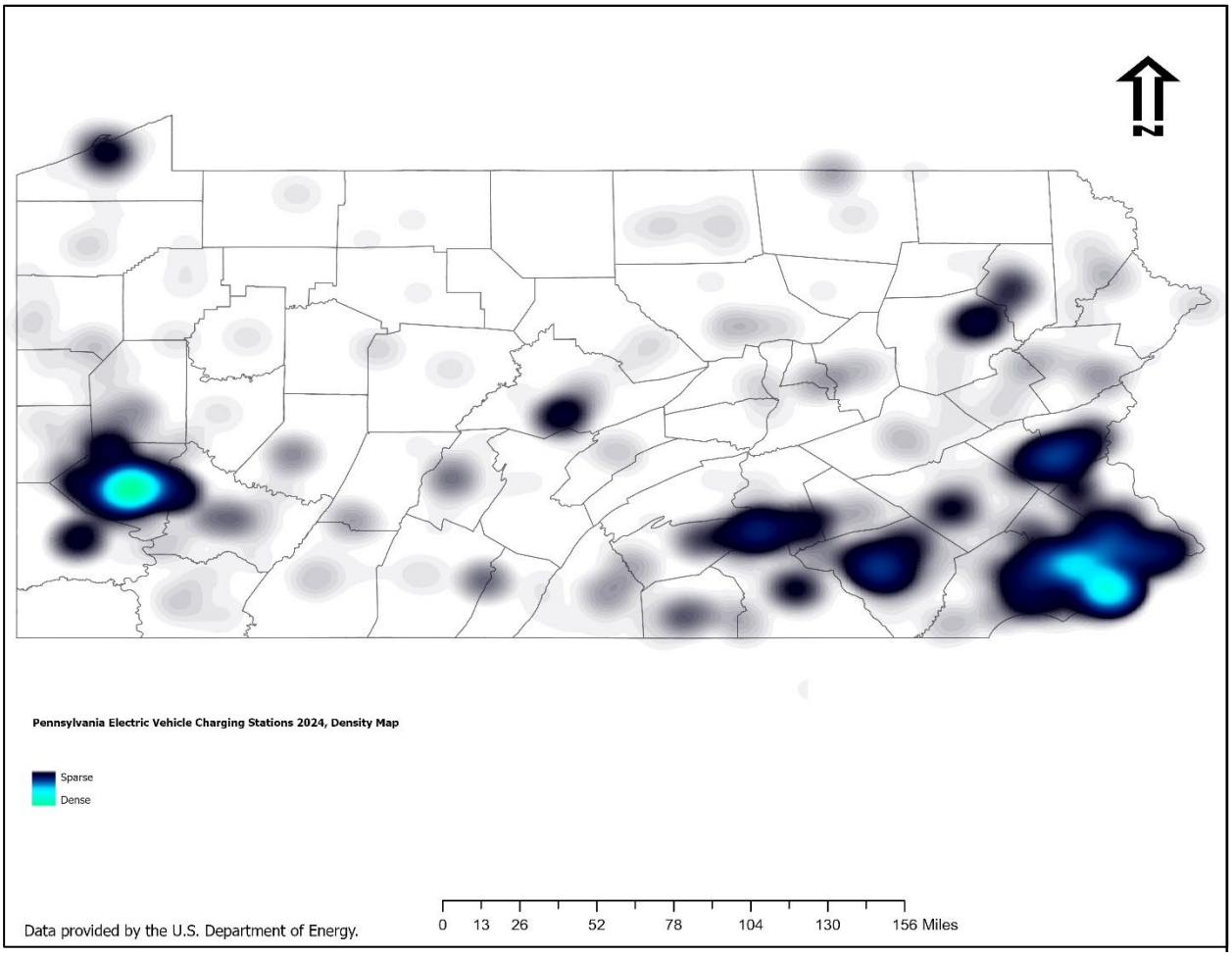
PennDOT 2022 5-Year Goals			
Metric	**Objective**	**5-Year Target**	**Purpose**
Expand EVSE network: EV chargers	Economic	2,000 charging ports	Install enough chargers to support and encourage growth of EVs
Expand EVSE network: EVSE locations	Economic	800 locations	Provide ample charging infrastructure across Pa
Complete Interstate and look-alike coverage	Mobility	One charging site every 20 miles* or less	Remove gaps ensuring complete coverage of the Interstate system and on Interstate look-alikes, and provide redundancy
Air quality: reduce GHG emissions	Environment	Reduce annual GHG emissions by 1.5M metric tons	Impact climate change by showing appreciable reduction in GHG emissions
EJ area chargers	Equity	320 locations	Support equitable EV charger deployment
Source: The Pennsylvania Department of Transportation			

Note: *To qualify as an AFC, this number is 50 miles. This plan recommends more extensive coverage

Level 2 chargers use a 7kW-19kW outlet supplied with 208-240V AC, and are commonly used in residential, workplace, and public locations. These chargers provide 10-20 miles of range per hour of charging with an estimated charge from empty time of four to 10 hours. DC Fast Charging (DCFC) use a 50-350kW outlet supplied with 400-1000V DC, and are more common in public locations. These chargers provide 180-240 miles of range per hour of charging with an estimated charging time of 20 minutes to one hour.[57] (*Note: Estimated charging times are assuming a 60-kWh battery. Full charge is being measured at 80 percent full charge, as the battery gets closer to full to prevent damage to the battery. Therefore, it is more cost- and time-efficient for EV drivers to use direct current (DC) fast charging until the battery reaches 80 percent, and then continue on their trip. It can take about as long to charge the last 10 percent of an EV battery as the first 90 percent.) As of February 29, 2024, there are currently 1,674 public Lv2 and DC-fast charging stations across the state, and 75 private Lv2 and DC-fast stations.[58]



Despite this progress, the following density map reveals many areas with little or no coverage. Densley populated areas contain more robust networks compared to rural regions. This lack of charging infrastructure across the state could deter long distance travelers from purchasing electric vehicles and increase range anxiety of electric vehicle owners.



In June 2023, Pennsylvania passed Senate Bill 656 to require Electric Vehicle owners to pay $290 each year to help fund bridge and road improvements. This measure would help alleviate the stress of lost fuel tax revenue (from combustion cars). The figure of $290 is the amount most Pennsylvania drivers pay for gas taxes. Pennsylvania has the second-highest state gas tax, however, which could deter some people from purchasing an electric vehicle.[59,60]

SEDA-COG is an economic development agency covering 11 central Pennsylvania counties, which helps find grants and supports funding through the state and federal levels, with an overall goal of bringing more electric vehicle charging stations to rural areas. It was reported that the Federal Infrastructure Bill awards Pennsylvania 171.5 million in funding to install electric vehicle charging stations across the state. During an interview at a recent SEDA-COG event, PENNDOT's Infrastructure and Implementation

Coordinator comments, "We just closed our second round of funding in January and intend to make some new additional conditional awards out in the April timeframe for about 25 to 30 new proposed locations." Fifty-five companies have received funding for the 2023 year.-[61,62]

Federal Policy

Federal laws and policies facilitate the implementation of a more robust electric vehicle infrastructure. Laws such as the Inflation Reduction Act and the Bipartisan Infrastructure Law aim to do just that by providing funding for electric vehicle infrastructure and other climate investments. By creating a reliable financial support system, federal laws aid in the adoption of electric vehicles in both the public and private sectors.

Inflation Reduction Act

The United States has implemented several policies regarding electric vehicle manufacturing. Passed in August 2022, the Inflation Reduction Act (IRA) supports a clean energy economy. Part of the act concentrates on accelerating electric vehicle adoption, with funding drawn from $369 billion allocated for climate investments.[63] The $369 billion is used to lower energy costs for families and small businesses, accelerate private investment in clean energy solutions, strengthen supply chains for everything from critical minerals to efficient electric appliances, and create good-paying jobs and new economic opportunities for workers. Additionally, the IRA will amplify existing programs such as the Justice40 initiative, which pledges 40 percent of the benefits of climate, clean energy, and federal investments to communities that are marginalized, overburdened by pollution, and underserved.[64]

The Clean Vehicle Tax Credit was extended under the IRA, introducing a new set of standards for electric vehicle models to qualify for incentives. Some tax credit requirements pertain to income level, vehicle price, and manufacturing guidelines. For example, manufacturing guidelines dictate that a certain percentage of each battery must be manufactured domestically.[65]

Bipartisan Infrastructure Law

The 2021 Bipartisan Infrastructure Law (BIL) allocated $7.5 billion in new funding for electric vehicle charging stations, making electric vehicle charging infrastructure eligible for additional federal funding programs and supporting numerous other electric vehicle-related initiatives. The Bipartisan Infrastructure Law allows for the installation of 500,000 public charging stations by 2030, with half of all new vehicles sold being zero-emission vehicles.[66] The BIL emphasizes equity regarding the placement of charger stations.[67]

Furthermore, a stricter U.S. fuel economy standard for 2024-2026 was legislated in 2021.[68] This standard proposed reductions to greenhouse gas (GHG) emissions by light- and medium-duty vehicles.[69] Due in

part to heavily supportive policies, U.S. electric vehicle sales are predicted to accelerate for the remainder of the decade, reaching the 50 percent target by 2030.[70]

International Policy

Policy support on all levels steers businesses toward electrification and helps popularize electric vehicle consumption. Internationally, not all countries partake in electric vehicle market policies – or even climate change policies. Engagement varies among countries that do participate in international policy. The United States has signed the Global Memorandum of Understanding (MoU) on Zero-Emission and Medium- and Heavy-Duty Vehicles. The MoU signifies a commitment to achieve 100 percent electric vehicle bus and truck sales by 2040, with an interim goal of 30 percent by 2030. Twenty-seven countries and territories have signed, which accounts for 15 percent of total annual sales of new medium and heavy-duty vehicles worldwide.[71]

Globally, electric vehicle sales reached 10 million in 2022, accounting for 14 percent of all new cars sold. Total spending surpassed $425 billion, an increase of 50 percent compared to 2021. The U.S. increased its electric vehicle sales by 55 percent in 2022 and is the third largest Electric Vehicle market in the world, following Europe and China. Electric vehicle sales, globally, in the first quarter of 2023 totaled over 2.3 million and were projected to reach 14 million by the end of 2023. Sales for light commercial electric vehicles have increased by more than 90 percent. Additionally, electric vehicle bus and medium-duty truck sales account for 4.5 percent and 1.2 percent of all sales in their respective categories. Generally, electric vehicle sales are lower outside major markets, but emerging markets such as India, Thailand, and Indonesia have tripled their sales. Battery manufacturing is anticipated to meet growing demands from benchmarks of electric vehicle sales. The available options of electric vehicles reached 500 in 2022, doubling the amount from four years prior.[72]

Strategies for Implementation

The deployment of electric vehicles is part of the global strategy to combat climate change. As more governments and industries commit to transitioning to the robust electric vehicle market, understanding the challenges and successes of deployment through case studies becomes more illuminating. Examination of the following studies can aid in various aspects of electric vehicle adoption.

Case Studies

The case studies below address specific state strategies for electric vehicle implementation.

Data-Driven Impact in California

Santa Clara, California, partnered with Siemens ITS Lab and Street Light Data to analyze different jurisdictions in the area for public charging station installation that would encourage and support electric vehicle adoption. To create human-centered metrics, the analysis considered factors such as trip type, trip duration, trip length, number of trips, travel purpose, residency, charger location, charger type, income, education, and family status. Findings informed prioritization of areas for electric vehicle charging sites. Additionally, the data showed that the majority of personal vehicle trips were less than 30 minutes in duration, and that commercial vehicle trips were even shorter in duration (less than 20 minutes and 10 miles, at an average speed of less than 20 miles per hour). Relatively short trips for both personal and commercial vehicles indicate potential for the shift to electric vehicles.[73]

Discounted Lease Programs in Vermont

In 2013, several municipalities in Vermont took advantage of a special leasing program that offered Mitsubishi i-MiEVs for economic use at a discounted rate ($110 per month). The Chittenden County Regional Planning Commission (CCRPC) leased two electric vehicles through this discounted program, alleviating costs of mileage reimbursement for work-related travel by employees and interns. The total cost of operating the two electric vehicles was approximately $17,248 for the three-year lease, and $7,360 was saved in mileage reimbursements. A level two charging station was installed to reduce charging costs. At 5,000 miles per year, however, it was found that lease limit restrictions on mileage per year reduce the amount of savings through this program. If these limits were increased to 7,000 miles annually, savings would have been $3,000 over the three years and would incentivize program use. Additionally, it was found that purchasing a Nissan Leaf without the discounted price would still result in reduced costs over a three-year lease period compared to reimbursement rates for mileage. The town of Milton and the City of Winooski saw similar reductions in cost when implementing electric vehicles into their fleets.[74]

Figure 2. Potential Cumulative CCRPC Operating Costs - Mileage Reimbursements vs. i-MiEV (7,000 miles per year) [10]

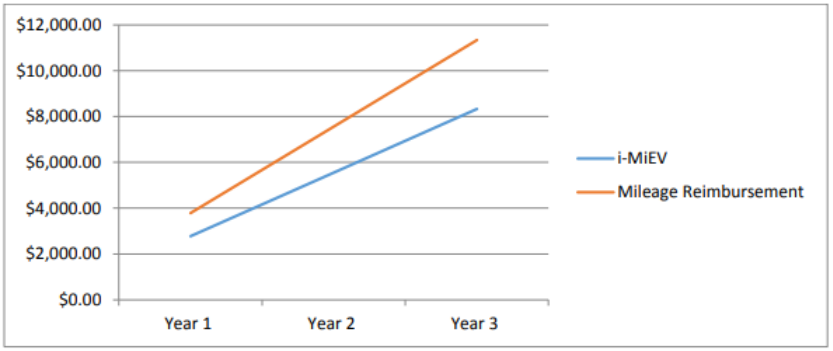
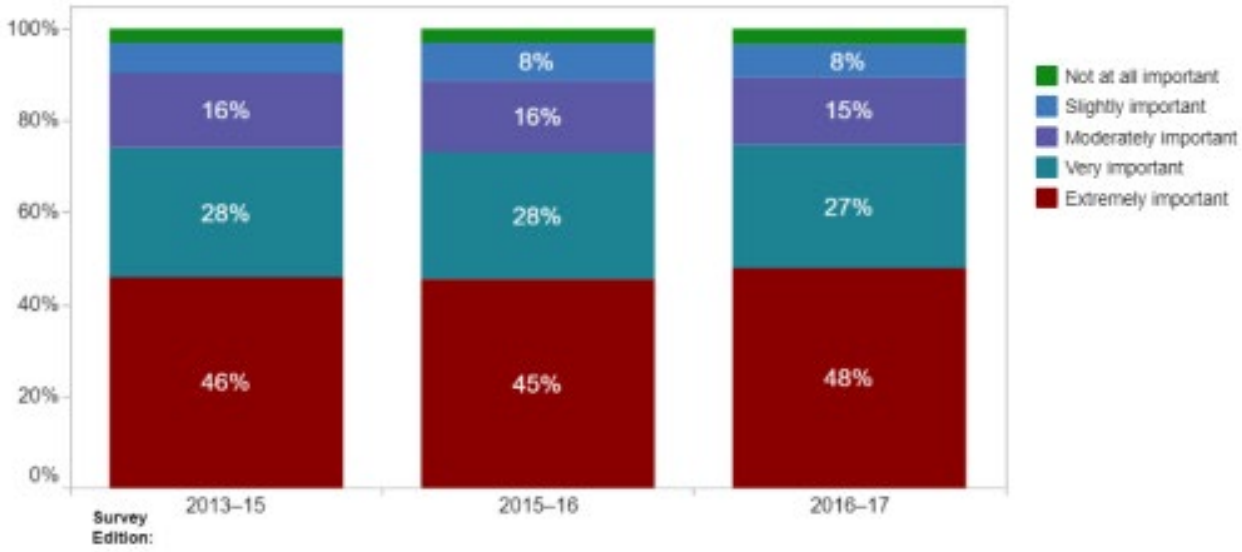


Image by: Vermont Energy Investment Corporation

New Mexico's Green Mobility Push

In November 2023, New Mexico adopted the Advanced Clean Cars and Advanced Clean Trucks rule. It was effective on December 1, 2023. This adoption would require 43 percent of new car and light-duty trucks delivered to New Mexico to be electric vehicles by 2026. By 2032 this share will increase to 82 percent. Also, by 2026, 15 to 20 percent of all new heavier-duty commercial trucks delivered to the state must be electric (rising to 40-70 percent, depending on class, by 2034). Early planning for electric vehicle infrastructure began in 2022 with the allocation of $10 million from the American Rescue Plan, which is funding the installation of 86 charging stations in 40 locations across the state. These locations include rural and urban communities, in order to encourage long-distance travel as well as adoption in all areas of New Mexico. In January 2024, the Federal Highway Administration approved $68 million to support New Mexico's charging network. It will largely be used to build two medium and heavy-duty commercial charging sites.

Additionally, New Mexico is pushing to grow its one percent (as of January 2023) electric vehicle ownership by improving access to the vehicles, increasing charging infrastructure, and rewarding buyers with savings at the point of sale. As of January 2024, residents receive a credit of $7,500 at the point of electric vehicle purchase.[75,76] A survey by the California Clean Vehicle Rebate Project found that the rebate or credit was very or extremely important by purchasers, as shown in the following chart.[77]



Source: California Clean Vehicle Rebate Project

State Strategies

California's Assembly Bill 2127 Second Electric Vehicle Charging Infrastructure Assessment requires the California Energy Commission to examine charging needs and goals for 2030 and 2035. Over one million

public and shared private chargers are needed to support 7.1 million passenger electric vehicles, and 114,500 chargers are needed to support 157,000 medium and heavy-duty vehicles (by 2030). The California Energy Commission has reported that investment into the current energy grid is needed to support these developments.[78]

With funding from the National Electrical Vehicle Infrastructure (NEVI) Formula Program, the Indiana Department of Transportation has planned to invest nearly $100 million in its Charging the Crossroads initiative. The investment is intended to support establishment of electric vehicle charging stations along interstates and highways throughout Indiana.[79]

Implementation Tool

In collaboration with the California Energy Commission, the National Renewable Energy Laboratory has created a tool (EVI-Pro) to estimate how much and where electric vehicle charging infrastructure should be implemented. The tool analyzes data related to detailed driving patterns, electric vehicle attributes, and charging station characteristics. A simplified web-based version (EVI-Pro Lite) of the tool has been released as well.[80]

Conclusion

It is pertinent that policies are implemented to address the barriers that customers face with regard to expense and infrastructure challenges. The inadequacy of charging station infrastructure has emerged as an overarching research theme – particularly considering rising electric vehicle sales. Furthermore, it is noteworthy that electric vehicle sales are much higher in countries where charging station infrastructure is more than adequate. These correlations highlight the interconnectedness of infrastructure and sales, and both must be addressed when attempting to grow an Electric Vehicle market.

Depending on the state and its policies, progress can vary greatly. California's high rate of electric vehicle sales in the United States may be credited to extensive policy support that allocates funds and incentivizes building infrastructure around the state. The U.S. and Pennsylvania both face the challenge of insufficient charging stations to accommodate electric vehicle sale milestones. With charging station location and electric vehicle mileage reported as top consumer concerns, mitigating these challenges could boost sales.

The environmental benefits of electric vehicles are numerous. Electric vehicles release significantly fewer amounts of CO_2 into the atmosphere than similar gasoline vehicles. Still, certain components of electric vehicles should be improved before mass adoption continues. The lithium-ion battery, which powers the electric vehicle, is composed of materials that are linked to environmental destruction and

human rights violations. Lithium-ion batteries are produced primarily in foreign countries, so regulation or oversight of the manufacturing processes is limited. Domestic production of electric vehicles and their parts would facilitate internal research and development, allowing for more environmentally friendly manufacturing. Domestic production would also allow for grants and reimbursements from the federal government.

Recommendations

Electric vehicle production is increasing across the world due to its long-term economic and environmental benefits. Government support of electric vehicle adoption greatly influences electric vehicle usage. Policies that incentivize or reimburse electric vehicle buyers or electric vehicle charger implementation appear to have the most promising effects.

Improvement to charging station infrastructure is a top priority, and it must follow the patterns of electric vehicle sales. With regards to the outlined goals and strategies in the research, it is important to focus on the installation of 2,000 new electric vehicle charging ports at 800 individual locations within a 5-year timeframe, ending by 2028. This initiative seeks to bolster the expansion of the electric vehicle market and increase range confidence among consumers. Additionally, setting clear goals for the location of charging sites, with the target of one charging site every 20 miles or less, is crucial to ensure comprehensive coverage of key transportation routes. Overall infrastructure goals should focus on interstate/long-distance travel, regional routes, and destination travel as primary objectives, accompanied by secondary focuses on Emergency travel, commuter travel, and medium/heavy-duty freight. Furthermore, it is recommended that charging stations be located near well-functioning infrastructure and equipped with 24-hour lighting sources to ensure safe charging experiences for users. Equitable allocation of new charging stations is also vital, guaranteeing that installation efforts prioritize underserved communities and promote accessibility for all residents.

Pennsylvania should compare policies and projections to states, such as California, that already lead in electric vehicle sales. Having such successful implementation comparisons can be helpful with the creation of new local electric vehicle policies. Ultimately, increasing incentivization, creating new chargers and charger infrastructure, and implementing more strict combustion regulations are some of the main approaches to success in increasing electric vehicle sales. With these recommendations, Pennsylvania can effectively support the diverse needs of all electric vehicle drivers and continue to establish itself as a leader in sustainable transportation.

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